

Fault Recovery in MPLS Network Using Case-Based Reasoning

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Abstract- The current Internet inherently has a degree of survivability due to the connection less IP Protocol. Dynamic routing Protocols are designed to react to faults by changing routes when routers learn about topology changes via routing information updates (e.g., link status advertisements). Loss of Quality of service (QoS) has not been an issue because current Internet traffic is the best -effort. On the contrary, the multi protocol label switching (MPLS) approach is connection -oriented, which implies greater potential vulnerability to faults. At the same time, MPLS will support integrated services, which are more sensitive to loss of service. Reliability is becoming more important as more users depend on the internet for critical communication services and expect a higher level of performance. Usually, fault recovery is attempted first at the lowest layer, and escalated to the next layer if recovery was unsuccessful or impossible. Fault recovery capabilities in the MPLS layer are needed as well to decouple MPLS from dependence on physical layer fault recovery mechanisms which may differ between networks. This paper proposes an enhanced-scheme for fast rerouting to pre-assigned label-switched paths (LSPs) in case of LSP or link failures. In order to minimize backup resources, it allows possibility of splitting traffic of faulty LSP onto available alternative LSPs for fault recovery. We use Pre-assigned backup LSPs for restoration, when fault occurs. Total traffic throughput and resource utilization can be maximized if the traffic of faulty LSP is split over multiple pre-assigned LSPs. In this paper a new approach to providing fault tolerance in MPLS networks using case -based reasoning (CBR) as a method to find out the amount of traffic forwarded on each pre -assigned LSP based on past experiences of loading process is presented. The pre -assigned LSPs and the percentage of traffic splitting are calculated off-line based on desired QoS and capacity constraints. Also we evaluate the operation of successful decomposition of traffic based on the two mentioned constraints by using CBR, when the number of backup LSPs as a complexity factor increase. In another point of view, in cases when there is no possibility of using the experiences successfully, there would be no other way than using the erroneous unsuccessful experiences. We thus solved our recovery problem by using, first incorrect databases in our experiments, to moving later towards decreasing the error rate in a gradual manner.

Keywords: MPLS- restoration- quality of service- performance- case based reasoning

1. Introduction

Recently a lot of research attention has

been directed to QoS routing [1]. Offering differentiation of services and service

guarantees in networks is promising to be a major revenue collector for service providers. This has increased the importance of gaining control over networks via automated traffic engineering (TE) [2].

A common technique for providing QoS guarantees is to reserve bandwidth along the data path. However, the QoS guarantees should be met even in case of network failures. This necessitates reservation of resilient bandwidth capacity along alternate tunnels to which Traffic could be switched over to in case of failures. When a link or node failure occurs, recovery is through the use of re-routing data over an alternative path-such

alternative paths can be established after a primary path failure is detected or, alternatively, it can be established beforehand in order to reduce the path fail over time.

Providing reliability/resiliency is an important TE function. Recently proposals have been made [3,4] to incorporate restoration mechanisms in MPLS. These restoration mechanisms allow backup tunnels or LSPs to be setup simultaneously with the primary LSPs. In this paper we concentrate on MPLS type restoration schemes. Pre-computation of backup LSPs differs from the traditional on-demand scheme where alternate paths are computed only when a failure strikes. Pre-assigned back up LSPs has the advantage of having a faster switch-over from primary to alternate backup LSPs and hence minimizes packet loss due to a primary path failure.

In MPLS networks, multiple LSPs can be used to forward packets belonging to the same forwarding equivalent class (FEC) by explicit routing. Once a failure is detected on a LSP, the traffic flow on this working LSP, will be split to pre-assigned corresponding backup LSPs. The amount of resilient capacity in the

network depends on the number of backup LSPs and on the protection scheme used. The contribution of this paper lies in the presentation of the performance of the traffic splitting problem-solving with satisfied QoS when the number of pre-assigned backup LSPs grows. The rest of the paper is organized as follows. Section 2 gives a brief background on the restoration mechanisms. Section 3 and 4 describe used traffic model and the proposed algorithms respectively. Section 5 provides performance evaluation of the schemes. Section 6 compares the proposed approaches with the 3 main existing approaches and section 7 concludes the paper.

