High-speed Satellite ATM Experimentations and Demonstrations using Ka-band Koreasat-3

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Abstract: In this paper, we present the experimentation and demonstration results of Korea-Japan high-speed satellite ATM network using Ka-band Koreasat-3. This experimentation consists of two items – TCP/IP and MPEG-2 video/audio transmission over 155Mbps ATM based satellite network. The goals of this experimentation are to measure TCP performance when the only standard mechanisms approved by IETF in order to improve TCP performance in LFN(long fat network) are used and to derive the effects of quality for the high definition video stream when MPEG-2 TS is transmitted through 155Mbps satellite ATM link. With on the results of the experiments, we demonstrated the applications suitable to the high-speed satellite ATM network. The first TCP/IP and MPEG-2 transmission experiments were done at the rate of 155Mbps using Ka-band KOREASAT-3 between Korea and Japan, and its results will be demonstrated with the ATM-based 3D-HDV(3 dimensional High definition video) and HDTV during 2002 Korea-Japan World Cup Soccer Game.

1. Introduction

To promote the technological development in the high-speed satellite communication area, Korea and Japan has performed the joint satellite communication experimentation since 2000 year. The first phase experiment of the Joint Korea-Japan HDR satellite communication was successfully completed by ETRI and CRL in Dec 2000. In the first phase experiments, HDTV transmission and IP over ATM was done using DS-3 satellite. In this paper, we describe the second phase of the joint experiments and its results, For the second phase experiments, we established bidirection OC-3 ATM link between Korean and Japan using Ka-band transponder of KOREASAT-3. Mainly we have done TCP performance measurement and MPEG-2 video/audio (3D HDTV) transmission over 155Mbps ATM based satellite network in the second phase experiments.

TCP is the most commonly used transport protocol in the Internet. But TCP was initially developed under the assumption that TCP would be used on terrestrial network – local Ethernet or FDDI. But modern high-speed networks include various physical media and link-layer protocols. GEO satellite network has some dominant characteristics – long round trip time (the typical long fat network: LFN), channel errors, etc. Lots of mechanisms and algorithms have been proposed to improve the TCP in satellite network. They are introduced well in RFC 2760. But many ideas of them focus on improving the TCP performance under satellite network only and can be used in private network including satellite link. RFC 2488 discusses the standard TCP mechanisms to improve the performance of TCP over satellite channels. Of them, TCP window scale option defined by RFC 1323 extends TCP window size to about 1GB. The use of large TCP windows in long delay network improves the throughput up to about 90% of theoretically maximum. But the large TCP window generates the burst traffic in short time. Especially in the case of the heterogeneous network that is composed of different physical media and different link-layer control protocols, there are serious packet losses in the intermediate router due to burst traffic. As a result the TCP throughput of the connection could be degraded and also the overall network could fall into serious congestion state. To avoid this situation, we tried shaping the burst traffic at TCP source. In the study, we present the several experiments and its results of TCP transmission over the OC-3 geo-stationary satellite network

3D-HDTV transmission system was developed by ETRI to provide more realistic video program. But it needs more bandwidth for good quality than general HD program. In the second phase the ATM-based 3D-HDTV transmission via OC-3 satellite link of Ka-band Koreasat-3 was done.

2. Network Configuration

Figure 1 shows the configurations of Korea-Japan high-speed satellite ATM network using Ka-band transponder of Koreasat-3. In this joint experimentation, the two ground stations with 7m antenna in ETRI located at Daejeon in Korea and 5m antenna in CRL located Kitakysushu in Japan were installed respectively. The main specifications of the Korea-Japan 155Mbps satellite ATM link are as follows;

- Satellite: Koreasat-3
- Frequency band: Uplink: 27.5 ~ 31 GHz, Downlink 17.7 ~ 21.2 GHz
- Max. TWTA power : 125 W
- Normal EIRP(Koreasat-3): 71 dBW
- G/T(45 EL): 32 dB/K(min)
- TC-8PSK modulation/demodulation
- Coding: K=7, 7/8 Convolutional RS code
- Information Bit rate : 155.52Mbps
- Allocated Bandwidth: two 80 MHz channels

