MULTI-STREAM VIDEO TRANSPORT OVER DIFFSERV WIRELESS LANS

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ABSTRACT

This paper presents a new transport scheme for embedded video streams over wireless local area networks. It introduces a differentiated service (DiffServ) solution for video streaming over mobile ad hoc networks (MANETs). It employs the concept of single-application multiple stream (SAMS) that can effectively take the advantages of both DiffServ network and multi-layer or progressive source coding techniques. The approach is to preferentially improve the transport quality of important data substreams under the of a fixed network throughput. The 3D-SPHIHT subband video coder is used in generating embedded source data streams. This video coder features high compression efficiency. It produces fully embedded bitstreams which can be easily segmented into multiple data streams with different QoS characteristics. In wireless network, a class based queuing (CBQ) mechanism is implemented to provide DiffServ for these different data streams. The integrated source coding and networking system prioritizes the layers for lower resolutions, so that they will experience less delay or packet loss in case of congestion or link breakage. Simulations have been conducted on the network simulator (ns-2), and significant improvements over traditional wireless LAN transport schemes have been observed.

1. INTRODUCTION

A wireless ad hoc network, or mobile ad hoc network (MANET) [1], is an autonomous system with a certain number of mobile nodes which operate not only as hosts but also as routers. Each node can send and receive data packets, as well as store and forward data packets for other nodes. The connection between any pair of mobile nodes can be setup and maintained dynamically. This type of network does not rely on any pre-existing network infrastructure and it allows rapid deployment and reconfiguration.

In the proposed local area wireless network environment, large amount of heterogeneous devices (PCs, PDAs etc.) are to be connected with a few major data and computing servers, and multiple sensing devices (microphones, cameras etc). Ad hoc networks can effectively reduce the bottleneck traffic, and the power consumption of each individual node. More importantly they provide a unique flexibility that allows forming and dissolving small working groups anytime and anywhere. They can also serve as an extension to the wired backbone networks.

Currently TCP/IP protocols have been adopted to support most multimedia applications over ad hoc networks. In general, video streaming over IP network is considered as one of the most demanding networking tasks. Traditional traffic engineering studies have been focused on packet loss and delay issues. However these metrics can not be easily translated to the reconstruction quality of the transmitted visual information. The characteristics of the compressed video streams have been frequently neglected. In this work, a new video transport scheme is proposed for wireless ad hoc networks. A concept of single-application multiple-stream (SAMS) is introduced to take advantage of differentiated service (DiffServ) models. SAMS is based on the progressive source coding property which is featured in many state-of-the-art video coders. Progressive coding can generate embedded or layered data streams, in which bits are arranged from high importance to low importance. The importance is measured as the contribution towards the video reconstruction quality.

According to the availability of multiple QoS models provided by DiffServ network, the compressed video stream can be segmented into several sub-streams. Each of these sub-streams takes a particular service class. The strategy is to allow more important sub-streams to travel over higher QoS paths, and less important sub-streams to travel over lower QoS paths. The overall performance is measured by the end-to-end video delivery quality with the constraint of the cost increase associated with the usage of above normal QoS paths.

The rest of this paper is organized as the following. Section 2 provides a brief description of the 3-D video coding method, while Section 3 introduces the CBQ based DiffServ for ad hoc network. Section 4 discusses the settings of our simulation environment. Finally, Section 5 concludes the paper.
2. THE 3-D SPIHT VIDEO CODER

The 3-D SPIHT video coder used in this study represents a typical 3-D subband video coding scheme [2]. It is an extension of the popular SPIHT image coder. In the 3-D SPIHT, both spatial redundancy and temporal redundancy are exploited through subband filtering. No explicit motion estimation and prediction is performed. The subband coefficients are organized into a 3-D zerotree structure, and coding of subband coefficients are performed through bitplanes using context-based arithmetic coding.

