RPC LSP detection and fuzzy control mechanisms in ATM based MPLS on BcN

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Abstract

A major goal of the BcN (Broadband Convergence Network) is to facilitate convergence of networks and services. Many transport-related technologies were considered. One technology discussed is ATM (Asynchronous Transfer Mode) based MPLS (Multi-protocol Label Switching) for its provisioning QOS (Quality Of Service) commitment, traffic management aspects and smooth migration to the BcN in Korea.

In this paper, we present preventive congestion control mechanisms for detecting RPC (Rare Probability of Connection) LSP (Labeled Switched Path) in ATM based MPLS systems. In particular, we introduce a RPC LSP detection method using network signaling information. RPC LSP control can handle 208% call processing and more than 147% success call, than those without control. It can handle 187% BHCA (Busy Hour Call Attempts) with 100 times less use of exchange memory. We concluded that it showed fast congestion avoidance mechanism with a lower system load and maximized the efficiency of the network resources by restricting ineffective machine attempts.

1. Introduction

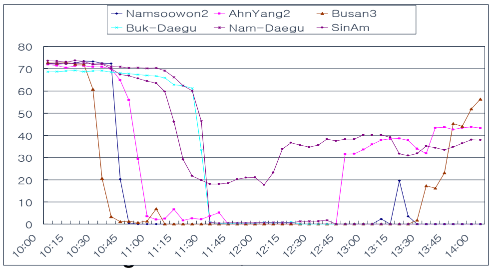
1.1 Background

BcN is the Korean name of NGN that we resolutely called IP (Internet Protocol) based B-ISDN. Most telecom operators use separate networks for voice and data services with different protocols and networking technologies.

Current packet switched networks (IP routers) historically have never supported quality of service due to the fact that they only look at packets and do not keep any state information on individual flows. An individual flow might be a voice call, video call, file transfer, or web access. The need to integrate interactive and distribution services, as well as circuit and packet transfer modes into a universal broadband network are gradually increasing [5]. For supporting QOS on the user side, network equipment venders try to introduce new mechanisms for converging circuit and packet switching into one. The nature of IP is random packet discarding during a congestion status. For provisioning QOS commitments in IP traffic, ATM based MPLS was introduced as a backbone system for traffic engineering and smooth migration from legacy networks. Finding a way for such the trail is an ATM based MPLS that will be used for the time being. In this paper, we introduce RPC LSP detection and fuzzy control mechanism in ATM based MPLS system on BcN.

1.2 Motivation

On February 28, 2005, there was a telecommunication disaster in Korea. The main reason for the disaster was call concentration at a specific time for telephone banking calls. The day was Monday and the following day was a holiday. Normally, telephone calls are concentrated on Monday during the week, and at the end of the month, when a user pays his bill by using the telephone banking systems.



concentration, relevant completion ratio, and system status are shown.

Controlling the RPC code should be done at the exchange (from which a desired call attempt is made) or at the switching system that is the near an originating exchange.

2. RPC Definition and effects

A call/ session for which the call/session completion ratio is lower than normal, is called a PRC LSP. Communication disaster on 2005 was call concentration at a specific time for telephone banking calls (using Intelligent Network). Such calls were hard to reach to the destination. Another telecommunication disaster was reported in May 5 1983. An airplane from the Republic of China was landed without notice or without any schedule. It was just happening, but the telecommunication network in Korea was congested. The reason for the disaster was different from those of 2005.

The main reason for this disaster (2005) was concentration of calls at a specific time for specific destination number that was hard to success. But in the 1983, call attempts that were beyond engineered system capacity were made to the network. Even though, a system properly controlling the excessive call attempts could have prevented a telecommunication disaster.

A conventional PSTN is directed to check the call completion ratio with regard to the RPC candidate code that was entered by an operator [15].

The exchange system cannot automatically generate RPC candidate code, because RPC candidate codes are different from the area that was located. Figure 2 shows the effect of the RPC code control on February 28, 2005 [18]. System shows a different call completion ratio even during the excessive call concentration.

