

On the Influence of Mobility on Mobile Ad Hoc Networks

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Abstract—Owing to mobile node movement, the link break problem always occurs in mobile ad hoc networks. It greatly influences the throughput, delay, jitter, and lots of performance issues of a routing protocol. This article is proposed to evaluate the influence of link break problem on two categories of most popular routing protocols, i.e. table-driven and on-demand routing protocols. This article briefly discusses the main differences, building up mathematical model, setting up simulation environment, running the simulation, and finally presenting the simulation results and analyzing the performance. We found that the influence of link break problem on table-driven routing protocols is much serious than that on on-demand routing protocols.

I. INTRODUCTION

A Mobile ad hoc network, as shown in Figure 1, is designed to overcome the natural limitation of wired backbone networks. It is a collection of mobile nodes sharing a wireless channel and dynamically forming a temporary network topology without the existence of network infrastructure or centralized administration. Restricted by transmission range, each node can only communicate with neighboring nodes within its radio coverage area; besides, forwarding packets for other nodes, it also acts as a router. Mobile ad hoc networks are also called multihop wireless networks because any message transmitted from a source node to a destination node may pass through many intermediate nodes, which requires multiple radio hops.

The advantages of mobile ad hoc networks are as follows. They are fast deployable and suitable for the situation where setting up or maintaining a communicating infrastructure is difficult or infeasible, for example, disaster recovery (earthquake, fire), battlefield, law enforcement, and vehicle-to-vehicle networking in intelligent transportation systems. Moreover, the mobile nodes can move freely without any constraints. However, they also have disadvantages. The battery life is significantly restricted and the radio frequency incurs interference. Most importantly, the network topology may change constantly because of node movement. This incurs link break problem, the main concern of this article.

A routing protocol maintains the network topology for a mobile ad hoc network. If a link breaks, routing protocols has the responsibility to repair that link in order to maintain the consistency of the network. Different routing protocols have various strategies to repair a broken link. The repair strategy is quite specific to each strategic routing protocol; therefore it is quite

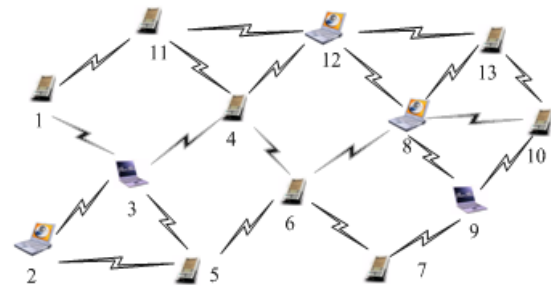


Figure 1 Mobile Ad Hoc Networks

hard to analyze the pros and cons of each protocol. What we can do is to find the link break probabilities of different categories of routing protocols since the problem greatly influence the efficiency of a routing protocol. Two categories of most popular routing protocols, table-driven and on-demand routing protocols, are discussed in this article. We will analyze the link break problem, its influence on each categories of routing protocol, and the incurred routing table update.

The rest of this article is organized as follows. The link break problem and its influence are presented in Section II. Section III provides the mathematical model. Moreover; Sections IV presents simulation environment, and Section V analyze the results and the performance Finally, Section VI concludes this article.

II. LINK BREAK ISSUE

A link is a wireless medium in wireless networks, which connects two or more network devices such as a computer, a router, or a mobile node together. Owing to mobile node movement, the link break problem always occurs in mobile ad hoc networks. The problem greatly influences the throughput, delay, jitter, and lots of performance metrics of a routing protocol.

A. Routing Protocols

Various routing protocols are proposed for mobile ad hoc networks to solve the problems of routing loop and provide fast convergence to topology change. Broadly speaking, they are categorized as table-driven (e.g., DSDV [1]) and on-demand (e.g., AODV [2], AROD [3], AVR [4], CLR [5]) routing protocols.

Table-driven routing protocols [1] demand that each mobile node should have up-to-date routing information of all nodes in the network. Therefore, a routing table is maintained within each node and broadcast network-wide when network topology changes. Moreover, the routing table has to be exchanged periodically by broadcasting to all nodes in the network to keep track of the newest messages even though the network topology is not changed.

However, on-demand routing protocols [2-5] have a totally different approach; they create routes only when needed. Having data for transmission, a source node initiates a route discovery procedure to find the destination node. Route maintenance procedure is triggered whenever a route has been discovered and is in progress until the route is no longer required. The control messages used in on-demand routing protocols record only the nodes on the route, not all nodes in the network.

