Intelligent Dropping Scenario for Motion JPEG2000 Transmission over Satellite Networks

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Abstract: Intelligent dropping service improves the quality of multimedia streams during network congestions. To extend its application, this paper presents an intelligent dropping architecture for Motion JPEG2000 transmission over satellite networks. Simulation results are also presented to compare quality improvement using intelligent dropping over random packing dropping. By integrating JPEG2000 scalable codec and DVB-S2 satellite link layer, the proposed design also optimises data quality during poor satellite link quality. These advantages make it viable for next generation multimedia services and other potential applications over satellite networks.

1. Introduction

Active Networking introduces a new networking concept of moving the intelligence to the network nodes. Active nodes examine the data, and then perform computation and modification up to application layer. The initial concept proposed by Tennenhouse at MIT [1] has evolved into different levels of active networking, including network level and application level. When applied to next generation multimedia services such as unicast and multicast multimedia streaming, active networking creates a huge potential to reduce node congestion and improve transmission quality. Multimedia streaming requires high transmission bandwidth and during node congestion in conventional networks, packets are randomly dropped. This leads to drastic degradation of data stream quality. Intelligent dropping is an active network scenario that can be applied to mitigate node congestion and optimise bandwidth usage at intermediate network nodes. In contrast to random dropping, intelligent dropping greatly improves the quality of images and video streams when link congestion occurs.

The demand for multimedia streaming over satellite networks is increasing due to wide coverage, massive broadcasting capacity and immediate service availability once launched offered by satellite communications [2]. But high link error in satellite transmission causes degradation of data stream quality and often reduction in transmission data rate. As a solution, intelligent dropping service can be integrated with adaptive error protection mechanism to improve transmission quality. Lower priority packets can be dropped to allow transmission of more error correction codes during high error rates. This increases the robustness and error tolerance of transmission without contributing to congestion at satellite nodes.

Much research has been done on selective dropping of packets for MPEG2 and MPEG 4 video streams over terrestrial Internet networks. Consequently, the promising results achieved [3, 4, 10] serve as a motivation for intelligent dropping to be extended to other networks. In this paper, we present an intelligent dropping architecture for video streams over satellite network by integrating Motion JPEG2000 (MJ2) scalable codec and DVB-S2 specification with intelligent dropping service and active packet encapsulation. The following sections will discuss the details of proposed architecture, results obtained and the potentials of this robust yet simple design.

2. Proposed Design

The integration of intelligent dropping at satellite nodes reduces congestion and optimises video streaming quality during link congestion and high link error rate. To achieve this objective, data stream transmitted must be strictly prioritised and the intelligent dropping service must be able to identify the priority of packets. Hence, three active components are introduced in the design i.e. active encapsulator, intelligent dropping service and active decapsulator; and they are integrated with MJ2 video codec and DVB-S2 codec/modem. The overall proposed architecture is shown in figure 1.

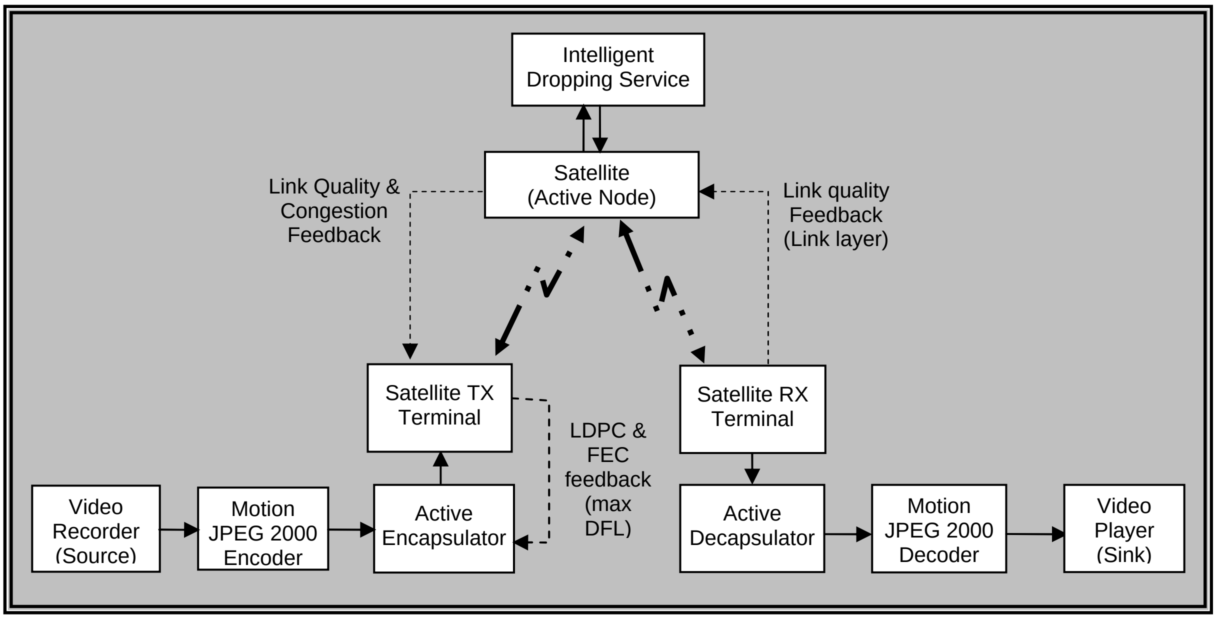

Figure 1: Intelligent dropping architecture for video streaming over satellite networks

