LSLP: Link Stability and Lifetime Prediction Based QoS Aware Routing for MANET

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Abstract

As mobile ad hoc network is burgeoning, different applications are developing with different service requirement. In particular multimedia applications and other real-time applications e.g. voice transmission requires very stringent and inflexible quality of service (QoS). A great magnitude of attention has been paid against cost and energy consumption and mobility for non-QoS-aware routing protocols. While QoS-aware routing protocols put emphasis on QoS matrices and mobility individually. Unrestricted mobility of nodes invalidates old paths, causing the packets of the flow to wait until the routing protocol is able to get information about the new paths. This degrades the performance of the network, reducing the throughput and increasing the delay and packet loss. In this paper, we mingled the idea of link stability and energy consumption to uncover better path in terms of both stability and cost along with QoS support.

Key Words: MANET, Routing, Quality of Service

1. Introduction

A mobile ad hoc network is envisaged as a collection of mobile nodes with no fixed infrastructure and with no central authority. Extensive use of portable mobile devices and the increasing demand of connectivity among the devices have made mobile ad hoc network as one of the flourishing frontier of wireless research. A variety of applications exist like personal area networking, disaster management, relief and rescue operation, military, business and other scientific applications. Mobile ad hoc network is a self-configured and self-maintained network with no centralized authority. Other remarkable features of MANET include quick and inexpensive deployment and network with unrestricted mobility. Every node in MANET acts as both a host and a router and must perform some network function. As a consequence MANET faces routing challenges for its dynamic nature.

With the development of the MANET, people pay more and more attention to the power aware routing strategy and QoS routing strategy. Because mobile hosts in the network such as PDA, notebook are mostly power constrained, saving their power and consequently prolonging the lifetime of the network is the focus of the power aware routing strategy. While with the wide deployment of MANET, the demand for providing different quality of service in the network has increased much. QoS routing strategy focused on routing strategy for different QoS in this dynamic network. Much progress has been made in both areas [18]. However, there is little research work has been done to combine these two strategies. It is very evident that there are some contradictories between QoS routing and power aware routing. For the traditional QoS routing scheme in the Internet, all routers in the network should know all nodes and links state before they make their routing decisions. Frequent information exchange about the network status occurs among all the nodes. This will aggravate the energy draining rate of the ad hoc network if it applied without any changes. For the power aware routing strategies in the MANET, its main purpose is to save the energy and to prolong the lifetime of the network. It can't provide any service quality guarantee. It's an interesting and complex problem to combine them together to satisfy both the QoS and the energy requirements.

Variable link conditions are intrinsic characteristics in most mobile ad hoc networks. Rerouting among mobile nodes causes network topology and traffic load conditions to change dynamically. Given the nature of MANET, it is difficult to support real-time applications with appropriate QoS. In some cases it may be impossible to guarantee strict QoS requirements. But at the same time, QoS is of great importance in MANETs since it can improve performance and allow critical information to flow even under difficult conditions. Unlike fixed networks such as the Internet, quality of service support in mobile ad hoc networks depends not only on the available resources in the network but also on the mobility rate of such resources. This is because mobility may result in link failure which in turn may result in a broken path. Furthermore, mobile ad hoc networks potentially have fewer resources than fixed networks. Therefore, more criteria are required in order to capture the quality of the links between nodes. Quality of service routing is a routing mechanism under which paths are generated based on some knowledge of the quality of network, and then selected according to the quality of service requirements of flows. Hence, the task of QoS

This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD)" (KRF-2006-521-D00394)

routing is to optimize the network resource utilization while satisfying application requirements.

From the above discussion it is very evident that two major factors mobility and energy efficiency need to be considered to assure better network performance. Specially while assuring QoS in MANET environment nodes should not die due to power constraint or the links should not expire due to mobility in the middle of the transmission. So our target is to choose a more stable path considering higher link stability and less cost along predicted higher life path. In this paper we combine the idea of link stability calculation based on mobility prediction and best path in terms of cost and lifetime along with QoS support. Considering these parameters we present a routing algorithm which performs better in terms of blocking history, cost and lifetime. Simulation justifies our claim in the latter section.

