Video Diffusion: A Routing Failure Resilient, Multi-Path Mechanism to Improve Wireless Video Transport

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1. Abstract

High quality video transport under ad hoc network is a challenging task due to low bandwidth, high loss rate, unpredictable node mobility, and severe interference characteristics of such kind of network. End to end packet delivery often exhibits low performance due to one hop-by-hop routing failure and mis-interpretation to such failures. We present video diffusion technique, which use redundant, multi-path delivery to mitigate failure problems. Video diffusion is error resilient in that the mis-interpretation to routing failure is offset. Redundant delivery will inevitably incur extra overhead. However, in video diffusion scheme, such kinds of overhead is controlled to the lowest level. We validated video diffusion algorithm using ns2 simulator. Compared with end-to-end UDP transport protocol, video diffusion outperforms up to 50% in packets delivery and 20 dB in PSNR for quality of received pictures.

Categories and Subject Descriptors

D.2.2 [**Network Protocols**]: Protocol architecture, Protocol verification, Routing protocols

General Terms

Management, Measurement, Performance, Design.

Keywords

Multimedia transport, communication, wireless ad hoc network, UDP, TCP

1. INTRODUCTION

Wireless ad hoc network provides user with convenience for communication without infrastructure setup and maintenance. Delivery of regular data poses challenges to transport protocols since wireless ad hoc network is connected with low delivery bandwidth, high loss rate, unpredictable node mobility, and severe interference. Video streaming is especially challenging because real-time, high quality picture delivery poses higher demand for video packet delivery bandwidth and latency.

In the simulation, we observed that end to end packet delivery often incurs routing failure, even for reachable nodes, due to contention for the shared channel. Such kinds of failures will exacerbate transport performance by temporarily blocking transmission, re-triggering path exploration and then re-enabling transmission. Such a long delay will significantly downgrade quality of received video.

In the simulation for the simplest topology shown in Figure 1, the left most node sends video segment to the right most node in the chain using UDP transport and DSR [2] routing protocols. During the simulation, many intermediate nodes frequently trigger route exploration. This is due to the mis-interpretation by DSR for routing failure: channel interference is interpreted by DSR as next hop unavailability. We call this phenomenon mis-interpretation for interference-resulted routing failure. For the same topology, if simple broadcasting/ flooding scheme is employed, the delivery performance can significantly improve up to 40% in simulation.

Figure 1. Simulated Chain Topology

Obviously, in a normal ad hoc configuration, if simple broadcast/ flooding is directly employed, the broadcast/ flood will dramatically downgrade the transport performance due to channel self-competition by those flooding packets.

In this paper, we propose a video diffusion mechanism for video transport in ad hoc network. Instead of delivering packets end-to-end in unicast mode, we *diffuse* packets from source to end. Video diffusion is an error resilient, multi-path transport mechanism for video delivery under wireless ad hoc network. Video diffusion tries to mitigate negative impact from routing failure by adopting multi-path, redundant packet delivery. At the same time, the redundancy is controlled in a level that the gained benefit is greater than incurred overhead.

The rest of this paper is organized as follows. In section 2, we will survey related work. In section 3, we discuss the video diffusion architecture. In section 4, we present our simulated results. We conclude this paper in section 5.

2. RELATED WORK

Multimedia transport protocols are extensively researched in wired network. Most media transport protocols in wired network, such as

Real Time Protocol (RTP) [10] and Real Time Streaming Protocol (RTSP) [8], sit in application layer and directly use underlying network transport layer (UDP or TCP) for communication. Whereas some other protocols, such as TCP Friendly Rate Control (TFRC), try to adapt existing protocols to suit for multimedia.

Video transport in wireless ad hoc network becomes a hot issue in recent years. Most researches focus on enhancing existing MAC/ Transport/ Routing protocols to improve multimedia delivery performance by suit existing protocols for ad hoc environment.

Fu et al [1] adapt the TFRC, originally designed for wired multimedia transport, to mobile ad hoc networks. By making correct responses to events specific to ad hoc network, the enhanced protocol is reported to exhibit better performance.

Dynamic QoS [13] uses service differentiation to guarantee smooth delivery of multimedia for ad hoc network.

Some new researches [6, 11, 12] studied multi-path transport in ad hoc network. In their schemes, video is encoded into multiple streams and transported through multiple paths. Video diffusion takes advantages of multi-path concept. However, different from other multi-path delivery scheme, in video diffusion, different path deliveries are redundant. Such redundancy is designed to compensate the performance degrade specific to ad hoc network.

Li et al [3] studied "nonstop" multimedia delivery when node mobility is considered and partition is generated. They use a set of middlewares to monitor, predict, and replicate service to ensure smooth multimedia delivery.

Directed diffusion [4] is a data dissemination method studied in sensor network. Their work motives us to diffuse video media through ad hoc network.

