A Framework for Evaluating Video Transmission over Wireless Ad Hoc Networks

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Abstract— **We propose a framework that facilitates the transmission of video over multi-hop wireless networks by using various routing techniques for route establishment. We denote this framework by Ad Hoc EvalVid. This framework allows the performance of different routing techniques to be studied under different network conditions. The results of our study show that 1) Dynamic Manet On Demand (DYMO) routing protocol can still deliver good quality of video streams under extreme network conditions, 2) Ad Hoc On Demand Distance Vector (AODV) routing protocol is best suited for large-sized networks with light loads and 3) Optimized Link State Routing Protocol (OLSR) is likely not suitable for real-time video transmission.**

I. INTRODUCTION

Video communications play a vital role in present and future wireless ad hoc networks. One of the key requirements for a successful deployment of multimedia applications in multi-hop wireless networks is the ability to provide acceptable video quality, even under a highly dynamic and perhaps unfriendly environment (e.g., in the presence of frequent node/link failure, interference, fading and so forth). Existing ad hoc routing protocols work well for data communications, but most of these protocols are not optimized for video, which is sensitive to latency and packet loss.

Routing protocols for ad hoc networks can be classified into two main categories; namely, Pro-active and Re-active protocols.

Pro-active protocols (or table-driven protocols) perform in a way similar to wired networks: they maintain an up-to-date map of the network by continuously evaluating the known routes and attempting to discover new ones. As such, when at a node, a path to a destination is needed or a packet needs to be forwarded, the route is already known and there is no extra delay due to route discovery. On the other hand, keeping the information up-to-date may require large bandwidth and battery power, which are limited in mobile ad hoc networks, and even then information may still be out-of-date. OLSR (Optimized Link State Routing) is a member of the pro-active protocol class.

Re-active protocols (on-demand protocols) only start a route discovery procedure when needed. When a route from a source to a destination is needed, a type of global search procedure is started. This does not require constant updates to be sent through the network, as in pro-active protocols, but it does introduce delays since the routes are not immediately available and thus must be found. In some cases the desired routes are still in the route cache maintained by nodes. When this is the case, there is no additional delay since the routes do not have to be discovered. AODV (Ad Hoc On Demand Distance Vector) and DYMO (Dynamic Manet On Demand) are members of the re-active protocol class.

In this paper, we introduce a framework and a tool-set for evaluating the quality of video transmitted over a simulated ad hoc wireless network. We call this framework Ad Hoc EvalVid. Besides measuring the quality of service (QoS) parameters of the underlying network, such as loss rates, delays and jitter, Ad Hoc EvalVid also supports a video quality evaluation of the received video based on the frame-by-frame peak signal-to-noise ratio (PSNR). The Ad Hoc EvalVid framework is based on both EvalVid [2] and Enhanced EvalVid [13], [3] frameworks. These tool-sets are publicly available. We use Ad Hoc-EvalVid to compare the performance of the following ad hoc routing protocols. AODV [5], [7], DYMO [6], [7], [14] and OLSR [10]. The results are presented in section IV.

II. AD HOC-EVALVID FRAMEWORK

To evaluate the performance of video transmitted over wireless ad hoc networks, we introduce the Ad Hoc EvalVid framework. This framework has the following advantages:

- It facilitates the transmission of video over multi-hop wireless networks by using various routing techniques for route establishment.
- It allows the study of the performance of the different routing techniques under different network conditions (e.g. mobility, route changes).
- It can be used to measure various video performance metrics (e.g. frame/packet loss, delay and signal-to-noise ratio parameters) and to evaluate the quality of video streams at different locations throughout the transmission path.

- It leverages the key frameworks for studying video traffic over IP networks (i.e. EvalVid [2] with its enhanced version [3]).

The main components of the Ad Hoc EvalVid framework are:

Video Source: The video source is responsible for generating video streams. The format of the video source used is YUV CIF (352 x 288)

Video Encoder and Video Decoder: These coders are used to convert the video file from YUV format to H.264/MPEG4 format at the sender side and transfer it back to YUV format at the receiver side [11]. In this study, we use H.264/MPEG4-AVC [9] codec for video coding.

Video trace generator: The video trace generator reads the compressed video file from the video encoder output. Before transmitting video frames via User Datagram Protocol (UDP) packets over the simulated network, the video trace generator fragments each video frame into smaller segments if the size of the video frame is larger than the maximum transmission unit. The framework records the information about every transmitted UDP packet in the sender trace file. It also generates a video trace file containing information about every frame in the real video file.