Next portion of our paper organizes as follows: Section 2 introduces related works regarding routing protocols for MANET, section 3 articulates the impact of mobility on the QoS of MANET and section 4 describes our proposed algorithm and then section 5 justifies our claim of improved performance through simulation results.

2. Related Works

A good number of routing protocols [13][16][17] already been proposed for mobile ad hoc network. Proposed routing protocols are often subdivided in two categories: Proactive (table driven) and reactive (on demand) routing protocols. Recent work on routing has focused primarily on investigating the impact of path selection criteria (e.g, shortest disjoint paths) and alternate or back-up routing for energy efficiency and load balancing [8]–[10]. Other related work is based on analytical models that do not take into account cross-layer interactions [11], [12]. That is, performance evaluations based on such models do not consider the impact of other layers on path selection and routing efficiency.

QoS-aware routing requires reservation of resources at the intermediate mobile nodes. However, with the changes in topology the intermediate nodes also change, and new paths are created. Thus, reservation maintenance with updates in the routing path becomes complicated. A number of QoS-aware research works have been presented in [4]-[8]. In [4] QoS aware source initiated ad-hoc routing protocol have been proposed that adds quality control to all the phases of an on demand routing protocol. Protocol gathers information about battery power, signal strength, bandwidth and latency during route discovery and uses in route choosing. The Flexible QoS Model for MANETs (FQMM) in [14] adopts the idea of DiffServ to MANETs. But it is not scalable and does not consider high mobility.

Our work is motivated by a novel idea represented [1] and [2]. The idea of mobility prediction is introduced in [1]. [2] Formulated the routing problem as maximizing the network lifetime while minimizing the routing cost. Cost and energy efficiency, mobility and QoS have paid a great magnitude of attention independently. Little research effort has been given to combine all these ideas. Our work coalesced the idea of mobility prediction and cost effective lifetime prediction along with QoS support to uncover more stable route.

3. Impact of Mobility on the Qos Of MANET

One of the main challenges in providing QoS in mobile ad hoc networks is the mobility of the nodes, which makes connectivity unpredictable. The movement of the nodes constantly invalidates old paths, causing the packets of the flow to wait until the routing protocol is able to get information about the new paths. This degrades the performance of the network, reducing the throughput and increasing the delay. This also intuitively implies that the performance of the network will be different under different mobility scenarios of the nodes. Arora et al [3] have analyzed the variation in the throughput and delay experienced by the packets under different mobility scenarios, varying parameters such as node speed and movement patterns. It is therefore very important to have an estimate of the average speed of movement of the nodes to provide QoS assurances to the applications of a network. The detail of performance evaluation under various traffics is out of the scope of our paper. We have articulated the necessity of measurement of link stability in order to provide QoS while selecting route. For detailed understanding of the impact on mobility on performance we refer [3].

4. LSLP: Proposed QoS Aware Routing

The need for QoS arises in the application layer. Application layer demands transport layer to provide QoS services. Transport layer requests the routing layer to compute routes satisfying QoS requirements. In Cost Effective Lifetime Prediction Routing [2] (CLPR) has given entire emphasis on the end-to-end energy consumption and based on that selects the minimum cost path based on total energy required to transmit on that path. To achieve QoS path along with prolonging the network life time and to reduce packet loss we need to calculate three parameters for a path:

i. Path Stability
ii. Lifetime prediction and
iii. Ratio of QoS support and requirements

To calculate the above parameter for path selection we define the network model first and then we will subsequently describe the process of calculation for each the parameters.

4.1 Network Model:

We define our network model as N = (V, E, C, Q) where V = {v1,….,vn} that represent nodes, a set E ⊆ V x V of edges $\{(v_i, v_j), 1 \le i, j \le n\}$ that connect all the nodes, and a weight function C: E→R (Rational number) for each edge (vi, vj) that indicates the transmission cost of a data packet between node vi and vj and parameter Q is added to represent the QoS constraint. Q is also defined as a function Q: T→R (Rational number) which indicates the quality of service support for a traffic. QoS matrices include many parameters e.g. delay, bandwidth, buffer level. For simulation we introduce a rational number to represent the QoS constraint. It is worth mentioning that real time deployment of the algorithm requires more specific value to represent QoS matrices.

