The Rain Attenuation on Real-Time Video Streaming via Satellite Links

Ting Ma, Yee Hui Lee, Maode Ma, and Stefan Winkler

***Abstract*—Nowadays the application of multimedia networks is rapidly growing due to the high demand for the real-time video transmission. The live video streaming via satellite is an ideal solution for people who want to share an event with others who cannot be there in person. However, the video transmission via satellite links is heavily affected by attenuation due to rain. This is especially so in the tropical region where the rainfall rate can be as high as 120mm/hr. In this paper, we will discuss the real-time video transmission via satellite links and analyze the rainfall attenuation on the quality of video.**

***Index Terms*—Rain attenuation, satellite link, video quality, video streaming.**

I. Introduction

With the widespread multimedia services, such as video-on-demand, e-learning and video conference, live video broadcasting is becoming popular all over the world. Due to the broadcasting characteristics and the high speed transmission rate, satellite links allow one to access live video coverage anytime and anywhere. The video streaming via satellite is widely used in broadcasting and remote communication.

Because of the limited resources, variability of channel conditions and high user demand, to provide user with a high quality of service (QoS) is a challenging issue in modern satellite networks. The variability of signal fade in satellite links is mainly due to atmospheric attenuations especially at frequencies above 10GHz. These atmospheric attenuations become severe at higher frequency bands in the Ku (12/14GHz) and Ka (20/30GHz) bands [1]. Consequently, the atmospheric attenuation results in rain fade causing random or burst errors for digital satellite broadcast systems. Although there are some publications of rain fade on the satellite transmission links, the direct rainfall attenuation toward video quality and exact level of influence is scarce. In order to study the effects of rain attenuation on satellite links, real-time video streaming experiments via an internet satellite link is performed in order to obtain the relationship between the rainfall rate and the video quality.

Our video transmission experiment is via the WINDS (Wideband Inter-Networking engineering test and Demonstration Satellite, also known as KIZUNA) which was launched in 2008 by the Japan Aerospace Exploration Agency (JAXA) [2]. The WINDS is capable of providing ultra-high speed internet connection anytime, anywhere. Since WINDS works in the high frequency spectrum within the Ka-band, it suffers from significant propagation loss due to atmospheric attenuation such as rainfall attenuation and cloud attenuation [3]. In order to provide high-quality real-time video that is pleasant to view, the video quality should be evaluated in a subjective way and the factors that lead to packet loss and signal attenuation should be analyzed.

Concerning the quality of experience (QoE) of a video streaming service, there are different factors existing in the process of video streaming procedure [4]. One of the biggest challenges that seriously affect the video streaming service, especially the wireless LAN, is packet loss. The video quality to the viewer can be severely impaired, meaning, the QoE of the video service can be degraded due to packet losses. In this paper, we will measure the packet loss during video streaming and the received video quality. The relationship of packet loss and video quality will be provided in our video analysis section. The rainfall rate during the corresponding experimental days will be measured. The analysis provided is based on the packet loss in the video streaming procedure via WINDS and the recorded point rainfall rate.

The organization of this paper is as follows. Section 2 is primarily aiming at introducing the video streaming system. Section 3 will focus mainly on real-time video streaming. In Section 4, the relationship between video quality and rain attenuation is analyzed. Finally, a conclusion with a summary is provided in Section 5.

II. Video Transmission System

Our video streaming system basically is composed of video server, Ultra-Small-Aperture-Terminal (USAT) and video receiver as shown in Fig.1. The USAT with two reflectors is an earth station developed for installation in homes and disaster areas. A significant characteristic of the USAT is seen in its ability to provide high-speed communication at a downlink rate of 155Mbps using an ultra-small reflector antenna with a diameter of 45cm. The Indoor Unit (IDU) in our system provides Stradivarius (TDMA) synchronization, communication data modulation and demodulation. In the transmit mode, IDU implements code modulation for the data on ETHANET I/F from the user command and outputs it to the Outdoor Unit (ODU) which is responsible of converting the IF signals to RF signal band and vice versa. Generally, the server first connects to the satellite channel by obtaining its identification via his ID.

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Then the media data can be accessed via satellite channel by its receiver terminals. According to the WINDS platform, we can stream video by either unicast-only or multicast transmission mode.