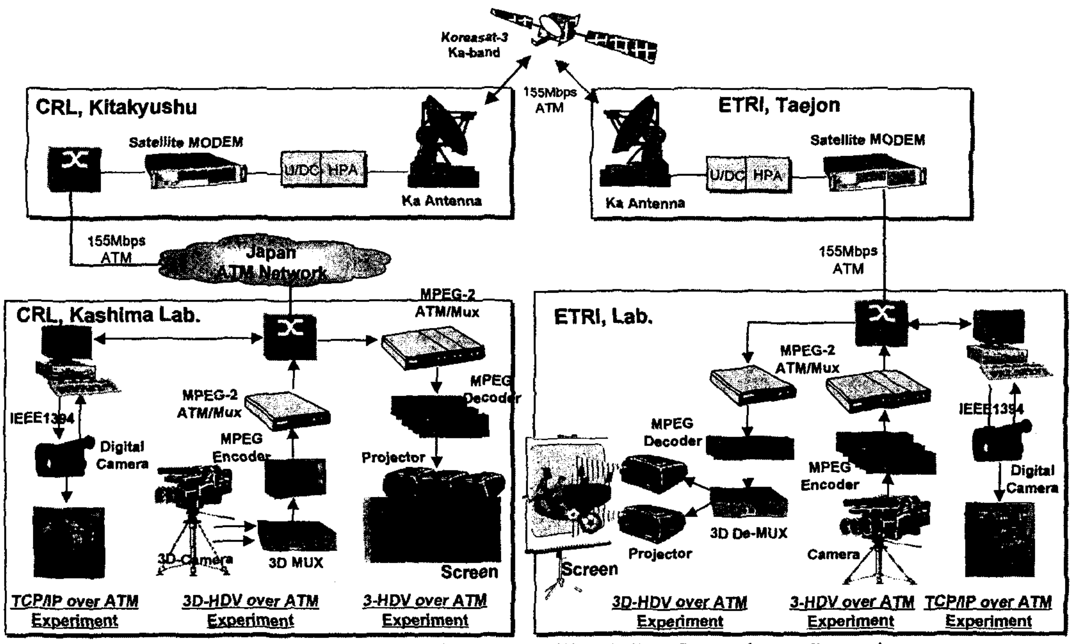

Figure 1 Korea-Japan 155Mbps Satellite ATM Network configuration

3. TCP/IP Transmission over 155Mbps ATM based satellite

Network configurations for TCP over satellite using IPv6/IPv4 tunnelling on ATM is shown in Figure 2.

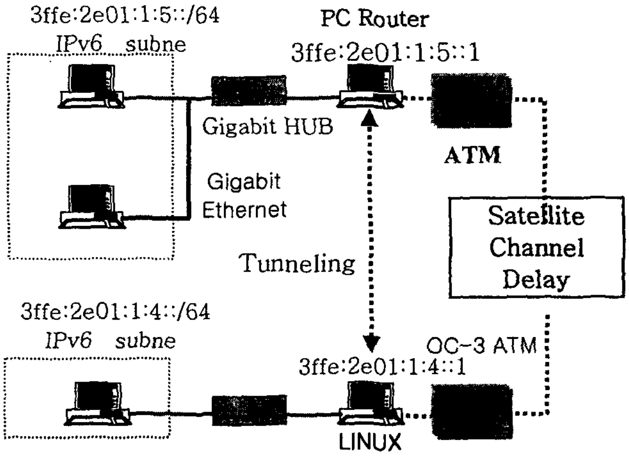

Figure2 Network configurations for TCP over satellite using IPv6/IPv4 tunnelling on ATM

The whole network could be divided into two networks – gigabit subnet and OC-3 ATM backbone network. PC based router that has both gigabit and ATM network interface interconnects two networks. And we configured the experimental network in IPv4 and IPv6 address for several purposes. – Establishment of experimental IPv6 network, measure TCP performance in long delay and multicast network in IPv6, etc.

