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An Approach towards Link Positions Routing in Wireless Network-A Review

G. D. Govindwar, Prof. P. A. Tijare

Abstract—Here we account for the fact that MAC protocols incorporate a finite number of transmission attempts per packet. The performance of a path depends not only on the number of the links on the path and the quality of its links, but also, on the relative positions of the links on the path Based on this observation, we propose ETOP (Expected number of Transmissions On a Path), a path metric that captures the expected number of link layer transmissions required for reliable end-to-end packet delivery.

We can analytically compute ETOP, which is not trivial, since ETOP is a noncommutative function of the link success probabilities. Although ETOP is a more involved metric, we show that the problem of computing paths with the minimum ETOP cost can be solved by a greedy algorithm. We will try to implement and evaluate a routing approach based on ETOP metric on wireless network.

Index Terms— Greedy choice, link position, noncommutative metric, optimal substructure property , transmission count, wireless network.

1 INTRODUCTION

Reducing the number of link layer retransmissions in a wireless mesh networks is critical for ensuring high overall throughput. This can be achieved by selecting routes with inherently reliable links. This has a two-fold effect. First, the throughput of the flows using these paths is higher. Second, the throughput of the network as a whole increases, since the fewer transmissions lead to lower network-wide contention.

The cost of a path when the link layer offers limited reliability depends not only on the number of links on the path and the quality of these links, but also on the relative positions of the links on the path. In more detail, one has to account for the possibility that a packet may be dropped at the link layer given the bounded number of retransmissions at that layer. With a reliable transport protocol, such a dropped packet will have to be retransmitted from the source. Thus, a packet drop close to the destination is expensive, since it induces retransmissions (in the subsequent transport layer retransmission attempt) on links that were successfully traversed prior to the drop.

Let us consider the example in Figure. 1. There are two paths from the source P to the destination Q. The number next to each link depicts the probability of a successful transmission (denoted as link success probability) across that link. At first glance, it may seem that it is better to use the path [P, L, M, Q] instead of [P, I, J, K, Q]. In fact, previous strategies such as [1] will choose that path. However, the path [P, I, J, K, Q] is better than [P, L, M, Q]. If the link layer performs at most two transmissions per packet (i.e., only one retransmission is allowed), it is easy to compute that the expected total number of link layer transmissions per packet is approximately 13 for the path [P, I, J, K, Q], while it is approximately 20 for the path [P, L, M, Q]. The higher cost is due to the bad link that is closer to the destination, in the path [P, L, M, Q].

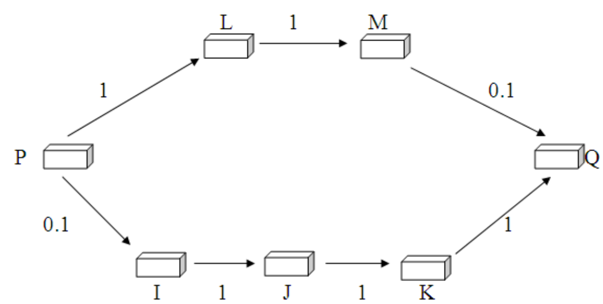

Figure. 1. The effect of the link positions on the performance of a path.

In [9] Author G. Jakllari has proposed a path metric, which accurately captures the expected number of link layer transmissions assuming a finite number of retransmissions at this layer. We call our metric the Expected number of Transmissions On a Path or ETOP for short. ETOP considers the relative position of the links and thus, it is a noncommutative function of the link success probabilities unlike the previously used metrics. Our analysis can be summarized as follows: 1. We derive a closed form expression to compute the ETOP cost of a path. Note that this derivation is nontrivial; the ETOP cost cannot be computed as a simple sum of link level metrics, because of the finite number of retransmissions at the link layer. 2. Despite its more involved calculation, ETOP satisfies: 1) the greedy-choice property, and 2) the optimal substructure property. Thus, computing the paths of minimum ETOP cost can be achieved with a greedy approach [1], and we develop an algorithm to that effect. 3. We develop and implement ETOP-R, an ETOP based routing protocol[2].

