An Analytical Model to Estimate Path Duration in MANETS- Ad Hoc Networks

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Abstract—Mobile Ad Hoc Networks (MANET) are formed by wireless devices that intercommunicate without the utilization of any centralized entity that manages the radio resources. As direct communication is only possible for neighbour nodes, the transmission of information between distant devices is supported by the cooperation of intermediate nodes that retransmit and route their packets. Path duration is an important design parameter that determines the performance of a mobile ad hoc network (MANET). For example, it can be used to estimate the route expiry time parameter for routes in “on demand” routing protocols. An analytical model to estimate path duration in a MANET using the random way point mobility model as a reference. This paper proposes the criterion based on the estimation of the Mean Residual Path Lifetime.

Keywords — MANET, Radio resources, Mobile Ad Hoc Network, Mean, Wireless Devices.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANET) is formed by wireless devices that intercommunicate without the utilization of any centralized entity that manages the radio resources. As direct communication is only possible for neighbour nodes, the transmission of information between distant devices is supported by the cooperation of intermediate nodes that retransmit and route their packets. The sequences of intermediate nodes involved in the retransmission process constitute route or path. Due to the mobility of the nodes that are part of the established paths, routes present a finite lifetime (path duration). When the utilized route is down, the source node should initiate the procedure to discover a new path in order to continue the on-going communications. Mobile Ad hoc Networks consist of several mobile nodes that are capable of communicating with each other without the use of a network infrastructure. Since MANETs are infrastructure less, each node acts as a router forwarding data packets to other nodes and it can be used for emergency situations like military applications, disaster relief and emergency services.

The methods for selecting the intermediate nodes as well as the response to any link break in the path are the main characteristics that differentiate the existing ad hoc routing protocols. These protocols can be roughly divided into three categories: proactive, reactive and hybrid. In proactive or table driven protocols nodes send messages periodically in order to update the topological information about the network, so that a route is immediately available as soon as a new connection is required. On the contrary, in reactive or on-demand protocols, nodes generate route queries in order to discover a needed route to a particular node.

II. RELATED WORK

The Ad hoc On Demand Distance Vector AODV routing protocol provides on demand route discovery in mobile ad hoc networks. Route finding is based on a route discovery cycle involving a broadcast network search and a unicast reply containing discovered paths. AODV relies on per node sequence number for loop freedom and for ensuring selection of most recent routing path. Ad hoc On Demand Multipath Distance Vector (AOMDV) routing protocol is an extension of AODV routing protocol. It is used to compute multiple paths during route discovery. It is designed primarily for dynamic ad hoc networks. The AOMDV protocol applies a route update rule to establish and maintain multiple loop free routes at each node Transition probabilities are calculated and a state based model of the movement among the cells is considered. Each connection between a mobile node in cell and the other mobile nodes among its neighbour cells is considered as the state of the wireless link. In this way, the wireless link dynamic is determined between a mobile node
and its neighbours, permitting the calculation of the link lifetime. Through the assumption of independent link failure, the route breakage probability is derived. It mainly considers power constraint of nodes for efficient packet transmission and also a new mobility prediction formula is used for Predicted LET calculation to select a stable path with minimal cost. It provides a quick response to changes in the network reduces the waste of network resources and produces significant improvement in data transmission rate and hence reduces control overhead for reconstructing a routing path Reliable and Energy are QoS Routing protocol for Mobile Ad hoc Networks (REQR) was proposed to find the maximum link reliable and minimally energy consumed multiple paths between the source and the destination.

III. PATH DURATION

In multi-hop wireless networks, a path is a sequence of communication links that are formed by adjacent neighbours. Due to node mobility, these links are broken and thus, the path lifetime becomes finite. This lifetime, called path duration, represents the elapsed time from the generation of the path to its break.