Our work is different from previous media delivery researches in that our work is not simply an adaptation of existing transport/MAC/routing protocols to ad hoc network. Instead, we use a brand new, controlled broadcast/flooding scheme to mitigate the negative effects brought by ad hoc network.

3. VIDEO DIFFUSION

Video diffusion mechanism tries to gain from two factors: correct interpretation for interference-resulted routing failure and multi-path, redundant routing.

Video diffusion uses redundant multi-path delivery to compensate end-to-end packet delivery failures, avoid routing protocol overhead, and thus provide guaranteed QoS.

Video diffusion adopts a two-pass process. We use configuration shown in Figure 2 as an example to illustrate the procedure. When node 4 tries to receive video from node 1, it broadcasts "View Request" through the network until it reaches the sender, node 1. Every node relays, and only relay, such request broadcast packets if it has never seen this node before. Relayed packet ID is cached by relaying nodes for a period. In this example, request is send to sender through three pathes: 4-3-1,4-2-1, and 4-2-5-1. Such relay is illustrated by solid line in the graph.

When the sender, here node 1, send out video packet, every node relays such video packet broadcast when and only when this node never "saw" this packet and this node saw "view request" before. In this case, if all node 2, 3, 5 receive packet from sender node 1, they will relay packet to next hop. However, when node 2 receive packet from node 5 and this packet is already "seen" from node 1 directly, this packet will be silently discarded. In this example, the video packets will be diffused, not routed, from source to destination along the dashed line.

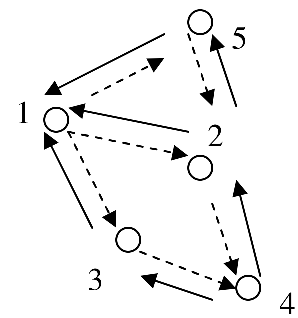

Figure 2. Video Diffusion

In video diffusion, when a packet encounters Interference-resulted routing failure, it will be silently ignored. It will not be attempted for several times (like MAC 802.11 did) before finally giving up. It is blessed that same packet can be transported in a different path successfully. This mechanism automatically balances the traffic and direct packets to a less competitive path.

We can see that video diffusion is a constrained broadcast scheme. In such a broadcast scheme, routing protocol can be avoided completely. In another word, video diffusion is both a transport and a routing protocol. This scheme fully takes advantages of broadcast nature of hop-by-hop communication for wireless network and compensates failures from end-to-end delivery. Table 1 summarizes the difference between video diffusion and UDP+DSR.

Table 1: Comparison between Video Diffusion and UDP+DSR

	Video Diffusion	**UDP+DSR**
Route (re-) Exploration	No	Yes
MAC Delivery Retry	No	Yes
Delivery Path	Multiple	One
Hop Failure	Ignore	Re-explore path

One natural concern for this scheme is the overhead of its broadcasting nature. We will use simulation to further verify that this constrained broadcast will not incur heavy overhead.

4. PERFORMANCE SIMULATION

We simulate video diffusion mechanism using ns2 [7] simulator version 2.28. The MAC layer used in our simulation is IEEE MAC 802.11b in DCF mode.

We use movie Foreman's sequences encoded from quarter common intermediate format (QCIF) for our test. This video segment comprises 400 frames, each with 176x144 pixels and they are encoded into MPEG 4 video with frame rate at 30 frames per second [5].

The simulation lasts 1 more second after the sender send out last packet. The maximum size for packet is defined as 1000 bytes.

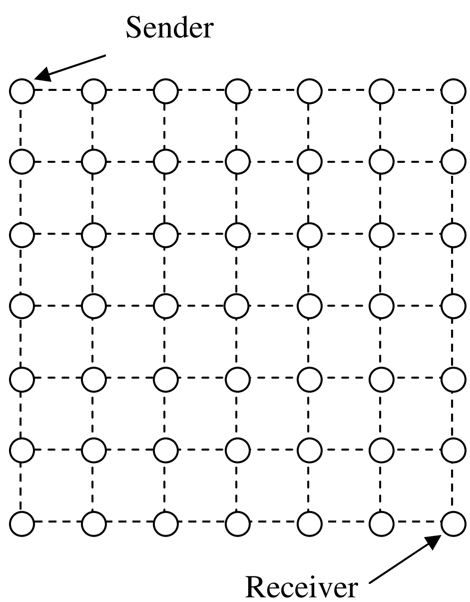

Figure 3. Simulated Grid Topology

We compare our solution with regular UDP transport with DSR [2] routing protocol. We evaluate results in terms of both packet delivery and picture quality.

Figure 3 shows the simulated grid topology. Nodes are arranged so that only the nodes with connected dashed lines are reachable for each other (the inter-node distance is 200m and the effective communication is configured as 250m for MAC). The node in top-left corner is chosen as sender and node in bottom-right corner is chosen as receiver.

