Study of Minimum Video Quality Guarantee of High Definition-Level Video in IPTV Multicasting Service

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Abstract

Objectives: To analyze the major factors affecting the quality of video on the multicasting service of HD (High Definition)-level video on Internet Protocol Television (IPTV). Methods/Statistical Analysis: We construct a lab test network environment similar to the real IPTV service network environment and measure the quality of video on the multicasting of HD-level video in IPTV, generating and increasing broadcast traffic in a situation that either applies the Quality of Service (QoS) technique to the network or does not apply the QoS technique. Findings: We discover the threshold value of factors allowing a minimum video quality guarantee on an HD-level multicasting service in IPTV. In order to produce a quality of received images similar to that of the original images and without distortion, the V-Factor value should be 4.6 or higher. When the V Factor value is 4.3, a viewer does not recognize errors in the video, although partial distortion can be displayed. Below a 4.3 V Factor, distortion can be recognized by a viewer, which makes watching IPTV uncomfortable, and with a V Factor below 4.0, IPTV watching is difficult. Application/Improvements: This paper can be used as basic data to guaranteeing this minimum video quality for an HD-level multicasting service in IPTV.

Keywords: CoS, HD-Level Video, IPTV, QoE, QoS, V-Factor

1. Introduction

1.1 Block Diagram of IPTV System

The block diagram of an IPTV system shown in Figure 1 consists of 4-parts: the Operational Support System (OSS), the head end, a network, and home. A head end is composed of a broadcast server that supports IP multicasting for real time broadcasting, a video server supporting IP unicast for Video-On-Demand (VOD) services, an application server that supports applications as a web server type, and a mail server.

The bandwidth required to transmit a single Standard Definition (SD) channel is 1–4 Mbps. To independently...
transmit SD picture quality to one million viewers simultaneously would require 1–4 Tbps bandwidth. This requirement cannot realistically be met. In order to overcome the bandwidth requirement, a server sends a single channel through several paths; it is then received by intermediate transmission devices (routers and switches) that retransmit the channel to surrounding transmission devices until the channel is received by a viewer. In the above situation, the retransmitted channel is sent only to a specific viewer as opposed to simply retransmitting the channel to everyone. This technique is called multicasting1,2.

1.2 Evaluation Method of Video Quality in IPTV

1.2.1 Definition of Quality of Experience

Quality of Experience (QoE) refers to the service quality experienced by an end user. QoE in IPTV means a degree of image quality experienced by a viewer who watches the IPTV. Methods of evaluation of IPTV images can include objective and subjective evaluation of picture quality. To make an objective evaluation of picture quality is to perform an evaluation numerically by substituting received images into a system that models human vision. Subjective evaluation of picture quality involves showing received images to many people and calculating a mean value of their evaluations3,4.

1.2.2 Objective Evaluation Method of Picture Quality

1.2.2.1 Full Reference (FR)

This method measures the quality of received images by directly comparing two images when both the original and processed images are available. Its application areas include codec performance evaluation and digital broadcasting and multimedia equipment performance evaluation. PSNR and VMOS can be measured by the FR shown in Figures 2 and 3, measuring method.

1.2.2.2 Reduced Reference (RR)

This method of measuring the quality of received processed images uses features extracted from original and processed images even when both of them are not available shown in Figure 4.

1.2.2.3 No Reference (NR)

This is a method in which no information about the original image is employed. That is, NR is a method to measure the quality of images by using processed images only, and it has wide application. On the other hand, since no information about the original video is available, it is very difficult to measure image quality accurately using NR. However, for encoded images using a block based image compression method such as MPEG, quality can be evaluated using NR by means of blocking artifacts where the block boundary is displayed at a low bit rate. For example, the VFactor5,6 of QoS metric is a typical NR method shown in Figure 5.

![Figure 2. Multicasting technique.](image1)

![Figure 3. Block diagram (FR).](image2)

![Figure 4. Block diagram (RR).](image3)

![Figure 5. Block diagram (NR).](image4)
1.2.3 Current Trend of Standardization of Objective Picture Quality Evaluation Technology

Currently, standardization has occurred based on ITU-R WP 6Q, ITU-T SG9 and VQEG (Video Quality Expert Group) to develop objective picture quality evaluation technologies. Based on the VQEG Phase II Test, standardization of ITU_R and ITU-T FRTV was completed in 2003. In VQEG, the objective picture quality evaluation technology has been defined in ITU-T Rec. J.144, ITU-R BT.1683 based on FR criteria. In VQEG MM, standardization of the FR, RR and NR models of objective image quality measurement has been underway. Also currently underway is RRTV and NRTV standardization with regard to three stages: video only, audio only, and audio-video and multimedia standardization for quality evaluation over a wireless communication and network.

