BISDN Adaptation Layer and Logical Link Control with Resource Reservation for a Flexible Transport System

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Abstract

Broadband-ISDN promises to integrate a wide range of services. CCITT standardized ATM as the transfer mode for BISDN. ATM network technology can support the quality of service (QOS) demands of emerging applications. These applications require transport systems with a high performance and with support of various services. This paper presents the requirements for the interface between ATM layer and a flexible transport component, together with resource management concepts in the ATM layer and in the transport system. An eXtended ATM Adaptation Layer (XAAL) is proposed, which offers enhanced AAL and LLC functionality for upcoming applications' communication needs in a flexible manner. This flexibility is accomplished by mapping QOS demands onto ATM resources. XAAL is function-based, rather than layered. It is designed to be implemented partially in hardware and partially in software. We demonstrate the mapping and configuration process of XAAL by some examples.

Introduction

In broadband networks, application programs can only use a small portion of the available bandwidth, due to protocol overhead. The processing of the logical link control (LLC) layer, the networking layer and the transport layer has been identified as a serious bottleneck. Therefore, a new de-layered communication reference model has been developed,[1] consisting of three components:

- the technology dependent layers 1 (physical) and 2a (medium access control);
- the layers 2b (logical link control), 3 (network) and 4 (transport) which are responsible for the transport of data within networks and over network borders;
- application dependent layers 5 to 7.

In this paper we shall examine the role of the transport component in a BISDN environment. We show, how a flexible transport system meets the requirements of upcoming applications, extending known transport system functionality by services like multipeer/multicast communication offering a wide range of services and performance parameters. We present a generic architecture, where such a flexible transport system can be implemented in ATM-based networks, without introducing new bottlenecks. This architecture is based on an eXtended ATM Adaptation Layer, providing a variety of services for the reservation of resources.

We analyze the functionality offered by the different ATM adaptation layer protocols and the functionality required in conjunction with existing data link, network and transport protocols. We introduce a function-based communication model, as opposed to the traditional layer-based approach. We show, how a set of functions can be configured to provide the services offered by the existing adaptation layer protocols, and how an extension of this basic set of functions allows to provide a flexible and efficient transport service in a BISDN environment. The proposed architecture provides a variety of services and is flexibly configurable and adaptable to meet varying application requirements. The next two sections show upper and lower interface of XAAL in more detail.

Key issue is the concept of resource management. Applying resource reservation mechanisms allows to guarantee specific Quality of Service (QOS). Providing a resource mapping mechanism allows application processes to deal with service classes, and provides transparent access to the actual resource parameters.

ATM Layer Resource Management

An important issue in broadband integrated services networks is to guarantee an application a specific quality of service (QOS) by the ATM network.[2] To do so, when requesting a connection establishment, an application specifies its traffic characteristics. According to them, the network shall reserve some resources.

The following are widely accepted as resources:

- transmission link bandwidth;
- switch buffer space;
- internal switching bandwidth.

In some publications,[3] link and switching bandwidth are comprised as one and are no further distinguished. For the provision of connections with a specific quality of service, several resource management mechanisms, strategies, and systems have been proposed so far. Amongst others, there are:

- the method used for usage parameter control (UPC),[4] often also denoted as policing method;
- the decision about marking or discarding[5,6] of violating cells;
- additional mechanisms like spacing,[7,8] and forward error control (FEC).[9,10]

In our model, these procedures are also denoted as resources. In order to distinguish the two types of resources, we shall denote the former as basic resources and the latter as virtual resources. This can be justified due to the fact that the mechanism of a virtual resource regulates the use of basic resources, and both virtual resources and basic resources are limited.

The type of service offered by the ATM layer depends on the concept and implementation of resource management. In the Asynchronous Time Sharing (ATS) system[11–14] support of the following four traffic classes is provided:

- Class I is characterized by zero packet loss and a maximum time delay, comparable to a circuit-switched service;
- Class II is characterized by an upper bound of packet loss and a maximum time delay, suitable for voice and video service;
- Class III is characterized by zero end-to-end packet loss which is achieved by a retransmission policy; it is also possible to characterize it by a minimum average user throughput and a maximum average time delay; it is suitable e.g. for file transfer;
- Class C traffic receives absolute priority, and will observe only negligible delays; it is to be used by the network management system.

The provision of these service classes is achieved by the establishment of four virtual networks on the underlying network, by hardware support of all traffic classes in all network elements, by a special scheduling algorithm[12] in the switches, and by distributed management concepts.[13]

Resources are allocated to the four traffic classes by a dynamically controlled contention mechanism. Access to switching and communication resources is regulated by a scheduling algorithm based on time sharing, while buffer management is achieved by applying space partitioning.