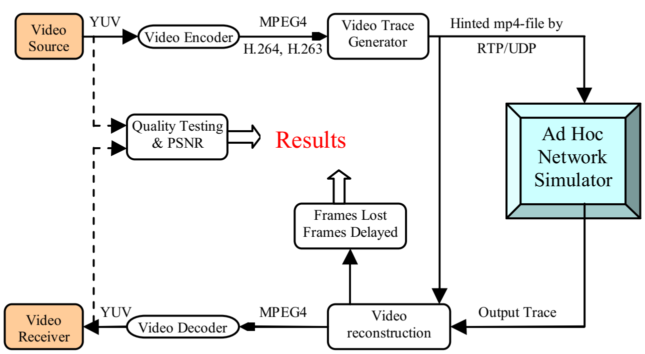

Figure 1. Ad Hoc EvalVid Framework

Video reconstruction: Once the video transmission is complete, the performance evaluation begins. The video reconstruction component compares the trace files, including the original encoded video file, the video trace file, the sender trace file and the receiver trace file and generates a report on the video frame/packet delay, frame/packet loss and frame/packet jitter. In addition, it creates a reconstructed video file, corresponding to the --possibly corrupted-- video frames at the receiver side as it would be reproduced to an end user.

III. Performance Study Using NS2 Simulation

A. *Performance Parameters*

The following sections provide a comparison of the routing techniques using the following parameters:

1) PSNR (Peak Signal-to-Noise Ratio):

PSNR is the most widespread objective metric used to assess the application-level QoS of video transmissions [13], [3]. PSNR measures the error between the reconstructed image and the original one frame by frame.

For frame n between the source image S and destination image D, PSNR is defined as:

$$\text{PSNR (n)}_{\text{dB}} = 20 \log_{10} \left(\frac{v_{peak}}{\sqrt{\frac{1}{N_{col} N_{row}} \sum_{i=0}^{N_{col}} \sum_{j=0}^{N_{row}} [Y_S(n,i,j) - Y_D(n,i,j)]^2}} \right)$$

Where Y denotes the luminance component, Vpeak = 2k-1 and k = number of bits per pixel (luminance component). $Y_S(n,i,j) \,\&\, Y_D(n,i,j)$ are the values of the luminance component of nth frame at pixel for the source and destination images respectively. $N_{col} N_{row}$ are the dimensions of the frame. The denominator in the above equation is the mean square error (MSE). Thus, PSNR can be abbreviated as

$$\text{PSNR (n)}_{\text{dB}} = 20\log_{10} \frac{V_{peak}}{MSE}.$$

2) Number of Lost Frames:

In this report, we use video file "akiyo_cif.yuv" which has 300 frames. It contains 10 I frames and 290 P frames. For each frame type, we measure the lost frames separately, and then we calculate the percentage of the overall frame loss.

$$\text{Overall Frame Loss \%} = \frac{\text{Lost I frames + Lost P frames}}{\text{Total Number of Frames}} * 100$$

The Lost Frames metric is important as it describes the loss rate that will be seen by the transport protocols. This metric characterizes both the *completeness* and the *correctness* of the routing protocol.

Generally, for any protocol to achieve a high delivery ratio independent of the load of the network, the protocol needs to always have up-to-date routes to ensure that data are not sent on a failed network.

B. *Simulation settings for ns2:*

An ad hoc mobile network is a collection of mobile nodes. These nodes are dynamically and arbitrarily located in a manner that allows the interconnections between nodes to change on a continual basis. As nodes belonging to ad hoc networks may move dynamically and unpredictably, the network should thus be able to react to the frequent topological changes. In this paper, we use Network Simulator2 (ns2) to simulate this environment.

Each node in the simulation moves according to the random waypoint model [1]. We created a set of movement scenario files which are characterized by the pause time and the mobility. Each node begins its movement to a randomly selected destination at a constant speed, after remaining stationary for a certain pause time. When nodes reach the destination, they pause again, and then move with the same speed to another destination. This behavior is repeated during the entire simulation time. The pause time of each node is set between 0 and 20 seconds while nodes are moving at a speed between 0 and 30 meters/second. The video streams start together at simulation time zero. In order to run different mobility settings for the simulation, we generated scenario files for node movement for every mobility and pause time setting. In order to enable fair comparisons between routing protocols, we used the same initial node position for all the scenarios generated [15]. To analyze the three different protocols, OLSR, AODV and DYMO, we use four different parameters: (1) Mobility (in meter/second): speed values (0, 5, 10, 20, 30) while pause time = 5 Sec. (2) Offered load parameters: 1 to 20 video sessions and different data traffic connections; all starting at the same time. (3) Number of nodes: (15 and 50).

