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Measurement and Analysis of Broadband Internet Access

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あらまし　本論文は，GPS 内蔵超高速 IP メータを用いたブロードバンド・インターネットアクセスサービス網の測定と解析について述べる．筆者らは，典型的なブロードバンドアクセスサービス網として，ADSL(Asymmetrical Digital Subscriber Line) 上の商用 IPv6 アクセスサービス網における測定を実施した．本論文では，超高速 IP メータを用いたトラヒック測定について述べ，ADSL インターネットアクセス網における一方向パケット遅延の非対称な性質について報告する．併せて，インターネットにおける代表的なマルチメディア・アプリケーションの測定結果を示し，インターネットアクセスサービス網におけるサービス品質について述べる．
キーワード　IP トラヒック測定, ブロードバンド・インターネット, ADSL, 性能測定, サービス品質, マルチメディア・アプリケーション

Measurement and Analysis of Broadband Internet Access

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Abstract　This paper presents measurements and analysis of broadband Internet access service networks using a high-speed IP meter with a GPS timestamp component. The authors performed measurements of traffic in a commercial IPv6 access service on ADSL (Asymmetrical Digital Subscriber Line) as a typical broadband access service network. This paper describes the measurement configuration using the high-speed IP meter and reports the asymmetrical characteristics in packet delay on ADSL access networks. It also presents the analysis results of some multimedia applications in the Internet, and discusses the quality of service on Internet access service networks.
Key words　IP traffic measurement, broadband Internet, ADSL, performance analysis, quality of service, multimedia application

1. Introduction

According to the improvement of Internet access service technology such as ADSL, the Internet has become a common infrastructure, and various services including multimedia applications are widely used. Moreover, Internet Protocol version 6 (IPv6), which is the next generation Internet technology, enables various devices including home electronics to connect to the Internet. In the near future, multimedia data transfer will be realized between home electronic devices over the Internet.

As the number of Internet applications in critical situations increases, the quality assurance of the network infrastructure becomes more and more important. The operators of such networks have to maintain the network as reliable and available with sufficient performance to provide various multimedia services with high quality.

Packet transmission delay and jitter are significant parameters for quality of multimedia application services on the Internet. These parameters are problematical especially when packets are transmitted over asymmetrical links and routes.

This paper focuses on ADSL asymmetrical networks, which is a typical broadband Internet access service network. It is usually assumed that one way packet delay is one-half the round trip time. Though, many measurement method of round-trip time are proposed, there are very few measurement studies on one-way packet delay in asymmetrical Internet access service networks.

This paper reports on a measurement of ADSL Internet access networks using a high-speed IP meter which has a GPS timestamp component. The authors performed measurements and various analyses of networks of commercial IPv6 service providers. By precise measurement of one-way delay on ADSL access networks, the characteristics of the access networks are revealed, and the relationship between the quality of networks and the quality of services was studied. An analysis of major multimedia applications was also conducted on the Internet environment and the required quality of networks was studied.

Section 2 provides a description of this high-speed IP meter, which is capable of the GPS timestamp function, and the measurement configuration of ADSL Internet access networks. Section 3 presents the results of the characteristics of major multimedia applications in the Internet. Section 4 presents the results of analysis, including one-way packet delay, and reveales the asymmetrical characteristics of Internet access networks. Section 5 discusses an observation of the application quality on Internet access networks. Section 6 provides an summary of the application quality on Internet access networks.

2. Traffic Measurement

2.1 High-speed IP meter

Measurement technology is the key to maintaining the network condition and providing a network that functions as an important infrastructure in the network society. Accuracy of the timestamp is critical for measurement of high-speed networks [1]. To perform analysis of the quality of service on the Internet, timestamps must have adequate precision. However, the experimental results show that software-based traffic measurement equipment cannot handle 100-μ second order timing information. Moreover, it is difficult to measure correct one-way delay in ADSL networks, which provide asymmetrical transmission speed.

