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# High Speed Asynchronous Transfer Mode Communication

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## ABSTRACT

*With the rapid growth of Communication Technology, the need for very high speed error-free transportation of all types of traffic: voice, data and video information across long distance has gained tremendous momentum. Existing voice and data networks cannot provide a uniform communication methodology for all. This triggered evolution of Asynchronous Transfer Mode (ATM) of communication over Broadband Integrated Services Digital Network (B-ISDN). It provides very high bandwidth (over Optical Fiber Media) with extremely low error rates. An important aspect of ATM is that it allows for the Quality of Service provided by the network connection management program to be negotiated at the beginning of the connection establishment thus resulting in optimal resource sharing and the user paying as per the usage of resources. We also discuss about some recent technologies which are showing potential as cheaper alternative to ATM.*

## 1 Introduction

The demand for high speed error-free communication for various types of information e.g. Voice, Data and Video has increased manifold. Earlier, the basic communication fell into two categories:

Communication through Voice Networks: Telephone conversation is one of the fundamental user of these networks. Essentially these are designed to handle Constant Bit Rate (CBR) traffic and operate in a circuit switching mode through a dedicated path during the call duration, are delay sensitive but not loss sensitive. Voice Networks, in general, offer very limited bandwidth. Recent shift from Analog to Digital switches and increased available bandwidth through Fiber Optic Cable has improved the situation. Still, these do not improve the efficiency of non-voice traffic on these lines because of the need for multiplicity

of protocols. The user also often pays more by buying higher bandwidth for a less demanding need thus resulting in non-optimal usage of the network as well.

Communication through Data Networks: Local Area Networks and Wide Area Networks are typical examples of Data Networks. These types of networks are easy to design and are less expensive and handle Variable Bit Rate traffic for email, file transfer type of applications, are loss sensitive but not delay sensitive. It provides only a portion of the available bandwidth to each node, using shared media concept. This type of solution, though adequate for standard applications, falls far short of expectation when the user wants to use these for demanding applications. With the present day high-power desktop computers, it is easy to support full color images, complex 3-D graphics, full motion video, visualization, multimedia applications. These applications need far higher bandwidth than what is normally available, [1],[2],[3],[5].

## 2 Integrated and Broadband Integrated Services Digital Network (ISDN and B-ISDN)

The ISDN is a network, designed to support both voice and data in an integrated fashion. Initial provision was for two 64 Kbps data lines and one 16 Kbps Signaling line. As mentioned earlier, the projected need for communication speed and bandwidth exceeds the capability of ISDN manifold. B-ISDN is an extension of the same idea with a much higher speed of 155 Mbps (lower and higher speeds are also supported). This network is designed to carry voice, data and video traffic, supports both bursty and continuous traffic. The present speed (155 Mbps) is adequate for most of the applications mentioned, for now. The medium used for packet transportation is Optical Fiber which provides very high bandwidth with a very low error rate.

## 2.1 Transmission Modes

Synchronous Transfer Mode (STM): STM uses circuit switching technique, reserving a path during the call. Many channels are multiplexed onto a link. Data from different channels are sent through Time Division Multiplexing, bandwidth availability is in multiple of 64 kbps. STM can support real time, delay sensitive, high bandwidth applications. Here, bandwidth availability is in units of 64 kbps, hence a communication requirement of 10 kbps will unnecessarily pay more for the 64 kbps channel and the unused capacity will not be available to other users. For a large bandwidth (e.g. Gigabit) application, either it has to run on a 64 kbps line where too much time will be wasted else the data is spliced, sent over many (available) 64 kbps lines in parallel, and then put back together after resynchronization. In case of bursty data, the number of channels required will also vary.

Asynchronous Transfer Mode (ATM): Due to these problems, an alternative solution was sought. Asynchronous Transfer Mode of Communication using Packet Transfer Technology was found to provide a solution to the problems mentioned.