1.2.4 Subjective Picture Quality Evaluation Method

The subjective picture quality evaluation method uses viewers who watch the video to evaluate picture quality. This is regarded as the most suitable method of reflecting humans’ perception capabilities with respect to picture quality. Subjective picture quality evaluation is used in a wide range of ways depending on the method and objectives. The multimedia picture quality evaluation models made by the VQEG and the ITU are the DSCQS (Double-Sequence-Continuous-Quality-Scale), the SSCQE (Single-Stimulus-Continuous-Quality-Evaluation) and the ACR (Absolute-Category-Rating method).

1.2.5 VFactor

The image quality evaluation method used in the IPTV multicasting experiment in this paper was the VFactor of the No Reference (NR) method proposed by QoSmetrics. The VFactor, corresponding to the video MOS value, is measured based on the MPQM (Moving Picture Quality Metrics) and the international standardization of the NR method for picture quality evaluation at IPTV is currently underway. The advantage of the NR is that it measures real-time image quality.

1.2.5.1 Measurement Model(VFactor)

The measurement of the VFactor can be done using the model shown in Figure 6. The general equation of $V_{\text{factor}} = Q_{\text{fr}}(q_s^2) \times (1 - e^{-q_s})$

2. Construction of IPTV Image Quality Measurement Test Environment

2.1 Characteristics of Test Image Data

For test data, we choose a dance scene of Singer Ivy, because it had the most severe changes in HD images broadcast by ground wave by the SBS (Seoul Broadcasting System); this scene was also recorded with the transport stream, which had the characteristics shown in Table 1. The multicast stream broadcast output used the MPEG2 TS-based UDP protocol.
### Table 1. Specification of the test image data

| Item                        | Standard                  |
|-----------------------------|---------------------------|
| Video name                  | IVY.trp                   |
| Video content               | Dance scene of Singer Ivy |
| Stream protocol output      | UDP                       |
| File Format                 | MPEG2 Transport           |
| Bit-Rate                    | 19.0 Mbps                 |
| File Resolution             | 1920 × 1080 i             |
| Bit-Rate Mode               | CBR                       |
| Frame-Rate                  | 29.97 fps                 |
| Image Compression Codec     | MPEG2 Video               |
| Voice Compression Codec     | AC3 × 2channel            |
| Image Compression Bit Rate  | 17.0 Mbps                 |
| Voice Compression Bit Rate  | 384.0 Kbps                |

### Table 2. Measured Items of Experiment

| Measured Item                | Meaning                                                                 |
|------------------------------|-------------------------------------------------------------------------|
| V-Factor                     | Measured value of received video quality                               |
| Measured factors of network performance | Probability value of transmitted frame loss                          |
| Network Loss                 | Number of received frames' arrival order errors                        |
| Out of Sequence              | Number of discarded frames due to jitter                               |
| Jitter Discards              | Synchronized stream's jitter (µs)                                     |
| Loss Episode Length          | Maximum number of lost frames during specific measured period          |
| Loss Episodes                | Cumulative frame number at specific measured period from first measured point |

Measured factor of video content performance | Program Rate (Kbps) | Stream transmission speed per second of video |
|---------------------------------------------|---------------------|-----------------------------------------------|
| Quantizer                                   | Measured video of quantization level number                            |
| Compression Ratio                           | Sum of I+P+B frame during measured period                              |
| I-Frames                                    | I-frame number during measured period                                  |
| B-Frames                                    | B-frame number during measured period                                  |
| P-Frames                                    | P-frame number during measured period                                  |

2.2 Test Measurement Items

The measured elements to be obtained through the multicast stream transmission of the test video data over the test network implemented in this study were mainly VFactor and related network performance measurement items as well as content-related measurement items according to the inner information of the video data. Table 2 summarizes the measured items and their definitions.

2.3 Construction of Test Environment

To construct a test environment, two Cisco-2,800 routers and two 2,950 switches were used in the test room. All ports were connected via fast Ethernet 100 Mbps. A network load generator (Smart Bit 6000 C) and a multicast broadcasting streaming server, which were part of the backbone core network domain, were connected to the same switch, and two routers were directly connected to the 100 M bps fast Ethernet port. A switch that played a role in the subscriber’s connection network measured the VFactor through the set-top box, through a multicast broadcast reception client system, Net warrior, stream broadcasting traffic measuring equipment, and through Net Advisor, a multicast stream broadcasting analyzer as shown in Figures 8, 9. A routing protocol between routers was set to the OSPF mode, and a multicast routing protocol was set to the PIM dense mode. For the multicast join, IGMPv3 was set, and the IGMP snooping protocol was activated in the switch.