The simulation program has the following setup [8], [13] :

TABLE I. SIMULATION SETUP

Simulator	ns2 network simulator with version ns-2.29 [12]
Examined protocols	AODV (already implemented in ns2), OLSR [10], DYMO [10]
Video file used	akiyo_cif.yuv [13] , [4]
Simulation duration	200 seconds
Channel	WirelessChannel
Mac	802.11
Antenna	OmniAntenna
Packet size	1024 Bytes
Propagation	TwoRayGround
QueueType	CMUPriQueue
Dimension	500m X 500m

For this study, the background traffic is defined as non-multimedia traffic generated by UDP traffic generators [7]. For the background data traffic, we use constant bit rate (CBR) traffic:

TABLE II. SIMULATION SETUP FOR DATA

Traffic type	CBR (UDP)
Packet rate	4 packets/ sec
Packet size	512 Bytes

IV. EXPERIMENTAL RESULTS

In our experiments, we test the three routing protocols (OLSR, AODV and DYMO) under different load conditions. First, we start with a single video session transmission. We then introduce some background data traffic to the existing video session. Finally, we show the results for multiple simultaneous video sessions transmitted over both small and large-sized networks.

A. One video session and 5 UDP connections (15 nodes):

In small-sized low traffic networks, DYMO protocol gives the best performance while OLSR has the worst PSNR and number of lost frames

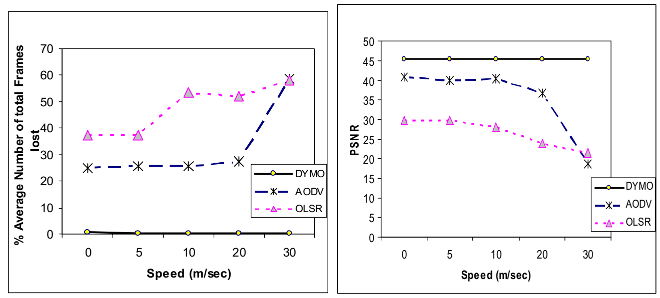

Figure 2. The average number of total frames lost and PSNR resulting from the transmission of one video session with 5 CBR traffic.

B. One video session and 50 UDP connections (50 nodes):

With the introduction of heavy background traffic in large-sized networks, AODV protocol gives the best performance while OLSR gives the worst performance.

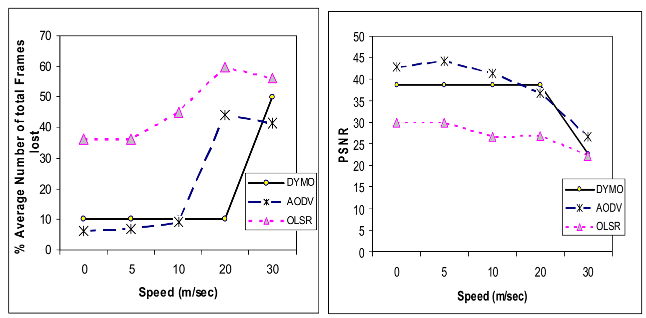

Figure 3. The average number of total frames lost and PSNR resulting from the transmission of one video session with 50 CBR traffic.

As OLSR gives the worst results, we did not use it in the heavy load comparisons. The main reason for its poor performance is that it is a pro-active protocol. As such, the continuous updating of the nodes' routing tables requires a high traffic overhead. Thus OLSR is not particularly suitable for ad hoc networks, in which nodes move a lot

C. Multi-video sessions

We did not introduce background data traffic in this section since we noticed that their effect is minor compared to the high traffic caused by the simultaneous video sessions.