To meet these requirements, a high-speed and accurate IP meter system, HIM, developed for precise timestamp information was employed. HIM is implemented on a specific hardware, which has been made to realize the necessary specifications that enable data capturing with 20-μ second order timing information from a gigabit class network. Figure 1 is a photo of HIM.

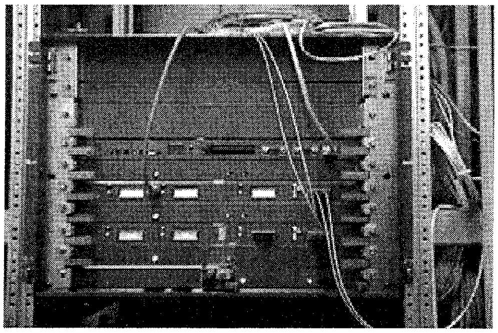

図 1 超高速 IP メータ
Fig. 1 High-speed IP-meter

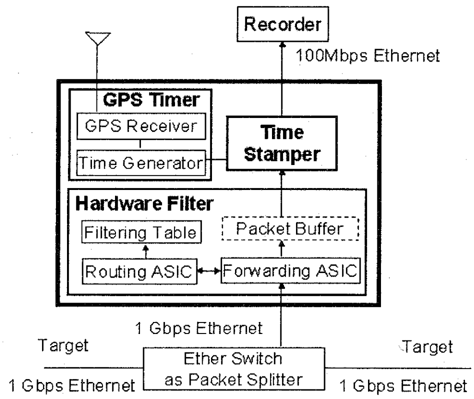

図 2 超高速 IP メータの構成
Fig. 2 Components of High-speed IP-meter

Figure 2 shows the components of HIM. HIM has a GPS (Global Positioning System) time and recorder component. The GPS component creates 100-nano second order accurate time information. This system collects all Internet protocol packets with accurate timestamps at the monitoring point. UNIX-based recorder software, which provides traffic data collection and data backup functions, was also developed. This software records IP packets in LIBPCAP-compatible format [2]. A detailed description of this system is described in [3].

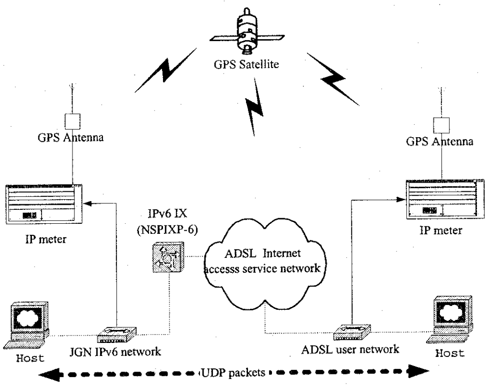

図 3 Network configuration of traffic measurement

2.2 Needs and scenario for measurement and analysis

ADSL networks have asymmetrical characteristics in transmission speed. It is expected that the characteristics of packet delay and jitter in ADSL networks depend on their direction of transmission. It is not enough to use the *ping* command, which only computes round-trip packet delay, to measure such characteristics. To solve this problem, it is suitable to measure one-way packet delay of transmitted UDP packets. Packet delay is computed by capturing UDP packets with timestamps at a pair of monitoring point in the target network. Sufficiently high timestamp precision is needed to compute the collect jitter values, which is required by multimedia applications. The high-speed IP meter system meets this requirement.

The configuration of the traffic measurement is shown in Figure 3. The target of this measurement is one-way packet delay between an Internet access point at the user site and Internet backbone. Access networks are commercial ADSL Internet access services with IPv6 tunneling capability. One monitoring point is located on the end user access hosts, and another point is located on the hosts at the JGN (Japan Gigabit Network) IPv6 network, which is connected to NSPIXP–6[4], an IPv6 based Internet exchange point in Tokyo. Two high-speed IP meter HIMs are located at each monitoring point. Their timestamps are synchronized to GPS clocks, and accurate one-way packet delay can be obtained in microsecond order.

