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Measurement and Application of Link Reliability for Wireless Mobile Networks

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Abstract

Radio channel characteristics of mobile nodes are quite different compared with the traditional stationary base station to mobile radio channel. Wireless link reliability estimation is necessary for self-organization of wireless mobile multihop networks. In this paper, we measure narrowband path loss measurements in a typical mobile-to-mobile radio environment. For application, we proposed a method to incorporate link reliability into path reliability evaluation and selection for multipath routing in wireless mobile networks. Simulations show that the proposed method has better performance.

Keywords: *multipath; mobile network; path loss; shadow fading*

1. Introduction

Mobile to mobile radio channels make wireless transmissions unreliable because of channel fading and collisions. Channel fading can result in substantial signal power fluctuations. This leads to a large number of transmission errors, especially when communicating nodes are moving [1].

The wireless radio channel poses a severe challenge as a medium in the design of any radio communications system or wireless system. The radio signal path loss will determine many elements of the radio communications system in particular the transmitter power, the antennas and the movement or static. The radio path loss will also affect other elements such as the required receiver sensitivity, the form of transmission used and several other factors. [1-2]. The radio propagation effect poses a severe challenge as a medium for reliable wireless mobile communication. The movements nodes will cause the received signal to fluctuate [10].

However, these characteristics have not been well considered for developing most of the routing protocol in mobile-to-mobile network environment.

During the recent years, statistical properties of mobile-to-mobile channels have been investigated concentrating on characteristic of the mobiles radio channels by many researchers[3-9].

Data communication in a mobile network differs from that of traditional networks in different aspects. The wireless communication medium has variable and unpredictable characteristics. The signal strength and propagation delay may vary with respect to time and environment where the mobile nodes are.

Kinds of methods could be used to estimate these parameters for practical of routing protocol. The network topology of mobile wireless ad-hoc is dynamic as their mobile nodes are free to move around and can even freely leave or join the networks. This mobile characteristic arose many challenging problems in routing design in mobile networks.

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One of the fundamental and most frequently addressed problems in these networks is to obtain a stable route so that mobile host can transmit or receive data from any other host in the network.

The node with lower link reliability selected to be the part of routes can ultimately induce the re-route discoveries. Path consists of a few low link reliability between neighbor nodes should be avoided to forward packets

One of the key reasons for understanding the various elements affecting link reliability is radio signal path loss. It is to be able to predict the loss for a given path, or to predict the coverage that may be achieved for a particular station.

Prediction or assessment can be fairly accurate for the free space scenarios. For real life applications it is not easy to gain accurate assessments as there are many factors to take into consideration.

Traditional approaches for multi-hop routing in mobile ad hoc networks adopt one single active path between source and destination nodes of a communication flow, typically established by using proactive or reactive protocols.

The proactive schemes are more expensive in terms of mobility consumption as compared to the on-demand schemes because of the large routing overhead incurred in the former. But, on-demand protocols suffer of considerable route discovery latencies under intermittent-data applications, when a new route is requested in large networks and high-populated scenarios.

Multipath on-demand protocols overcome this inefficiency. An on-demand protocol typically uses the source initiated route discovery procedure. Whenever a traffic source needs a route, it initiates a route discovery process by flooding a route request for the destination, and waits for a route reply. Each route discovery flood is associated with significant latency and overhead [14].

Most traditional on demand ad-hoc routing protocols establish a single path at this route discovery procedure. Multi-path ad-hoc routing protocols, which establish multiple disjoint paths during a single route discovery phase. A single path protocol has to invoke a new route discovery whenever the only path from the source to the destination fails. In contrast to multipath protocol, a new route discovery is needed only when all these paths fail. Thus, on-demand multipath protocols cause fewer interruptions to the application data traffic when routes fail. They also have the potential to lower the routing overhead because of fewer route discovery operations [15].