Similar to many latest subband video coders, the 3-D SPIHT is able to achieve high compression efficiency, especially on low-motion sequences. In general its performance is comparable to MPEG-2 and H.263. Because of its bitplane coding procedure, this video coding algorithm is progressive in accuracy resolution and the resulting bitstream is fully embedded. This feature provides much needed scalability for video streaming over wireless LANs. Heterogeneous users can receive and decode the same bitstream at different bit rates according to their computing and display platforms. An embedded bitstream can also be segmented into multiple quality layers or sub-streams. The first layer or base layer represents a reconstruction of the video sequence at the lowest possible resolution, and each of the following layers represents a refinement of the reconstruction built upon all previous layers. Consequently each of these layers has a different contribution towards the final reconstruction quality. Because a refinement layer will not be effective if the quality of the previous lower resolution layers are poor. Therefore lower layers generally have higher QoS requirements than higher layers. This QoS characteristic can be easily accommodated by differentiate service networking techniques.

3. AD HOC NETWORK WITH DIFFSERV

In a traditional data network, all packets are treated as equal entities. However it has been realized that this does not reflect the reality of multimedia traffics. The Differentiated Services Working Group (DiffServ) under IETF has been working on defining and standardizing the provision of different quality of services and associated network management, traffic handling techniques for IP networks [3, 4]. In particular, the DiffServ architecture redefines the TOS (type-of-service) octet in the IPv4 header and the Traffic Class octet in the IPv6 header as the DiffServ (DS) header. Each packet is assigned a DiffServ code point (DSCP) in the DS field, which specifies the class of service this packet is expected to receive. The DSCP will invoke a particular per-hop behavior (PHB) at each DiffServ router to provide the specified packet forwarding treatment. In general, when network congestion occurs, packets belonging to less important classes are more likely to be dropped in order to ease the traffic.

DiffServ networking structure involves three basic elements:

- Policy: the class of service specified by the application and managed by the network administrator.
- Edge router: the first router in the DiffServ network assigns a code point to each packet based on the corresponding policy.
- Core router: all the interior routers in the DiffServ network forwards these packets according to the PHB associated with the code point.

Although DiffServ was mostly proposed for backbone IP networks, its potential application in ad hoc network has been studied recently [5]. This is motivated by the structural similarities between ad hoc networks and DiffServ.

- Ad hoc network resembles the backbone IP network in node functionalities. A mobile node in ad hoc network has the function of a router, it can store and forward packets for other nodes whenever it is necessary.
- DiffServ features lightweight design. Comparing to Integrated Service (IntServ), DiffServ requires less operation at interior nodes, which is suitable to ad hoc networks.

In this work, traffic handling techniques at interior nodes are studied. A DiffServ ad hoc networking structure is implemented using class based queuing (CBQ) [6] mechanism. CBQ introduces multiple queues at each interior nodes, which effectively partitions the queue space into several sub-spaces, each of which is assigned to a particular class of service. Traffics belonging to the same class will be passed into the same queue at the router.

In backbone network, the major challenge of CBQ is traffic control, because the priority is relative to aggregated traffic load. An overloaded class can not achieve a satisfactory performance regardless the priority settings. However this appears less problematic in ad hoc network, because of its small-scaled, well-contained and application
oriented environment. In the proposed local area wireless network environment, normally only one or two streaming video services will be running at a particular time, which will generate the dominate traffic flow. Background traffic may include discussions, interactive instructions and file exchanges. Therefore traffic management is relatively easy, and can be adapted to specific situations.

In our implementation, CBQ mechanism dynamically partition the queue space into two equal-spaced sub-queues upon the presence of two traffic classes. Each of these sub-queues will be assigned to one of the class. Priority queuing scheme is then applied. When channel is available, the packets in the higher priority queue will have a higher probability to be transmitted than those in the lower priority queue. This prevents the high priority traffics blocking all the low priority traffics.

