Energy-Aware Path Selection Metric for IEEE 802.11s Wireless Mesh Networking

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Abstract—**The IEEE 802.11s working group has commenced activities, which would lead to the development of a standard for wireless mesh networks (WMNs). The draft of 802.11s introduces a new path selection metric called airtime link metric. However, there are various types of restrictions. The biggest restriction is the confined energy of the batteries. Thus, energy consumption is crucial in the design of new mesh routing protocols. This paper presents a new energy-aware routing metric for HWMP to balance the energy consumption among the nodes of the network. This work will be simulated using NS-2 and a test-bed implementation using the MERAKA test-bed.**

I. INTRODUCTION

The upcoming IEEE Standard 802.11s [1] is defined as an IEEE 802.11 WLAN Mesh using the IEEE 802.11 MAC/PHY layers that supports both broadcast/multicast and unicast delivery over self-configuring multi-hop topologies. This kind of network is also called Wireless Mesh Network (WMN). When compared with the typical mobile Ad hoc network, WLAN mesh network is with less mobility and powered by the battery [2]. An excellent option for scaling the capacity of a wireless access network is to configure a layer-2 architecture as described in IEEE 802.11s [3]. This implies a direct wireless inter-connected set of mesh point to form a multi-hop network.

The draft 802.11s has recommended Ad hoc On Demand Distance Vector Protocol (AODV) to be used as a baseline routing protocol [1]. But it suggests a new metric called airtime link metric. While AODV works on layer 3 with IP addresses and uses hop count as a routing metric, RM-AODV works on layer 2 with MAC addresses and uses a radio-aware routing metric for the path selection. Radio-Aware Optimized Link State Routing (RA-OLSR) is an optional proactive routing protocol. The reactive and proactive feature of RM-AODV and RA-OLSR makes the protocol to be hybrid and it is called hybrid wireless mesh protocol (HWMP). In power-controlled WMNs, battery energy at the nodes is a very limited resource that needs to be utilized efficiently. The failure of some nodes' operation can greatly impede performance of the network and even affect the basic availability of the network, i.e., when routing, energy depletion of nodes has been one the main threats to the availability of WMNs. The potential problem in current protocols for WMNs is that they find the shortest path and use that path for every communication.

However, that is not the best thing to do for network lifetime. Using the shortest path frequently leads to energy depletion of the nodes along that path and in the worst case may lead to network partitioning. To counter this problem, we propose a new metric that we call energy-aware path selection (EAPSM) that will increase the survivability of the network.

II. ENERGY AWARE ROUTING

Energy should be under consideration when a path selection metric is designed for wireless mesh networks. The reason is because how much energy the network retains is directly related to how long the network can work. It may be necessary to use the sub-optimal paths occasionally. This ensures that the optimal path does not get depleted and the network degrades gracefully as a whole rather than getting partitioned [4]. To achieve this, multiple paths are found between source and destinations, and each path is assigned a probability of being chosen, depending on the energy metric. But due to the probabilistic choice of routes, it can continuously evaluate different routes and choose the probabilities accordingly. The protocol has 3 phases [5]:

i. Setup phase – Localized flooding occurs to find all the routes from source to destination and their energy costs.

ii. Data Communication phase – Data is sent from source to destination, using the information from the earlier phase.

iii. Route maintenance using localized flooding from destination to source to keep all the paths alive.

A. Setup Phase

1. The destination node initiates the connection by flooding the network in the direction of the source node. It also sets the energy costs field to zero before sending the request.

$$Cost(N_D) = 0 \qquad (1)$$

2. Every intermediate node forwards the request only to the neighbors that are closer to the source node than oneself and further away from the destination node. Thus at a node N_i, the request is sent only to a neighbor N_j which satisfies

$$d(N_i, N_S) \geq d(N_j, N_S) \qquad (2)$$

$$d(N_i, N_D) \leq d(N_j, N_D) \quad (3)$$

where $d(N_i, N_s)$ is the distance between N_i and N_j.