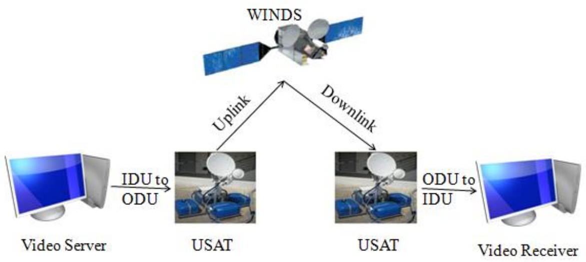

Fig. 1. The architecture of video transmission via winds.

III. Video Transmission Experiment

A. The Video Clips Generation

In view of limited bandwidth resources and the requirement for high-definition TV transmission, uncompressed raw videos in YUV format which generates high traffic volumes poses a problem. Therefore, there is a need to reduce the bandwidth requirements of the transmitted video over bandwidth-constrained access networks. Encoding is an efficient way to economize on transmission cost. The video codec is the key element that allows for a more compact visual information demonstration using the spatial and temporal correlations of the frame sequence. Consequently, high compression efficiency and low complexity is required in terms of limited bandwidth and transmission environment. In our case, H.264/AVC video compression codec, which achieves better compression efficiency of raw videos compared to MPEG-2, is adopted to provide good video quality at lower bit rates [5]. The information of pre-generated video file using H.264/AVC is illustrated in Table I.

In our implementations, a sequence of raw video is transformed into a series of bit being delivered as depicted in Fig. 2. In the first step, the raw format video will be encoded by the H.264/AVC codec. After that, the compressed video shall be undergone the procedure of packetization to ease the analysis of video quality and packet loss. Thus in this stage, the elementary stream shall be divided into packets by encapsulating sequential data bytes from the elementary stream inside packet headers. These elementary streams are then multiplexed into the transport stream (TS) [6]. The TS is designed for application in unreliable environment where a specific container format encapsulating packetized elementary streams is used. Furthermore, the TS uses a fixed length packet size and a packet identifier to identify each transport packet within the transport stream.

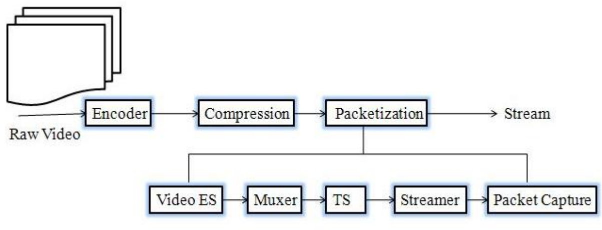

Fig. 2. The diagram for video clip implementation units.

TABLE I: The Video File Generated by H.264 Encoder.

Video File	
File Size	137MB
Video Format	Advanced Video Codec
CABAC	YES
Bit Rate Mode	Variable
Width	720 pixels
Height	480 pixels
Frame Rate	30.00 fps
Chroma Subsampling	4:2:0
Color Space	YUV

B. Video Transmission Experiment

We have conducted our real-time video streaming experiments via WINDS links for almost one year. The real-time video transmission experiment is conducted at Nanyang Technological University (NTU). The experiments of real-time video streaming at NTU were conducted twelve times (once a month) over the year from October 2009 to October 2010. Each experiment usually last for a period of 2 days.

In our video streaming platform, there are three computers. One computer running on windows XP operating system is to observe the status of our satellite link signal and device parameters. And the other two machines are streaming media server and client which are running on a regular Linux operating system. During our real-time video streaming experiment, we adopt tcpreplay [7] on the streaming computer to play back the pre-encoded H.264/AVC video over WINDS links [8]. While the other computer running tcpdump which is a tool for logging network traffic in the Pcap format performs capturing the video packets.

Generally before conducting video streaming, we would conduct a diagnostic Iperf [9] test where a signal is transmitted over the communication links and then returned to the sending device to test the satellite links and make sure the video streaming equipment is working properly. After that, a loopback mechanism of the video streaming is performed at the station. The media client machine uses the VLC player from Videolan [10] to decode and watch the captured video streams. At the same time, the media client machine is responsible for capturing the video sequence and writing them into trace file by tcpdump technique. The objective of our experiment is to transmit real-time video via WINDS links and to study the rain attenuation on the perceived video quality.

