CENTRALIZED PEER-TO-PEER VIDEO STREAMING OVER HYBRID WIRELESS NETWORK

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ABSTRACT

Video streaming over wireless network has drawn a great interest. In traditional wireless local area networks (WLANs), when the number of the users and the number of the flows increases, the contention for the wireless channel will lead to packet loss and packet delay. In this paper, we propose a centralized peer-to-peer video streaming over hybrid wireless network to improve the performance of the video transport over wireless Internet. The base layer of the video is transported from the server via the WLAN mode, which benefits the centralized management of the video distribution, while the enhancement layers are delivered over the multiple paths via the ad hoc mode, which can reduce the congestion in the access point (AP). The simulation results show that our proposed scheme can achieve a better perceptual video quality compared to the WLAN deployment.

1. INTRODUCTION

Streaming video over Internet has drawn a lot of attention for its applications in numerous areas such as video on demand (VOD), telemedicine, distance education, and videoconference. The advances of the wireless communication technology and the increasing computing capacity of the mobile devices make video streaming over the wireless Internet of great interest. Video transport typically requires stringent bandwidth and delay guarantee. However, most wireless networks installed today are deployed as the wireless local area networks (WLANs), where all the packets are forwarded by the access point (AP). When the number of the users and the number of the flows in the WLAN increases, the contention for the wireless channel will lead to packet loss and packet delay, which degrade video perceptual quality.

In this paper, we propose a centralized peer-to-peer video streaming over hybrid wireless network to improve the performance of the video transport over wireless Internet. The hybrid wireless network is a combination of the infrastructure network and the ad hoc network [1]. The proposed scheme is shown in Fig. 1. The video is encoded into multiple layers, and pre-stored in the server. When a mobile station (MS) requests a video from the server, the server will first check if any MS in the initiating cell caches the video content. We refer to the MS, which caches the video content, as the super-peer. If super-peer is found, it will be requested to transport the enhancement layers to the requesting MS over multiple paths via the ad hoc mode, while the server will transport the base layer to the requesting-peer via the WLAN mode. The advantages of our proposed scheme are: First, it sustains a centralized management of the content distribution. Second, it reduces the traffic contention in the AP, hence increasing the system throughput and decreasing the packet loss and delay in wireless network.

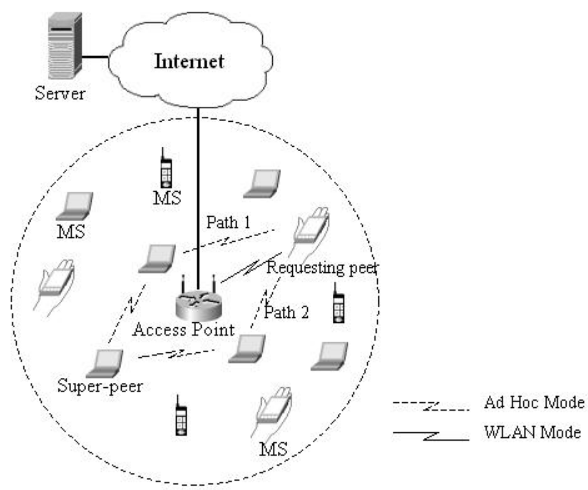

Fig. 1. The centralized peer-to-peer video streaming over hybrid wireless network

Some related work has been reported in the literature in the video streaming and wireless hybrid network. The centralized peer-to-peer video streaming over wired Internet was proposed in [2]. Yang et al [3] investigated the end–to-end architecture for video streaming from wired Internet to wireless network, but the contention in the AP wasn't discussed in that paper. [1], [4] studied the hybrid wireless network (also called mixed-mode wireless network), which integrates the infrastructure network and the ad hoc network. Voice application in hybrid wireless network was discussed in [1], [5].

2. CENTRALIZED PEER-TO-PEER STREAMING OVER HYBRID WIRELESS NETWORK

The centralized peer-to-peer video streaming over hybrid wireless network aims to offload the traffic of the server and release the congestion in the AP. The layer encoded video streams are pre-stored in the server. Each video is encoded into one base layer and several enhancement layers. Some video coding schemes, such as fine granularity scalability (FGS) and progressive fine granularity scalability (PFGS) [6], can provide such layered video streams.