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2 LITERATURE REVIEW & RELATED WORK

We have to account for the possibility that a packet may be dropped at the link layer given the bounded number of retransmissions at that layer. With a reliable transport protocol, such a dropped packet will have to be retransmitted from the source. Thus, a packet drop close to the destination is expensive, since it induces retransmissions on links that were successfully traversed prior to the drop. We have a link metric called ETX (Expected Transmission Count) [2], which is equal to the inverse of a link's reliability. The end-to-end cost of a path is the sum of the ETX values of the links on the path; the routing layer simply computes routes that minimize this cost. A mechanism for estimating the link reliabilities, based on dedicated broadcast packets. Experiments on a 29-node 802.11 testbed showed that ETX based routing results in better end-to-end throughput as compared to minimum-hop routing.

Other related efforts in [3], [4] and [5] have used the inverse of the link reliability (ETX) in combination with other parameters (such as the link bandwidth) for improving routing performance in multihop wireless networks. In [4] Draves et al. propose a new routing metric, WCETT (Weighted Cumulative Expected Transmission Time), that considers the link bandwidth and interference in addition to the (inverse of) the link reliability. In this multi-radio, multiple channel technology is a visible solution to increase the capacity of wireless mesh network. On the one hand, the interference can be reduced by tuning neighbouring nodes on different channels. On the other hand, multi-hop coordination schemes that exploit the presence of multiple radios can be deployed at the MAC layer so author has proposed a cross layer architecture that provides efficient end-to-end communication in multi-radio multi-channel wireless mesh networks.

In [5], C. Koksal and H. Balakrishnan propose a mETX (modified ETX) and ENT (Expected Number of Transmission) that extend ETX to account for highly variable link reliabilities. These quality aware routing metric expected number of transmission count can improve the throughput of wireless mesh network by significant amount compared to traditional shortest hop-count routing protocol, it does not cop well with short-term channel variations because it uses the mean loss ratios in making routing decision. For example radio channel may have low average packet loss ratios, but with high variability, implying that metrics that use mean loss ratio will perform poorly because they do not adapt well to burst loss conditions.

The number of transmission of the packet on radio link is an appealing cost metric because minimizing the total number of transmission maximizes the overall throughput. moreover, this metric minimizes the transmission energy consumed in transferring the packet along a path in a network when the nodes transmit at a constant power level. Although experimental result in [5] shows that ETX performs better that traditional shortest-path routing under static network condition, it may perform poorly under highly variable channel condition, because ETX consider only the average channel behaviour. In particular, the routing protocol measures the channel state using a set of probe packet sent once every second, averaging the loss ratio over an interval of about 10 seconds. The reciprocal of this estimate is assigned as the ETX of the link. In this procedure, the number of transmissions is implicitly is assumed to be a geometric random variable; if successive packet are lost independently with probability equal to the average packet error rate of channel, the assumption is accurate. Packet losses generally occur in burst, however, and the packet loss probability is usually not constant.

The used metric is similar to ETX for finding minimum energy paths used in [6]. There are two more models. In first model, the link layer performs no retransmissions and all the reliability is handled end- to-end. In the second model, referred to as the mixed model, the link layer either performs no retransmissions, and the reliability is handled end-to-end, or it performs an unbounded number of retransmissions. For both the models design optimal algorithms. However, the case in which the link layer offers a finite number of retransmissions is not considered. In [7] the product of ETX with the distance traversed toward the destination is used for energy-efficient geographic routing.

A similar model is used for energy efficient routing. In [14], routing is jointly considered with power control, and in addition to the unicast case, the multicast case is also considered based on measurements, it uses broadcast packets to estimate the link reliability for data packets could lead to inaccuracies. Therefore, both efforts propose algorithms for data-driven link reliability estimation.

