Distance and Frequency based Route Stability Estimation in Mobile Adhoc Networks

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Abstract-**This paper discusses the link stability estimation for Mobile Ad hoc Networks (MANETs). In this approach the total time for which the link remains connected with the neighboring nodes is estimated. This helps to predict the stability of the route which is required to forward the packets to the destination. This method does not use the selection of the next hop on the basis of shortest distance, but is based on the time period for which the next hop link remains connected. The parameters we use, are the distance and frequency and signal quality. These provide the way for a node to decide the best next hop neighbor and hence a perfect Quality of Service (QoS) is also obtained.**

Index Terms— **Route stability, frequency, distance, MANETs, QoS.**

I. Introduction

An ad hoc network is a dynamic multihop wireless network that is established by a set of mobile nodes. Such networks are, therefore, suitable for the environments where it is a difficult to create a fixed infrastructure. In this network, mobile nodes randomly move and communicate over radio channels. If two mobile nodes are in a radio transmission range, they can communicate with each other directly, otherwise, the source node sends/receives the packets via some intermediate nodes. Hence a proper routing algorithm is required to route the packets from source to destination. Most routing algorithms, like in [1] estimate the link stability based on the distance between the two neighboring nodes. In [2] the electric field as a parameter is used to find the stable route to the destination. The algorithm given in [3], finds the best route to the destination based on link perdurability. These, however, do not lead to the reliable solution in Mobile Ad hoc Networks (MANETs), as the environments are dynamic and hence the route estimation depends on the factors like mobility and direction as well. In this paper we have taken these factors into account and the next hop route is selected not on the basis of distance only but on mobility as well. The quality of strength is also taken into consideration. Our results show that our method can also be applied in the selection of the best neighboring node.

The rest of the paper is organized as follows.
In Section II we discuss the related works. In Section III, the node distance, position and mobility is estimated. The quality of signal along with the algorithms to be executed on intermediate and destination nodes are presented in Section IV. In Section V the practical scenario of estimating the parameters like distance, frequency, mobility, RSSI, etc. and their performance results are obtained. Finally the article is concluded in Sections VI.

II. Related work

Many routing protocols in the past have been proposed on route stability. In [4] the technique of signal stability is used for adaptive routing in Mobile Ad hoc networks. In this approach the on demand longer lived routes are discovered based on signal strength and location stability. The signal strength of the neighboring nodes are detected by sending beacons, and based on that, the classification of strong and weaker channels are established. This is further strengthened by choosing a channel which has existed for a longer period of time. This signal strength feature in combination with the location stability helps in selection of the next hop neighbor and hence the overall route is established. The protocol mentioned even though gives good results in establishing stable route, however, fails when the node density increases or the node mobility increases. The Global positioning system based reliable route discovery proposed in [5] used a different approach. The algorithm discovers routes based on two zones, the stable zone and the caution zone. The zones are decided based on the location and the mobility of the nodes using the Global positioning system (GPS). The stable zone and the caution zone change dynamically depending on the mobile nodes speed and direction information. The mobile nodes speed, direction and position is estimated based on GPS system. This method is the perfect method of determining the stability of the route as the critical parameters like direction and mobility is determined. The method mentioned however, has a serious drawback of additional cost involvement and more power requirement for the GPS based device. In [6] a model to find the best

