

Robust Multipath Source Routing Protocol (RMPSR) for Video Communication over Wireless Ad Hoc Networks

Wei Wei and Avidah Zakhor

*Department of Electrical Engineering and Computer Sciences
University of California at Berkeley, CA 94720, USA*

Abstract

Multipath routing is effective in wireless ad hoc networks, since connectivity along multiple paths is less likely to be broken. We propose a multipath extension to Dynamic Source Routing to support multipath video communication over wireless ad hoc networks. The proposed scheme is compared to others for interactive video applications. Simulations show effectiveness of our proposed scheme.

1. Introduction

A wireless ad hoc network is a collection of wireless mobile nodes that dynamically form a temporary wireless network without an infrastructure. Video applications are expected to become available in wireless ad hoc networks in a near future. However there are many challenges for supporting them over wireless ad hoc networks. Due to mobility of wireless nodes, the established connection route between a source node and a destination node is likely to be broken during the transmission, which may cause interruptions, freezes, or jerkiness in the received video signal. Other factors that influence the quality include high random packet loss and small capacity.

Multipath routing is effective for video communication applications over wireless ad hoc networks, especially for live or near live video applications, since connectivity along multiple paths is less likely to be broken than connectivity along a single path, thus resulting a more smooth video delivery. In this paper, we propose a multipath extension to Dynamic Source Routing (DSR) [1] to support multipath video communication over wireless ad hoc networks.

2. Overview of multipath source routing protocols

In this subsection, we provide a brief overview of DSR and Split Multipath routing (SMR) [2]. DSR is an on-demand source routing protocol, where the packet

carries the end-to-end path information in its header. When a source needs routes to a destination, it originates a route discovery process. A route discovery process typically involves a network-wide flood of Route REQuest (RREQ) packets targeting the destination, and the return of Route REPLY (RREP) packets from the destination. DSR obtains multiple paths for the communication pair, but because duplicate copies of RREQ packets at intermediate nodes are discarded, those paths are highly correlated [2][4], and hence are not suitable for multipath communication.

SMR is one of the best known multipath extensions to DSR[2][5]. It uses a modified RREQ packets flooding scheme in the process of route query. The destination node returns the shortest path and another path that is most disjoint with the shortest path to the source node.

3. Robust multipath source routing protocol (RMPSR)

To facilitate video communication, we propose RMPSR, a multipath extension to DSR, which both inherits desirable features of other multipath routing approaches, and applies several new rules to address requirements of video communication applications. The main design goal of RMPSR is to minimize video packet loss caused by network topology changes.

To describe RMPSR, we need to introduce several definitions first. **Definition 1:** The correlation factor of two routes is defined as the ratio between the number of the shared nodes of the two routes, and the number of nodes of the shorter route. **Definition 2:** Two routes are nearly disjoint, if their correlation factor is smaller than the given threshold value. **Definition 3:** A route set consists of one primary route and several alternative routes. The primary route connects the source node and the destination node; alternative routes connect intermediate nodes and the destination node. An alternative route and the corresponding subroute of the primary route, which connects the same starting and ending node of the alternative route, are required to be nearly disjoint. While it is not necessary to require each

intermediate node to have an alternative route, RMPSR does build as many qualified alternative routes as possible for each route set. Two route sets are nearly disjoint, if corresponding primary routes are nearly disjoint.

The basic idea behind RMPSR is to build multiple nearly disjoint route sets for the communication pair. Similar to DSR[1] and SMR[2], we also use an on-demand source routing approach. The reasons for choosing source routing are that (a) it has been shown to outperform table based approaches in many scenarios[3], and (b) it is convenient to build multiple disjoint route sets using source routing, since the destination node knows the entire path of all the available routes.

To increase the probability of discovering multiple disjoint routes, we use a modified form of the RREQ packet forwarding scheme in [4]. Specifically we choose to construct route sets at the destination node. The destination node collects multiple copies of RREQ packets of the same session within a time window, then builds multiple nearly disjoint route sets, and returns primary routes to the source node, and alternative routes to corresponding intermediate nodes.

Our proposed RMPSR uses a per-packet allocation scheme to distribute video packets over two primary routes of two route sets. When one transmitting primary route is broken, the intermediate node that corresponds to the broken link will send a Route ERRor (RERR) packet to the source node. Upon receiving the RERR packet, the source node removes the broken primary route from its route cache, and switches the transmission to another primary route.

