Proceedings of National Seminar on Recent Advances on Information Technology, 6-7 February, 2009, Pages 17-24

A STUDY OF DIFFERENT ENERGY AWARE METRICS IN AD HOC NETWORKS

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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. Since the network interface is a significant consumer of power, considerable research has been devoted to low power design of the entire network protocol stack of wireless network in an effort to enhance energy efficiency. Different metrics have been proposed so that packets can be delivered in an efficient manner with little delay, using shortest path. These metrics may have a negative effect in wireless networks because they result in the overuse of energy resources of a small set of mobiles, decreasing mobile and network life. This paper discusses on different techniques to minimize the energy consumption, in a network to maximize the network life.

KEYWORDS: Wireless ad hoc networks, energy efficient routing, maximum energy saving, power aware routing, maximum network life

1. INTRODUCTION

Wireless networks are based on the IEEE 802.11 standards and become increasingly popular in the computing industry. It is organized in two ways [1]. The first one is known as infrastructured networks, i.e., those networks with fixed and wired gateways. The bridges of these networks are known as base stations. A mobile unit within these networks connects to, and communicates with, the nearest base station that is within its communication radius. Energy efficient routing does not apply to infrastructure networks because all traffic is routed through the base station.

The second type of mobile wireless network is the infrastructure-less mobile network, commonly known as ad-hoc network. These networks have no fixed routers; all nodes are capable of movement and can be connected dynamically in an arbitrary manner. They can be deployed anywhere without the need of any fixed infrastructure like base stations. Nodes of these networks function as routers which discover and maintain routes to other nodes in the network [2, 5].

2. ROUTING PROTOCOLS IN AD HOC NETWORKS

Application programs using the network do not interact directly with the network hardware. Instead an application interacts directly with the protocol software. The notion of protocol layering provides a conceptual basis for understanding how a complex set of protocols work together with the hardware to provide powerful communication systems. Along with that energy efficiency is studied at each layer in order to maximize network life and minimize energy consumption [2].

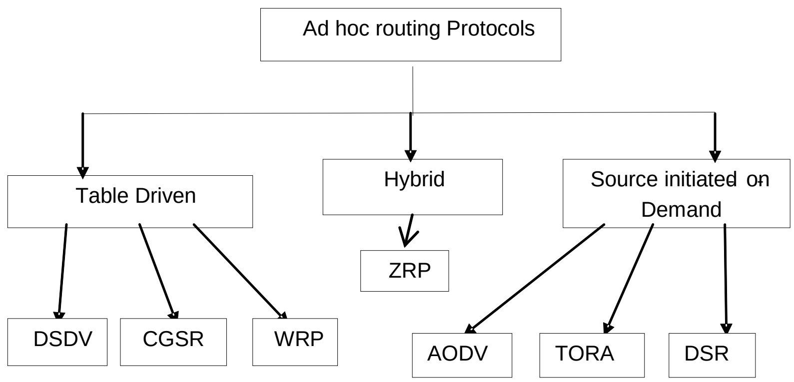

Fig. 1 Categorization of Ad hoc routing Protocols

Fig. 1 shows that ad hoc routing protocols are classified into 3 categories: (a) Table Driven (proactive), (b) Source initiated-on Demand (reactive), and (c) Hybrid [1, 5].
The Table Driven routing protocols require each node to maintain one or more tables to store routing information and they respond to changes in network topology by propagating updates through out the networks in order to maintain consistent network behaves. Different approach from table driven routing is Source initiated-on-demand routing. This type of routing creates routes only when desired by source node, when a node requires a route to destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutation has been examined. This introduces a route-computation delay for the packets. The third type of routing protocol is Hybrid routing protocol. This protocol combines the advantages of Table Driven and source-initiated-on Demand protocol. The problem of routing is complicated due to user mobility resulting in frequently changed network topologies. The rate of topology change depends on many factors including user mobility speeds and terrain characteristics.

3. DIFFERENT POWER AWARE METRICS

Typical metrics used to evaluate ad hoc routing protocols are shortest hop, shortest-delay and locality stability. However these metrics may have a negative effect in wireless networks because they result in the overuse of energy resources of a small set of mobiles, decreasing mobile and network life. The performance measures by these metrics are delay, average cost per packet, and average maximum node per cost. Therefore by adjusting routing parameters a more energy efficient routing scheme may be utilized for wireless networks.
Power efficient routing protocols are designed to select the best path such that the total energy consumed is minimized or the system life is maximized. The shortest path algorithms are still used but with other carefully designed power-aware cost metrics instead of simple hop count metric. Power-aware metrics for determining routes with various objectives have been proposed in [4]. One metric that aims to maximize the life of all nodes in the network is defined as follows:

$$c_j = \sum_{i=1}^{k-1} f_i(x_i) \qquad (1)$$

Where c_j is the cost of sending packet j from node n_1 to node n_k via intermediate nodes $n_2 \ldots n_{k-1}$, x_i represents the total energy expended by node i so far and $f_i(x_i)$ denotes the cost or weight of node i. Since f_i represents a node's reluctance to forward packets. We have chosen

$$f_i(x_i) = \frac{1}{E_i - x_i} \qquad (2)$$

Where $f_i(x_i)$ denotes the current cost of using node i, x_i denotes the energy expended by node i so far, and E_i is the initial energy of node i when network is deployed. Thus, f_i is the reciprocal of the residual energy of node i. Therefore, as the energy of a node decreases the cost of using that node increases.

