Consolidating the ATM networks – traffic issues

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Abstract

The next article deals with the problem of traffic management in ATM networks. Existent solutions are presented and enhancements are proposed in the form of Enhanced Selective Cell Discard mechanism – with the help of simple and therefore fast mutual notifying between ATM switches the transfer of selective cell discard mechanism closer to the traffic sources is enabled. This in consequence enables more efficient load reduction in ATM networks. Our proposal has following features:
- congestion vanishes faster or it doesn't even occur,
- the load in transit ATM switches is reduced,
- previously unnecessarily used bandwidth can now be efficiently used,
- all together the efficiency of ATM network is increased,
- our proposed flow control mechanism is independent of individual connection routes, due to control information broadcast in all directions,
- control information spreading is very fast, which is very important in broadband networks,
- our proposal represents a good flow control mechanism for combined fix/mobile ATM networks.

It has to be emphasised that our proposal does not replaces the existent traffic management mechanisms, but is rather supplementary to them in the areas that were not covered until now. The proposed method of information exchange is reasonable in ATM networks with transit ATM switches. To say the other way, mutual notifying is reasonable, when output queues in ATM switches collect tributaries from remote traffic sources.
Introduction

The next article handles the traffic flows in ATM networks. ATM technology enables transfer of various data. There are four basic classes of service available: CBR, VBR, ABR and UBR. Class of service specifies more or less accurately the transfer requirements needed for individual services and applications. At connection set-up time, precise adjustments are made for each virtual connection. The capacity requirements are specified by PCR (Peak Cell Rate), SCR (Sustainable Cell Rate), MBS (Maximum Burst Size) and MCR (Minimum Cell Rate); in accordance with selected service class. The quality of service is typically connected to the terms CTD (Cell Transfer Delay), CDV (Cell Delay Variation) and CLR (Cell Loss Ratio).

In order to assure agreed quality of service to the users, traffic management in ATM network is essential. The following set of traffic and congestion control functions is available for traffic management [Afd96]:
- CAC (Connection Admission Control),
- UPC (Usage parameter Control),
- SCD (Selective Cell Discard),
- Traffic Shaping,
- EFCI (Explicit Forward Congestion Indication),
- Resource Management using Virtual Paths,
- Frame Discard,
- GFC (Generic Flow Control),
- ABR Flow Control.

ATM networks can implement one or a combination of these functions in order to meet quality of service objectives of compliant connections.

ATM technology was designed especially for broadband communications. Flow control was realised mostly through preventive methods (CAC, UPC, SCD, Traffic Shaping,...) [Sch96] [Rop96] [Key95] [Onv93]. The use of backward information (feedback loops) was very limited (EFCI). The major change happened with specification and realisation of ABR (Available Bit Rate) service class. ABR uses feedback traffic control loops, one for each virtual connection [Fah98] [Jai96] [Bon95] [Kun95]. Current state of traffic control mechanisms in ATM networks can be represented with following two extremes:
- CBR, VBR in UBR classes of service do not consider and do not adjust to the current network conditions (except during connection set-up time – CAC),
- ABR class of service uses closed control loops of end-to-end type, one for each virtual connection. This enables precise adjustments to the current traffic conditions, with some delay.
We derive from the fact that existent (previously listed) traffic monitoring and control functions take care for prevention and suppress of heavy traffic congestion in ATM networks. Most of unexpected difficulties (congestion) are caused by VBR traffic sources. At VBR connection set-up time, CAC function uses rules of statistical multiplexing. Term "statistic" implicitly says that situations can occur, where too many VBR sources are transmitting at high speed at the same time. Congestion in such situation is inevitable, for ABR control loops need some time to respond. Such congestion is usually short lasting and is simultaneously occurring only on certain parts in the ATM network.

Integration of mobile users into ATM network requires introduction of special functions for enabling fast and reliable tracking of moving users. Those users sooner or later arrive into area, where change over to the next base station is necessary. Change over requires adequate adjustment of virtual connections in fix ATM network – beside routing and other functions, the use of traffic management functions like CAC is required. ABR connections require adequate adjustment of ABR algorithms inside ATM switches.

The purpose of our proposal is introduction of traffic control mechanism, which will be, in contrary to ABR connections, independent of currently set-up virtual connections. This will alleviate actions required when change over has to be performed. The proposed mechanism should also improve traffic conditions inside fix ATM networks. Selective cell discard mechanism showed to be the most promising starting point.

