國立交通大學

電機資訊學院 資訊學程

碩士論文

IP over ATM 效能問題探討在 ADSL 網路上

Assessing the Overhead of IP over ATM in ADSL Networking

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摘要

非對稱數位迴路(ADSL)成為目前最普遍的上網方式之一，但傳統的 ADSL DSLAM 建立於 ATM 環境下，導致 IP 封包必須切成 ATM cell 或 ATM cell 必須重組成 IP 封包才能進行傳送。本論文將利用 ADSL modem 與 ATM based DSLAM 和 IP based DSLAM 間的效能比較測試，來證明 overhead 將影響傳輸效能。實驗證明，在 IP DSLAM 下傳送效能確實優於 ATM DSLAM，封包越大情況越明顯。此外，並針對 ADSL 的 fast mode、interleave mode 和 trellis code encode 是否影響傳輸效能，做實驗來驗證。Interleave mode 須要將資料打散和重組，其效能會略低於 fast mode。Trellis coding 的影響不容易從這實驗中觀察到。另外 ADSL 其非對稱的特性是否也會影響其傳輸效能，本論文會從三種不同組合的連線速率上，找出最佳的雙向傳輸連線速率。當上傳的連線速率越接近下傳時，其雙向傳輸的效能將會最大。所以 7616/800 得到最佳的雙向傳輸效能。最後，利用三種不同封裝方式在實際的網路上做效能測試，再次證明 overhead 將影響傳輸效能。且證明經過 IP DSLAM 的效能優於經過 ATM DSLAM 封裝協定的 overhead 越多也直接影響傳輸的效能。總結上述結果，封包的分割與重組為影響效能之最主要原因，其次才為封包的封裝方式。ADSL 內其它參數的改變，影響效能最小。

關鍵詞：非對稱用戶數位回路、IP over 非同步傳輸模式、IP over 乙太網路、測試

Assessing the Overhead of IP over ATM in ADSL Networking

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Abstract

ADSL has becomes one of the most widely broadband access technologies. But the traditional ADSL connector DSLAM, is built on the ATM environment. ADSL segments IP packets into ATM cells and an ATM cells which are reassembled back to IP packets. This study compares the performance of ADSL modems with ATM based DSLAMs or IP based DSLAMs, for assessing the influence of the overheads. We design some tests to compare the performance of two types of DSLAM. After test result be proved, IP DSLAM achieve better performance than ATM DSLAM. Transfer packet size more long the phenomenon more clearly. Additionally, experiments are also performed to demonstrate that the performance is affect by fast mode; interleave mode and trellis encode. The experimental results reveal that the interleave mode performs worse than the fast mode. Due to interleave mode frame interleaver and de-interleaver must be performed. However, the trellis code encoding does not affect the performance. On the other hand, ADSL has asymmetric links rate, downstream and upstream has difference link rate. A key issue is weather asymmetry affect the bi-directional traffic performance. This study uses three types of line rate combinations and selects the best one. This study found that when the upstream link rate approaches the downstream link rate in the bi-directional throughput performance is maximized. The optimum throughput performance thus was obtained 7616/800 kbps. Finally, three types of encapsulations are applied to a real ADSL network to re-confirm whether overheads influence performance**.** This study again confirms that IP DSLAM achieve superior performance to ATM DSLAM. Encapsulation protocol overheads directly affect the throughput performance. Summary above test result, the packets segmentation and reassemble is the most important factor about throughput performance. Packets encapsulation method is next effect factor. ADSL physical parameter changes will not huge effect throughput performance.

Keywords: ADSL, IP over ATM, IP over Ethernet, Testing

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在就讀碩士這段時間，非常感謝許多人的幫忙，在此致上十二萬分的敬意。

首先，在師長方面，要謝謝我的指導教授林盈達博士給予我的指導，對於在處理問題的方法、論文撰寫上都給我很大的幫助；並感謝修課期間所遇到的任課老師的教導。其次對於合勤科技的同事，無論在技術上的討論或提供實作環境的支援，也是由衷的感謝。同時我也要感謝我的口試委員簡榮宏教授、孫雅麗教授對我的論文指導與建議，使我的論文能更加豐富及嚴謹。此外我要謝謝我身邊的朋友，平日對我的鼓勵。

感謝我的家人多年來的支持；感謝我的妻子郁婷與女兒品智，在這段期間的默默包容與鼓勵。

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Chapter 1 Introduction

Asymmetric digital subscriber line (ADSL) is a high-speed data transmission technology that provides large bandwidth increases over the existing copper infrastructure. ADSL modem works by transmitting Internet data in a frequency range that is separate from the 4 KHz range used for voice transmission, thus allowing simultaneous voice and data communications over one copper line. ADSL can support a wide variety of high bandwidth applications, such as high speed Internet access, telecommuting, and video-on-demand. ADSL is asymmetric in that it provides higher bandwidth for downstream traffic than that for upstream traffic. This can be sufficient and efficient because many user activities on the Internet are inherently asymmetric (e.g., Web browsing, file transfers, software downloads).

ADSL system support multiple services, such as Frame Relay, ATM, and Local Area Network (LAN) services for the purposes of interoperability. The ADSL Forum has recommended ATM over ADSL as a reference mode [1]. The ATM over ADSL architecture preserves the high-speed characteristics of ATM and ADSL, and guarantees Quality of Service (QoS) support as well. The upper layer protocols carried over ADSL are typically TCP and IP, from the Internet protocol suite. The Internet Protocol (IP) provides global addressing and routing for the Internet, using connection-less network layer. The Transmission Control Protocol (TCP) provides reliable data transfer on top of IP, using a connection-oriented transport layer.

There are some performance problems that need to be addressed for the architecture of TCP over ATM over ADSL. First, TCP experiences performance degradation on ATM networks [2]. The performance problems are primarily due to the segmentation and reassembly process of ATM networks. Second, the network asymmetry affects TCP performance because TCP relies on acknowledgment as feedback from the receiver to ensure reliability.

This study, addresses some specific issue. The first issue addressed IP over ATM and IP over

Ethernet and experiments are used for discussing how both types of DSLAM influence the performance. This issue is also considered for different link rates and packet sizes. Second, this study discusses how the fast mode; interleave mode and trellis encoding influence the throughput performance under ATM DSLAM. Specifically, this study examines why interleave mode and trellis encoding have higher overheads during data transmission. The interleave mode should be have worse performance than fast mode. The third issue examined is that of asymmetry. Specifically, this study attempts to prove that the asymmetry influences the bi-directional transfer throughput during the performance. The best combination among three different link rate combinations then is selected Finally three encapsulations are performed for a real ADSL network to re-confirm whether overheads influence performance. Again, the performance of IP DSLAM is proved to be better than that of ATM DSLAM. Overheads associated with the encapsulation protocol directly influence the performance.

The remainder of this paper is organized as follows. Chapter 2 describes the ADSL background. Chapter 3 then introduces the test configurations and methodology used here. Subsequently, chapter 4 further extends the result of the test case and analyzes the test result. Finally, conclusions and future research directions are presented work in chapter 5.

Chapter 2 ADSL Background

2.1 RFC1483

Figure 1 illustrates the protocol stacks that are employed.

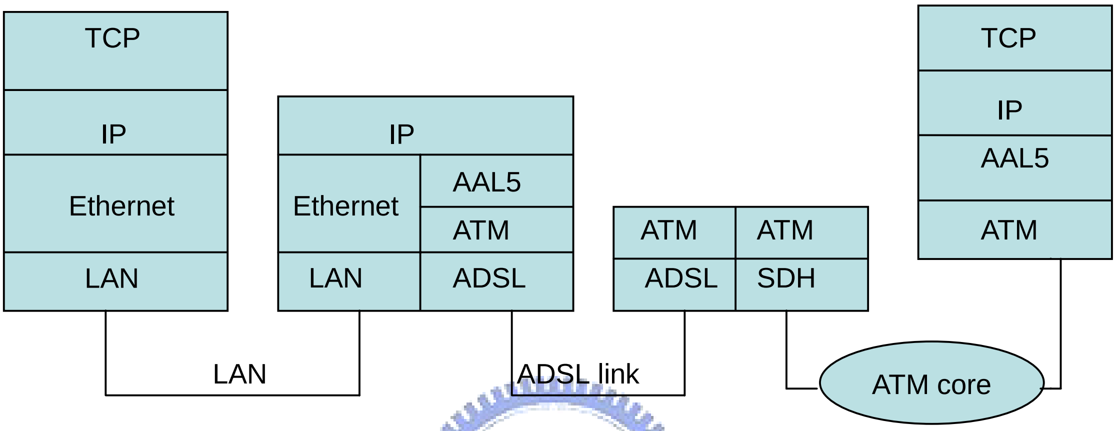

Figure 1 Modeled Protocol Stacks

TCP/IP packet via Ethernet transmits to remote side. It will become segmented to ATM cell (48 byte per cell) and then used ATM network to reach remote side. It reassembles to Ethernet packet. The segmentation and reassembly will increase the overhead about packet transmission. It only will affect the performance of data throughput.

The aim of RFC1483 is to develop a standard for carrying multiple protocols, of which IP is one. The IETF note two methods for supporting multiple protocols, VC-based multiplexing and LLC encapsulation. Those two protocol to multiplex different protocol onto a single AAL5 connection. The first 8 bytes indicate that the payload is routed Non-ISO PDU, with the EtherType associated with IP packet (0x800).

The LLC/SNAP header may be removed where VC based multiplexing is used, saving 8 bytes per packet. However, this will only be useful in environment where both ends can agree on the mapping between ATM connections and network layer protocols. From the standard, the VC-based multiplexing performance should be better than LLC multiplexing.

2.2 ADSL Frame Type

Frame carry bit stream is the main method used for data transmission. ADSL also uses this method. ANSI T1.413 divides ADSL data transmission into two modes. One is Synchronous Transfer Mode, and another is Asynchronous Transfer Mode. Basically, ADSL data can be divided into two types. The first type of ADSL data is fast data. Fast data has low latency and uses the fast path. Its latency lasts about 2ms. The other type of ADSL data is interleaved data. Interleave data has much higher in latency and uses interleave path. Its latency lasts approximately 20ms. One ADSL physical channel can simultaneously support seven bearer channels, all of which are logical channels. Four of these seven channels are simplex channels (A0 to A3) that support downstream transfer. Meanwhile, the remaining three are duplex channels (LS0 to LS2) that support downstream and upstream transfer. ADSL systems need to support at least AS0 simplex bearer channel and LS0 duplex channel. Meanwhile, the data transfer rate needs to be based on 32kbps, from 32Kbps to 8Mbps for the downstream transfer and from 32Kbps to 800Kbps for the upstream transfer.

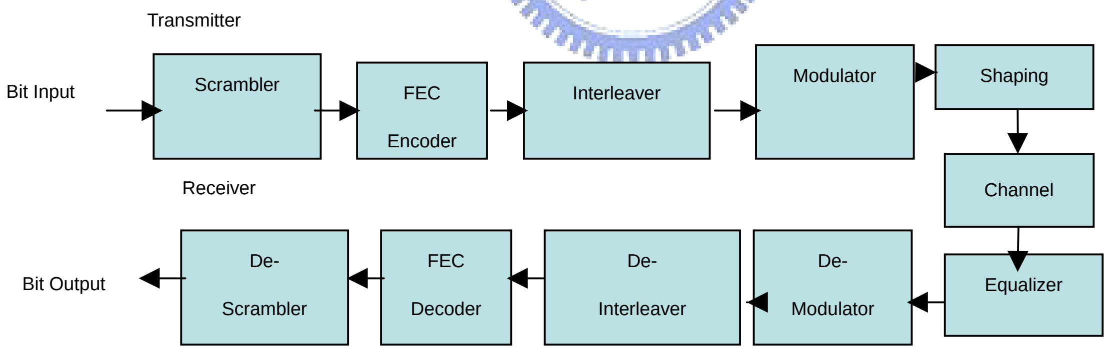

Figure 2 Simple Modulator Flow

Figure 2 illustrates the ADSL modulator flow. The figure includes Scrambler/De-Scrambler, FEC Encoder/FEC decoder, Interleave/De-Interleave, Modulator/De-Modulator and Shaping/Equalizer, DMT has become a standard ADSL line code standard. The ADSL protocol on the lower layer is the bit of the DMT encoder. These bits comprise frames, some of which merge to a superframe. Figure 3 illustrayes an ADSL superframe and an ADSL frame.

