

## IP OVER DIRECT LINKS (SONET)

### ABSTRACT

The explosive growth of internet traffic, especially data traffic from late 90's and currently due to the rapid and widespread success of mobile broadband services created the need to transport IP on high-speed links. In the days of low traffic volume between IP routers, bandwidth partitions over a common interface made it attractive to carry IP over a frame relay and/or an ATM (Asynchronous Transfer Mode) backbone. The ATM appeared to be the only viable method of aggregating voice and data traffic on very high speed multiservice networks. But new approach of IP over SONET also called packet over SONET (POS) offers a backbone architecture that protects investments in SONET infrastructure and supports the deployment of IP-based video and voice applications. This position paper describes the views and counter views of considering IP directly over SONET by removal of ATM or IP over ATM as it is in many networks. This paper takes the position of removing the ATM layer from the networking stack and running IP directly over SONET for backbone and Wide Area Networks (WAN), Metropolitan Area Networks (MAN).

### 1. INTRODUCTION

ATM (Asynchronous Transfer Mode) is a standards-based multiplexing and switching technology used to deliver multimedia services over broadband networks. It uses fixed length cells and virtual circuits (VCs) to transport data, voice and video traffic in a rapid manner while providing deterministic behavior between endpoints in the network. The ATM technology is being used for quite some time as it has the advantages like providing multimedia transport services. It uses VCs to set up an end-to-end data path for which a QoS (Quality of Service)

can be guaranteed in a deterministic fashion. Also, ATM switches interpret cell headers on the fly, using embedded information to route traffic efficiently through the switching fabric. This dynamic method of path determination provides scalability and network adaptability. These are the reasons why ATMs are considered viable solution for the increasing traffic needs in broadband networks.

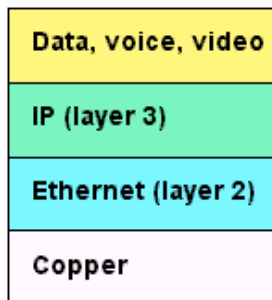
SONET (Synchronous Optical Network) is an American National Standards Institute (ANSI) standard (SONET's international equivalent is called the Synchronous Digital Hierarchy-SDH and is specified by International Telecommunication Union ITU-T) providing rates, formats, and optical parameter specifications for optical interfaces ranging from 51 Mb/s (OC-1) to 9.8 Gb/s (OC-192) capacities. SONET is typically used as the bearer layer for higher layer protocols such as ATM, employed on devices that switch or route traffic to a particular end point. SONET achieves rapid point to point transport of data with little overhead. It has highly survivable/reliable networking because of standardized protection switching architectures. It achieves multivendor internetworking and interoperability because of mature standards.

Even though ATM is widely in use, for IP backbone networks, internet service providers (ISPs) are increasingly turning to IP directly over SONET technology. The main reason given by most ISPs is that they cannot afford the ATM overhead "cell tax". It is also well known that using ATM to transport IP adds to a 10 percent ATM "cell tax" because of the overhead of the ATM header; however, that overhead percentage fails to take into account the distribution of packet sizes. Some traffic studies have shown that nearly half of all the packets are 40 or 44 bytes [4]. Neither size can be encapsulated into a single ATM cell using the IP

over ATM mapping described in Internet Engineering Task Force (IETF) Request For Comments (RFC) 1483 [5].

There is much more to this debate than overhead efficiency. In particular, carrying IP directly over SONET uses up the whole link bandwidth for traffic between a pair of routers even when the traffic volume requires only fraction of it. ATM proponents say that because the technology is circuit switched and offers quality of service (QoS), it can more reliably deliver voice, video and other time sensitive packets. Rest of the paper describes two positions and then tries to strengthen the argument that IP over SONET (Packet over SONET- POS) implementation surpasses the IP over ATM technology.

