Link Prediction in Mobile Ad hoc Network

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Abstract

Mobility is the main cause of frequent route breaks in mobile ad hoc network. This results in frequent route changes that adversely affect the QoS in the network. QoS can be improved by using alternative routes before current route gets broken. Therefore, it is important to know how long a route will be available. The status of the routes can be determined if the availability of links between the nodes can be predicted. In this paper, we introduce an analytical model for link prediction. Since, the exact distribution of link availability is unknown, we have applied Laplace distribution. Epoch length and cumulative contribution of other factors causing link breaks between nodes have been considered as two key parameters of the distribution.

Keywords – QoS, Link Prediction, Laplace Distribution,

1. Introduction

Mobile Ad hoc Network (MANET) [1] is co-operative collection of mobile nodes communicating with each other through wireless links, without requiring any supporting infrastructure. In MANET [2] all the nodes can connect dynamically in an arbitrary manner due to their mobility. The nodes in the network behave both as autonomous nodes and as routers. In MANET, node mobility affects the quality of service requirement of applications by causing frequent link failures. Quality of Service can be assured by achieving a more deterministic network behavior [3, 4]. In MANET, because of the random mobility of the nodes network behavior is not deterministic mostly. Therefore, probabilistic approach can help in predicting the network behavior and thus providing QoS.

In this paper, a probabilistic approach is used that can help in using the alternative routes before the current route is broken. This will help in better transmission and lesser end-to-end delay of message delivery. Availability of a route in future mainly depends on the availability of links between the nodes forming the route. Therefore, it is important to predict the future availability of a link that is currently available. Here, we have introduced an analytical model for link prediction using Laplace distribution. Since the exact distribution of link availability is unknown, we have applied Laplace distribution considering epoch length and cumulative contribution of other factors (such as energy dissipation, congestion, fading, etc.) as two parameters of the distribution.

The paper is organized as follows. In section 2, brief introduction of the related work done in the area of link prediction is given. Section 3 gives the details of link prediction model proposed for estimation of link availability. The analytical results based on the proposed model are discussed in section 4. Finally, section 5 summarizes the work and suggests future research directions.

2. Related Work

Damla Turgut, Sajal K. Das and Mainak Chatterjee [5], present an algorithm that predict the expected lifetime of the link which is independent of speed and direction of nodes in the networks for different mobility models. They predicted the lifetime of a route based on transmission range of node.

Shengming Jiang, Dajiang He and Jianqiang Rao [6] have proposed a prediction based link availability estimation model for MANET. This model predicts the probability of an active link between two nodes being continuously available for a given period based on the node movement. They used exponential distribution for prediction of link availability. In this model authors considered the change of node movement, but did not consider other factors that may affect the link availability.

Min Quin, Roger Zimmermann and Leslie S. Liu [7] developed a model for predicting the availability of link between mobile peers for supporting multimedia streaming. The authors have presented a mathematical framework for analyzing the link predictability for a short duration.

Dario Pompili and Marco Vittucci [8], proposed a probabilistic predictive multicast algorithm for ad hoc networks. This algorithm predicts the next position of a mobile node after a time interval based on the current position of the node. The knowledge of the next position of the node helps routing algorithm to get a stable link in the network. Authors developed an analytical model based on the next position and remaining energy of a node for the link prediction.

K´aroly Farkas, Theus Hossmann, Lukas Ruf, and Bernhard Plattner [9] proposed an approach to predict link quality variation based on pattern matching which is affected by mobility of nodes. This approach called XCoPred. Authors used SNR (Signal to Noise Ratio) for link prediction. For link prediction, a node tries to detect the pattern similar to the current situation in the history of the SNR values of its link by applying normalized cross-correlation function.

Most of the prediction models are simulated with DSR algorithm. DSR is one of the most common dynamic source based routing algorithm for MANET [10]. However, AODV is another on-demand routing table based routing algorithm [12]. DSR and AODV are topology based routing algorithms. In MANET position based routing algorithms that use location information for route discovery or data transmissions are also important [14]. LAR algorithm is one of the most common algorithms used in MANET research in position based routing [13].

3. Link Prediction Model

In this section, we introduced a model to estimate the future status of link availability using Laplace distribution. In this model, we assume that the mobility epoch lengths are exponentially distributed with mean μ, and b the cumulative contribution of other factors. An epoch is considered as a random variable and defined as a random length interval during which a node moves in a constant direction at a constant speed. The probability of epoch length lesser than equal to x is given as

$F(x) \cong$ P {Epoch length ≤ x}

$F(x)$ is cumulative distribution function for Laplace distribution and is given below:

$$F(x) \underline{\underline{\Delta}} \frac{1}{2b}\int_0^{\mu} e^{\frac{(x-\mu)}{b}} dx + \frac{1}{2b}\int_{\mu}^{t_p} e^{-\frac{(x-\mu)}{b}} dx$$