3. Chareacteristics of Multimedia Applications

It is important to realize the characteristics of various multimedia applications for high-quality video and audio services. There are two kinds of multimedia applications in the Internet environment: a streaming-type application, and an interactive-type application. They differ in their characteristics of application traffic. Measurement and analysis of two applications, *Microsoft WindowsMedia* and *Microsoft NetMeeting*, as samples of these typical multimedia applications was performed.

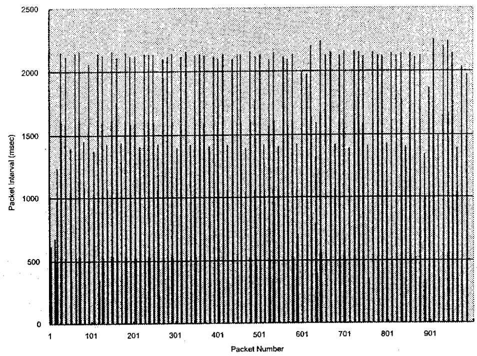

図 4 Windows Media アプリケーションのパケット間隔
Fig. 4 Packet intervals of Windows Media application

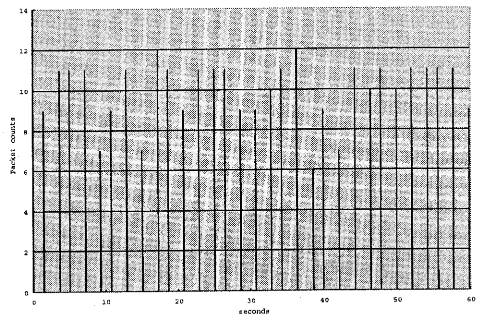

図 5 Windows Media アプリケーションのパケット送出パターン
Fig. 5 Packet transmission patterns of Windows Media application

3.1 Streaming-type application — Microsoft Windows Media

Microsoft Windows Media is an example of streaming-type multimedia applications. These types of applications transmit real-time / live video contents, or stored video contents on the Internet. Generally, multimedia applications require low jitter data transmission over networks; however, streaming-type application allows delay and jitter in transmitting packets. These applications use UDP (User Datagram Protocol) or TCP (Transmission Control Protocol) for their transport protocols.

The results of the traffic measurement of Microsoft Windows Media application are shown in Figure 4 and 5. Figure 4 shows the intervals of every transmitted packet. Figure 5

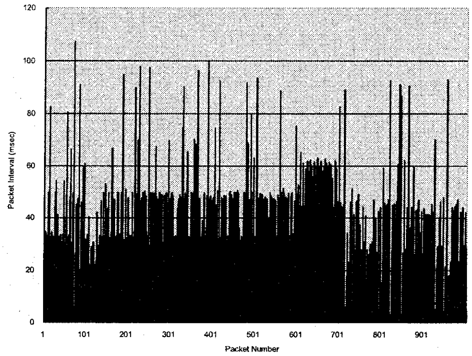

図 6 NetMeeting アプリケーションのパケット間隔
Fig. 6 Packet intervals of NetMeeting application

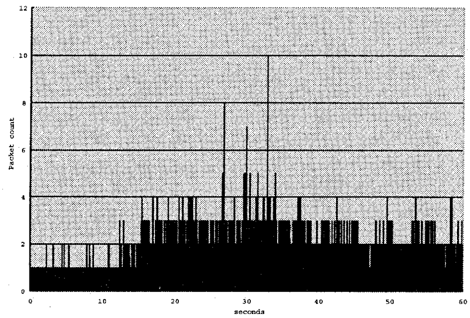

図 7 NetMeeting アプリケーションのパケット送出パターン
Fig. 7 Packet transmission patterns of NetMeeting application

shows the packet counts in each 10-msec periods. These figures show the results of packet interval during data transmission with a typical application configuration. These graphs clearly shows that the Windows Media application transmits 6–12 packets every 1.5–2 seconds. The absolute transmission delay of this application is larger than that of interactive-type multimedia applications. It is expected that packet transmission delay and jitter do not affect the quality of video and audio severely.

