Path Selection Algorithms in Mobile Ad Hoc Networks

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ABSTRACT
The connectivity richness in mobile ad hoc networks, there are paths between a source and a destination. There are many applications those require uninterrupted connections between the nodes while transferring the packets, the long-living paths can be very useful to provide Quality of Service. In this paper, we propose path-selection algorithms and evaluate their performance in a mobile ad hoc network based on two criteria: 1) the selected path is the most likely to meet a target energy consumptions, and 2) the selected path has the longest residual path lifetime among all the available paths. We also develop performance metrics (PMs) to compare the proposed algorithms among themselves and with a baseline random-selection algorithm. It is found that path selection algorithms demonstrate comparable performance than existing algorithm. As the number of node increases, the proposed algorithms yield even greater performance gain over the baseline algorithm.

Keywords
Quality of Service, Performance Metrics, Mobile Ad Hoc Network, full link lifetime

1. INTRODUCTION
In Mobile Ad Hoc Network (MANET) research have generated a growing interest in carrying Multimedia-intensive traffic in such a network. Multimedia traffic is known to require more cost metric performance of Energy consumption, Packet Loss, Packet delay, jitter, throughput etc., in order to ensure an acceptable quality of service (QoS).

The provisioning of Quality of Services in a Mobile Ad hoc Networks presents both challenges and opportunities. On one side the dynamic network topology leads to frequent link breakdowns as all the mobile nodes are mobile. This makes the path maintenance operations such as path failure notifications and path rediscovery very costly. Furthermore, if an alternative path cannot be established in a time while a transferring the packets data may be loss. On the other side, because of the more number of nodes in the MANET, and thus connectivity richness, multiple paths occur in between a source-destination pair. This is a reason that researchers to study multi-path routing as a promising technique for supporting QoS in MANET (see, for example, [2], [6], [8], [9], [12], [13],[14]).

A typical path in the MANET consists of multiple hops, and therefore prone to frequent breakage in the link. In many applications, it is desired to select best path, from all available paths, one that best path serves the requirement to carry the packets from source to destination. For example, one may wish to choose a path that consists of nodes with the largest average battery power. In our research, we associate the desirability of a path with its residual lifetime. In the path-selection algorithm, we take into consideration the impact of node mobility (i.e., mobility-induced) on the residual path lifetime (RPL), which is defined as the duration from the time the path is first discovered to the time when any one of its links get breakage.

This paper is organized as follows. Section II provides relevant background information; Section III proposes path selection algorithms, section IV performance and simulation parameters and Results. In Section V discusses some future work we plan to undertake. Finally, Section VI concludes the paper.

In many of the proposed algorithm in MANET routing protocols have limited provision for QoS and use paths discovered without regard to path reliability or longevity. Possessing knowledge of the mobility-induced RPL in a path-selection algorithm will reduce the cost metrics as a result of fewer path failure notifications and of poor path re-discovery. Because of this will make better use of the insufficient bandwidth in the network.

The study of path selection based on mobility-induced RPL is a large in the research field. Because of the difficulty in modeling the multi-hop path, most published work takes the approach of extend the results of individual link lifetime to evaluate the overall path lifetimes. In [3] designed two methods to identify the “stable” links from several available links. Unfortunately, due to the correlation between adjacent links on a path, this approach often does not produce sufficiently good results. One measure in assessing the stability of a link is the length of the linkage, to measure this pause time. Here choosing one value for the pause time will cause algorithm to perform unsatisfactorily in a mobility environment with a different pause time. Our researchers are working to find, a path-selection algorithm should base its path-selection decisions only on information that can be observed by the mobile node. Furthermore, it should be able to do so with hardware/software support in each node.

2. PROPOSED PATH SELECTION ALGORITHMS
We propose path-selection algorithms that select the best path from a set of available paths. In defining “best”, we consider the following two criteria:

1) The chosen path is most likely to meet a target residual path lifetime requirement, or
2) The chosen path has the longest residual path lifetime.

