Link Analysis of Mobile Nodes in Ad Hoc Network Using Ricean Fading Channel Model

Bineet Kumar Joshi and N. Mishra

***Abstract*—Communication channels are one of the important components of the wireless mobile ad hoc network. The link connectivity among mobile nodes moving in these channels can be measured through various performance metrics. This paper analysis the link connectivity of mobile nodes in one of the well known channel model, the Ricean fading channel, in which a strong dominant signal component is always present among several multipath signals received by receiver. Two performance matrices have been used to evaluate the link analysis of nodes. These are Link duration and Link ratio. It is discovered that the link duration is dependent on Ricean Factor K where as Link ratio shows irregular results, which represent true picture of link connectivity in the presence of fading.**

***Index Terms*—Mobile ad hoc networks, ricean fading, ricean factor k, mobility model, link duration, link ratio.**

I. Introduction

All Mobile ad hoc networks (MANETs) [1] are collections of mobile nodes, dynamically forming a temporary network without pre-existing network infrastructure or centralized administration. These nodes can be arbitrarily located and are free to move randomly at any given time, thus allowing network topology and interconnections between nodes to change rapidly and unpredictably. Node mobility can vary from almost stationary to constantly moving nodes, depending on the particular network's structure and purpose. As a general rule, high mobility usually results in low link capacity, whereas low mobility leads to high capacity links.

Recent advances in wireless technology have enhanced the feasibility and functionality of wireless mobile ad hoc networks (MANETs). There has been significant research activity over the past 5-10 years into performance of such networks with the view to develop more efficient and robust communication protocols. However, the vast majority of the research has concentrated on either developing appropriate mobility models for node movement [2] or on developing performance metrics [3]. The channel itself has been ignored.

In [4], [5] all calculations are based on geometry with no consideration given to channel properties. In many of the works on mobility metrics, the transmission range r, is defined as being dependent upon many system dependent factors, including fading, but none actually addresses the issue of fading in any meaningful way. All such models are of no practical use and unrealistic for describing the nature of Mobile Ad hoc networks.

In wireless communications, the presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path [7]. Each signal copy will experience differences in attenuation, delay and phase shift while traveling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. This phenomenon is known as fading. Fading refers to the distortion that a carrier-modulated telecommunication signal experiences over certain propagation media. Fading is used to describe the rapid fluctuations of the amplitudes, phases, or multipath delay of a radio signal over a short period of time or travel distance, so that large-scale path loss effects can be ignored. Fading channel is a communication channel that experiences fading. In wireless systems, fading is due to multipath propagation and is sometimes referred to as multipath induced fading [10].

Rayleigh fading model is used to describe channels which have a number of multipath signal component caused by reflection from objects in the environment such as hill and buildings [6]. A comparison of the performance of an ad hoc network operating in a Rayleigh fading channel with In range channel model has shown that link duration metric is inadequate for describing performance of Rayleigh fading channel and a new metric link ratio have been introduced

This work will analyze the link connectivity of mobile nodes in a Ricean channel fading channel, which differs from Rayleigh channel as Ricean channel always contain at least one dominant signal component. Two metrics, link duration and link ratio have used for this purpose.

Our contributions are as follows: Section II introduces Ricean fading channel model and Ricean Factor K. Section III describes link duration and link ratio mobility metrics mobility metrics. Simulation parameter and results are presented in Section IV. Section V summarizes, draws conclusions and indicates direction for further research.

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II. Ricean Fading Model

The Ricean fading model is used to describe channels where a strong dominant component present in multipath signals [7], [8]. The dominant component can be the line-of-sight wave. Beside the dominant component, the mobile antenna receives a large number of reflected and scattered waves. It is most useful in microcellular channel, vehicle to vehicle communication and indoor areas. Fading

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can be modeled using Rice distribution.

Its probability density function may be written as

$$P_{Rice}(r) \equiv \frac{r}{\sigma^2} e^{-\frac{(r^2+s^2)}{2\sigma^2}} I_0\left(\frac{r^2}{\sigma^2}\right) \quad (1)$$

where *s* denotes the peak amplitude of dominant signal, Io is modified bassels function of the first kind and zero-order.

