Interoperability Control between Heterogeneous ATCs in ATM Public Networks

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Abstract

In this paper, we described the necessity of interoperability control between heterogeneous ATM transfer capabilities in the public networks and proposed the service interworking method and the network interworking method for the interoperability control mechanism depending on the closed-loop range of each ATM transfer capability. Additionally, we proposed the DBR with Backward Explicit Congestion Notification method for the ABR / DBR interoperability control and the Block Cell Rate Re-negotiation with State Dependent mechanism for the ABR / ABT interoperability control when DBR and ABT capabilities are implemented in public networks. Also, we analyzed the performance of the proposed interoperability control mechanisms in terms of the maximum queue length and the bandwidth utilization through the simulation.

1. Introduction

An ATM Transfer Capability (ATC) specifies a set of ATM layer parameters and procedures that is intended to support an ATM layer service model and a range of associated Quality of Service (QoS) classes. These ATCs are classified by the transmission characteristics of the ATM layer. The four ATCs, which are Deterministic Bit Rate (DBR), Statistical Bit Rate (SBR) for open-loop control ATCs and ATM Block Transfer (ABT), Available Bit Rate (ABR) for closed-loop control ATCs, were currently specified in the recommendation I.371 of ITU-T SG 13.[1]

On the other hand, the ATM Forum has defined five service categories in Traffic Management Specification Version 4.0. These are Constant Bit Rate (CBR), Real-time / Non-real-time Variable Bit Rate (VBR), ABR and Unspecified Bit Rate (UBR). These service categories relate traffic characteristics and QoS requirements to network behavior.[2] However, ATM Forum does not accommodate the ABT capability recommended by ITU-T and ITU-T also does not define the UBR of ATM Forum in its recommendation. Meantime, Guaranteed Frame Rate (GFR) is recently being studied as a new ATC and a new service category in the both ITU-T and ATM Forum.

A service request from a user may implicitly specify the requested ATC as a traffic parameter in call / connection control messages. For the implementation of B-ISDN call / connection control, Q.2961 series of ITU-T SG11 specified ATM traffic descriptors and set-up parameters for each ATC. The choice of a suitable ATC by the user is determined by following factors.

- Service requirements of an application.
- Availability of transfer capabilities supported by the network and the terminal.
- Attainable QoS from each ATC.
- Capability of an application to cope with degradation of the ATM layer transfer characteristics.
- Tariff policy, etc.

These factors are related to QoS requirements and tariff of application data. Meanwhile, from the viewpoint of network side, the ATCs may be generally accommodated according to the service demand and the progress status of standardization. So, all ATCs defined in the recommendation may not be provided in ATM public networks at any point of time. Therefore, even though the public switching system does not have the requested ATC, it has to assign the other proper ATC which can guarantee the required QoS instead of the requested ATC using the interoperability control function.

ITU-T SG13 has recommended that the DBR transfer capability is mandatory and all ATCs can be accommodated by DBR ATC.[1] This means the DBR ATC can emulate all other ATCs even if the bandwidth utilization is low. The ATM public switching system may implement only the DBR ATC in the first implementation stage. The accommodation of ABR ATC in public networks is recently considered actively. However, the most of all implementations are the binary mode operation. The Explicit Rate (ER) mode switching system is rarely implemented.[4] Under these circumstance, it may be valuable that the consideration of the possibility of ABR ATC accommodation using DBR ATC.

Another possibility is the internetworking between ABR and ABT ATC. Since ABR and ABT capabilities can accommodate same type of user services, it is reasonable to implement one ATC among ABR and ABT capabilities in the public switching system and the other ATC can be emulated using the interoperability function. In this case, we propose the ABR emulation using ABT capability network, since ABT capability can request the required bandwidth at the source switching system.[5] This is also valuable for the interoperability between private network and public network.

This paper focuses on the interoperability controls of ABR / DBR transfer capability and ABR / ABT capability in terms of service interworking method and network interworking method when DBR or ABT capability is implemented in the public networks. Section 2 describes the interoperability control functions according to the interworking methods. Section 3 provides some detailed mechanisms on the implementation of each proposed interoperability control and describes the mapping of traffic parameters for signaling. Section 4 evaluates the performance of proposed interoperability mechanism through the simulation. Finally, section 5 gives conclusions.

2. Interoperability Control between heterogeneous ATCs

There are two distinct interworking methods for the interoperability control between heterogeneous ATCs in ATM public networks. These are the service interworking method and the network interworking method.

