# Analysing Link Stability Using QoS to Support Routing in Mobile Ad-hoc Networks

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***Abstract***
An Ad-hoc network is a wireless network without any centralized authority. Because of the lack of this centralized authority many of the wireless protocols at various layers of the TCP Stack becomes inefficient. In addition to the lack of a centralized server, the nodes of an Ad-hoc are mobile which introduces challenges when designing routing and MAC protocols. This paper deals with finding the stability of links among nodes in mobile ad-hoc networks and a new protocol named Quality of Service Based Medium Access Control Protocol for Mobile Ad Hoc Networks(QB-MAC). To calculate link stability we use certain Qos Parameters. This stability value can then be used to support routing. In this way we guarantee the Quality of Service required by the user for the transfer of messages. This simulation is done using the Network Simulator (ns2) and the results obtained along with other graphical data are given.

***Keywords***
*QB-MAC, Wireless ad hoc networks, quality of service, user, link stability, routing, Markovian model*

## 1. INTRODUCTION

Mobile Ad-hoc networks are nothing but a type of wireless networks having certain specific characteristics which differentiates them from certain conventional wireless networks. The challenges in Ad-hoc networks are the lack of a centralized authority and an infrastructure. Such type of applications are used in battlefields and in areas affected by floods and earthquakes where the deployment of any wired or wireless network quickly is not feasible. They are also used in areas where fast and efficient deployment is a major concern. Though Ad-hoc network is an instance of a mobile and a wireless network, the protocols that exists for mobile and wireless networks can't be used as it is for ad-hoc networks The TCP layer protocols for wireless has to undergo a major change, to fit for ad-hoc networks and it poses a major research area.

The MAC Layer used here is IEEE 802.11[2](Wireless LAN), which is responsible for transferring the packets from one node to the (immediate) next node. This paper provides an interface named Quality of Service Based Medium Access Control Protocol for Mobile Ad Hoc Networks(QB-MAC) which is an extension of IEEE 802.11 between the MAC and the Network Layer providing the information ( Link Stability factor ) calculated by the MAC layer to the network layer. The mobility of nodes in any network can be described using some predefined standard models like random walk, random waypoint , markov chain etc. The Mobility Models, Random walk and Random way point has a serious disadvantage as the movements of the nodes as per these models may be unrealistic because of sudden acceleration and changes in their directions.

We use markov model to describe the mobility of nodes in the network. Markov model calculates the next state of a node based on the present state and the future states is independent on the past state( i.e., the future state depends only on the present state) Our aim is to calculate the stability of the links and use the path with more highly stable links to transfer the data. The link stability is calculated based on weights of the Qos parameters of the source and the destination. The weightage is based on the Quality of Service required by the user. The Qos Parameters we use here are data rate, buffersize, distance, signal to noise ratio, and transmission range of the nodes.

This link stability factor may be given to any Routing Algorithms like ABR[8],AODV[7][8] etc. and thereby we can enhance the performance of the routing algorithm for the particular Quality of Service How to calculate stability of a link and how this information is used in Routing is discussed in the forth-coming sections. Section 2 contains details about 802.11, which is the MAC protocol employed.Section 3 contains details about the Markovian model for mobility. Section 4 discusses about the what's and how's of the Qos parameters. Section 5 details the procedure how QB-MAC protocol for Mobile Ad Hoc Networks calculates the link stability factor and its support for routing protocols and finally Sections 6, 7 dealing with the implementation details and results & future work respectively.

## 2. MAC PROTOCOL : 802.11(WLAN)

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The MAC layer's primary function is to arbitrate and statistically multiplex the transmission requests of various multiplex stations that are operating in an area. The MAC layer supports many auxiliary functionalities such as offering support for roaming, authentication, and taking care of power conservation. The following are the main issues that need to be addressed in a MAC protocol for ad hoc networks.

**Bandwidth Efficiency**

The MAC protocol must be designed in such a way that the scarce bandwidth is utilized in an efficient manner. Bandwidth efficiency can be defined as the ratio of the bandwidth used for actual transmission to the total available bandwidth.

