MULTICAST ALGORITHMS EVALUATION USING AN ADAPTATIVE ROUTING IN ATM NETWORKS

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ABSTRACT. The routing in ATM networks consists in assigning a path to the incoming connections demands. For each new call the network must select a path that has sufficient bandwidth available to support the new connection. Every cell of this call will use the same route path. The adopted call admission control (CAC) policy has a strong influence in the routing performance. The CAC proposed for the evaluation of the best routing option is the Enhanced Convolution Approach.

In the future broadband network an additional requirement arises. Indeed, some services have a distributive nature, and thus require of future ATM switches the capability to provide a multicast and broadcast functionality.

In this paper we propose an multicast implementation based on the adaptive routing with anticipated calculation. Three different cost measures for a point-to-multipoint connection: bandwidth cost, connection establisment cost and switching cost can be considered. The application of the adaptative routing method based in pre-evaluated routing tables makes possible the reduction of bandwidth cost and connection establishment cost individually.

1. INTRODUCTION. The routing in ATM networks consists in assigning a path, virtual channel (VC) or virtual path (VP), to the incoming connection demands. For each new call the network must select a path with sufficient bandwidth available to support the new connection with a required Quality of Service (QOS). The routing algorithm is the part of the network layer software responsible for deciding which output line an incoming call should be transmitted on. Every cell of this call will use the same route path. When a cell arrives at a switch, the switch determines its output link by looking at the VC number in the header of the cell, and using a routing table in the switch's memory. Both the VC number of every call and the routing tables of every switch are determined by the routing algorithm, [2] and [6].

Usually, when there is an incoming connection demand, each node evaluates the possibility of setting the new virtual path connection to all outputs through which the new connection can achieve the destination. If the subnet uses virtual circuits internally, routing decisions are only made when a new virtual circuit is being set up. When there is a new connection, the switch must actualize the tables' values before the routing algorithm decides the output link. The response delay can be substantial depending on the complexity of the source model and the bandwidth allocation scheme that have been used.

The following section shows a bandwidth allocation survey and its influence over the ATM network performance. The Connection Acceptance Control and its relation with routing are explained in section 3. Sections 4 and 5 present the application of the adaptative routing methods with anticipated calculation, whereas in section 6, in the case of multicast is explained.

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2. <u>BANDWIDTH ALLOCATION.</u> The basic objective of a bandwidth management and traffic control strategy in ATM network is to allow for high utilization of network resources, while sustaining an acceptable QOS for all connections. Several network traffic control functions, such as congestion control and routing, depend on the characterization of the equivalent bandwidth of individual connections and the resulting load on network links.

It is possible to classify networks according to the homogeneity of sources and the presence of statistical multiplexing [5]. The network is homogeneous whenever all the connections have the same parameters; else it is heterogeneous. When the calls are not admitted according to their peak bandwidth requirements all the existing connections on a link are statistically multiplexed. Note that statistical multiplexing is efficient and allows more calls to enter the network than in the case of peak rate allocation, since it exploits the small probability that a larger number of calls will be active simultaneously. This statistical multiplexing gain can only be achieved if the network knows the probability distribution function of the individual sources; therefore, each type of source must be modelled.

It is possible for each source to assign an equivalent bandwidth that reflects its characteristics. Since the required bandwidth for heterogeneous sources is given by the sum of the assignments of each class, the effect of statistical multiplexing is only considered within each class. Furthermore, the value of the equivalent bandwidth for homogeneous sources overestimates the actual bandwidth requirements. In this process, the accuracy of the bandwidth evaluation is seriously affected.

To provide traffic control functions in real-time is a major challenge. Usually this involves a reduction in the complexity, and not less the accuracy, of the evaluation models.

The convolution approach is the most accurate method used in bandwidth allocation, but it has a considerable computation cost and a high number of accumulated calculations. Nevertheless, in critical near-congestion situations, the convolution is the only algorithm that gives enough accuracy in both types of networks (homogeneous and heterogeneous).

In this way, the convolution approach obtains the maximum statistical multiplexing gain. In [7] and [4], we propose the use of the Enhanced Convolution Approach (ECA). These works have studied an evaluation of the usage requirements (complexity as processor capacity and memory required to do the calculations) of bandwidth allocation based on the convolution approach. These papers show reasonable evaluation cost and storage requirements whenever the multinomial distribution function and some cut-off mechanisms are used. In this case the ECA offers a possible real-time evaluation without accuracy loss.

This study has been carried out according to the General Modulated Deterministic Process (GMDP) model. GMDP allows modeling two-state sources (ON/OFF) and more defined states can be modelled if necessary. Sources are grouped in types; a type of source has identical GMDP parameters.

3. <u>CONNECTION ACCEPTANCE CONTROL AND ROUTING.</u> One important aspect of Bandwidth Allocation is Connection Acceptance Control (CAC) application. CAC is the set of actions taken by the network at the call set-up phase (or during the call renegotiation phase) in order to establish whether a virtual connection can be accepted or has to be rejected. The decision is based on the resources occupied by the existing connections and the characteristics of the new connection. The importance of equivalent CAC for achieving preventive control is widely recognized.