A layered approach to congestion control has been proposed[15,16] called Bandwidth Management (BWM). It consists of controls on three levels:

- the core network congestion control performs traffic monitoring, violation-tagging of cells, pre-marking of cells, and cell discarding;
- call-level control performs call admission based on traffic characterization;
- end-device flow and error control applies shaping mechanisms, window mechanisms, and forward error correction methods.

Resources must be allocated for each connection to ensure the integrity of traffic according to its pre-specified characteristics, whereas exceeding traffic may be corrupted. The bandwidth management call-level control will accept calls only if there are sufficient resources available.

There is an additional, very interesting aspect in this approach, the principle of an operational traffic descriptor.[17] This means that traffic characterization takes place in terms of the applicable traffic monitoring algorithm instead of statistical parameters. The use of an operational traffic descriptor allows traffic characterization in terms of the applicable traffic monitoring algorithm, instead of using statistical parameters. This approach avoids the complex task of mapping statistical parameters into ATM layer basic functionality and is one possible solution to limit the arising complexity of the ATM layer.

Resource Management in the Transport Component

The requirement to allow an easy and efficient support of a variety of transport services led to the development of a configurable, function-based transport system, known as FCSS (Flexible Communication SubSystem). FCSS[18,19] utilizes a de-layered communication architecture by configuring a protocol machine (which performs the complete transport component functionality for a specific data stream) out of elementary protocol functions. It provides flexibility and dynamics of QOS selection and control, supporting the application-specific configuration of the protocol machines. A set of predefined service classes is provided. These classes are:

- Class I: Unreliable real time;
- Class II: Reliable real time;
- Class III: Unreliable non-real time;
- Class IV: Reliable non-real time.

FCSS enables applications to express their requirements using a set of qualitative and quantitative parameters. According to these requirements, a protocol machine is generated by the protocol configurator, accessing a protocol resource pool of available protocol functions. The protocol configurator has also access to a system resource data base, where information on system resources and their utilization is kept. Subsequently, the code configurator is invoked, interacting with the system resource manager to ensure the availability of needed resources. In the description of FCSS,[18,19] the aspect of resource management is emphasized on local resources that perform protocol functions in end nodes. FCSS provides various types of transport service and mainly deals with transport layer functionality, while regarding intermediate nodes and transmission links as black boxes so far.

FCSS is also envisioned to serve as a transport system for ATM,[20] being suitable for a variety of applications. FCSS may take advantage of the variety of services offered by XAAL. Since FCSS is function-based, the basic functions and mechanisms of XAAL may be integrated into FCSS, providing high flexibility and efficiency.

The resource mapping capability of XAAL is not only of use for a flexible transport system, but also for a network layer implementation which applies resource reservation. There are layer 3 protocols for network resource reservation in packet-switching networks. The Internet Stream Protocol ST-II[21] has been developed to support efficient delivery of streams of packets to either single or multiple destinations in applications requiring guaranteed data rates and controlled delay characteristics. Admission control and the dynamic addition and deletion of multicast receivers is provided. Every intervening ST entity maintains state information for each stream that passes through it, including forwarding information and resource information, which allows network or link bandwidth and queues to be assigned to a specific stream. This pre-allocation of resources allows data packets to be forwarded with low delay, low overhead, and a low probability of loss due to congestion.

The use of internet protocols over ATM networks has been discussed.[22] In the case of running ST-II over the public BISDN network, ATM connections can be considered as resources which have to be reserved during the stream setup phase. The resource reservation of intermediate ATM switches, in order to guarantee a specific QOS on that ATM connection, is not a task of ST-II. This task has to be performed by the ATM layer management.

There exist a number of resource reservation protocols for QOS assurance in packet switched networks which partially enhance the functionality provided by ST-II. Some of them (e. g. SRP[23]) support only point-to-point-connections, others (e.g. SRVP[24]) also support multicast connections. In particular for dynamic connections where the QOS is subject of renegotiation, an efficient interworking of the ATM resource reservation mechanisms with these protocol agents should be provided.

AAL and LLC as Part of the Transport Component

Required Functionality

The ATM adaptation layer performs several tasks. First, it enhances the service offered by the ATM layer to meet the QOS requirements of higher layer functions. Another task is the separation of data flow into the three planes of ATM: user, control and management. BISDN provides applications with a number of services by the adaptation layer. In CCITT recommendation I.362, the following four service classes are currently specified:

- Class A: provides circuit emulation with a constant bit rate, isochronous, connection-oriented service;
- Class B: provides a variable bit rate, synchronous, connection-oriented service;
- Class C: provides a connection-oriented data service;
- Class D: provides a connectionless data service.

