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Visual Importance-based Cross-layer 3D Model Streaming over Lossy Network

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Abstract

This paper proposes a visual importance-based cross-layer 3D model streaming method over lossy network. Before the transmission, we build an important criterion for each packet of a 3D model from the aspect of rendering dependence among packets. Thus, each packet will have a rendering importance value. And then, the progressive model is streamed by the modified protocol based on a cross-layer optimization. In this optimization method, we will use the unequal FEC and Mac_Lite protocol guided by the rendering importance value of each packet. The simulation result demonstrates our method's effectiveness.

Keywords:Cross-layer streaming; Importance Packet; Mac-Lite; Mode Transmission

1. Introduction

With both the mature of the mobile network infrastructure and wide use of mobile handheld devices, 3D applications based on mobile devices among wireless network such as online simulation and virtual reality have got rapid development. However, lossy wireless network is considerably different from wired networks. The transmission over lossy wireless links stays challenging due to narrow bandwidth, fading and obstacles which result in high transmission error rates.

To address these problems, retransmission is scheduled. Evidently, this retransmission mechanism affects the network's throughput and end-to-end delay badly. Factually, most dropped packets are caused by bit-errors in the frame during transmission in the wireless network and a packet with this kind of errors

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can still be utilized for some error-tolerant transmission such as audio, video and graphics. To allow corrupted frames being passed to higher layers, the Mac-Lite[1] is proposed. Now, Mac-Lite has been used to transmit voice in WLAN [2] and video [3].

What's more, FEC (Forward Error Correction)[4] is a technique extensively adopted to decrease packet error. The FEC is better attractive for providing reliability without increasing latency than others. FEC-based methods send the redundant information with important information in order to recover lost packets. Factually, how to protect the most important packets with the FEC and decrease the transmission delay is the key of the 3D model streaming.

Cross-layer design (CLD) is a new paradigm in network architecture design that takes into account the dependencies and interactions among layers, and supports optimization across layer boundaries [5]. During the transmission of the 3D model, we can design a cross-layer protocol to optimize the transmission procedure while taking the application layer and data link layer into accounts with the help of the decision of the importance data of a 3D model.

In this paper, we propose a visual importance-driven cross layer 3D model transmission protocol to transmit the 3D model over lossy network. In our method, we will first build the visual importance criteria to differ the visual important graphics data and less important data respectively.

The reminder of this paper is organized as follows. Section 2 introduces the rendering importance criteria for 3D model packet. Section 3 is our cross-layer optimization of 3D model streaming. The simulation results are achieved in section4, followed by conclusions in section 5.

2. Rendering Importance Criteria for 3D model packet

Progressive Mesh[6], as a good solution to the transmission of 3D models over network, is represented by a base mesh M0 followed by an ordered list of vertex split (VSplit), which is in the form of {M0, {VSplit 1,VSplit 2, . . . ,VSplitn}}. There exists dependency relationship among these VSplit operations. In practice, these VSplits will be packed into packets for transmission over networks. Hence, these packets also have dependency relationship. Consequently, VSplits could not be rendered unless their dependent VSplits arrived at the client. If some of the received packets are dependent on the lost packet, the client will endure a rendering delay since the lost packet retransmission will be invoked. On the contrary, if no or just a small number of the received packets are dependent on the lost packets, the client could render more vertices at a given period of time and the delay will be reduced.

Thus, in our past work [7], we have presented a novel packetization scheme that is to decrease the dependencies among packets. In this packetization method, two steps will be performed. First, a Non-Redundant Directed Acyclic Graph (NR-DAG) will be constructed to encode all the necessary dependencies among the VSplit operations. Second, a Global Graph Equipartition Packing Algorithm (GGEPA) is applied to minimizing the dependencies among different partitions while separating the whole dependency DAG into k equal size partitions.

Though this method can decrease the dependencies among these packets, the dependencies are still existed. If the dependencies between one packet with other packets are higher, more VSplits, which are included in the dependent packets, should wait this packet be arrived at the client side. Thus, we here regard this packet are rendering-importance packet. As we knew, if the VSplits belongs to the base mesh or upper levels, the packets that contain these VSplits are also rendering important packets. Unfortunately, these packets maybe not have many packets that dependent on them. To assign this kind of packets those have many dependent packets and the packets those have in the upper level of our model, we will deal with them in a unified way.

In our GGEPA, we will record each packet's dependencies noted as PD. As we knew, the NR-DAG we built is a graph. We will translate them into a tree structure thus all nodes will have been arranged as level by level. Manifestly, the nodes in the upper level are the parents of the lower level's nodes. To assign each packet with a rendering important (RI) value, we browse this tree level by level with depth-first visiting method and calculate each packet's RI value. While finishing this depth-first visiting, we can obtain each packet's RI. However, this method only records the RI between neighboring levels. To obtain the RI among all the levels, we should add all the children's RI into their parents. Now, we can give each node with an accurate RI value.