First we measured the TCP throughput in pure ATM network with 540msec GEO satellite round trip delay. We used IPv6 tunnelling because IPv6 in IP over ATM was not completely implemented yet. The MTU(Maximum Transfer Unit) size in IP over ATM is usually 9180 bytes. Therefore the MTU size in IPv6/IPv4 tunnelling interface is 9160 bytes because IPv4 header size is 20 bytes. Therefore the MSS (Maximum Segment Size) is maximum 9100 bytes (The sizes of IPv6 header and TCP header are 40 and 20 bytes respectively). However when TCP scale option is used to enlarge TCP window size in ATM based satellite network, the MSS is reduced by the TCP option bytes. When IP packets are encapsulated into AAL5, we can calculate the maximum theoretical bandwidth. The number of bytes of padding necessary is

$$PAD = 48 - ((8 + 20 + 40 + 20 + 9100 + 8)\%48) = 28$$

Then the PDU utilization is

$$\eta = \frac{9100}{(8 + 20 + 40 + 20 + 9100 + 28 + 8)} = \frac{9100}{9224} = 0.986$$

The pure cell rate of STM-1 is about 149Mbps and the bandwidth of 48 bytes payload in ATM cells is about 134.94 Mbps. Therefore the theoretical maximum bandwidth of TCP in OC-3 network is given by

$$BW_{TCP} = 134.94 \cdot \eta \cong 133.05 Mbps$$

Figure 3 shows the TCP throughput with various TCP socket (or window) size. When TCP socket size is 6Mbytes, we could get 113Mbps throughput in IPv4 and 106Mbps in IPv6 that are 95% of the throughputs without any satellite delay.

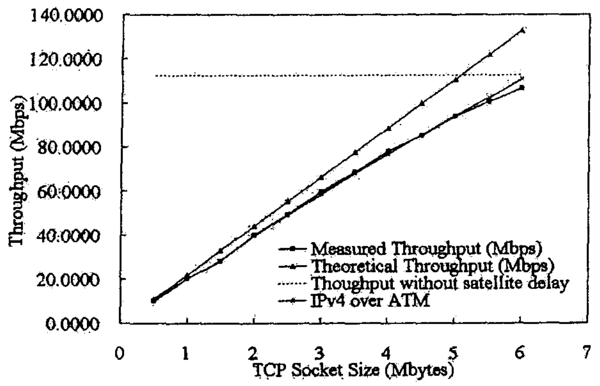

Figure 3 TCP throughput of ATM based satellite network with various TCP window size

Next we measured TCP throughput from the source on gigabit subnet to the destination located in another gigabit subnet. Two-gigabit subnets are interconnected by ATM based satellite network. Figure 4 shows the protocol stack.

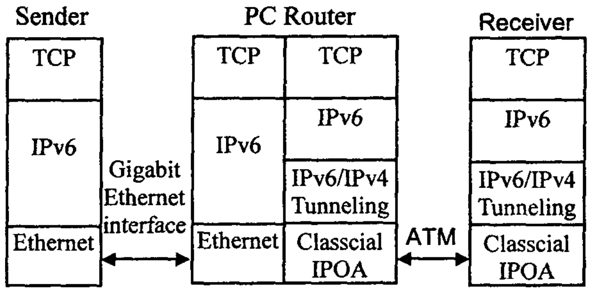

Figure 4 Protocol stack of heterogeneous network with long delay

When the TCP socket size was set to about 6 Mbytes in 540 msec delay network, the maximum throughput was only about 2~3 Mbps. This is due to the burstiness of the TCP traffic due to the large TCP window size. When the TCP window size is increased to utilize full bandwidth of long fat network, the TCP traffic is in the form of burst because the physical interface of the sender is gigabit Ethernet interface that is faster than the speed of ATM backbone. To prevent the packet losses in the intermediate router, the router should have large buffer. But the existing routers do not have enough buffers for large TCP window size. Therefore the packet loss of intermediate route degrades the TCP throughput.