2. Background

Through the use of dynamic routing protocols, IP networks have the capability to re-route traffic around node or link failures. Using the current routing protocols, this re-routing process may take several seconds to minutes. During this period of time, black holes or transient loops may occur in the network, causing traffic delivery to interrupted. For a certain type of application (e.g. www, mail and file transfer) this is, if not optimal, at least acceptable. For other applications (e. g. real time applications) it is a greater concern. The need to provide a much faster re-routing mechanism has been identified. Path failures can be attributed to the failure of any network element (node or link) along the path. For this reason it is preferable that backup paths do not have network elements in common with the primary path [5].

To protect against the failures, backup tunnel needs to be computed for each primary tunnel. In the 1+1 path protection scheme, there is a dedicated backup path for every primary path and data is simultaneously sent

on both. On detection of a primary path failure, the receiver starts using data from the alternate path. However, because of its double-booking nature, this scheme suffers from the overhead of reserving high amount of bandwidth. In 1:1 protection scheme, the backup path is used only after a failure is detected. Hence; at other times the backup tunnel can be used to carry lower priority traffic, or they might be shared between connections. Fast protection/re-route of LSP in case of link/or node failure by means of alternative backup LSPs has been suggested in haskins [3] and Krishnan [6] schemes.

In haskins the ability to quickly re-route data traffic around a failure or congestion on an alternative label switch path is described. This can be important for critical mission applications.

3. Self-Similar analysis

Recent extensive studies of high quality measurements in various data networks have convincingly demonstrated that traffic processes exhibit self-similarity, which can not be captured by traditional Poisson models [7, 8, 9]. As a consequence, self-similar models have been proposed in order to characterize the real statistical behavior of the traffic in today's high-speed network. The self-similar traffic model used in our approach is based on the traffic model as reported in [10].

We denote by $A(t)$ the amount of traffic entering the Label Switch Router (LSR) in the interval $(0, t]$, where

$$A(t) = mt + \sqrt{am}Z(t), \quad t \in (-\infty, \infty) \quad (1)$$

$Z(t)$ is a normalized FBM. m , a , H with the following interpretations and intervals of allowed values: $m > 0$ is the mean input rate, $a > 0$ is a variance coefficient and $H \in [\frac{1}{2}, 1]$ is

the self-similarity parameter of $Z(t)$. We have define the index of dispersion of arrivals as

$$\delta(t)_{real} = \frac{Variance A(t)}{mean A(t)}, \quad (2)$$

$$\delta(t)_{ideal} = at^b \text{ where, } b = 2H - 1 \quad (3)$$

If we choose $H = \frac{1}{2}$ then in (3), $\delta(t)$ would be a constant value and the traffic type would be Poisson.

If H surfs toward one, $\delta(t)$ will traverse to become linear and the real $\delta(t)_{real}$ approaches the ideal $\delta(t)_{ideal}$ and the traffic type would be a self-similar process in the form of figure1.

For inspecting the direction of the correlation in long distance interval which is the indicator of the self-similar traffic, it is necessary to find the $A(t)$ correlation and observe the results.

Considering the real and the ideal values for the $\delta(t)$ function, there would be two different values for the correlation function therefore,

$$r(t)_{real} = Correlation(A(\alpha), A((t+1)\alpha) - A(t\alpha))$$

$$= \frac{1}{2} \frac{[Var A((t+1)\alpha) - 2 var A(t\alpha) + var A(t-1)\alpha]}{\sqrt{var A(\alpha)} \sqrt{var(A(t+1)\alpha - A(t\alpha))}} \quad (4)$$

α is resolution factor and also

$$r(t)_{ideal} = \frac{t^{b+1}}{2} (1 + \frac{1}{t})^{b+1} + ((1 - \frac{1}{t})^{b+1} - 2) \quad (5)$$

As it is observed in figure 2, when $H = 0.9$ the correlation between distant intervals decreases towards Zero (assuming that $b < 1$) but very slowly. This property is often called long-Rang dependence (LRD).