The Ricean distribution is often described in term of a parameter *K* which is defined as the ratio between the deterministic signal power and the variance of the multipath. It is given by

$$K \equiv 10\log\frac{s^2}{2\sigma^2} \quad (2)$$

The Parameter *K* is known as the Ricean factor [8], and completely specifies the Ricean distribution. As $s \to 0, K \to \infty$ and the as the dominant path decrease in amplitude, the Ricean distribution degenerates to Rayleigh distribution.

III. Link Duration And Link Ratio

The link duration has been shown to be useful mobility metrics giving a good indication of protocol performance in mobile ad hoc networks over a range of mobility models [3]. In [8] an expression was determined for probability distribution function (pdf) of the link duration in an ad hoc network.

The link duration is the average time that a communication link between a given pair of nodes lasts without breaking. It is a measure of stability of the link between these nodes. For the in-range model a link is said to exist between a given pair of nodes as long as they are within a distance *r* of each other, where *r* is the chosen link distance threshold. For a given system, *r* depends upon many system factors such as transmitted signal power, clutter in the signalling environment (e.g., hills and buildings), noise and interference. For the Ricean fading model, a communication link is said to exist between a given pair of nodes as long as the signal strength at each node is above a given threshold. For our purposes, it is assumed that this link is symmetric. The average link duration can be calculated as follows [9].

Consider a network of *N* nodes and take an arbitrary pair of nodes *i* and *j*. Let $L_k(i, j)$ be an indicator variable which equals 1 if a link exists between these nodes at time step *k* and 0 otherwise. The *link time* LT(*i, j*) is the number of time steps for which the link has existed between the pair of nodes, over a period of *K* steps, where *K* is sufficiently large, such that

$$LT(i, j) = \sum_{k=1}^{K} L_k(i, j) \quad (3)$$

Let $C_k(i, j)$ be another indicator variable which has value 1 only when the link appears, i.e., $C_k(i, j) = 1$ iff $L_k(I, j) - L_{k-1}(I, j) = 1$. The number of *link changes* LC(*I,j*) is the number of times the link has existed during the *K* steps.

$$LC(i, j) = \sum_{k=1}^{K} C_k(i, j) \quad (4)$$

The average link duration LD(i; j) between the pair of nodes can be expressed as

$$LD(i, j) = \left\{\frac{LT(i, j)}{LT(i, j)}\right\} \text{ if LC}(i, j) \neq 0 \quad (5)$$

0 otherwise

If there are *N* nodes in the network, the average link duration LD for the network is simply the average of LD (i, *j*) over all $\frac{N(N-1)}{2}$ possible (symmetric) links.

$$LD = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} LD(i, j) \quad (6)$$

If node locations are generated according to some random process, the average link duration LD will approach the expected link duration as $K \to \infty$ according to the law of large numbers. In the following, we calculate the expected link duration for an arbitrary pair of nodes. As the movements of all nodes are i.i.d. and all nodes have identical transmission ranges, the expected link duration between a given pair of nodes is equal to the expected average link duration over all possible node pairs.

Link ratio is the amount of time that a communication link exists between a pair of nodes, compared with the amount of time that the link is broken [6]. In presence of fading components a link would exist between two nodes for a significant amount of time, however, the link would not necessarily last very long. Thus link duration metric would not be necessarily being a suitable indicator of communication link performance while link ratio provides good results.