**Quality of service support**

QOS support is essential for supporting time-critical traffic sessions such as in military communications. The MAC protocol for ad hoc wireless networks that are to be used in such real time applications must have some kind of resource reservation mechanism that takes into consideration the nature of the wireless channel and the mobility of the nodes.

**Synchronization**

Synchronization is very important for bandwidth reservation by nodes. Exchange of control packets may be required for achieving time synchronization among the nodes. The control packets must not consume too much of network bandwidth.

**Hidden and Exposed terminal problem**

The hidden terminal problem refers to the collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the transmission range of the receiver. The exposed terminal problem refers to the inability of a node, which is blocked due to transmission by a nearby transmitting node, to transmit to another node.

## 3. MOBILITY MODEL : SIMPLE INDIVIDUAL MARKOVIAN MODEL (SIMM)

### 3.1 Mobility Model – An Introduction

Mobility models are used to represent the mobility patterns of the nodes. These models are used in performance evaluation of applications and communication systems, allowing analysis of the impact caused by mobility on their functioning. Mobility models can be applied in many studied environments, such as the management of cryptographic key distribution, packet loss evaluation, traffic management, performance evaluation of routing protocols, partition prediction, service discovery in partitionable networks and medium access protocols for MANETs, among others. These models can be further classified in two types: individual mobility models and group mobility models.

One of the most used models in ad hoc networks is the random walk mobility model [9]. In this model, the direction and speed of movement at some point in time has no relationship with the direction and speed at previous points, making this model memory less, and also generating a nonrealistic movement for each mobile nodes, with sharp turns, sudden stops and sudden accelerations. Some other models based on the random walk mobility model have also been proposed [10], [11].

The Waypoint Mobility Model, described in [12], divides the course taken by the mobile nodes in two periods, the movement period and the pause period. The node stays at some place for a random amount of time and then moves to a new place chosen at random with a speed that follows an exponential distribution between [minspeed, maxspeed]. This model is also memory less, and has the same drawbacks of the random mobility model. In [13], is presented a study about the harmful behavior of waypoint model.

Individual mobility models represent the movement pattern of a node independently of the other nodes, and are the most used models in the performance evaluation of ad hoc networks. Group Mobility Models deal with both the movement of the node individually and as a group.

### 3.2 Related Work

**General Markov Model :**

The Markovian Random Path Model (MRP) was proposed by Chiang[13], and uses a markov chain to model the movement, introducing memory in the movement behavior. This model has three states to represent the movement coordinates *x* and *y*. The state zero (0) represents the current position of the mobile nodes, while state one (1) represents its previous position and state two (2) represents its next position. Fig. 2 shows the markov chains for the movement coordinates *x* and *y*.

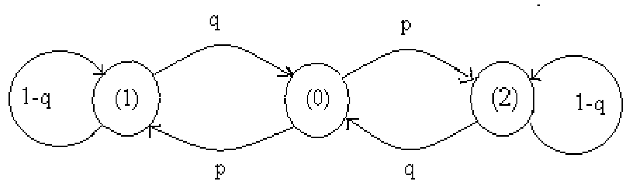


**Fig. 1. state transition diagram of markov chain**

In this model, movements in the horizontal and vertical directions as well as stops are not possible for an interval of time greater than one step Another property of this model is that it doesn't allow sudden changes of the way of the movement, because there aren't one step transitions between states (1) and (2), that is, before changing the way the node first has to stop. Compared to the Random Walk and the Waypoint, the MRP model tries to describe a more realistic movement. However, it still has some drawbacks. Besides doesn't allowing stops and movements in the vertical and horizontal directions for an interval of time greater than one step, this model doesn't support speed changes while moving in some direction. The proposed modeling address the problems mentioned above. These models were based on the markovian processes.

### 3.3 Simple Individual Mobility Markovian Model – SIMM

The SIMM model[14] uses a discrete-time Markov chain that allows horizontal and vertical movements, besides allowing stops. However, it doesn't support speed changes. The Markov chains used in the SIMM model are shown in Fig. 2. This model is an extension of the MRP model. As can be seen in the Fig., the model introduces a transition from state (0) to the same state (0) with a probability $1 - 2p$, allowing the node to remain at the same position in $x$ or $y$ during some interval of time.