4. The Proposed Approach

4.1. Problem Definition

The method for splitting the traffic of faulty LSP, in our approach, is based on the idea that no band-width should be Pre-reserved on the Pre-assigned protection LSPs [11].

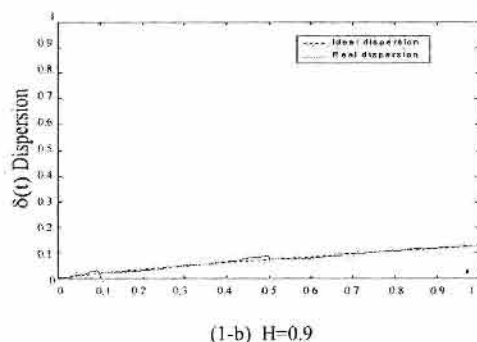
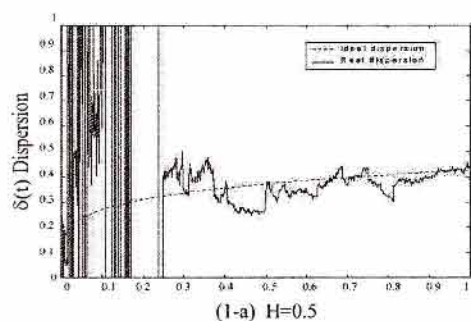


Figure 1 Ideal and real dispersion with two H values. Time is in packet slots

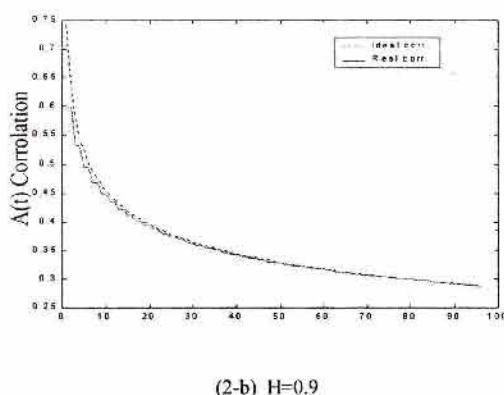
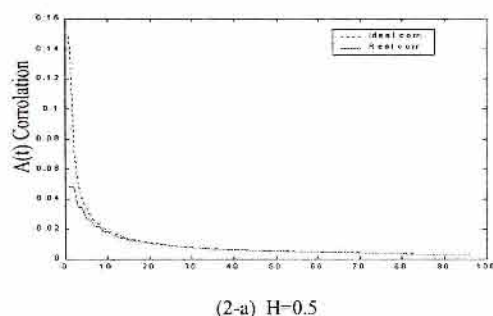


Figure 2 Ideal and real A (t) correlation with two H values

This is because the same band-width may at the same time be requested by other demands, thus leading to an occasional conflicts. Suppose that N is the number of Pre-assigned LSPs for the traffic flow of a faulty LSP. The traffic of the faulty LSP is shown by $a(t)$, and the percentage of the traffic forwarded into the i -th alternative path is represented by α_i ,

where we have $\sum_{i=1}^N \alpha_i = 1$

So the new flow in the i -th LSP will be $\alpha_i \cdot a(t) + b_i(t)$, where $b_i(t)$ is the ongoing traffic of the i -th LSP before the breakdown. The objective would be to solve the following problem.