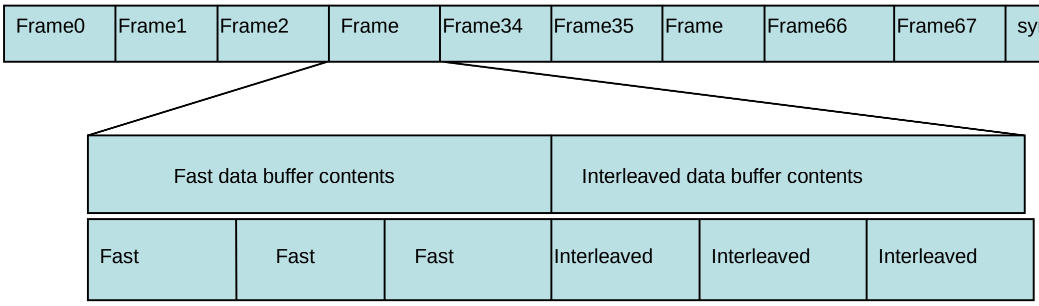

Figure 3 ADSL SuperFrame Architecture

An ADSL superframe comprise of 68 data frames and one synchronous frame. ATU-R and ATU-C both have two related paths, the fast and interleave paths. Both paths have flow of CRC, scrambling and FEC and so on. However, only interleaved path interleave on the transmitting and de-interleaves on the receiving side. The interleaved thus is located between the FEC module and modulation. If DSL transfers data to produce a series of long stream errors, then the FEC will have difficult in correcting this error. The interleave mode spans an average of one FEC codeword on average, and this mechanism can be used to span the error on this data stream.

In addition to the error correction afforded at the modulation level by Trellis-encoding, additional forward error correction is provided by using Reed-Solomon code. The code word sizes vary, depending on the number of bits assigned to the two data buffers.

2.3 Trellis Coding

In recent years, trellis coding has become a powerful means of increasing SNR margins in multilevel transmission systems. Trellis coding is a concatenation between two operations that previously had been effectuated separately, modulation and coding. With up to 6 dB of additional coding gain it is an approach very close to the cutoff rate. Binary convolutional error correcting codes, as they had been known already for many years, were not able to increase achievable data rates on bandlimited channels significantly. This was mainly due to the fact that they were working on binary data, or in other words on hard decisions. In trellis coded modulation, on the other hand, decisions are made on unquantisised data or at least data that has been digitised with much smaller step sizes than the decision steps of the signal. Therefore not only a decision for one or the other signal is made, but moreover the information about the distance between the received signal point and the estimated transmit signal point is used.

2.4 Modulation

Two modulation schemes used in various ADSL implementations, Discrete Multi-tone (DMT) is usually favored for its higher throughput and greater resistance to adverse line conditions. It effectively compensates for widely varying line noise conditions and quality levels.

The ADSL frequency spectrum is divided as figure 4:

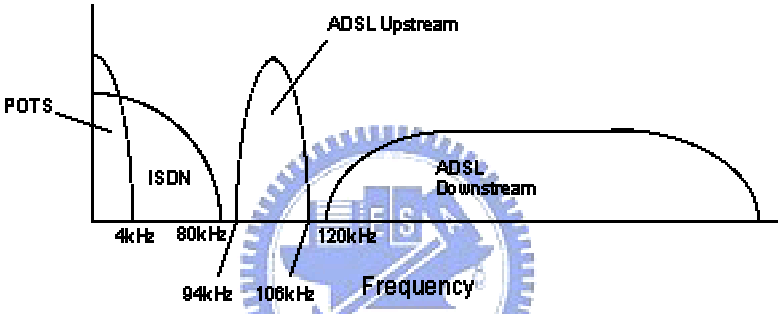

Figure 4 ADSL Frequency Spectrum

The lower 4kHz of the spectrum are occupied by Plain Old Telephone Service (POTS), and the lower 80kHz by ISDN. ADSL coexists with these services by using higher frequencies in the spectrum. Sufficient space is left between adjacent bands to allow passive filtering of the signal. This ensures that POTS remains in operation--even during a power failure which might render the modem inoperative. Some implementations of ADSL overlap the frequencies used by the upstream and downstream channels, and use echo-cancellation to decode the resulting signal.

Remaining bandwidth, the downstream band is split into 256 discrete channels, each 4kHz wide. The highest channel at the Nyquist frequency is not used for data. On the ADSL Transceiver Unit installed in the central station (ATU-C), channel 64 (276kHz) is used for transmission of constant timing data. The ADSL Transceiver Unit at the remote location (ATU-R) uses 31 channels for data transmission with channel 16 reserved for timing. Each carrier is modulated using Trellis-

Encoded Quadrature Amplitude Modulation (QAM).

2.5 Asymmetry

Network asymmetry affects the performance of reliable transport protocol such as TCP, because these protocols rely on feedback in the form of cumulative acknowledgements from the receiver to ensure reliability. For a unidirectional flow of data, the TCP acknowledgement (ACKs) flow over the slow reverse link (upstream), regulating the flow of data packets over the forward link (downstream). TCP throughput thus depends upon the feedback that flow on the restricted upstream. The timely reception of this feedback when disrupted will cause considerable throughput degradation along the faster downstream. The slower upstream thus may become the primary bottleneck for the downstream throughput. Bi-direction transfer is observed to further exacerbate this asymmetry problem [3,4,5].

2.6 ADSL Encapsulation

EoA[6], PPPoA[7] and PPPoE[8] are the most popular encapsulations for IP over ADSL. Ethernet frame over ATM. These are simple encapsulation into ATM Adaptation Layer 5 (AAL5) using RFC1483. The encapsulation supports both routing and bridged. This is based on standard RFC1483 “Multi protocol Encapsulation over AAL5”. Figure 5 draws a sample configuration of Ethernet over ATM using in the field.

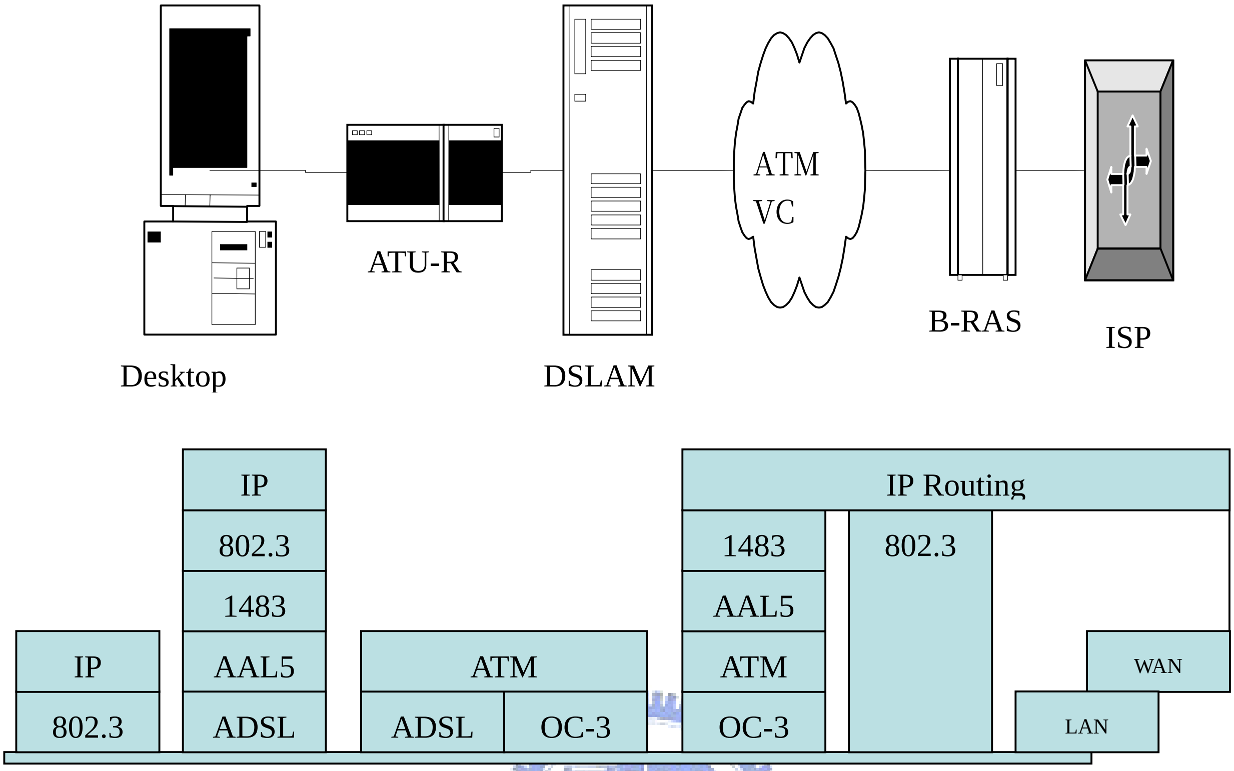

Figure 5 Ethernet over ATM Protocol Stack

PPP over ATM (PPPoA) is based on the standard RFC2364 “PPP over AAL5”. The PPP session is opened with the Broadband-Remote Access Server (B-RAS). The LCP session is handled between the B-RAS and the PC (CPE) to manage the authentication of username and password. Figure 6 shows the PPPoA protocol stack.

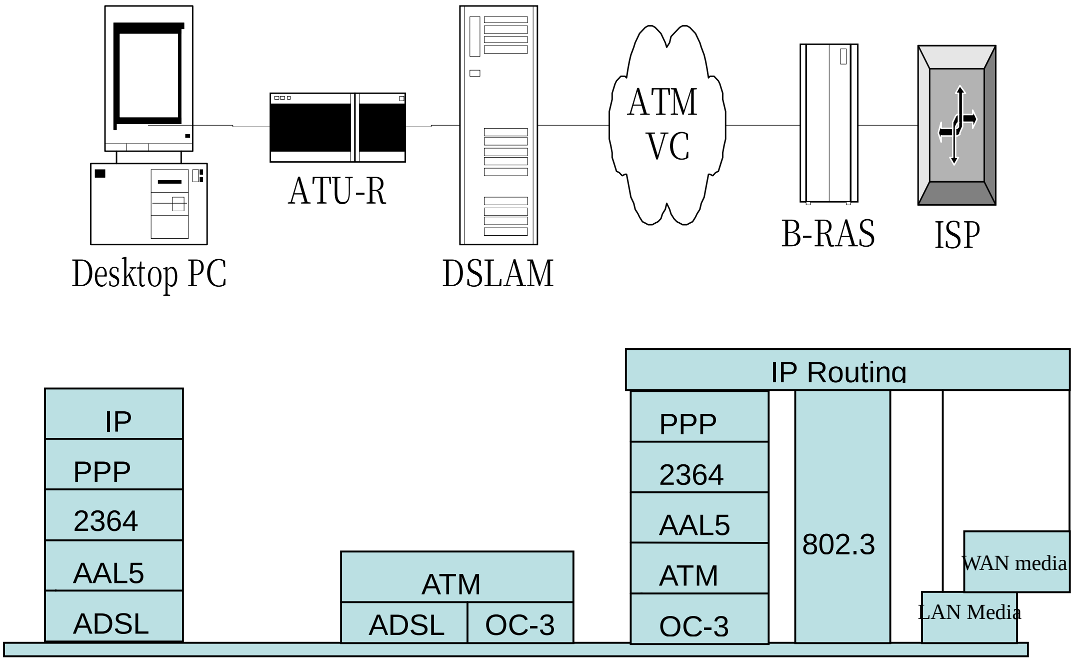

Figure 6 PPP over ATM Protocol Stack

Figure 7 shows the PPPoE protocol stack. The configuration and principles for PPPoE are similar to those described for PPPoA. The only difference is which encapsulation technology is in use. PPPoE uses Etherbet networking with in an encapsulation scheme designed for multi-PC homes and small business. PPPoE enables multiple PCs to connect to multiple destinations through a single, shared CPE, where it uses only one PVC. This is based on the standard RFC2516 “PPP over Ethernet”.