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route based on link lifetime has been proposed. In this model the edge effect has been explored to find more stable route to the destination. The lifetime and the stability of the route is calculated by eliminating the edge effect to reduce route maintenance and route overheads. The disadvantage of this model however is that each method proposed under the model requires either pilot signal generation and monitoring of the pilot signal of the other nodes or monitoring of signal strength of the other nodes. With these weaknesses, the stable route still gets established and performance of the network also gets increased. Lifetime Prediction Routing (LPR) proposed in [7] also was suggested to find the stability of the route. In this the service life of the MANET is predicted and correspondingly the route is established. The service lifetime is predicted based on the past activity of the battery lifetime of the node. A simple moving average predictor is used to keep track of last N values of residual energies and the corresponding time instances for the last N packets received/ relayed by each mobile node. This way LPR not only captures the remaining battery capacity but also accounts for rate of energy discharge. This way the route stability and lifetime is estimated based on the battery life which is also an important factor. This method has some serious concerns like, when the node mobility increases it becomes difficult to predict the lifetime of the node and also the use of LPR involves certain overheads. One more model to predict the link stability was proposed in [8]. This model was named as the signal stability based routing protocol (SSA^+) model. SSA^+ is the enhanced version of SSA for finding the route stability in MANETs. In this method a route is maintained with the help of active neighbouring nodes. The neighbours are considered active if it relays or originates at least one packet within the most recent active timeout period. The SSA^+ solution was mainly offered to remove the problems of high node density and high mobility and the low node density and low mobility. In high node density and high mobility scenario the mobility is high, the probability of link failures remain also high. To cater to the problem the signal strength of the link is estimated and classified into the categories of weak, normal and strong signals. The nodes exchange information regarding the signal strength by sending the hello packets and based upon the signal strength value stored in the link state table, the life time of the route is determined. In low node density and low mobility the signals of the nodes remain weaker and the stability and the route lifetime is maintained based on two important conditions.

1) The distance between any two nodes gets shorter for the past few clicks.
2) Secondly the distance between any two nodes gets longer but the distance changes larger slowly for the past few clicks (the condition of low mobility).

The method above mentioned above, even though showed better results compared to SSA in terms of low node density and low mobility and high node density and high mobility has the drawback of predicting the lifetime of the route in a complicated way as the node has to maintain the Link stability table which adds lots of overheads in terms of route control and maintenance and which are difficult to maintain. In [9] [10] and [11], algorithms are proposed as DV-Hop, Hop-TERRAIN, and link stability with dynamic delay prediction, to determine the location of nodes based on hop counts and the appropriate route to the destination. The hop counts provided an estimate for the overall distance between the nodes and the dynamic delay ensured stability. These however, were mainly focusing on the Quality of service (QoS) based route establishment and hence were silent on the route lifetime parameters like mobility and battery power. A Novel route metric based on the fragility of the route was also proposed in [12]. In this approach the dynamic nature of the route is captured by studying the distance variation of the next hop neighbor in terms of expansion and contraction. A distributed algorithm is executed in every node to calculate the relative speed estimate of the neighbours. The destination node gets the information of every route and selects the best route based on the route fragility coefficient (RFC) which in turn depends on the cumulative expansion metrics (CEM) and cumulative contraction metrics (CCM). This approach finds the stability of the route and is good in terms of not requiring time bound measurements, like the global positioning system. This method however, fails to predict the node mobility and includes the destination latency. The estimation of link quality and residual time in vehicular Adhoc networks proposed in [13] is also the method to determine stability of the route in MANETs by predicting the active time of the link. In this method the signal processing along with empirical decomposition and robust regression is used to predict the link quality and the residual time. This method unlike the method proposed in this paper uses a three stage approach which involves lots of complexity in terms of practical deployment. This also involves additional burden of calculating the various essential parameters mentioned under signal processing, empirical decomposition and robust regression methods. The above mentioned literature even though provides excellent way of estimating the distance and the location of neighboring nodes through different techniques, however, are mostly silent on the mobility issue. This paper provides the route stability estimation based upon the neighboring node distance ,mobility and signal strength.