When invoking the algorithms, we assume the paths are discovered a priori. At present, we consider only paths that are node- not joint; it means that paths do not shares common links or intermediate nodes. Such paths have the property that the failure of one path is independent of the others. Before we introduce the algorithms, we first present a simple statistic-collecting mechanism that would be used in two of the three algorithms.

2.1. Statistical FLL-Collecting Mechanism
Analytically computing the full link lifetime (FLL) in a mobility model is computationally intensive and requires sophisticated HW/SW. Instead, we employ a simple mechanism in each node that collects empirical FLL statistics, based on

which an algorithm makes path-selection decisions. A node A periodically broadcasts a beacon to identify itself. A neighbor node B which hears this beacon assumes there is a link from A to B. The FLL is therefore the entire duration between the first and last time Node B hears Node A's beacon. Each node continuously collects FLL statistics in this fashion until a sufficient number of FLLs has been collected. The generated FLL statistic is then used to create a histogram. From this point on, path-selection algorithms may be invoked using this histogram. A similar scheme was also used [4] in their work.

In our simulations, all the nodes operate under the same mobility model with the same set of mobility attribute values. This makes the network homogeneous, where a similar FLL histogram will be computed at each node. This mechanism is used differently in two of our three proposed path-selection algorithms.

2.2.Path Selection Algorithm I (PSA1)

During the initial phase of the network deployment, each mobile node collects FLL statistics to construct an FLL histogram. After a set Ψ of disjoint paths is discovered at the destination (using, e.g., Split Multi-path Routing [6]), each upstream node j along an Li-hop path i, where i i $\varepsilon\{1 \dots\dots . . |\Psi|\}$ and$j\epsilon\{1 \dots\dots . . L_i\}$ computes the probability that the link with its downstream neighbor k, denoted as $l^{i}_{j,k}$ has a residual lifetime of at least T [sec] given its current age t^{i}_{jk}.The link age is easily obtained by counting the number of times Node j has heard the beacon from Node k. Denote $\sim T^{i}_{jk}$ as the random variable of the residual lifetime of Link l(j;k) of Path i, and T^{i}_{jk} the corresponding full link lifetime.

The following relation holds: $T^{i}_{jk} = T^{i}_{jk} + t^{i}_{jk}$ The required probability can be computed as:

$$P^{i}_{jk}(\tau) = P\{T^{i}_{jk} \geq \tau | t^{i}_{jk}\} = P\{T^{i}_{jk} \geq \tau + t^{i}_{jk} | t^{i}_{jk}\}$$

$$= \frac{P\{T^{i}_{jk} \geq \tau + t^{i}_{jk}\}}{P\{T^{i}_{jk} \geq t^{i}_{jk}\}} \quad (1)$$

The numerator and denominator in the third equality of Eq. 1 can be numerically computed from the FLL histogram that each node keeps. Node j then reports P^{i}_{jk} to the source node via the means of RouteReply (RREP) packets. Upon receiving the RREP, the source computes the probability of Path i's residual lifetime being at least, denoted $p_i(\tau)$as follows:

$$P_i = \prod_{i=1}^{L_i} \{P^{i}_{jk}(\tau)\}, \quad i \in \{1 \dots\dots |\Psi|\} \quad (2)$$

Here, we make a simplified assumption that the residual link lifetimes along the path are treated as independent random variables. In reality, this is not true as correlation exists between two adjacent links that are incident on the same node. Nevertheless, we make this assumption since it is very difficult to incorporate the correlation factor in a multi-hop path.

The decision of selecting the path with the highest probability of meeting the target RPL of τ [sec] is then given by:

$$i^{*} = \arg\max\{P_i(\tau)\} \quad (3)$$

If more than one path has the same $P_i(\tau)$, the shortest path (in hops) is chosen as i^{*}.