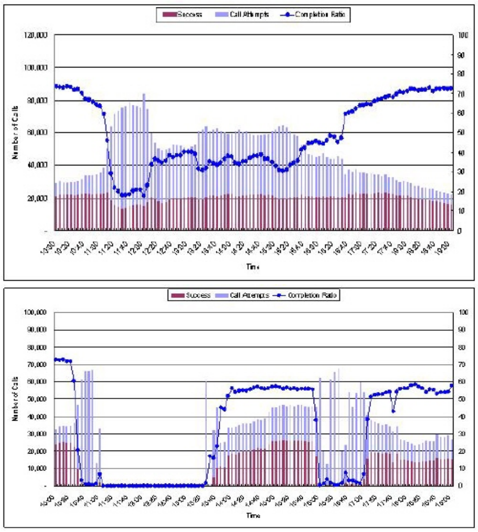


Figure 2 With/Without RPC control [18]

In PSTN, RPC code information should be able to be transmitted on a per-call basis via a CCS (Common Channel Signalling) system to other switching systems. This capability applies to CCS SS6, but at present is not supported by SS7.

2.1 RPC Detection method in PSTN

When the call completion(session establishment) ratio for the corresponding code falls below a predetermined threshold value, the calls to the corresponding code are controlled [2].

The originating exchange processes

the call attempt, as an incomplete call by sending a busy tone to the user or to the switching system. However, when judging all of the busy tones or an absence of response, to set an RPC code should be because of numerous system errors. This is because the meaning of RPC is that the call completion ratios regarding the lack of resources in a specific toll/terminating exchange or that the user is busy. Therefore, it is necessary to measure the statistical probability of an incomplete call due to a lack of system resources and user busy.

In addition, when performing a function that is based on a conventional candidate code, the control will only perform for a predetermined length of time after the operator enters the predetermined code. Therefore, it is impossible to prevent the call concentration problems on a predetermined switching system due to the possibility of unpredictable failures in the system.

2.2 RPC control mechanisms in PSTN

Two congestion control mechanisms were used in PSTN, that is “Automatic call gap” and “percentage based” congestion control. The time difference between congestion recognition and proper control action creates improper call/connection restrictions. The nominal time difference is 5 minutes for most conventional PSTN exchanges.

When an ACG control is initiated, a duration timer should be set to mark the duration of the control. Permissible values for the control’s duration are 0.1, 0.25, 0.5, 1, 2, 5, 10, 15, 30, 60, 120,300, 600 sec. as well as an infinite interval [14]. This mechanism was introduced by Bellcore and most of legacy PSTN uses this mechanism.

The percentage call/connection blocking algorithm is also useful for immediate traffic control [14]. A conventional percentage call/connection blocking algorithm uses the predefined input of an 8 class limit ratio from 0% to 100% with a 12.5% incremental unit for each congestion level

3. RPC LSP detection method in BcN

This paper proposes RPC LSP detection mechanisms using signaling information during the call active state. Conventional RPC code detection in PSTN was made based on the call completion ratio that makes a late response between congestion recognition and control. The main reasons for proposing mechanisms are summarized in Table 1. In a legacy ATM system, UNI/NNI (User Network Interface/Network Node Interface) signaling protocol was used for a connection establishment between a CEQ (Customer premise Equipment) and an ATM system. During call active phase, relevant information can be gathered that can be used for controlling congestion and other useful system status. But in the ATM based MPLS system, since we do not have ATM aware terminals and protocol for a connection setup, most of cell/call level information that would be useful for knowing cell/call level detailed connection/system status cannot be gathered. Only soft PVC (Permanent Virtual Connection) (Q.2724) signaling is available for connection establishment that it can be activated by operator. Most of legacy ATM system was implemented using it, own proprietary protocol for the soft PVC establishment. None of cell/call level information can be available. New mechanisms should be introduced for controlling network congestion.

The CAC function does not react against system congestion and it does not even recognize symptoms of congestion. Without the proposed mechanism, MPLS systems will easily face network congestion even with a small call/cell fluctuation. The followings are relevant information from the ATM based MPLS domain.

3.1 EFCI/EBCI

The main purpose of the PTI(Payload Type Identifier) is to discriminate between user cells from non-user cells. Code points 0 to 3 are used to indicate user cells. Within these points, value 2 and 3 are used to indicate that congestion has been experienced in the network.