## 3 Asynchronous Transfer Mode (ATM) of Communication

So far we have discussed some of the problems involved in using the circuit switching mode for the high speed B-ISDN applications. The international body C.C.I.T.T. (Comite Consultatif Internationale de Telegraphic et Telephonique) looked into these points and then decided on the ATM as the transfer mode for the high speed B-ISDN applications, [4].

Why ATM: ATM technology merges voice, data and video data into a common format. It provides equally efficient service for all three types of traffic thus obviating the earlier problem of a service being optimal only for a particular type of traffic but not for all.

What is ATM: The ATM (Asynchronous Transfer Mode) is a packet switching technology which implements the B-ISDN communication equally efficiently for all three types of traffic. All types of data is segmented into fixed size cells. It is also used for high speed interconnection of existing Local Area Networks (LAN) and Wide Area Networks (WAN).

## 4 ATM Technology and its advantages

ATM Technology supports multiple types of traffic: Data, Voice and Video, employing small, fixed-size cells, cell switching and provides bandwidth-on-demand.

### 4.1 Cell Switching

ATM has fixed size cells having 53 bytes, 5 bytes of Header and 48 bytes of Data. As ATM cells are of small and fixed size, the Latency ( delay between Cell Transmissions) is reduced a lot in comparison to other types of traffic e.g. where packet size is typically several kilobytes in length. ATM has the advantage of sending Delay-Tolerant (Data) and Delay-Sensitive (Video and Voice) traffic together.

### 4.2 Scalable Architecture

ATM can operate between several Mbps (typically 25) to several Gbps (speed of up to 4.8 Gbps is being experimented and this upper limit is likely to go up) thus providing the user with great flexibility of choice. Users can only use the bandwidth they need which eliminates the problem of unnecessary bandwidth wastage. Economy is achieved with the elimination of unnecessary payment for not-required bandwidth in many cases.

### 4.3 Connection-Oriented Transmission and better Resource Allocation

ATM connection establishes a path between two stations. The Quality of Service (described later) which was asked for and was negotiated by the user is adhered to. This is in contrast to the LAN type communication where pre-establishment of a communicating path is not required. Here, the advantage lies in supporting aggregate demand of all the users by allocating bandwidth-on-demand. This process is governed automatically.

### 4.4 Simplified configuration and Management

ATM provides a uniform and simplified network management compared to other types of networks. Existing LAN and WAN are also supported by the ATM by creating LAN Emulation environment (LANE) where the LAN users get a ride on the fast ATM backbone but the users are insulated from the ATM protocol. This greatly saves the existing resources deployed in the LAN and WAN industry.

## 5 ATM Protocol

The ATM protocol can be best understood by looking at the Layer Structure on which the mode of ATM communication depends.

**ATM Adaptation Layer (AAL):** This layer is the interface between the higher layer protocols to the lower i.e. ATM Layer. While sending information from higher layers to the outside world, this layer segments the Data into ATM Cells. In the reverse direction, while receiving, it takes in the ATM cells and reassemble them into an appropriate format, understandable to the higher layer. It is also termed as Segmentation and Reassembly Layer (SAR).

**ATM Layer:** This is another interface layer which is in between the AAL and the physical layer. It helps in routing the cells to the proper destination. It also monitors the (a) The Rate of Transmission (Traffic Shaping) and (b) Conformance to the Service Contract (Traffic Policing).

**Physical Layer:** As ATM is not bound by any particular medium by definition, this layer is not pre-defined. But, for practical purposes, Optical Fiber is commonly used.

## 6 Basic Operations

### 6.1 Data Segmentation

In ATM, data is segmented into fixed size cells. One cell is 53 bytes long with the first 5 bytes corresponding to the header (required for routing). The remaining 48 bytes correspond to the user field.

The header contains the following fields :

1. VPI (Virtual Path Identifier) and VCI (Virtual Channel Identifier) fields: These fields act as tags to a particular link in the path taken by the all the cells corresponding to a traffic source, useful only for a specific connection.
2. Payload Type: This is a 3 bit field used to differentiate between user traffic and various forms of Operations, Administration and Management (OAM) traffic.
3. Cell Loss Priority (CLP) bit: This is the priority bit. If a cell's CLP bit is set, then the cell loses out to another cell whose CLP bit is not set, in case of contention for a network resource (such as a place in the buffer of a switch).