Description of Path Duration

Since a path between two nodes becomes invalid as soon as one of its links is broken, the path duration is equal to the minimum of the residual life of the links that conforms that route. Consequently, the distribution function of route duration \( R \) can be mathematically expressed as:

\[
P(R \leq t) = \mathcal{P}\left[ \min_{i=1}^{N} L_i F_i \leq t \right]
\]

(1)

It is necessary to include the \( F_i \) factor as each link may have already been active an interval of time before the path was discovered. We suppose that the lifetimes of different links in the path could be considered mutually independent except for the case of adjacent links as the Movement of a node may simultaneously affect the duration of two adjacent links. However, we will assume that the effect of the correlation of the duration for adjacent links is negligible as it has been reported. Under this assumption and considering that the distribution for the duration is the same for all the links, the previous expression can be further simplified into:

\[
P(R \leq t) = 1 - \prod_{i=1}^{N} [P(L_i F_i > t)] = 1 - (P(L \cdot F > t))^N
\]

(2)

\( Fi \) and the link duration \( Li \) are independent variables, so:

\[
P(R \leq t) = 1 - \left[ \int_{0}^{\infty} f_L(y)dy \right]^N
\]

(3)

\[
P(R \leq t) = 1 - \left[ \int_{0}^{\infty} f_L(y)^Ndy \right]
\]

(4)

where \( f_L(x) \) is the probability density function of the fraction of use while \( fR(x) \) is the probability density function of the link duration. We assume that the factor of use can be modelled as a uniformly distributed random variable in the [0-1] interval (which implies \( fR(x) = 1 \)). So the above equation is further simplified into:

\[
P(R \leq t) = 1 - \left[ \int_{0}^{\infty} fL(y)^Ndy \right]
\]

(5)

IV. EVALUATING THE MOBILITY IN A MANET

Random Waypoint:

One of the most extended individual mobility models is the Random Way Point (RWP). According to this pattern, the nodes of an ad hoc network move along a straight line between two destination points (waypoints) placed in a finite space. In the literature, this space is normally bi-dimensional and restricted to a rectangular area of dimensions \( x_{max} \) and \( y_{max} \). Once a node reaches a destination point, a new one is uniformly selected from this area. The speed for a movement is also chosen from a uniform distribution in the interval \([v_{min}, v_{max}]\). Both speeds and waypoints are generated independently of all the previous destinations and speeds. In addition, the model allows nodes to pause between two consecutive trips for a certain period of time. This period (Pause Time) is habitually fixed to a constant value. By varying the values of the transmission range of the nodes, \( x_{max}, y_{max}, v_{min}, v_{max} \) and the pause time, it is possible to control the movement conditions of the simulated scenario.

Real Mobility Traces:

Real position traces extracted from the public buses in Seattle are employed to compute link duration. These traces are collected by the periodic transmission of the buses informing about their position along two days. Straight trajectories are assumed between consecutive position data. As conventional DSRC (Direct Short Range Communication), the transmission range was set to 1500 m. The fitting of the link duration is accomplished by means of the K-S test.
V. LOGNORMAL FITTING

From the previous sections, we can conclude that link duration could be accurately approximated by a lognormal function. This function is usually employed in the reliability research area as it is able to model the lifetime of electronic devices. Formally, the probability that a link lifetime \( L \) is lower than \( t \) is computed by where \( \mu, \gamma, \sigma \) are the parameters of the lognormal function. These parameters are correlated to the characteristics of the scenario.

\[
F(t) = \frac{1}{2} + \frac{1}{2} \text{erf} \left( \frac{\log(t/\mu)}{\sigma \sqrt{2}} \right). \tag{1}
\]

From this model, the path duration could be analytically described the results.

MEAN RESIDUAL PATH LIFETIME

The mean residual life (MRL) is often used as a metric of the time that a component is expected to work given that the component has already lived a survival time \( t \). In wireless multi-hop networks, this parameter can be employed as a measure of the stability associated to the routes of the nodes.

Formally, the MRL is defined as:

\[
\text{MRL}(t) = E[X - t | X > t] = \int_{t}^{\infty} F(u) du / F(t) = \frac{\int_{0}^{\infty} \frac{1}{2} - \frac{1}{2} \text{erf} \left( \frac{\log(u/\mu)}{\sigma \sqrt{2}} \right) du}{\frac{1}{2} - \frac{1}{2} \text{erf} \left( \frac{\log(\mu/\gamma)}{\sigma \sqrt{2}} \right)} \tag{2}
\]

Where \( F(t)=1-F(t) \) corresponds to the survivability function, the Complementary Cumulative Distribution Function or CCDF. In this case, the \( F(t) \) corresponds to the distribution function of path duration which is analytically derived from link duration model.

CONCLUSION

In this paper, we discussed about the Mobile Ad Hoc Networks (MANET), analytical prediction of average path duration is useful and can be used as a parameter to optimise the functionalities of a given protocol. Here show that the link duration can be accurately approximated by a lognormal function and mean residual life (MRL).

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