Figure 5 show TCP sequence graph of TCP sender. In first 8 seconds, there was a TCP slow start. That is, after one round time delay, TCP source sends data two times. But as TCP window size was increased up to more than a limit, there were a lots of packet losses due to buffer overflow of the intermediate router. We know that there are many retransmissions due to packet losses and the TCP restart slow start behaviour after long time.(about 27 seconds later). This transmission pattern (loss and retransmit) repeats and the overall TCP throughput performance become poor. As a possible solution for burstiness in the TCP source, we used the traffic shaping technique. For the traffic shaping mechanism we used TBF(Token Bucket Filter) that is supported Linux advanced networking option. The TBF regulates the rate of TCP burst traffic. The basic parameters for TBF queuing discipline are composed of "rate", "bucket size" and "limit". "Rate" is the rate the bucket refills with tokens – which represents the average transmission rate of a traffic flow. The "bucket size" or "burst size" is the number of tokens the token bucket can store. The "limit" parameter is the sum of the bucket size and the size of the queue. It decides if the TBF shapes of policies.

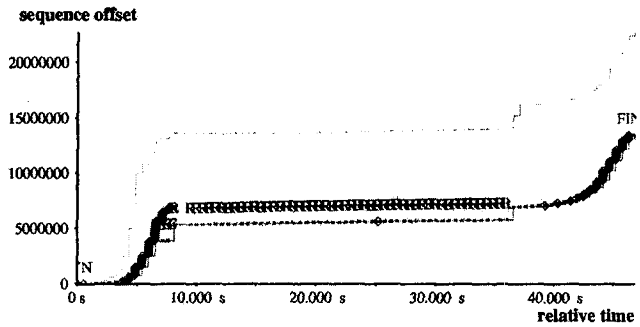

Figure 5 TCP Sequence Graph in the TCP traffic source

Figure 6 shows the TCP throughput with various TCP socket size when TBF was used in TCP sender with 6MB fixed TCP window size. For comparison, we show the graph when there is no satellite delay in the same configuration. Figure 7 shows the TCP throughput with various token bucket sizes. When the size of token bucket is 120KB ~ 130KB, we could get the best throughput. When above 130MB of bucket size, there were packet losses in the intermediate router due to the burstiness of the TCP traffic.

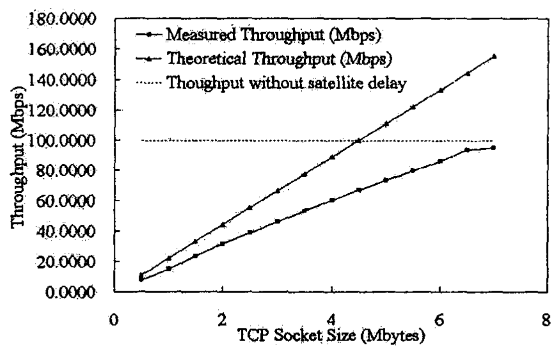

Figure 6 TCP throughputs with various TCP socket size when TBF was used in TCP sender

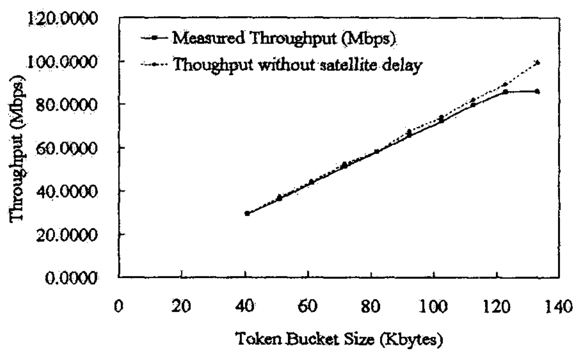

Figure 7 TCP throughputs with various token bucket sizes

4. 3D-HDV Demonstration via Satellite

3D-HDTV transmission system was developed by ETRI to provide more realistic video program. But it needs more bandwidth for good quality than general HD program. In the second phase the 3D-HDTV transmission via OC-3 satellite link was done. It multiplexes two HD streams from left and right HD camera into one HD stream. After multiplexed video stream is transmitted via existing digital video transmission system (HD Encoder/Decoder and ATM Adaptor,), it is de-multiplexed into two HD stream. Two HD stream are project onto large screen simultaneously. For MPEG-2 over ATM-based Satellite experiment, we will use 3D-HDV contents to measure the following items;