It has been shown that multi-path ad-hoc routing protocols have a number of benefits. Multi-path protocols typically have a lower overhead, lower packet loss rate and increased reliability compared to their single-path counterparts.

In this paper, path loss exponent and shadowing parameters are derived for a simple power law path loss model based on measurement with low elevation antennas for a transmitter and a receiver at 900 MHz band. Then, we develop a method that considers the link reliability for path stability evaluation and path selection of multipath routing.

The remainder of this paper is organized as follows. In Section 2, the measurement configurations are described. The empirical propagation model that is tuned with measured data is shown. The measurement results are presented in Section 3. Section 4 presents a method to evaluate link reliability of multipath routing protocols. Conclusion is in Section 5.

2. Measurement Configuration

2.1. Measurement Parameters

To validate that the model works for channels of mobile nodes, experiments were done in spring at an urban and rural area. Table 1 summarizes the measurement parameters [16].

Table 1. Measurement Configuration

Parameters	*Values*
Transmitter	PCS-20
Receiver	FSL6 Spectrum Analyzer
TX Antenna	3.0 dBi
RX Antenna	3.0 dBi
Frequency	914MHz
Antenna Height	1.5m
Antenna Height	1.5m
Feeder Loss	2.9 dB
Cable Loss	2.0 dB

2.2. Reference Mobile-to-Mobile Path Loss Model

A base-to-mobile power law path loss model was used for predicting the distance of reliable communication between mobile-to-mobile nodes [16].

$PL(d)$ is the mean path loss value, d represents the distance from the transmitter. $PL(d_0)$ is the reference path loss at distance d_0. Variable n is the path loss exponent and it describes how quickly the signal attenuates. Where $N(0,\sigma)$ follows a zero-mean Gaussian distribution with a variance σ to reflect effects of shadowing and fading [10-11].

3. Measurement Results

We first measured the path loss in urban region. Then, we measured it in rural region. The measurement environment are two different propagation environments.

3.1. Measurement Results

$$PL(d) = PL(d_0) + 10n\log(\frac{d}{d_0}) + N(0,\sigma) \tag{1}$$

A continuous wave signal was fed to the transmitter antenna with the carrier frequency of 914 MHz. The transmitter antenna and the receiver antenna were omni-directional antennas. The antennas and a spectrum analyzer were mounted on the cars with height of 1.5 meters which corresponds well to the definition of mobile-to-mobile propagation scenarios [1-2].

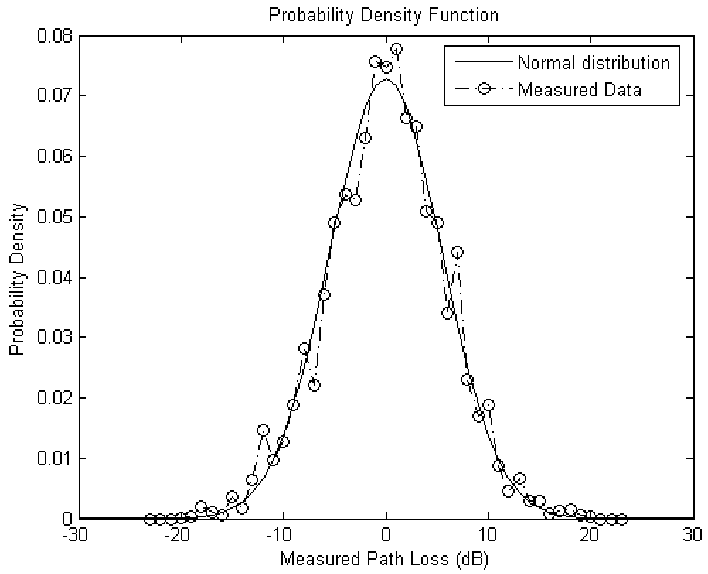

Figure 1. The Measured Pat Loss (Db) at 914mhz is Curve-Fitted by a Normal Distribution with a Given Standard Deviation Σ Value 5.48 in Urban Area

Figure 1 shows the measured path loss urban area. The solid curve shows the normal distribution with standard deviation. The dashed line shows the measured Probability Distribution Function (PDF). We found that the measured n is 4.3, and a zero-mean normal distribution with a given standard deviation σ 5.48 can fit the curve of measured data well [13].