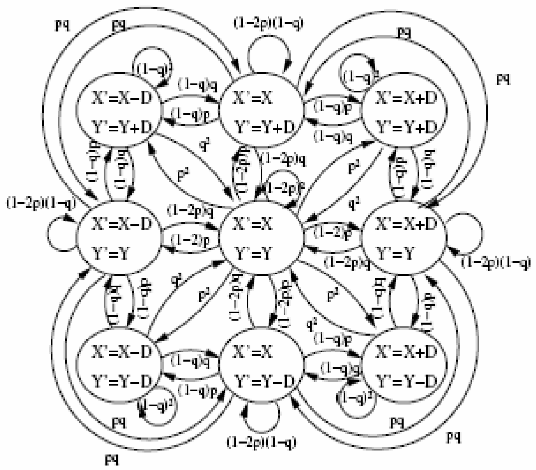


**Fig. 2. Diagram with two state variables (x and y coordinates)**

Initially the node is at position (x, y). In this model, the movement is represented by the increment or decrement on the coordinates $x$ and $y$ by a value of $D$. From the initial position the node may move to any of the nine possible states. There is a probability for each node to move from one state to another state. The node in position (x + D , y) can move to four states. In the above the value of D is taken as 1 for simplicity sake.

## 4.QUALITY OF SERVICE PARAMETERS - AN INTRODUCTION

QoS stands for Quality of Service. In ad-hoc networks providing the Qos as specified by the user is a difficult task[1]. For our purpose of calculating the stable link we have taken four Qos Parameters. The definition of the Qos parameters and their roles are described below.

### 4.1 Data Rate

Datarate is defined as the amount of data(in bits) transferred per sec. It is defined for a link connecting the source and the destination. As the datarate increases the amount of data transferred increases. The weight of this parameter is kept high when the user wants a faster and efficient data transfer. In this case, we have mapped the data rate supported by the links onto a range of 1-10.

The region for the link is taken as i, as the data rate is satisfies the following constraint.

DataRate( i-1 ) <= data rate < DataRate( i )

| Data rate | 28 | 56 | 100 | 150 | 200 | 300 | 600 | 750 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Region | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**Fig. 3. Data rate**

As the region number increases, the data rate supported by the region increases(ie) the difference between the max data rates supported by two successive regions increases from left to right. The reason behind this logic is that an user feels a difference when he is operating at 28kpbs and when is working at 56kbps(28 + 28) whereas this difference will not be felt between 1000kpbs and 1028kbps(1000 + 28).

### 4.2 Buffersize

Here we are considering the size of the buffer at the receiver end. The buffer is kept in order for the router to prevent dropping of packets when two packets arrive simultaneously. Each node in an ad-hoc network are required to perform a routing function, so all the nodes must be equipped with a buffer. More the size of the buffer less the probability for the packets from being dropped. The weight of this parameter should be kept high when the user wants the data to reach the destination safely without being discarded without leading because of congestion(which will prevent the retransmission of the data packets).

### 4.3 Transmission Range

This gives the transmission range of the source node in meters. As the ad-hoc nodes are wireless nodes, a link can only be established only when a node lies within the transmission range of the source node. Fig. 4 shows the transmission range of node A. Nodes B, D and E are in transmission range of A, whereas node G, F are not in transmission range of A.

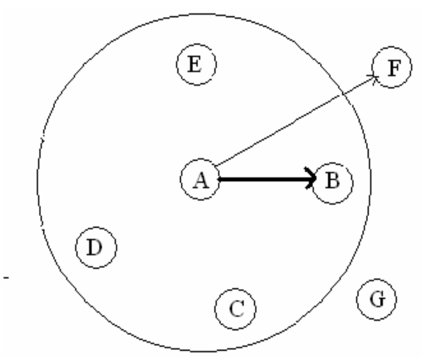


**Fig. 4. Transmission range of A**

### 4.4 Signal To Noise Ratio(SNR)

Signal to Noise Ratio gives the ratio of the signal(data) strength to the strength of the noise in that particular link. As the SNR increases the effective transmission range of the source node decreases, so we are addressing the SNR value in calculating the link stability.