To support video applications better, three new schemes are introduced. **Scheme 1:** when the transmitting route is broken, alternative routes in the same route set are used to salvage packets that are in the mid-way. This scheme increases delivery ratio of video packets without retransmission. Unlike traditional salvaging schemes, rather than transmitting new packets, alternative routes are only used for salvaging ongoing packets. The reason is that routes in the same route set are correlated, so if the primary route is broken, it is likely that alternative routes have been broken or will be broken shortly. Thus in order to avoid further loss of future packets, the transmission is switched to another primary route as soon as the transmitting primary route is broken. **Scheme 2:** RMPSR triggers new route request process before the connectivity is entirely lost in order to reduce the number of temporary network outages during the transmission. In our implementation, the protocol triggers new route request process when there is only one primary route left in the route cache of the sender. Since each temporary network outage may cause a “freeze” in video playback, this scheme enhances the performance of

video at the expense of additional control overhead.

Scheme 3: Similar to other multipath extensions, RMPSR increases the probability of discovering multiple disjoint routes at the expense of an increase in control overhead. To alleviate the impact of routing overhead on the network, both RMPSR and DSR are deployed at each node with different classes of traffic being handled by different routing protocols. Video traffic is given higher priority using RMRSR, while other traffic is given lower priority using DSR. This scheme helps to maintain high quality of video applications when the number of data traffic in the network increases.

4. Performance evaluation of interactive video applications

In this section, we test performance of interactive video applications with Multiple Description Coding (MDC) using RMPSR. Each packet of interactive video applications has a strict delay constraint. So end-to-end retransmission or Forward Error Correction Code (FEC) are unsuitable here, as they both increase the delay. MDC is a source coding scheme in which the signal is compressed into multiple independent bitstreams in such a way that quality of the reconstructed signal at the receiver improves as the number of received bitstream increases[6]. In this paper, we primarily deal with two description coding. Packets forming different bitstreams are transmitted through different routes.

4.1. Comparison of RMPSR, SMR and DSR

We compare the following three schemes for interactive video applications with MDC. (a) DSR [1] with single path video transmission. (b) SMR [2] with multipath video transmission. (c) RMPSR with multipath video transmission. We use a simulation model based on NS-2 [8] with CMU wireless extension[3]. The random waypoint model [3] is used to model mobility. A 60 nodes network in a 1200 meters by 800 meters rectangular region is used. A rectangular shape area is chosen to make the average length of routes longer, so as to observe more route breaks during the simulation. The bit rate of video is 192 kilobits per second (kbps), and the frame rate is 12 frames per second (fps). Each frame consists of two 8 kilobits packets, each one representing one description. The playback deadline of each packet is 100 milliseconds (ms) after it is generated. If both packets of a frame are received before their deadlines, the frame is called a good one. If only one packet is received on time, the frame is called an acceptable one. Otherwise, it is called a bad frame. Simulations are run for ten hours. There are five random 12 kbps cross traffic sessions in

the network. We only consider the continuous mobility case. To change the mobility level of the network, we vary the maximum speed from 2.5 m/s to 15 m/s.

The ratio of the number of bad frames over the number of all frames is shown in Figure 1(a), and the number of bad periods, consisting of contiguous bad frames, is shown in Figure 1(b). The smaller the two metrics are, the better the video experience. As shown in Figures 1(a) and 1(b), the performance of interactive video is enhanced using RMPSR as compared to SMR and DSR, in the sense that both the ratio of bad frames to total number of frames, and the number of bad periods are reduced. MDC can potentially be a suitable match for multipath communication in a sense that even only one path is broken, packets corresponding to the other description on the other path can still arrive at the receiver on time. With MDC, quality of these frames is still acceptable. To fully utilize this property of MDC, it is important for multipath routing protocols to maintain multiple routes as long as possible. RMPSR builds more than two nearly disjoint routes in the route request process and triggers new route request process before all the routes are broken. These steps help RMPSR maintain multiple routes longer than SMR and DSR. Another reason for the enhanced performance of RMPSR is its effective packets salvaging scheme. For example, as shown in Table 1, when the maximum speed is 12.5 m/s, the ratio of the number of salvaged packets to the total number of transmitted packets over a ten hour simulation period is much larger for RMPSR than that for SMR and DSR. We also ran simulations with ten 12 kbps cross traffic flows, and RMPSR outperforms both SMR and DSR.

