Multipath Routing Protocol Combined with Least Hop Backup Path and Packet Salvaging for MANETs

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Abstract

We propose a multipath routing protocol for Mobile Ad hoc NETworks(MANETs), which combines Split MultiPath - Dynamic Source Routing(SMP-DSR) and Shortest Multipath Source routing(SMS) and changes those backup paths selection criteria. Our proposed scheme improves the transmission success rate and the energy consumption by considering two features. One of the feature is to construct the least hop backup paths without the failed link away. The other feature is to reduce the packet drop by using the packet salvaging method. By providing the alternate paths to the intermediate nodes of the primary path, the proposed scheme ensures to salvage the packets that might be lost at the intermediate nodes. Therefore, hop counts of backup paths and data packet loss are reduced. It is shown by simulations that our scheme improves the transmission success rate and the energy consumption efficiency in MANETs.

1. Introduction

In MANETs, nodes exchange information to other nodes in the network without any infrastructure over wireless medium. Due to the ease of deployment, MANETs have been studied widely in recent years[1]. Topology of MANETs is changing continuously because of the node movement. To maintain the routes between nodes, many routing protocols have been proposed, which are classified into three categories: table-driven, on-demand and hybrid[2]-[4]. Table-driven routing protocols require periodic route-update messages to propagate route information in the entire networks. When network topology changes frequently due to the node movement, route maintenance overhead increases considerably, whereas routes are readily available at all network nodes for data transmission with small delay. Also nodes can smoothly change the route when link failure happens, because each node knows the path information of the entire network. On the other hand, on-demand routing protocols discover routes only when the source node needs to send packets. Therefore, there is almost no route maintenance overhead. However, there are delays of the route construction and overheads of the control packets because data communication starts after a source node searches for a new route to the destination node. In addition, the protocols should reconstruct the route each time when the route breaks and results in a high route construction overhead. The hybrid routing protocols combines both the features of table driven and on-demand routing protocols.

Several routing protocols have been proposed [5]-[7] that overcome the increasing overhead of the route reconstruction due to the link failure. Some protocols add a function to construct multiple paths for on-demand routing protocols such as Dynamic Source Routing(DSR) and Ad hoc On-demand Distance Vector(AODV). Split Multipath Routing(SMR)[5] based on DSR, constructs a primary path and a completely disjoint backup path. The primary path is the main data communication route with the smallest delay, and the disjoint backup path is the route that does not include the same intermediate nodes of the primary path. The source node maintains these routes in the routing table, and restarts data communication immediately over the backup path when the primary path breaks. In SMR, if any link in the primary path breaks, the disjoint backup path is available for data communication. As a result, the overhead of the route reconstruction is decreased. However, there are two problems in SMR. One of the problem is the data packet loss at the intermediate nodes located before the failed link in the primary path. The data packets in the buffer of the intermediate nodes are dropped due to the unavailability of the transmission route from these nodes to the destination node. As a result, the transmission success rate decreases. The other problem is that it constructs the disjoint but long backup path, which increases the energy consumption in the network. The energy consumption increases because the data packets flow through the long route to the destination node.

These problems are solved in SMP-DSR[6], which reduces the data packet loss occurred due to the route change by using the packet salvaging method. The packet salvaging is a method to transmit data packets that might be lost at the intermediate nodes. However, it consumes more energy due to long backup path. Also, the packet loss at the early state of the network is high in SMP-DSR, because the packet salvaging in SMP-DSR requires the cache information of the intermediate nodes. On the other hand, SMS[7] reduces the energy consumption by constructing the least hop multiple backup paths that include the intermediate nodes of the primary path. If any link fails in the primary path, then the SMS forwards data packets through backup path, which includes all the links before the failed link in the primary path. However, those backup paths do not use packet salvaging because disjoint backup paths are not selected. Due to the difference of the backup path(s) selection criteria in SMP-DSR and SMS, the energy consumption and packet loss can not be reduced even by combining the backup path selection criteria of these protocols.