EFCI/EBCI(Explicit Forward/Backward Congestion Indication) is a congestion notification mechanism which may be used to assist the network to avoid and recover from a congested state. It is also used to indicate a network's congestion state ABR or ABT services.

3.2 ACL(Automatic Congestion Level)

ACL message is one of the information elements that can be generated by the call processing procedures. RELEASE and RELEASE COMPLETE message is sent by the user/network to request the network to clear the end-to-end connection.

Among the RELEASE message, CAUSE information element that indicate detailed release causes is involved. We can get accurate call completion rates from the exact reason for the RPC code [1,2,3,4,15].

3.3 AIS/RDI(Alarm Indication signal/Remote Defect indication)

AIS/RDI OAM cell will be generated by connection point or connection end point. VP/VC-AIS cells shall be generated and sent down stream on all affected active VPC (Virtual path Connection)/VCCs from the VP/VC Connecting point (e.q. at an ATM switch) which detects the VPC/VCC defect at VP/VC level. VP/VC-RDI cells are generated and transmitted periodically while the VP/VC-AIS state persists in order to indicate in the backward direction an interruption of the cell transfer capability. These cells reflect the physical layer fault like LOS, LOP (Loss Of Pointer), LOF (Loss Of Frame) etc. and ATM layer fault.

3.4 Resource Management Cell

Resource management functions that have to operate on the same time-scale as the round trip propagation delays of an ATM connection may need ATM layer management procedures to use resource management cells associated with that ATM connection in ABR or ABT services[6,7,17].

3.5 Comparison of proposed RPC gathering methods

We propose 4 new RPC gathering techniques; however some proposed methods have some restrictions that apply to the ATM based MPLS system. As shown in Table 1, various cell or call level information are gathered. That can be used for controlling congestion and other useful system status.

Table 1 Necessity of proposed mechanisms

<table>
<tr><th></th><th colspan="2">Legacy ATM</th><th colspan="2">ATM Based MPLS</th><th></th></tr>
<tr><td>Cell level</td><td colspan="2">Cell Tagging
Priority Control
Frame Discard
UPC/NPC
EFCI/EBCI
RM</td><td colspan="2">AIS/RDI

UPC/NPC
EFCI/EBCI</td><td>Soft PVC
PVC

Optional for CEQ</td></tr>
<tr><td rowspan="3">Call level</td><td colspan="2">CAC
Routing</td><td colspan="2"></td><td rowspan="2">CAC by BW
LSP set-up
LSP withdraw</td></tr>
<tr><td colspan="4">Routing Resource Allocation</td></tr>
<tr><td colspan="3">Call Completion (ACL)</td><td>No Signal</td><td></td></tr>
<tr><td></td><td colspan="5">Can not recognize congestion within MPLS Domain. Only preventive UPC/NPC is available</td></tr>
</table>

Cell tagging option, priority control, and frame discard capability in cell level information are not available, only AIS/RDI and EFCI/EFCI signal will indicates symptoms of congestion in the MPLS domain. Because of the lack of signaling capability in ATM based MPLS system, the proposed information will be useful for controlling the network congestion for showing good performance by that RPC control mechanism.

4. Fuzzy RPC Control

Fuzzy logic was first proposed by Lotfi A. Zadeh of the University of California at Berkeley in a 1965 paper. He elaborated on his ideas in a 1973 paper that introduced the concept of "linguistic variables", which in this article equates to a variable defined as a fuzzy set. Other research followed, with the first industrial application, a cement kiln built in Denmark, coming on line in 1975.

In telecommunication networks, several research studies which apply FCS to traffic control have been reported [9,11,12,13].One of previous research study using UCR(Uncomplete Call Ratio) with proper fuzzification rules are the same measurement interval as conventional PSTN exchanges, but they use UCR from current uncompleted rate at specific interval, in addition to another input CUCR (Change of UCR) which is the difference between the current UCR and previous UCR. However, gathering UCR data takes the same amount of time as conventional control mechanisms.

As stated previously, studies have shown that FCS(Fuzzy Control System) RPC control mechanisms cannot reflect the network congestion status. But, this method results in better performance and simpler control algorithms [15].