The inverse of the link reliability estimates the expected number of transmissions (including retransmissions), IE, needed to send a packet across a link, with the implicit assumption that an infinite number of retransmissions is allowed on the link. Therefore, the link layer never drops a packet. To elucidate this, let p be the probability of a successful transmission across a link. Assuming that the outcomes of the transmission attempts on the link are independent and identically distributed, IE can be computed as

$$IE = \sum_{i=1}^{\infty} j(1-p)^{j}\, p = 1/p \tag{1}$$

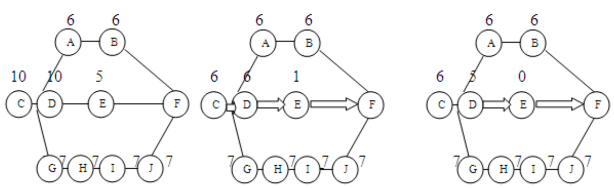
Since the link layer never drops a packet, there is never a need for a transport layer retransmission. This simplifies the calculation of the retransmissions needed for reliable packet delivery over a path; the number of retransmissions depends only on the link quality and not on their positions, i.e., the calculation is commutative. In practice, however, there are a bounded number of link layer transmission attempts (as with 802.11) per packet and a reliable transport protocol will need to perform an end-to-end retransmission to cope with link layer packet drops. In this case, as discussed with example in Figure. 1, the relative position of the links on a path becomes important when computing the cost of a path.

3 ANALYSIS OF PROBLEM

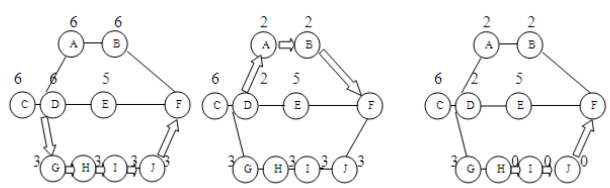
Conventional routing protocols for adhoc networks select the routes under the metric of the minimum hop count. Such min-hop routing protocols can use energy unevenly among the nodes and thus it can cause some nodes to spend their whole energy. A mobile ad hoc network is a collection of wireless devices that come together to form a self-organizing network without any support from the existing fixed communication infrastructure. In such a network, each device plays the role of a router and has limited battery energy. In addition, the network topology can constantly change. Thus, it is widely accepted that conventional routing protocols are not appropriate for mobile ad hoc networks, and, consequently, the design of routing protocols for such networks is a challenging issue taking power factor into consideration. To reduce the energy consumption in mobile devices, there have been efforts in physical and data link layers as well as in the network layer related to the routing protocol.

The physical layer can save energy by adapting transmission power according to the distance between nodes. At the data link layer, energy conservation can be achieved by sleep mode operation. The purpose of power-aware routing protocols is to maximize the network lifetime. The network lifetime is defined as the time when a node runs out of its own battery power for the first time [13]. If a node stops its operation, it can result in network partitioning and interrupt communication. The power-aware routing protocols should consider energy consumption from the viewpoints of both the network and the node levels. From the network point of view, the best route is one that minimizes the total transmission power.

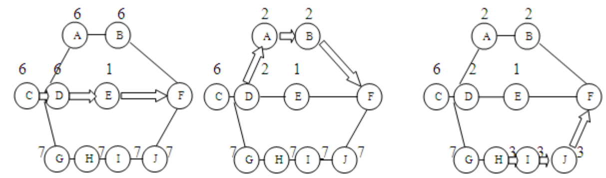
On the other hand, from the viewpoint of a node, it is one that avoids the nodes with lower power. It is difficult to achieve these two objectives simultaneously. Minimizing the total energy consumption tends to favour min-hop routes. However, if the min-hop routes repeatedly include the same node, the node will exhaust its energy much earlier than the other nodes and the network lifetime will decrease on the energy level of each node may select longer-hop routes, which spend more energy.



Min-hop routing. The first graph is the initial network state



Routing for fair battery usage. The initial network state is the same as (a)



(c) Compromising routing between Min-hop routing and fair battery usage. In this case, the routing algorithm sets up the route which has the smallest hop with an
average battery power of at least 5.