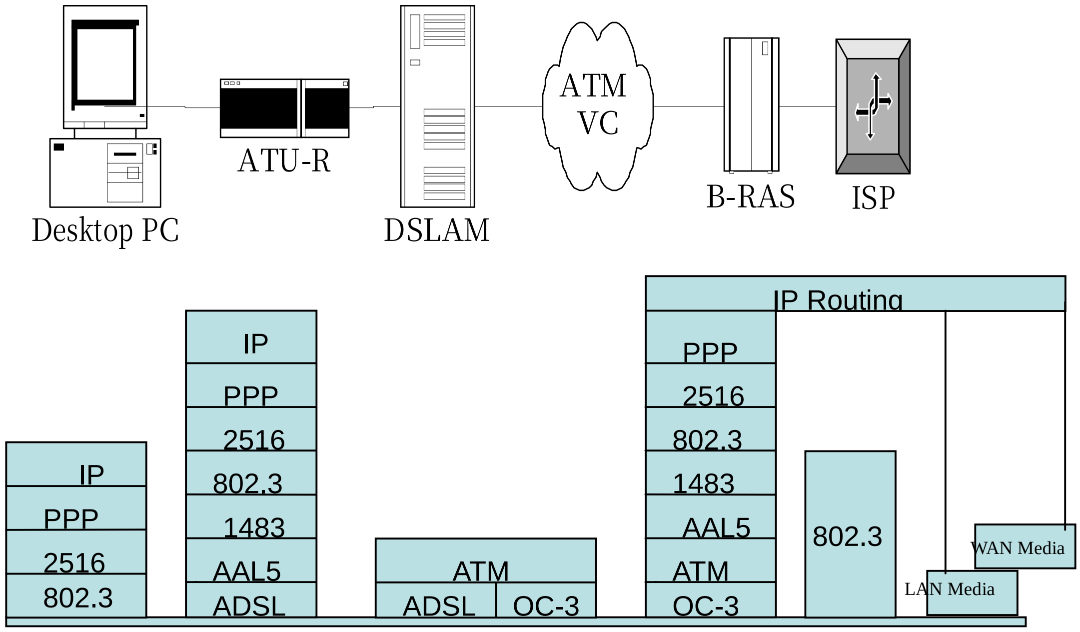

Figure 7 PPP over Ethernet Protocol Stack

From these three types of encapsulation, we learnt whenever encapsulation gets the better performance, then the more overhead will be affected the throughput.

Chapter 3 Test Methodology

To further test the proposed hypothesis, This study designs four test cases using two test configuration models. The first case involves the issue of IP over ATM throughput performance. The performance influence of interleave and fast mode is discussed. The trellis code enabling and disabling are also discussed. The Second case involves testing the performance under IP over ATM and IP over Ethernet. Observations can be made regarding the difference in the performance of ATM and Ethernet. The third case study investigates the affect of asymmetric. Bi-directional throughput testing is performed, and optimum combination of bi-directional transmissions is selected. Finally, the performances for different encapsulations are performed for a real ADSL network. To demonstrate that the performance of encapsulations relies on their packet header, the FTP application is run under RFC1483, PPPoA and PPPoE Encapsulation.

3.1 Test Configurations

3.1.1 Emulation Model

The first configuration emulates the closed ADSL network in the laboratory for measuring the throughput. Figure 8 shoe the configurations prototype The figure show that ADSL modem (ZyXEL Prestige 650H-11[9] ADSL modem) connects to ATM Based DSLAM (Lucent stinger[10]) or IP Based DSLAM(ZyXEL IES-1000[11]) between DLS4000[12], the loop simulator, and AX4000[13], the packet generator and analyzer. The AX4000 generator module then is used to forward the Ethernet packet or ATM cell and receive data from the analyzer module. The traffic packets pass through the ADSL modem and DSLAM. The throughput result is recorded when date passes the ADSL modem at each test item. Some parameters are changed and the throughput performance is measured.

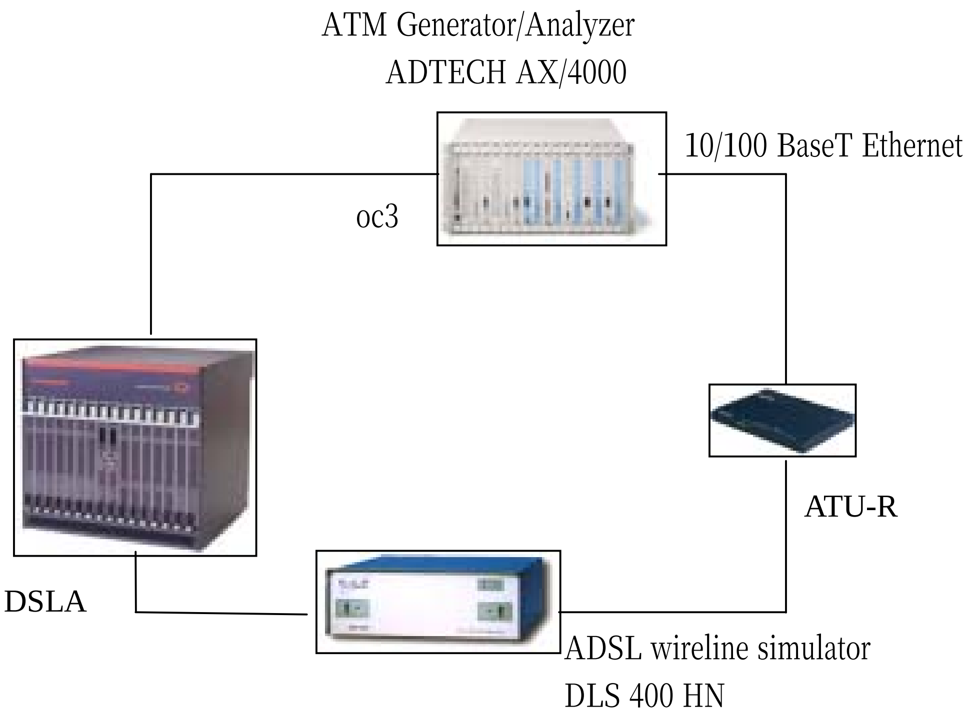

Figure 8 Test Configuration 1

3.1.2 Real Line Model

The second configuration simulates the real ADSL line on the Internet using ZyXEL PQA lab. Figure 9 shows this configuration. This figure uses P650H-11 to pass through Hinet to reach the FTP server on the Internet. Traffic packets should pass through the ZyXEL PQA Lab to access to the Internet. P650H-11's LAN PC is used to connect to an FTP server. Moreover, three times downstream and upstream file transfers are performed to measure the FTP throughput result..

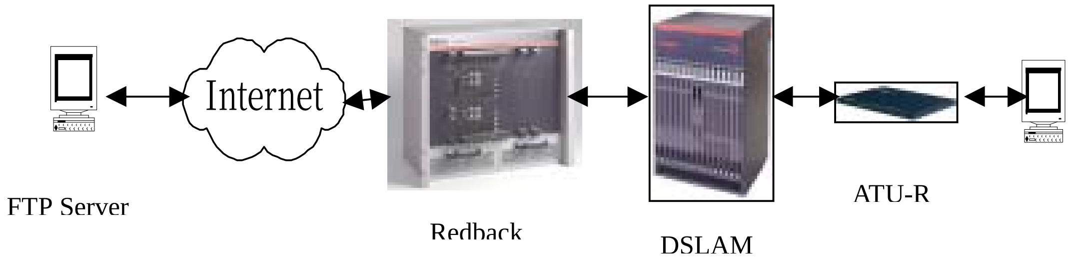

Figure 9 Test Configuration 2

3.2 Test cases

Four test scenarios are created based on two configurations in this study. The first three test cases follow configuration 1.To emulate close ADSL network for uni-direction and bi-direction transmissions on the lab. The last test case is based on configuration 2.To do real ADSL line test on Internet. Each test case can be divided into several test items. Information on all test items needs to be collected for analyzing the test results.

3.2.1 Test Case 1 IP over ATM Throughput

Based on configuration 1, an ZyXEL Prestige 650H-11 ADSL modem is used as ATU-R and an ATM Based DSLAM Lucent Stinger is used as ATU-C to test the uni-directional throughput performance under ATM based DSLAM. The AX4000 generator module then is used to send the Ethernet packet or ATM cell and receive data from the analyzer module. These test traffic packets passes through the ADSL modem and DSLAM. This study records the throughput result when ADSL modem passes each test item. Some parameters then are changed and the throughput performance is measured. Test items includes: fast mode/trellis on, fast mode/trellis off, interleave mode/trellis on and interleave mode/trellis off conditions. The traffic packet size is 64, 128, 256, 512, 1024, 1280 and 1518 for each test case. Each test case runs both downstream and upstream throughput. The above procedure is repeated the following link rates: 7616/800, 6144/768, 4096/512, 3072/256, 1536/128 and 512/64kbps.

3.2.2 Test Case 2 IP over ATM V.S IP over Ethernet

Based on configuration 1 and test case 1, this study uses IP based DSLAM ZyXEL IES-1000 instead of ATM based DSLAM Luccent Stinger. However, due to test equipment’s limitation, IES-1000 can only test interleave mode/trellis no condition. The AX4000 generator module is used to send the Ethernet packet or ATM cell and receive data from the analyzer module. These test traffic packets passes through the ADSL modem and DSLAM. The throughput result when data passing the ADSL modem at each test item. The packet size is 64, 128, 256, 512, 1024, 1280 and 1518 for each test case. Each test case runs both downstream and upstream throughput. The above procedure is repeated at the following link rate: 7616/800, 6144/768, 4096/512, 3072/256, 1536/128 and 512/64kbps. Based on the result of the two DSLAM tests the performances of IP over ATM or Ethernet are analyzed.

3.2.3 Test Case 3 Asymmetry Problem

Based on configuration 1, the DSL link rate is set to 7616/800, 7616/512 and 7616/32 Kbps for downstream/upstream. Based on the line rate, AX4000 is used to send bi-directional packet traffic nearing the data rate. Seven packet sizes are also sent, namely: 64, 128, 256, 512, 1024, 1280 and 1518 byte. The test items should be tested include fast mode/trellis no, fast mode/trellis yes, interleave mode/trellis no and interleave mode/trellis yes conditions. Lastly, the throughput performance is proved if the effect of line rate is asymmetric.

3.2.4 Test Case 4 Real Line Model

Based on configuration 2, using P650H-11 on ZyXEL PQA Lab, the test traffic packets passes through Lucent DSLAM, Redback[14](ATM packet terminator) and finally connects to Hinet (Internet Service Provider) via CHT ADSL line. This test item uses a FTP client PC behind the LAN port of P650H-11 and connects to an FTP server via Internet. FTP throughput can be tested PPPoA, PPPoE and RFC1483. The test result could compares their performances under different encapsulations. Additionally, it could also use IES-1000 to replace Lucent Stinger and connect to Hinet via CHT ADSL line. Only in this item can throughput performance be determined under PPPoE and RFC1483. Throughput comparison is also conducted between ATM and Ethernet.

Chapter 4 Test Results

The section presents and analyzes the test results of proposed four test cases. The throughput about IP over ATM is displayed for different situations. This test case should indicate the optimum performance situation. This study also compares the throughput with IP over ATM and with IP over Ethernet. The effect of overheads on performance can be checked. The third test case displays three link rates for bi-directional throughput performance. This test case proves that asymmetric networks influence bi-directional transmission. Finally, the performance table on the ADSL network can be viewed using different encapsulations. This table will be helpful in the present analysis of the overhead issue.

4.1 IP over ATM Throughput

Figure 10 to 15 illustrate the downstream throughput that ADSL connected to Stinger DSLAM at line rate of 7616/800, 6144/768, 4096/512, 3072/256, 1536/512 and 512/64 kbps line rate. In these figures, please note that the x-axis denotes variable packet size as following: 64, 128, 256, 512, 1024, 1280 and 1518 byte, and the y-axis denotes the value of pass through packet size per second of test items. Each figure illustrates four test items result. Those test items include interleave/trellis on, interleave/trellis off, fast/trellis on and fast/trellis off. Appendix A table 2-7 shows detail numerical result for reference.