4. SIMULATION ENVIRONMENT AND RESULTS

The simulation of this integrated source coding/networking system is based on the network simulator (ns-2). It is a discrete event-driven simulator providing support for most of TCP, routing, and multicast protocols over wired and wireless networks. It was developed in the VINT project at UC Berkeley, and is currently maintained at USC. The wireless extension with ad hoc capability was provided by CMU. It has been a widely used research tool in networking community.

The simulation topology is shown in Figure 2. Node0 is the source node and Node1 is the destination node. Node2, Node3, Node4 and Node5 are normal interior nodes. Node5 and Node6 produce background traffics destined to Node7 and Node8 respectively. The dynamic source routing protocol (DSR) is used at network layer. The radio propagation model is a combination of the friis free space propagation model (attenuation $1/r^2$) for short distance and the two-ray ground reflection model for longer distance (attenuation $1/r^3$) with omni-directional antenna. The distributed coordination function (DCF) of IEEE 802.11 for wireless LAN is used as the MAC layer model to prevent hidden terminal problem and capture phenomenon. The shared radio media has a nominal bit rate of 2 Mbps, and radio range of 200 meters. Mobile nodes are initially set apart at a minimum distance of 200 meters, and with slow motion of 0.1 m/s along the directions indicated in the figure.

Node0 uses UDP as the transport agent. The video streams are transmitted as ns-2 CBR traffic. The background traffics are modeled as random telnet transactions using TCP transport agents. Different TCP data rates are used to achieve two major sets of background traffic levels, roughly corresponding to $5 \sim 10\%$ packet loss and $0.5 \sim 1\%$ packet loss in the video streams. Small packets with size of 96 bytes are used. No RTS/CTS handshake is used at MAC layer.

We have implemented CBQ with priority queuing in the form of “interface queue” for ns-2 ad hoc module. Each node has a queue size of 20 packets. At initialization, all the queue space is allocated to a single (low-priority) queue. It can be dynamically reconfigured into two 10-packet queues when the node receives the first high-priority packet. In the priority queuing scheme, at each given time the probability for high priority packet to be transmitted is $70\%$ and the probability for low priority packet is $30\%$. These settings can be easily modified according to the requirements of applications.

The coded video streams can be segmented into two sub-streams, one is transported through high-priority HP class, and the other is transported through normal low-priority LP class. All cross traffics are taking LP path. Four segmentation ratios in the video streams are tested, i.e. (0% HP with 100% LP), (25% HP with 75% LP), (50% HP with 50% LP) and (75% HP with 25% LP).

The test video sequences are AKIYO and FOREMAN in CIF resolution (352, 30 frames/sec). A total of 128 frames are coded at $\sim 200,000$ bits/sec (bps) or $0.065$ bits/pixel (bpp). Every 16 frames are grouped together in the subband coding, which results in a constant bit rate traffic of $13,178$ bytes every $\frac{16}{50}$ sec.

A simple and effective error control mechanism is used for the embedded video streams. The decoder will stop decoding process if it reaches the first packet loss. This method works particularly well for the 3-D SPIHT coding algorithm, in which a global zerotree structure introduces correlation among all the coded symbols in the bitstream.

Figure 3 shows the simulation results. Each value represents the average result of 50 trials at the same network and traffic condition.

From these results we can see that the increase of end-to-end video quality is not linear to the usage of high priority class. More specifically, the (25% HP with 75% LP) setting produces a significant PSNR increase over normal 100% LP transport. Further increase of HP usage appears to be less effective. This is because resolution segmentation based on progressive coding effectively provides higher QoS to more...
5. CONCLUSION

A multi-stream video transport scheme over DiffServ wireless ad hoc network is introduced and studied. This scheme can be applied to many existing embedded or layered video coding techniques, including MPEG-4 and H.263/H.264. However it is particularly suitable for the 3-D subband video coding technique discussed in this paper. The advantages come from the effective use of different class of services for video sub-streams with different QoS characteristics. The resulting performance improvement is higher than the increase of the high priority class usage. Therefore this scheme is cost efficient. Simulation results clearly demonstrated the viability of this approach.

6. REFERENCES