2.3 Path Selection Algorithm II (PSA2)

As the destination discovers a set ª of paths each with Length Li[hops], for each path it sends back to the source in the reverse direction of a path an RREP packet. Each node that receives the RREP packet includes in it the age of the link between itself and its downstream neighbor. The node then passes on the packet to its predecessor on the path. When the source node receives the RREP, it now knows the age information of the path's constituent links. We define the path age of a Path i to be the age of the youngest link of the path:

$$a_i = \min\{a^{i}_{j}: j = 1, \dots\dots\dots\dots, L_i\}$$

(4)

The path-selection algorithm then chooses the path with the minimum age:

$$i^{*} = \arg\min(a_i: i = 1, \dots\dots\dots, |\Psi| \quad (5)$$

This simplistic path-selection algorithm, therefore, is based on the assertion that a younger path should have a longer residual path lifetime. When more than one path has the same path age, the shortest one in chosen as i^{*}.

3. PERFORMANCE EVALUATION

All the nodes move with the random mobility (RM) model. In this model, each node independently and randomly chooses the speed and direction of the node, then travels for a constant time duration. At the end of this time period, the node, without pause, randomly chooses a new speed and direction, and repeats the above procedures. The node-disjoint path set is discovered by a multi-path Dijkstra's algorithm in our simulation. Treating the network from a graph-theoretic point of view, each time a path is found using Dijkstra's algorithm, all the intermediate nodes and links incident on them are removed from the graph, and the Dijkstra's algorithm is employed again to find the next path in the residual graph. We have shown previously through simulations that from a set of available paths, the shortest path tends to have a longer residual path lifetime than any longer path [5]. A path selection algorithm that simply chooses the shortest path from all available paths can generally achieve good performance. However, such an algorithm fails to handle situations in which some of the discovered paths are of equal length. Therefore, the performance evaluation below focuses on the special case of equal-length path sets.

3.1. Performance Metrics

We develop two performance metrics to evaluate the effectiveness of the proposed algorithms. It is worth noting, first of all, that evaluating their ability to find a path that meets the target RPL requirement is not as straightforward as it appears. The target RPL is a system parameter in our simulation. If it is set too high, it is likely that none of the paths would meet this requirement; likewise, if the target RPL is set too low, all the paths would likely meet this requirement. Therefore, some adaptive normalization must be built into the performance metrics in order to compensate for the arbitrary choice of the target RPL and make the evaluation meaningful.

In the first performance metric (PM1), we compare each Proposed algorithm with a baseline random-selection algorithm to evaluate the former's ability to find a path that meets the target RPL requirement. The baseline algorithm arbitrarily selects a path from Ψonly if at least one path in Ψ meets the target RPL requirement. We devise two path selection reward schemes, one for the proposed algorithm, and the other for the baseline algorithm. Denote the path selected by the proposed algorithm asi^{*}. For the k-th experiment during the simulation, the reward scheme for the proposed algorithm making a path-selection decision is defined as:

$$D_k = \begin{cases} 1 & , \quad T_{i^{*}} \geq \tau \\ 0 & , \quad O.W \end{cases} \quad (6)$$

Where T_i denotes the actual residual lifetime of i^{*}. The reward scheme for the baseline algorithm is defined as:

$$E_k = \begin{cases} 0 & T_i < \ \forall_i \in \Psi \\ \frac{1}{|\Psi|} & o.w \end{cases} \quad (7)$$

Denote $N_\Psi$as the total number of path-selection decisions for path-set size Ψ made during the simulation. PM1, denoted asγ_1, is therefore defined as follows:

$$\gamma_1 = \frac{\sum_{k=1}^{N_\Psi} D_k}{\sum_{k=1}^{N_\Psi} E_k} \quad (8)$$

The denominator of Eq. 8 is the average number of times the baseline algorithm finds a path that meets the target RPL in the long run, thereby making $100(\gamma_1 - 1)\%$ the performance gain of the proposed algorithm over the baseline algorithm. It can be seen that the range of values λ_1 takes on is $0 \le \gamma_1 \le |\Psi|$.