- Service Interworking : this method allows direct communication between heterogeneous ATC users. IWF (InterWorking Function) provides mapping function of different traffic parameters and QoS requirements.
- Network Interworking : this method provides transparent transport of end user's ATC protocols through public networks using virtual the trunking mechanism.

2.1 ABR / DBR interoperability controls

2.1.1 Service interworking

In the service interworking method of the ABR / DBR transfer capability interoperability control, two IWFs are required such as figure 1. The ingress IWF / DBR switching system includes the ABR virtual destination (VD) function and the egress IWF / DBR switching system includes the ABR virtual source (VS) function. ABR Forward RM cells are converted to ABR backward RM cells at the ABR virtual destination of the ingress IWF and only data cells are transmitted to the ABR virtual source through the DBR connection of the DBR networks. The second ABR closed loop controls the ABR flow between the egress IWF / DBR switching system and an ABR destination.

However, if congestion is occurred at the second ABR closed loop, it makes the congestion situation to the egress IWF / DBR switching system which performs as an ABR virtual source. It is because the DBR transfer capability does not have any closed loop flow control algorithm in the DBR networks, whatever the ACR value of the virtual source is decreased, input traffic from the ingress IWF / DBR switching system sustains as same DBR transmission rate. Therefore, for preventing the egress IWF / DBR switching system from the congestion situation, the Backward Explicit Congestion Notification (BECN) RM cell is needed between DBR switching systems within public networks. This BECN RM cell can reduce the DBR transmission rate of the DBR network in the service interworking method.

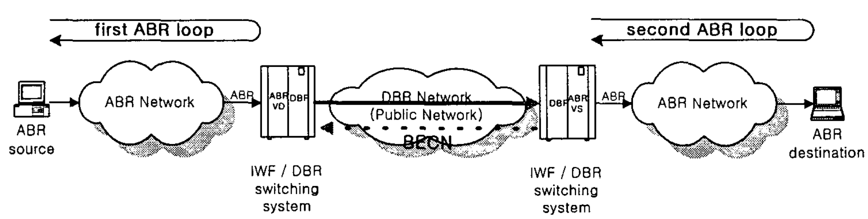


Fig. 1 Service interworking method for the ABR/DBR interoperability control

2.1.2 Network interworking

In the network interworking method of the ABR / DBR transfer capability interoperability control, single ABR closed-loop between the ABR source and the ABR destination is allocated such as figure 2. The ingress IWF / DBR switching system transfers transparently ABR forward RM cells through the DBR connection of the DBR networks to the egress IWF / DBR switching system. Therefore, the network interworking method is simply implemented in the

DBR switching system by performing the virtual trunking path of ABR flow control. Furthermore, the ABR function of the ingress and egress IWFs can provide the feedback information to the ABR source using the ABR backward RM cell flow in case of congestion in both IWFs.

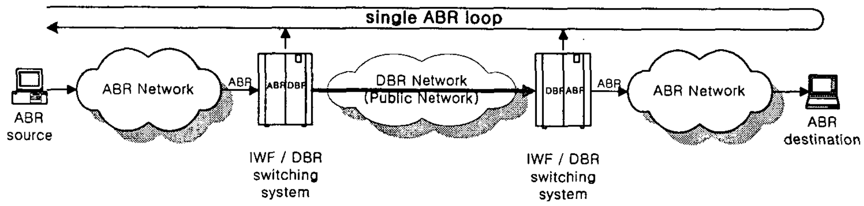


Fig. 2 Network interworking method for the ABR/DBR interoperability control

2.2 ABR / ABT interoperability controls

2.2.1 Service interworking

In the service interworking method of the ABR / ABT interoperability control, each ATC is controlled within each ABR and ABT closed-loop such as figure 3. Therefore, the ABT switching system having only ABT flow control mechanism has to have IWFs to support the ABR VS and ABR VD functions for ABR flow control. The ingress IWF / ABT switching system terminates the ABR forward RM cells and transmits the ABR backward RM cells to the ABR source using the ABR VD function. This ingress IWF / ABT switching system also generates the ABT RM cells for the Block Cell Rate (BCR) bandwidth request according to the ACR values extracted from the ABR forward RM cells. The egress IWF / ABT switching system has to perform the ABR source behavior for another ABR closed-loop control.