This service classification is not the only possible one, and each class may represent different services provided by a number of AAL protocols. The CCITT recommendations follow a strictly layered approach. The AAL layer is subdivided into a Segmentation and Reassembly Sublayer (SAR) and a Convergence Sublayer (CS). The basic functions are performed in the lower SAR sublayer. It segments and reassembles a CS protocol data unit and offers services at the cell level. The CS sublayer offers services at the frame level. Different upper CS sublayers may provide a variety of services. The CS sublayer may be further subdivided into a Common Part Convergence Sublayer (CPCS) and into a Service Specific Convergence Sublayer (SSCS). This is the case for the AAL 3 and 4, which have many commonalities. They share a common SAR and a common part of the CS sublayer. Figure 1 shows, how a limited set of sublayers provide the four basic service classes for the application. It also shows, how the necessary adaptation for the signalling functions may be performed.

The currently specified functionality of the adaptation layers is listed below:

- AAL 1 recovers the service clock at the destination, handles cell delay variation, recovers a limited number of errors applying forward error correction, detects lost or corrupted data and provides means for source data structure recovery;
- AAL 2 extends the functionality offered by AAL 1 for variable bit rate data streams;
- AAL 3/4 handles corrupted cells with a per cell CRC, handels lost cells with a sequence number, provides a message and a streaming mode with options for multiplexing, segmentation/reassembly and blocking/nonblocking; mechanisms for retransmission and flow control are also applicable;
- AAL 5 handles lost and corrupted cells with a CRC for the entire frame, supports variable-sized frames and does not provide multiplexing .

It remains an open question if the service offered by AAL 2 will be required by future applications. The original target application was the transmission of compressed video streams. Existing

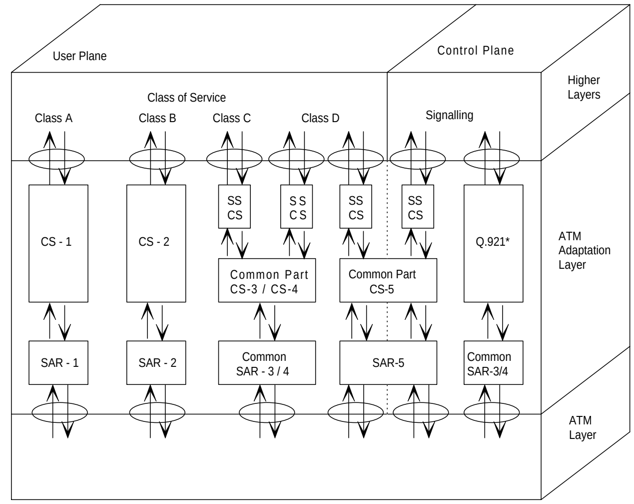

Figure 1: ATM AAL protocol architecture

decoders do not use frame reception time for synchronization and therefore do not require an AAL 2 service. Since there is no urgent need for the AAL 2 service, standardization of AAL 2 is still in its infancy.

Since the service provided by the AAL is application specific, a larger number than the currently standardized adaptation layers will appear.[25–27] Two examples shall be presented here:

- BLINKBLT[28] provides complete OSI data link service across an ATM network with mechanisms to recover lost cells. It is connection oriented, (with connections established by a three-way-handshake), and uses positive acknowledgements.
- BBN-SAR[29] detects lost and misordered cells using a larger sequence number than AAL 4, and provides error correction using a 10 bit CRC.

Analyzing these adaptation layers, the following functions can be identified: multiplexing, segmentation and reassembly, error detection, error correction, acknowledgement, sequence control, corruption control. In order to increase functionality and flexibility, a set of mechanisms may be offered for each of the functions, providing a configurable extended service. We call this the eXtended Adaptation Layer XAAL. Its functionality may not be limited to the service offered by the adaptation layers presented above. Since there are commonalities of adaptation layer service functionality with data link layer service functionality, and since many higher layer protocols are designed to use a data link layer service, XAAL functions shall be configurable to provide LLC services, too:

- LLC Type 1 provides a simple connectionless service with multiplexing. No error detection, frame retransmission, error recovery, acknowledgement, or flow control is performed.
- LLC Type 2 provides a connection oriented service, with limited error detection and error recovery.
- LLC Type 3 provides acknowledged connectionless service for a reliable transaction mechanisms.
- LLC Type 4: Standardization efforts[30] are made for a LLC Type 4 service which provides point to point and multicast high performance stream data transfers. The proposals are based on XTP.