The parameter b represents the effects of variance in cumulative contribution of other failure such that probability of link availability changes rapidly for higher value of b. For an active link between two nodes at time t_0, the availability of this link $L(Tp)$ for T_p time period is defined as

$$L(T_P) \underline{\underline{\Delta}} P\{epoch > t_0 + T_p \mid \text{Link available at } t_0 \}$$

$L(T_P)$ is calculated in two parts. First, the link availability $L_1(T_P)$ is calculated when the velocities of the two nodes keep unchanged between t_0 and $t_0 + T_p$. In second case, $L_2(T_P)$ represents the condition when both the nodes change their velocity. Therefore, $L(T_P)$ is calculated as

$$L(T_P) \cong L_1(T_P) + L_2(T_p) \quad (1)$$

We can easily calculate $L_1(T_P)$ as the nodes are not changing velocity. It will be equal to the $P\{epoch > t_0 + T_p$ | link is available at t_0 } and is given as

$$L_1(T_p) = [1 - F(T_p)]^2$$
$$= \frac{\left(e^{-\frac{\mu}{b}} + e^{-\frac{(t_p-\mu)}{b}}\right)^2}{2} \quad (2)$$

Let Φ is a random variable that denotes variable time interval $t_0 < \Phi < T_p$ during which one or both the nodes change velocity. We assume that $t_0 < \phi$ is time interval in which nodes are not changing their velocity. After $t_0+\phi$ time, nodes change their velocity. $P\{\phi<\Phi<T_p\}$ denotes the probability that both the nodes do not change their velocity between t_0 and $t_0+\phi$ and either of them or both change velocity after $t_0+\phi$. Therefore, $P\{\phi<\Phi<T_p\}$ is given as

$$P(\phi<\Phi<T_p)=2[F(T_p)-F(\phi)][1-F(T_p)]+[F(T_p)-F(\phi)]^2$$

$$=\left[e^{-\frac{\phi}{b}}-e^{\frac{T_p}{b}}+e^{-\frac{(T_p+\phi+2\mu)}{b}}+e^{-\frac{2(T_p-\mu)}{b}}\right] \quad (3)$$

$l_2(\phi)$ denotes the estimate of link availability, when nodes are changing their velocity after ϕ time interval. This is given as

$$l_2(\phi)=\frac{\phi+(T_p-\phi)pL_1(T_p-\phi)}{T_p}+\varepsilon$$

$$=\frac{\phi+(T_p-\phi)\frac{p}{4}\left(e^{-\frac{\mu}{b}}+e^{-\frac{(T_p-\phi-\varpi)}{b}}\right)^2}{T_p}+\varepsilon \quad (4)$$

where p represents the probability that two nodes move closer to each other after changing their velocity. $\varepsilon\geq 0$ is an adjustment to the link availability.

Now $\overline{l_2}$ denotes the average $l_2(\phi)$ over ϕ, and is used to estimate $L_2(T_p)$. $\overline{l_2}$ is given as

$$\overline{l_2}=\int_0^{T_p} l_2(\phi)f(\phi)d\phi \quad (5)$$

where $f(\phi)\geq 0$ is given by

$$f(\phi)=\lim_{\Delta\phi\to 0}\frac{P(\phi\leq\Phi\leq T_p)-P(\phi+\Delta\phi\leq\Phi\leq T_p)}{\Delta\phi}$$

$$= -\frac{dP(\phi \le \Phi \le T_p)}{d\phi}$$

$$= -\frac{1}{2b}\left(2e^{\frac{\phi}{b}} - e^{\frac{2(\phi-\mu)}{b}} - e^{\frac{(T_p+\phi+2\mu)}{b}}\right) \quad (6)$$

By substitute $l_2(\phi)$ and $f(\phi)$ in Eq.5 from Eq. 4 and 6, respectively, we obtain the following.

$$\overline{l_2} = \int_0^{T_p} L_2(\phi) f(\phi) d\phi \quad (7)$$

Therefore, $L(T_P)$ is estimated as follows:

$$L(T_p) \approx L_1(T_p) + \overline{l_2} \quad (8)$$

4. Analytical Result

The analytical model derived for the link prediction is solved to obtain the results. The results were calculated for different values of parameters μ and b. Result for two epoch length intervals, i.e. 60 s and 100s is considered. For both values of µ different three different values, i.e. 150, 200, and 250 of b are assumed. The results show that the probability of link availability decreases as the epoch length increases since the nodes are mobile the links between them cannot remain for a longer time period. As the value of b increases, the probability of link availability decreases. Since b represents cumulative contribution of other factors, therefore, increases in b denotes faster energy loss, more congestion or fast fading and the link will not last longer.