III. DESCRIPTION

Mobile Ad hoc Networks (MANETs) being dynamic in nature create challenges in terms of Quality of Service (QoS) at each level from application to physical. In physical layer level the mechanism to predict the lifetime of the neighboring node increases reliability from source to destination delivery. To achieve this we have identified the following three parameters for next hop path selection

1) Node Distance and position
2) Mobility
3) Signal quality

A. Node Distance and position

Let two circles with radii R_1 and R_2 intersect in a region as shown in Fig. 1 Let the circles be centered At A (0, 0) and B(d, 0). Then equations of the circles are

$$x^2 + y^2 = R_1^2 \quad (1)$$

$$(x-d)^2 + y^2 = R_2^2 \quad (2)$$

This implies that

$$x^2 - 2dx + d^2 - x^2 = R_2^2 - R_1^2 \quad (3)$$

$$x = \left(\frac{d^2 - R_2^2 + R_1^2}{2d} \right) \quad (4)$$

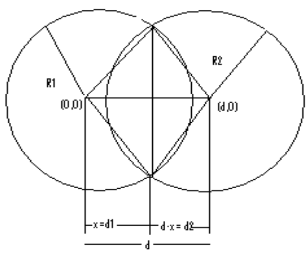

Figure 1. Showing the wireless range intersection.

Now y is half of the length of chord connecting the two circles, we have

$$y^2 = R_1^2 - x^2$$

$$y^2 = \frac{4d^2 R_1^2 - (d^2 - R_2^2 + R_1^2)^2}{4d^2} \quad (5)$$

To find out d_1 and d_2 the distances from centre on nodes to the circle intersection point, we use the relation

$$d_1 = \frac{(d^2 - R_2^2 + R_1^2)}{2d} \quad (6)$$

$$d_2 = \frac{(d^2 + R_2^2 - R_1^2)}{2d} \quad (7)$$

To find the distance d, and position parameters x, y we assume the following:

1) That all the nodes are of equal strength and technical specifications
2) That the radii are known and are same for all the nodes because of same transmission power.

With these assumptions and from (1-7), the distance can be found using the method as given in [14], known as round trip time based method. This works on the concept that every data packet can be acknowledged. Under this work the time span from the moment at which a packet starts to occupy the wireless medium to the time at which the immediate acknowledgment is received is measured and denoted by T_R. The time duration between the reception of a data packet and issuing the corresponding immediate acknowledgment is also measured and denoted by T_L. The distance is computed based on the relation between the distance traveled and the speed of light as follows:

$$d = \frac{(TR - TL)}{2} \times C \quad (8)$$

Where C= 3×10^8 is the speed of light. Now solving for d_1, d_2, x, y from (7) and (8), the position P(α, β) of the neighboring node can be estimated. Now link stability L_s is, given by:

$$L_S = \begin{cases} 1, if\ d < \mu\ and\ |AP| \le |AC| \\ 0, if\ d < \mu\ and\ |AP| \le |AC| \end{cases}$$

$$\text{Where } AP = \sqrt{\alpha^2 + \beta^2}$$

$$AC = \sqrt{m^2 + n^2}$$

and μ and C(m, n) are respectively the maximum permissible distance and maximum co-ordinate position allowed to communicate between the nodes

B. Mobility

Measurement of distance and position as mentioned above are easy to compute and provides the route stability especially when the nodes are static. In case the nodes are dynamic the mobility plays an important factor. The distance and position in mobile environment will provide the feasibility of communication but will not provide the life time of the route with the neighboring node. To find mobility, we calculate the frequency of the neighboring node from the following equations using [10].

$$f_r = f_e \left[\frac{v}{v + v_{sr}} \right] \quad (9)$$

Where in (9), f_r is the received frequency, f_e is the emitted frequency, v is the speed of the waves in the medium and v_{sr} is the radial component of the velocity of the neighboring node with respect to the medium (positive if moving away from the observer, negative if moving towards the observer). A similar analysis for a moving observer and a stationary source yields the observed frequency from the following equation (the receiver's velocity being represented as v_r):

$$f_r = f_e \left[\frac{v}{v + v_r} \right] \quad (10)$$

where the same convention applies. We note that v_r is positive if the observer is moving away from the source and negative if the observer is moving towards the source. These can be generalized into a single equation with both the source and receiver moving as given below:

$$f_r = f_e\left[1 - \frac{v_{sr}}{v + v_{sr}}\right] \tag{11}$$

Where v_{sr} is the source to receiver velocity radial component. Now since the source nodes have equal power so frequency of transmission will remain same for all the nodes within the vicinity. From (11) above we get the velocity of the neighboring nodes as

$$v_{sr} = v\left[\frac{f_e - f_r}{f_r}\right] \tag{12}$$

Now overall time period for which the link remains established will depend on the following relation

$$T = \frac{d}{v_{sr}} \tag{13}$$

where T in (13) is defined as the time period for which the link with the neighboring node will remain established. The time period depends on d because if the node covers the maximum distance away from the other node, then a small velocity of it in the opposite direction will disconnect the link. The time T will be more if it is negative as the velocity will be having +ve or –ve sign depending upon the direction of motion.

C. Signal Quality

The distance, and position plays an important role in finding mobility and hence the link stability. However, the stability of the link also depends on the quality of signal as well. In Mobile Adhoc Networks (MANETs) the signal quality plays an important role in selecting the route to the destination. The parameters like distance and mobility proposed above effects the signal quality, however in spite of the feasible distance and mobility threshold values, the node may not receive from the neighboring node the good quality signal due to noisy surroundings. When there is a signal transmission from a node with certain power in the noisy environment, the Bit error rate of the signal increases apart from the normal path loss in the medium. The receiver on the basis of the receiver sensitivity, and the threshold *Signal to Noise Ratio* (SNR), predicts the quality of signal. Overall it is the Receiver signal strength indicator (RSSI) which provides the details of the quality of signal received. RSSI which is basically a measurement of how well the radio is receiving or 'hearing' data to determine the quality of signal received. It's typically measured in -dBm, which is the power ratio in decibel (dB) of the measured power referenced to one milliwatt (mW). Normally in the real testing environments the RSSI above -60 dB is considered the threshold required to perform good networking functions and any value higher than that is the stable value. We denote this value by M_{RSSI}. Therefore overall link stability which is denoted by L_{SSO} should satisfy L_S, T *and* M_{RSSI} the three important parameters to determine the stability of the route.

IV. ROUTING

The above parameters calculated can be used to enhance the routing procedures already available. To inco-orporate the changes, the nodes needs to be modified. Below are the node level modifications suggested when the node behaves as, the intermediate and the destination node.

A. Intermediate node operation

When the intermediate node receives the RREQ packet from the source or from any of its neighbors it provides the additional information of the distance and the frequency in the RREQ packet and forwards it to the destination. The Algorithm 1 provides the operational details to be performed at each intermediate node.

Algorithm 1 Algorithm to be executed in the node

1 Set μ , (m, n), M_{RSSI}
  Set k stable link time threshold
2 Measure d
3 if $d < \mu$ L_s= 1 Goto x
  Else $d > \mu$ L_s = 0 stop.
3 x: calculate RSSI
4 if RSSI < M_{RSSI} goto 8 else
5 calculate v_{sr}
5 if vsr -ve calculate T
  Else if v_{sr} +ve calculate T
6 if $T < k$ reject
6 Else if $T > k$ select and modify RREQ
7 stop

B. Destination node operation

The destination node on receiving RREQ packets from the several nodes sends the reply to the source by selecting the best path on the basis of the T, M_{RSSI} value. Algorithm 2 provides the process details of the destination node when RREQ arrives from different nodes of the destination node.