4.1 Simulation model

We now formally describe the network to be dealt which in the rest of the paper and introduce our notation.

The network will be modeled as a directed graph (N, K) where the set N denotes the set of N nodes of the network and the set K denotes the set of K links.

Let P denotes the set of all source/destination (SD) pairs, [i, j], and P the cardinality of P. Each SD pair has associated with it a set R [i, j] consisting of all paths that a call corresponding to SD pair, [i, j] can take. Usually R [i, j] consists of paths that are at most two links. In this paper, we use [i, j] to denote both the SD pair between nodes i and j and the link connecting nodes i and j, but this will not cause confusion in what follows. (When convenient we may also number the links arbitrarily from 1 to K.) For link [i, j], let s_{ij} be the number of circuits or trunks. Any call which utilizes this link requires the use of one trunk.[8,10]

A call that is routed on a path with ***l*** links is treated as if it consisted of ***l*** independent calls for the purposes of call termination. This implies, among other things, that there cannot be simultaneous call terminations at different links. The dynamics of the network evolution can then be described by means of a network state $\underline{s}(t)$=([i, j](t), $x_1(t)$, $x_2(t)$, $x_3(t)$, … $x_K(t)$) where [i, j](t) denotes the SD pair corresponding to the last call arrival before time t and where $x_k(t)$ denotes the number of busy trunks in link k at time t ($0 \le x_k(t) \le \underline{s_k}$). When necessary we will refer to ($x_1(t)$, $x_2(t)$, $x_3(t)$, … $x_K(t)$) as $\underline{x}(t)$ The state space of the network states will be denoted by S and the state space for the $\underline{x}$'s will be denoted by X.As mentioned earlier, when a call corresponding to SD pair [i, j] arrives, it is either routed, rejected or blocked. If the state of the network was ([m, n], $\underline{x}$) when the call arrived and the call is routed over a path utilizing links k_1, k_2,

…k_l , then the state of the network after the call is routed is

$$\left([i, j], \underline{x} + \sum_{i=1}^{l} u_{k_i} \right) \quad (4.1)$$

where u_m represents a vector which consists of a 1 in the m^{th} component and zeroes elsewhere. Similarly, if a call terminates on link l, $1 \le l \le K$, when the state of the network is ([m, n], $\underline{x}$), the new state of the network becomes

$$\left([m, n], \underline{x} - u_l \right) \quad (4.2)$$

If a call corresponding to SD pair [i, j] is blocked or rejected when the network state is ([m, n], $\underline{x}$), the network state becomes ([i, j], $\underline{x}$). It is important to note here that the only decision making times are the call arrival times; no decisions need be made when calls terminate.

The use of call gap and percentage control depends on operator's decision. But as shown in the formulas, remaining resources between SD are

$$\mathbf{R\ [i, j]} - \left([i, j], \underline{x} + \sum_{i=1}^{l} u_{k_i} \right) \quad (4.3)$$

Let number of call attempt on specific time interval as CAij(Call attempts), current call blocking rate should be increased for preventing system congestion.

$$\mathbf{CAij * PCBt >= R\ [i, j]} - \left([i, j], \underline{x} + \sum_{i=1}^{l} u_{k_i} \right) \quad (4.4)$$

(where, CBt denotes call blocking ratio on interval on the time t)

As same as percentage control, call blocking gap interval also modified depending on incoming call attempts.

$$\mathbf{CAij * GCBt >= R\ [i, j]} - \left([i, j], \underline{x} + \sum_{i=1}^{l} u_{k_i} \right) \quad (4.5)$$

(where, GCBt denotes call gap interval on the time t)

Figure 3 shows simulation results with call gap control (0.1 sec, 0.25sec, 0.5sec) and Percentage control(12.5%, 25%) within the engineered system capacity. Less call blocking algorithm shows good performance within the engineered capacity. Beyond the engineered capacity, quite different results are generated. Generally, Gall gap shows good performance in a severe congestion state and percentage control is good for a moderate congestion state.