By considering the above facts a node should be chosen to maintain network connectivity. A routing algorithm is proposed based on minimizing the amount of power (or energy per bit) required to get a packet from source to destination [6]. The problem is stated as

$$Minimize \sum_{i \in path} P\ (i,i+1) \tag{3}$$

Where $P\ (i,i+1)$ denote the power expended for transmitting (receiving) between two consecutive nodes, i and i+1 in route P . The link cost is defined for two cases: (a) when the transmitter power is fixed and (b) when the transmit power is varied dynamically as a function of the distance between the transmitter and intended receiver. For the first case energy for each operation (receive, transmit, broadcast, discard etc.) on a packet is given by:

$$E(packet)=b\ *\ packet\_size + c \tag{4}$$

Where b and c are the appropriate coefficient for each operation. Coefficient b denotes the packet size-dependent energy consumption where c is a fixed cost that accounts for acquiring the channel. Route selection depends on the packet size; hence in case of variable packet size transmission many routes should be selected.

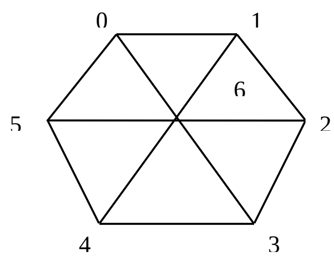

Fig. 2: A network illustrating the problem with Energy/packet as a metric

Consider the network described in fig. 2. Here node 6 will be selected as the route for packets going from 0-3, 1-4 and 2-5. As a result node 6 will expend its battery resources at a faster rate than other nodes in the network and will be the first to die. So the cost of a node increases as its residual battery energy decreases. So a route is to find out with a care to minimize

$$\sum_{i \in path} \frac{p_{(i)}}{g_{(i)}} \tag{5}$$

For global (all end-to-end hops) optimization.

as given in [8]. Where $g(i)$ is the residual battery energy of the ith node and $p(i)$ is the power cost per packet from node i-1 to node i. the residual battery capacity can be evaluated as the amount of energy remains in the battery, that is, the time duration for the battery to discharge when the transmitter is consuming power. The residual battery capacity is reduced for the amount of energy consumed by the transmission. A typical mobile node exists in 3 modes: (a) transmit, (b) receive and (c) standby. Maximum amount of energy can be expended in transmit mode and least amount of energy consumed in standby mode. If we define $f(i)=1/g(i)$ and expand $p(i)$

$$\frac{p_{(i)}}{g_{(i)}} = [p_{loss}(i\text{-}1,i) + p_{rx}(i) + p_c(i)] \cdot f(i) \tag{6}$$

Where power cost per packet $p(i)$ from node i-1 to node i can be expanded to the sum of the power loss of this link (from node i-1 to i), the power cost to receive the packet at the ith node, and the power cost for routing messages to maintain this connection. The algorithm favors a link with less power loss and hence reduces the amount of energy consumed by potential re-transmission and link error. The value of propagation loss is calculated as the difference between transmitting power and receiving power. Usually the minimum threshold of receiving power of the receiver is constant for all receivers (i.e. independent of the node index i). So the minimum value of $p_{rx}(i)$ can be set as a constant p_{rx}. Since the routing message for the route discovery and maintenance are the same for all nodes for on-demand routing protocols, we can consider $p_c(i)$ a constant value p_c too. Hence, both control and data packets are considered to consume energy according to their packet sizes. If more link error occurs, more routing maintenance is needed and hence more energy is consumed.

The most obvious metrics that reflects our intuition about conserving energy [4]. Assume that some packet j traverses nodes $n_1 \ldots n_k$ where n_1 is the source and n_k is the destination. Let $T(a,b)$ denote the energy consumed in transmitting (and receiving) one packet over one from a to b.

$$e_j = \sum_{i=1}^{k-1} T(n_i, n_{i+1}) \tag{7}$$

Thus the goal of this metric is to, Minimize e_j, $\forall$ packets j. The metric will minimize the average energy consumed per packet. Under light loads, the routes selected when using this metric will be identical to routes selected by shortest hop routing. If we assume that $T(a,b)=T$(a constant), If the route is selected using this metric may differ from the route selected by shortest-hop routing. If one or more nodes are heavily loaded, the amount of energy expended in transmitting one packet over one hop will not be a constant since we may expend variable amount of energy (per hop) on contention. So energy consumption may lead to the early death of some nodes causing the network to get partitioned.