**Selective cell discard mechanism**

Selective cell discard mechanism is intended for suppressing possible congestion inside ATM switches. Congestion appears most often in switch output queues – in point where cells are accumulating and waiting for their opportunity to be transmitted across transmission lines to the next ATM switch.

At congestion appearance or if congestion is imminent, selective cell discarding is started. SCD may only discard low priority cells. Priority is determined by CLP bit (Cell Loss Priority), that is located inside 5 byte ATM header. CLP on (CLP = 1) stands for lower priority cells, which can be discarded if needed.
SCD mechanism's influence on particular class of service

We want to determine the meaning of SCD mechanism for individual classes of service. To say the other way, we want to know, when cell discarding makes sense. General conclusion, that derives from previous section says, that use of SCD mechanism is reasonable if ATM cells and switches make use of CLP bit (CLP-significant cell transfer). For particular classes of service following assessments hold good:

1. CBR class of service has strict demands for cell delay and cell loss. Therefore the use of CLP bit has no sense. SCD mechanism is useless since no deliberate cell discarding is allowed.

2. VBR class of service is split on two subclasses: rt-VBR (real time information transfer) and nrt-VBR (non-real time). For rt-VBR the ATM cell delay is critical, therefore it has higher priority than nrt-VBR. On the other hand, typical nrt-VBR is more cell loss sensitive since it usually carries computer data. In both cases the use of CLP bit is possible and preferred. SCD mechanism is most suitable for VBR sources, mostly due to use of statistical multiplexing.

3. ABR class of service is usually cell loss sensitive. The use of CLP bit is possible but is not used for now – all cells have high priority (CLP = 0). ABR uses it's own mechanism of closed traffic control loops that enable fluent exchange of network status information. Due to lack of low priority cells SCD mechanism is useless.

4. UBR class of service has the lowest priority among all service classes, regardless to state of CLP bit. It makes no guaranties to the users. UBR connections can be classified among so called best-effort transport media. SCD mechanism is reasonable in connection with other classes of service. For UBR class of service, SCD mechanism makes no difference between low (CLP = 1) and high (CLP = 0) priority cells.

We conclude with the statement that the use of selective cell discard mechanism is reasonable for VBR and UBR classes of service.

Purpose of information exchange

Let's take a simple example for better understanding. We have an ATM network comprised of three ATM switches, as shown on Figure 1.
In ATM switch, for each output link (for each neighbouring ATM switch), there is usually one output queue for each class of service. Different scheduling methods exists. Typically CBR has the highest priority. Rt-VBR has higher priority than nrt-VBR, which in term has higher priority than ABR. UBR has the lowest priority.

Internal connections (inside one ATM switch) are not interesting for us since information exchange is not required. We are interested in connections that pass at least one transit switch. As can be seen from Figure 1, interesting connections are those that extend from A over B to C (connections X), and vice versa. Transit connections are interesting due to merger of traffic flows from different (remote) directions. Let's take a look at ATM switch B in our example. In output queues toward C, traffic tributaries from internal users (connections Y) and from users in ATM-switch A (connections X) are collected.

Now, let's assume situation where congestion occurs in just mentioned output queue. This triggers SCD mechanism. Existent SCD mechanisms focus on congested queue, as shown on Figure 2. All tributaries are considered equally – SCD discards rightful share of low priority cells from all tributaries. Existent SCD mechanisms can be improved by introducing information exchange function, as shown on Figure 3. The basic idea is to inform ATM switch A about congestion in ATM switch B. Switch A now knows about congestion toward ATM switch C and can make some immediate actions:
- it lowers or interrupts the throughput of UBR traffic flows in traffic flow X,
- it starts discarding less important VBR cells (CLP = 1) in traffic flow X,
- it sharpens criterions in bandwidth allocation algorithm for ABR virtual connections in traffic flow X (it lowers the throughput of proper ABR connections).
The basic idea of our proposal is to transfer the SCD function from congested queue closer to the traffic sources. Cells that are discarded in ATM switch A would so or so be discarded in ATM switch B. Early discarding of ATM cells reduces load in ATM switch B and releases some bandwidth between A and B. Released bandwidth can be used to increase traffic flow Z. Realisation of our proposal enables following improvements:
- congestion vanishes faster or it doesn't even occur,
- the load in transit ATM switches is reduced,
- previously unnecessarily used bandwidth can now be efficiently used.
Realisation of information exchange

Information exchange can be limited to space between neighbouring ATM switches, or it can be extended to narrow or wider surroundings. Congestion in ATM networks usually vanishes fast as a consequence of traffic flow variations in VBR tributaries and corresponding reduction of ABR tributaries. Wider information exchange (e.g. informing of all ATM switches in the network) makes no sense, therefore. Due to transfer delay, it can even have negative effects, like unnecessary discarding of ATM cells and thus lowering the network efficiency.