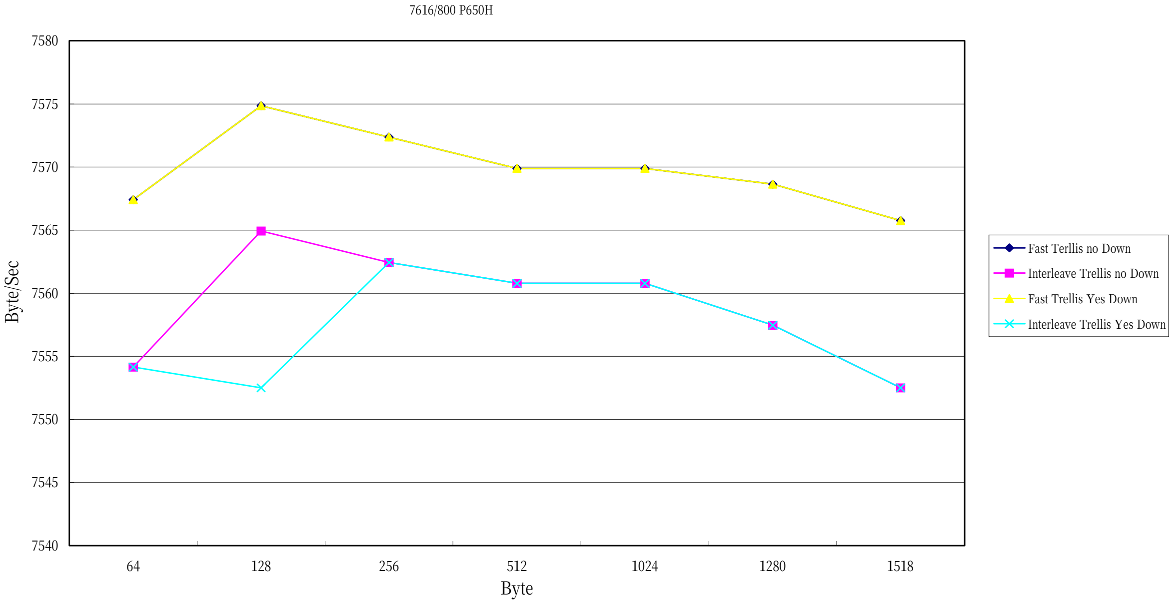

Figure 10 P650H-11 VS. Stinger 7616/800 Kbps Downstream Throughput

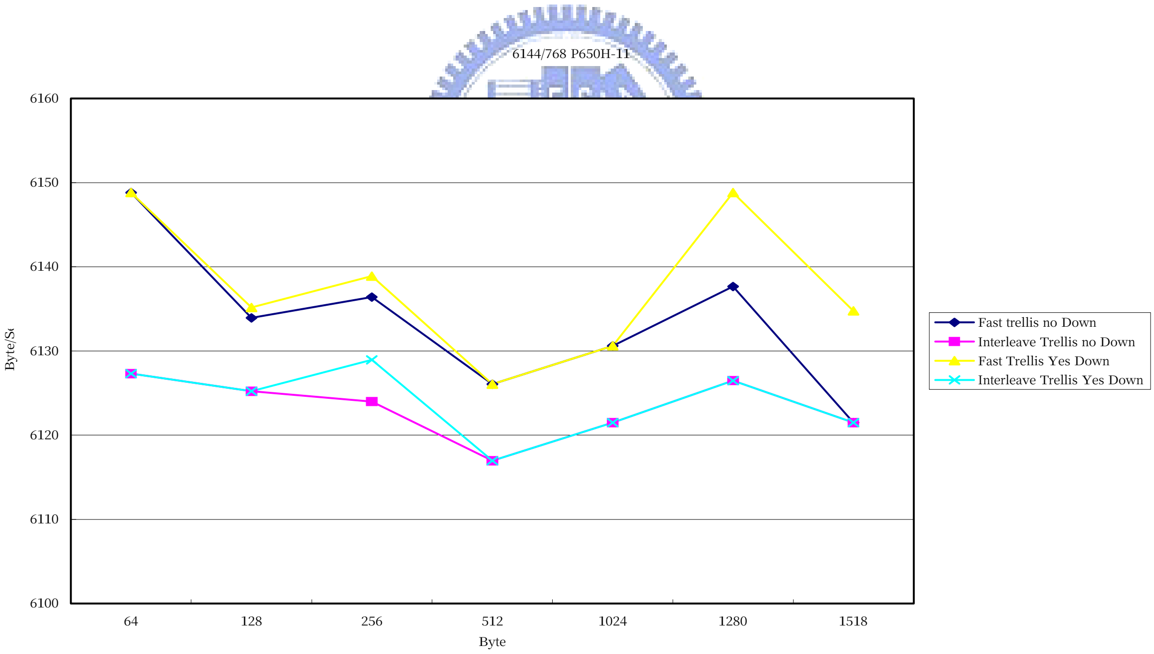

Figure 11 P650H-11 VS. Stinger 6144/768 Kbps Downstream Throughput

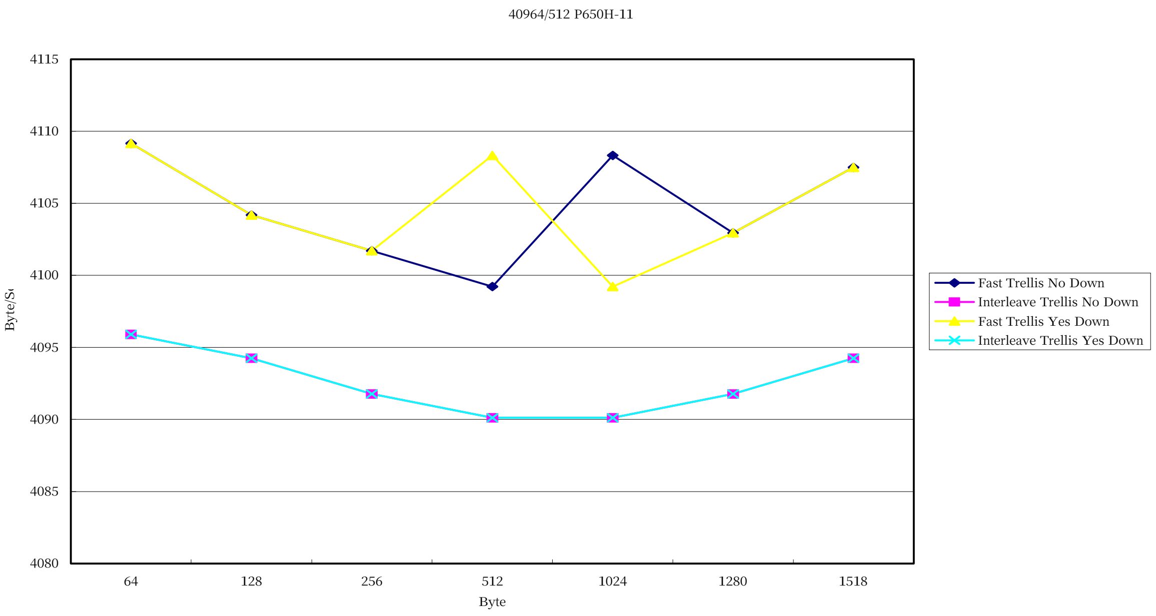

Figure 12 P650H-11 VS. Stinger 4096/512 Kbps Downstream Throughput

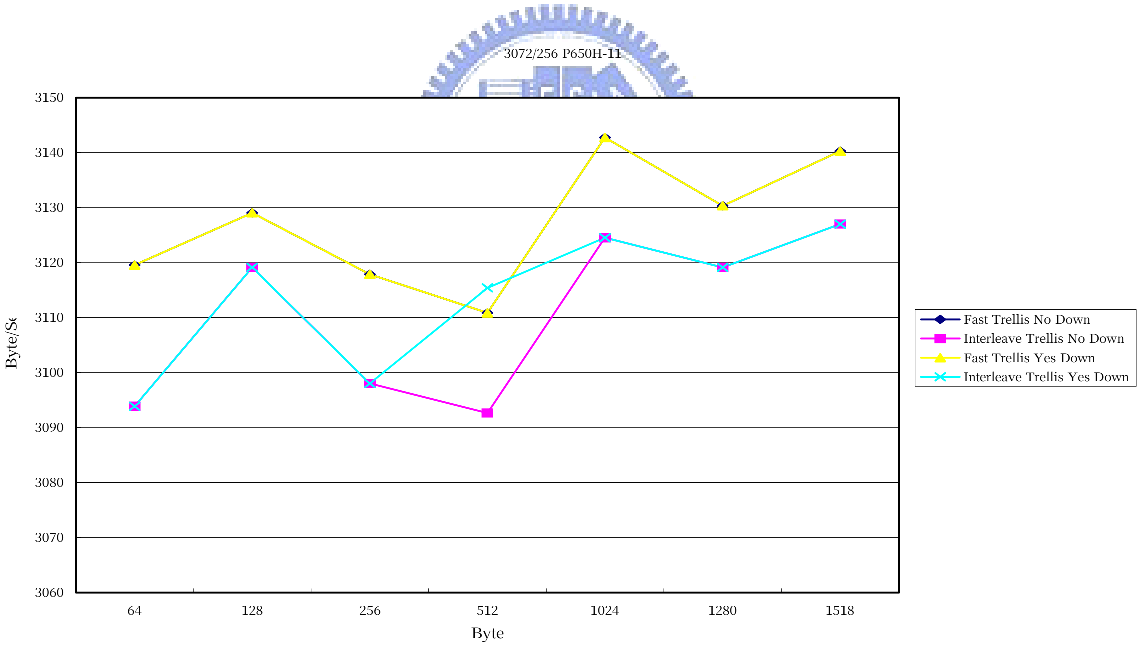

Figure 13 P650H-11 VS. Stinger 3072/256Kbps Downstream Throughput

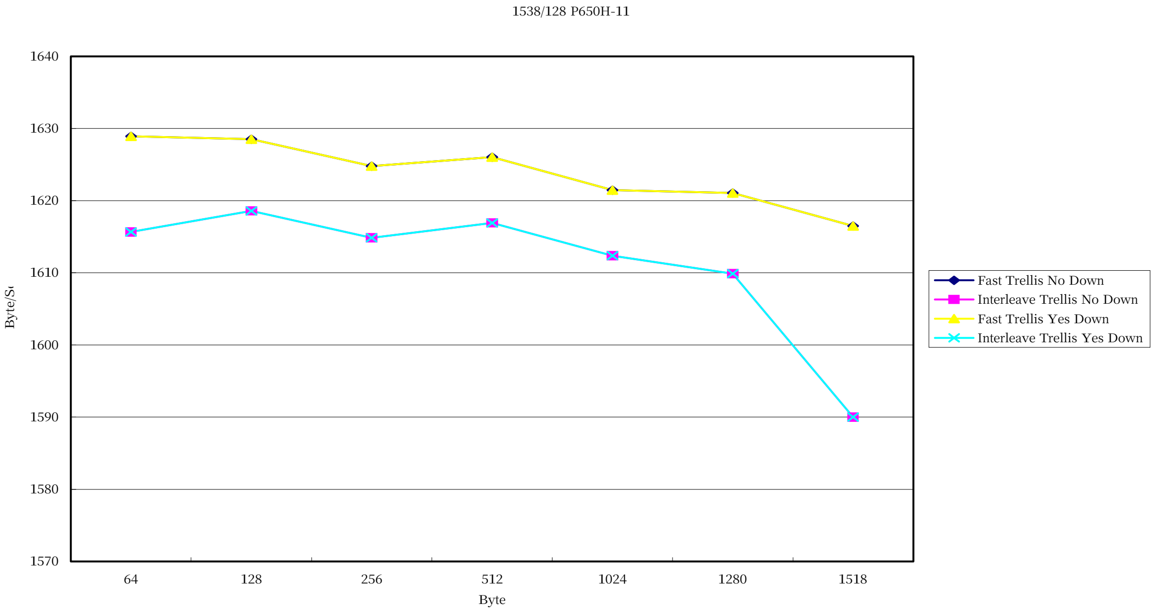

Figure 14 P650H-11 VS. Stinger 1536/128Kbps Downstream Throughput

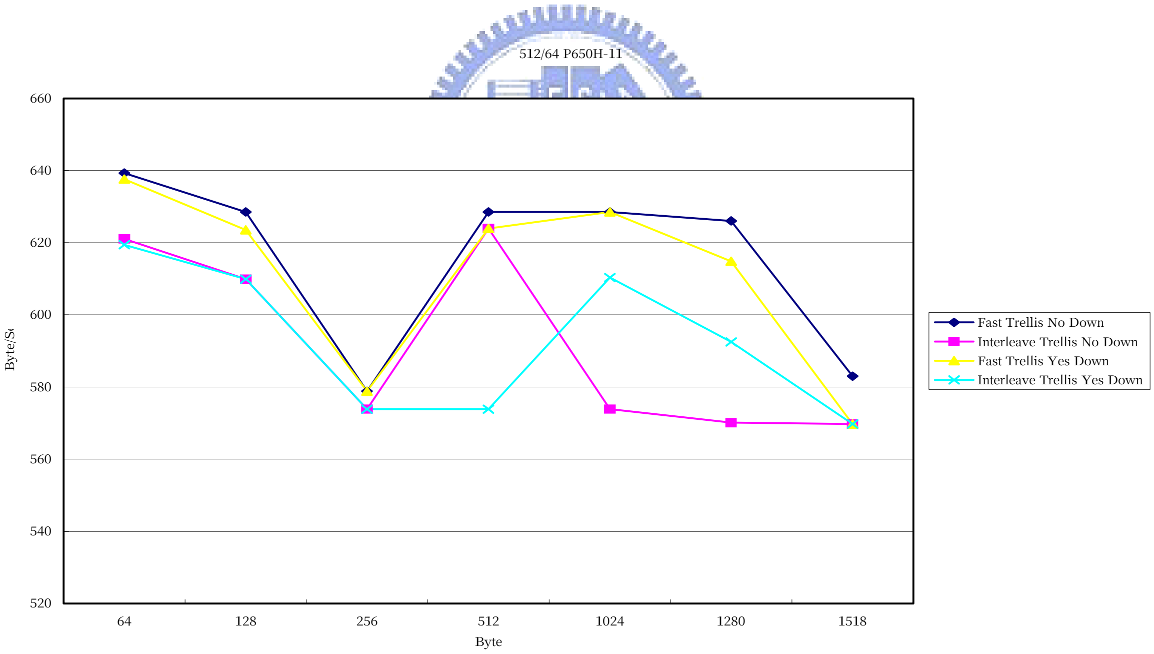

Figure 15 P650H-11 VS. Stinger 512/64Kbps Downstream Throughput

Figure 16 to 21 illustrate the upstream throughput that ADSL connected to Stinger DSLAM at line rate of 7616/800, 6144/768, 4096/512, 3072/256, 1536/512 and 512/64 kbps line rate. In these figures, please note that the x-axis denotes variable packet size as following: 64, 128, 256, 512, 1024, 1280 and 1518 byte, and the y-axis denotes the value of pass through packet size per second of test items. Each figure illustrates four test items result. Those test items include interleave/trellis on, interleave/trellis off, fast/trellis on and fast/trellis off. Appendix A table 2-7 shows detail numerical result for reference