![Image](image-url)
2.3.1 **Main Measuring Equipment Specifications**

The specifications and details of the main measuring equipment used in the test were as follows Table 3.

| Name               | Function                                                                 | Picture |
|--------------------|---------------------------------------------------------------------------|---------|
| NetAdvisor         | Symmetricom company’s QoSmetrics measure equipment used for V-factor. Management / Configuration / Reporting (Real-time QoS and data analysis) SOAP/XML interface for third party OSS | ![NetAdvisor](image) |
| NetWarrior         | Measuring equipment for the received part that investigates hardware traffic based IPv4 or IPv6 and reports the data to the NetAdvisor | ![NetWarrior](image) |
| OptiView Pro integrated network analyzer | Generates network traffic and captures and analyzes the traffic data on the LAN/WAN | ![OptiView Pro](image) |

2.3.2 **Test Scenario**

By changing the network utilization in the 100 Mbps bandwidth during a multicast streaming broadcast, a traffic load was created to have various distributions of VFactor values. Since a variance in video image quality reacts sensitively as the allowable bandwidth of network utilization approaches the streaming broadcasting bandwidth, the sensitive area was divided more densely to generate a traffic load. The order of traffic load generation in the test is shown in Table 4. A shard area refers to a traffic-generated region in which a sensitively reacting area is divided more densely.

As shown in Table 4, we performed picture quality measurements of the received images according to traffic loads under two conditions: first, when the QoS between switches and routers over the test network was guaranteed, and second, when no QoS was applied over the test network.

| Measuring order | Max bandwidth (Mbps) | Total-bit-rate (fps) | Total-frame-rate (fps) | Allowable bandwidth |
|-----------------|----------------------|----------------------|------------------------|---------------------|
| No.1            | 100.0                | 0.00                 | 0                      | 100.00              |
| No.2            | 100.0                | 78.931               | 6561                   | 21.071              |
| No.3            | 100.0                | 79.923               | 6643                   | 20.084              |
| No.4            | 100.0                | 80.414               | 6681                   | 19.595              |
| No.5            | 100.0                | 80.425               | 6683                   | 19.587              |
| No.6            | 100.0                | 80.453               | 6684                   | 19.558              |
| No.7            | 100.0                | 80.478               | 6687                   | 19.533              |
| No.8            | 100.0                | 80.497               | 6691                   | 19.514              |
| No.9            | 100.0                | 80.529               | 6692                   | 19.481              |
| No.10           | 100.0                | 80.534               | 6693                   | 19.474              |
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| No.  | Data Rate (kbps) | Program Rate (kbps) | Quntizer | CoS |
|------|-----------------|---------------------|----------|-----|
| No.11| 100.0           | 80.555              | 6694     | 19.455 |
| No.12| 100.0           | 80.587              | 6698     | 19.426 |
| No.13| 100.0           | 80.601              | 6699     | 19.402 |
| No.14| 100.0           | 80.635              | 6700     | 19.373 |
| No.15| 100.0           | 80.647              | 6701     | 19.365 |
| No.16| 100.0           | 80.668              | 6703     | 19.346 |
| No.17| 100.0           | 80.699              | 6705     | 19.313 |
| No.18| 100.0           | 80.711              | 6707     | 19.291 |
| No.19| 100.0           | 80.735              | 6709     | 19.276 |
| No.20| 100.0           | 80.759              | 6710     | 19.254 |
| No.21| 100.0           | 80.770              | 6712     | 19.236 |
| No.22| 100.0           | 80.792              | 6714     | 19.217 |
| No.23| 100.0           | 80.828              | 6716     | 19.188 |
| No.24| 100.0           | 80.841              | 6718     | 19.169 |
| No.25| 100.0           | 80.867              | 6721     | 19.144 |
| No.26| 100.0           | 80.883              | 6723     | 19.123 |
| No.27| 100.0           | 80.904              | 6725     | 19.101 |
| No.28| 100.0           | 80.935              | 6727     | 19.075 |
| No.29| 100.0           | 80.954              | 6729     | 19.056 |
| No.30| 100.0           | 80.991              | 6730     | 19.017 |
| No.31| 100.0           | 81.104              | 6741     | 18.901 |
| No.32| 100.0           | 81.202              | 6745     | 18.803 |
| No.33| 100.0           | 81.301              | 6756     | 18.705 |
| No.34| 100.0           | 81.415              | 6765     | 18.592 |
| No.35| 100.0           | 81.896              | 6807     | 18.114 |
| No.36| 100.0           | 82.388              | 6846     | 17.625 |
| No.37| 100.0           | 82.892              | 6887     | 17.116 |

In the test, complex traffic occurring at the network edge using QoS technology was classified and QoS was applied to all sub-modules of the combined adjustable network models, thereby applying class of service (CoS) at the user priority 802.1p that supports ISL 802.1q as a two-layer frame, as shown in Figure 10.