In this paper, we propose a multipath routing protocol which improves the transmission success rate and reduces the energy consumption by combining SMP-DSR and SMS and changing those backup paths selection criteria. The proposed scheme constructs the least hop backup paths without the failed link away. In addition, by providing the alternate paths to the intermediate nodes of the primary path, the proposed scheme ensures to salvage the packets that might be lost at the intermediate nodes. Therefore, the data packet loss and the energy consumption are reduced.

The rest of the paper is organized as follows: Section 2 describes the conventional SMP-DSR and SMS schemes. In Section 3, we explain our proposed scheme which consists of two stages, route constructing process and the method of packet salvaging. Section 4 shows the simulation results and demonstrates the effectiveness of our scheme. Finally, Section 5 concludes the paper.

2. Conventional Schemes

In this section we discuss the multipath routing protocols in the literature that are considered as the conventional schemes to compare the performances with our proposed scheme.

2.1 SMP-DSR

SMP-DSR has an additional function to SMR, that is the packet salvaging, which improves the transmission success rate. Route constructing process and the packet salvaging methods of SMP-DSR are explained as follows.

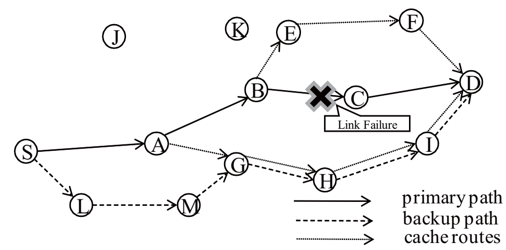

Figure 1. Packet salvaging method in SMP-DSR

2.1.1 Route Constructing Process

This protocol reduces the route reconstruction overhead by constructing a completely disjoint backup path similar to SMR. The source node maintains information of primary and backup path at the destination node, and also stores the route information in the cache of the intermediate nodes after the communication ends. This cache information is one of the optional functions in DSR, which stores route information of the past data communications.

2.1.2 Packet Salvaging Method

SMP-DSR decreases the data packet loss due to the route changing by using the cache information of the intermediate nodes. Figure 1 shows the example of the backup path and the cache routes in SMP-DSR, where node S is a source node and D is a destination node. When the primary path breaks, data packets remain in the intermediate nodes located before the failed link. When the link failure happens, the intermediate nodes select an alternate path from their cache information and transmit the packets through that route to the destination node, called packet salvaging. The packet salvaging increases the transmission success rate. If there is no entry of the route to the destination node in the cache, the packets in the buffer of the intermediate nodes are dropped. In Fig.1, node B transmits the packets by using route E-F-D when link failure occurs between B and C. Similarly, node A sends the packets through G-H-I-D.

2.1.3 Problem of SMP-DSR

SMP-DSR consumes more energy due to long backup path, because it constructs completely disjoint backup path. Also, the packet loss at the early state of the network is high in SMP-DSR, because the packet salvaging in SMP-DSR requires the cache information of the intermediate nodes.

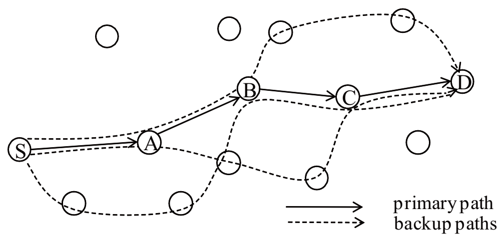

Figure 2. Backup paths in SMS

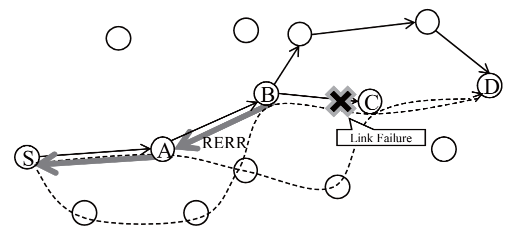

Figure 3. Path selection in link failure of SMS

2.2 SMS

SMS reduces the energy consumption by constructing the least hop multiple backup paths. Those paths are constructed as the least hop without the failed node. As a result, the energy consumption is reduced due to decreasing the number of transmitting and receiving nodes. Route constructing process and the maintenance methods of SMS are explained as follows.