3. On receiving the request, the energy metric for the neighbor that sent the request is computed and is added to the total cost of the path. Thus, if the request is sent from node N_i to node N_j, N_j calculates the cost of the path as

$$C_{N_j, N_i} = Cost(N_i) + Metric(N_j, N_i) \quad (4)$$

4. Paths that have a very high cost are discarded and not added to the forwarding table. Only the neighbors N_i with paths of low cost are added to the forwarding table FT_j of N_j

$$FT_j = \{i \mid C_{N_j, N_i} \leq \alpha.(\min C_{N_j, N_K})\} \quad (5)$$

5. Node N_j assigns a probability to each of the neighbors N_i in the forwarding table FT_j, with the probability inversely proportional to the cost

$$P_{N_j, N_i} = \frac{1 C_{N_j, N_i}}{\sum_{k \in FT_j} 1 C_{N_j, N_k}} \quad (6)$$

III. LINK COST METRIC

The energy link cost metric that is used to evaluate routes is a very important component of the protocol. Depending on the metric, the characteristics of the protocol can change substantially. As mentioned earlier, the metric can include information about the cost of using the path energy health of the nodes along the path, topology of the network etc. We have adopted the cost metric proposed on [5]. Equation (7) shows our adopted cost metric:

$$C_{ij} = e_{ij}^{x_1} R_i^{-x_2} E_i^{x_3} \quad (7)$$

There are three parameters to consider in calculating the energy link cost metric C_{ij} for link (i, j). One is the energy expenditure for unit flow transmission over the link, e_{ij}, the second is the initial energy E_i, and the third is the residual energy at the transmitting node i which is denoted by R_i, where x_1, x_2 and x_3 are nonnegative weighting factors for each item. A link requiring less transmission energy is preferred ($e_{ij}^{x_1}$). At the same time, a transmitting node with high residual energy ($R_i^{-x_2}$) that leads to better energy balance is preferred. Note that if { x_1, x_2, x_3 }={0,0,0} then the shortest cost path is the minimum hop path, and if it is

{1,0,0} then the shortest cost path is the minimum transmitted energy path. If $x_2 = x_3$ then the normalized residual energy is used, while if $x_3 = 0$ then the absolute residual energy is used. While E_{ij} and $Init_i$ are constant for a wireless link (i, j), R_i continues to drop as communication traffic moves on. An optimal solution at one moment may not be optimal at a later time because R_i's and the corresponding links costs have changed. For this reason, flow argument routing (FAR) solves the overall optimal solution in an iterative fashion. Because the path cost C_{pi} is computed by the summation of the link costs on the path. Therefore, the path cost algorithm can be represented as:

$$C_{pi} = \sum_{\substack{i=m \\ j=i+1}}^{n} C_{ij} = C_{m,m+1} + C_{m+1,m+2} + C_{m+2,m+3} + \ldots + C_{n-1,n} + C_{n,n+1} \quad (10)$$

$$= \sum_{\substack{i=1 \\ j=i+1}}^{n=10} C_{ij} = C_{1,2} + C_{2,3} + C_{3,4} + \ldots + C_{10-1,10} + C_{10,11} \quad (9)$$

IV. CONCLUSION AND FUTURE WORK

In power-controlled WMNs, battery energy at the nodes is a very limited resource that needs to be utilized efficiently. The potential problem in current protocols for WMNs is that they find the shortest path and use it for every communication. However, that is not the best thing to do for network lifetime. Using the shortest path frequently leads to energy depletion of the nodes along that path and in the worst case may lead to network partitioning. To counter this problem, we propose an energy-aware path selection (EAPSM) that will increase the survivability of the network. The next will be to simulate EAPSM, to validate the performance compared to airtime link metric and multi-metric AODV etc.
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V. REFERENCES

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