Algorithm 2 Process execution when RREQ arrives

1 Analyze RREQ
2 Extract, d, v_{sr} $M_{RSSI}{}^*$
3 Compare
  d with d^* and M_{RSSI} *with* $M_{RSSI}{}^*$ and v_{sr} with $v_{sr}{}^*$
4 if $d > d^*$ and $M_{RSSI} < M_{RSSI}{}^*$ and $v_{sr} > v_{sr}{}^*$
  Reject Route
  Else select Route

The source node when sending the RREQ packet, calculates before, the distance, mobility and SNR of the neighboring nodes. It then embeds the information in the RREQ packet and sends it to the destination via. Next hop neighbor.

V. RESULTS

The experiments were performed in the indoor environments. In the experiment, we used one wireless access point namely Wireless-G WAP54Gv.2 of Linksys make and a WLan laptop. The access point and the Laptop were supporting the wireless 802.11 b/g model protocols. For sending the ICMP packets, we used a Graphic tool namely Multiping Grapher to send the ping requests every second.The payloads in bytes were kept constant at 512bytes. The purpose of doing so was to see the graphic outcome of the response. Figures 2 and 3 show the details of the ping at a max of 6ms and 7ms by varying the indoor distance from maximum to minimum and vice versa.

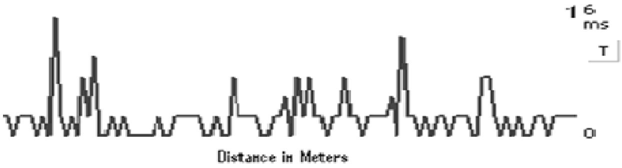

Figure. 2 Ping Response at 6ms Max

The physical and the operational mode rates have been fixed at 802.11g and 54mbps, 11mbps. The distance *d* as calculated in (8) is measured from the tool Snuffle. From this tool the T_R and T_L is computed from the MAC time stamps recorded on the transmitted request and received acknowledgment packets and by subtracting the MAC time stamps of the received reply and the issued acknowledgment packets.

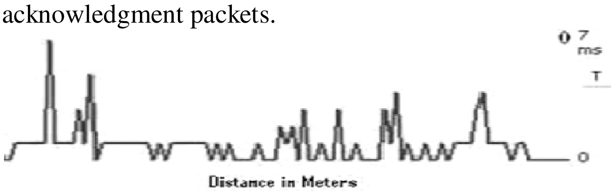

Figure. 3 Ping Response at 7 ms Max.

Figure 4. shows the distance calculated vs the difference in MAC delay. The calculated distance is however not the actual physical distance. The intension here is to check the distance between the nodes and to compare it with the threshold maximum allowable radial distance in this case we have fixed as μ . Now that the distance between the nodes is calculated, the mobility can be calculated by specifying the frequency of the source at rest which is 2.4 GHz and wave velocity 300,000 Kms/second. The experiments were carried in the indoors were the speed of the access point were varied and the frequency it was calculated by using the above equations and the Doppler's effect calculator.

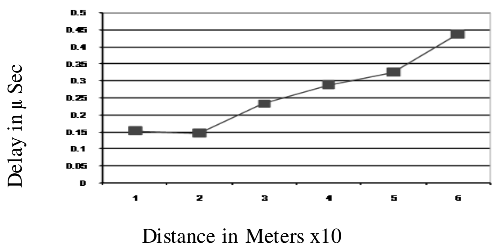

Figure. 4 Calculated distance vs Delay

TABLE I.
Velocity and Frequency Recorded Readings

S.No	velocity in m/s	Frequency in GHz
1	-2	2.4140
2	-3	2.4212
3	-4	2.4283
4	-5	2.4356
5	-6	2.4421
6	-7	2.4497
7	-8	2.4573
8	-9	2.4643
9	-10	2.4719
10	-11	2.4793
11	-12	2.4868

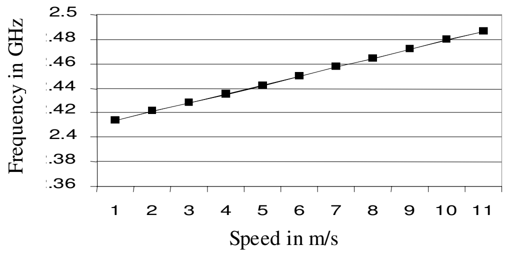

Figure. 5 Frequency vs Speed

The data collected are as shown in Figure 5. The velocities in the table 1 above are shown negative this indicates that the node is approaching the other node which is recording the frequency. By calculating the velocity we can find the link stability as per the equations given above in (13) and (14).