#### LAN



#### WAN

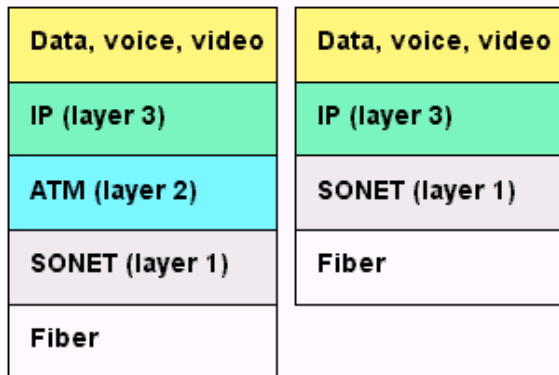


Fig 1: In a LAN, IP generally runs over Ethernet. In a WAN, it typically is transported by ATM, which rides over SONET, and increasingly, directly over SONET

## 2. ATM Viewpoint

Originally, ATM was conceived as a complete end-to-end replacement for all other technologies. It was expected by proponents to dominate in all three networking domains: desktop, backbone and wide area network. Cost and complexity defeated ATM to the desktop because of much cheaper Ethernet technology. However, ATM is widely used in the backbone networks and wide area networks because of its efficiency and most importantly the Quality of Service (QoS) it provides. Transporting IP over ATM has following advantages.

- ATM efficiently supports the aggregate transmission requirements of a network by allocating bandwidth on demand, as user needs. Network bandwidth is scalable to meet future user needs.
- ATM is highly flexible, accommodating a wide range of traffic types, traffic rates and communications applications.
- Quality of Service and reliability of data receiving for voice and multimedia data
- Using an IP over ATM network, the service provider has an opportunity to sell differentiated IP VPN (Virtual Private Network) services. Service provider can provision a VPN for an individual customer.

To run IP directly over SONET, a layer two protocol is needed and for this purpose PPP (Point to Point Protocol) defined by IETF in RFC 1619 is used. The biggest counter argument over POS is the inability of it to provide Quality of Service as that provided by IP over ATM when it was first being used. SONET alone with IP on top had some problems of reliability and security of bits passing through the network. Also the 7-bit SONET payload scrambler is not well suited for data transport required by POS. The implementation and enhancements provided to POS solved most of the associated

issues with it. The implementation details are provided in the next section.

### 3. SONET/SDH Implementation Details

The layer 2 protocol used by POS technology offers a standardized way of mapping IP packets into SONET/SDH payloads. Data is first segmented into IP datagram that includes a 20 byte IP header. This datagram is encapsulated via Point-to-Point Protocol (PPP) packets and framing information is added with High Level Data Link Control (HDLC) framing. HDLC framing is used to delineate the packet boundaries so that the receiver can extract them from SONET/SDH frame. The HDLC frame has 16 bit or 32 bit FCS, acting as a CRC checksum, protects the entire frame and gives an idea of traffic integrity. Some important implementation related details are described in subsections.

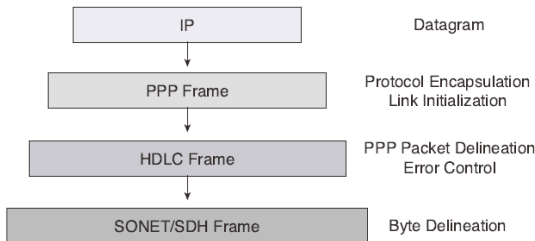


Fig 2: Encapsulating IP into a POS Frame

#### 3.1 Scrambling

Payload scrambling added through the hardware is transparent to the user and adds network stability. The addition of payload scrambling occurs when the HDLC framed PPP packets are inserted into SONET/SDH frame. POS scrambling ensures that a malicious user cannot bring the network down by sending pattern which result in SONET/SDH layer low-transition-density synchronization problems, emulating the SONET/SDH frame synchronous scrambler pattern, or replicating the SONET/SDH frame alignment word. POS uses the  $x^{43} + 1$  self synchronous scrambler to alleviate these potential security problems. Guessing the

correct pattern probability will be  $9e^{-16}$ . With internet traffic this level of security is crucial.

#### 3.2 Octet Stuffing and de-stuffing

Packets do not necessarily arrive at a router at fixed intervals. Indeed, the interval between packets varies depending on the volume and distribution of traffic between routers. The octet value 7E is used to indicate start and end of frame. In data if 7E occurs, an escape sequence 7D-5E is used to replace it. Entire process will be reversed at the receiver.