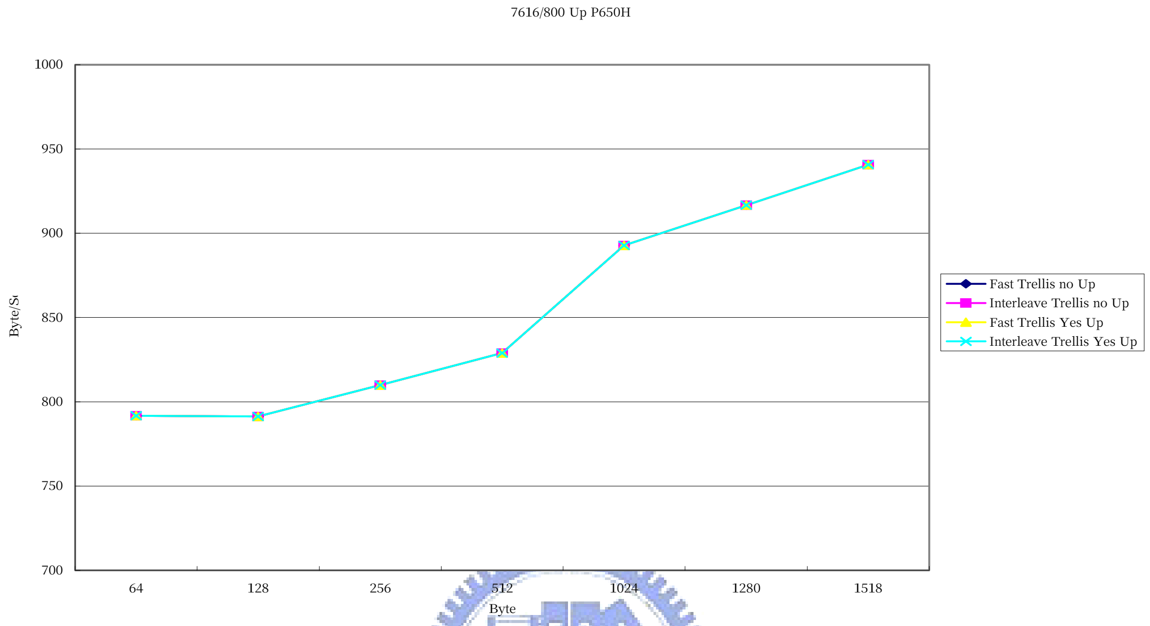

Figure 16 P650H-11 VS. Stinger 7616/800 Kbps Upstream Throughput

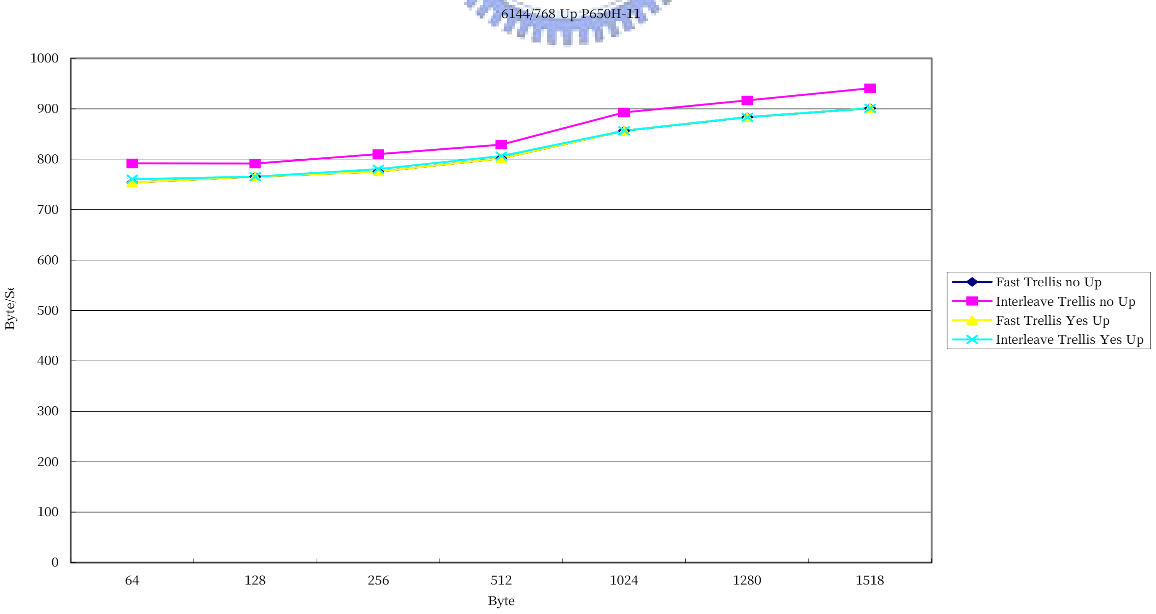

Figure 17 P650H-11 VS. Stinger 6144/768 Kbps Upstream Throughput

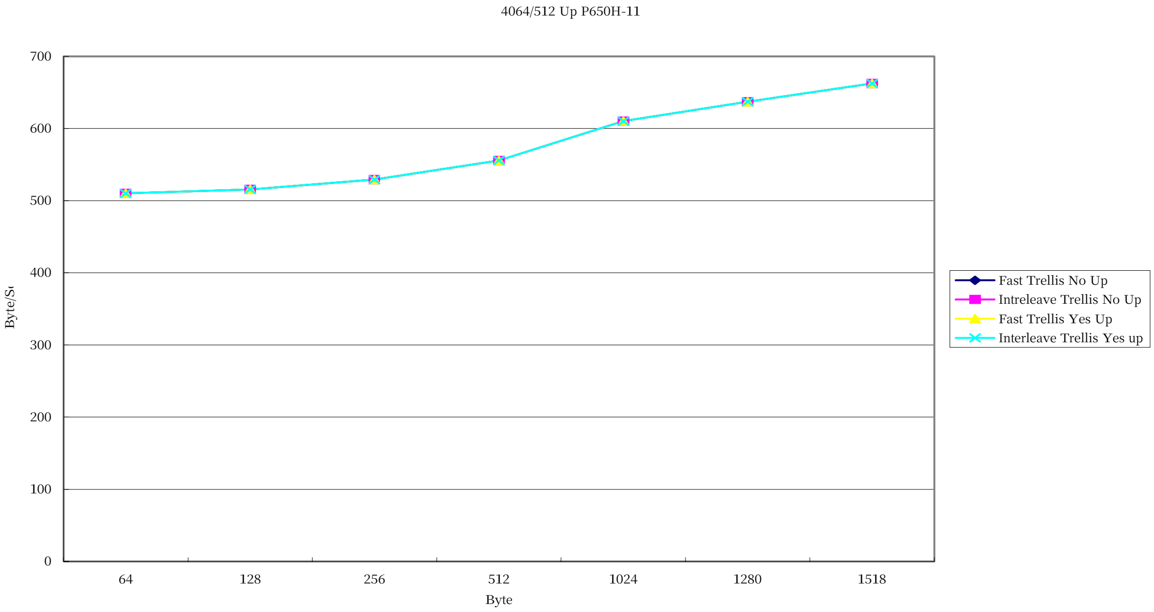

Figure 18 P650H-11 VS. Stinger 4096/512 Kbps Upstream Throughput

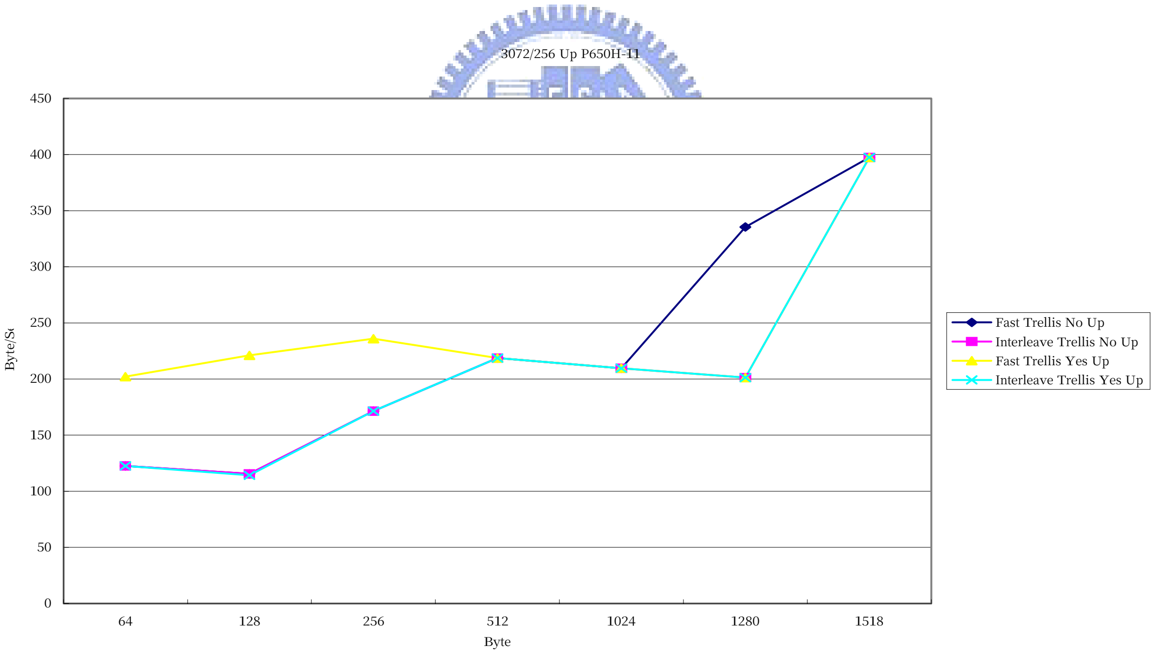

Figure 19 P650H-11 VS. Stinger 3072/256Kbps Upstream Throughput

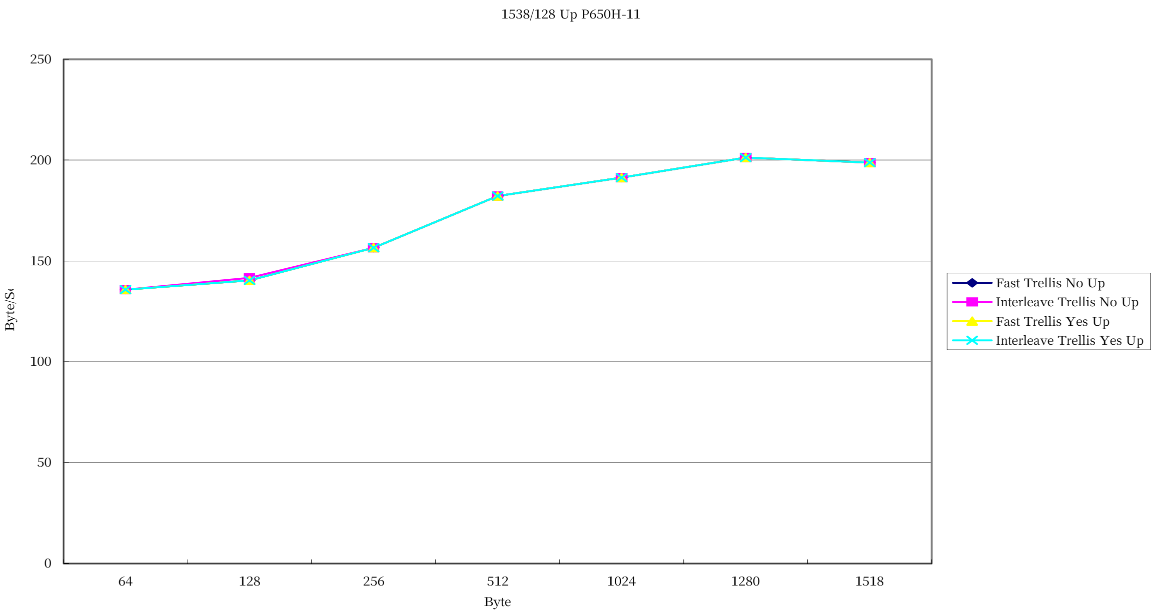

Figure 20 P650H-11 VS. Stinger 1536/128Kbps Upstream Throughput

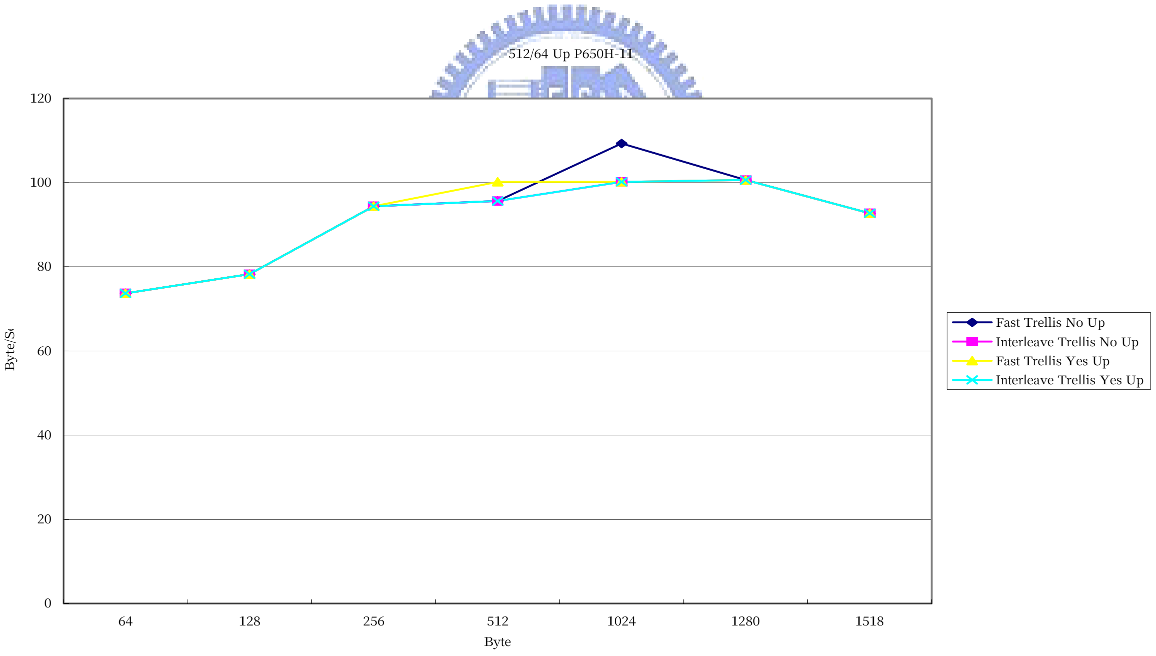

Figure 21 P650H-11 VS. Stinger 512/64Kbps Upstream Throughput

Figure 10-21 illustrates six downstream and six upstream link rate performance involving four situations. Generally, the fast mode throughput outperforms the interleave mode in for downstream situation. Moreover whether the trellis code is on or off does not influence the throughput. Thus the throughput data is similar regardless of whether the trellis encoding is enabled or disabled. Thus, this test result indicates interleave mode has do extra interleave and de-interleave on traffis sending and receiving caused the throughput worse that fast mode. However, trellis code enable has more algorithm to modulation the frame when data transmission. The effect of performance can not be observed based on this experiment. Due to that is application layer test. These test result figures also indicated two problems. First, although the though fast mode has better performance than interleave mode, sometimes the performance becomes unstable. The unstable performance problem may be a transmission error and cannot be recovered. If frame has serial bit loss, the system can not recovered automatically causing poor throughput compared to be interleave mode. Second, the curve is not so smooth when the link rate is low (like 512/64). This situation that more law rate is more clearly. The following are suspected to be causes for this situation. First one is characteristic of ADSL. Because of ADSL uses less bearer channel when the link rate is low. The fewer bearer channels can not guarantee the transmission quality. Second, test equipment limitations mean that the same data throughput in situation with low link rate. And it appeared the performance unstable problem. Regarding upstream throughput, some rules cannot be indicated due to similarity and irregularity.

4.2 IP over ATM V.S IP over Ethernet

Figures 22-27 reveal that the throughput of ADSL connects to IP based DSLAM (IES-1000) and then connects to the ATM based DSLAM (Stinger) at 7616/800, 6144/768, 4096/512, 3072/256, 1536/128 and 512/32 link rate. In this figure, the x-axis shows variable packet sizes. The packet sizes are 64, 128, 256, 512, 1024, 1280 and 1518 byte, and the y-axis displays the value of pass through packet size per second. Each figure shows four test item results. These test result figures should have both downstream and upstream direction. Furthermore, ATU-R connects to IP based DSLAM and ATM based DSLAM. All test items tested performance under interleave mode and trellis no only. Appendix A table 8-13 shows detail numerical result for reference