The AP in our proposed scheme is responsible for not only forwarding the packets, but also managing the cached videos and the MSs in the local wireless network. The AP maintains two tables: the *video table* and the *MS table*.

The format of the *video table* is shown in Table 1. This table indicates the video ID, video supplier, and the corresponding video quality, which depends on the number of the enhancement layers. Once a peer obtains a video from outside or inside the local network, it will send immediately a REGISTRATION message to the AP to update the *video table*.

Each MS may move beyond AP's transmit range or may power off. Also, a new MS may join in the network. Therefore, the AP needs to manage the status of each MS in the local wireless network by the *MS table*, which is shown in Table 2. Each MS sends an ALIVE message periodically (e.g., every 5 s) via the WLAN mode to inform the AP of its existence. If the AP doesn't receive the ALIVE message in a pre-determined interval (e.g., 20 s) from a MS, the AP will update the *MS table* by setting the alive status of the MS to false. When a new MS joins in, the AP will create a new entry in the *MS table*.

When a MS requests a video, it will send a SETUP message to the server. The server will first validate the authentication, authorization, and accounting (AAA) for this request. If the request is valid, the server will look up in its database to check if the requested video is available. If available, the server will send a SEARCH message to the AP of the initiating cell. Upon receipt of the SEARCH message, the AP will look up in the *video table* and the *MS table* to check if a super-peer is caching this video and the super-peer is currently alive. If no such super-peer is found, a negative acknowledgement (NACK) will be sent back to the server, and then the server will transport the base layer and the enhancement layers to the requesting peer via the WLAN mode. If one or more active super-peers are found, the AP will send a VERIFY message to the best super-peer, which owns the best quality (highest enhancement layer) of the video content. If the super-peer is able and willing to provide a sufficient upload bandwidth to stream the enhancement layers to the requesting peer, it will feed back a positive acknowledgement (ACK) to the AP. Then, the AP sends an ACK to the server to inform the server to transport the base layer to the requesting peer via the WLAN mode. Meanwhile, the AP also sends an EL-START message to the chosen super-peer to command it to transport the enhancement layers to the requesting peer via the ad hoc mode. If the super-peer leaves the cell or powers off during the streaming period, the AP will be able to detect the disappearance of the super-peer by checking the MS table periodically. In that case, the AP will assign another super-peer to transport the remaining video content. This is called the hand-off among super-peers. If the requesting peer stops the video transmission, it will send a TERMINATION message to the AP, which will forward this message to the server informing the stop of the base layer transmission, and also forward this message to the super-peer to terminate the transport of the enhancement layers. If the AP detects the disappearance of the requesting peer during the streaming, the AP will generate the TERMINATION message and send it to the server and the super-peer.

Table 1. Format of the video table in the AP

Video ID	MS ID	Number of Enhancement Layers
0001	M002	4
	M005	3
0002	M003	3

Table 2. Format of the MS table in the AP

MS ID	Is Alive	Time of Last ALIVE message
M002	True	05:03:23
M003	False	02:06:21

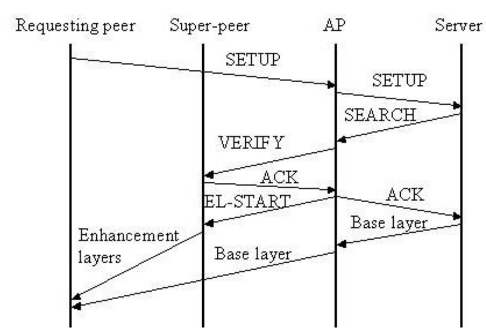

Fig. 2. Flowchart: the server transports the base layer, and the super-peer transports the enhancement layers, respectively

Fig. 2 shows the flowchart in the case where the server transports the base layer, and the super-peer transports the enhancement layers, respectively.