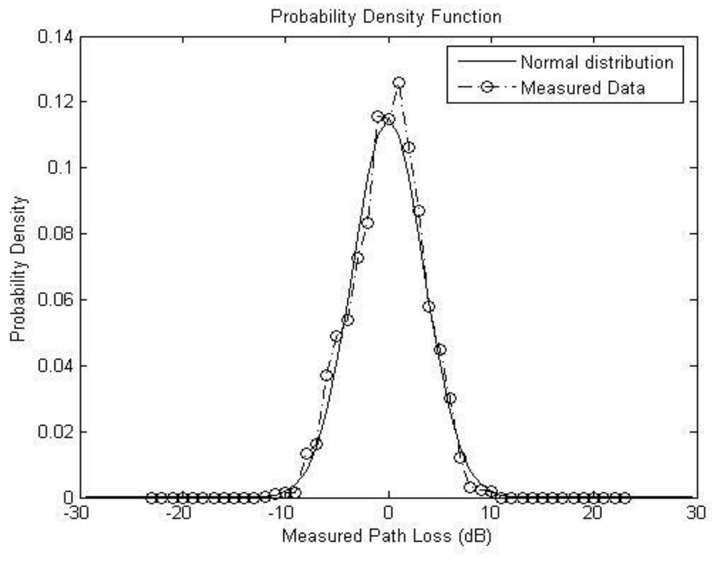

Figure 2. The Measured Pat Loss (Db) at 914mhz is Curve-Fitted by a Normal Distribution With a Given Standard Deviation Σ Value 3.47 in Rural Area

Figure 2 shows the measured path loss in rural area. We found that the measured n is 3.6, and a zero-mean normal distribution with a given standard deviation σ 3.47 can fit the curve of measured data well. The measured results are similar to the results measured in other mobile-to-mobile scenarios [7-9].

3.2. Estimation of Link Reliability

In wireless systems there is typically a target minimum received power level P_{min} below which performance becomes unacceptable [1].

In the design of routing protocol, the link reliability LR_i for a radio link i is defined to be the probability that the received power at a given distance d_i , $Pr(d_i)$, falls above P_{min}:

$$LR_i = p(P_r(d_i) \geq P_{\min}) \tag{2}$$

With Eq.(2) and some derivations [1][9], LR_i is given by

$$LR_i = Q\left(\frac{P_{\min} - (P_t - PL(d_0) - 10n\log(\frac{d_i}{d0}))}{\sigma}\right), \tag{3}$$

Where $Q(z)$ is a complementary error function and is defined as:

$$Q(z) = \int_z^{\infty} \frac{1}{\sqrt{2\pi}} e^{-x^2/2} dx \tag{4}$$

A path consisted of links with higher link reliability values can be considered more stable than other path that consisted of link with lower reliability value. Thus, the path has high link reliability can be selected with a higher priority for data routing.

4. Application Analysis

We develop a method to evaluate path reliability for AOMDV [14] multipath routing. The resulting protocol is referred to as path stability evaluation method (PSEM).

4.1. Including Path Reliability

As shown in Table 2, each route reply message in PSEM now carries an extended field called stability to indicate stability of each path, which is minimum value of all the nodes in the path. When a route reply (RREP) travels along the reverse path from the destination, it piggybacks the link reliability value. A comparison between the value in the RREP packet and the link reliability of current node is done at each intermediate node, the lower value is going to be updated into the RREP packet field. The minimum value of all intermediate nodes along the reverse path is obtained when RREP packet reaches the source node. Table 2 shows an example of PSEM that includes the path reliability into routing table.