From simulation, packet delivery of video diffusion is far better than that of UDP. Video diffusion can deliver 93% of packets whereas UDP can only deliver 61%. Video diffusion outperforms UDP by about 52%. From UDP trace, we do see that transport is interrupted again and again by the routing failure and wait for DSR to explore a new path.

Peak Signal Noise Ratio (PSNR) is a publicly accepted metric to measure the quality of video. Figure 4 shows the PSNR comparison between video diffusion and regular UDP frame delivery. We can see that video diffusion is significantly better than UDP in some sections and similar in other sections. In frame 210~250 section and 360~400 section, the PSNR of video diffusion is about 20 dB better than UDP.

In figure 5, we show some example video frames recovered from packets received by UDP and video diffusion respectively. The top 3 pictures are from UDP and bottom 3 ones are same frames form video diffusion. From the pictures, we can clearly see that video diffusion can still deliver high quality pictures when UDP performs extremely poor. Please also note that UDP transported frames often significantly lag after real-time frames for display.

We also simulated same topology while nodes are mobile with speed 5m/sec. We got similar (even a little bit better) result with static topology so we don't repeat the plotting.

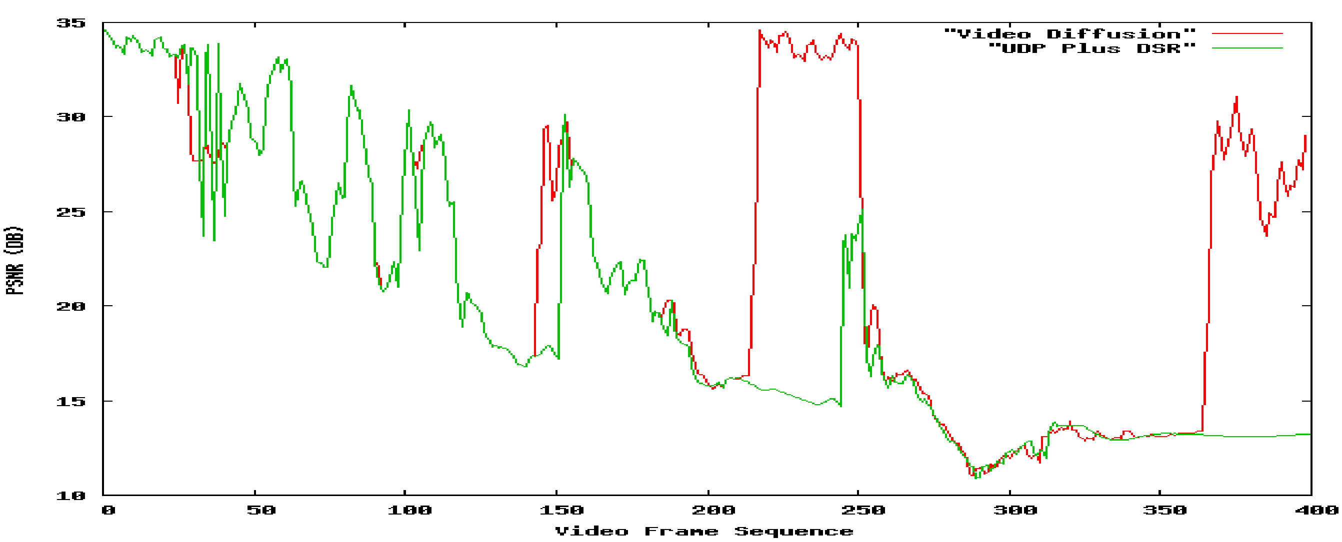

Figure 4. PSNR between Video Diffusion and UDP+DSR

Figure 5. Some Example Frames for UDP (Top) and Video Diffusion Transport (Bottom)

From receiver's perspective, we only see 12% more packet delivery than UDP+DSR. Actually redundant delivery is not severe due to:

1. Controlled flood, seen packets before will not be forwarded again
2. Flooding is not too expensive in shared channel environment
3. Avoiding re-trying for packet delivery

5. CONCLUSION

In this paper, we present video diffusion transport for wireless ad hoc network. Video diffusion is a controlled flooding scheme. Using controlled broadcast, video diffusion can mitigate the mis-interpretation of interference-resulted routing failure and use multi-path delivery to guarantee QoS in wireless ad hoc network. Simulation shows that video diffusion performs better than UDP based transport, in terms of both packet delivery and quality of picture. In best cases, video diffusion outperforms UDP by 52% in packet delivery and 20 dB in PSNR.

Video diffusion method can also be easily enhanced to support multicast, which will be very useful for some scenarios such as classroom lectures, seminars, among others. We are working toward this direction.

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