Articles [6-8] were proposed to make performance analysis and comparison regarding table-driven and on-demand routing protocols recently, especially DSDV and AODV. They analyze the performance issues such as routing overhead, throughput, delay, and jitter; however, they did not trace the causes. From a different point of view, this article explores the main reason, i.e., link break problem, which influences the update probability of routing protocols and various performance issues. This is unique.

B. The Influence of Mobility on Routing Protocols

The two categories of routing protocols of mobile ad hoc networks are table-driven routing protocols and on-demand routing protocols. Table-driven routing protocols have to maintain up-to-date routing information of all links in the network. The responsibility of the table-driven routing protocol is to maintain the brand new routing table so that an mobile node can send message to any node at any time. However, the concerned issue is that if any link breaks, the protocol has to trigger an update to maintain the up-to-date routing information. To maintain achievability to each node, the routing update is broadcasted network-wide till each node receives it when any link breaks.

On the contrary, on-demand routing protocols create route only if they have message for transmission. And, the protocol maintains the route until the route is no longer required. It focus only on the route they created, not on the whole networks. Hence, these protocols only need to maintain the links on a transmission route, not all the links of a network. Therefore, the on-demand routing protocols has lower update probability than the table-driven routing protocols.

III. MATHEMATICAL MODEL

To introduce the mathematical model, we first define some key terms and then present the model for measuring the influence of link break problem on mobile ad hoc networks.

Each wireless link l of a mobile network can be viewed as an experiment ε with outcome $\{B, \bar{B}\}$, where B represents a link that breaks during a short time interval Δt , and \bar{B} a link that does not break during the same time interval. Suppose that the probability $P(B)=p$. and because a link only has two state at any time, that is, break or un-break, therefore, $P(\bar{B})=1-p$.

Assuming that a network has m links, let X be a binomial random variable based on the m links (i.e., m repetitions in

mathematical term) . Then

$$P(X = k) = \binom{m}{k} p^k (1 - p)^{m-k} \quad \text{where } k = 0,1,\dots,m \quad (1)$$

Equation (1) tells us that the network remains unchanged, if the value of k is 0, i.e. $X=0$. On the other hand, if any link breaks, $k > 0$, namely $X > 0$, this means that the network topology has been changed.

A. Math model for table-driven routing protocols

Firstly, we would like to analyze table-driven routing protocols. Suppose that there are 10 nodes and average 15 links in a network. Further, assume that the link break probability is 0.1 during a short time interval, say 5 seconds. To obtain up-to-date information, the protocol has to notice about each link condition, that is, if any link breaks, it will launch an update. The following equation is the best representative of the update probability P_{ud} .

$$P_{ud} = P(X > 0) = \sum_{i=1}^{15} P(X = i) \quad \dots\dots\dots (2)$$

Substituting each term of Equation (2) by Equation (1),

$$P_{ud} = \binom{15}{1}(0.1)(0.9)^{14} + \dots\dots + \binom{15}{15}(0.1)^{15}(0.9)^0 = 0.794 \dots\dots (3)$$

This means that during 5-second interval, table-driven routing protocols have an update probability of 0.794. Moreover, the highest probability of Equation (3) occurred at $P(X = 1) = 0.343$. That is, under such assumption the most probable number of broken links is one.

B. Math model for on-demand routing protocols

As for on-demand routing protocols, we assume that there are also 10 nodes and the link probability is 0.1 during 5-second interval also. However, the maximum number of links is five in the transmission route. If any one of the five links breaks, the protocols will trigger an update. Hence, the update probability P_{ud} of the protocols is

$$P_{ud} = P(X > 0) = \sum_{i=1}^5 P(X = i) \quad \dots\dots\dots (4)$$

Substituting each term of Equation (4) by Equation (1),

$$P_{ud} = \binom{5}{1}(0.1)(0.9)^4 + \dots\dots + \binom{5}{5}(0.1)^5(0.9)^0 = 0.41 \dots\dots (5)$$

This means that during 5-second interval, on-demand routing protocols have an update probability of 0.41. The highest probability of Equation (5) occurred at $P(X = 1) = 0.328$. That is, under such assumption the most probable number of broken links is one.