#### 3.3 POS Protection Scheme

POS uses the SONET APS (Automatic Protection Switching) 1+1 protection scheme. A failure in the SONET network that affects the customer's working path causes a failover at the client side. This failover time occurs under 50 ms in the SONET layer 1 network. The router interface uses keepalive to determine whether the other side of the connection is alive. SONET APS works at layer 1 providing switchover times significantly faster than any protocols operating at layer 2 or 3.

#### 3.4 Multi Protocol Label Switching

MPLS is a technology that provides additional functionality in IP over SONET/SDH implementations by appending labels onto each IP packet. These labels are associated with paths through the network and are used to specify traffic handling characteristics in order to guarantee Quality of Service (QoS) and Class of Service (CoS). The goal of MPLS is to take advantage of the higher bandwidth offered by IP over SONET/SDH, without the additional overhead of ATM. It provides public internet functions and enables routing equipment to setup a path through the network for a particular packet stream. The primary advantage of this implementation is to allow operators to increase the efficiency of their router networks, because a label is easier to switch than an IP packet is to

route. From Version 2 MPLS offers VPNs and some QoS guarantees.

#### 4. POS Advantages

As mentioned earlier, ISPs cannot afford the ATM overhead “cell tax” which is around 10% and the average ATM overhead across the entire distribution of packet sizes, seen in internet backbones today, is roughly 25%. By comparison, the IP over SONET overhead tax on same distributions is roughly 2%. Thus, ISPs planning IP over ATM backbones need to account for the 25% ATM cell tax when planning their networks. Another reason for mapping IP directly over SONET without the intervening ATM layer is the scalability of the solution. The ATM segmentation and reassembly (SAR) function becomes increasingly complex as the interface speed increases.

Moreover benefits of using IP over SONET/SDH technology are:

- Quality of Service and Class of Service achieved by MPLS
- Payload scrambling technique for the security and reliability of the data traffic using Automatic Protection Switching (APS)
- Bandwidth saving due to the use of channelization for interconnection
- Lower capital and operating costs by eliminating the intermediate SONET elements

With POS line cards, an ISP or enterprise network designer can scale speed of interconnecting SONET links without experiencing the overhead tax associated with other transmission methods.

It promises to offer significant advantages by providing efficient bandwidth usage, higher performance and greater simplicity. The most interesting feature of this technology is that it

leverages existing SONET infrastructure built for the ATM technology for data services. SONET’s widespread acceptance in high speed data transport lies partly in its ability to switch transport lines automatically (APS) when a problem is detected. The seamless traffic rerouting causes no noticeable data loss or service disruption on the network. From year 2000 till recently the POS has been deployed in many Wide Area and Metropolitan Area Networks. Cisco provides many SONET interface modules which are widely used which go till the highest OC-192c data speeds.

#### 5. Performance Study

Overhead efficiency is a critical topic for Service Providers that charge for the amount of bandwidth capacity customers use. ATM uses fixed-sized ATM cells of 53 bytes. Each cell’s composition includes 5 bytes of fixed overhead and 48 bytes of data. Also ATM Adaptation Layer decreases the usable bytes to only 44 bytes from the total of 53 bytes. SONET’s Transport Overhead (TOH) is 27 bytes and Path Overhead is 9 bytes which is total 4 % of the 810 byte STS frame. The figure illustrates the POS efficiency over ATM in both line graph and table, which compares efficiency based on packet size. SPE is Synchronous Payload Envelope which is used to transport a signal across the network.

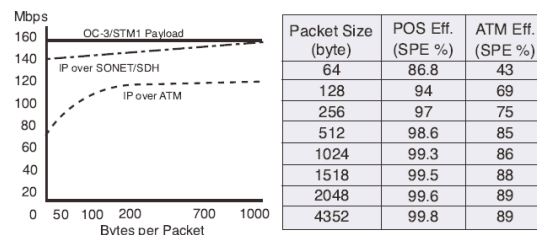


Fig 3: POS efficiency Compared to ATM

The next performance statistics are from the software package OPNET modeler used to

examine dynamic IP traffic over SONET using PPP and IP over ATM by Sam et al. [2]. The simulation was done on HTTP (data) and VoIP (voice) protocols using PPP and ATM in terms of throughput, link utilization and jitter. The simulation in the experiment may not be as per all the implementation standards now used for IP over SONET and so results may vary but it gives fair results to an extent.