The routes between these partitions may go through one of these critical nodes. If this critical nodes die before the death of any other node in the network then network lifetime will be decreased causing packets to be delivered with little delay as the loads of other nodes get increased. So by considering the factor of energy as a criterion for choosing a route and not the shortest path, we use the power aware metric of link cost of a route as the only principle of route selection. We notice that as the remaining energy of a node decreases, the cost of the node increases. The main objective is to extend the useful service life of an ad hoc network [6, 7]. The problem of finding a route $\prod$, at route discovery time t is given by the following cost function

$$C(\prod, t) = \sum_{i \in \prod} C_i(t) \tag{8}$$

$$\text{Where } C_i(t) = p_i \left[\frac{F_i}{E_i(t)} \right]^{\alpha} \tag{9}$$

Where p_i is the transmit power of node i and F_i is the full charge battery capacity of node i. $E_i(t)$ represents the remaining battery capacity of node i at time t. The Exponent α is a discrete function of the ratio of the remaining battery capacity, over full-charge battery capacity. As this ratio decreases and successively becomes less than a specified set of threshold values.

Since our main aim is to maximize the network lifetime, which is defined as the first node failure due to exhaustion of battery power. To achieve this goal, we propose two schemes: first, the routing protocol should route around nodes whose energy is much lower than the network average energy, second, a novel energy related routing metric cost equation composed of hop count, together with residual energy and energy consumption is designed in selecting a better route [8]. The cost metric could be defined as

$$g_i = \frac{pt\_consume_i}{(\frac{E_i}{E})\alpha} \tag{10}$$

$$G = \sum_{i=1}^{hopcount-1} g_t \tag{11}$$

Where $pt\_consume_i$ is the energy consumption to transmit from node i to its next hop node, E_i is the residual battery energy of node i, E is the network average energy and α is a parameter to modulate the weight of residual energy in the equation. The link cost from node i to its next hop is expressed by (10) and the cost of the whole route is expressed by (11). The source node will choose a better route with a lower cost G. Here $pt\_consume_i$ is not equal to pt. It represents the energy consumed within the transceiver and it is the true energy required to complete a transmission. In (11), there are three considered factors: the energy required for a transmission, the node's residual energy and the hop count.

4. OBSERVATIONS

By considering all above power metrics we come to a conclusion that while a network is set up, each node is leveled with a threshold value of energy. The node's energy is decreasing gradually as it is used in network connectivity. The remaining energy left with the node gives the idea of its cost.

$$\text{Cost of a node } \alpha \quad \frac{1}{\mathrm{Re}\, sidual\_Energy} \tag{12}$$

So the less is the energy the more is the cost of using that node in a network. All mobile should drain their power at equal rate as a minimal set of mobile exist such that their removal cause network to partition. Such node is called as a critical node. The route between these two partitions must go through one of these critical nodes. A routing procedure must divide the work among these nodes to maximize the life of the network. This problem is similar to load balancing problem. A packet to be routed through a path contains mobiles having grater amount of energy though it is not a shortest path. Delay is minimized as no congestion and nodes having less number of loads. For example if in a network to forward our packet we have chosen the shortest path to transfer my packet. But let my packet number is 11 to transfer it through the shortest path. Then my packet gets a chance after sending 10 numbers of packets which are already there in node's queue. So there is a serious delay while using shortest path as it is heavily loaded as compare to longest path, which may not be loaded as much as the shortest path. However each node in a network has definite period of life i.e. it can actively participate in n number of paths to transfer n number of packets. If we are using that particular node in n+1 number of paths then it will reduce energy and tend to die earlier than other node in the network. So all the nodes in a network should give an equal chance, or the node is to be selected in round-robin fashion. Because death of one node cause network to loose its connectivity which leads a serious delay in packet receiving. So all the nodes in a network are equally important and no node must be penalized more than any of the others. It ensures that all nodes in a network will remain up and running together for as long as possible, by increasing the longevity of our network which is our main criteria.

5. CONCLUSIONS

In this paper we have discussed several power aware metrics proposed by various authors during last several years. From which we put a conclusion that to maximize network life we have to give emphasis on node's battery energy, which should be consumed as less as possible during establishment of network connectivity, by which longevity of network can be more. As cost of a node increases as its residual battery decreases, so each node should operate at same priority level. Since each node in a network is having a threshold energy level, which can be used for transferring n number of packets, then it cannot be penalized to transfer more number of packets. Unless it will die, making the network to incorporate serious delay in packet forwarding and may lose network connectivity. So we need to develop a power-aware metrics which can eliminate all these problems and make network to operate longer, which is our future task and study its simulated behavior using ns-2 Simulator.

6. ACKNOWLEDGEMENT

This research was 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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