Architecture of Resource Management of ATM Switching Systems

D.KAGKLIS*, M.MANOUSOS*, D.REISIS**, E.SYKAS*, G.SYNNEFAKIS*, and A.TAVOULARIS*

*Telecommunications Lab., Dept of Electrical & Computer Engineering
National Technical University of Athens
Zografou Campus, Heroon Polytechniou 9, 157 73 Athens,
GREECE
**Electronics Laboratory, Physics Dept.
University of Athens
Panepistimiopolis, Building 4, 157 84 Athens,
GREECE

Abstract: - The operation of the management entities of the Asynchronous Transfer Mode switching systems plays a crucial role in the overall system's performance. This paper shows two designs for accomplishing the management tasks, targeting to improving on the performance as well as the expandability, the scalability and the fault tolerance characteristics. A centralized and a distributed design utilize efficiently the interconnection for fast exchange of control information. To achieve this target the effort has been concentrated on optimising the processes handling the resources and in providing an effective organization for the data structures used by the switch management. Further, in the distributed approach, a set of negotiating policies enhances the ability of the processors in decision taking regarding the switch's resources.

Key-Words: - ATM, multi-board switching systems, call admission control, centralized and distributed resource management.

1 Introduction and Problem Description

The operation of a VC switching node in an ATM network requires the handling of resources defined by the ATM protocols as well as the management of internal resources necessary for the node's operation. The resource management is performed during the establishment and release of connections, when the allocation and the de-allocation of the respective resources take place. The performance of the node resource management algorithms affects the overall performance of the switching system in terms of calls/sec. Another important issue, which has to be considered in the design of the resource management architecture, is the capability to recover from failures during system's operation.

The resources that are defined by the ATM protocols are: the storing memory of VPI/VCI values, CRV/ERV, the interconnection bandwidth and the routing information regarding the ATM addresses of the switch's ports. The VPI/VCI values have local significance between two nodes [3]. Resource management is responsible for the validation of the values proposed by another node in an incoming SETUP message as well as for the proposal of new values for the outgoing SETUP message. The CRV and the ERV are used as the unique identifiers of the connection on a port of the switch in the Q.2931, Q.2971, UNI 3.0, UNI 3.1 and UNI 4.0 protocols [3] [10] [11] [12]. Bandwidth reservation and release are the results of the operation of the CAC (Call Admission Control) [18]. The ATM address of each port of the switch is used for the routing of the incoming and outgoing calls among the ports of the node [13] [14]. The resources mentioned above are significant and unique for each of the physical ports of a switch.

The operation of the switching node implies the use of resources with significance within the node. A resource used in many switching nodes is an internal TAG. The TAG is used as an identifier of the ATM cells, which belong to a specific connection while the cell remains within the switch [22]. The value of the TAG is calculated using a function f-in (VPI, VCI, input port)=TAG when the cell is received by the switch. The TAG is translated in new VPI, VCI and output port when the cell is sent by the system using a function f-out (TAG). The application of the TAG requires the coherency of the entities, which perform the f-in and f-out functions, while these entities may be controlled by different processors in a distributed environment. In this distributed multiprocessor system each processor is located in each board of the switching system. The use of systems with multiple I/O boards and a shared bus as switching core is quite common [23]. This is because of the modularity achieved in terms of system ports, and the efficiency of using any internal resource as the board identifier, which should be handled from resource management. The board identifier and the TAG are internal resources of the switch and are used for the routing of the ATM cells to the appropriate output board and port in a multi-board switching system.

The purpose of resource management is to maintain a database of system's resources, perform validation of the values which have been requested by other nodes, propose valid resources to the next node of the network and to interact with other entities within the switch providing information elements of the database which maintains.

This paper presents efficient solutions to the organization of the management functions. The first uses a centralized approach. The second follows a distributed approach in an attempt to improve on the performance of the switching system as well as the scalability and the fault tolerance features.

