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IMA: technical foundations, application and performance analysis

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Abstract

Using WAN established infrastructure, one of the main problems ATM network planners and users face, when greater than $T1/E1$ bandwidth is required, is the disproportionate cost associated with $T3/E3$ links. The technology to cover the gap between $T1/E1$ and $T3/E3$ bandwidth at a 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 this purpose, an IMA simulation tool has been developed. The IMA simulator 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 an $M/D/C/(N+C)$ queue system. Under Poisson input traffic, an approximation for the cell loss ratio (CLR) is derived and an estimate of the cell delay in an IMA multiplexer obtained. In addition, the suitability of these results for two types of bursty traffic is investigated. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The growing demand for high speed services is accelerating broadband integrated services digital network (B-ISDN) deployment to support conventional and new data, voice, video and multimedia applications in a single network. This network is based on the asynchronous transfer mode (ATM) to carry any type of traffic efficiently.

The dominant role of ATM in the LAN scenario is still unclear in comparison with other competing technologies such as switched Ethernet, Fast Ethernet and even Gigabit Ethernet. ATM is well introduced in the backbone area, especially in private corporate environments. Regarding WAN,

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network operators are first providing access to the ATM network using the existing infrastructure and then gradually deploying the new one, implementing pure ATM interfaces over it. Users, however, want the ATM bandwidth benefits for their high speed applications soon, but in a cost-effective manner.

Currently, there are basically two available options to provide access to the ATM services on a WAN scale. One consists of $T3/E3$ links offering considerable bandwidth (44.736/34.368 Mbps) but is usually not justified since it would be underutilized by most of the prospective users. Furthermore, the rates that carriers charge for them are very high. The other alternative is substantially cheaper and uses $T1/E1$ links (1.544/2.048 Mbps), but the offered bandwidth is insufficient for some user needs.

Prices depend on several factors such as distance and each particular carrier. As an example, the average cost per month of a 25 km $T1/E1$ link is \$850/\$2900, respectively, and \$7500/\$29,000 for a $T3/E3$ line of the same length [7]. However, in general, $T3/E3$ links have their point of presence and are only available in big cities [7,14]. Due to cost and availability of service, an intermediate solution offering enough bandwidth at a reasonable cost is required.

In July 1997, the ATM Forum published the inverse multiplexing for ATM specification, known as IMA [3], the last version of which was released in April 1999 [4]. IMA defines the transparent transmission of a high speed ATM cell stream over one logical link composed of several $T1/E1$ lines. IMA distributes and transfers a single flow of ATM layer cell traffic onto multiple physical links. At the remote end, the traffic is recombined and the original ATM cell sequence fully recovered and delivered to the higher layers that will further process it. Up to 32 $T1$ or $E1$ links can be used to form an IMA group that operates at an aggregated bit rate of some multiple of the $T1/E1$ speed. Up to 48/64 Mbps can be reached. These bit rates are enough to support many current user broadband applications requiring a fractional $T3/E3$ bit rate but using bandwidth more efficiently, and utilizing readily available and less expensive $T1/E1$ services.

The inverse multiplexer (IMUX) is the device responsible for grouping several $T1/E1$ physical circuits into a single logical trunk. An IMUX accepts ATM cell streams coming from different traffic sources, in addition to traffic coming directly from LANs (e.g., from a router without an ATM interface). This non-ATM traffic is adapted and converted to ATM cell format, using ATM layer segmentation and re-assembly functionality. In both cases, the IMUX distributes the resulting cells in round-robin fashion over the physical links maintaining the QoS required by each individual connection. To configure, control, maintain and synchronize the links belonging to an IMA group, the IMUX introduces two types of operation and maintenance (OAM) cells. That is, IMA control protocol (ICP) and Filler cells.

Thus, in this paper, the origins, application and technical foundations of inverse multiplexing are explained in tutorial style. Then, a model for an IMUX is presented and intensively evaluated. To perform the evaluation under different input traffic distributions an IMA system simulator was developed. The idea was to elaborate a methodology to help engineers and network planners to characterize and dimension an IMUX device, that is, to obtain the buffer size and the number of $T1/E1$ output links that guarantee the required QoS parameters demanded by users, basically measured as cell loss ratio (CLR) and average cell delay. An approximate analysis allowing easy computation of the IMUX performance was derived, obviating the need to perform costly simulations. The IMUX dimensioning study was conducted under Poisson input traffic. More realistic traffic patterns are also presented in this study. Due to their simplicity, we decided to use two models of bursty traffic instead of those described in other surveys [5,9,19,20]. These bursty models are an on–off pattern [6], and a WWW traffic characterization [11] for residential networks. Of course, the usefulness of these patterns is limited to certain scenarios (e.g., Poisson traffic is a characterization of multiple traffic aggregations), but equally obviously, the performance of the IMUX is traffic dependent. For this reason and since the actual traffic behavior is subject to short-term future changes depending on user requirements, we present this study as a more

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