MJ2 codec is used to generate encoded codestream in a decreasing order of priority for data reconstruction. JPEG2000 image compression standard [5] allows images to be divided into smaller tiles, each encoded independently based on discrete wavelet transform. The resulting codestream of each tile is made of image data packets in specific progression orders, i.e. layer, component, resolution and precinct. When layer progression mode is used, the image data packets are arranged in the order of decreasing data priority for reconstruction of encoded image [6]. MJ2 [7] is an extension of JPEG2000 standard based on intra-frame coding. Hence, it uses JPEG2000 codec to generate frame-by-frame independent codestreams which are ordered based on priority. This makes MJ2 an excellent candidate for video codec in the proposed design. Furthermore, the absence of inter-frame dependencies, as used in MPEG2 and MPEG4, reduces the processing complexity. In turn, this reduces the additional processing load imposed on satellite nodes where resources are limited and expensive.

To achieve optimum video quality during high error rates, the intelligent dropping service requires a robust and error-rate adaptive link layer transport. Hence, second generation Digital Video Broadcast specification (DVB-S2) [8] has been adopted as the underlying satellite link layer transport mechanism. Developed for broadband satellite communication, DVB-S2 offers enhanced error protection and flexible input data stream format. Using adaptive coding and modulation (ACM) enables operation within CNR of -2.4dB to +16dB by means of a return channel [9]. During high link error, data field length (DFL) in each physical frame is reduced to allow more FEC codes.

Video streams will be encoded into MJ2 codestream before it is sliced and attached with active headers by the active encapsulator. The active encapsulator is adapted to optimise transmission efficiency and provide tight control over data dropped at satellite nodes by adaptive slicing algorithm that receives feedback of DFL size from DVB-S2 codec. This ensures the resulting active packet (sliced codestream + active header) size varies according to link quality. Critical information such as sequence number, priority range, video frame sequence number and terminating packet marker; are required for packet priority identification and it is stored in the active header fields. The packets are then transmitted as DVB-S2 frame via RF uplink to satellite node.

At the satellite node, intelligent dropping algorithm will decide the number of packets dropped based on the header information and link quality feedback received. The feedback is obtained via incoming packet queue size for congestion information and DVB-S2 DFL size for link error rate. Selective priority based packet dropping will occur when link quality falls below certain threshold. The dropping algorithm is kept small and simple to minimise additional load and resource requirements at the satellite node where resource onboard are limited and expensive. If packets are dropped, the least important packet transmitted in each video frame will be tagged as the terminating packet. At the ground receive (Rx) terminal, active decapsulator will retrieve the header information from the packets received before reconstructing the JPEG2000 codestream and modifying markers to reflect the truncated data size. Finally, JPEG200 codec will decode the codestreams to rebuild the video stream.

3. Simulation and Results

The proposed architecture was simulated using Java implementation and JJ2000 reference software for JPEG2000 standard was adapted as the image codec. Since each frame is encoded independently, still images were used in this simulation. The results obtained for both intelligent dropping and random dropping are shown in figure 2. Clearly, intelligent dropping improves reconstructed image quality as compared to random dropping for a given percentage of packets dropped.