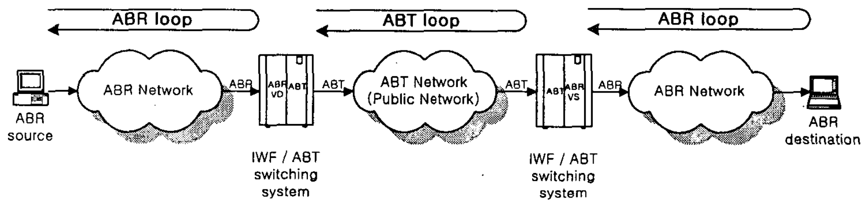


Fig. 3 Service interworking method for the ABR/ABT interoperability control

2.2.2 Network interworking

In the network interworking method of the ABR / ABT interoperability control, single ABR control loop is allocated between the ABR source and the ABR destination such as figure 4. The ABR forward RM cells are not extracted in the ingress IWF / ABT switching system but are transferred transparently as user data cells to the ABR destination through the ABT connection in the ABT networks. ABR functions of the ingress IWF are the extracting ACR value from the ABR forward RM cells and the providing the feedback information to the source using the ABR backward RM cell flow in case of congestion in the IWF. And, ABR function of the egress IWF can also provide the feedback information to the ABR source in case of the congestion situation.

The ABT closed-loop flow control is maintained internally by requesting BCR bandwidth or acknowledging the requests between ABT switching systems according to the ACR values extracted from the ABR forward RM cells. However, the network interworking method needs the large buffer since ABR RM cells pass through several switching nodes and the response time is increased due to the long ABR closed-loop control.

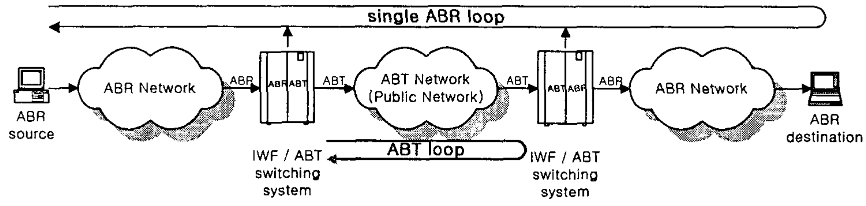


Fig. 4 Network interworking method for the ABR/ABT interoperability control

3. Implementation of interoperability control

3.1 Implementation mechanisms

In this section, we describe the implementation mechanisms of the ABR / DBR and ABR / ABT interoperability controls. Implementation of the ABR / DBR interoperability control is rather simple because we can use the DBR virtual trunking function in the DBR switching system. However, the service interworking method of ABR / DBR interoperability control should consider the additional congestion control method using the BECN RM cell as described in section 2.1.1. This mechanism can be implemented in the egress IWF / DBR switching system using the buffer with maximum and minimum thresholds.

On the other hand, the ABR / ABT capability interoperability control should consider the mapping function between ABR and ABT flow control mechanism. Furthermore, since an ACR is time-varying according to the network control, the BCR of ABT traffic should be changed according to the variation of the ACR of ABR traffic for the ABR / ABT interoperability control. This can be implemented by the two approaches, BCR Re-negotiation According to the ACR Change (BRAC) mechanism and BCR Re-negotiation with State Dependent (BRSD) mechanism.[6]

The BRAC mechanism transmits the BCR bandwidth change request RM cell whenever the ACR value is changed at each ABR source. Therefore, the BRAC mechanism requires the buffer of each ABR connection. Also, the BRAC mechanism increases the number of BCR re-negotiation frequency when the ABR input traffic change increases. However, BRSD mechanism uses one common buffer with two thresholds for all ABR connections and requests the BCR bandwidth allocation according to the buffer state such as figure 5. This buffer queue of BRSD mechanism is implemented in the ingress IWF. The BCR bandwidth allocation is requested with PCR of ABT connection when the queue length of the common buffer exceeds the high threshold (HT) value and the data transmission stops when the queue length becomes less than the low threshold (LT) value. When the queue length exceeds the maximum threshold value, the congestion state is also indicated by setting the CI bit of the ABR backward RM cell using the BECN method. It prevents increment of the queue length of the ABT switching system continuously by suppressing the ABR source traffic. Therefore, the proposed BRSD mechanism can reduce the buffer size and increase the bandwidth efficiency.