4. Header CRC: Any error in the header is likely to create a false routing of cells to a wrong destination or even loss of cells. To ensure more reliability to the Header field the last field in the header is reserved for the CRC which can be used to correct bit errors.

A subscriber is provided with access to link rates of 155 Mbps. Data from the traffic is segmented into cells and transmitted at 155 Mbps. A packet starts filling up with data at a rate depending on the traffic source. When a packet is filled it is transmitted. If the data source is bursty then the rate at which the packets fill will be arbitrary. The link is connected to a buffer to handle this problem.

### 6.2 Statistical Multiplexing

Several such subscriber lines, each terminating in a buffer are connected to a statistical multiplexer. Once a buffer is filled, a cell belonging to the buffer is selected for transmission. If several buffers are simultaneously full then a suitable contention resolution algorithm is used for the selection e.g. buffers corresponding to real time applications may be given preference as they are more delay-sensitive. This technique differs from ordinary multiplexing in the sense that empty buffers are not considered for transmission.

## 7 ATM Call Management

### 7.1 Call Set-Up

Before starting any information transfer, a connection between the nodes which carries the traffic is established. Signals are passed to the ATM network to set-up a connection and to negotiate the connection's parameters.

### 7.2 Routing

A 'virtual circuit' is maintained between the source end and the destination end of the traffic. All cells belonging to the same traffic source travel along the same route throughout the duration of the call. The word 'virtual' is used because the route is not reserved for that source. Traffic belonging to different sources can also make use of the intermediate links.

The route through the network is decided at call set-up time. Various routing algorithms may be used. A route is selected by one such algorithm. This is followed by the call set-up phase. The call is patched through

and the connection is made only if the network has enough resources to support the call. The VPI and VCI fields are allocated to the various links during this phase.

The VPI and VCI fields form a hierarchical set-up with the VPI tag used to refer to a number of channels to be routed together. A pair of the VPI and VCI fields have significance only for one link. These values are changed as the cell moves to another link. The concatenation of all such VPI and VCI fields is unique to a particular connection.

The translation of the VPI and VCI fields is done at every switch e.g. every intermediate nodes. A simple table look-up with the incoming VPI and VCI fields used as memory addresses and the outgoing VPI and VCI as the memory contents suffices for the task.

### 7.3 Quality of Service (QoS) Parameters

The whole idea of statistical multiplexing is to utilize the network resources efficiently. The channel resources are allocated dynamically and bandwidth is provided 'on demand'. The implications are that, if a user has variable bandwidth requirements they will be provided to him as and when required. The idea works on the premise that it is unlikely that all subscribers will require maximum bandwidth at the same time.

Proper management of the network is required for this idea to be viable. At the time of call set-up the user defines his Quality of Service requirements (e.g. maximum delay, acceptable loss probability etc.). The network allows the call to be patched through only if the resources available are sufficient to support the call. The resources demanded by a subscriber are measured using a set of parameters defined by the subscriber at the time of call set-up. These parameters could be variables such as maximum bit rate, average bit rate, maximum burst length etc.

If a call is set-up the user is expected to adhere to these parameters. He should not be allowed to violate them at will as this can have detrimental effect on the service provided to other more 'obedient' users.

This requires proper traffic policing and congestion control methods.

### 7.4 Traffic Policing

Traffic policing is generally based on some algorithm which monitors the user's traffic and takes corrective action in case of violation. All traffic that does not violate the QoS parameters is allowed to pass through without hitches. If there is a violation, cells are tagged and their priority is set low so that they are the first to

be dropped in case of contention with cells whose CLP bits have not been set.

### 7.5 Congestion Control

In spite of Traffic Policing many users may flood the network with demand for bandwidth which can choke the network. An automatic process exists which (a) discards cells where the CLP bits are set, (b) propagates the knowledge of congestion back to the clients whereby they can reduce their demand for resources or can reroute their traffic.