Table 2. Route-List Structure of Routing Table Entries for AOMDV and PSEM

AOMDV	*PSEM*
destination	destination

route-list
{
(next-hop1,hopcount1,
last-hop1),
(nex-thop2,hopcount2,
last-hop2),
…
}
	route-list
	{
	(next-hop1,hopcount1,
	last-hop 1,stability1),
	
	(next-hop2,hopcount2,
	last-hop 2,stability2),
	…
	}

Path stability calculation depended on equation 2. For the practice of routing protocol of mobile-to-mobile communication system, some profiles with different parameters should be set up for the environment [10-11].

We set up there profiles with different parameters for the outdoor urban and rural environment. This makes the protocol that uses these parameters arrives at optimal performance in specific wireless environment.

It is noted that the path loss exponent n and the variance σ should be made adaptive to the propagation environment. Hence, these parameters are statically configured in the proposed protocol by doing sufficient field-tests in the applied environment [9,13].

Here, n is 4.3 and σ is 5.48 for the urban environment. For the rural area n is 3.6 and standard deviation σ is 3.47, which are derived from our field tests. The measured results are similar to the results measured in other urban and rural mobile-to-mobile scenarios [7-9].

The parameters Pt and Pmin can be configured based on transmission power and target minimum received power, respectively.

From Eq.(3), each node should know its own position to calculate link reliability. We define the one-hop radio link reliability as the radio link reliability between the receiving node itself and its neighbor who sent the message [13].

4.2. Dynamic Link Reliability Information Collection

A novel dynamic link reliability information collection method is described here. AOMDV broadcasts the HELLO message to update the neighbor caches. The HELLO message used in AOMDV only keeps the address of the host who initiates this message.

We extend the HELLO message to include two fields. The first field records stability of path. The value is updated periodically and piggyback broadcasted when a node broadcast HELLO messages. The second field records the last-hop of the path. The last-hop of a path serves as a unique path identifier provided there are any nodes shared by any path with different source-destination pairs. Knowing the last hop of a path at a intermediate node is sufficient to compare and relay the updated stability value along the path.

The TTL(Time-to-live) of a HELLO packet is only one, thus it can not piggyback information in AOMDV. In contrast to AOMDV, the extension enables HELLO to relay information along the whole path.

Since HELLO message is already used to maintain routing path in AOMDV, PSEM avoids increasing the number of control overhead.

When each node along a path broadcasts HELLO message periodically, following procedure is carried out to collect link reliability information.

Procedure SendHello:

1: ***Foreach*** entry ***in*** Routing Table ***do***

2: $Hello_{stablity}$ = ***MIN***($Rtable_{stability}$,Current-link-reliability);

3: $Hello_{last\text{-}hop}$ = last-hop;

4: ***End***

5: DoSendRoutines();

$Hello_{stablity}$ is the first field extended to indicate the stability of current path in HELLO message. As explained in Section 3.1, the path stability is simply a link reliability value which is the lower one between $Rtable_{stability}$ and Current-link-reliability. Here, $Rtable_{stability}$ is the field extended in routing table as shown in Table 1. Current-link-reliability means the link reliability value of current node when this node is going to send HELLO message. $Hello_{last\text{-}hop}$ is the second field extended to record the last-hop of the path in use. DoSendRoutines() takes care of all the routines need to be done in original AOMDV HELLO message sending procedure.

For each valid entry in the routing table receives the HELLO message, a comparison between path stability (the link reliability) in HELLO message and the link reliability of current node is done, and the lower one will be updated to routing table.

No matter which path we adopt, we should not let the link reliability of source node and destination node be a component in our collection, otherwise the link reliability would always be equal if the source node or destination node holds the minimal link reliability value. In order to reduce unnecessary calculation, comparison is only done when HELLO message comes from the node of next hop in routing table.

Upon receiving a HELLO message, following procedure is invoked.