IV. SIMULATION ENVIRONMENT

The objective of the simulation is to set up a simulation environment, to run the simulation, and finally to provide results for analyzing the effect of link break on the two categories of routing protocols, i.e. table-driven and on-demand routing protocols. The main consideration is the link break probability, that is, the routing table update probabilities. A higher link break probability will incur a higher routing table update transmitted network wide. The simulation parameters are shown in Table I.

TABLE I
SIMULATION PARAMETERS

Roaming Area	1000 x 1000 m ²
Number of Nodes	10, 20, ..., 90
Average Links	Random generated by the Number of mobile nodes
MAC Protocol	DCF (IEEE 802.11)
Radio Propagation Model	Free Space and Two-Ray ground fading model
Bit Rate	2 Mbps
Max. Radio Range	250 m
Routing Protocols	DSDV for Table-Driven AODV for On-Demand
Packet Dimension	512 Bytes
Moving Speed	low, low+, moderate, high-, and high, which represents 10, 20, 30, 40 and 50 km/hr
Traffic Pattern	The data packet inter-arrival time are exponentially distributed with a mean of 50, 30, and 10 ms, representing light, moderate, and heavy traffic respectively.
Simulation Time	900 seconds

V. RESULTS AND PERFORMANCE ANALYSIS

The simulation results are provided and used as evidences to analyze the two categorizes of routing protocols. Three issues, number of mobile nodes, the moving speed, and traffic pattern, are analyzed in this article. The effect of these issues is presented in the form of update probability, i.e. the link break probability. The higher the update probability, the more frequently a protocol triggers routing table update and the worse the protocol is.

A. The Effect of Number of Mobile Nodes

By utilizing different number of mobile nodes, Figure 2 presents the update probability graphs. The x-axes of these graphs represent the number of mobile nodes. Please note that the traffic pattern is moderate in this section.

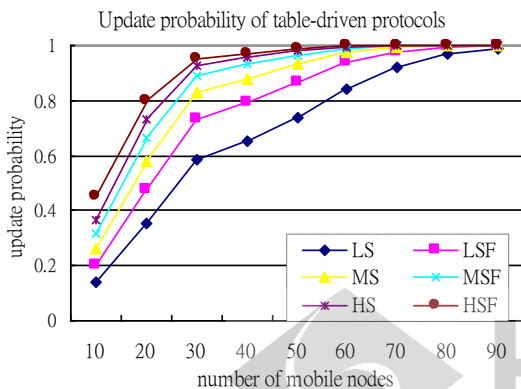
By using free space and two-ray ground fading propagation model, Figure 2(a) shows that the update

probabilities of table-driven routing protocols increase exponentially with the number of mobile nodes. The reason is that the average number of links in the network increases exponentially with the number of mobile nodes. This graph also tells us that as moving speed increases, the update probability also increase rapidly. When moving speed is low and the number of mobile nodes is 30, the update probability P_{ud} reaches approximately 0.583. As for moderate speed, P_{ud} already arrives at 0.581 when the number of nodes is 20. However, under the same number of mobile nodes P_{ud} achieves nearly 0.730 for high moving speed. That is the reason why table-driven routing protocols have such a high probability to execute routing table updates. When comparing different propagation model, i.e. the free space and two-ray ground fading propagation model, we also knows that the update probabilities in a fading model are slightly higher than that in a free space model.

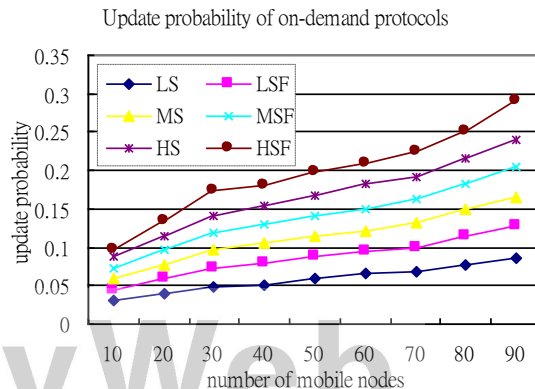
Based on free space and fading model, Figure 2(b) shows that the update probabilities of on-demand routing protocols increase linearly with the number of mobile nodes. The reason is they focus only on the links of a requested route, not the whole links of a network. The average links of a requested route increase linearly with the number of mobile nodes. The update probabilities never reach 0.5 no matter what moving speed the mobile nodes move. This compares superiorly with that of table-driven routing protocols. Also, in Figure 2(b), we also know that the update probabilities in a fading model are slightly higher than that in a free space model.