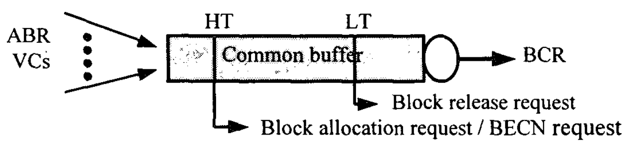


Fig. 5 Conceptual model of the BRSD mechanism

3.2 Traffic parameters mapping

For the implementation of interoperability control, we should consider the mapping of traffic parameters of signaling messages. The SETUP message for a call/connection control contains traffic descriptors, setup parameters related to the QoS requirements and the requested ATC.

These traffic descriptors and setup parameters should be transmitted to the destination equipment for the guarantee of requested QoS through the public networks. Therefore, the mapping of traffic descriptors and setup parameters should be performed in the connection setup procedures for the conversion of flow control algorithms in the ingress and egress IWFs having the interoperability control function. Moreover, even if some traffic descriptors and setup parameters do not perform mapping, these parameters should also be transmitted to the destination. It is because that the egress IWF can not regenerate traffic parameters of the source ATC. For example, The PCR of ABR ATC can be conversed to the PCR of DBR and ABT ATC in the ingress INE and vice versa in the egress IWF. Also, MCR and Initial Allowed Cell Rate (IACR) traffic parameters should be transmitted transparently to the destination equipment through the DBR or ABT networks.

4. Performance evaluation of interoperability controls

4.1 Simulation model

We analyze the performance of the proposed mechanisms for the ABR / DBR transfer capability and the ABR / ABT capability interoperability controls in terms of queue length behavior and bandwidth utilization, as each mechanism is applied to the service interworking method and the network interworking method respectively. Figure 6 illustrates the simulation model for the performance evaluation of the interoperability controls. The following input traffic parameters and assumptions are used.

- ABR input sources, n = 5, are assumed as the persistent traffic model.
- The transmission rate of the DBR ATC is 30 Mbps per each DBR connection.
- ABT connection between the ABT source and the ABT destination starts at 400 ms with 50 Mbps and is maintained for 400 ms.
- The propagation delay between each node is assumed as 1 ms.
- For the service interworking method, the ABR VD function is performed at the ABT switching system 1 and the ABR VS function is performed at the ABT switching system 2.
- Bandwidth for transmission of the ABR backward RM cell is assumed to be allocated in the network interworking method.

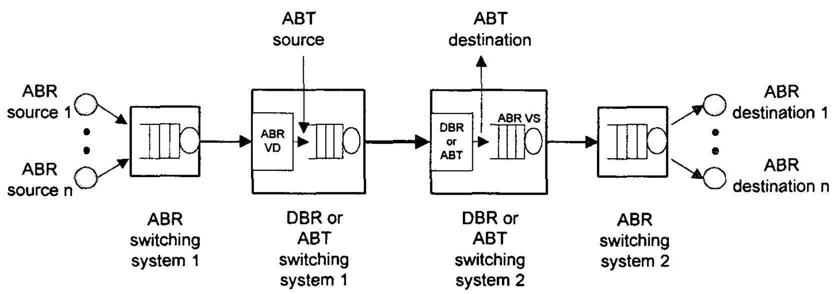


Fig. 6 Simulation model.

4.2 Simulation results

4.2.1 ABR / DBR interoperability controls.

Figure 7 shows the queue length behavior of the service interworking method in the DBR switching system 1 and 2 when congestion is occurred in the ABR switching system 2. When there is no BECN RM cell within the DBR switching system, the buffer of the DBR switching system 2 increases continuously and experiences queue full state. The other hand, the buffer of the DBR switching system 1 is almost empty. Since the maximum queue length of the DBR switching system 1 is only 15, it does not plotted in figure 7. However, the proposed method using the BECN RM cell can sustain the queue length of the DBR switching system 1 and 2 below the maximum threshold value where the buffer threshold is 2500 as in figure 7. It is because the DBR switching system 1 reduces the transmission rate when it receives the BECN RM cell.