Figure. 2. Lifetimes of different routing algorithms. 4 data packets are delivered for each session in order of C→F, D→F and H→F

Figure 2 (b) exemplifies the problem when a routing algorithm sets up a route with the largest residual battery energy. Therefore, the power aware routing protocols should have a mechanism to balance the two objectives. Figure 2 (c) shows that the scheme that skilfully chooses routes can have better performance. This paper focuses on how to balance the two objectives. In a wide sense, ad hoc routing algorithms can be classified into the pro-active and the on-demand routing algorithms. The on-demand routing algorithms [9][15] start to find out the suitable route when a route is requested while the proactive scheme [9] exchanges routing information periodically and generates the routing table in advance. Paper [16] shows that the on-demand routing outperforms the pro-active in terms of both delivery ratio and routing overhead. This is because it is difficult to find out the proper exchange rate of control packets, which depends on the mobility. The pro-active scheme has the possibility that some routing information exchanged is useless. That is, a slow exchange rate can make the routing information stale, and a fast rate results in excessive routing overhead. Therefore, it is a natural choice to design a power-aware routing protocol based on the on-demand scheme.

The Max-min zPmin [13] and CMMBCR [11] can be classified as routing protocols that balance two conditions for the lifetime. The Max-min zPmin algorithm has difficulty in implementing into the on-demand scheme. On the other hand, the CMMBCR needs to add the overhead of control packets for the on-demand version, and also it is not easy to decide the optimal threshold value that determines the operation modes. This paper proposes an on-demand power-aware routing algorithm called DEAR (Distributed Energy-efficient Ad hoc Routing). Our proposed routing algorithm balances between minimum transmission energy consumption and fair node energy consumption in a distributed manner. This goal is achieved by controlling the rebroadcast time of RREQ packets. In addition, we design a mechanism of estimating the average energy level of the entire network without additional control packets. The estimated average energy is useful to adaptively control the rebroadcast time.

MTPR (Minimum Total Transmission Power Routing) sets up the route that needs the lowest transmission power among possible routes. This scheme can be applied in the environment where transmission power adjustment is available. Because the required transmission power is proportional to the nth power of the distance between nodes, this scheme prefers shorter links and has the tendency to select the route with more hops. However, MTPR has some problems [10]. It turns out that the adaptation of transmission power can bring a new hidden terminal problem. The hidden terminal problem makes more collision, and it results in more energy consumption due to retransmission. Even if there is an algorithm proposed for the problem, it cannot be implemented with the current technology. And, MTPR has a similar problem to min-hop routing in that it makes no efforts to use energy evenly among nodes.

MBCR (Minimum Battery Cost Routing) tries to use battery power evenly by using a cost function which is inversely proportional to residual battery power. One possible choice for the cost function of a node i is given as f(bi) = 1/bi , where bi is the residual battery energy of a node i. The total cost for a route is defined as the sum of costs of the nodes that are the components of the route, and MBCR selects a route with the minimum total cost. This method seems to extend the network lifetime because it chooses the route composed of the nodes whose remaining battery power is high. However, because it considers only the total cost, the remaining energy level of an individual node may hardly be accounted for. That is, the route can include a node with little energy if the other nodes have a plenty of energy.

To prolong the lifetime of an individual node, MMBCR (Min-Max Battery Cost Routing) introduces a new path cost, which is defined as Rj =maxi€route- j f(Bi), and it selects the route with the minimum path cost among possible routes. Because this metric takes into account the remaining energy level of individual nodes instead of the total energy, the energy of each node can be evenly used.

However, this scheme can set up the route with an excessive hop count and then consume a lot of total transmission energy. CMMBCR (Conditional Max-Min Battery Capacity Routing) [11] tries to balance the total transmission power consumption and the individual node power consumption. This algorithm operates in two modes according to the residual battery power. If there are nodes that have more battery power than threshold power, it applies MTPR to the nodes. Otherwise, it mimics MMBCR. Roughly speaking, when battery power is plentiful, it minimizes the total energy consumption like MTPR, and in the other case it considers the nodes with lower energy like MMBCR. The performance of CMMBCR is heavily influenced by the threshold value. In a case where the threshold value is 0, it is identical to MTPR. As the threshold value grows by infinity, it is transformed into MMBCR [12]. The max-min zPmin algorithm [13] is another balancing power-aware routing protocol. This scheme selects the route that maximizes the minimal residual power fraction under the constraint of the total power consumption. Total power consumption is limited to z times the minimum total transmission power. This algorithm is much more complex than the others mentioned before, and it is not easy to choose a suitable z value.