B. The Effect of Moving Speed

Applying various moving speeds to these protocols, we presented Figure 3. The x-axes of these graphs are the moving speeds, which are low, low+, moderate, high-, and high moving representing moving speeds 10, 20, 30, 40, and 50 km/hr respectively.



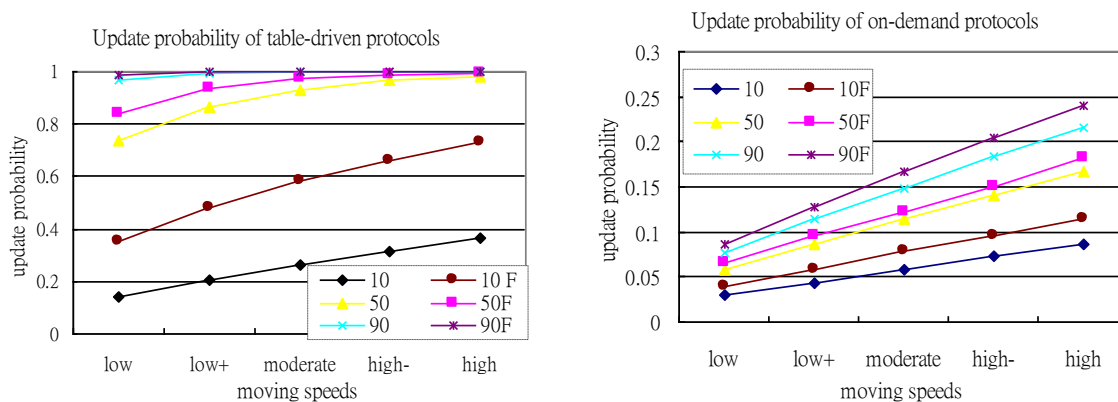
(a) table-driven routing protocols



(b) on-demand routing protocols

(LS, MS, HS are short for low, medium, and high speed, and LSF, MSF, HSF represents low, medium, and high speed with fading channel)

Figure 2 Update probabilities (different number of mobile nodes)



(a) table-driven routing protocols
(10, 50, and 90 represent the number of mobile nodes, and 10F, 50F, and 90F have the same number of mobile nodes but with fading channel)
(b) on-demand routing protocols
Figure 3 Update probabilities (varying moving speeds)

Figure 3(a) shows the effect of moving speed on update probabilities of table-driven routing protocols. The update probability in a fading model is slightly higher than that in a free space model. It also shows that the update probability increases linearly with the moving speed. No matter what speed the mobile node travels. If there are 10 mobile nodes, the update probability never exceeds 0.4. However, there is still one distinguished feature that if the number of mobile nodes is greater than 50, the update probability enlarges rapidly no matter what speed the mobile node utilizes. Among these, the lowest update probability is 0.737 when the number of mobile node is 50 and moving speed is low. At the same case, if the moving speed is changed to be high, the update probability achieves 0.983. The main reason is the protocols maintain all links of a network.

Figure 3(b) presents the update probabilities for on-demand routing protocols based on varying different moving speeds and propagation models. The update probability also increases linearly with moving speed. It also tells us that the update probabilities in a fading model are slightly higher than that in a free space model. The update probabilities of Figure 3(b) never exceed 0.25. The main reason is the protocols focus only on the links of a requested route, not the whole links of a network. This tell us that on-demand routing protocols have lower update probabilities than table-driven routing protocols.

VI. CONCLUSION

A mobile node could freely move without the constraints of wired backbone. This also presents the fragility of the networks. To enable the transmission, table-driven routing protocols have to maintain the whole topology of a network, i.e. all the links. If any link breaks, the protocols must trigger an update to maintain up-to-date routing information. Therefore, as the number of mobile nodes and moving speeds increase, routing table update increases rapidly. However, data traffic nearly has no influence on the protocols. On the contrary, on-demand routing protocols focus only on the links of a specific route, not the whole

links of a network. Excluding the unnecessary information, the protocols largely reduce the update probability as compared with table-driven routing protocols. According to the simulation result and performance analysis, we found that the update probability of on-demand routing protocol increases both linearly with the number of mobile nodes and moving speed. However, data traffic has higher influence on the protocols than the former two issues.

We conclude that the effect of link break problem on table-driven routing protocols is much serious than that on on-demand routing protocols since the former has to maintain each link of the network but the latter only the links of a specific route. Table-driven routing protocols are not scalable; however, on-demand routing protocols are.

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