The most appropriate cells for information exchange are RM cells (Resource Management). Those cells are already in use for transfer of current traffic situation report in ABR class of service. Detailed descriptions of formats and codes of RM-cell are out of scope of this document. We limit our proposal to specify the parameters, which are essential for realisation of our proposal. Those parameters are extracted in the following table:

<table>
<thead>
<tr>
<th>parameter name</th>
<th>octet no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>switch ID</td>
<td>2</td>
</tr>
<tr>
<td>queue destination ID</td>
<td>2</td>
</tr>
<tr>
<td>notice ID</td>
<td>1</td>
</tr>
<tr>
<td>hop counter</td>
<td>1</td>
</tr>
<tr>
<td>congestion level</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: Essential parameters in control cells

*Switch ID* identifies originating switch. Originating switch is where congestion has occurred – originating switch starts transmitting notification to all neighbouring ATM switches. Identification can be made in the same manner as in telephone networks (14-bit identification code PC – Point Code).

*Queue destination ID* is essential if traffic reduction is to be made only for congested output queue – reduction is to be made only on virtual connections that traverse through congested queue. Identification can be made the same way as for switch ID. The point code number of ATM switch that receives cells from congested output queue identifies congested queue.

*Notice ID* is necessary due to possible multiple receipt of the same control cells. This situation can occur due to information broadcast if network is not hierarchically regulated. Any switch is obliged to check the value of notice ID at receipt of new control cell. If the new value is the same as in previous cell (or a little lower), cell is discarded. This is necessary for prevention of unnecessary usage and broadcast of
already received control cells. Notice ID numbers are rotating from zero in ever increasing order. In order for notice ID number to get its meaning, the appropriate switch ID and queue destination ID numbers have to be included.

*Hop counter* determines the depth of information exchange. Originating exchange determines the hop counter value based on level and nature of congestion. At the receipt of control cell in next ATM switch, the value of hop counter is reduced for one. If the new value is nonzero, copy of received control cell is forwarded to all neighbouring ATM switches, except to the switch that has send control cell to the current switch in the first place. If the new hop counter value is zero, no copies are send – control cell has reached its final destination. For example, if originating switch wants to send control cells to the neighbouring switches only, the initial hop counter value of 1 has to be selected.

*Congestion level* determines the level and possibly the nature of congestion for congested output queue in originating ATM switch. For now, following two values have been specified:
- zero (0) indicates end of congestion; it can be used for testing of control connections,
- one (1) indicates unknown or unspecified congestion level.

**Switch and source behaviour**

*Originating ATM switch* sends new control cells to all neighbouring switches immediately after congestion appearance or if congestion is imminent. Just before sending, appropriate notification depth (hop counter value) and congestion level has to be determined – here a special algorithm is required. If congestion is still present after a period of $T_S$, new control cell is sent. Each newly sent control cell contains a new, for one higher value of parameter notice ID. With regard to level and nature of congestion, the originating switch has following parameters available:
- congestion level,
- notification depth (hop counter),
- period $T_S$ – notification frequency.

After receipt of new control cell, *receiving ATM switch* has to identify originating ATM switch and congested output queue first. If notice ID indicates repeated reception of the same control cell, cell is discarded. Otherwise the hop counter value is reduced and checked. Rules for hop counter have been defined in previous section. The control cell has now been properly received; therefore identification of appropriate virtual connections has to be made. We are looking for those connections that extend from receiving ATM switch over originating ATM switch toward ATM
switch, which is identified by congested output queue. If any such connection exists, SCD mechanism is started. SCD may only discard low priority cells from identified virtual connections. Percentage of discarded cells is determined by special algorithm based on congestion level and on number of control cells received (for same output queue) in time period $T_R$. If no new control cell is received within time period $T_D$, SCD mechanism terminates – congestion cessation is assumed.

In special cases the notification depth (hop counter value) is big enough for control cells to reach access ATM switches. In this case possibility exists to inform individual ATM sources about congestion in ATM network. Those notifications are optional and not obligatory – users are not obligated to respond.