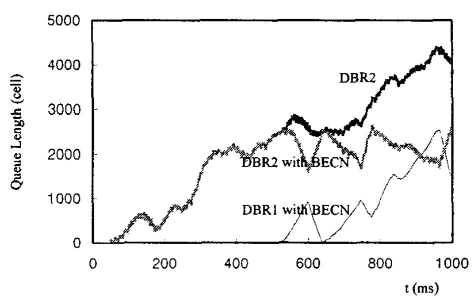


Fig. 7 Queue length behavior of the DBR switching system

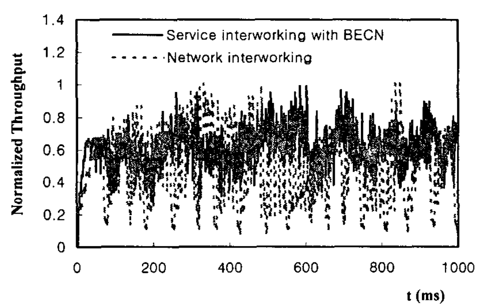


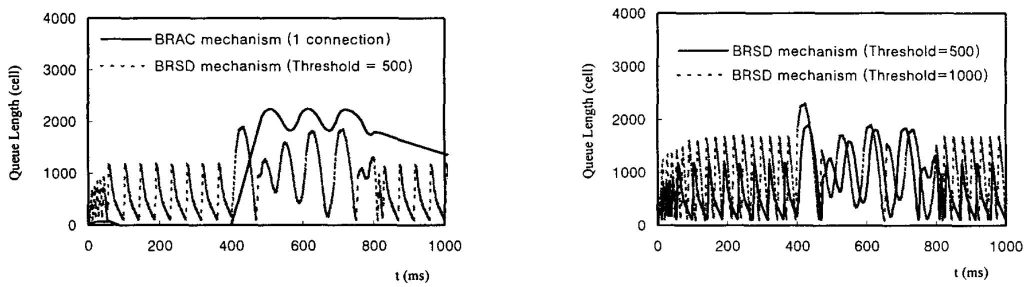
Fig. 8 Normalized throughput in the DBR switching system

The normalized throughput of the real bandwidth usage of the DBR switching system is shown in figure 8. Here, we can see that the normalized throughput of the network interworking method plotted as the dotted line is under average 0.5. However, the normalized throughput of the service interworking method using the BECN RM cell plotted as the solid line is over average 0.7. It is because that the network interworking method reduces the source transmission rate through the ABR backward RM cell flow when the ABR switching system 2 encounters congestion situation. Therefore, the throughput of the DBR switching system decreases.

4.2.2 ABR / ABT interoperability controls.

Figure 9 shows the queue length behavior of the service interworking method in the ABT switching system 1. In figure 9(a), the queue length of one ABT connection of the BRAC mechanism is plotted as the solid line and the dotted line indicates the result of the BRSD mechanism when the threshold value is 500. The maximum queue length of the BRAC mechanism is larger than the BRSD mechanism though only one ABT connection. When a new ABT connection is added from 400 ms according to the simulation scenario of the section 4.1, each bandwidth of ABT connections of the ABR / ABT interoperability control is decreased and the congestion is occurred in the ABT switching system. Therefore, the queue length of the BRAC mechanism is increased abruptly from 400 ms. Meanwhile, the BRSD mechanism can reduce the maximum queue length comparing with BRAC mechanism by using the common buffer for all ABR source connections and requesting the BCR bandwidth allocation according to the buffer state.

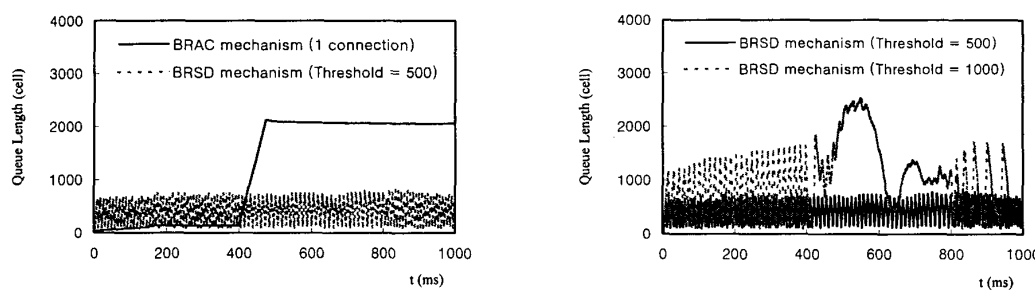
Figure 9(b) shows the queue length behavior of the BRSD mechanism according to the threshold value. The maximum queue length increases only about 10 % of the maximum queue length of the BRSD with threshold = 500 even though the threshold value increases to 1000.



(a) Queue length behavior of two mechanism (b) Queue length according to the threshold in the BRSD

Fig. 9 Queue length of the service interworking method

Figure 10 shows the queue length behavior of the network interworking method in the ABT switching system 1. The queue length of the BRAC mechanism is also increased from 400 ms and the maximum queue length is larger than the BRSD mechanism such as figure 9(a) of the service interworking method. Furthermore, as the round trip time of ABR RM cell is longer than the service interworking method, the maximum queue length of the network interworking method of BRAC mechanism is sustained after the congestion situation is finished as in figure 10(a). Meanwhile, the maximum queue length of BRSD mechanism is decreased due to the BECN effect than the service interworking method. However, if the threshold value of BRSD mechanism is 1000 such as figure 10(b), the queue length is increased. It is because the response time is longer than the service interworking method.