Procedure RecvHello:

1: ***Foreach*** HELLO message ***do***

2: ***If*** HELLO_{source} ***is*** intermediate node ***do***

3: ***If*** exists $\text{Rtable}_{nexthop}$ ***is*** HELLO_{source} ***do***

4: ***If*** exists $\text{Rtable}_{last\text{-}hop}$ ***is*** same as $\text{Hello}_{last\text{-}hop}$ ***do***

5: $\text{Rtable}_{stability}$= ***MIN***($\text{Hello}_{stablity}$, Current-link-reliability);

6: ***End***

7: ***End***

8: ***End***

9: ***End***

10: DoRecvRoutines();

HELLO_{source} is the node Where the HELLO message is coming from. Line2 keeps the source node and destination node out of the path stability calculation. Line3-4: If the hello source is next hop of current node, and if both of them have same last-hop value, it means path stability value is relaying along the same path.

Line5: $\text{Hello}_{stablity}$ in the incoming HELLO message holds the path stability (the link reliability). Current-link-reliability means the link reliability value of current node when this node is receiving HELLO message.

After comparison between them, the lower one is updated into $\text{Rtable}_{stability}$ which is the field extended in routing table as shown in Table 1. $\text{Rtable}_{stability}$ by far holds the minimal link reliability in the nodes from last-hop to current node. In other words, the path stability value is relayed by HELLO message.

DoRecvRoutines() function takes care of all the routines need to be done in original AOMDV HELLO message receiving procedure.

4.3. Path Selection and Packet Allocation

An important part of a routing protocol is the packet forwarding algorithm that chooses among neighboring nodes the one that is going to be used to forward the data packet [10].

By utilizing the HELLO message broadcasted during the path maintenance process, PSEM collects the up-to-date link reliability information periodically. A more reasonable packet allocation can be made according to the l information, by which we can make a quick response to the changing situation in network.

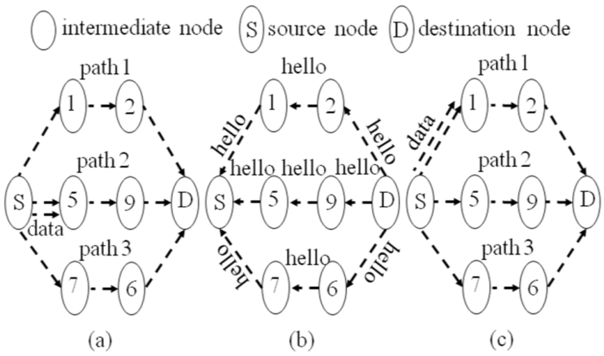

Figure 3. An Example of Path Optimization and Packet Allocation

In our proposal, we send packets priority to the path with maximum link reliability value. With the dynamically link reliability information updating, the path in use may hand the traffic over to other paths when its link reliability value becomes lower, thus avoids the intensive using of one path and possible path breaking.

Figure3 shows an example of path optimization and packet allocation. Initially, as shown in Figure3a, multipath is established and packets are distributed to the path with minimum link reliability which is collected at the route discovery stage.

As the data transmission going on, the link reliability value of each node changes. The packet allocation is readjusted to accommodate such a change. In this proposal, this readjustment is done by using HELLO messages. Thus it will not incure extra overheads (Figure3b).

After receiving the HELLO messages along upstream nodes, the link reliability information of each path is updated (Figure3c), and new packet allocate decision is made according to the up-to-date link reliability information.

5. Simulation

To evaluate and compare the effectiveness of the proposed path stability evaluation method, we performed simulations in NS-2.32 [17]. Each simulation is carried out under different mobility and traffic pattern to obtain the average value.

5.1 Simulation Parameters

The simulation parameters are listed in Table 3.

Table 3. Simulation Parameters

Parameters	*Values*
Nodes number	50
CBR rate	512kb/s
Transmission range	250 m
Speed (m/s)	1-5
Packet type	UDP, CBR
Packet size	1000 bytes

5.2 Performance Metrics

Performance was evaluated in our simulation with following metrics:

Packet Delivery Rate. It is the ratio between the number of packets received by the application layer of destination nodes to the number of packets sent by the application layer of source nodes.