Section 2 describes the architecture, in which the resource management is performed on one Central Processor board of the system. Section 3 shows the distributed approach, in which the resource management is performed locally on each board of the system. Finally, Section 4 concludes the paper.

2 Centralized Management Architecture

In this approach the ATM switch consists of one (1) central processor board, one (1) network access board and N user access boards. The Central Processor board performs the Call Admission Control and the Resource Management of the entire system. The Internal Communication Protocol (ICP) [23] has been designed and implemented to accommodate the communication among the boards.

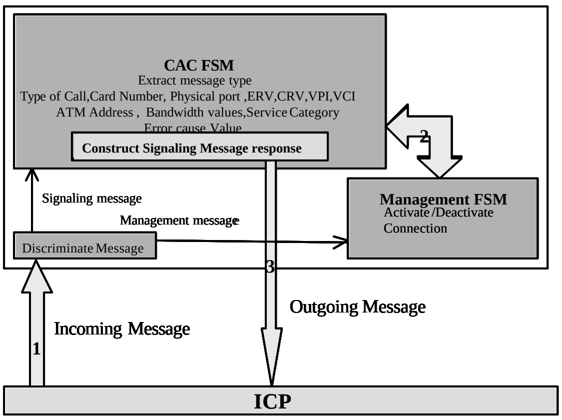

Fig. 1: Software architecture of centralized approach

Each data packet is forwarded to the Central Processor Board and the ICP entity sends them to the CAC Management Layer (direction 1 in Fig. 1). According to the type of message the Management or CAC entity is triggered. The Call Admission Control extracts the information of the message received through the ICP (CAC FSM in Fig. 1). Then the Management entity decides whether the requested connection can be established (direction 2 in Fig. 1). Finally the CAC entity constructs the appropriate signaling messages and through the ICP the messages are forwarded to the originator and destination boards (direction 3 in Fig. 1) [15].

2.1 The performance of the CAC entity

This entity performs the call admission algorithm for each incoming message requesting an establishment or release of a connection. Upon the reception of a SETUP message, from one of system's ports, the switch verifies the validity of VPI/VCI and CRV/ERV values that have been proposed from the calling node. The CRV/ERV values are mandatory elements of every signaling message, unique to the originating side, only assigned at the beginning of the call and remain fixed for the lifetime of the call [3]. Next, it is examined whether the ATM address of the called node is located in the routing tables of the switch in order to forward a SETUP message to the appropriate port. The CAC algorithm uses the available bandwidth of the incoming and outgoing ports to compute the bandwidth, which is going to be allocated to the new connection. If the CAC decides that the new connection can be established, a new SETUP message will be constructed with valid VPI/VCI, CRV/ERV values, and it will be forwarded from the outgoing port to the next node of the network. At the end of the call, the RELEASE message triggers the de-allocation of the resources, which have been reserved for this particular connection (Fig. 2).

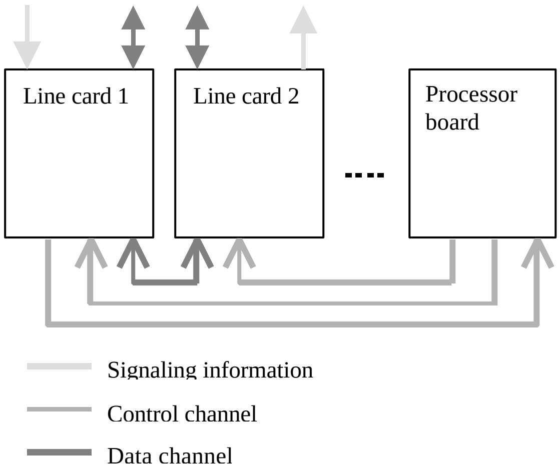

Fig. 2: Information flows in centralized approach

2.2 The performance of the Management entity

The Management entity begins its function following the system's power up sequence and initializes the boards of the system. The initialization is accomplished by configuring the type (user or network) of each board and the net-prefix of the ATM switch [14]. During system's operation the management entity handles the established connections, the allocated resources and the routing information. The management entity utilizes the information extracted by the CAC entity and activates or deactivates the requested connection according to results of the CAC algorithm. All the aforementioned resources (VPI/VCI, CRV/ERV, ATM addresses and Bandwidth) of the system are stored on the database of the Management entity.