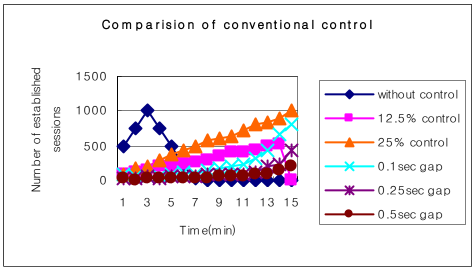


Figure 3 Comparison of conventional control mechanisms

4.2 Fuzzy RPC code control mechanisms

The main part of an FCS is a set of control rules of linguistic form that comprises an expert's knowledge.

In this paper, we use NCS (Network Congestion Status) and CNCS (Change of Network Congestion Status) as two inputs, to create a FCV (Fuzzy Control Value).

The first input, NCS indicates the network congestion status for a certain period and is gathered during data transmission. The time period may be changed along with the status of the ATM system. These scaled inputs NCS and CNCS have their own fuzzy values in the set {NB (Positive Big), NS (Negative Small), ZO (Zero), PS (Positive Small), PB (Positive Big)}. The elements of the fuzzy set have their own triangular shaped membership functions.

Using heuristic knowledge to decide the call blocking rate, we present the next three rules.

► If NCS is high, then it increases CNCS fast.

► If NCS is not high, but not too low neither, when CNCS is positive, it increases the call blocking rate fast, but if it is negative or equal to zero, it holds the current call blocking rate.

► If NCS is low, when CNCS is positive, it increases the call blocking rate moderately, and when CNCS is negative or equal to zero, it decreases call blocking rate slowly.

Based on the above rules, the knowledge based part of the FCV consists of 15 specific rules that uses two inputs and creates one output.

Overall fuzzy control system in this paper is following

1. **Measurement: NCS, CNCS = NCSn – NCSn-1**
2. **Fuzzy value NCSf = NCS/α, CNCSf = CNCS/β (Where 1< α, β < 100)**
3. **Apply Fuzzy rule(MS: Member Ship)**
   (Sncs(f), SCNCS(f))
   Sncs(f) = {(MS1, MS value), (MS2, MS value)}
   Scncs(f) = {(MS1, MS value), (MS2, MS value)}
4. **Apply Center of area**

K = Σ (Sncs(f) x Scncs(f)(I,J) MS value) x (Sncs(f) x Scncs(f)(I,J) Domain)

$$\mathbf{CBR} = \frac{K}{\Sigma\ (Sncs(f) \times Scncs(f)(I,J)\ MS\ value)}$$

In this paper, we use EFCI/EBCI factor for simulation, other factors described in chapter 4 will not be used for its uncertainty of correlation with each factor. The easy use of composite criteria for recognition of congestion is applying center of area rule for the composite factor. For example, if we use EFCI/EBCI and AIS/RDI, the composite values of NCS and CNCS are following.

$$\mathbf{NCS} = \frac{NCSefci + NCSAIS}{2}$$

Consequently, we can get CNCS value.

$$\mathbf{CNCS} = \frac{CNCSefci + CNCSais}{2} = \frac{(NCSefcin - NCSefcin\text{-}1) + (NCSaisin - NCSais\ n\text{-}1)}{2}$$

Figure 4 shows performance comparisons between traditional RPC control (percentage and call gap control) and fuzzy UCR under the less fluctuation of call attempts. 25% percentage control shows better performance. But if we apply 12.5% control (control is initiated by an operator), quite different results will appear.

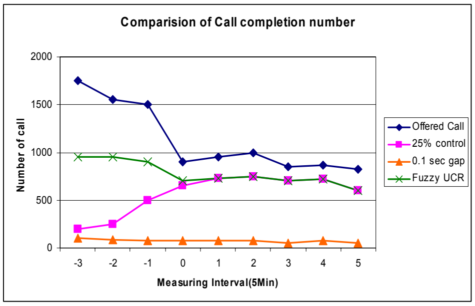


Figure 4 Measuring interval vs. call processing

Generally, processor's call handling capacity is expressed as Erlang. In this simulation, call duration is highly related to the call processing capacity. Figure 5 explains the effect of call duration vs. admission calls. In multimedia service, actual call durations are important factor for determining MPLS system capacity. Also, Erlang equivalent capacity indication should be provided for the network equipments. Such a theoretical analysis and efforts are still being processed.