The most important requirements for the CAC function are: resource allocation must meet QOS requirements for all established connections, which means that the network has to be protected from overload; the CAC should be able to function with a limited set of parameters that characterize the traffic, with fairness in distribution of blocking probabilities, and that could be enforced by a policing function;

reasonable real-time processing and storage requirements are needed; and maximal statistical multiplexing gain should be obtained.

The adopted call admission control (CAC) policy has a strong influence in the routing performance. Although the performance of routing algorithms may change when different QOS criteria are required or different call admission schemes are adopted, we consider the choice of QOS criterion and the design of the call admission scheme to be orthogonal issues to the routing problem.

4. WORKING SCENARIO. In an ATM network, when there is an incoming connection demand each node evaluates the possibility of setting the new virtual path connection to all outputs through which the new connection can achieve the destination. When a new connection arrives the node must actualize the routing tables' values before the routing algorithm decides the output link. This paper assumes that a complete route is precalculed and is known at the originating node. As shown in Fig. 1, we focussed our study on a link of the selected route.

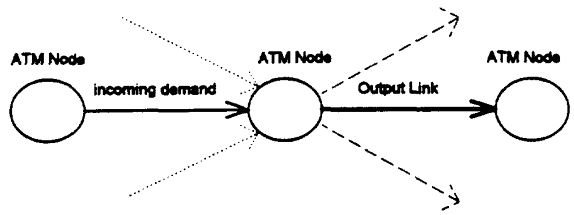

Figure 1. Working Scenario.

ECA is applied over this link to decide whether the new connection can be established or not. This scheme corresponds to both adaptative and isolated algorithms: routing decisions attempt to change according to the system load, and the routing algorithm run separately on each node.

The behaviour of the node is verified by comparison to both ordinary and anticipated evaluation. Incoming connection demands are used with exponential distribution under different traffic characteristic assumptions. Sources are modelled by GMDP and grouped in types with identical parameters.

5. ADAPTATIVE ROUTING WITH PRE-EVALUATED TABLES. Some well known algorithms, (peak-rate, linear procedure, etc), offer small delay, although over-estimate bandwidth necessary wasting network resources. However, a more accurate schemes, the convolution approach, offers a good bandwidth allocation. The response delay could be inadmissible; still, we used ECA, which skipped this problem.

Figure 2A shows the response delays corresponding to the incoming demands (a, b and c) over the selected output link. This delay depends on the bandwidth allocation scheme applied.

To offer immediate response to a new incoming demand, pre-evaluated calculations are needed [3]. The interarrival time between calls is from a few of seconds to minutes, during which the evaluation sub-system can be idle. During these periods the status of the system can be dynamically updated. For each type of source a new virtual connection is considered. This process allows to know whether it is possible to allocate or not this hypothetical new call. Later on , the evaluation sub-system restores data structures to the real status. A response vector R is used to store results: $R = R_0, R_1, \ldots, R_j, \ldots, R_{ST-1}$, where Rj can be: YES (Y), NOT (N) or Unknown (U) non-evaluated response, and ST is the number of Source Types.

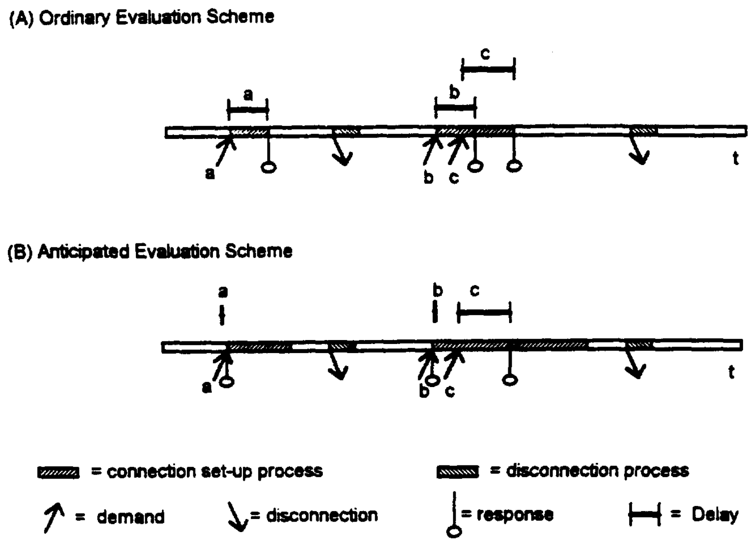

Figure 2. Ordinary and Anticipated Evaluation Schemes.

Figure 2B shows a scenario with an anticipated scheme. In this case, the incoming demands a and b obtain immediate response; the response to c is delayed because the evaluation sub-system is still evaluating the response vector R after the b connection.