Higher layer functions may be a flexible, function-based transport system, or a layer 3 resource reservation protocol. It eases the implementation of these protocol machines if a mapping of ATM layer resource management notation to application QOS notation is already performed by the ATM Adaptation Layer. According to changes in QOS demands, support is required for renegotiation of resources allocated to that connection.

In figure 2, a functional model of the XAAL is presented. As an example, it shows ATM layer service access points offering in send and receive direction data streams with different qualities of service (QOS RA, QOS RB, QOS TA, and QOS TB). Using these services, XAAL offers to the application data streams with a wider QOS range: QOS R1 to R4 and QOS T1 to T4. This is done by configuration of necessary basic functions and by appropriate administration of available resources.

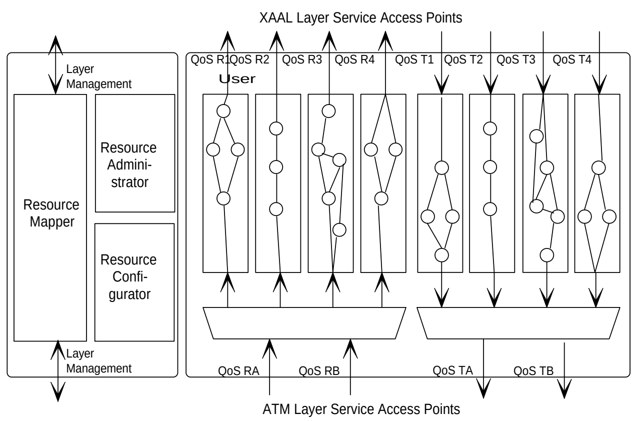

Figure 2: XAAL Functional Model

Signalling

Signalling is performed in the control plane using dedicated Signalling Virtual Channels (SVCs). For different service types, different SVCs can be established using a Metasignalling Virtual Channel (MSVC), which is a permanent Virtual Channel with a reserved VCI unique for each UNI. Initially, the control functions at the BISDN UNI will be based on NISDN control functions with additional traffic parameters. For the long term, new signalling protocols shall be applied. The signalling entity is comparable to any other user of an AAL service in the way it uses the AAL. There are different ways how to configure a signalling protocol stack. Older CCITT recommendations propose the signalling protocol stack with AAL-SAR Type 3 sublayer for segmentation and reassembly, and with a Q.921 (modified LAPD) convergence sublayer protocol. Newer proposals are based on a common part convergence sublayer and the segmentation and reassembly sublayer of AAL 5. On top of this, a service specific convergence sublayer for signalling is proposed.

Resource Mapping

The resource mapper is an essential part in our concept of an eXtended ATM Adaptation Layer (XAAL). Its tasks are twofold. The first task is to offer resource classes to the application. The resource mapper, as part of the adaptation layer management, sends requests for available resource types to the ATM layer management. Note that the responses to these requests contain only resource types and not actual resources. The second task is to map the QOS demands of the transport component into requests for resources that may be allocated by the ATM network. Therefore the mapping depends both on the QOS requirements of the upper layer and on the allocatable resources of the network technological component.

Flexibility is a requirement of this mapping component. It must be adaptable to mechanisms such as a peak bit rate allocation scheme (which could be the only means of resource allocation in a simple ATM network), as well as to sophisticated allocation mechanisms as fast reservation mechanisms[31,32] or the layered approach of bandwidth management.[15]

The resource mapper must be aware of the resources that are generally offered by the network. Note that it is not responsible for managing these resources. In particular, its task is not the decision about the acceptance or denial of a call.

As an example, we consider how the mapping of FCSS service classes onto ATM service classes could take place, see table 1.

FCSS	ATM	Remarks/Additional Functionality
I	A	if constant bit rate required
	B	if variable bit rate required
II	A, B	plus forward error control,
		if upper bound on cell loss guaranteed
	A, B	plus (fast) acknowledgement and retransmission,
		for small round-trip delay
III	C, D	
IV	C, D	plus acknowledgement and retransmission

Table 1: Mapping FCSS service classes onto ATM

As another example, we shall consider the mapping of FCSS transport service classes onto ATS[11–14] service classes, including the necessity of some additional functionality, see table 2.