We also compare these three protocols for video on-demand applications with FEC. We use two metrics: (a) goodput ratio, which is ratio of the number of data packets played at the receiver to those transmitted from the video source, and (b) the number of buffer rebufferings. RMPSR is still the best, followed by SMR and DSR, in the sense that it has 25% fewer rebufferings and 5% higher goodput ratio than SMR.

4.2. Comparison of MDC with SDC

In this subsection, we compare performance of multipath transmission of MDC and single description coding (SDC) content. Unlike [7], which tests the performance of MDC under a simple static network scenario, our simulations are for a dynamic network scenario with mobile nodes and cross traffics. For the same quality of video, bit rate of MDC has been shown to be approximately 30% - 40% larger than that of SDC [6]. For MDC we encode one frame into two packets, while for SDC we encode one frame into one packet. For

simplicity, RMPSR is used for all the schemes. Other simulation settings are the same as the previous simulation.

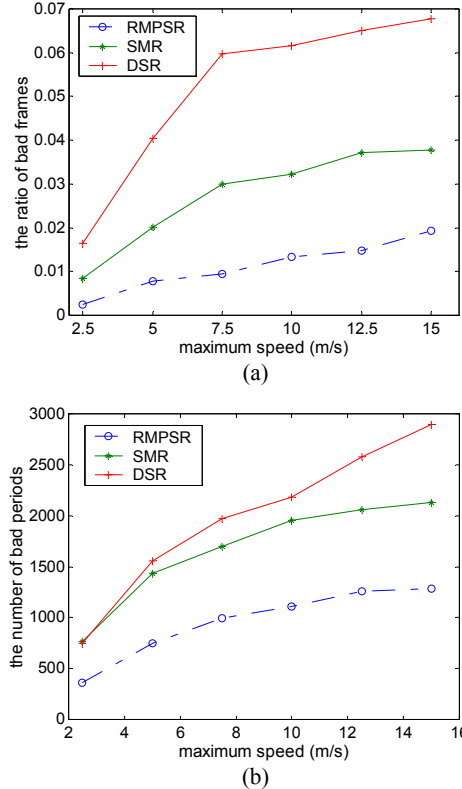


Figure 1: Comparing RMPSR, SMR and DSR for interactive video applications using MDC; (a) Ratio of bad frames; (b) Number of bad periods.

Table 1. Comparison of salvaged packets.

	RMPSR	SMR	DSR
Ratio of salvaged packets	0.0078	0	0.0023

Figure 2 shows results of performance comparison of MDC with a bit rate of 192 kbps, SDC with bit rates of 150 kbps (SDC1), and 192 kbps (SDC2). As shown in Figure 2(a), SDC1 has the smallest number of bad frames, followed by MDC, followed by SDC2. When only one path is broken, MDC can conceal the effect by decoding only one description. Thus MDC reduces the number of bad frames as compared to SDC schemes with the same rate. However since the bit rate of SDC1 is smaller than that of MDC and SDC2, it results in lower level of network congestion, thus causing fewer packet drops. Figure 2(b) shows distribution of late packets of both schemes in one hour simulation. It shows that the number of late packets for MDC is much larger than that of SDC1. Figure 2(c) compares distribution of bad periods for MDC and SDC1 under a scenario with

maximum speed of 12.5 m/s. As seen, MDC has fewer short bad periods, but has more long bad periods as compared to SDC1. MDC conceals scattered packet losses in one route, thus reducing the number of short bad periods, while the lower bit rate of SDC helps to reduce the number of long consecutive packet losses.

