OPSP: Opportunistic Path-set Selection Protocol in Mobile Ad Hoc Networks

Author(s) Name(s)

Author Affiliation(s)

E-mail

Abstract

The current multi-path routing protocol ignores the segments status at stage of end-to-end route discovery, as a result, the best segments and the worst segments are maybe allocated in the same path. So the max rate of the whole path is limited by the worst link, while the better segments in the path waste their bandwidth. We propose a new path selection framework that utilizes the opportunistic forwarding in multi-path routing protocols. Nodes in one path have opportunity to send data packets to neighbor nodes in the other path, which the chosen next hop is on a better link. This traffic strategy utilizes effectively the networks resources with little overhead. We evaluate the performance of our scheme by extensive simulations.

# 1. Introduction

Mobile ad hoc networks (MANETs) consist of mobile nodes connected by multi-hop communication paths without any base station or infrastructure support, and can establish and maintain a network in an autonomous manner. As a result, MANET has the characteristics of the rapid deployment and self-configuration, and therefore it can be widely used in many fields, such as battlefields, disaster relief, wide area sensing and surveillance. However, nodes run with power limited by batteries, low bandwidth constrained by wireless networks and node mobility, which results in low data delivery rates and large delays. So Destruction-Resistant Routing Algorithm become more and more important, the current research focus on multi-path routing and opportunity routing are designed far from these needs of MANET.

In wireless ad hoc networks research fields, multi-path routing have been the focus of active research in recent years. Mobile ad hoc networks consist of nodes that are often mobile and vulnerable to failure. Multipath routing enables a network’s traffic to be split into two or more possibly disjoint paths in order to reduce latency, improve throughput, and balance traffic loads. As such, it is important to provide redundancy path-set in terms of providing multiple paths from a source to a destination. Multipath routing protocols in mobile ad hoc networks have been proposed in [], [], [], []. Both Ad hoc On-Demand Multipath Distance Vector routing protocol (AOMDV) [] and AODV-Backup Routing (AODV-BR) [] are designed based on the Ad hoc On Demand Distance Vector routing protocol (AODV). Another important work in this area is presented in [] called Split Multipath Routing (SMR), which h is similar to DSR, and is used to construct multipath routing with maximally disjoint paths.

Opportunistic routing (OR) takes full advantage of the broadcast features of wireless medium. OR determines dynamic the next hop node based on which nodes receive the packet, instead of choosing a specific node proactively. The basic idea of OR improves throughput at the two aspects. Firstly, it is more easily for packet to be successfully sent to an unspecific next top node. Secondly, some packets can be transmitted to destination through fewer hops. ExOR [] is a first opportunistic routing protocol, which choice the next hop after packet transmission, so that the receiver nearest to the destination will forward the packet. As a result, ExOR can be effectively utilized at long radio links with high loss rates, which would otherwise be avoidable at traditional routing. However, opportunistic routing selection process, exists when every data packets are transmitted. It, as a result, is brought that unnecessary overhead of communication control packets.

We propose an opportunistic forwarding strategy that determines the most reliable segments from end-to-end path-set. Selected links are as reliable as possible. We argue that providing opportunistic selections in the intermediate nodes is beneficial in wireless network communications, particularly in mobile ad hoc networks. The protocol allows node-disjoint or node-joint paths.

On one hand, OPSP takes advantages of the mobility support of on-demand multi-path routing protocol, and the throughput of opportunistic routing protocol; on the other hand, it avoids unnecessary overhead of communication control packets in opportunistic routing protocol, and problem of links statics unbalance of every paths in multi-path routing protocol.

The remainder of this paper is organized as follows. Section 2 describes the opportunistic path-set selection protocol mechanism in detail. Performance evaluation by simulation is presented in Section 3. The last section discusses the results and concludes.

# 2. Opportunistic Path-set Selection

All of the multipath routing protocols try to find short paths from source to destination, so many paths with the same source and same destination often locate near to each other. OPSP, as a result, take advantage of feature that the paths can allocate data flow each other, so that end-to-end throughout and reliability is improved, and delay time is reduced.



Fig1. Opportunistic selection at node A. EXTs at links are ETX of every link, while ETXs at nodes are ETX of every segment from the node to destination D. Shadow around A signed radio scope of node A.

We assume that each node in the network can measured Expected Transmission Count (ETX) between with every neighbors. This metric estimates the number of retransmissions needed to send unicast packets by measuring the loss rate of broadcast packets between pairs of neighboring nodes. A node can calculate the loss rate of probes on the links to and from its neighbors.

OPSP is a framework based multi-path routing protocol, which modify multipath routing protocol in the follow three items: firstly, at multipath establish stage ETXi->D (ETX value of segment from node i to destination node D) is put into the RREP packets; secondly, each node must maintain tow tables for OPSP, 2-hop ETX values table and one-hop neighbors delivery rate table; thirdly, at data transport stage, if ETXs different value between segment from neighbor to destination with segment from local to destination is more than a threshold, opportunistic path-set selection process will be triggered off.

Unlike other opportunistic routing protocol, OPSP need not use a link-state flooding scheme to build the whole network link-state matrix. For OPSP, except route table, every node in the networks has one-hop neighbors delivery rate table and tow-hop ETX values table. The former consists of route table of every neighbor by overhearing route control messages from every neighbor, and the later is composed of ETX between any two directly neighbors each other in tow hops scope.

## 2.1 Multi-path establish and maintenance

Because OPSP is framework upon multipath protocol, it can be ported into several multi-path protocols in mobile ad hoc networks. In this paper, we take Ad hoc On-demand Multipath Distance Vector (AOMDV) [] routing protocol as a example.

AOMDV algorithm extends AODV [] to build and store several paths in the routing table, so that when one route is broken, it does not necessarily result in a new flood of route request packets. Instead, the source node can simply select the next available route from its tables.