The second performance metric (PM2) evaluates the ability of the proposed algorithm to choose the path with the longest residual lifetime. Since all the paths in $\Psi$are node-disjoint, the probability of randomly selecting a path from Ψ that has the longest residual lifetime is $1/|\Psi|$ In the simulation, an algorithm selects a path i^* from Ψ, and all the nodes continue moving until the last path breaks. If it is i¤ that breaks the last, the selection decision made by the algorithm is called a success. Denote $N_{\Psi,s}$ as the number of successes for path-set size Ψ in the simulation. PM2, denoted byγ_2, is defined as:

$$\gamma_2 = \frac{\frac{N_{\Psi,s}}{N_\Psi}}{\frac{1}{|\Psi|}} = \frac{|\Psi| N_{\Psi,s}}{N_\Psi} \quad (9)$$

The range of PM2 is$0 \le \gamma_2 \le |\Psi|$ with a larger value indicating a greater gain of the proposed algorithm over the baseline algorithm.

4. SIMULATION ENVIORNMENT

To test the performance of cost metric values and to compare with tree based architecture send all packets queued in the send buffer destined for this destination. Observe the performance of cross layer path metric algorithm, simulations are performed using the ns-2 simulator; Here the two ray/ground propagation models are discussed. Simulation parameters are presented in Table I. Then the random way-point mobility model is used for nodes moving within a 5000m by 5000m area. There are 42 mobile nodes in this scenario and the source node is located in the various end of the network. The transmit range of neighboring node is 200m. Radio model is used as transmission model.

The TCP (Transport Control Protocol) and loss monitor is used as agent. The queue maximum size is 512 packets. The parameters like total energy, residual energy, throughput, packet delivery, end to end delay are considered for the evaluation of performance.

TABLE I

Simulation Parameter	VALUE
Network area	5000m x 5000m
Number of Nodes	42
Traffic Type	CBR
Radio Propagation Model	TwoRayGround
MAC Protocol	IEEE 802.11
Ad hoc Routing Protocol	AODV
Proposed Algorithm	PAODV
Simulation Time	20,40,60,80 Seconds
Transmit range	200 m
Initial energy	60 J
Maximum energy	240 J

5. RESULTS AND DISCUSSION

We generate a number of simulation scenarios that apply the PMs to each of the three proposed path-selection algorithms. For each scenario, 42 nodes statistics are collected to compute the PMs. In order to maintain consistency of the results, all the algorithms perform path-selection operations using the same statistical data as input.

We also evaluate the performance of the proposed algorithms by comparing γ_1 and γ_2 obtained in simulation with their theoretical upper bounds (i.e., $|\Psi|$). We define the ratio of $\gamma_i$to $|\Psi|$ to where i = 1, 2, to be the metric efficiency of Performance Metric i. Similarly, by fixing the path-set size, the metric efficiency decreases as the path length increases. The above evaluation method may also be applied to compute the metric efficiency for PM2. Since the best that any algorithm can do is to achieve 55% performance gain over the baseline algorithm.

A. Average Energy Consumption

The whole simulation time is 80s. The initial energy is given as 60J. The entire graph shown below in Fig.1 for energy consumption of wireless nodes is comparison of PADV and CPAODV algorithm.

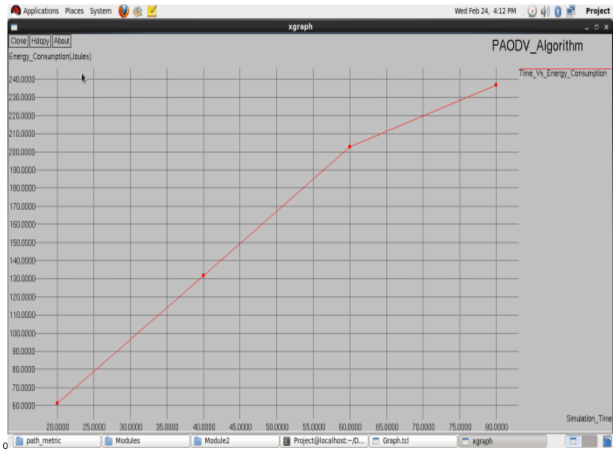

Fig 1: Performance Metric 1 for Path AODV Energy

B. Throughput

Throughput is the amount of data per unit time that is delivered from one node to another node via communication link. The throughput is measured in bits/second. In the Fig. 2, throughput of PAODV algorithm for 42 nodes simulation time is 80seconds.