2.2.1 Route Constructing Process

In SMS, the destination node selects a primary path from the first received RREQ(Route REQuest) route, and the source node starts data communication by using the primary path. Afterwards, the destination node receives RREQs from the various routes, and selects backup paths that do not include each intermediate node of the primary path. Figure 2 shows an example of the backup paths in SMS.

2.2.2 Route Maintenance

When the primary path breaks, intermediate nodes of the primary path located before the failed link transmits RERR(Route ERRor) to the source node as a link failure notification. After that, the source node changes communication route to the backup path without the failed node. Figure 3 shows an example of route maintenance. When the link fails between B to C, the source node selects a backup path that does not include the node C. Due to this selection, this backup path has less hop counts compared to the completely disjoint backup path. Therefore, the energy consumption is reduced.

2.2.3 Problem of SMS

Those backup paths are not applicable for packet salvaging because disjoint paths are not selected. Moreover, each backup path corresponds to a part of failed node. However, in the large movement of nodes, more than two parts of the link failure occur, and the source node should reconstruct these paths again. Consequently, the route reconstruction frequency increases, and the energy consumption increases.

3. Proposed Scheme

3.1 Outline of Proposed scheme

Due to the difference of the backup path(s) selection criteria in SMP-DSR and SMS, the energy consumption and packet loss can not be reduced even by combining the backup path selection criteria of these protocols. Here, we try to solve the problems of SMP-DSR and SMS, and combine these two protocols by changing their backup path(s) selection criteria. As a result, the proposed scheme has better performance of the transmission success rate and the energy consumption efficiency than those conventional schemes.

3.1.1 Improvement over SMP-DSR

In SMP-DSR, the cache information of the intermediate nodes is constructed by the past data communications. Therefore, SMP-DSR can not reduce the data packet loss at the early state of networks. As an improvement over SMP-DSR, we propose a method to construct the alternate paths for the intermediate nodes at the beginning of the route construction. The destination node selects the alternate paths from RREQs and transmits RREP(Route REPly) to each intermediate node.

3.1.2 Improvement over SMS

In SMS, the backup paths can not correspond to more than two link failures. As an improvement over SMS, we propose a method to construct backup paths that have the least hop without the failed link away. As a result, the backup paths are available for using the packet salvaging and correspond to more than two link failures. Therefore, the route restructuring frequency is decreased. We explain how we construct the backup paths in the next section.

3.1.3 Combining the both protocols

Here, we propose a multipath routing protocol by combining the improvements over SMP-DSR and SMS. The proposed scheme constructs backup paths that have the least

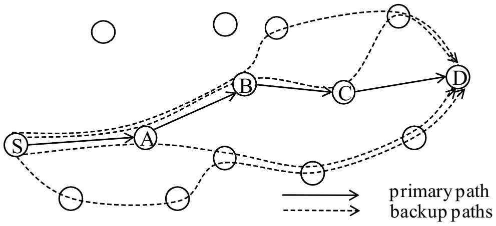

Figure 4. Backup paths in the proposed scheme

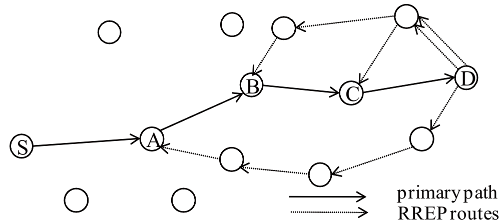

Figure 5. RREP routes

hop without the failed link away. In addition, by providing the alternate paths for the intermediate nodes of the primary path, the proposed scheme ensures to salvage the packets that might be lost at the intermediate nodes. Therefore, the data packet loss and the energy consumption are reduced.