3.2 Interactive-type application - Microsoft NetMeeting

Microsoft NetMeeting is an example of interactive-type multimedia application. These types of applications transmit and receive video and audio in real time. The low jitter and delay requirement is very important. These applications usually use UDP for their transport protocols to achieve better transfer performance.

The results of traffic measurement of Microsoft NetMeeting application are shown in Figure 6 and 7. Figure 6 shows

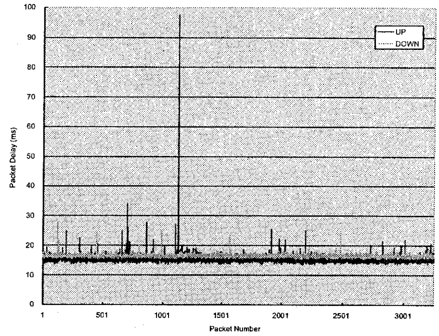

図 8 ADSL 上の一方向パケット遅延 — UDP 112 バイト
Fig. 8 One-way Generated Packet Delay through ADSL - UDP 112 bytes

表 1 パケット遅延の統計 (UDP 112 bytes)
Table 1 Statistics of Packet Delay (UDP 112 bytes)

Packet delay	Down(ms)	Up(ms)
Average	15.2	16.5
Standard Deviation	2.1	0.60
Maximum delay	97	28
Jitter	0.97	0.55

the intervals of every transmitted packet. Figure 7 shows the packet counts in each 10-msec periods. These figures show the results of packet interval during the data transmission with a typical application configuration. As is shown in these figures, NetMeeting application's packet transmission intervals vary from 5 to 100 msec and its average is about 30–50 msec. The absolute delay of this application is smaller than that of the Windows Media application. It is expected that the quality of this type of application is affected by packet delay and jitter in 10-microsecond order, so the timestamp precision in measurement should be in microsecond-order to perform analysis of such applications.

4. Performance Analysis of Broadband Internet Access Services

This section shows the results of one-way packet transmit delay under the condition described in Section 2. The transmission speed of each direction of the network is 8 Mbit/s (downward; from servers to users) and 2.4 Mbit/s (upward; from users to servers). Round trip time, which is measured by *ping6* command, is about 30 ms. One-way delay and interarrival jitter (mean deviation of the difference of packet arrival, defined in [5]) are computed from our measurement results.

4.1 One-way packet delay of short UDP packets

This section shows the results of measurement of one-way

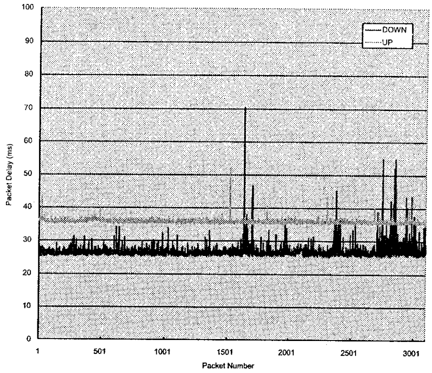

図 9 ADSL 上の一方向パケット遅延 — UDP 1280 バイト
Fig. 9 One-way Generated Packet Delay through ADSL — UDP 1280 bytes

表 2 パケット遅延の統計 (UDP 1280 bytes)
Table 2 Statistics of packet delay (UDP 1280 bytes)

Packet delay	Down (ms)	Up (ms)
Average	26.9	35.9
Standard Deviation	2.2	0.56
Maximum delay	71	52
Jitter	1.37	0.44

packet delay of short UDP packets. The UDP packets are transmitted one per second between two monitoring points. Figure 8 shows the one-way packet delay of the UDP 112-byte sized packets for one hour. Packet delay statistics are shown in Table 1.