FCSS	ATS	Remarks/Additional Functionality
Service	Class	
I	I	
II	I	additional acknowledgement and retransmission
	III	additional time constraints
III	II	unnecessary delay constraints
	III	unnecessary retransmission
IV	III	

Table 2: Mapping FCSS service classes onto ATS

As can be seen from the examples in tables 1 and 2, there is no one-to-one mapping of FCSS service classes onto ATM/ATS classes. This results from the lacking of standards for the new applications and network technologies, so far. But therefore, it is essential for the XAAL, and in particular for the resource mapper, to offer a flexible way of mapping QOS requirements into basic network functionality.

Resource Administration

Status of local resources is kept in a local resource database. Call admission functions decide not only on the basis of the local resources, but also need information on remote resources to guarantee specific QOS end to end. In large networks, there is always the problem that entities can not be sure whether their status information of a remote site is still valid. Therefore, the mechanisms that are applied need to be stable under such conditions. For example, if burst level bandwidth allocation (as the fast reservation protocol FRP[33]) is applied, a complete round trip delay time is necessary if the protocol for bandwidth allocation needs to send a request to the remote side. An alternative approach would be based on a local data base containing information of remote resources as copies of a remote data base. For this approach, status information will be exchanged periodically.

On each case, establishing and maintaining this information is a network management task, in particular of ATM layer management. Thus, the resource administrator interacts closely with the ATM layer management. For exchange of information, ATM layer management protocols are used.

An Example

In this section, we demonstrate the way that XAAL works. When the XAAL in the end node is initialized, the resource mapper requests the resource types from the ATM layer management. Assuming an underlying ATM network with BWM[15,16] congestion control, it might receive the information: 155 Mbit/s link, the leaky bucket usage parameter control method, the choice of violation-discarding or violation-tagging, the option of pre-marking of cells, and an additional spacing mechanism.

An application requesting a connection might specify a medium data rate of 10 Mbit/s, a maximum burst rate of 50 Mbit/s and a maximum burst length of 20 Mbit. It might not be loss-tolerant, but delay-insensitive. Thus, the resource mapper could take the choice of a leaky bucket with a medium data rate of 12 Mbit/s, but very small pool size, a spacing mechanism to reduce the burst rate of 50 Mbit/s to 12 Mbit/s, sufficient memory in the sending node (16 Mbit) for buffering the bursts, no pre-marking of cells. Note that there is no decision to be made on violation-tagging or violation-discarding, because there will never be any violating cell, due to the spacing mechanism that is applied.

Additionally, the resource mapper allocates a windowing mechanism (a typical LLC functionality) to ensure the full integrity of the data. Next, these demands for resources are passed to the resource administrator, which checks the actual availability of the amount of resources and, if available, reserves the resources in end-nodes and in the intermediate ATM switches, and assigns the VCIs for the ATM connection. Finally, the resource configurator combines the various functional blocks in order to form the appropriate connection for the XAAL data stream.

Implementation

There are different possibilities for implementing our concept of a configurable ATM adaptation layer with resource reservation. The XAAL implementation should provide support for multiple concurrent data streams. If performance is the main goal, the target architecture will be highly parallel and will make extensive use of hardware components. A possible implementation to achieve hardware support for a parallel transport system has been demonstrated by PATROCLOS.[34]

However, it is not mandatory to use a target system where every functional block will be provided exclusively with system resources. All kinds of resource sharing should be supported by the implementation.

An integration of hardware components for checksumming and cyclic redundancy check (CRC), forward error control (FEC), list and timer management, multiplexing, PDU header detection and formating is planned. For cell demultiplexing at the receiving side, a content addressable memory can be used advantageously. Hardware components for buffer management, message queue administration, scheduling and hashing functions also have a high impact on system performance, as they limit the influence of time-critical system functions. High efforts are necessary to be able to configure these components appropriately, to synchronize their operation with the remaining functionality implemented in software, and to administer the resources represented by the components appropriately.

Summary

In this paper we introduced the XAAL, which offers the functionality of the LLC and of various AALs. The main goal of XAAL is to offer a maximum of flexibility for QOS demands of upcoming applications.

Its basic ideas are the mapping of QOS demands onto ATM resources, and the administration of ATM and XAAL resources. It is function-based, as opposed to layer-based, by means of functional decomposition and fusion of layers.

For the implementation, hardware must be used for time-critical functionality, and configurable hardware is necessary in order to provide the aimed flexibility. One single XAAL implementation serves for different service classes. XAAL also offers the possibility of a concurrent treatment of data streams belonging to different service classes.

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