3. Cross-layer optimization of 3D model streaming

Our Cross-layer optimization from the application layer to data link layer is for the 3D model streaming. Our basic idea is, in the application layer, we adapt an unequal FEC method guided by our importance criteria. For the link layer, we will use a the MAC_Lite protocol to transmit different frames guided by the importance criteria. Following is the details.

3.1. Unequal FEC method for 3D model

For traditional FEC algorithms, redundant data is added to transmission data in a given number. The traditional FEC advantage is easier to implement. However, the traditional FEC disadvantage is that it does not flexibly adapt network condition changes. When packet loss rate is very low, traditional FEC algorithms can occupy a large bandwidth. On the other hand, when network traffic load is high, traditional FEC algorithms leads to additional packet loss.

In our method, we will add the redundant data to the most important model data for ensuring these data arrived at the destination safely. As we knew, we have obtained each packet's rendering important value in the application layer. If the RI of one packet is high, we will add more FEC to the sending packets. On the contrary, if we found the RI of one packet is very low, we will do not use the FEC to protect this packet. By this method, the most important data can be recovered by the FEC and be rendered fully while the network is lossy. For the unimportant data, we cannot render them at the client side since these data are not protected by the FEC. However, these data will not affect the overall appearance of the 3D model.

3.2. Mac_lite protocol

In the data link level, we adopt the Mac-Lite adopted rather than traditional MAC. As we knew the traditional MAC adopts CRC mechanism for the entire packet (frame) to make sure that the received packet is error-free. Any error in a packet, retransmission is scheduled until reach the maximum number of retry limit and then the packet will be discarded. Evidently, this retransmission mechanism affects the network's throughput and end-to-end delay badly. In fact, most dropped packets are caused by bit-errors in the frame during transmission in the WLAN and a packet with this kind of errors can still be utilized for some error-tolerant transmission.

In our method, we will adopt the MAC-Lite, which will modify the CRC in the MAC layer to allow corrupted frames being passed to higher layers. What's more, the coverage of Mac-Lite's checksum can be set freely and how to set the coverage of checksum for a frame is the key. In our method, all headers information should be covered. Nevertheless, the checksum just covering the headers data is not enough. Factually, the model data is divided into important data and unimportant data by the RI value. Thus the high RI value model data should be transmitted as safely as the frame headers information. Therefore, the coverage of Mac-Lite checksum is the summary of MAC header (28bytes), IP header (20bytes) and UDP header (8bytes) and high RI value model data.

4. Experimental Results

In our simulation model, three nodes A, B and C are used as an ad hoc network and the topology is shown in Fig 1. In order to set the different loss rate in the PHY layer, the Gilbert Error model should be added. The bit errors generated by this model are introduced to MAC frame.

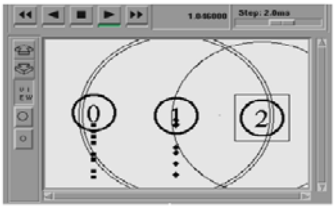

Fig. 1. Topology in NS2 2.33

Fig. 2. Test model

Before the transmission of model, we will adopt the presented method in this paper to encode the 3D model with base mesh and a sequence of VSplit . Each VSplit including only the basic topology and geometry information is 30-byte quantity. Thus, one packet whose max size is 512-byte defined in this paper will contain roughly 17VSplit. We will report the experimental result for Bunny model as shown in figure 2.

Table 1. Measured ε_{mn}, ε_{rms}, and H between the original model and test model

	ε_{mn}	ε_{rms}	H
FEC+MAC	0.02344	0.03496	0.92833
Ours	0.00934	0.00832	0.75321

In our experiment, we mainly present the visual quality of the 3D model received at the client side while the network is lossy. We will measure the geometry distortion for the models. In our experiment, we will employ the Metro tool to get the mean distance ε_{mn}, root-mean-square distance $\varepsilon_{rms}$and the Hausdorff distance H, which works successfully in measuring the quality of the meshes. Table 1. shows the above values for the bunny model comparing with the original model. It can be seen that our transmission method can achieve the rendering result than the traditional equal FEC protection at the application level and MAC protocol at the data link level.

5. Conclusion and future work

In this paper, we proposed a visual importance-based 3D model transmission streaming scheme over lossy wireless network. We presented the rendering dependent criteria mesh. What's more, we will utilize a cross-layer optimization method constituted by unequal FEC and MAC_Lite to transmit the visually important part and unimportant part. The simulation results show that the quality of the 3D model received at the client only is better than original method.

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