JOURNAL OF INFORMATION, KNOWLEDGE AND RESEARCH IN ELECTRONICS AND COMMUNICATION

INVERSE MULTIPLEXING OVER ATM

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ABSTRACT*— *The growing demand of bandwidth users made, indicates that access to ATM networks is an important issue. The inverse multiplexing over ATM (IMA) is a technology that combines multiple links to create a single logical data trunk which bandwidth is aggregate of T1/E1 links (1.544Mbps/2.048Mbps) and T3/E3 links (44.736Mbps/34.368Mbps) minus a small amount due to overhead. The inverse multiplexing distributes traffic across multiple T1 circuits. The T1 lines acts as a single circuit rather than multiple separate circuits, this optimizes bandwidth. A round robin approach is used to distribute cells across lines it maintains the quality of service characteristics. Also, it is interesting to have expressions easy to compute that approximate the quality of service parameters of Inverse Multiplexers. This technology covers the gap between T1/E1 and T3/E3 bandwidth at a reasonable cost characterising multiple applications, thereby reducing the total cost of the accessing the network.

This paper details the IMA Operation, Applications, IMA protocol, Implementation of the IMA protocol and key concepts of inverse multiplexing over ATM.

I. INTRODUCTION

In a wide area network (WAN) established infrastructure, one of the main problems ATM network planners and users face, when greater than T1/E1 bandwidth is required, is the high cost associated to T3/E3 links. The technology to cover the gap between T1/E1 and T3/E3 bandwidth at reasonable cost is known as inverse multiplexing for ATM (IMA). IMA allows multiple T1/E1 lines to be aggregated to support the transparent transmission of ATM cells over one single virtual trunk.

In this paper, the fundamentals and major applications of IMA technology are described. Also, the behavior of IMA multiplexers is carefully analyzed and a method to dimension them proposed. For that purpose an IMA simulation tool has been developed, which permits the study of individual devices and the evaluation of the end-to-end performance of a logical trunk under several ATM input traffic patterns. The analytical study is based on the comparison with a M/D/C/(N+C) queue under Poisson input traffic.

The high speed services are accelerating the B-ISDN deployment to offer and integrate data, voice and video applications in a single network. This network is based on Asynchronous Transfer Mode (ATM) to handle any type of traffic efficiently. Inverse multiplexing over ATM defines the transparent transmission of high speed ATM cell stream over one logical link composed of several T1/E1 (1.544Mbps/2.048Mbps) links.

Inverse multiplexing (IMA) provides a means of access to ATM networks at rates between DS1/E1 and DS3/E3 levels (1.544 Mbps/2.048 Mbps to 44.736 Mbps/34.368 Mbps) by combining the bandwidth of multiple DS1/E1 links into groups that collectively provide higher intermediate rates. These multiple links are especially desirable in networks where DS3/E3 links are scarce.

IMA breaks up the ATM cell stream and distributes the cells over the multiple physical links of an IMA group (inverse multiplexing) and then recombines the cells into a single stream at the other end of the connection. The ATM cells are distributed in a round-robin fashion over the physical links of the IMA group, demultiplexed at the receiving IMA group, and passed in their original form to the ATM layer. Using the multiple links of an IMA group increases the logical link bandwidth to approximately the sum of the individual link rates.

IMA spreads out digital data cell by cell, optimizing the efficiency with which available bandwidth is utilized and preventing the occurrence of bottlenecks in a network. When additional bandwidth is needed, data streams can be added. Speeds of up to 1.2 gigabits per second (Gbps) are possible for individual customers, along with load sharing for guaranteed Quality of Service (QoS).

IMA can work with all types of physical transmission media including cable, fiber optic, satellite and plain old telephone service (POTS). Other features include fault tolerance and traffic consolidation, enhancing network reliability, reducing complexity and minimizing data redundancy.

The T1/E1 IMA features offer the following benefits:

- High-bandwidth performance at a lower cost than DS3 transmission facilities.
- Migration path to high bandwidth without the need to change transport facilities.
- Link recovery that passes cells from a failed IMA group link to the other IMA group links.

II. Objectives

Engineered around the IMA standard

- Full implementation of ATM capabilities for traffic management
- Complete fault tolerance capabilities, including self-monitoring and self-healing links

• Connectivity with legacy technologies
• A range of product offerings for locations of all sizes.

Local area networks are now being used to transport voice and video traffic together with traditional data traffic that they have already supported. And in the case of voice and video applications, not only is these is a need for more bandwidth, but there is also a need for guaranteed levels of receive because these applications are very sensitive to latency and delay.