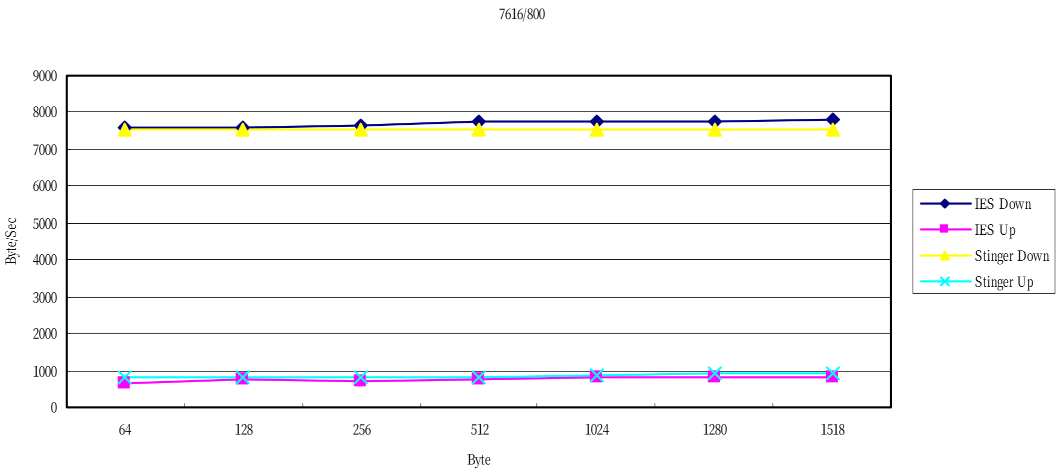

Figure 22 P650H-11 VS. Stinger & IES 7616/800Kbps Throughput

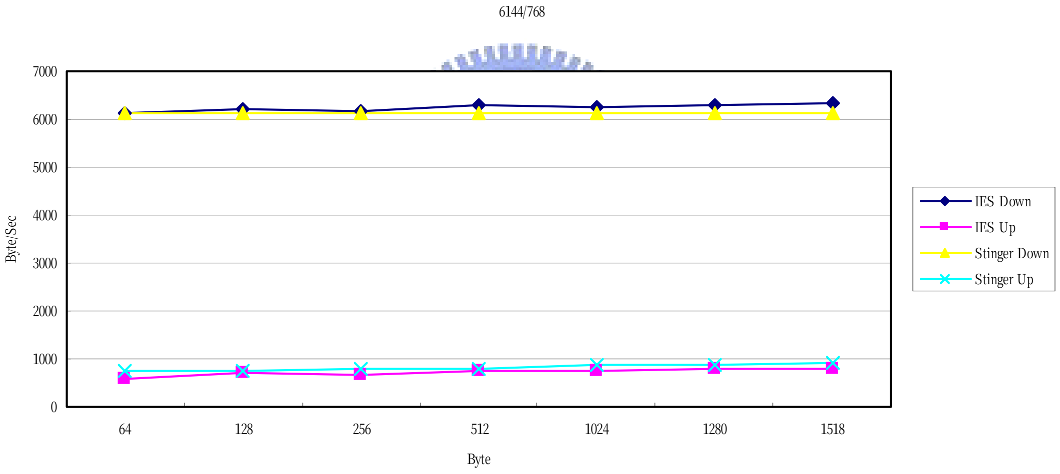

Figure 23 P650H-11 VS. Stinger & IES 6144/768Kbps Throughput

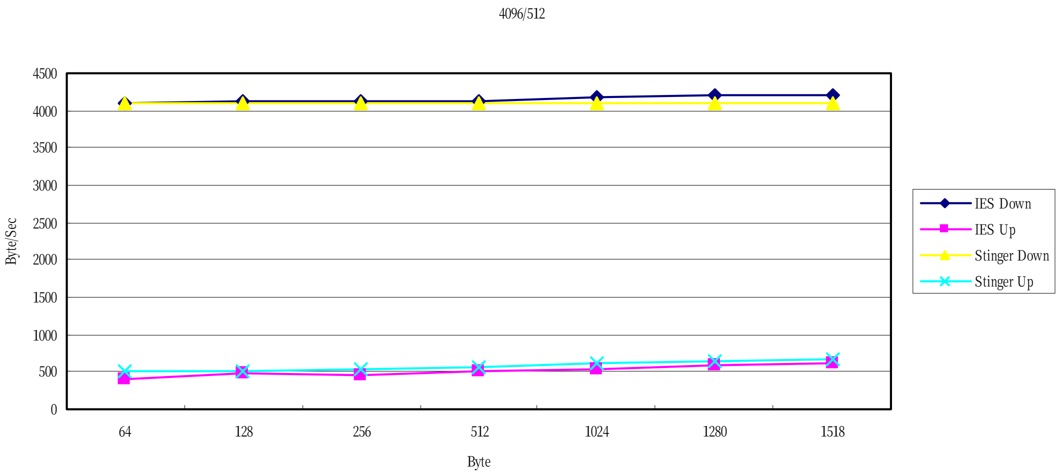

Figure 24 P650H-11 VS. Stinger & IES 4096/512Kbps Throughput

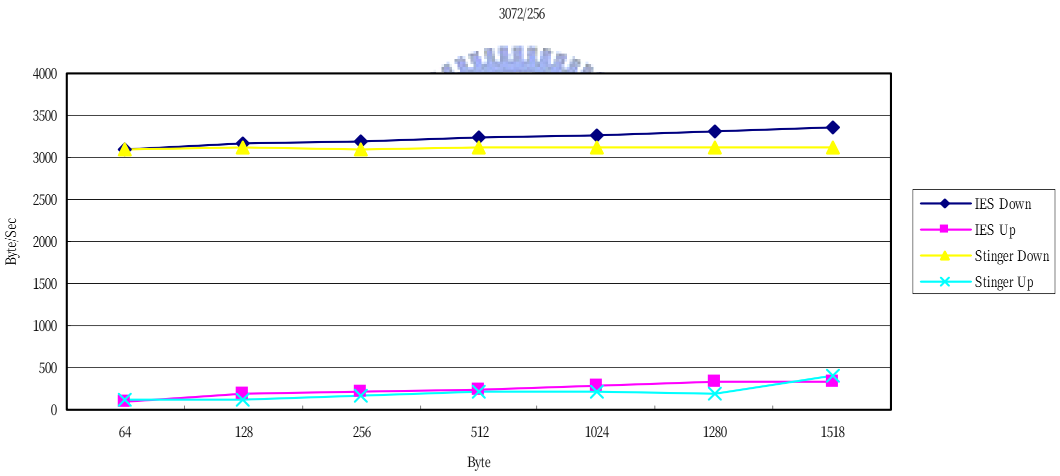

Figure 25 P650H-11 VS. Stinger & IES 3072/256Kbps Throughput

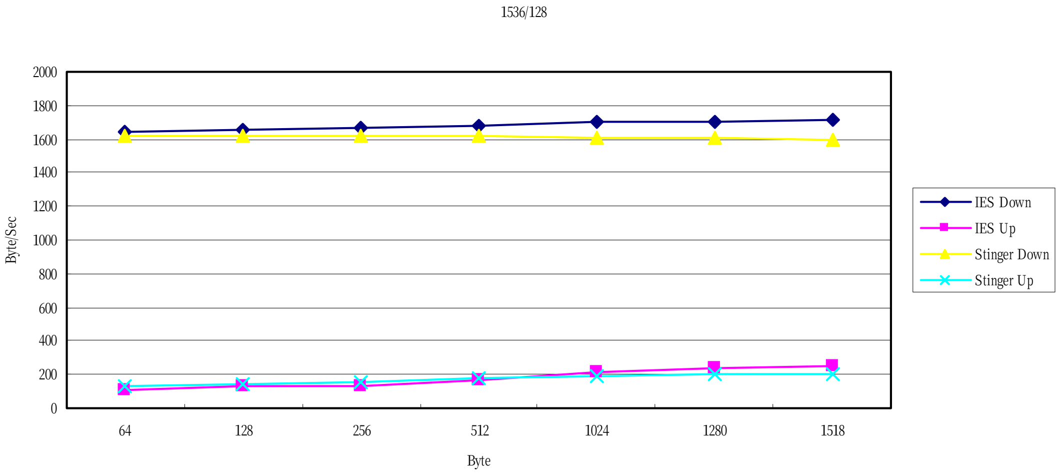

Figure 26 P650H-11 VS. Stinger & IES 1536/128Kbps Throughput

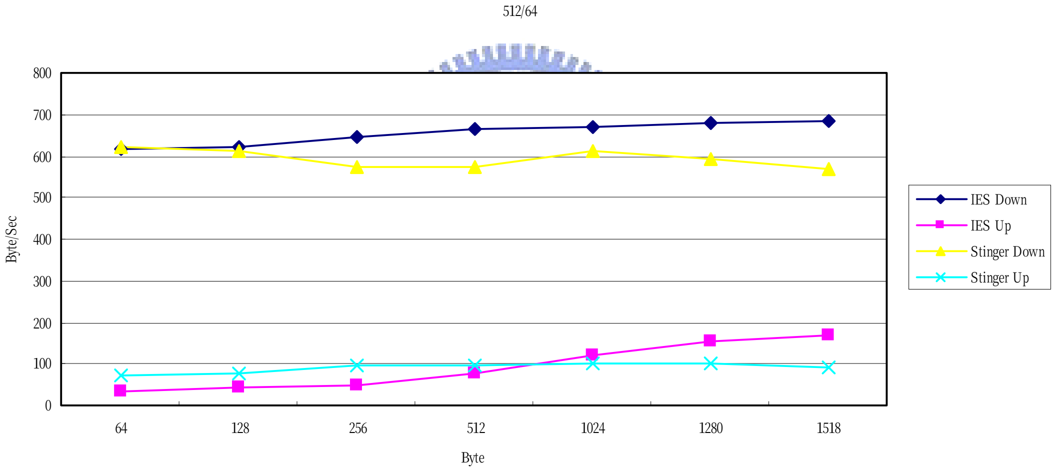

Figure 27 P650H-11 VS. Stinger & IES 512/64Kbps Throughput

Figures 22-27 illustrate that the performance of ADSL over IES is better than the performance of ADSL over ATM for each downstream link rate. The performance difference becomes especially large for large packet sizes. Because long packets require segmentation to 48 byte ATM cells for transmission the throughput performance must be affected. The test results revealed a 0.01% to 3% throughput gap between the IP based and ATM based DSLAM form small packet to large packets. However, a large throughput gap exists when link rate is low. This phenomenon should have two reasons for explanation. The reason same as test case 1. One is a characteristic of ADSL. Second one is test equipment limitations. Upstream throughput should display the same situation. However, the upstream performance display is not clear in the test figures.

4.3 Asymmetry Problem

Figure 28-31 illustrate the downstream throughput when IP over ATM bi-direction transmission under interleave/trellis no, interleave/trellis yes, fast/trellis no and fast/trellis yes situation. The figures display seven types of packet size throughput on each figure. Each figure displays 7616/800, 7616/512 and 7616/32 test result. Appendix A table 14-16 shows detail numerical result for reference

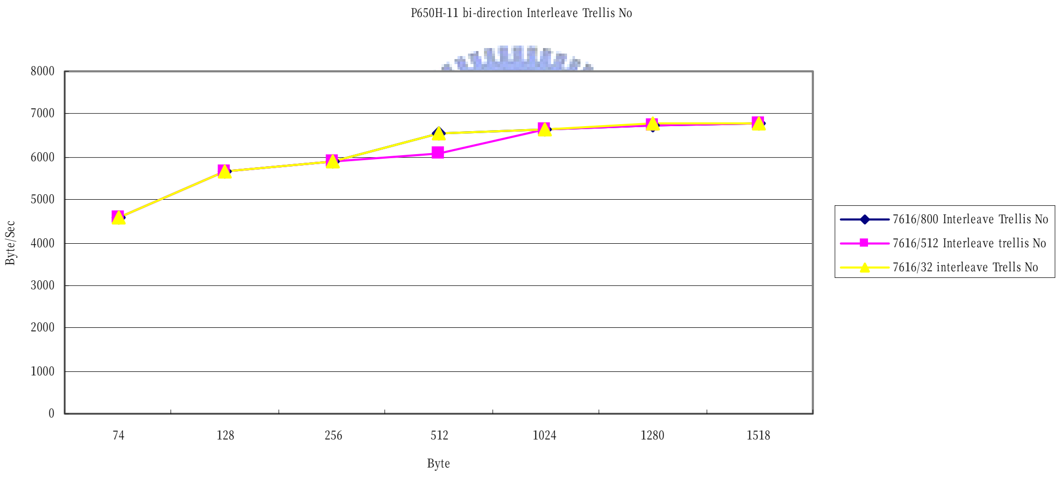

Figure 28 Interleave mode/ Trellis No bi-directional Throughput

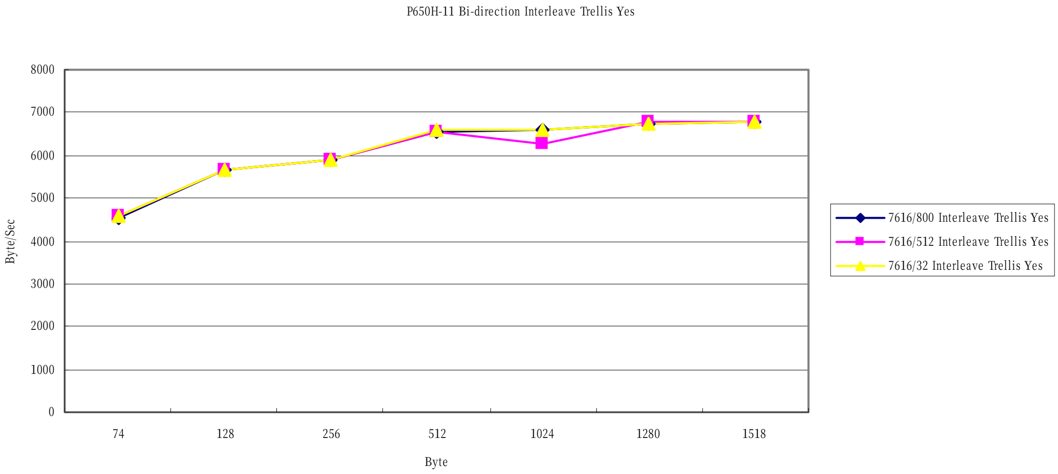

Figure 29 Interleave mode/ Trellis Yes bi-directional Throughput

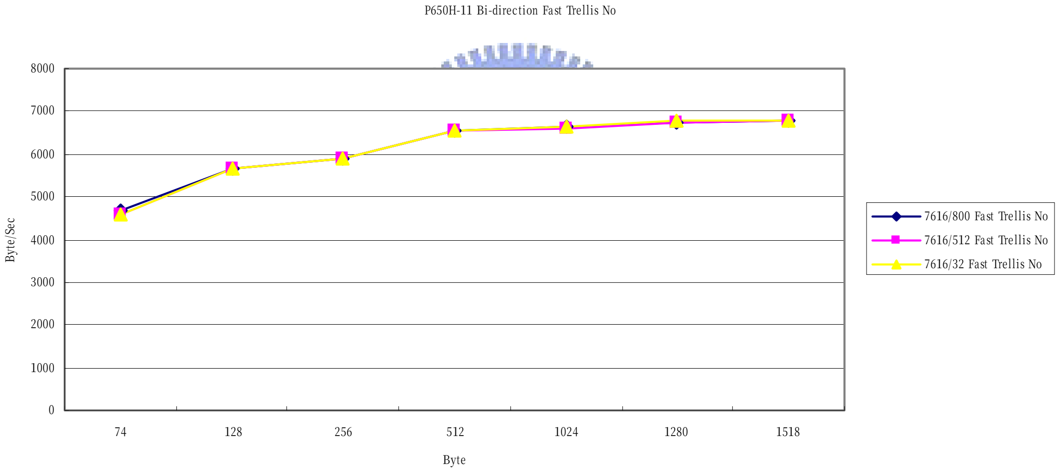

Figure 30 Fast mode/ Trellis No bi-directional Throughput

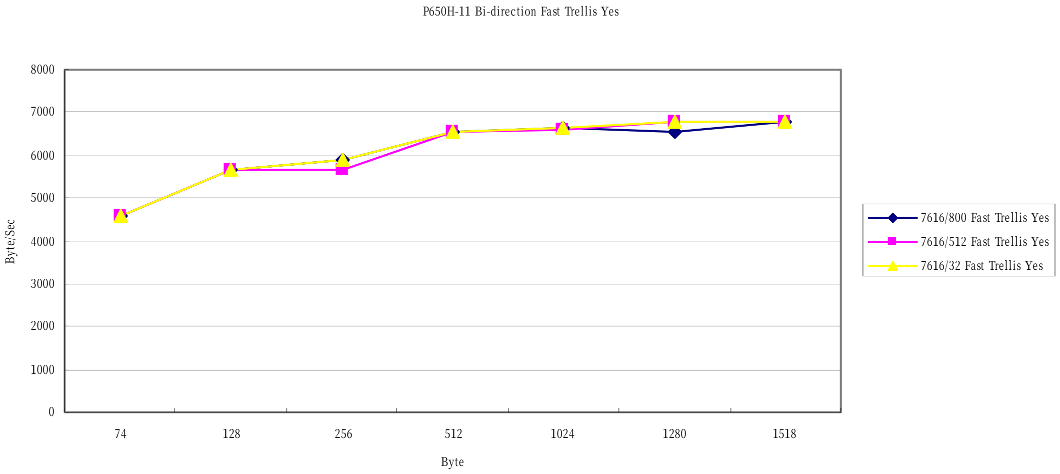

Figure 31 Fast mode/ Trellis Yes bi-directional Throughput

Figures 28-31 show that the 7616/800 achieves optimum performance in the bi-directional test case. Especially interleave mode/trellis no test item in the bi-directional test case. The test result indicates that upstream will reach the full rate and decade the downstream throughput on asymmetry network for ADSL. However, the same bearer channel must be used for bi-directional throughput. The owner upstream rate becomes a bottleneck of bi-direction transmission.

4.4 Real Line Model

Table 1 lists the FTP throughput with different encapsulations. This table includes PPP, PPPoE and RFC1483 encapsulation throughput performance. The table also illustrate the FTP throughput result under ATM based DSLAM and IP based DSALM. However, the PPPoA result under IP based DSALM is missed, due to test equipment limitations. The test result is a average value of three times test for each test item.