These figure and table show the following results:

- The packet transmission delay is affected by the direction of the packets.
- The average packet delay of the downward packet is smaller than that of the upward packet. Packet delay of downword packet is about 16.5 msec, and that of upword packet is about 15.2 msec. The difference between them is about 1.3 msec.
- The value of packet delay occasionally increases up to 100 msec. It is expected that such a large packet delay will affect the quality of interactive-type multimedia applications.

4.2 One-way packet delay of long UDP packets

Figure 9 shows the one-way packet delay of the UDP 1280-byte sized packets for one hour. Packet delay statistics are shown in Table 2. The measurement configuration is the same as that of UDP 112-byte packets.

This figure shows the following results:

- As same as in the case of short UDP packets, the values of packet transmission delay are different between downword packets and upward packets.

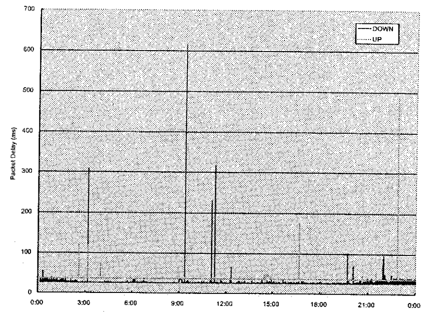

図 10 ADSL 上の一方向パケット遅延 (24 時間)
Fig. 10 One-way Packet Delay through ADSL - 24 hour period

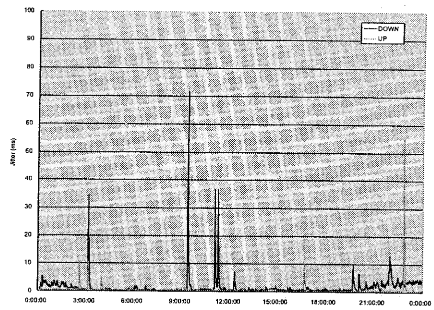

図 11 ADSL 上の一方向パケットジッタ (24 時間)
Fig. 11 One-way Packet Jitter through ADSL - 24 hour period

- The average packet delay of the downward packet is smaller than that of the upward packet. Packet delay of downword packet is about 27 msec, and that of upword packet is about 36 msec. The difference between them is about 9 msec. It is larger value than that of the short UDP packets.

4.3 UDP packet delay and jitter of 24 hours

Figure 10 and 11 show the one-way packet delay and average jitter of a 24-hour period. The configuration is the same as that of previous measurement. 112 bytes UDP packets are used for these measurements.

- Upward packet delay and jitter are almost constant.
- However, downward packet delay and jitter values increase between 8 p.m. to 3 a.m.
- The value of the packet delay and jitter are ocassionally increases up to several hundred mil seconds.

Figure 12 and 13 show the one-way packet delay and average jitter of 11-12 oclock of the day. The transmission delay of downward packets are about 26 msec, and that of upward packet are about 36 msec. These values are almost constant during this period, and the average jitter values are under 1 msec.

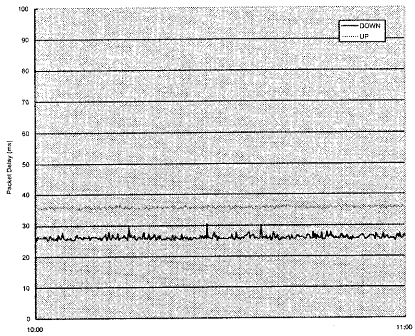

図 12 ADSL 上の一方向パケット遅延 (10–11 時)
Fig. 12 One-way Packet Delay through ADSL - 10:00-11:00