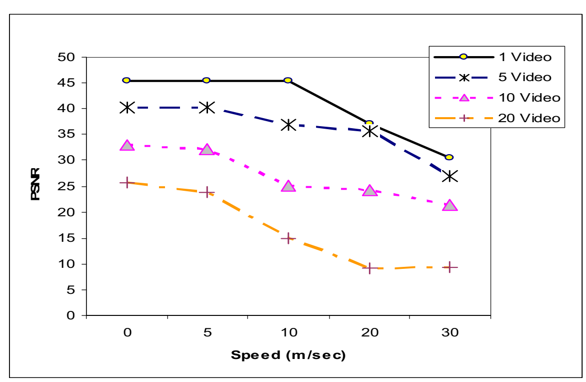

Figure 4. PSNR resulting 1,5,10 and 20-video sessions transferred over a large-sized network (50 nodes) using AODV routing protocol

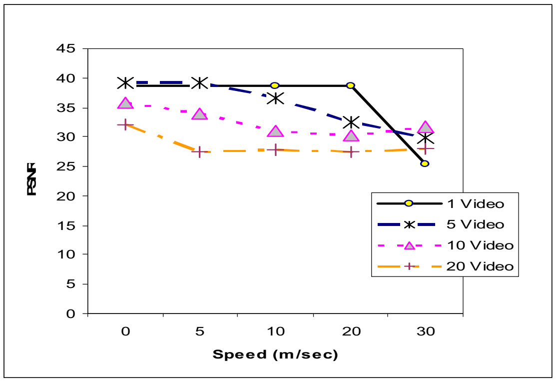

Figure 5. PSNR resulting from 1,5,10 and 20-video sessions transferred over a large-sized network (50 nodes) using DYMO routing protocol.

In large-sized networks (50 nodes), AODV gives the best results for light traffic networks because DYMO needs more control packets than those delivered by AODV. But as the load gets heavier and there is increased traffic, fewer routing states need to be maintained, thus DYMO gives much better results as seen in Figure 4. and Figure 5. Only routing information related to active sources and destinations must be maintained in DYMO. This is in contrast to AODV, which requires maintaining routing information to all nodes within the autonomous system.

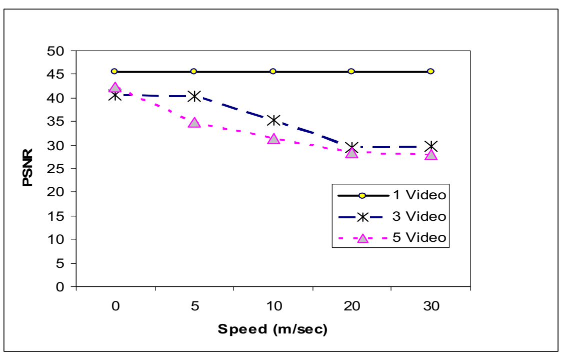

Figure 6. PSNR resulting from 1,3 and 5-video sessions transferred over a small-sized network (15 nodes) using DYMO routing protocol.

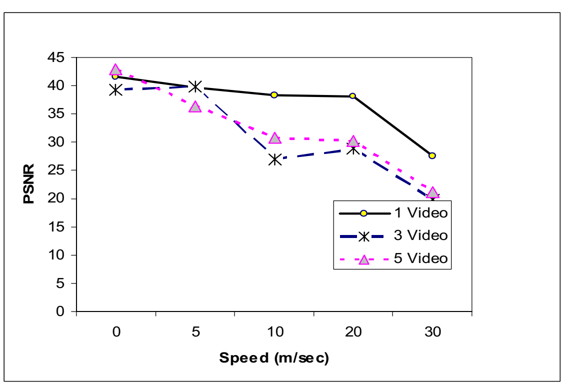

Figure 7. PSNR resulting from 1,3 and 5video sessions transferred over a small-sized network (15 nodes) using AODV routing protocol.

In small-sized networks (15 nodes), DYMO routing protocol achieves the best results in all types of loads as seen in Figure 6. and Figure 7. This is because the difference in the number of control packets between AODV and DYMO is minor compared to the routing information which is larger in AODV.

V. CONCLUSION AND FUTURE WORK

In this study, we proposed a new framework for studying video transmission over multi-hop wireless ad hoc networks. This framework assisted us in studying the performance of several routing techniques and their suitability in video transfer over ad hoc networks.

We conclude that OLSR is not suitable for real-time video transmission over ad hoc networks, especially for networks with high mobility. DYMO is best suited for small to medium size networks and in high traffic large-sized networks, while AODV is best suited for low traffic large-sized networks.

This framework can be further extended to enable the study of the effects of rate adaptive transmission on video quality. This will require a flow control mechanism for end-to-end video sessions that guarantees efficient network's resource utilization while providing fairness amongst video sessions without affecting real-time video quality. This proposed framework could also be extended to provide performance evaluation for combined audio-video streams. This work may focus on issues such as audio/video synchronization and QoS for individual streams.

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