Table 1 Real Line Model Test Result

		PPPoA	PPPoE	RFC1483
ADSL+ATM DSLAM	Downstream	348.49	325.87	345.08
	Upstream	85.53	86.26	84.00
ADSL+IP DSLAM	Downstream	N/A	335.83	353.69
	Upstream	N/A	86.98	86.37

(kbps)

Table 1 reveals that the best downstream performance under ATN based DSLAM is RFC1483, followed by PPPoA andfinally PPPoE. This ordering is reasonable due to PPPoE having more overheads for encapsulation. For upstream performance, the ranking is PPPoE , PPPoA and RFC1483. The results are reversed for downstream. However, the data presented here is approximate only. Actuality the upstream performance is difficult to observe based on this test environment. Table 1 also reveals that the best downstream performance under Ethernet based DSLAM is RFC1483, PPPoE. The result also is reasonable for overheads due to PPPoE having more overheads for encapsulation than RFC1483. Both types of DSLAMs also has a 3% throughput gap. Appendix A table 18 shows detail numerical result for reference.

Chapter 5 Conclusion and Future Work

5.1 Conclusion

In this paper we have investigated the overhead affect the ADSL performance. We conducted four research issues. Firstly, we compare performances of IP over ATM and IP over Ethernet under four different situations. This test case can compare fast or interleave mode on traditional ADSL network. This test case also discusses the effect of the trellis encoding. We can see the fast mode performs better than interleave, because of fast mode lacks the frame scramble and de-scramble. But if large packet is lost, fast mode will not be recovered. The throughput will suddenly slow down. Though trellis code enable, the modulation and de-modulation need extra coding and de-coding, but we cannot see the different results from application layer's experiment. Secondly, we compare the performances with ADSL connection with Stinger (ATM based DSLAM) or IES 1000 (IP based DSLAM). The performance of IP over Ethernet also describes better result than the performance of IP over ATM. Due to Ethernet frame is larger than ATM cell. Thirdly, we discuss asymmetry problem. We test bi-direction throughput performance at 7616/800, 7616/512 and 7616/32 kbps link rate. We found the best downstream performance is at the 7616/800. That means upstream link rate is bottleneck of bi-direction throughput. So upstream rate is close to downstream rate the bi-direction throughput has the best result. Finally, we test the performance on physical ADSL environment using RFC1483, PPPoE and PPPoA Encapsulation. We know PPPoE has more overhead when its encapsulation and the RFC1483 has the less overhead. We also observe this behavior from this experiment regardless the result from IP over Ethernet or IP over Ethernet. Summary above test result, we get the overhead must affect the throughput performance. Normally it has 0.01% to 3% throughput gap between IP based and ATM based DSLAM.