In our proposed scheme, the super-peer transports the enhancement layers to the requesting peer over multiple paths via the ad hoc mode. Several on-demand multi-path routing protocols have been proposed in the literature, such as ad hoc on-demand multi-path distance vector routing (AOMDV) [7], and split multi-path routing (SMR) [8]. After the super-peer obtains the multiple paths to the destination from the route discovery, it will allocate the traffic of the enhancement layers over these multiple paths. The allocation policies we proposed are: First, the enhancement layer 1 has the lowest bit rate and the highest priority among the enhancement traffic, thus it is copied to every available path and redundantly delivered to the destination. Second, the paths are prioritized based on the packet loss ratio and delay. The traffic of the rest enhancement layers is split into several streams according to the number of the paths available. In order to reduce the drifting error in every group of pictures (GOP), we allocate the stream of the first several frames in the GOP over a higher-prioritized path, and the stream of the frames in the end of the GOP over a lower-prioritized path.

3. SIMULATION RESULTS

We evaluate the performance of the centralized peer-to-peer video streaming over hybrid wireless network using network simulation version 2 (NS2) [9].

We put 1 AP and 15 MSs in a square region of 600m × 600m. The AP is placed in the center of the region, and each MS is randomly placed in the region initially. The mobility of the MS follows a simplified version of the *random waypoint model*, where each MS chooses a random destination in the region, and then moves towards it at a constant speed, which is uniformly distributed between 0m/s and 5.0m/s. Once the destination is reached, the MS will move towards another randomly chosen destination after a pause of 1.0 s.

We use the IEEE 802.11 protocol in the media access control (MAC) working in distributed coordination function (DCF). The two-ray reflection model is used to simulate the radio propagation. Each node has a transmission range of 250m, and a MAC data rate of 2 Mbps. UDP packets are used to deliver the video streams, and all the packet sizes are set to 512 bytes.

Among the 15 MSs, we choose one as the requesting peer, and the requesting peer never goes out of the range of the AP in the simulation. Since any of the other MSs may own the best quality of the requested video, we randomly choose one as the super-peer from the left 14 MSs. The base layer is transported from a wired node to the requesting peer via the WLAN mode. All other MSs randomly generate 5 pairs of background sessions. Each background session has a continuous bit rate (CBR) of 0.2Mbps, and starts at a random time in the simulation.

We compare the performances of the peer-to-peer video streaming among three scenarios. In scenario 1 (WLAN), enhancement layers are transported via the WLAN mode from the super-peer to the requesting peer. All the background sessions also run in the WLAN mode. In scenario 2 (hybrid with 1 path), enhancement layers are delivered via the ad hoc mode, and only one path is established between the sender and the destination. Ad hoc on-demand distance vector (AODV) routing protocol [10] is applied in this scenario. Scenario 3 (hybrid with 2 paths) represents our proposed scheme. In scenario 3, the enhancement layers are transported over two maximally disjoint paths from the super-peer to the requesting peer. The AOMDV [7] multi-path routing protocol is used in this scenario.

Table 3. Comparison of average packet-loss-ratio

Scenario	Layer	Packet-Loss-Ratio
WLAN	Base	29.0%
	Enhancement	58.7%
Hybrid with 1 path	Base	0
	Enhancement	45.0%
Hybrid with 2 paths	Base	0
	Enhancement	37.6%

We use PFGS [3] codec to encode the video sequences into one base layer and three enhancement layers. The length of the GOP is 15 frames with one I frame and 14 P frames. The CBR bit-rate for base layer is 0.2Mbps, and the CBR bit-rate for the enhancement layers is 1.5Mbps. The 300-frame sequence is transported within 10 s. In scenario 1 (WLAN) and scenario 2 (hybrid with 1 path), three enhancement layers are interleaved into one stream with a one-frame interval. In scenario 3 (hybrid with 2 paths), enhancement layer traffic is split into two streams and delivered over two paths. In order to reduce the drifting error, we allocate the enhancement packets of the first 7 frames in every GOP into the better path (e.g., with less packet-loss-ratio) and those of the rest 8 frames into the other path.