4.2 Reckoning of Path Stability:

To identify path stability we need to know individual link stability along the path. We define link stability in terms of link expiration time which means maximum time of connectivity between any two neighbor nodes. In order to calculate the link expiration time we assume motion parameters of any two neighbors are known. Let n1 and n2 be two nodes within the transmission range r and x′1, y′1 and x′2, y′2 be the coordinate for node n1 and n2 with velocity v1 and v2 and direction θ_1 and θ_2 respectively. Let after a time interval t the new coordinate will be x1, y1 for n1 and x2, y2 for n2. For time t let d1 and d2 be the distance traveled by node n1 and n2. We can calculate d1 and d2 using the following formula:

$$d_1 = v_1 t \qquad (1)$$

$$d_2 = v_2 t \qquad (2)$$

New coordinates (with respect to old coordinates) can be calculated using the following formula:

$$x_1 = x'_1 + x_1 = x'_1 + d_1 \cos\theta_1 = x'_1 + t(v_1 \cos\theta_1) \qquad (3)$$

$$y_1 = y'_1 + y_1 = y'_1 + d_1 \sin\theta_1 = y'_1 + t(v_1 \sin\theta_1) \qquad (4)$$

$$x_2 = x'_2 + x_2 = x'_2 + d_2 \cos\theta_2 = x'_2 + t(v_2 \cos\theta_2) \qquad (5)$$

$$y_2 = y'_2 + y_2 = y'_2 + d_2 \sin\theta_2 = y'_2 + t(v_2 \sin\theta_2) \qquad (6)$$

Distance between two nodes at time t will be obtained from:

$$D = \sqrt{\begin{array}{l}\{(x'_1 - x'_2) + t(v_1 \cos\theta_1 - v_2 \cos\theta_2)\}^2 \\ +\{(y'_2 - y'_2) + t(v_1 \sin\theta_1 - v_2 \sin\theta_2)\}^2\end{array}} \qquad (7)$$

When the distance between two nodes becomes larger than the transmission range the nodes will be disconnected. For transmission range r link stability Sl between any two nodes overtime period t can be calculated by:

$$L_{st} = \frac{r}{\sqrt{\begin{array}{l}\{(x'_1 - x'_2) + t(v_1 \cos\theta_1 - v_2 \cos\theta_2)\}^2 \\ +\{(y'_2 - y'_2) + t(v_1 \sin\theta_1 - v_2 \sin\theta_2)\}^2\end{array}}} \qquad (8)$$

Note that Lst is the link stability of individual links between any two nodes and for a path it is a concave parameter and it is same as the minimum link stability along the path. For a path from source to destination path stability Pst is given by

$$P_{st} = Min(L_{st}(1), L_{st}(2), L_{st}(3)......, L_{st}(n)) \qquad (9)$$

Where 1,2,3…n is the number of links along the path.

4.3 Cost Effective Lifetime Prediction for a Path:

For n paths (π1, π2,….πn) from source to destination, lifetime of a path is bounded by the lifetime of all the nodes along the path. When a node dies along a path we can say that the path does not exist any longer. So we can consider the lifetime of a path is a concave parameter and it is the same as the minimum lifetime among all the nodes along the path. The lifetime of a path πi can be defined as:

$$\tau_i = Min(T_j(t))......\{j \in i\} \qquad (10)$$

Tj(t): predicted lifetime of node j in path πi
The cost of a path is the sum of all the costs calculated between two consecutive nodes along the path from source to the destination. Cost of a path πi can be defined as:

$$\varsigma_i = \sum_{j=1}^{\pi_{i_m}-1} c_{\pi_{i\,j,j+1}}(t) \qquad (11)$$

Where π_{i_m} is number of nodes in path πi and $c_{\pi_{i\,j,j+1}}$ is the cost between node j and j+1 of the path πi. We represent the cost effective predicted lifetime L_{pt} by:

$$L_{pt} = \frac{\tau_i}{\varsigma_i} \qquad (12)$$

4.4 QoS Aware Route Selection:

QoS is an agreement to provide guaranteed services, such as bandwidth, delay, delay jitter and packet delivery rate, to users. Supporting more than one QoS constraint makes the QoS routing problem NP-complete [17]. Therefore we must consider any of the above mentioned services. We can adopt 'listen' or 'hello' based available bandwidth estimation described in [17]. Note that paths satisfying the requirement of minimum bandwidth specified by traffic will be considered as a candidate of our final route choice. Our intension is to select a more stable path with lower communication cost to achieve reduction in packet loss and prolonged lifetime of the network along with QoS support. We obtain the stability P_{st} of the path from equation (9) and lower cost path based on lifetime prediction L_{pt} from equation (12). Finally our path selection parameter χ is represented by:

$$\chi = \frac{P_{st} \times L_{pt}}{abs(P_{st} - L_{pt})} \qquad (13)$$

We select the path that maximizes the value of χ. It is to be noted that the multiplication of link stability and cost effective lifetime prediction may result same value for different parameter value (e.g P_{st} =5 and L_{pt} = 10, again P_{st} = 25 L_{pt} = 2, both results 50 but one with better link stability and the other with better cost). To get the best possible path with higher link stability and lower cost we divide the result by their difference. In the route discovery process each node will decide the next hop which maximizes the value of χ for the desired destination. It should be noted that selected path must satisfies the QoS requirement requested by the traffic.

5. Simulation

We evaluate the performance of the proposed LSLP using simulation and compared it with that of the LPR (Lifetime Prediction Routing), CLPR (Cost Effective Lifetime Prediction Routing) and PAR (Power Aware Routing). In this section we describe the simulation environment, experimental results and comparison of the four related protocols.

5.1 Simulation Setup:

For our simulation, we used up to 28 nodes distributed randomly over the simulation area; confined in a 500X500 m^2. Every node has a fixed transmission power resulting in a 50 m transmission range. We use "random waypoint" model to generate node movement. Random connections were established between nodes within the transmission range. The lifetime of a node is varied between 1 and 600 while the transmission cost between two neighboring nodes is varied between 2 and 11. For the simplicity of simulation we set the range of the stability parameter with the same value that is considered incase of lifetime. The simulation was run for 400 times. Each packet relayed or transmitted has a cost factor. If the cost factor is n then $n-1$ is considered as the cost at the transmitter node and remaining unit cost goes to the receiving node. So transmission band may vary with in 1 to 10 where receiving band is same (unit cost) for all the nodes in the network

5.2 Simulation Result:

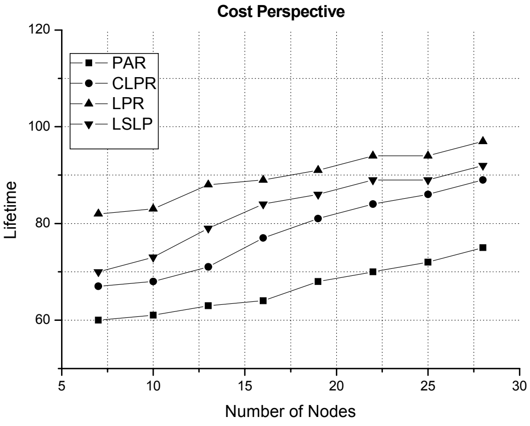

Fig. 1. Comparison of Cost among four related protocols

Figure 1 depicts the results of our simulation in cost perspective. Transmission cost of LSLP lies between PAR and LPR and it is closer to CLPR. The mobility property incorporates the extra cost to LSLP as compared to CLPR. Figure 2 shows the time for individual node to run out of power. In PAR, first node run out of power shortly as it is frequently selected by neighboring nodes. LPR maintains the longest lifetime for individual node among the three protocols as nodes are selected based on the remaining energy of that node. However, it can also be observed from the figure that LPR goes closer to other protocols after 25% of the total nodes die. As LSLP maintains the balance between PAR and LPR, it is not inferior to CLPR much. Figure 3 shows the average of the observation of network lifetime. The lifetime of a sensor network is defined as the time for the certain percentage of network nodes as in [16] to run out of power. In our simulation, we considered network lifetime until 40% of total nodes die. Some of the nodes, alive at this point are also rendered unreachable since many of the nodes have exhausted their energy and hence they cannot reach other nodes consistently.