3.2 Route Constructing Process

Here, we show the process of route construction in the proposed scheme. First, the source node broadcasts RREQ to the destination node, and the destination node selects a primary path from the first received RREQ route. After the destination node transmits RREP to the source node by unicast, the source node starts data communication. Here, the destination node stores the intermediate node IDs of the primary path in order of the route. Afterwards, the destination node receives RREQs from various routes, and preserves these routes information in the own memory storage. After a moment, the destination node selects the backup paths that do not include each intermediate node away. Table 1 shows an example of the backup paths in the proposed scheme.

Table 1. Backup paths in proposal scheme

Path ID	Route
primary path	S A B C D
backup path "s"	S * D (not A, not B, not C)
backup path "a"	S A * D (not B, not C)
backup path "b"	S A B * D (not C)
backup path "c"	S A B C ? D

Node S is a source node, D is a destination node, A,B,C are the intermediate nodes, * is arbitrary string, and ? is an arbitrary character. Figure 4 shows an example of the backup paths that are selected on the basis of Table 1.

The backup path information is delivered to the source node by transmitting RREP using only path "s". Those backup paths are the least hop communication routes without the failed link away, when the primary path breaks. And those paths are applicable for more than two link failures. Therefore, the proposed scheme reduces the hop counts of the backup paths and the route restructuring frequency.

3.3. Constructing the alternate path for the Intermediate Nodes

Another feature of the proposed scheme is the packet salvaging. The destination node transmits RREP to the paths as shown in Fig.3. Each intermediate node does not transmit RREP to the destination node, and only preserves those paths as the alternate paths. Figure 5 shows the routes of RREP. When the primary path breaks, all intermediate nodes transmit data packets by using alternate paths. Therefore, the proposed scheme reduces the data packet loss. Moreover, the proposed scheme reduces the energy consumption by using packet salvaging, because the proposed method reduces the data packet retransmissions.

4. Performance

We evaluate the performance in term of the transmission success rate, hop counts of backup paths, route reconstruction frequency, and the energy consumption by using computer simulation. Table 2 shows the simulation parameters, and Figure 6 shows the simulation models. In the simulation, we assume the one side of square network size to be A, and extend A from 1000 to 2200[m]. Allocations, velocities, and directions of nodes are random, and every node does not have any cache information at the early state of networks.

First, we evaluate the transmission success rate of data packets by taking into account the number of dropped packets occurred in the link failures. Figure 7 shows the transmission success rate in the proposed scheme and conventional schemes versus network size. When the network size becomes large, the density between nodes decreases, and the link failure frequency increases. Therefore, the transmission success rate in the conventional schemes gradually decreases. On the other hand, the rate of the proposed scheme decreases not much, because the proposed scheme can utilize packet salvaging by providing the alternate paths for the intermediate nodes. Our proposed scheme improves

Table 2. Simulation parameters

Name	Value
Network size (A)	1000∼2200[m]
Number of mobile node	200
Velocity of mobile node	0∼15[m/s]
Radio range	250[m]
Movement pattern of node	random way point
Transmission power	700[mW]
Data packet size	512[byte]
Control packet size	52[byte]
Bit Rate	40,000[bps]
Transport layer	Constant Bit Rate