Inverse multiplexing can be proved as technology that overcomes the bandwidth gap that exists between LAN and WAN. Inverse multiplexing is exactly the opposite of traditional multiplexing.

In traditional multiplexing, multiple streams of data are combined into one single but larger data pipe,
here as inverse multiplexing combines multiple circuits into single logical data pipe.

Asynchronous Transfer Mode (ATM) has compelling business as a WAN technology and is on a steep growth curve both in public carrier networks and in private organisations with requirements for networking video, voice and data traffic.

IMA divides an aggregate stream ATM cells across multiple WAN links on a cell by cell basis and hence the name inverse-multiplexing. In combination with ATM, IMA simplifies and reduces WAN cost of ownership.

Implementation Issues:

While in the implementation of the IMA there are various parameters are considered. Some of the issues are explained below.

• Inverse Multiplexing over ATM Data Cell Rate (IDCR)

IDCR is the rate at which IMA data cells should be exchanged between the IMA sub-layer and the ATM layer. This was one of the key issues in the ATM Forum Specification and one of the most difficult requirements to implement. It demanded fast and accurate algorithms that can only be implemented in hardware.

The accuracy of this real time calculation would impact the ATM traffic management and the CDV (Cell Delay Variation) through the physical layer. An integration period is used to count the cells arriving or departing through the reference link.

The number of cells is multiplied by the number of links in the group and used to request present cells to the ATM layer at the correct rate.

• Cell Delay Variation (CDV)

CDV is the difference between cell delays in two points of the network. This parameter is particularly important for CBR (Constant Bit Rate) traffic.

The ATM Forum specifies that this delay variation should be kept as low as possible by the IMA implementations.

• Compensating Differential Delays

Receiver links arrive with different delays that must be compensated for, in order to achieve the proper cell recombination. The ATM Forum specifies that any implementation must absorb at least 25 ms of differential delay between all the links. For some applications, 125 ms or more would be desirable.

This solution was well received by customers who welcome the flexibility of the solution and the amount of absorb able delay. A guard band delay is de-fined to help add links without disturbing traffic.

Faster links can be added at any time and Slower links can be added at any time if their recombination delays are positive (they fit in the existing guard band).

Features

The PA-A3-IMA has the following features:

1. Up to four IMA groups
2. Eight standard T1/E1 (1.544/2.048 Mbps) interfaces, with two integrated quad RJ-45 connectors
3. Inverse multiplexing over ATM
4. Up to 4096 total virtual connections (open VCs)
5. Mixed mode operation, with some links in User Network Interface (UNI) mode and the others in IMA groups
6. Maximum differential delay of 250 milliseconds for T1 and 190 milliseconds for E1 between the individual circuits that constitute part of an IMA group
7. Binary 8-zero substitution (B8ZS) line encoding for T1 and High-Density Bipolar (HDB3) line encoding for E1 in accordance with ATM UNI standards; also alternate mark inversion (AMI) line encoding for both T1 and E1
8. Super Frame (SF) and Extended Super Frame (ESF) framing for T1; and Basic Frame, Clear E1, and CCS-CRC framing for E1
9. Header Error Control (HEC)-based cell delineation for ATM framing
10. Facility Data Link (FDL) processing for T1
11. Selectable Tx clock sources for T1/E1 lines
12. Online insertion and removal (OIR)
13. VP shaping
14. IP-ATM class of service mapping
15. These QoS classes are UBR (unspecified bit rate), VBR (variable bit rate), ABR (available bit rate)

A. Abbreviations

IMA- inverse multiplexing over ATM
ATM- asynchronous transfer mode
WAN- wide area network
LAN- local area network