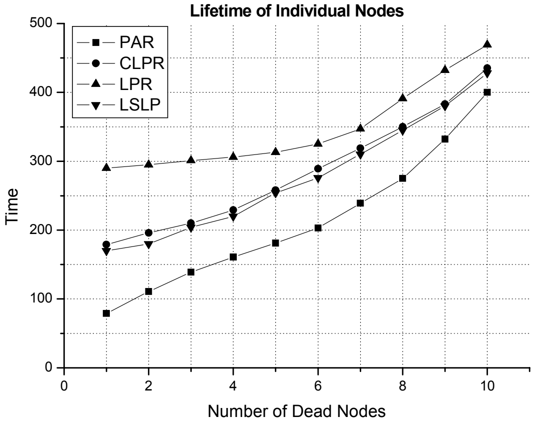

Fig. 2. Lifetime of individual node among four related protocols

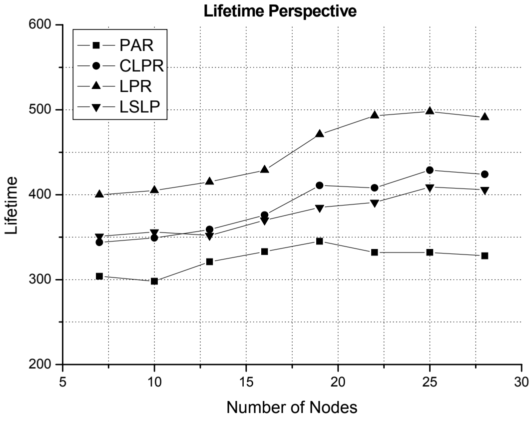

Fig. 3. Comparison of Lifetime/stability among four related protocols

Figure 4 shows the blocking probability of the protocols over simulation time. It can be observed that LSLP outperforms all the three protocols through out the whole simulation. As LPR, PAR and CLPR can't provide any

QoS guarantee, if the selected route cannot provide the required QoS, the requests are simply ignored. The lower blocking probability of LSLP is incorporated from its combination QoS, lifetime and cost parameters. LSLP does not suffer extremely from either of the routing cost or network stability, as it is not biased by a single parameter. Similar to CLPR, it maintains a balance between these two parameters and additionally offers low blocking probability.

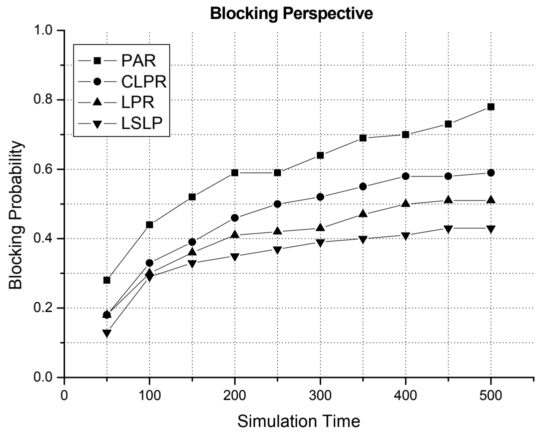

Fig. 4. Blocking probabilities among four related protocols

6. Conclusion

In our work, we have formulated the QoS aware routing problem as maximizing the link stability and lifetime while minimizing the cost. Link failure due to mobility or power failure always hinders communication and increase number of packet loss which in turn cause glitch for quality assurance. Our algorithm selects the best path in terms of link stability and lower cost lifetime prediction to minimize blocking probability along with QoS support. LSLP can reduce blocking probability up to 20% than that of other algorithms. LSLP decreases network life time a little than that of CLPR at the cost of better network performance and throughput as it will reduce packet loss due to network disconnection. Our proposed method formulates a tradeoff between link stability and cost which will ensure a disruption free communication for transmission.

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