A. Received Signal Strength Indicator

To calculate the link stability based on RSSI parameter, we used a graphical tool called Wirelessmon. This tool provided the details of the RSSI Value recorded and the signal strength percentage which is proportional to the RSSI value. The more the percentage of signal strength the more the RSSI value closer to zero. Some of the Graphs plotted are shown from Fig. 6 to Fig. 8. The graphs clearly show that the percentage of signal received is good when the distance is only 1m and hence the RSSI value approaching –ve value towards zero. As soon as the node is moving away from the access point and some aluminum wall partition included in between, It shows the decline in the signal and hence in the RSSI value as well.

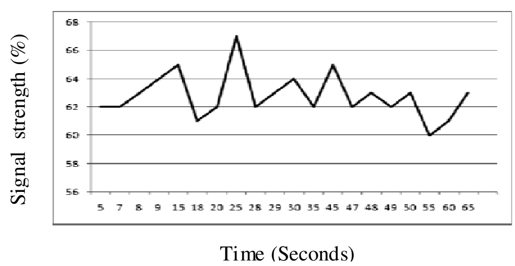

Figure. 6 Signal strength % vs time in seconds

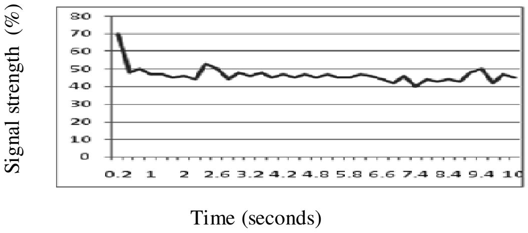

Figure. 7 Signal strength % vs Time in seconds distance =3m and one aluminium partition in between the nodes

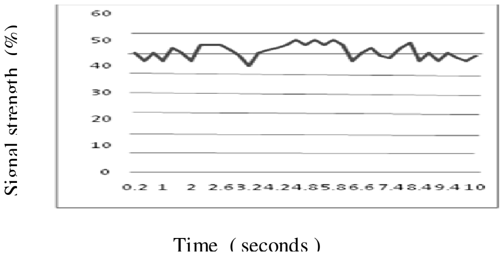

Figure. 8 Signal Strength % vs. time in sec with distance = 6m and two aluminum partitions between the nodes.

VI. CONCLUSIONS

We have presented an approach on how to measure the distance and position based on the propagation time of IEEE 802.11 packets. We used commercial WLAN card of linksys make supporting IEEE 802.11b and 802.11g. The distance and the position measure however is logical and has no relation with the physical distance or position in the co-ordinate system. The frequency measurement results reveal the mobility of the neighboring nodes. The distance parameter can be used to detect the location of the node especially when two nodes are static and is therefore, sufficient to determine next hop link stability. The frequency measurement to determine the logical mobility is however important to determine the next hop route stability if any one or both of the nodes are mobile. The signal quality also adds the QoS factor. This paper in spite of exploring three important factors like distance and mobility RSSI value however is silent on the other factors like S/N ratio, BER and overall signal quality. The distance factor can somehow presume the strength of signal but cannot provide the details of the quality parameters like S/N ratio, BER. These parameters S/N ratio and BER combined with the above mentioned parameters like distance and frequency may be used to find the best route life in near future. The algorithms depicted also will be incorporated in the nodes and a routing protocol will be used to see the performance enhancement of this method over others.

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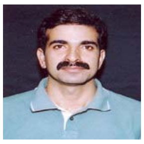

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