IV. Video Quality Analysis

To assess the video quality, the V-Factor using Moving Picture Quality Metrics (MPQM) [11] metric and the internet protocol packet loss (IPloss) are used to evaluate the quality of the video images and the number of internet packet loss during the streaming. The V-Factor metric, an objective measurement, is based on deep packet inspection of the video stream. It analyzes the bit stream in real time to collect static parameters such as picture size and frame rate as well as dynamic parameters such as the variation of quantization steps. In addition, the IPloss indicates the packet loss ratio before QoS recovery. So we mainly take into account the two metrics in our video streaming experiment. The analysis of video quality and rain attenuation is discussed as follows.

The measured rainfall rate, packet loss and V-Factor for 20th to 21st May 2010 are plotted in Fig.3. From this figure, it can be seen that there is no loss and good quality of video during the first 17 hours. On the 18th hour, there was a rain event, the packet loss increased and V-Factor dropped correspondingly. Note that IPloss is measured in percentage and V-Factor on a scale from 5 for best visual quality to 1 for worst visual quality for the human quality impression. As shown in Fig.3, the packet loss is around 2% and the V-Factor decreases to 1 when the rainfall rate is around 0.15 mm/min. This is a stratiform rain event with low rain rate but long duration. When the rainfall rate decreases to 0, the packet loss correspondingly decreases to zero while the V-Factor increases to 5. This shows that the satellite link is affected by rain events.

Fig. 4 illustrates the relationship among the measured rain rate, IPloss and V-Factor at the NTU experimental site for the experiment performed on the 15th September 2010. The similar phenomenon of experimental results could be seen. As illustrated in Fig. 4, the video quality was good when there is no rain during the initial period of the experiment time. However, when it began to rain with a relatively high rainfall rate of 1 mm/min and above, the packet loss ratio increased up toward nearly 100%, on the other side, the V-Factor value rapidly decreased to a minimum of 1 indicating very annoying human perceived visual quality. In other words, the quality of video goes down as indicating by the V-Factor values. Hence we can conclude that rain attenuation has a significant effect on the video quality.

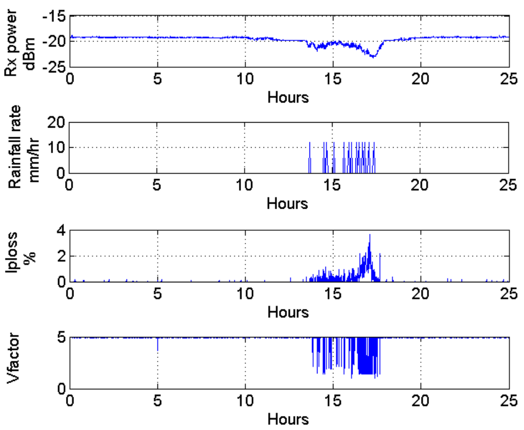

Fig. 3. The rain rate, IPloss and v-factor for 20th and 21st May 2010 at NTU.

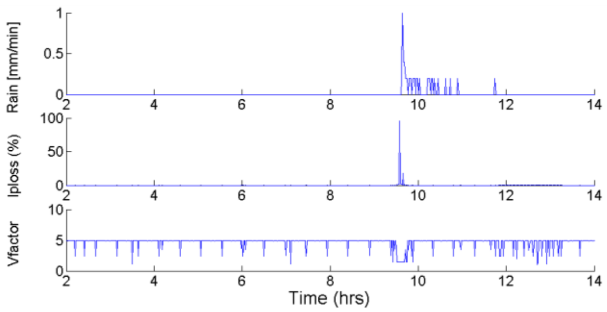

Fig. 4. The rain rate, IPloss and v-factor for 15th September 2010 at NTU.

Fig. 5 and Fig. 6 show the cumulative distribution function (CDF) of recorded six-month IPloss and rainfall rate respectively. The experiment results illustrate a good correlation between packet loss and rainfall rate. As seen in Fig. 5 and Fig. 6, the month of May has the highest rainfall rate and the month of June has the lowest rainfall rate among the six months. A similar trend is observed in Fig. 5 where the month with the highest IPloss, corresponds to the month with the highest rainfall rate, and the month with the lowest IPloss, corresponds to the month with the lowest rainfall rate. Therefore, the packet loss ratio is inversely proportional to the rainfall rate.