3 Distributed Management Architecture

In the distributed management approach, the ATM switch consists of one (1) network access board and N user access boards. The network access board is connected to the ATM network and the user access boards are connected to the user equipment. This approach leads to lowering the system's cost by avoiding the realization of a Central Processor board as compared to the centralized approach. Each board of the switch is capable of obtaining and handling management information such as VPI/VCI values and ATM addresses. The Internal Communication Protocol (ICP) accomplishes the communication among the boards. Moreover, the switch's ATM address net-prefix (13 bytes) [14] is stored on the network access board, usually on a non-volatile memory, and is transmitted to the other system's boards of the ATM switch during the initialization phase. For this purpose the system uses the ICP.

The distribution of management requires that the functions performed by CAC will be also realized in a distributed fashion in all the access boards of the system. As mentioned above, the CAC algorithm is based on the available bandwidth of the incoming and outgoing ports. This requires the maintenance of information about allocated bandwidth on each port.

Furthermore, the distributed management approach requires the existence on each board of an entity performing the allocation, de-allocation, storage and retrieval of system resources. This entity is called Local Resource Manager (LRM). The following paragraphs present the operations accomplished by the LRM regarding each resource of the ATM switch.

3.1 ATM Address Management

All the ports of the ATM switch have a common address part with size 13 bytes, which is called net-prefix. The complete ATM address (20 bytes) of a physical port of the switch is formed when the user equipment connects to this port [13]. The Local Resource Manager (LRM) of the board performs the validation of the ATM address. This procedure verifies that each ATM address is unique among all system's ports by broadcasting this address to all the boards of the system. If there is no response from any other board, within a certain time interval, the ATM address is considered unregistered and the LRM of the board will register and store this address and physical port into the local resource base. Furthermore, the information of the ATM address, the board and the port number, is broadcasted to all the boards of the system for their LRM update. Otherwise, upon reception of a reply, the ATM address is rejected and the user equipment selects a new unregistered ATM address.

Whenever a message has to be forwarded to a specific ATM address (e.g. a SETUP message), by using the ICP, the board where this address has been registered must be located. The LRM performs this lookup of the board. If this address is already registered locally, the LRM will return the destination board's identifier. If the address is not registered locally, the board identifier will be obtained by broadcasting this address to all the boards of the system. A reply from a board indicates that this ATM address is registered on it. The LRM will update its local resource base and will return the board identifier. If there is no response from any board, within a certain time interval, the ATM address will be considered unregistered and an error message will be returned.

3.2 TAG management

The process of connecting two (2) ports through the interconnection network requires the allocation of a TAG (16 bits number) on both boards. This number (TAG) is used by the switching components of each board to identify the cells that will use the path of the established connection between the boards. There are two techniques regarding the process of the common TAG selection.

- The board C1 requesting the establishment of a data path with another board C2, proposes a TAG, free on C1, to C2. If the proposed TAG is also free on C2, then it sends back a positive acknowledgement to C1 and the procedure is terminated. If the proposed TAG is reserved on C2, then it sends back a negative acknowledge to C1 and the TAG selection procedure restarts.
- The board C1 requesting the establishment of a data path with board C2, constructs a message,