4 PROPOSED WORK AND OBJECTIVES

Computing ETOP

An analytical model for computing the ETOP cost of a path. In our model, unlike previous efforts, we account for the bounded number of retransmission attempts at the link layer (leading to possible packet drops at this layer). We then assume that a transport layer protocol (such as TCP) performs end-to-end retransmission attempts (e2e attempts) until the packet is finally delivered to the destination.

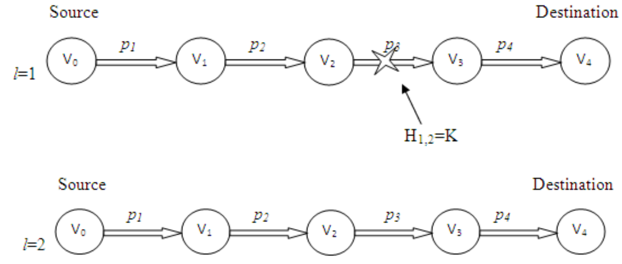
Assumptions:

1. The probability of a successful transmission on a link does not change between retransmission attempts. In other words, the outcomes of link layer transmission attempts are independent and identically distributed (IID).

2. Implicitly, assume that the power and bit-rate used for each transmission by a node does not change. If nodes are allowed to change their transmission properties, the probability of success will vary.

Network representation and notation.

Author model the wireless network as a directed graph G(V,E,w), where V is the set of nodes and E the links. Every link i € E is assigned a weight 0 < pi ≤ 1, which represents the packet delivery probability over that link with a single transmission attempt. Consider the problem of sending a packet from a source node v0, to a destination node vn, along a n-link path via nodes v1, v2, … vn. The source, node v0, initiates an end to end attempt. First, the packet is passed on to the link layer, which will transmit it to node v1. If successfully received by node v1, it will then be transmitted to node v2, and so forth, until the packet reaches node vn. There is a probability 0 < pi ≤ 1 where i = 1,2,… n that the packet, when transmitted by node vi-1, will reach node vi. If the packet transmitted by node vi-1 does not reach node vi, it is transmitted again by the link layer of node vi-1. Upto K transmission attempts (including the initial attempt) are made, and the packet is dropped if the K th transmission fails to reach node vi.



First e2e attempt (l=1) failed after crossing two links - > M1=2

Second e2e attempt (l=2) succeeded - > M2=4
There were two e2e attempts on a 4 links path - > Y4

Figure. 3. An example to illustrate our modelling assumption and highlight notation

The drop is reported to the transport layer of node v0. In response, the transport layer of v0 initiates a new e2e attempt for the same packet. For every e2e attempt, there is a cost: the number of link level transmissions during this attempt. Let Tn be a random variable that represents the sum of the costs of all the e2e attempts made in order for a packet to be delivered from node v0 to node vn. Our goal is to compute the expected value of Tn, the ETOP cost of the path, as a function of link weights, pi, and the bound on the number of link level transmissions, K. Let Yn denote the random variable representing the number of e2e attempts required in order for the packet to be delivered to the destination on the n-hop path. Let Ml denote the number of consecutive hops that are successfully traversed along the path, beginning at node v0, in the lth e2e attempt. Thus, Ml= 0 if the packet fails to reach node v1 from node v0, and Ml= n if the message has reached vn. If Ml < n, the (l+1)st e2e attempt begins. We assume that the random variables M1,M2, . . . , are independent and identically distributed (IID) and can be represented by a single random variable M. Let Hl , j denote the number of link layer transmissions needed to deliver the packet from node vj to node vj+1 in the lth e2e attempt If the message has successfully traversed the link from vj to vj+1, Hl , j ≤ K; else, if the message fails to reach node vj+1 from node vj, then, Hl , j =K and a new e2e attempt is started at node v0. For each node vj, we assume that H1,j,H2,j, . . . , are IID random variables and we use the notation Hj to represent this common random variable. To elucidate the meaning of the variables defined so far, we consider a simple scenario, depicted in Figure. 3, that can occur when a packet is transmitted from v0 to v4. Let there be two e2e attempts (Y4= 2) to deliver a single packet from the node v0 to node v4. On the first e2e attempt, the packet crosses links (v0,v1) and (v1,v2) after being transmitted only once. However, it is dropped at node v2. Therefore, H1,0 = H1,1= H1,2 = K, and M1= 2. The cost in terms of link level transmissions incurred on this e2e attempt is K + 2. On the second attempt, the packet is delivered to the destination, node V4, and crosses each link with a single link layer transmission attempt. Therefore, H2,0 = H2,1= H2,2 = H2,3= K and M2 = 4.
The cost in terms of link level transmissions incurred on this e2e attempt is 4. The total cost incurred in terms of link level transmissions to deliver the packet from node v0 to node v4, is T4 =K + 6. The cost of a path, using the model and the random variables defined above, for the general case of a n-link path, the cost, Tn, is given by