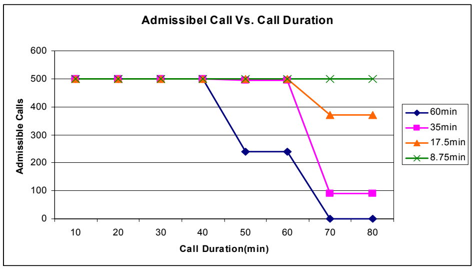


Figure 5 Admissible calls vs. Call Duration

As shown in the Table 2, RPC code control can handle 208% call processing and more than 147% success call than those without control. This simulation was made in ATM exchange developed by ETRI by the actual situation.

Table 2 With/without RPC vs. call capacity

	With HTR Control	Without HTR Control	Effects
Call attempts	4058/Min	2160/min	208%
Number of completion calls	2104/min	1427/min	147%
BHCA	243,480BHCA	129,636BHCA	187%
Memory	1.73 M (10K per call)	173M (173K per call)	100 times

If there is no RPC control, the system will close down gradually due to excessive call processing.

Generally, call gap control algorithms show a good performance when calls are peaking during a short period. But if the total accepted calls are exceed the system engineered capacity, the system will go down. This tells that if call attempts are gradually increased under the engineered capacity, percentage control is effective mechanism.

5. Effects of RPC control in the ATM based MPLS networks

We dynamically use the network congestion related information during the call/connection. Therefore the reaction time is short and even for a temporary congestion, the performance is better than any other control methods.

In the Figure 6, fuzzy NCS shows better performance than fuzzy UCR and all of the four simulation results excepts fuzzy NCS have the same performance when calls are under the engineering capacity. However, beyond the engineering capacity quite different results are generated.

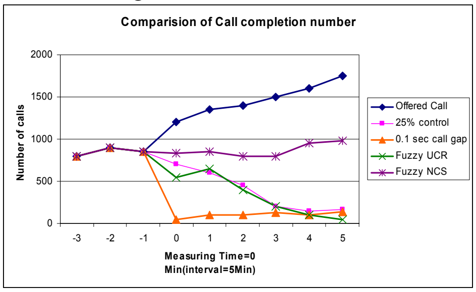


Figure 6 Fuzzy UCR vs. NCS

We generated total call attempts exact same as the telecommunication disaster on 2005.

We generated 0 to 40% EFCI/EBCI state randomly every specific intervals. In the Figure 7, we assumed that before the specific measurement interval (not shown in the figure), system was severe congestion status. The relevant previous UCR indicates 25% call blocking for any reason.

The figure7 shows relevant performance for each control methods. FCS control method that is based on current NCS and CNCS shows better performance. But in the x-axis near 86 times shows quite different behavior. It is because congestion status indicator (EFCI/EBCI) has abnormally generated on the time.

We concludes UCS based control methods can not control a burst traffic, especially it can not control rapid change of call concentration and normal state.

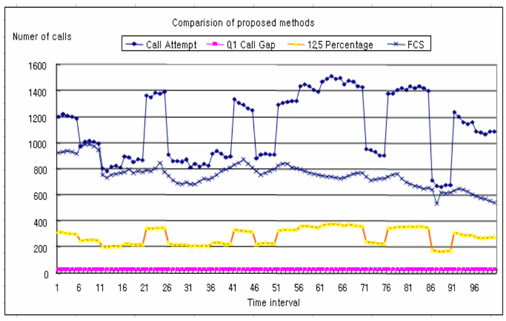


Figure 7 Successful calls during rapid change of congestion status

6. Conclusions

We already have experienced a telecommunications disaster. The main reasons for this disaster was call concentration at a specific time for telephone banking calls and call concentration over a system engineered capacity due to the national specific situation. Reports show that even a simple RPC code control by call completion can prevent such a disaster. We would like to extend this concept to the ATM based MPLS system on BcN networks.

In this paper, we present preventive congestion control mechanisms for detecting RPC LSP in ATM based MPLS systems. In particular, we introduce a RPC LSP detection method using network signaling information.

RPC code control can handle 208% call processing and more than 147% success call, than those without control. It can handle 187% BHCA with 100 times less use of exchange memory.

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