- ATM cell performance for MPEG-2 video traffic
- MPEG-2 video quality according to compression ratio or transmission speed in Satellite ATM link

The main issue at mapping the MPEG transport stream to ATM network is to protect the defect of ATM bearer service such as cell lost, cell error, miss-insertion and delay variation. For transmitting MPEG-2 transport stream to ATM network, we can consider two methods such as the method of utilizing the existing ATM adaptation layer(AAL) and define the special AAL for transmitting the MPEG transport stream. The existing AAL utilization method is able to consider to use AAL-1 or AAL-5. But in case of AAL-1 it can not provide the extra space for error protection, and provide the variable rate. In case of AAL-5, even though it can directly mapping MPEG packet to ATM cell, there is no reliable method to protect the cell lost. Basically MPEG-2 TS is segmented to ATM cells using AAL-5 as shown Figure 7.

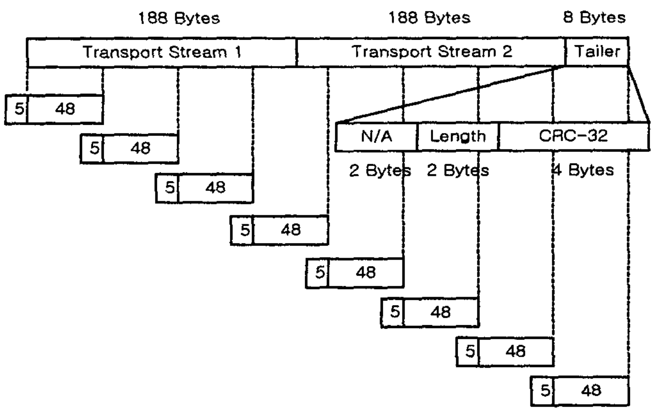

Figure 7 AAL-5 mapping of MPEG TS

Figure 8 shows the Satellite ATM-based 3D-HDV transmission facilities such as 155Mbps satellite MODEM, MPEG-2 Player, ATM Switch, 3D-camera, 3D display, etc. CRL side in Japan transmitted the ATM-based MPEG-2 TS to ETRI side in Korea using 155Mbps Ka-band satellite link. Basically MPEG-2 TS is segmented to ATM cells using AAL-5. The received ATM-based MPEG-2 TS measured and analyzed its quality by real-time MPEG Analyzer, MTS-300. This 3D-HDV demonstration was performed during 2002 Korea-Japan World Cup Soccer game.

Figure 8 Satellite ATM-based 3D-HDTV transmission facilities

5. Conclusions

In the second phase of the Joint Korea-Japan HDR satellite communication experiment, we have done the transmission of TCP and MPEG-2 video/audio over Ka-band 155Mbps satellite link. In TCP experiment, we measured TCP throughput and analysed the TCP internal behaviours in the high-speed long delay network. For the maximum TCP throughput of 155Mbps satellite network, about 6MB TCP socket size is needed. And when TCP source is on another network media that is faster than ATM based satellite backbone, the mechanisms for burst traffic due to large TCP window are need. To prevent packet losses due to the burst TCP traffic, we used token bucket filter that is supported Linux. With the TBF we could get the throughput of about 95Mbps that is 95% of the throughput without satellite delay. 3D HDTV transmission was done. The ATM-based 3D-HDTV via Ka-band Koreasat-3 was demonstrated at several demonstration rooms in Korea during 2002 Korea-Japan World Cup Soccer Game. The obtained results by this 155Mbps satellite ATM experiment will be utilized to the recommendations or specifications for providing the optimized TCP services and high quality video services over the high-speed satellite ATM network in the future.

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