### 5.1 Throughput

The IP/PPP/SONET packet end-to-end delay is lower than IP/ATM/SONET and therefore its throughput is higher as shown in figure 4. As for real time application like VoIP, throughput is higher for IP/ATM/SONET than IP/PPP/SONET.

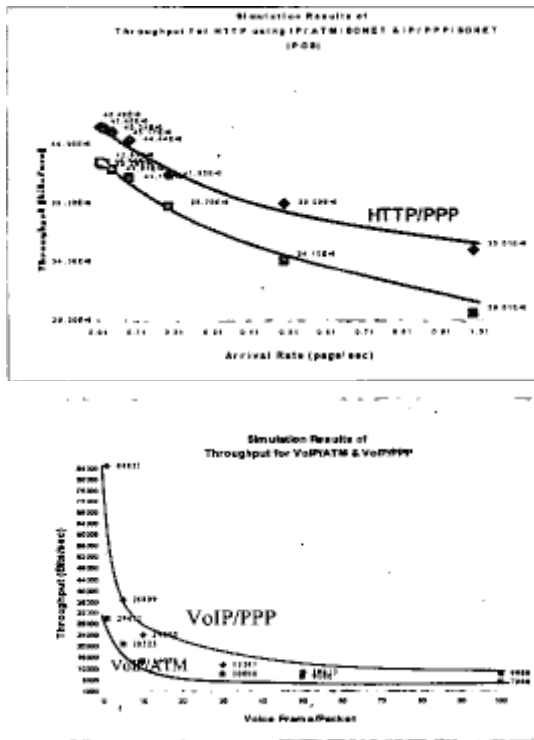


Fig 4: Throughput for IP/PPP/SONET and IP/ATM/SONET for HTTP (4a) and VoIP (4b) Application

### 5.2 Link Utilization

IP can achieve up to 95% of the available line rate when running over PPP compared to 80% of the available line rate when running over ATM. The difference is the overhead or cell tax required to support ATM.

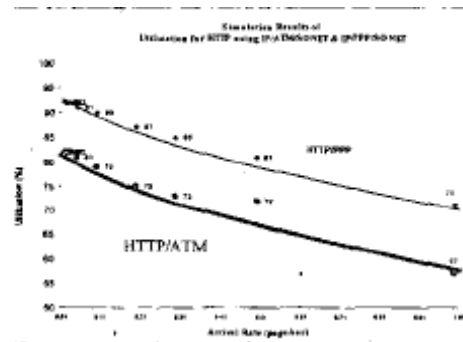


Fig 5: Link utilization for HTTP using IP/PPP/SONET and IP/ATM/SONET

### 5.3 Packet Delay Variation

The packet delay variation also known as jitter is found to be lower in IP/PPP/SONET in HTTP (non real time) application while higher in VoIP compared to IP/ATM/SONET as shown by the performance study.

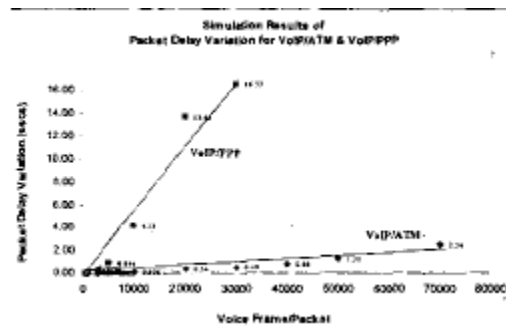


Fig 6: Packet Delay Variation for VoIP/PPP/SONET and VoIP/ATM/SONET

### 6. Conclusion

IP backbone providers are seeking expedient, cost-effective solutions for providing high-capacity interconnection between gigarouters. IP

over SONET (Packet over SONET) technology is a leading solution to this need. Apart from some flaws with early IP over SONET specification which have been fixed as described in implementation details, IP directly over SONET using HDLC provides robust, reliable, bandwidth efficient solution for the transport of IP. Currently this technology is widely in use in networks of service providers like GTE internetworking, Qwest, Sprint and UUNet in WAN and MAN implementations.

For future purposes, work is going on to introduce WDM (Wave Division Multiplexing) which will increase the overall capacity with maximizing the reuse and minimizing the life cycle cost of existing fiber facilities. It also allows multiple interface types on the same fiber (IP/ATM/SONET and IP/PPP/SONET).

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