When a reverse path is set up and a valid route to the destination is available at the intermediate node, it sends back a RREP to the source. OPSP specifies the ETXi->D (ETX of segment from local node i to destination D) in the header of RREP, therefore, neighbors overhearing thee RREP packet and its every neighbor can know the ETXi->D . Thereby, ETXi->D is saved in route table of the receiver of the RREP, and in neighbor delivery rate table of every neighbor.

|  |
| --- |
| **For** each received RREP packet, **do**  **If** RREP follows AOMDV route update rules, **then**  ETXi->D = ETXi->j + ETXj->D  Update route table belong RREP with ETXi->D  Add ETXi->D to head of RREP  Forward RREP  **Else**  Add path to N  **End For** |

Fig2. For the AOMDV route update rules, we reference to []. Multipath establishment rules of AOMDV with OPSP for node *i. ETXj->D*is ETX value of segment from j to D, and j is neighbor of i. N is one-hop neighbors delivery rate table.

In mobile ad hoc networks, because of mobility, power exhausted or any other reasons, links often are fault. As a result, link fault results in a route error message (RERR) which is sent back to the originator of the packet. Each intermediate node will remove its table entry upon relaying the RERR, and their neighbor will also remove table entry from delivery rate matrix.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| destination |  | destination |
| sequence\_ number |  | sequence\_ number |
| advertised\_hopcount |  | advertised\_hopcount |
| route list  {(nexthop1, hopcount1),  (nexthop2, hopcount2), …} |  | route list  {(nexthop1, hopcount1, ***ETX1***),  (nexthop2, hopcount2, ***ETX2***), …} |
| expiration\_timeout |  | expiration\_timeout |
|  |  |  |

(a) AOMDV (b) AOMDV with OPSP

Fig3. Structure of routing table entries for AOMDV and AOMDV with OPSP, ETXi is ETX value of segment to destination by the ist path.

## 2.2 Selecting Path

OPSP’s path selection process reference Simple Opportunistic Adaptive Routing SOAR [], working at the network layer. The algorithm choose the nodes closest to destination as next candidate forwarding nodes, and distance to destination determine priority in candidate list. The node with highest priority forward data packet firstly, then other nodes hearing the data packet transmission automatically discard it, thereby minimizing the number of duplicate transmissions in a cheap and distributed way. Different from SOAR, OPSP is based on multipath routing protocol, and determine the priority order by ETX of segment to destination.

We begin with an overview of the process to supply details in the subsections below. The path selection process consists of two stages: selecting the forwarding candidates and deciding whether to forward a received packet.

When node decided to select path, it chooses a candidate subset from all its neighboring nodes. There are usually multiple routing paths between candidate nodes and destination with less ETX. The forwarding node lists this candidate set in the data packet header, prioritized by ETX value of segment from local to destination. After transmission, each node that receives the packet looks for its address in the candidate list in the header. Each recipient then delays an amount of time determined by its position in the list before forwarding this data packet. Each node looks at the data packet it receives to decide whether it should forward the data packet. The remainder of this section describes each phase in detail.

**2.2.1. Selecting the candidate set**

Choosing prioritized neighbor paths is crucial issues of improving of OPSP’s performance, which is done by selecting the forwarding candidate set.

|  |
| --- |
| **PHASE I:** gain ETX metric and multipath establish  **PHASE II:** candidate forwarding nodes selection  Node i receive a data packet  **For** jk in i’s delivery rate table, **do**  **If** (ETXi->j->D - ETXi->jk->D < threshold  and ETXj->jk < threshold), **then**  Add jk to candidate set  **EndIf**  **EndFor**  **If** candidate set is null, **then**  Forward the data packet to j; break  **Else**  Sort candidate nodes by ETXi->jk->D  **EndIf**  **PHASE III:** forwarding a received packet  **For** each received OPSP data packet, **do**  Delay for (i-1)\*t  **If** receive the same data packet, **then**  Discard the data packet  **Else**  Forward the data packet  **EndIf**  **EndFor** |

Fig4. Node j is neighbor of node i on the local path, while node *jk (j1, j2 … jn)* denote neighbors of node i on the neighbor paths.

In network ruing OPSP node chooses the forwarding nodes that must satisfy the following two conditions. Firstly, *ETXi->jk->D - ETXi->j->D > threshold*, the inequality ensures that link-state of segment, which is from local node i through neighbor jk on the other path to destination D, is enough good, data packet transmit to other path is worthy. Secondly, *ETXj->jk < threshold*, the inequality ensures that the links quality among A and its any forwarding nodes are reasonably good so that they can hear each other’s forwarding and avoid duplicate transmissions.

**2.2.2. Deciding whether to forward a packet.**

After a node send a data packet out, the node with highest priority in the candidate set performs forwarding first, and other nodes hearing the transmission automatically discard the data packet. If other nodes do not hear transmission of more priority nodes before its forwarding timer is fired, it will forward the data packet. The process of forwarding data packets minimizes the number of duplicate transmissions in a cheap and distributed way. The forwarding timer is determinate by the position in the candidate set.

## 2.3 Example Transmission

# 3. Performance Evaluation

## 3.1 Simulation Environment

## 3.2 Results and Analysis

# 4. Conclusion

We presented opportunistic path-set selection protocol (OPSP), an approach to improve end-to-end delivery performance for ad hoc networks, by exploiting the use of helper clusters. We demonstrate that OPSP reduces end-to-end cost and delay for generic routing protocols. Designed as an architectural extension, OPSP can be easily plugged into existing communication stacks to improve performance. We believe this design choice makes OPSP particularly attractive to sensor network system designers. Furthermore, by using the technique of cooperative communication, OPSP represents a growing direction of wireless communication protocols.