### 4.5 Distance between the Source and the destination of the link

As the distance between the source and the destination decreases, the strength of the signal reaching the receiver will be more, which ensures error less data transfer. One added advantage of considering the distance is secure data transfer. When the distance between the source and the destination is low, it implies that the source and the destination are physically near and hence the source can physically see the destination (at very short distance) which enables the source node to (trivially) authenticate the destination without using any key management mechanisms. This may be handled in applicable scenarios in order to reduce the control overheads.

## 5 .QB-MAC: CALCULATING LINK STABILITY FACTOR USING QOS PARAMETERS

As explained, the Qos Parameters are taken along with their individual weights, whose values are based on the Quality of Service specified by the user. When the user wants a faster transfer, the weights of data rate and buffer size should be kept high compared to others as increasing the weight of the buffersize reduces the probability of packet retransmission which indirectly increases the data rate. If the user wants a error less transmission increase the weight of buffersize and decrease the weight of the distance (since decrease in distance means the signal strength reaching the receiver is high , in other words the signal being affected by external factors is less, which enables less error in signal ).When the user wants a secure transmission, the weight of the distance factor should be considered as the distance between the source and the destination is less, the source can physically authenticate the destination.

Let us assume that the weights of data rate, buffersize, distance, transmission range with SNR are a, b, c, d respectively. The future position of the destination node in its worst case can be determined based on the markov model described above. As the nodes move, the distance between the source and the destination changes which eventually affects the state of the link. This is also taken into consideration when calculating link stability.

All the Qos parameters determined for each node are mapped to a value in the range 0 to 1.The weights of the Qos Parameters should be in the range of 0 to 10. The parameter values of the source is obtained from it in a control packet(or in the case of nodes which follow Table driven routing, these parameters are sent along with the table). These values are then multiplied with the weights and added to get the link stability factor from destination to source(Since the destination calculates the link stability factor for the link from destination to source on receiving information from the source)

The procedure for calculating link Stability is
{ data rate parameter weight }*{ data rate parameter value }
+ { buffersize parameter weight}*{buffersize parameter value}+ { distance parameter weight }*{ distance parameter value } + {parameter value of transmission range with SNR}* {parameter value of transmission range with SNR}

Based on the above formula the link stability factor for the link between any source and any destination can be calculated. This can be done easily when the source and the destination are directly connected. In case when the source and the destination are not directly connected, the path which has the maximum number of stable links in it can be chosen.

## 6. SUPPORTING ROUTING PROTOCOLS RELAYING ON LINK STABILITY

The link stability values that were calculated in the section 3 can be used to demonstrate which links are stable. This QB-MAC protocol information can be used by routing protocols for finding out the available stable links in the Mobile Ad Hoc Network(MANET). In this section we are going to discuss some routing protocols which can use the link stability information to improve their performance.

### 6.1 Ad Hoc On-demand Distance-Vector Routing Protocol (AODV)

In AODV[7][8], the source node floods the RouteRequest packet in the network when a route is not available for desired destination. It may obtain multiple routes to the desired destination from single RouteRequest. The DestSeqNum is used to determine an up-to-date path to the destination. A RouteRequest carries the source identifier (ScrID), the destination identifier (DestID), the source sequence number (SrcSeqNum), the destination sequence number (DestSeqNum), the broadcast identifier (Bcast ID), and the time to live(TTL) field. When a node receives a RouteReply packet, it is send to the destination. It may get more than one path to the destination, by incorporating our link stability factors for the available links, route selection based on link stability information can be done which reduces the complexity of the task and an efficient route can be selected.

### 6.2 Associativity Based Routing

Associativity Based Routing protocol[8] is a distributed routing protocol that selects routes based on the stability of the wireless links. A link is classified as stable or unstable based on its temporal information. The temporal stability is determined by counting the number of beacons that a node receives from its neighbours. The RouteRequest is send by the source node, the packet traverses through intermediate nodes and also gets the beacon count of each node before reaching the destination. Using this beacon count information and the link stability information calculated in the previous section the stable links are determined. The destination now selects the path with large number of stable links. The performance of the protocol can be improved by making use of our stable link factor values.