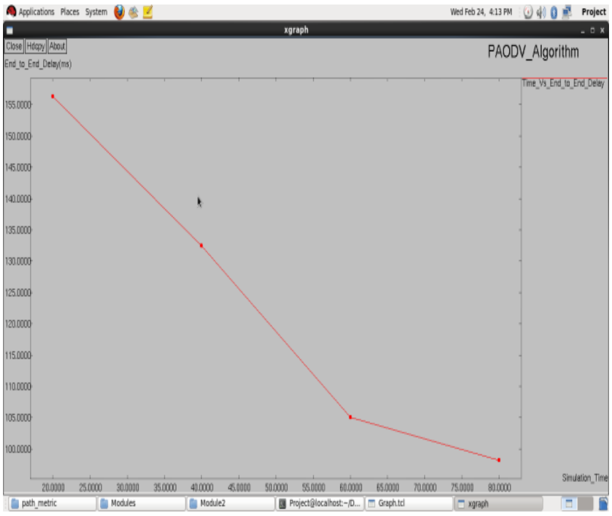

Fig 2: Performance Metric Throughput 2 for Path AODV Algorithm

C. End to End Delay

The Fig. 3 shows the result for delay for existing and proposed algorithm. The delay is high in PAODV algorithm due to high congestion in the network. But the proposed cross PAODV architecture achieves low delay in high congestion.

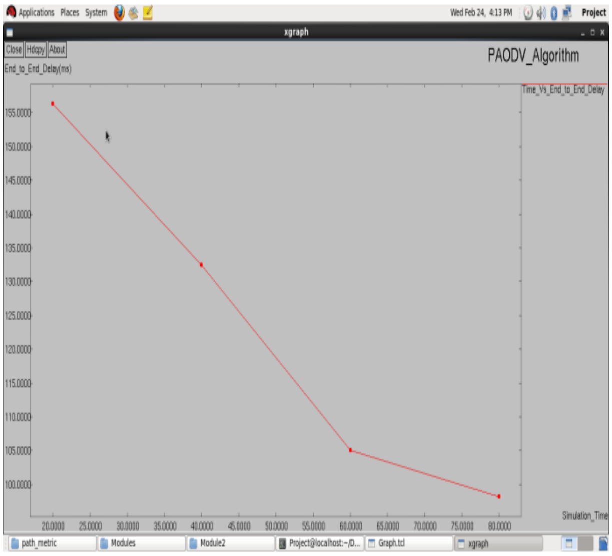

Fig. 3: Performance Metric End to En d Delay for Path AODV Algorithm

D. Packet delivery ratio (PDR)

The Fig. 4, Shows the result for packet delivery ratio (PDR) for PAODV and CPAODV algorithm. The CPAOD algorithm achieved high packet delivery at the destination compared to PAODV algorithm. The mechanism is followed to achieve high PDR even though the path is failure.