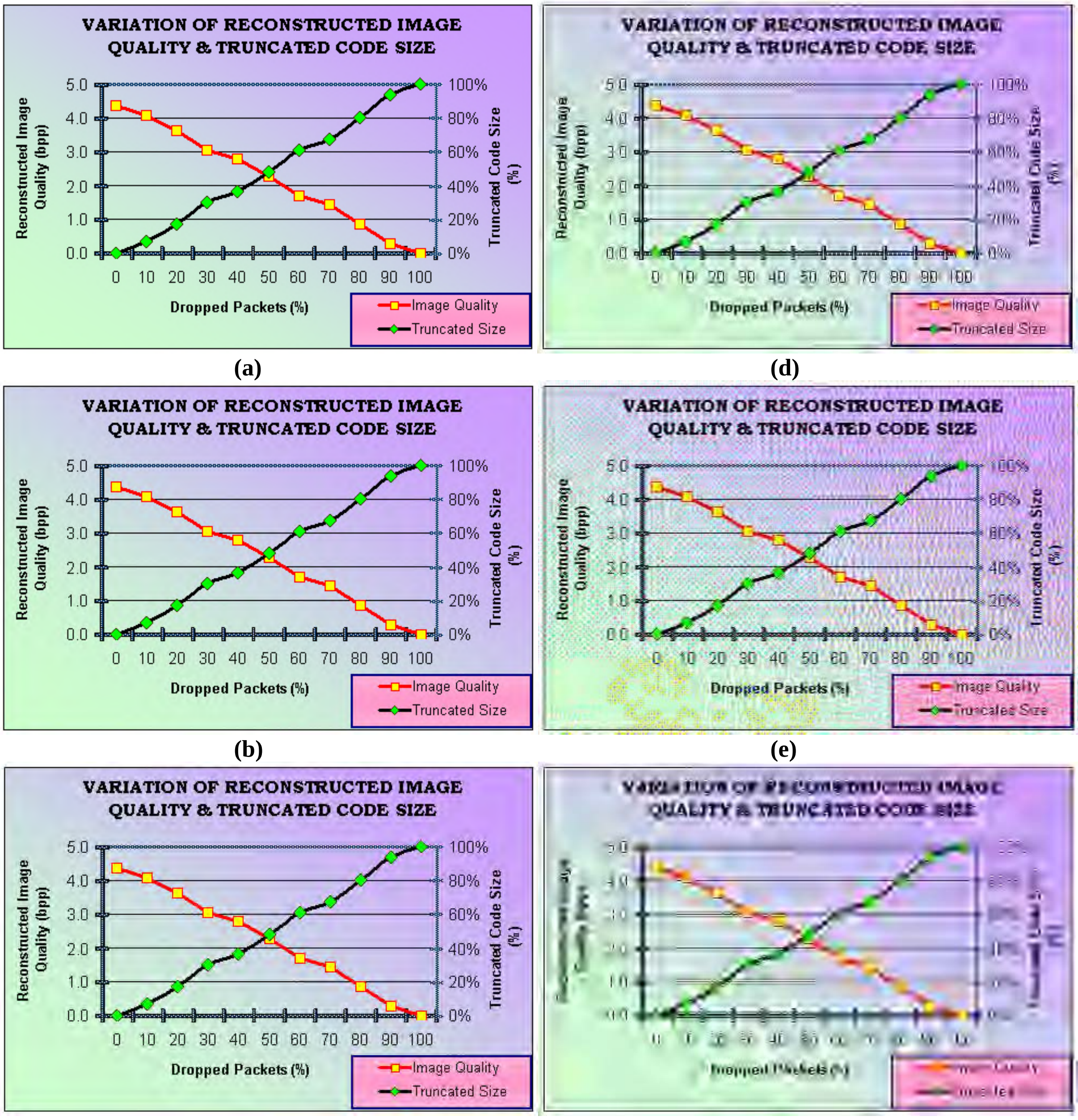

Figure 2: Simulation results of intelligent dropping and random dropping. Figure used shows effect of increasing percentage of packets dropped on image quality with reference to truncated codes size. (a) Original image – no dropping; (b) 50% packets dropped using intelligent dropping; (c) 70% of codestream dropped using intelligent dropping; (d) 90% packets dropped using intelligent dropping; (e) 50% of codestream dropped randomly; (f) 70% of codestream dropped randomly

4. Conclusion

The results obtained via simulation shows remarkable improvement in reconstructed images using intelligent dropping while random dropping leads to drastic degradation of images. Although simulations were obtained using still images but it can be extended to video streams as MJ2 uses intra-frame coding without interdependencies. This reveals the potential of intelligent dropping service at satellite nodes to optimise unicast and multicast multimedia streaming quality during congestion. Combined with DVB-S2, the proposed design also creates a robust and resilient solution to optimise streaming quality during poor link quality.

Conceptually, the proposed architecture introduces a generic protocol above link layer, in the form of active headers. Thus, this design can be extended to other applications that have data hierarchy or transmission packet priority. Intelligent dropping service could also be seen as a bandwidth shaping service at network nodes. By dropping packets of low priority, multiple users with different bandwidth requirements can be support. This is especially important in satellite networks because satellite services cater to different footprints and different link conditions. In this case, intelligent dropping can be implemented at each transponder to act as rate adaptation mechanism by adaptively dropping packets to meet the required bandwidth. This eliminates the need for rate adaptation techniques that are currently used in conventional networks. Furthermore, intelligent dropping and encapsulation could be employed at gateway nodes of heterogeneous networks to support the different MTU rates and bandwidths as required by connecting networks.

The limitation of the proposed design is the resource usage and additional processing load at satellite nodes. Dropping algorithm must be kept simple to minimise resource requirements, as storage and power are limited and expensive onboard satellites. To minimise the additional load and latency introduced at intermediate nodes by intelligent dropping, the service should only be activated on demand. When link congestion and quality is not an issue, intelligent dropping should be deactivated to allow satellite nodes to perform normal forwarding functions without any degradation in service.

5. References

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