## 7. IMPLEMENTATION DETAILS

The link stability of the links are calculated using the formula given in the section 5. For each link the stability value is calculated. The links which have a stability value more than 7 are stable links and links which have a stability value less than are unstable links.

Initially a test bet of 25 nodes is taken and each node transmit packet to the nodes in its transmission range. The node sends parameters like data rate, transmission range, buffer size and SNR value along with the packet. The receiving node gets the parameter values from the packet and calculates the link stability.

In Fig. 5 *X axis in time(seconds) for a time interval of 1s and Y axis in No. of links(number) shows* Total number of links and the Number of stable links .The number of stable links is always greater than that of unstable links.

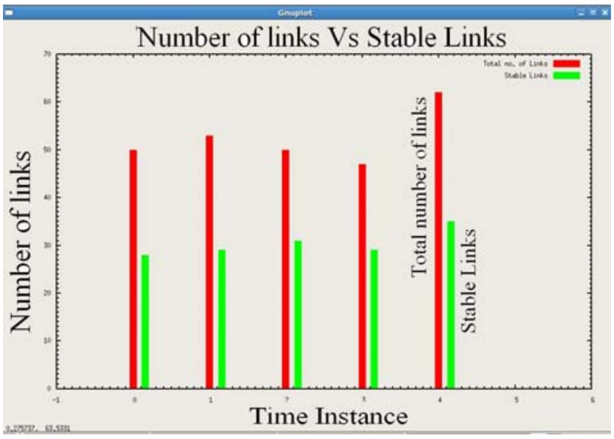


**Fig. 5. Number of stable links**

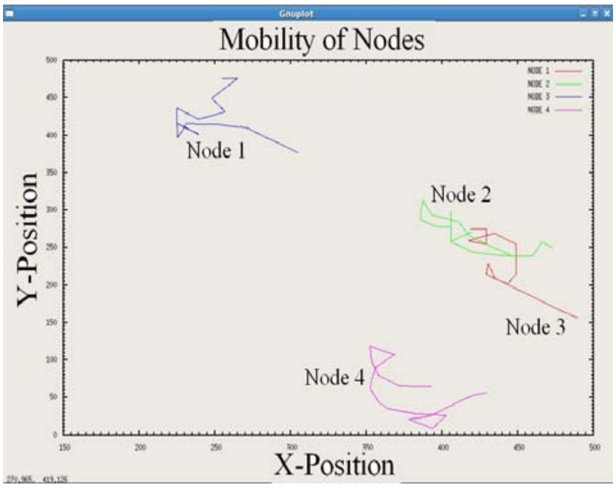


**Fig. 6. Mobility of Nodes**

In Fig. 6 *X axis in X-Position for an interval of 50 units and Y axis in Y-Position for an interval of 50 units* shows the mobility of nodes, a test bed of four nodes are taken. The mobility has been implemented using the markov model.