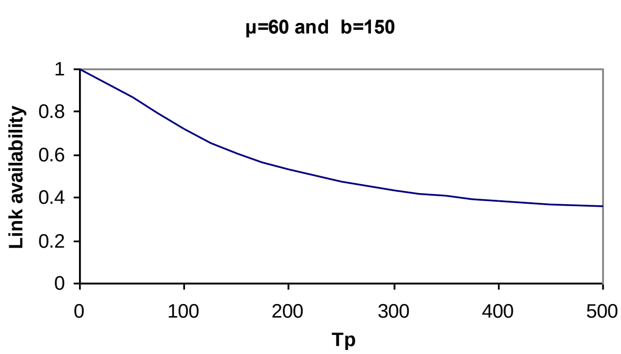

Fig. 1

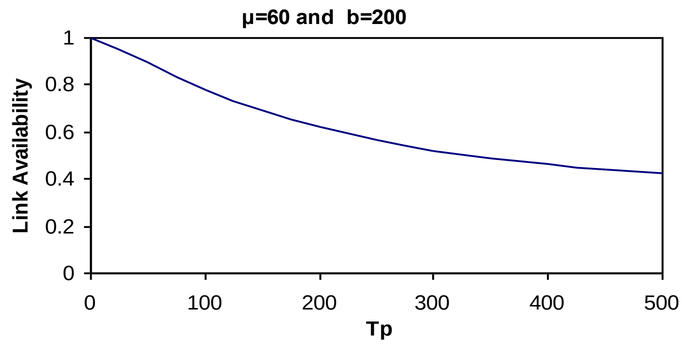

Fig. 2

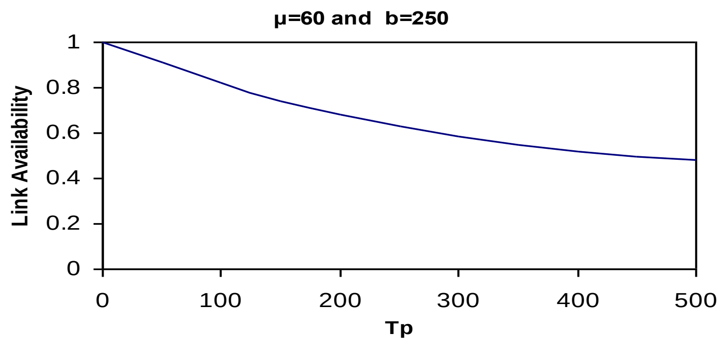

Fig. 3

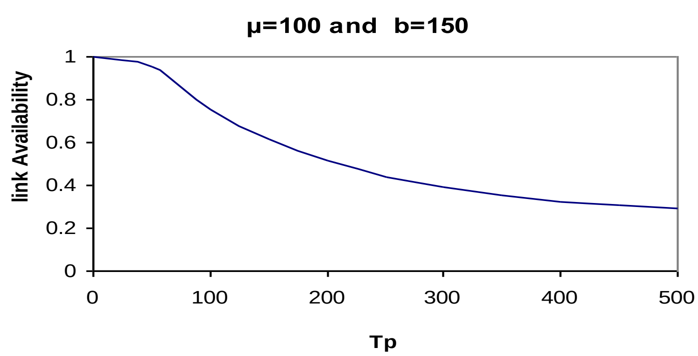

Fig. 4

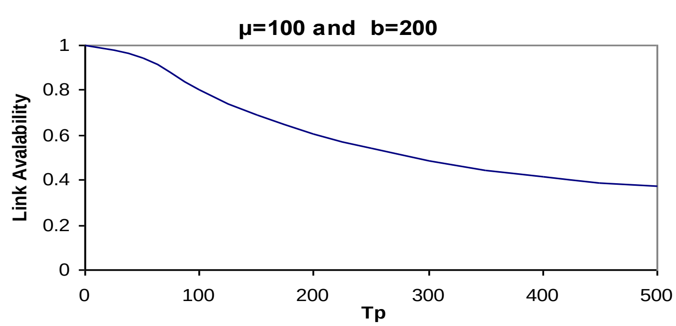

Fig. 5

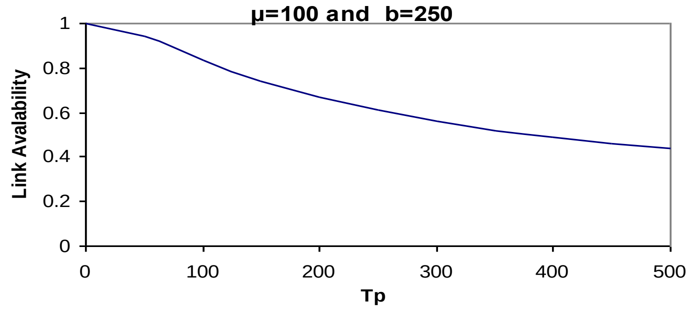

Fig. 6

5. Conclusion

In this paper, we have proposed an analytical model for link prediction in mobile ad hoc network using Laplace distribution. The value of parameter *b* is chosen from experiments. However, a model is required to estimate the value of *b*. This forms the future extension of our current work along with developing a model using other distributions. Also, the performance of the model can be evaluated for other routing algorithms.

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