which contains all the TAGs of the board, properly encoded, and their availability (whether they are allocated for existing data connections or they are free). The message is sent to board C2 which decodes the TAGs and their availability and based upon the locally free/allocated TAGs selects a free TAG, common to the two boards, and replies with a positive acknowledgement containing the selected TAG. The following of this paragraph describes the realization of this procedure. We will assume that each board maintains a table inside the LRM with all its TAGs and their availability. Each TAG is encoded as 1 bit. According to the number of TAGs supported by the switching components of each board (65.536), the size of the TAG table will be 65.536/8bytes=8.192bytes or 8Kbytes. A value of '1' represents an available TAG, a value of '0' represents an allocated TAG. When there is need for a selection of a common TAG between two boards of the system, the first board will send its TAG table (TAG-R[0…65535]) to the second. Upon reception of this information, the second board will perform a check against its TAG table (TAG-L[0…65535]), bit by bit, RES[i]=(TAG-L[i] logical-AND TAG-R[i]). The first non-zero result of the check, that is, RES[i] = 1, indicates that the i-th TAG of each board is free and can be used for the establishment of a data connection.

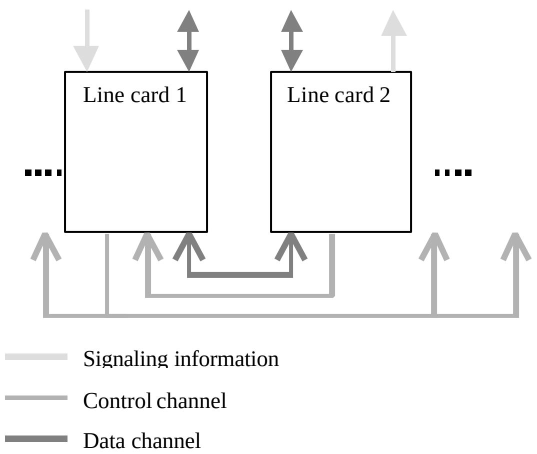

Fig. 3: Information flows on the distributed approach

The first method is straightforward to implement and the exchanged messages between the two boards have the length of a single cell. This leads to minimizing the response time for each negotiated TAG. The disadvantage of this method is that, it will produce a TAG in a number of iterations non deterministic. The second method is more involved than the first. The complexity lies in the strategy used to encode the TAGs of one board and then to let the second board decode the TAG information. Also, due to the large number of TAGs supported by the switching components of each board (65536), the message transmitted from board C1 to board C2 is considerably long. The advantage of this method is that the TAG negotiation procedure can be completed within a single iteration.

3.3 CRV/ERV Management

This entity performs the validation, allocation and de-allocation of the CRV/ERV values of the system's connections. On receipt of a connection establishment request (e.g. SETUP, ADD PARTY) by a board C1, the CRV/ERV values are extracted and checked by the LRM whether they are already reserved. In this case the LRM will propose novel CRV/ERV values to the calling node. Through the ATM Address Management the board (C2) where the called user has been registered, is traced. Then the LRM will reserve a TAG, returned by the TAG management, for the requested connection. The ICP will forward the call request to the board C2.The LRM of C2 will propose new CRV/ERV values, characterizing the connection between board C2 and the called user, and will forward the request to him (Fig. 3).

In case of a call acceptance, the LRM of C1 will register the calling user's values of CRV/ERV and the TAG reserved of the established connection. Respectively, the LRM of C2 will register the called user's values of CRV/ERV and the TAG registered by the LRM of C1.

In case of a receipt of a RELEASE message, by a board C1, the LRM computes the connection requested to be released by extracting the CRV/ERV values. Then it de-allocates the locally reserved resources and forwards the release request, by using the ICP, to all the boards participating in the connection.

3.4 VPI/VCI Management

This entity supplements the CRV/ERV management. It is responsible for the verification and allocation of the VPI/VCI values of each requested connection. The handling of VPI/VCI and the CRV/ERV values is similar. The difference lies in that the VPI/VCI values are included only in SETUP messages. In case of a call acceptance, the LRM of each board participating in the connection stores the associated VPI/VCI values.

4 Conclusion

This paper has presented two architectures for resource management on ATM switching systems following a centralized and a distributed approach. The centralized architecture is characterized by the concentration of management information. This leads to a low cost system with minimal design complexity.

In the distributed architecture, the management information is shared out on all the boards of the system. As a result, the system is fault tolerant and highly scalable.

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