### 7.6 Call Termination

When the Data Transfer is completed, the ATM client again signals the network to inform that the traffic communication is complete and the Virtual Circuit is broken by removing the VPI/VCI entries from the in between nodes which were acting as switches.

## 8 Connection through ATM

**LAN Emulation:** There is a huge existing base of LAN (Local Area Network) and WAN (Wide Area Network) users all over the world. The purpose of LAN Emulation is to create an effective solution through which communication is possible through the ATM backbone where the ATM modalities are kept transparent from the users. Thus the LAN based clients keep using the existing LAN based protocols.

**IP over ATM:** It is possible to run IP (Internet Protocol) over ATM Networks either through LAN Emulation or through usage of modified IP implementation which directly runs over ATM.

## 9 Other Means of Fast Communication for Mixed Mode Traffic

The ATM protocol was designed for applications which run from Desktop Computers to Complex application e.g. large telephone switches. Relatively higher cost is detrimental for the lower spectrum user. Inexpensive frame relay, IP WANs and Gigabit Ethernet are the contenders which could replace or coexist with ATM solutions for the same type of applications. Eventually ATM is likely to be more useful to high-end users like phone companies who have spent lot of money and resources for ATM usage. The increasing speeds of frame relay along with new IP services e.g.

guaranteed bandwidth and voice over frame, are inching towards ATM's dominance as a public WAN service. Frame relay is based on IP addresses whereas ATM's addressing scheme is based on ISDN phone numbers. IP-based services at the local exchange carrier (offered by many Internet Service Providers, ISPs, coupled with new technologies to speed up packet services and to counter congestion) promises to preserve familiar IP addresses and routing protocols, [6], [7].

## 9.1 ATM and FRAME RELAY

ATM is no longer the only way to get a high-speed WAN connection. Frame relay is breaking through its T1 (1.544 Mbps) and T3 (45 Mbps) speed barriers. Serious laboratory testing is on for more rigorous testing to remove the kinks to bring out the product in the market.

The Internet Engineering Task Force (IETF) and the Frame Relay Forum have improved frame relay performance by adding some ATM-line features, including voice, guaranteed bandwidth, and flow control management. FRF.11, a standard for voice over frame relay, and a proposed scheme for a fragmentation implementation agreement outlining how to break frame relay frames into smaller frames will give frame relay even more ATM like capabilities making the Frame relay as a serious future contender to ATM. Moreover it is going to be possible to let customers or carriers specify the number of frames that could be discarded over a given time period, and provide an optimal service.

But for now, the high speed (155-Mbps) frame relay has a long way to go and the Frame Relay Forum group has not crossed the threshold of frame relay speeds beyond T3. Secondly, voice over frame relay is not yet ready for widespread use as voice communication performance degrades in case of peak traffic and congestion. Fragmentation will help frame relay reduce latency and deliver advanced services, even for video traffic. The proposed standard will not work with anything other than constant bit rate (CBR) for the time being for the Frame relay, while ATM provides data at a guaranteed rate with rigorous latency control.

## 9.2 ATM, IP, and QoS

The future WANs may depend on the modalities of providing priority service for critical traffic. The Resource Reservation Protocol (RSVP) relies on network devices (e.g. routers) making a best-effort attempt to deliver isochronous traffic, such as video. Simply prioritizing non-time sensitive packets that can still live with some latency could be an initial solution. ATM

specifies QoS classes with guarantee of end-to-end latency at a price. Once an ATM switch reaches its capacity of virtual circuits, the switch refuses additional connections, and routing must again restart to carry the excess traffic around the congestion.

Switched Virtual Circuit (SVC) service for ATM offers customers more flexible usage-based billing and are more affordable for lower usage customers than Permanent Virtual Circuits (PVCs). Interexchange Carrier (IXC) offers ATM SVC as a public service. IXCs are also widening their ATM pipes, from OC3 and OC12 today to OC48 in near future. This is one area where frame relay is lagging.