$$T_n = \sum_{l=1}^{Yn} \left(\left[\sum_{j=0}^{M_l - 1} H_{l,j} \right] + K\mathrm{II}(l < Yn) \right) \quad (2)$$

where $\sum_{i=0}^{-1} = 0$ and II(l < Yn) represents the indicator function that takes on a value 1 when l< Yn and 0 otherwise. If l < Yn, the specific e2e attempt failed to deliver the packet to the estimation, i.e., the packet was dropped somewhere along the path. We know that the node at which the packet was dropped performed exactly K transmissions. The summation inside the parentheses simply represents the number of link level transmissions in the process of crossing Ml links during the lth e2e attempt.
We will implement a routing strategy based on the algorithm described in ETOP using greedy algorithm on indoor wireless mesh network. While Routing implementation, We will use ETOP-based routing as part of a modified version of the DSR(Dynamic Source Routing) protocol for the Linux kernel. We chose DSR because 1) it is one of the most popular protocols for multihop wireless networks and hence, its implementations are readily available and 2) it allows a source to decide on the path to the destination (required by ETOP-R since it is noncommutative). Furthermore, we consider the ETX metric for comparison and use the implementation of the routing strategy based on ETX. For ease of notation we refer to ETOP-based routing as ETOP-R and to ETX-based routing as ETX-R.
With DSR , a node attempts to find a route to a destination by broadcasting a route request message (RREQ). The RREQ is subsequently rebroadcasted once by each nodes in the network, upon receipt. A node inserts its own address in the RREQ before rebroadcasting it. The sequence of addresses in the forwarded RREQ specifies the route traversed from the source to the destination. Upon receiving a RREQ, the destination sends a route reply message (RREP) to the source (with the route embedded within), along the reverse route recorded in the corresponding RREQ. The source stores the routes collected from all the RREPs received in a cache and uses, for a limited time, the route with the minimum hop count for forwarding data. The route error messages (RERR messages) induced by DSR are disabled during the experiments; this functionality of DSR is not utilized with either ETX-R or ETOP-R.

5 APPLICATION

We can implement ETOP based routing and perform extensive application on a various nodes in indoor mesh network for the better performance of the paths computed with our metric with those computed with a routing strategy based on ETX. Our scheme outperforms the ETX-based routing, by some percent in many cases, in terms of better overall throughput.

6 CONCLUSION

Here we revisit the problem of computing the path with the minimum cost in terms of the number of link layer transmissions and retransmissions in multihop wireless networks. The key feature that distinguishes is that we consider a finite number of link level retransmissions, unlike previous efforts (such as ETX). We demonstrate that in addition to the magnitude of the link reliabilities on a path, the relative ordering of the links is critical in computing the correct minimum cost path. We provide an analytical model to compute a noncommutative path metric, ETOP that captures this cost. We show that in spite of ETOP's complex form, the problem of computing the path with the minimum ETOP value can be solved using our greedy routing strategy. We will implement ETOP based routing and perform extensive experiments on a mesh network to quantify and evaluate its performance. We compare the performance of the paths computed with our metric with those computed with a routing strategy based on ETX.

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