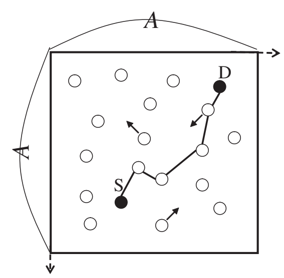

Figure 6. Simulation models

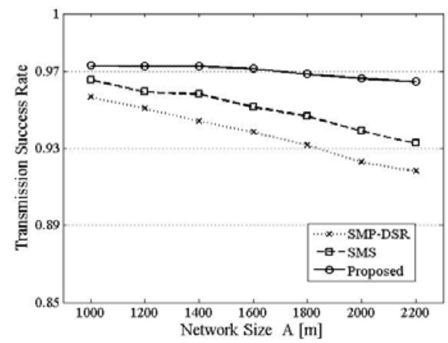

Figure 7. Transmission success rate

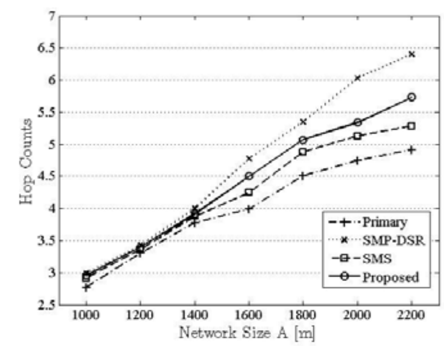

Figure 8. Hop counts of backup paths

the transmission success rate by up to 5% compared to SMP-DSR at the early state of networks, because all nodes have the cache information in the proposed scheme.

In Fig.8, we compare the hop counts of the primary and the backup paths in each protocol. Those primary paths are equal in each protocol. When there are more than two backup paths in SMS or the proposed scheme, average hop counts are obtained. The differences of the hop counts of the primary and the backup path increase when the network size becomes large. In SMS, the difference of the hop counts is the smallest due to the shortest backup paths. In the proposed scheme, the hop counts increase a little compared to SMS, because the backup paths of the proposed scheme are selected for the least hop without the failed link away.

Figure 9 shows the route restructuring frequency in 100 seconds of data communication. In each protocol, the incidence of the link failure rises more by the network size, and the route restructuring frequency increases. In SMS, the route maintaining time is long because the hop counts of backup paths are smallest. Therefore, the route restructuring frequency is fewer than SMP-DSR. In the proposed scheme, the route restructuring frequency is the lowest because those backup paths are applicable for more than two link failures.

Figure 10 shows the energy consumption versus the network size. In each protocol, the energy consumption increases because the hop counts of data communication increase as the network size increases. SMS overcomes the increase of the energy consumption because the hop counts of the backup paths are the smallest. Although the proposed scheme increases the hop counts of the backup paths than those of SMS, it decreases the number of retransmission and the route restructuring frequency. Consequently, the proposed scheme maintains the energy consumption to the same to or lower than SMS.

5. Conclusion

We have proposed a multipath routing protocol, which improves the transmission success rate and the energy consumption efficiency by combining SMP-DSR and SMS and changing those backup path(s) selection criteria. The proposed scheme constructs the least hop backup paths without the failed link away. In addition, by providing the alternate paths to the intermediate nodes of the primary path, the proposed scheme ensures to salvage the packets that might be lost at the intermediate nodes. Therefore, the data packet loss and the energy consumption are reduced. We perform

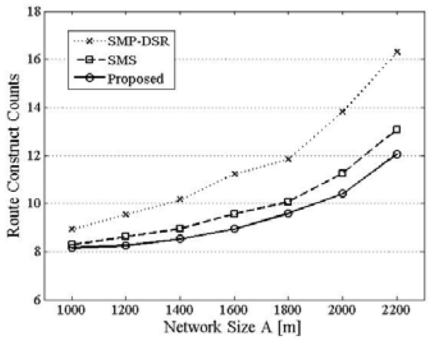

Figure 9. Route restructuring counts

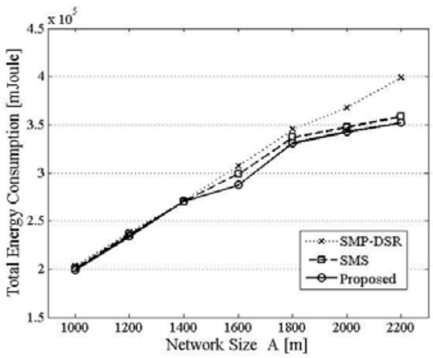

Figure 10. Energy consumption efficiency

simulations and it is shown that our scheme improves the transmission success rate and the energy consumption. As a result, our proposed scheme can improve the transmission success rate by up to 5% compared to SMP-DSR, and improve the energy consumption efficiency to the same to or lower than SMS.

6. Acknowledgment

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