IV. Result

A. Simulation Parameters

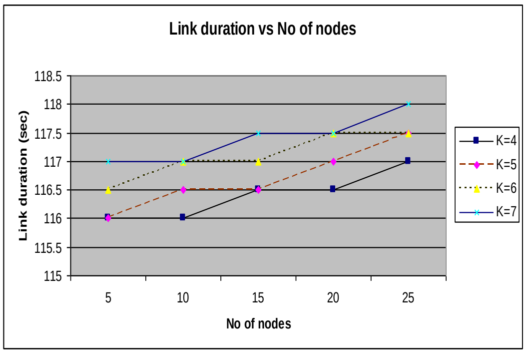
The nature of mobile ad hoc networks makes simulation modeling an invaluable tool for understanding the operation of these networks. Wireless channels experience high variability in channel quality due to a variety of phenomenon, including multipath, fading, atmospheric effects, and obstacles. While real world tests are crucial for understanding the performance of mobile network protocols, simulation provides an environment with specific advantages over real world studies [9]. This aids in deeper understanding of how the changes impact the performance results. Movements of number of nodes have been simulated in Ricean fading channel using Random Waypoint mobility model [12]. To make the result meaningful the following parameter were chosen.

All the simulation work is done in QualNet wireless network simulator version 4.0. Simulation time was taken 120 seconds and it remains fixed throughout all simulation work. All the scenarios have been designed in 20m x 20m area. Mobility model used is Random Way Point (RWP). In this model a mobile node is initially placed in a random location in the simulation area, and then moved in a randomly chosen direction between [0,2∏]at a random speed between [$Speed_{Min}$,$Speed_{Max}$]. The movement proceeds for a specific amount of time or distance, and the process is repeated a predetermined number of times [14]. We chose Min speed = 0 m/s, Max speed = 1m/s, and pause time = 5 seconds. Maximum data rate was chosen at 2Mbps. The total number of nodes varied from 5 nodes to 25 nodes with a step size of 5 nodes and Ricean fading channel with different rice constant K is used. Value of K is varied from 4 to 7 with step size of one. All the simulation work was carried out using DSR routing protocol.

B. Result Analysis

By looking at Fig. 1, we can say that Link Duration increases in all four cases as the number of nodes increases. Link duration is maximum in case of *K*=7 i.e. 118 seconds, it means that in this case nodes remains connected 118 seconds out of 120 second. Two nodes are said to be connected in Ricean channel if the signal strength at receiver is above than some threshold value. Link duration increase steadily for all values Ricean factor *K*. Here it seems that Link duration metric remain unaffected from fading effects and hence it does not represent a true picture of real life where signal strength varies as nodes moves from one place to other.

Link ratio varies irregularly for all values of Ricean Factor *K*, it does not depend on number of nodes as seen in Fig. 1. When the value of *K* increases from 4 to 8, graph shows an irregular pattern, Link ratio varies irregularly as the number of nodes increases. Link ratio generally not depends on the numbers of nodes in indoor model. But it shows relative smooth curves for higher values of *K*. This is because as the value of *K* increase line of sight (dominant) component of signal increases, this leads to increase in probability that the signals are received correctly and hence most of times receiver received signals greater than the threshold value. This leads to increases in link ratio values as the value of K increases.



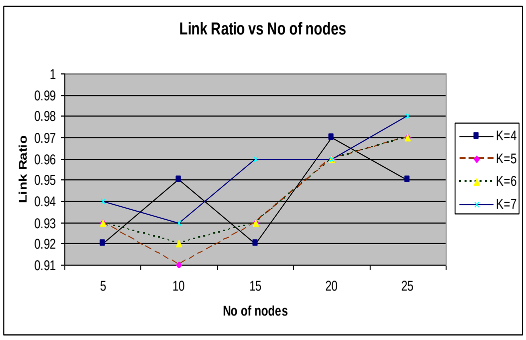


Fig. 1. Comparison of Link duration and Link ratio mobility for the Ricean fading channel using different values of the Ricean factor K for indoor model

V. Conclusion

Link ratio metric have truly shown the effects of fading which cannot be predicted from results obtained from Link duration metric. Some application may require longer communication links while others, presumably in the majority, will require a greater guarantees overall of a communication link existing. It is clear that the link ratio is a much more appropriate measure than the link duration for the applications which fall into the latter category.

As part of future work, one of our immediate goals will be to develop this work for more general channel models. It would be interesting to see, how efficient the link ratio metric for various other mobility models.

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