Both approaches have their merits with applications needing QoS. There has been an effort for improvement by not switching all traffic but by building faster routers. Maintaining the existing democratic routing hierarchy, which gracefully degrades service but does not deny it could be a meaningful option.

This, of course, leads to a dilemma of whether to go for ATM or for IP WAN. The present trend indicates that there will be a mixture of Frame relay and ATM. Frame relay lacks SVC type service, the ability of providers to charge the customers sensibly for it. It is very hard to count IP packets but it is easy to check the duration a circuit has been kept open by a customer. Effort is on for this to become a part of IP services, so Internet access can be metered instead of flat-rate. ATM has traffic management capabilities, segregation, and prioritization of traffic which is difficult to get done with IP alone. A good amount of Internet traffic, including frame relay, is carried across backbones in ATM cells today.

## 9.3 Gigabit Ethernet

Gigabit Ethernet, because of its relatively low cost and easy interface with existing Ethernet, will be adopted quicker than previous high-speed technologies like Asynchronous Transfer Mode (ATM) and the Gigabit Ethernet standard is being worked upon by the Gigabit Ethernet Consortium.

## 9.4 Capability of 100-Mbps Ethernet

Gigabit Ethernet-based solutions may be compared with 100-Mbps Ethernet. If Gigabit Ethernet cards for servers are tested, solutions such as the quad-fast ethernet adapter giving four 100 Mbps Ethernet ports on one card can be used with new trunking software, with an additional need for a 100-Mbps switch port for each connection. Similarly, another Fast Ether Channel technology connects switches, routers, and servers

with up to four 100 Mbps Ethernet links. One can aggregate the links or use them in redundant, parallel fashion. Upgradation of Ether Channel to support multiple Gigabit links is on the cards in the future. Price/performance is a big attraction of Gigabit Ethernet. Gigabit Ethernet often costs around four times more than 100 Mbps ethernet. If one can get four times the performance, lowered management and equipment costs e.g. fewer switch ports, it may make the jump worthwhile.

Performance improvement expected with Gigabit ethernet will not be proportional i.e. due to the limitations of most of present servers (e.g. CPU, bus, OS, and protocol stack), it is not possible to get 10 times the application throughput of the 100 Mbps ethernet. A gigabit ethernet connection on a relatively respectable server can deliver three to five times more TCP throughput than 100-Mbps Ethernet before the server CPU runs out of cycles.

Whether it is better to upgrade the server adapter to Gigabit ethernet or to go for a quad-fast ethernet card depends largely on the computation power of the server and also on the adapter used. A high-end server will be able to take better advantage of the gigabit card. Intelligent adapters, which off-load host processing functions such as TCP/IP checksum computation, can also maximize host CPU availability and increase throughput.

Performance varies tremendously from server to server, and only testing can give a realistic idea of what Gigabit Ethernet can really do for a set of applications. If the 100 Mbps Technology is used, it may be the case in real life that there is not enough traffic for the servers to justify Gigabit speeds, possibly multiple 100 Mbps links may serve the purpose for now. It is a question of waiting for an optimum cost/benefit ratio being reached at some stage of time as prices drop and the technology matures. On the other hand, with high-end servers, it is possible that Gigabit ethernet will speed things up, save money and simplify management, even if it delivers only half its nominal throughput.

## 10 Conclusion

Question of replacement of ATM equipment which is doing an adequate job with new and largely untested gigabit ethernet does not arise, yet. However, there are arguments for migrating toward a purer ethernet environment over the long run. Management will be simplified. Equipment that supports only ethernet will probably be much less expensive than equipment that supports ATM. In addition, translating ethernet frames

into ATM cells and back again increases the latency of the network. However, there are good arguments for sticking with ATM in the long run, too. Carriers are not offering gigabit ethernet WAN services yet. For now, ATM may be the best way to interface with the WAN. It could be good for now to integrate the existing ATM with Gigabit ethernet. The solution may involve switches, routers, multiplexers, and hubs that support both technologies.

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