**Recommended class of service**

Our proposed traffic control mechanism is best suited for VBR class of service. For transfer of computer data we suggest the user of nrt-VBR class of service with the following adjustments: Parameter MBS (Maximum Burst Size) should be set to zero (0). Conformance definition 2 or 3 is to be used, in accordance with ATM Forum specifications [Afd96] – for SCR (Sustainable Cell Rate) only high priority cells (CLP = 0) are verified for compliance and for PCR (Peak Cell Rate) compliance of all cells (CLP = 1 and CLP = 0) is verified.

With just mentioned adjustments, users can transmit ATM cells with maximum speed (PCR) all the time. Reliable transfer is guaranteed for high priority cells only (CLP = 0). Those cells can be transmitted with maximum speed of SCR, if transmission quality is to be guaranteed. SCR can be compared with MCR (Minimum Cell Rate), which is used in ABR class of service. Low priority cells may be discarded if congestion occurs. Nrt-VBR connections with SCR speed set to zero (0) can be compared with UBR connections. Therefore, no special UBR class of service is required.

Main disadvantage when using nrt-VBR class of service (with suggested adjustments) for data transfer is undefined cell loss ratio (CLR) for low priority cells (CLP = 1). One of the advantages in comparison with ABR class of service is simpler implementation of usage parameter control (UPC) function – no adjustment to the current traffic situation and no synchronisation with traffic sources is required.
Comparison of our proposal with ABR traffic control

Let's take a simple example, as shown on Figure 1. Now, suppose congestion occurs in output queue toward ATM switch C inside ATM switch B. We also suppose, that 1000 connections is established through this queue form A toward C.

First, let's suppose all connections are of ABR type. The ABR traffic control mechanisms are used. At congestion occurrence, each traffic source has to be notified separately. This denotes that 1000 notifications have to be sent toward ATM switch A. Notification speed depends on individual connection speed and on time spent till arrival of new RM cell.

Now, our proposed traffic control mechanism is used – all connections are of nrt-VBR class of service with suggested adjustments, as stated in previous section. Nature of information transferred is the same as when ABR connections are used. At congestion occurrence, only one notification is sent from ATM switch B toward ATM switch A. Information exchanged is switch bound in contrary to connection bound exchange in ABR traffic control mechanism.

Conclusions

In this article we have discussed problems concerning traffic flow control in ATM networks. First, existent solutions have been introduced. Afterwards, our proposed solution in the form of Enhanced Selective Cell Discard mechanism is presented. With the help of simple and therefore fast mutual notifying between ATM switches, information about congestion in individual ATM switches is spread throughout the network. This in term enables the transfer of SCD mechanism closer to the traffic sources. Our proposal has the following advantages:
- congestion vanishes faster or it doesn't even occur,
- the load in transit ATM switches is reduced,
- previously unnecessarily used bandwidth can now be efficiently used,
- all together the efficiency of ATM network is increased,
- our proposed flow control mechanism is independent of individual connection routes, due to control information broadcast in all directions,
- control information spreading is very fast, which is very important in broadband networks,
- our proposal represents a good flow control mechanism for combined fix/mobile ATM networks.
Our proposal has, in addition to presented advantages, also some drawbacks. Those can be condensed in the following lines:
- cell loss probability of low priority cells (CLP = 1) is undefined and changes in accordance with current traffic situation in ATM network, as is the case for UBR class of service,
- appropriate adjustments of higher layers would have to be made, if just mentioned problem with low priority cells is to be eliminated (e.g. higher priority packets should be sent with CLP = 0, entire packet should be sent with the same CLP bit state, ...),
- ATM switch has to know the entire route for all virtual connections that traverse through it. This is necessary for identifying appropriate virtual connections on which SCD mechanism is to be performed.

It has to be emphasised that our proposal does not replaces the existent traffic management mechanisms, but is rather supplementary to them in the areas that were not covered until now. The proposed method of information exchange is reasonable in ATM networks with transit ATM switches. To say the other way, mutual notifying is reasonable, when output queues in ATM switches collect tributaries from remote traffic sources.

Much of the work is still to be done in the future, if our proposal is to revive in real ATM networks. First, appropriate algorithms for ATM switches have to be elaborated. The next step will be extensive simulations of our proposal's behaviour. During the future work, modifications and completions of our proposal are expected.

References