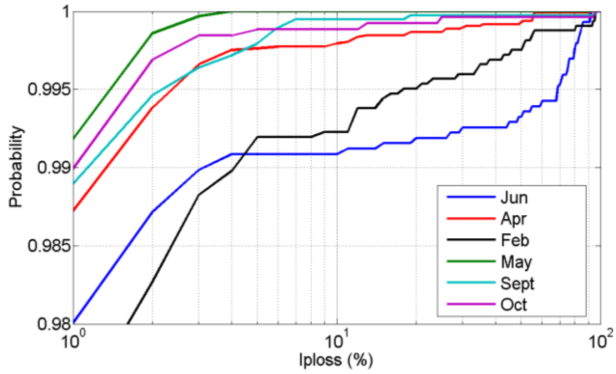

Fig. 5. The CDF of IPloss of six month data.

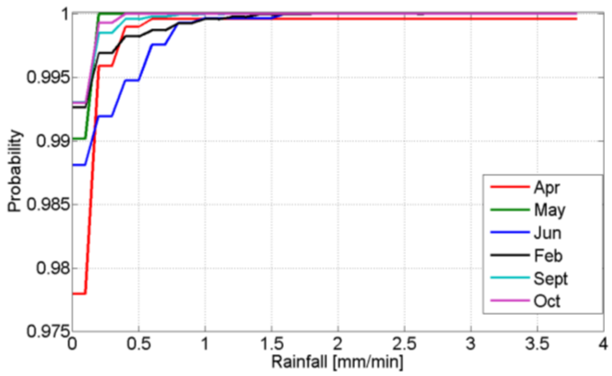

Fig. 6. The CDF of rainfall rate of six month data.

In order to better demonstrate the relationship between IPloss and V-Factor, we compile all the experimental data together to gain a statistical view. The V-Factor values ranging from 1 to 5 are partitioned into 8 segments and each segment step size of 0.5. As shown in Fig. 7, the average IP packet loss rate corresponding to each segment of V-Factor range can be obtained. It can be concluded that high definition TV transmission has a low tolerance to packet loss. As seen in Fig. 7, an IP packet loss rate of nearly 7.5% will lead V-Factor to the lowest value of 1, which indicates the video quality is not acceptable for the viewing. For the video with pleasant viewing quality, the least V-Factor required is 4, which means that the IP packet loss rate of 0.47% or less is required. If slightly annoying of video quality is acceptable by the applications, then V-Factor of 3 is the minimum and 0.485% IP packet loss rate should be maintained to guarantee the video quality.

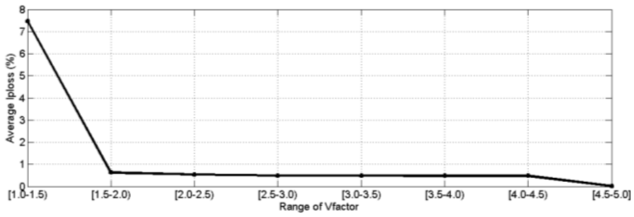

Fig. 7. The relationship between the average IPloss and v-factor.

V. Conclusion

This paper is about real-time video streaming via satellite links which using H264/AVC as video compression coding standards. Studies have been done to go into video transmission. We have provided a detailed description of video streaming and its quality analysis. Several important conclusions could be summarized as follows.

First of all, the weather condition plays a significant role in video streaming via satellite channel. From measured statistics, the increase of rainfall rate directly leads to decrease of perceived video quality and increase packet loss. A rainfall rate of 1mm/min can result in a 100% packet loss. In addition, the video quality, which is measured by V-Factor, is directly connected to the IPloss. It was found that an IPloss of less than 1.5% will result in the minimum video quality. For the video quality to be acceptable for viewing purposes, an IPloss of almost 0% (0.12%) is required.

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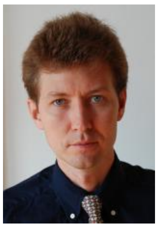

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