The average packet-loss-ratios in 10 runs for three scenarios are shown in Table 3. In WLAN scenario, all the packets compete for the common channel, which leads to a larger packet loss in both base layer and enhancement layers. While in hybrid wireless network, enhancement layers are transported via the ad hoc mode, which reduces the congestion in the AP. The loss of enhancement packets in hybrid wireless network is due to the channel contention from the dynamic background traffic during the streaming. It can be seen that our proposed scheme (hybrid with 2 paths) has the least packet-loss-ratio among three scenarios.

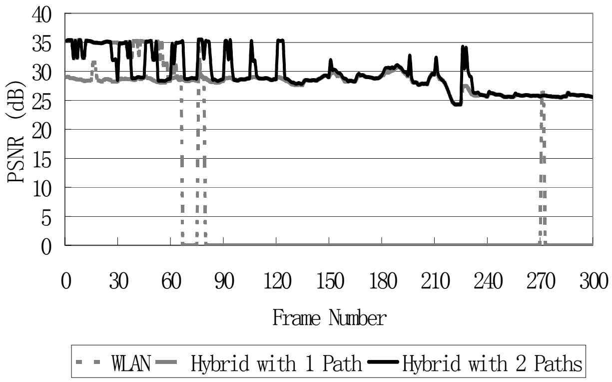

Fig. 3. PSNR comparison for Foreman CIF sequence

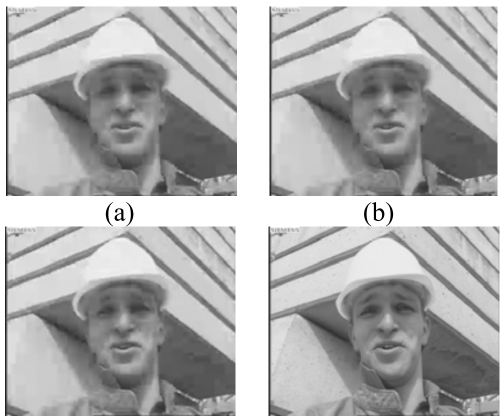

Fig. 4. Comparison of the reconstructed frames (a) WLAN, (b) Hybrid with 1 path, (c) Hybrid with 2 paths, (d) Original frame

Table 4. Comparison of the average PSNRs

Sequence	Average PSNR (dB)		
	WLAN	Hybrid with 1 path	Hybrid with 2 paths
Foreman	6.87	29.08	29.43
Akiyo	7.98	32.51	32.93
News	5.76	29.61	30.07

Fig.3 shows the peak-signal-to-noise-ratio (PSNR) comparison for Foreman CIF sequence. No channel coding is applied in the three scenarios. If the base layer packet is lost or corrupted, the PSNR of this frame will go down to 0. We can see that in WLAN scenario, about 75% of the frames cannot be reconstructed (PSNR=0) due to the loss of the base layers and the error propagations. In hybrid scenarios, all the base layer packets are correctly received, which guarantees an acceptable video quality. Our proposed scheme outperforms the other two schemes with a higher PSNR.

Fig.4 shows the comparison of the reconstructed No.62 frame. It can be seen that the perceptual quality of the decoded frame in our proposed scheme is better than those in the other schemes.

Table 4 compares the average PSNRs of the reconstructed videos in the three schemes for difference sequences, respectively. In the WLAN scenario, the average PSNR is very low due to a higher packet-loss in the base layer. The result shows that our proposed scheme can achieve a better perceptual video quality.

4. CONCLUSIONS

In this paper, we proposed a centralized peer-to-peer video streaming over hybrid wireless network to improve the performance of the video transport over wireless Internet. The base layer of the video is transported from the server via the WLAN mode, which benefits the centralized management of the video distribution, while the enhancement layers are delivered over the ad hoc multiple paths to reduce the congestion in the AP. The simulation results show that our proposed scheme can achieve a better perceptual video quality compared to the WLAN scheme.

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