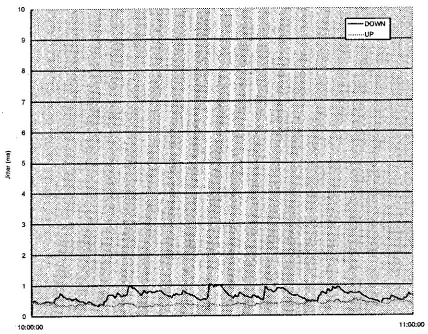

図 13 ADSL 上の一方向パケットジッタ (10–11 時)
Fig. 13 One-way Packet Jitter through ADSL - 10:00-11:00

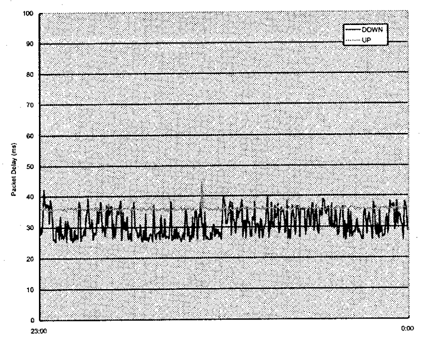

図 14 ADSL 上の一方向パケット遅延 (23–24 時)
Fig. 14 One-way Packet Delay through ADSL - 23:00-24:00

Figure 14 and 15 show the one-way packet delay and average jitter of 23-24 oclock of the day. The transmission delay of downward packets varies between 26 and 40 msec. On the other hand, dalay of upward packets are almost constant. This characteristics are shown more clearly in the

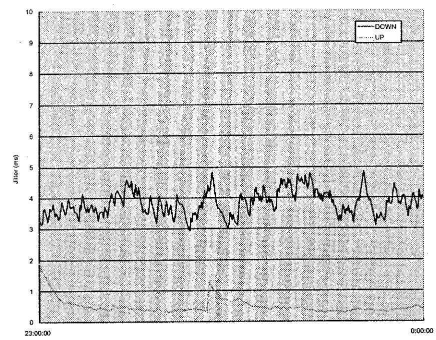

図 15 ADSL 上の一方向パケットジッタ (23–24 時)
Fig. 15 One-way Packet Jitter through ADSL - 23:00-24:00

jitter graph. The average jitter values of downward packets are about 3-5 msec, and that of upward packets are under 1 msec. As described in this section, the characteristics of one way packet delay and jitter in this measurement heavily depends on the time of day.

5. Discussion

The following measurements and analysis were performed using a high-speed IP meter.

- Characteristics of typical multimedia applications in the Internet.
- One-way packet delay through ADSL Internet access service networks.

The experimental results showed:

- Asymmetrical characteristics are found in one-way packet delay through ADSL Internet access networks.
- Delay and jitter of long packets are larger than that of short packets.
- Variance of packet delay and jitter varies in one day

In addition to this, the following measurements about various multimedia applications were performed.

- The two kinds of multimedia applications, streaming-type and interactive-type, have different characteristics in packet transmission.
- In streaming-type applications, the interval of a group of packets is larger than packet delay and jitter, which were measured. The quality of video and audio of the applications will not be affected by packet delay or jitter. On the other hand, in interactive-type applications, the intervals of transmitted packets are in 10-ms order.

From these analysises, the following results were obtained to serve various multimedia applications. through ADSL Internet access networks.

(1) From the point of packet transmission and jitter, It is expected that the quality of streaming-type applications

is not affected by characteristics of ADSL access networks.

(2) On the other hand, it is expected that interactive-type applications may be affected by the packet delay and jitter values in ADSL networks. The packet transmission delay and jitter values of downward direction offen vary according to the conditions of the networks.

6. Conclusion

This paper reports measurements of Internet access service networks. Multimedia application traffic and one-way packet delay of ADSL networks are measured using a high-speed IP meter, The relationship between the quality of network (packet delay and jitter) and the quality of application services was discussed. Measurement of application-level quality is essential. The authors intend to use these results to analyze the quality of services of various Internet applications.

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