![Figure 10. CoS at 802.1 p.](image)

The meaning of priority in the CoS field value is shown in Figure 11.

![Figure 11. Meaning of priority the CoS field value.](image)

3. Test Results

The test video data of Ivy’s dance scene was multicast streamed for two min and was measured using Net warrior at the receiving end.

3.1 Image Content-Related Measured Items

Figure 12 shows the basic characteristics of the test image data. The left side of the y-axis is a complexity level that represents a quantizer of the image data, and the right side of the y-axis shows the program rate of the image data. The x-axis refers to the measuring order of sampling every 10 sec at the receiving end, as the sending end transmits video data for two min. According to the complexity of the image data, the program rate showed a nearly similar pattern to that shown in the Figure 12.

![Figure 12. Characteristics of the test video data.](image)

3.2 Network-related Measured Items

Figure 13 shows the ratio of the I, B and P-frames in the test data transmitted for two min.

![Figure 13. Characteristics of the frame composition in the test video data.](image)
Figure 14 shows the VFactor and loss episode length and the loss episode relationship when QoS was not set in the test network, that is, CoS=0 and a load were applied via broadcasting, as shown in Table 4.

**Figure 14.** Comparison of VFactor and loss frame according to traffic load (CoS=0).

Figure 15 shows the VFactor and network loss (probability value). Figure 16 shows the VFactor and out of sequence items. The network loss and out of sequence items are inversely proportional to the relative VFactor value.

**Figure 15.** Comparison of VFactor and network loss according to traffic load (CoS=0).

**Figure 16.** Comparison of VFactor and out of sequence items according to traffic load (CoS=0).

Figures 17 to 19 show test result values when CoS=1. Compared to cases when CoS=0, tiny differences in performance improvement can be seen, but the overall trend is similar.

**Figure 17.** Comparison of VFactor and loss frame according to traffic load (CoS=1).

**Figure 18.** VFactor and network loss according to traffic load (CoS=1).

**Figure 19.** Comparison of VFactor and out of sequence items according to traffic load (CoS=1).

Figures 20 to 22 show test result values when CoS=2. When CoS=2, even if the load was increased, it did not affect the received image quality and measured network characteristic items. Figures 23 to 25 show test result values when CoS=5. Compared to cases when CoS=2, differences in performance cannot be distinguished and are very similar. From Figure 26 on, the Figures show changes in the VFactor according to each CoS value with a load increase rate. CoS=2 and CoS=5 show the same performance, and CoS=0 and CoS=1 also have a similar performance. That is, when CoS=2 or higher, the same performance as CoS=5 can be obtained.

**Figure 20.** Comparison of VFactor and loss frame according to traffic load (CoS=2).

**Figure 21.** Comparison of VFactor and network loss according to traffic load (CoS=2).
Figure 22. Comparison of VFactor and out of sequence items according to traffic load (CoS=2).

Figure 23. Comparison of VFactor and loss frame according to traffic load (CoS=5).

Figure 24. Comparison of VFactor and network loss according to traffic load (CoS=5).

Figure 25. Comparison of VFactor and out of sequence items according to traffic load (CoS=5).

Figure 26. VFactor value as per CoS value according to traffic load.

VFactor ranges and thresholds of the measured network items for each grade are summarized as the picture quality of the received images through the test is classified into five grades: Excellent, Good, Average, Mediocre, and Bad shown in Table 5-10.