To summary above test results, we got some overhead influence the ADSL throughput performance. The packets segmentation and assembly has the major influence. We can observe the problem, when we compare the throughput performance under ATM or IP DSALM. The maximum performance gap can reach 3 percents on large packet size. If we try to reduce link rate to 512/64 for downstream and upstream, the performance gap will reach to 10 percents. Next source of overhead is encapsulation’s header. PPPoE has maximum protocol stack layer. So PPPoE need add the most header when its encapsulations. RFC1483 has the best throughput performance due to less overhead than others encapsulation. Others source of overhead, including interleaveing, trellis encoding and LLC multiplexing. .Even though these factor influence the performance, the effect result is not clearly.

5.2 Future Work

ADSL is still a developing technology with numerous obstacles left to overcome before it can be implemented on a wide-scale basis. Telephone companies are still doing tremendous amounts of research to get ADSL to market as rapidly as possible to order to provide fast Internet access to user. ADSL 2 and ADSL 2+ provide faster and steady transmission rate. To research performance problem on new ADSL technology will be future issue. For asymmetry issue, we may compare with ADSL and G.SHDSL.

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Appendix A Test Numerical Result

This appendix shows the detail numerical result about this research. Table 2-7 displays the test result of test case 1. This test case tests throughput performance under four situations. The table reveals downstream and upstream throughput performance under six link rates.

Table 2 P650H-11 V.S. Stinger 7616/800 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	7567.4	7574.8	7572.3	7569.8	7569.8	7568.6	7565.7
Interleave Trellis No Down	7554.1	7564.9	7562.4	7560.7	7560.7	7557.4	7552.5
Fast Trellis Yes Down	7567.4	7574.8	7572.3	7569.8	7569.8	7568.6	7565.7
Interleave Trellis Yes Down	7554.1	7552.5	7562.4	7560.7	7560.7	7557.4	7552.5
Fast Trellis No Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7
Interleave Trellis No Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7
Fast Trellis Yes Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7
Interleave Trellis Yes Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7

(Kbps)

Table 3 P650H-11 V.S. Stinger 6144/768 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	6148.8	6133.9	6136.4	6126.0	6130.6	6137.6	6121.5
Interleave Trellis No Down	6127.2	6125.2	6096.6	6116.9	6121.5	6126.4	6121.5
Fast Trellis Yes Down	6148.8	6135.1	6138.8	6126.0	6130.6	6148.8	6134.7
Interleave Trellis Yes Down	6127.2	6125.2	6128.9	6116.9	6121.5	6126.4	6121.5
Fast Trellis No Up	753.5	765.1	775.1	801.6	856.2	883.1	901.0
Interleave Trellis No Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7
Fast Trellis Yes Up	753.9	765.1	775.1	801.6	856.2	883.1	901
Interleave Trellis Yes Up	760.2	765.1	780.0	806.1	856.2	883.1	901.0

(Kbps)

Table 4 P650H-11 V.S. Stinger 4096/512 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	4109.1	4104.1	4101.7	4099.2	4108.3	4102.9	4107.5
Interleave Trellis No Down	4695.9	4094.2	4091.7	4090.1	4090.1	4091.7	4094.2
Fast Trellis Yes Down	4109.1	4104.1	4101.7	4108.3	4099.2	4102.9	4107.5
Interleave Trellis Yes Down	4095.9	4094.2	4091.7	4090.1	4090.1	4091.7	4094.2
Fast Trellis No Up	510.1	515.5	529.1	555.6	610.3	637.2	662.5
Interleave Trellis No Up	510.1	515.5	529.1	555.6	610.3	637.2	662.5
Fast Trellis Yes Up	510.1	515.5	529.1	555.6	610.3	637.2	662.5
Interleave Trellis Yes Up	510.1	515.5	529.1	555.6	610.3	637.2	662.5

(Kbps)

Table 5 P650H-11 V.S. Stinger 3072/256 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	3119.5	3129.0	3117.8	3110.8	3142.7	3130.3	3140.2
Interleave Trellis No Down	3093.8	3119.1	3098.0	3092.6	3124.5	3119.1	3127.0
Fast Trellis Yes Down	3119.5	3129.0	3117.8	3110.8	3142.7	3130.3	3140.2
Interleave Trellis Yes Down	3093.8	3119.1	3098.0	3115.4	3124.5	3119.1	3127.0
Fast Trellis No Up	122.5	115.5	171.4	218.6	209.5	335.3	397.5
Interleave Trellis No Up	122.5	115.5	171.4	218.6	209.5	201.2	397.5
Fast Trellis Yes Up	202.0	221.1	236.0	218.6	209.5	201.2	397.5
Interleave Trellis Yes Up	122.5	114.2	171.4	218.6	209.5	201.2	397.5

(Kbps)

Table 6 P650H-11 V.S. Stinger 1536/128 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	1628.9	1628.5	1624.7	1626.0	1621.4	1621.0	1616.5
Interleave Trellis No Down	1615.6	1618.5	1614.8	1616.9	1612.0	1609.8	1590.0
Fast Trellis Yes Down	1628.9	1628.5	1624.7	1626.0	1621.4	1621.0	1616.5
Interleave Trellis Yes Down	1615.6	1618.5	1614.8	1616.9	1612.3	1609.8	1590.0
Fast Trellis No Up	135.8	140.3	156.5	182.1	191.2	201.2	198.7
Interleave Trellis No Up	135.8	141.6	156.5	182.1	191.2	201.2	198.7
Fast Trellis Yes Up	135.8	140.3	156.5	182.1	191.2	201.2	198.7
Interleave Trellis Yes Up	135.8	140.3	156.5	182.1	191.2	201.2	198.7

(Kbps)

Table 7 P650H-11 V.S. Stinger 512/64 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
Fast Trellis No Down	639.3	628.5	578.8	628.5	628.5	626.0	583.0
Interleave Trellis No Down	621.0	609.9	573.8	623.9	573.8	570.1	569.7
Fast Trellis Yes Down	637.6	623.5	578.8	623.9	628.5	614.8	569.7
Interleave Trellis Yes Down	619.4	609.9	573.8	573.8	610.3	592.5	569.7
Fast Trellis No Up	73.7	78.2	94.9	95.6	109.3	100.6	92.7
Interleave Trellis No Up	73.7	78.2	94.4	95.6	100.2	100.6	92.7
Fast Trellis Yes Up	73.7	78.2	94.4	100.2	100.2	100.6	92.7
Interleave Trellis Yes Up	73.7	78.2	94.4	95.6	100.2	100.6	92.7

(Kbps)

Table 8-13 displays the test result of test case 2. This test case tests the throughput performance under ATM and IP based DSLAM. The table reveals downstream and upstream throughput performance under six link rates

Table 8 P650H-11 V.S. Stinger & IES 7616/800 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	7567.8	7565.3	7639.5	7730.6	7748.4	7739.0	7810.1
Stinger Down	7554.1	7552.5	7562.4	7560.7	7560.7	7557.4	7552.5
IES Up	624.0	736.5	702.9	760.5	799.3	802.3	814.4
Stinger Up	791.6	791.2	809.9	828.9	892.7	916.7	940.7

(Kbps)

Table 9 P650H-11 V.S. Stinger & IES 6144/768 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	6128.7	6197.5	6175.5	6284.2	6255.8	6307.0	6344.2
Stinger Down	6127.2	4738.9	6128.9	6116.9	6121.5	6126.4	6121.5
IES Up	600.4	712.2	674.9	735.6	766.6	771.8	778.0
Stinger Up	760.2	765.1	780.0	806.1	856.2	883.1	901.0

(Kbps)

Table 10 P650H-11 V.S. Stinger & IES 4096/512 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	4108.1	4111.6	4118.4	4114.6	4184.1	4194.3	4194.3
Stinger Down	4095.9	4094.2	4091.7	4090.1	4090.1	4091.7	4094.2
IES Up	403.5	478.6	454.9	507.0	546.4	578.9	607.8
Stinger Up	510.1	515.5	529.1	555.6	610.3	637.2	662.5

(Kbps)

Table 11 P650H-11 V.S. Stinger & IES 3072/256 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	3103.4	3161.1	3186.9	3229.4	3262.5	3360.7	3364.3
Stinger Down	3093.8	3119.1	3098.0	3115.4	3124.5	3119.1	3127.0
IES Up	97.7	193.0	222.0	241.0	285.4	325.0	328.2
Stinger Up	122.5	114.2	171.4	218.6	209.5	201.2	397.5

(Kbps)

Table 12 P650H-11 V.S. Stinger & IES 1536/128 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	1640.6	1655.7	1664.6	1683.2	1696.5	1706.2	1718.2
Stinger Down	1615.6	1618.5	1614.8	1616.9	1612.3	1609.8	1590.0
IES Up	104.3	127.1	131.5	162.0	212.0	233.5	255.2
Stinger Up	135.8	140.3	156.5	182.1	191.2	201.1	198.7

(Kbps)

Table 13 P650H-11 V.S. Stinger & IES 512/64 Kbps Throughput Performance

	64	128	256	512	1024	1280	1518
IES Down	616.2	623.2	646.8	665.0	668.8	680.4	684.8
Stinger Down	619.4	609.9	573.8	573.8	610.3	592.5	569.7
IES Up	32.8	43.9	49.5	78.9	122.3	152.4	170.1
Stinger Up	73.7	78.2	94.4	95.6	100.2	100.6	92.7

(Kbps)

Table 14-16 displays the test result of test case 3. This test case tests bi-directional throughput performance on three ADSL link rate. The table reveals downstream performance at seven packet size

Table 14 7616/800 Kbps Bi-directional Transfer Downstream Throughput Performance

	64	128	256	512	1024	1280	1518
Interleave Trellis No	4595.7	5650.7	5888.2	6550.0	6622.6	6756.4	6779.9
Interleave Trellis Yes	4528.1	5648.8	5890.2	6565.4	6619.3	6756.4	6774.6
Fast Trellis No	4663.9	5659.2	5890.2	6546.0	6636.6	6756.4	6779.9
Fast Trellis Yes	4596.4	5649.8	5882.3	6549.3	6627.5	6562.4	6767.9

(Kbps)

Table 15 7616/512 Kbps Bi-directional Transfer Downstream Throughput Performance

	64	128	256	512	1024	1280	1518
Interleave Trellis No	4604.6	5650.7	5900.0	6084.0	6622.6	6759.7	6764.5
Interleave Trellis Yes	4604.4	5650.7	5890.2	6558.1	6246.2	6769.9	6767.9
Fast Trellis No	4595.4	5654.5	5883.3	6558.1	6619.3	6756.4	6790.1
Fast Trellis Yes	4603.3	5647.9	5678.7	6558.1	6619.3	6766.5	6767.9

(Kbps)

Table 16 7616/32 Kbps Bi-directional Transfer Downstream Throughput Performance

	64	128	256	512	1024	1280	1518
Interleave Trellis No	4597.7	5650.7	5889.2	6560.6	6620.8	6766.5	6779.9
Interleave Trellis Yes	4598.2	5659.2	5884.2	6616.2	6617.8	6756.4	6778.4
Fast Trellis No	4593.1	5649.8	5890.1	6554.1	6620.8	6766.5	6779.5
Fast Trellis Yes	4598.2	5656.4	5895.1	6560.6	6627.5	6766.5	6767.9

(Kbps)

Table 17 display the result of test case 4. This test case tested throughput on ADSL real Line via Hinet. The table shows PPPoA, PPPoE and RFC1483 test result under ATM and IP based DSLAM.

Table 17 Real Line Model Full Test Result

		PPPoA	PPPoE	RFC1483
ADSL+ATM DSLAM	Downstream	350.8	324.8	347.3
		347.3	321.8	347.3
		347.3	330.9	340.5
	Upstream	87.2	86.1	86.4
		82.2	86.1	83.3
		87.0	86.4	82.2
ADSL+IP DSLAM	Downstream	N/A	332.2	352.1
			338.9	355.3
			336.3	353.6
	Upstream	N/A	86.2	87.4
			87.1	87.3
			87.5	84.3

(kbps)