4. Summary

A large class of data applications are sensitive to performance and reliability factors that are aggravated by cell loss. An FEC scheme at the AAL level that can provide support for improving effective packet delay and reliability is extremely desirable. Current efforts in the ITU-IT SG15 group on an AAL level FEC do not address the data application needs but rather the problems of multimedia transmission. By initiating work on FEC processing at the AAL layer for improving effective packet throughput and delay and reliability, the ATM Forum can increase the attractiveness of ATM usage to a broad range of data applications that include supercomputing, cluster computing, remote data backups and I/O systems.

References

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at the physical level. The former would work well when data rates are low and the processing load on the host entity executing the application is minimal. Error control at the physical level only addresses bit errors on the transmission medium and therefore does cannot provide cell loss recovery. We believe the optimal approach would be the provision of FEC at the AAL level, specifically at the service specific convergence sublayer (SSCS) [95-0150, 95-0325].

There are three salient reasons for an AAL-level FEC versus an application level FEC.

- *High throughput communication*: When the application requires a high throughput communication, say at OC-3 and beyond, it will be extremely difficult to achieve the required high throughput when the FEC processing is performed at the application level. In contrast, the implementation of FEC at the AAL can be optimized for a specific network adaptor and operating system to perform the cell-level functions. One could extend existing VLSI-based AAL implementations to include FEC-SSCS, thereby offering a high-performance cell-based FEC implementation to some (or all) applications. In comparison, an application-level FEC scheme is typically i) available only for a single application, ii) implemented in software, and iii) operates on larger data units (i.e., packets or frames).
- *Retransmission latency*: An AAL-level FEC scheme can detect and indicate the loss of or error in the received data to the application through the transport protocol entity much faster than if the FEC processing is performed by the application. Therefore, when the application is sensitive to quality degradation due to the latency of retransmission for lost or erroneous data, an FEC scheme performed by the application level will not be appropriate.
- *High quality pipe among routers*: When routers are used to transmit application data over an ATM cloud, packet loss can occur both in the routers as well as in the ATM network. The use of AAL-level FEC will complement any application-level FEC to recover from cell loss related packet loss. Therefore, to recover from such packet loss, a FEC scheme may be used in the application process. However, since routers will rely on a secure and high-quality ATM pipe to transfer (IP) packets, an AAL-level FEC scheme can provide such a service transparent to the application.

3. Comparison with the ITU-T SG15 Video Expert Group FEC Scheme

Besides the application-level FEC approach, the ITU-T SG15 video expert group is also developing an AAL-level FEC scheme for the purpose of audio-visual signal (e.g., MPEG or H.261) transmission over ATM networks. The target FEC scheme is for high quality services for real-time audio-visual signals, which are continuous bit streams. This class of applications targeted by the ITU-T SG15, however, has fundamentally different requirements than the data applications we are concerned with:

- We require that the FEC scheme, referred to as FEC-SSCS for distinction, provide efficient data communications even in the case where the ATM network can not guarantee a sufficiently low cell loss ratio. In contrast, the FEC scheme by ITU-T SG15 assumes that the ATM network provides a sufficiently small cell loss ratio.
- The latency requirement for the general data transmission is generally less strict than that for the audio-visual signal considered by the ITU-T SG15.
- The data applications of interest to requires an error-free data transmission unlike many multimedia applications that can tolerate loss.
- In order to optimize the data transmission, the FEC-SSCS will have to interact with the transport layer entity. Interaction with a transport layer entity is not necessary for multimedia transmission.
- While a real-time audio-visual signal is a continuous bit stream, the data transmission we consider is usually an asynchronous data stream. The data source can produce both short (e.g., less than 50 bytes) to long (e.g., 64 Kbytes) packets.

More importantly, the FEC scheme under development by ITU-T SG15 video expert group and an AAL-level FEC at the SSCS proposed for consideration here are not conflicting schemes, but rather complement each other nicely. However, it must be recognized that the ITU-IT FEC scheme does not address the performance and reliability needs of data applications.

needs of a broad class of applications that will benefit from the use of error control based on forward error correction (FEC) at the AAL level.

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NOTICE:

This contribution has been prepared to assist the ATM Forum. It is offered to the Forum as a basis for discussion and is not a binding proposal on Network Systems Corporation, MCI, Toshiba or the University of Karlsruhe. The statements are subject to change in form and content after further study. Specifically, the above institutions reserve the right to add to, amend or modify the statements contained herein.

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1. Introduction: The Need for Error Control

A major concern among potential users of ATM networks has been the reliability and performance of statistical multiplexing. Where such data applications as clustered computing, distributed supercomputing, and high-bandwidth memory and I/O systems are concerned, loss of data under any condition reduces delay guarantees and goodput. Unlike pure multimedia applications that benefit from the multiplexing capability of ATM and are not deleteriously affected by occasional cell loss, these applications are more sensitive to loss in reliability and performance [Guha 95]. The effects of cell loss in ATM manifests itself in terms of high packet loss and increases in effective packet delay. Unfortunately, even modest levels of cell loss are magnified when sending large data packets typical of many data applications. For instance, a 64 KB data unit will have an error with probability of 1.3×10^{-3} when the cell loss rate is 10^{-6}. This packet error rate increase dramatically with increasing number of receivers when reliable multicast is required [95-0326].

The obvious approach to avoiding cell loss is by overprovisioning. Unfortunately, overprovisioning at peak rates for variable bit rate (VBR) traffic, typical of many data applications, is inefficient and expensive since it leads to very low utilization of the links. Furthermore, it defeats the multiplexing advantage of ATM.

The second approach to minimizing cell loss is by controlling the traffic sources. Current work in progress in the Traffic Management subgroup addresses this issue for the Available Bit Rate (ABR) services by shaping the source traffic based on the information provided by the destination entity or by the switch when explicit congestion control is possible. The use of such traffic management schemes allow end station sources to shape and control their traffic flow and thereby decrease the possibility of cell loss and “goodput”. However, such traffic control relies on feedback mechanism and cannot optimize the effective throughput and packet delays for delay and loss sensitive applications.

The third approach to improving performance is to overcome cell loss by recovering lost cells and minimizing the need to retransmit frames of data that have lost cells or have cells in error. Such a cell recovery mechanism requires the use of forward error correction (FEC) at the cell level and is *orthogonal and complementary* to the traffic control schemes currently under definition. Moreover, a proactive cell loss recovery scheme provides the option of optimizing the use of the available bandwidth. We believe that the provision of FEC at the AAL together with traffic control mechanisms will enable a large class of data applications to benefit from the use of ATM networking.

2. An AAL-Level Forward Error Correction (FEC) Approach

An AAL level FEC scheme is necessary where reliable data transmission with bounds on performance, i.e., where end-to-end data transmission throughput and transmission latency, data transmission reliability, and data transmission costs are of concern. There are, however, many approaches to providing FEC in ATM networks. The alternatives to an AAL-level approach is to provide support at the application level or

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ABSTRACT:

This contribution proposes that the ATM Forum consider a separate ad hoc working group to study the use of error control at the ATM Adaptation Layer for supporting loss sensitive and performance sensitive applications over ATM. The current focus in the SAA working group do not address the