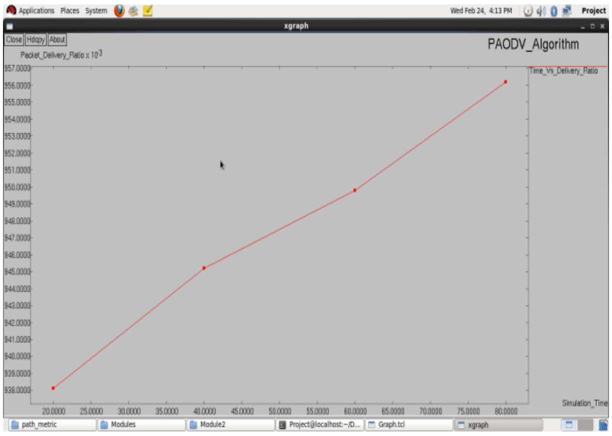

Fig 4: Performance Metric PDR for Path AODV Algorithm

The Performance is consistently better at high average speed than at low average speed. Similar results are observed for the other two algorithms as well. This shows that these algorithms perform better in a high-mobility environment than in a low mobility one.

Another interesting observation from the simulation results above is that PSA2 has comparable performance to PSA3 in both the path-selection criteria. Although its performance suffers a little compared with PSA1, PSA2 is a very simple and straightforward algorithm that, unlike PSA1 and PSA3, does not rely on the construction of a FLL histogram in each node; all it requires is the beacon mechanism. This means that PSA2 can be invoked as soon as the network is deployed, without undergoing the initial FLL-collecting phase.

6. FUTURE WORK

Selecting the best path from all the available paths based on mobility-induced residual path lifetime is, to the best of our knowledge, a largely unexplored area of study in MANET research. One of the strengths of the proposed algorithms is that it does not require any sophisticated HW/SW. This simplicity, however, imposes some fundamental limitation on their performance. Our preliminary investigation shows this limitation may be related to the shape of the probability density function of FLL, in which the density of a very large range of FLLs may be approximately modeled by the memory less exponential distribution, which implies that any prediction for FLL that falls in this range given current link age may not be possible. The true cause of this fundamental limitation is currently under further research. For the PSA3, where we consider a path that consists of links neither too old nor too young, there are some open issues to be studied. In particular, we wish to study how to optimally define the boundaries of different FLL groups in a mobile environment that would allow PSA3 to yield better performance.

Furthermore, we are studying new approaches to collect empirical link lifetime statistics that will aid the decision making of path selection, and are working on a new algorithm to investigate its performance potential. We are also developing a testing mechanism that would allow us to evaluate the performance of the class of age-based path-selection algorithms expediently over a wide range of mobility scenarios.

7. CONCLUSION

Selecting the best path from all the available paths based on mobility-induced RPL is a relatively unexplored new area of study. In this paper, we propose three simple, implementable path-selection algorithms that are aimed at making intelligent path-selection decisions to choose the best one from a path set. By "best," we mean either a path is most likely to meet a requirement for desired residual path lifetime, or that it is most likely to have the longest residual lifetime among all paths in the path set. We evaluate the performance of the proposed algorithms with respect to two path-selection criteria which we have introduced, by introducing two performance metrics for the criteria. The algorithms are compared with each other and with a baseline random-selection algorithm, which arbitrarily chooses any one of the available paths. Our simulations show that the proposed algorithms have comparable performance among themselves, with PSA1 achieving the best performance with respect to the two criteria. The performances of all three algorithms over the baseline algorithm improve as the size of the path set increases. Furthermore, we showed in simulation that these algorithms perform better in a high mobility environment than in a low-mobility one.

For future work, we wish to improve the performance of presented in this paper. We also want to investigate the cause of the fundamental limitation on the performance of the proposed algorithms. Furthermore, we are designing a new path-selection algorithm with a different technique of utilizing link lifetime statistics collected empirically by each node.

8. ACKNOWLEDGMENTS

Mr.M.D.Nikose received the BE. Degree from the Rashtra Sant Tukdoji Maharaj Nagpur University in 2008, and the M-TECH degree in Electronics and telecommunication Engineering from the V.J.T.I University of Mumbai, India in 2010. He is currently perusing PhD from Rashtra Sant Tukdoji Maharaj Nagpur University. His current research interests focus on cross-layer designs for resource-efficient network function for wireless ad hoc networks and improve different QoS parameters for TCP/IP performance.

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