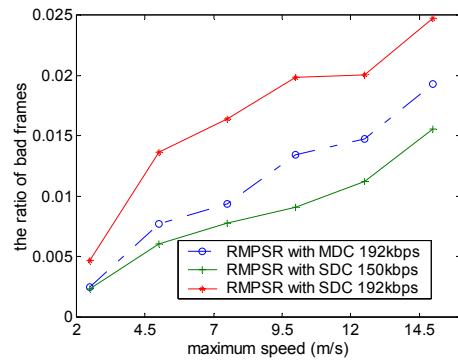
Figure 3 compares performance of MDC and SDC as a function of bit rate for a scenario with maximum speed of 5 m/s and without cross traffic. The x-axis corresponds to bit rate for SDC, while corresponding bit rates of MDC are 33% higher. The ratio of bad frames increases for both schemes with the increase of bit rates. When bit rates are low enough not to cause congestion at all, MDC outperforms SDC. When the bit rate is around a crossover threshold value, which is 150 kbps for SDC and 200 kbps for MDC in this scenario, the performance of two schemes is almost the same. For bit rates above the threshold value, SDC outperforms MDC. We also carried out simulations with different level of cross traffic and mobility of the wireless network, and have obtained similar results. We have empirically found the crossover threshold value to depend on available bandwidth, which in turn depends on cross traffic, link capacity and mobility level of the network.

From simulation results and the analysis, we see that as compared to SDC, MDC scheme does not necessarily improve quality of interactive video applications over wireless ad hoc networks. The lower bit rate and fewer number of packets of SDC scheme in some situations make it suffer less from possible network congestion, offsetting the inherent robustness of MDC.

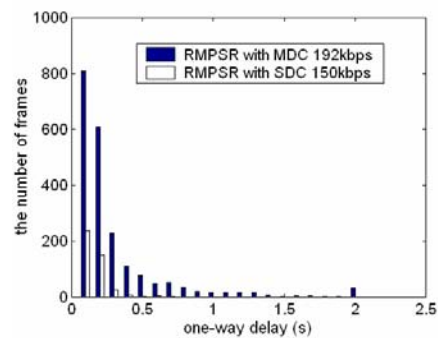
5. References

- [1] D B. Johnson, D A. Maltz, and Y. Hu, "The dynamic source routing protocol for mobile ad hoc network," Internet-Draft, draft-ietf-manet-dsr-09.txt, April 2003.
- [2] S.J. Lee and M. Gerla, "Split multipath routing with maximally disjoint paths in ad hoc networks," ICC 2001, pp.3201-3205.
- [3] J. Broch, D.A. Maltz, D.B. Johnson, Y. Hu, and J Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols", ACM MobiCom 1998, pp.85-97.
- [4] K. Wu and J. Harms, "On-demand multipath routing for mobile ad hoc networks", EPMCC 01, Vienna, Austria, Feb. 2001, pp.1-7.
- [5] P. Pham and S. Perreau, "Performance Analysis of Reactive Shortest Path and Multi-path Routing Mechanism With Load Balance", IEEE Infocom 2003.
- [6] Y. Wang, and S. Lin, "Error-resilient video coding using multiple description motion compensation," IEEE Trans. on Circuits and Systems for Video Technology, June 2002, pp. 438-452.
- [7] S. Lin, Y. Wang and S. Panwar, "Video transport over ad-hoc networks using multiple paths", 2002 IEEE International Symposium on Circuits and Systems, May 2002, pp. 57-60.

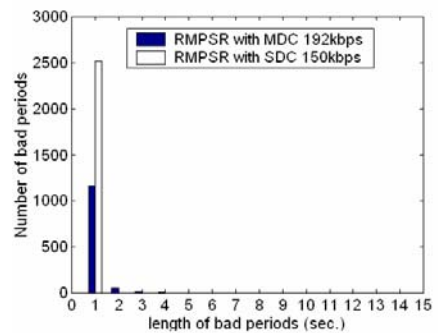
[8] ns-2: network simulator. <http://www.isi.edu/nsnam/ns/>



(a)



(b)



(c)

Figure 2: Comparing MDC with SDC; (a) Ratio of bad frames; (b) Distribution of late packets; (c) Distribution of bad periods.

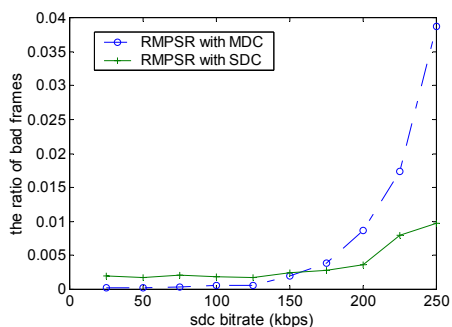


Figure 3: Comparing MDC with SDC with various bitrates.