B. Figures and Tables

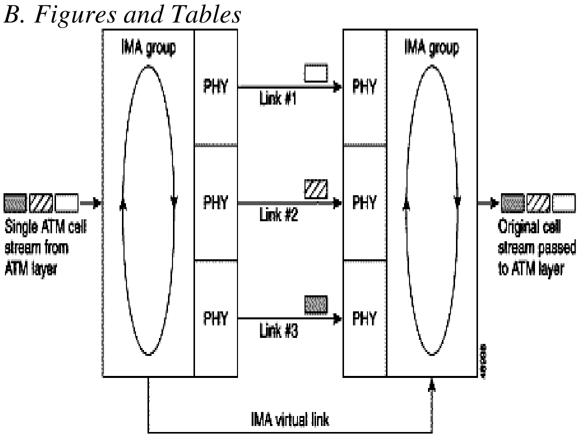

Figure IMA Inverse Multiplexing and Demultiplexing

TABLE 1 configuration commands and their purposes

	Command	**Purpose**
Step 1	DSLAM> **enable**	Enter enable mode.
Step 2	DSLAM# **configure terminal**	Enter global configuration mode. You have entered global configuration mode when the prompt changes to DSLAM (config)#.
Step 3	DSLAM(config)#**interface atm 0/2**	Enter interface configuration mode. You have entered interface configuration mode when the prompt changes to DSLAM (config-if)#.
Step 4	DSLAM(config-if)#**ima-group 2**	Assign the ATM interface to an IMA group (numbered from 0 to 3). After the interface is assigned to an IMA group, individual ATM functionality is no longer available on the link.
Step 5	DSLAM(config-if)#**no shutdown**	Enable the individual link by canceling the shutdownstate. Repeat Step 3 through Step 5 if your DSLAM has more than one interface that you need to configure.
Step 6	DSLAM (config-if) # **interface atm0/ima2**	Begin configuring the IMA interface.
Step 7	DSLAM(config-if)#**ima clock-mode independent**	Select the transmit clock mode for the selected IMAgroup.
Step 8	DSLAM(config-if)#**ima differential-delay-maximum 68**	Enter the maximum differential delay in milliseconds for the selected IMA group.
Step 9	DSLAM(config-if)#**ima active-links-minimum 2**	Enter the minimum number of links that need to be operational for the selected IMA group.
Step 10	DSLAM(config-if)#**no shutdown**	Enable the IMA group by canceling the shutdownstate.
Step 11	DSLAM(config-if)#**end**	When you finish configuring interfaces, return to enable mode.

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a. Sample of a table footnote. *(table footnote)*

Verifying the IMA Configuration

After configuring IMA interfaces, use the following commands to verify their operational status.

Table 2 commands to verify their operational status

	Command	**Purpose**
Step 1	DSLAM# **show interface atm0/ima2**	Displays interface configuration, status, and statistics for the IMA interface.
Step 2	DSLAM# **show controller atm0/ima2**	Displays diagnostic information for the specified IMA group.
Step 3	DSLAM# **show ima interface atm0/ima2**	Displays configuration information and operational status for the specified IMA group.
Step 4	DSLAM# **show ima interface atm0/2**	Displays information for a single link in an IMAgroup.

Advantages

- Transport of a single ATM cell stream at rates between T1/E1 and T3/E3, taking advantage of cost-effective bandwidth at sub-T3/E3 rates
- Provisioning of bandwidth in T1/E1 increments, which lets network planners increase or decrease bandwidth based on need
- Bandwidth consolidation across T1/E1 link groups, leading to more efficient use of Circuits
- Automatic and transparent adjustment to accommodate added/restored and deleted/failed T1/E1 links, minimizing provisioning and maintenance
- Transparent transport of the ATM layer and higher layers, which preserves cell order and ATM traffic management techniques and makes IMA compatible with the existing ATM architecture
- provides bandwidth-efficient transmission of low-rate
- Each IMA group can be configured with IMA Frame Length
- Inverse Multiplexing for ATM is a promising technology poised to enter the low-speed ATM interface ag-gressively.

CONCLUSIONS

- In this paper the inverse multiplexing over ATM and it's implementation issues, applications along with features and limitations are described. IMA comprising a promising solution for the bandwidth requirement lies at aggregate of low and high speed links.
- IMA represents a physical layer technology; therefore, it can be used to transport any service previous its adaptation to ATM cell format.
- To study the behaviour and evaluate the performance of IMA systems a flexible and object-oriented simulation tool has been developed. IMA multiplexer have been characterized and analysed under Poisson input traffic.
- CLR as a func-tion of the offered load and the number of output links has been investigated. The performance of the IMA system is studied aided by an IMUX simulator.

ACKNOWLEDGMENT

I would like to extend my gratitude towards my seminar guide **Dr. G. S. Sable** for his valuable guidance, support and scholarly advice imparted throughout this seminar report.

Also I am extremely thankful to our respected principal sir **Dr. U. B. Shinde** and HOD **Dr. G. S. Sable** for their motivation, inspiration and co-operation towards completion of our seminar report. Last but not least I am very grateful to our seminar co-ordinator **Prof. A. N. Shaikh** for his kind support.

I also thank all the other faculty members of Electronics department and my friends for their help and support.

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