End-to-end delay: measured as the average end-to-end latency of data packets.

5.3. Results and Analysis

Figure 4 demonstrates the effect of node speed on both protocols. Increasing mobility deteriorates them due to the increasing amount of route changes. More routes will become invalid and new requests are required with increasing mobility. AOMDV always forwards data packets with the shortest path. PSEM always forwards data packets with the stable path.

A route having minimum hop count does not necessarily maximize the throughput of a flow [13]. The packet drops at intermediate nodes at lower mobility are dominated by packets with lower link reliability. PSEM performs better with considering the reliability of the path.

Meanwhile, Figure 5 shows the effect of mobility on latency. As indicated by Figure 5, while the network becomes more mobile, the latency of both protocols undergoes increase. As there is more probability of link failures and route change, in cases where no alternate paths are available at source node. RREQ message is generated by source node. This message will be sent to all nodes in order to reroute. As a result, large amount of route request messages are transmitted. The time taken to transmit these messages and paths reestablishment leads to traffic delay.

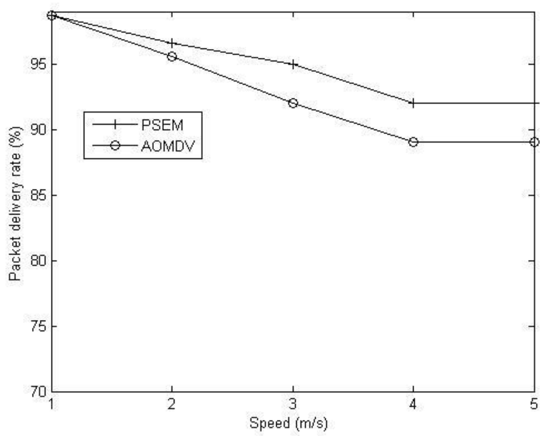

Figure 4. Packet Delivery Rate

While the network becomes more mobile, the difference in latency of both protocols gradually decreases.

Since the difference in latency of both protocols is primarily determined by the packet drops due to path switching. As mobility increases, more routes will become invalid and frequently switching to alternate paths are required. While the source node is switching to a new path, buffers of intermediate nodes in previous path will get full and packets are dropped. In contrast to AOMDV, PSEM always forwards data packets to path with the higher link reliability and performs better.

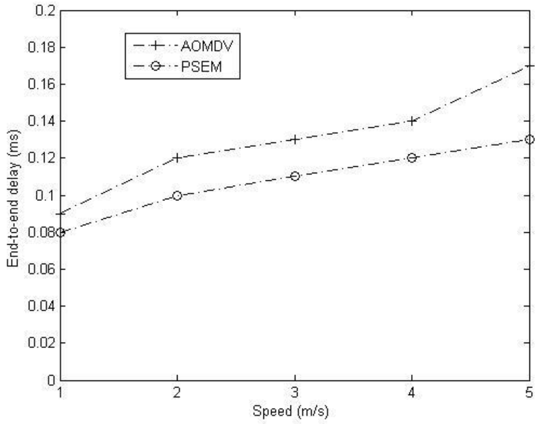

Figure 5. End-to-End Delay

5. Conclusion

This paper provides field-test values for path loss models of mobile-to-mobile wireless systems at 900 MHz band. These parameters were derived from a base-to-mobile path loss model by measurement in mobile environment. These parameters of the derived model should be determined by carrying out measurements in the area where the mobile-to-mobile system will be operated. For the practice of routing protocol of mobile-to-mobile communication system, some profiles with different parameters should be set up for the environment. For application, we proposed a method to incorporate link reliability into path stability evaluation for multipath routing. Simulation shows that proposed method performs better than related work.

Acknowledgments

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