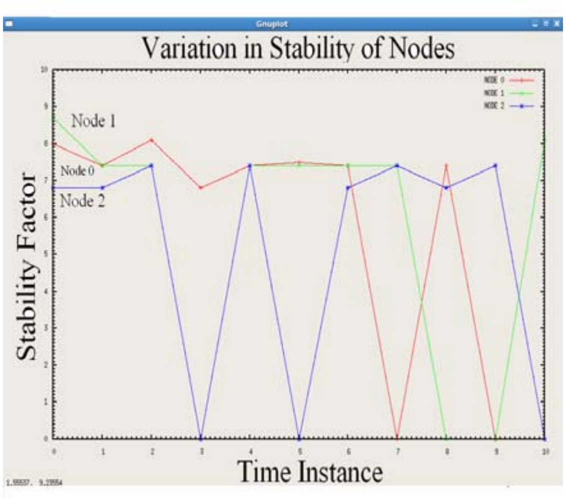


**Fig. 7. Link stability of links**

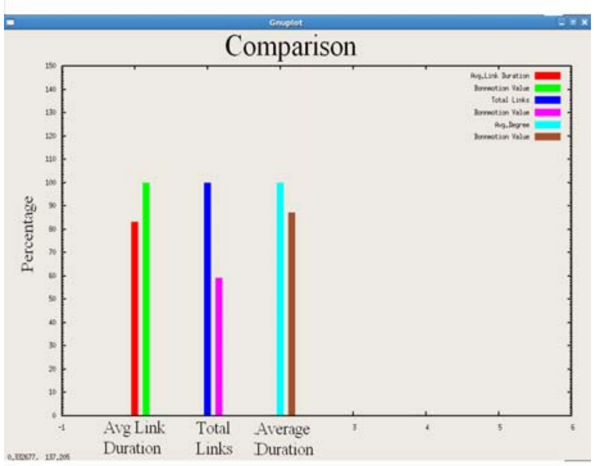


**Fig 8. Comparison between bonnmotion and QB-MAC Protocol**

In Fig. 7 *X axis in time(seconds) for a time interval of 1 second and Y axis in stability factor which can vary from 0 to 10 with an interval of 1 unit.* Link stability of 3 links at different time instances are shown.

In Fig. 8 *X axis represents service parameters and Y axis in percentile values with an interval of 10 units* shows a comparative study of QB-MAC protocol with the conventional stability based protocol in bonnmotion. This comparison is done based on three parameters (Average link duration, total number of links formed and average duration) which are shown. The maximum value obtained in each case is scaled to 100 and the other values is accordingly for each case(something similar to percentage) and the results obtained are plotted in a graph.

Fig. 9 shows the path taken by Dynamic Source Routing (DSR)[5][6] protocol to send a packet from source A to destination E. As DSR protocol chooses the path with the least cost, it follows the path A --> C --> E to reach E from A. As shown the link A to C is unstable though it has a low cost. Since this link is unstable following DSR for routing increases the probability of retransmission of data packets and data loss. Since QB-MAC protocol follows the path that has the maximum number of stable links it takes the route A --> B --> D --> F --> E to E from A. This prevents retransmission of packets and thereby guarantying required quality of service.

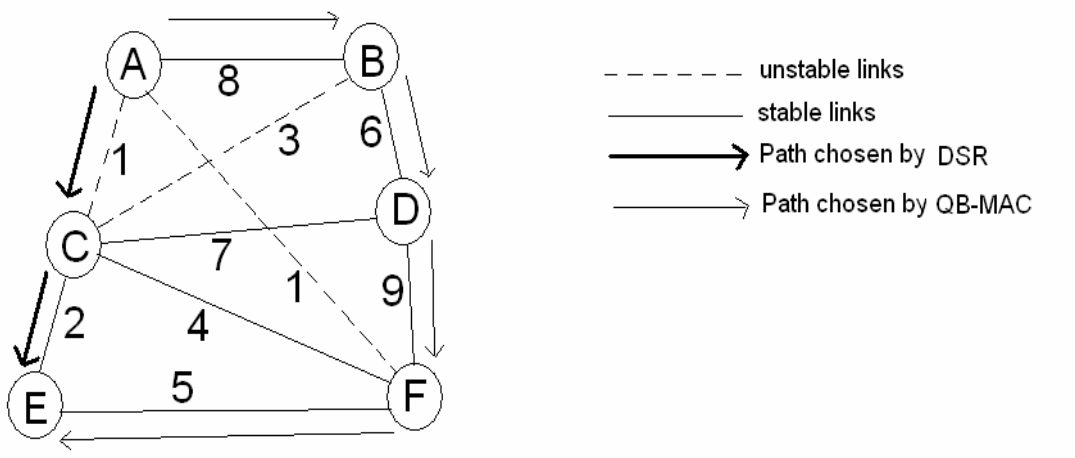


**Fig. 9. Path taken by DSR and QB-MAC protocol**

## 8. CONCLUSION AND FUTURE WORK

As Stability of links is a major concern in Mobile Ad Hoc Networks, we work on MAC layer of Ad Hoc Networks and introduced a new MAC protocol called Quality of Service Based Medium Access Control Protocol for Mobile Ad Hoc Network QB-MAC. The results cum the graphical data shows the availability of stable links for nodes at various instances which are mobile. A path is represented using the stable links and compared with a conventional routing protocol. These values act as a good starter for any routing protocol which prefers stability. Developing a novel routing protocol based on these values and introducing more categories in stability values can be a worth full future work.

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