(a) Queue length behavior of two mechanisms (b) Queue length according to the threshold in the BRSD

Fig. 10 Queue length of the network interworking method

From the results of figure 9 and 10, we recognize that the BRSD mechanism has a benefit that the proper buffer size according to the threshold value can be estimated since the maximum queue length of the BRSD mechanism was not fluctuated abruptly in the service interworking method and network interworking method.

Figure 11 and 12 are the comparison results of the normalized throughput of the BRAC and BRSD mechanisms in the ABT switching system 1 for the service interworking and network interworking methods, respectively. The BRSD mechanism can always sustain the high throughput during the BCR bandwidth allocation since it negotiates PCR for the BCR according to the buffer state. But, the BRAC mechanism has lower throughput than the BRSD mechanism. It is because that when the ABT switching system is in the congestion state, the ABR source decrease the ACR value according to the congestion information transmitted from the ABR VD function of the ABT switching system. Therefore, the bandwidth utilization of the ABT link bandwidth is decreased such as figure 11. Also, the normalized throughput of BRAC mechanism of the network interworking method has very low from 400 ms as in figure 12. It is because that after congestion situation of the ABT switching system, the recovery of bandwidth utilization needs long time due to the long response time of the network interworking method.

Furthermore, The BRAC mechanism in the service interworking method of figure 11 reaches maximum throughput about 100 ms faster than the network interworking method of figure 12. It is because service interworking method has shorter RM cell response time than the network interworking method.

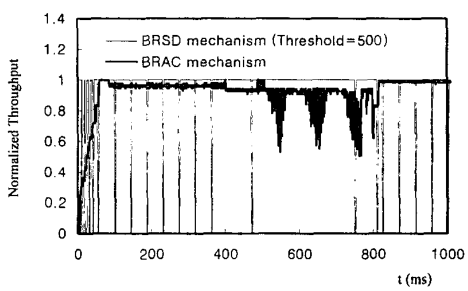


Fig. 11 Normalized throughput of the service interworking

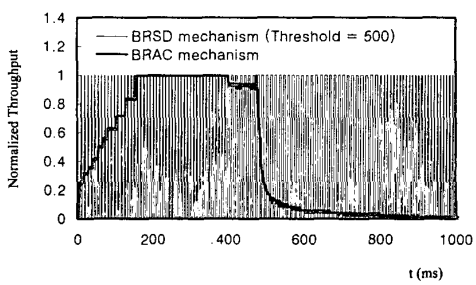


Fig. 12 Normalized throughput of the network interworking

5. Conclusions

This paper described the necessity of interoperability control between heterogeneous ATCs in the public networks and proposed the service interworking method and the network interworking method for interoperability control mechanism. For the implementation, we propose DBR with BECN method for the ABR / DBR interoperability control and the BRSD mechanism for the ABR / ABT interoperability control when DBR and ABT capabilities are accommodated in public networks and studied mapping of traffic parameters between different ATCs. Also, we analyze the performance of the interoperability control methods in terms of the maximum queue length, bandwidth utilization through the simulation. These simulation results show the possibility of interoperability control processing in the public networks.

[References]

[1] ITU-T SG13 Recommendation I.371, Geneva, June 1998.
[2] ATM Forum Traffic Management Spec. Version 4.0, Feb. 5 - 9, 1996.
[3] ITU-T SG13 I.371 Living List, Geneva, June 1998.
[4] Flavio Bonomi, Kerry W.Fendick, "The Rate-Based Flow Control Framework for the Available Bit Rate ATM Service", IEEE Network Magazine, pp25-39, March/April 1995.
[5] Fabrice Guillemin, "A Protocol for supporting the ATM Block Transfer with Delayed Transmission Capability", ITU-T SG13/8, Delayed Contribution No.1044, Geneva, April 29 - May 10, 1996.
[6] Woo-Seop Rhee, Yoon-Young An, Hwa-Suk Kim, Hong-Shik Park, "Interoperability mechanism of ABR/ABT capability in ATM public networks", IEEE ICC'97, Montreal, 8-12 June, 1997.