Table 5. Measured network item value; VFactor=4.723

| VFactor | Network loss | Out of sequence | PCR-Overall jitter (us) | Loss Episode length | Loss Episodes |
|---------|--------------|-----------------|------------------------|---------------------|--------------|
| 4.723   | 0.004058     | 18              | 4,560                  | 13                  | 8            |

Table 6. Measured network item value; VFactor=4.534

| VFactor | Network loss | Out of sequence | PCR-Overall jitter (us) | Loss Episode length | Loss Episodes |
|---------|--------------|-----------------|------------------------|---------------------|--------------|
| 4.534   | 0.002929     | 5               | 3,030                  | 15                  | 6            |

Table 7. Measured network item value; VFactor=4.264

| VFactor | Network loss | Out of sequence | PCR-Overall jitter (us) | Loss Episode length | Loss Episodes |
|---------|--------------|-----------------|------------------------|---------------------|--------------|
| 4.264   | 0.007966     | 5               | 5,454                  | 15                  | 10           |

Table 8. Measured network item value; VFactor=4.049

| VFactor | Network loss | Out of sequence | PCR-Overall jitter (us) | Loss Episode length | Loss Episodes |
|---------|--------------|-----------------|------------------------|---------------------|--------------|
| 4.049   | 0.009316     | 42              | 5,590                  | 14                  | 16           |

Table 9. Network measuring item value; VFactor=3.869

| VFactor | Network loss | Out of sequence | PCR-Overall jitter (us) | Loss Episode length | Loss Episodes |
|---------|--------------|-----------------|------------------------|---------------------|--------------|
| 3.869   | 0.012503     | 75              | 5,538                  | 14                  | 21           |
Table 10. VFactor for each grade and the thresholds of the measured network items

| VFactor range | VFactor mean | Network loss | Out of sequence | PCR-Overall jitter (us) | LossEpisode length | LossEpisodes | Picture quality grade |
|---------------|-------------|--------------|-----------------|------------------------|-------------------|-------------|----------------------|
| 5.00~4.60     | 4.71        | 1.64E-03     | 9.67            | 5,047                  | 6.50              | 4.02        | Excellent            |
| 4.59~4.30     | 4.47        | 5.76E-03     | 24.28           | 4,514                  | 12.52             | 9.99        | Good                 |
| 4.29~4.10     | 4.21        | 9.39E-03     | 37.29           | 4,578                  | 14.18             | 14.63       | Average              |
| 4.09~3.90     | 4.00        | 1.15E-02     | 43.83           | 4,555                  | 14.27             | 18.20       | Medium               |
| 3.89~3.50     | 3.71        | 1.36E-02     | 56.82           | 4,984                  | 14.44             | 21.13       | Bad                  |

Figure 27 shows the “Excellent” received image for VFactor=4.723 with no distorted area and the same quality of picture image as the original image. In the “Good” image of Figure 28, the most degraded image frame was selected and marked with a white rectangular shape to show a distorted part. Distortion was uniformly displayed in the specific line. The “Average” image of Figure 29 has a wider distorted area than that of the “Good” image. The “Mediocre” image of Figure 30 has severe distortion at the leg part where motion movement is high so that the original image information may not be recognized.

The “Bad” image of Figure 31 had more error than the “Mediocre” image of Figure 30, so that the bottom part was severely distorted. Table 10 shows the VFactor for each grade of the picture and the calculated thresholds of the measured network items.

When we look at the threshold values of the network, if the PCR-OJ (PCR-Overall Jitter) value was within the 100 ms recommended by the ETSI TR 101 290 v1.2.1, the PCR-OJ value did not affect the picture quality of the received image of the IPTV. In this test, PCR-OJs of all received images were within 5 ms, and the PCR-OJ in the case of a 4.7 VFactor was higher than that in the case of a VFactor of 4.47. If the PCR-OJ was within 100 ms, it did not affect the picture quality of the received image of the IPTV, and other network items such as out of sequence items and loss episodes influenced the picture quality more than PCR-OJ.
4. Conclusion

In this paper, changes in received IPTV picture quality were studied according to traffic loads over the network through multicasting services of HD picture image data after constructing a test network environment similar to real IPTV service environments. Thresholds of the measured network items were derived according to image quality. In order to produce a quality of received images similar to that of the original images and without distortion, the VFactor value should be 4.6 or higher. When the VFactor value is 4.3, a viewer does not recognize errors in the video, although partial distortion can be displayed. Below a 4.3 VFactor, distortion can be recognized by a viewer, which makes watching IPTV uncomfortable, and with a VFactor below 4.0, IPTV watching is difficult.

The following findings resulted from this test. For a part where load traffic disturbed the bandwidth of the original image data, the VFactor was reduced significantly, with a very tiny increase (of several Kbps) in load traffic, which significantly degraded picture quality. Furthermore, if the PCR-OJ was within 100 ms, it did not affect the picture quality of the received image of the IPTV, and other network items such as out of sequence items and loss episodes influenced the picture quality more than did the PCR-OJ. When HD-quality videos are serviced via multicasting in IPTVs, the network-related items for “Good” picture quality in Table 10 should be satisfied as the minimum requirements to guarantee a minimum HD-level picture quality in IPTV watching.

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