Disconnection process consists in a re-evaluation of all the elements of the response vector R that are equal to N (No). After the call termination the responses of R equal to N are transformed to U to be re-evaluated. Note that Y responses do not need to be updated because the system load has decreased. These responses will continue equal to Y. However, the connection set-up process consists in a re-evalualuation of all the elements of R that are equal to Y (Yes), so that those elements equal to Y are transformed in U. In this case the N responses do not vary because the system load has increased.

There is a certain probability of collision between a new connection demand and the last set-up connection process. If the table has not been completely calculated, the system will compute the element of the vector R corresponding to the new connection. This is an analogous situation to the ordinary case.

6. MULTICASTING ISSUES. In the future broadband network an additional requirement arises. Indeed, some services have a distributive nature, and thus require of future ATM switches the capability to provide a multicast and broadcast functionality. Broadcast can be defined as the provision of the information from one source to all destinations, where multicast provides the information from one source to many destinations.

Multicast is an additional problem, since a source node wishes to transmit the same packets to a number of destination nodes. The number of copies and the destination addresses of each of those copies are determined using the table of multicast virtual circuits. Usually this table is updated whenever a connection requires an additional multicast destination, or whenever a connection changes from unicast to multicast.

There are two possible straightforward approaches to provision of multipoint connection mechanisms in an ATM network:

a) Multiple Direct Point-to-Point VC's: Set-up a point-to-point connection with each of the destinations. Its major drawback is that the data may be duplicated needlessly.

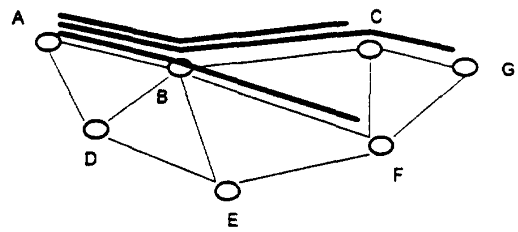

Figure 3. Multiple Direct Point to Point.

Figure 3 shows a network where a connection between node A and destination set {C, G, F} is desired. Note that link (A, B) carries each multicast message three times, once for each destination.

b) Point-to-Multipoint Virtual Path: Set-up point-to-multipoint VP's in the same way that point-to-point VP is set-up. In this case the ATM switches possess multicast capability (i.e., the capability of copying from one input port to several output ports). The major drawback of this technique is that it requires that a VP be set up for every possible combination of source and destination set.

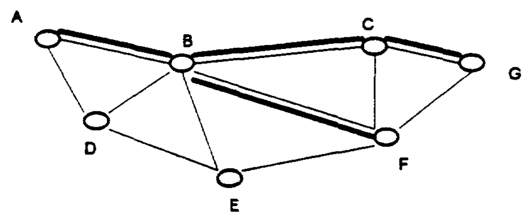

Figure 4. Point-to-Multipoint Virtual Path.

Figure 4 shows a route for the A to {C, G, F} connection using a point-to-multipoint VP.

In [1] Ammar et al., present mathematical formulations of the multicast routing problem a develops heuristics for finding a low cost multicast routing tree. They consider three different cost measures for a point-to-multipoint connection:

- Bandwidth Cost (Cb). This is the total bandwidth allocated to the connection on all the links it uses.
- Connection Establishment Cost (Ce): This is the number of VP's that are used to provide the multipoint connection. This is a measure of the complexity of the routing set-up procedure.
- Switching Costs, (Cs): This is a measure of the source resources used for the duration of the connection.

This study determines optimal routes that can be used to establish a VP tree for multipoint connection. The optimization objective is to minimize the cost above, individually or combined to form a total cost

$$C = \alpha \cdot \mathrm{Cb} + \beta \cdot \frac{\mathrm{Ce}}{\mathrm{T}} + \gamma \cdot \mathrm{Cs}$$

where T is the call duration and α, β and γ are weights assigned to the bandwidth, establishment and switching costs respectively, to reflect their importance. These weights could be conversion factors from the cost units we use to actual economic units.

The application of the adaptative routing method based in pre-evaluated routing tables makes the reduction of Cb and Ce individually possible. This is so, because the individual bandwidth allocated to each connection and the complexity of the set-up connection are reduced, insofar as the proposed method of routing is based on the enhanced convolution approach for the evaluation of the best routing option.

7. CONCLUSIONS AND FURTHER WORK. In this paper, the behaviour of routing in an ATM node is verified by comparison to both ordinary evaluation and anticipated evaluation. Incoming connection demands are used with exponential distribution under different traffic characteristics assumptions.

The method proposed for the evaluation of the best routing option is the Convolution Approach. This method is chosen because is the most accurate among all the studied ones. An enhanced version of the convolution approach, which surpasses the limitations of calculation time, is used.

Results show that the use of the pre-computed routing tables improve the performance of the multicast virtual circuits set-up. Aditional reductions of cost, bandwidth and set-up connection, can be achieved.

We are continuing our investigations into multicast routing in a number of ways. First, by looking at the performance of these algorithms for centralized an distributed routing. Secondly, we are looking at ways of improving multicast routing when an adaptative scheme is used.

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