Subject to:

$$\alpha_i \cdot a + b_i < c, \quad i = 1, \dots, N \quad (6)$$

$$\text{QoS is satisfied for all } i \quad (7)$$

Where constraint (6) is the LSP capacity constraint and is for stability, while constraint (7) is the QoS constraint, where $\alpha = (\alpha_1, \dots, \alpha_N)$ is vector of all resource assignments, and h is the set of all points located on the hyper plane $\sum_{i=1}^N \alpha_i = 1$, and positive quadrants, namely,

$$h = \{\alpha \mid \alpha_i > 0, i = 1, \dots, N, \sum_{i=1}^N \alpha_i = 1 \text{ where, } a \text{ and } b_i$$

b_i are the mean rate of the broken LSP and the i -th alternative path, and c_i is the capacity of the i -th LSP. If constraint (6) is violated, the system will be unstable and the corresponding queue size will grow to infinity. Constraint (7) is to guarantee a certain level of desirable QoS for users. If the problem has not any solution by the mentioned conditions we allow the

faulty LSP to be totally disconnected and discard its traffics. Here, we use some kind of priority so the traffics with higher priority will get a better chance to be served on a link break down. The lower priority either should wait in the boundary of the network or totally be refused to access to the network.

In this case, if we have to let some traffic be thrown away, h is then to be redefined as

$$h = \{\alpha \mid \alpha_i > 0, i = 1, \dots, N, \sum_{i=1}^N \alpha_i \leq 1\}$$

4.2 The Proposed Approach based on CBR

In case-based reasoning (CBR) systems expertise is embodied in a library of past cases, rather than being encoded in classical rules. Each case typically contains a description of the problem, plus a solution and/or the outcome. The knowledge and reasoning process used by an expert to solve the problem is not recorded, but is implicit in the solution. To solve a current problem; the problem is matched against the cases in the case-base, and similar cases are retrieved. The retrieved cases are used to suggest a solution which is reused and tested for success.

If necessary, the solution is then revised. Finally the current problem and the final solution are retained as part of a new case [12]. All CBR methods have in common the following process [13] that the process is illustrated in figure 3.

- Retrieve the most similar case (or cases) comparing the case to the library of past cases;
- Reuse the retrieved case to try to solve the current problem;
- Revise and adapt the proposed solution if necessary;

- Retain the final solution as part of a new case.

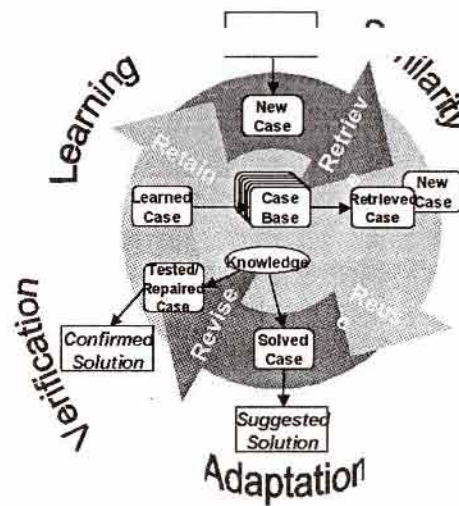


Figure 3 CBR Cycle

From a mathematical viewpoint it is normally difficult to derive h in an analytical way. This is because traffic has a self-similar nature missing a well-defined mathematical formalism to be handled.

To circumvent this problem, it is preferred to make use of the unused capacity of the network for recovering the occasional faults. In this sense, the capacity in each link is split into appropriate traffics for LSPs, based on constraints of capacity and QoS.

To solve the problem of traffic forwarding, different approaches may be utilized for example, one can regard the problem as a type of constraint satisfaction problem, where the $\alpha_i a + b_i$ for all pre-assigned LSPs should satisfy some criteria; e.g. constraints (6) and (7) as mentioned above. This is a direct solution, which is very time-consuming for such a real time problem. Also, we may suppose that there is an unknown function estimating the α_i values in an efficient and satisfactory manner. Therefore we should

approximate this function in same manner.

Generally, one can consider the function approximations as a learning task, where the machine-learning techniques can be used to estimate parameters based on some observation. Choosing the appropriate model and learning algorithm somehow seems to be difficult.

To circumvent this problem, we prefer to use an approach which can make use of past experiences of traffic forwarding in a systematic manner. CBR can be a good alternative in this regard. Using such an approach, when an online situation of a faulty link is confronted, similar cases are retrieved from the library, and the solutions belonging to these cases are then combined, by using a compositional adaptation technique, to derive the final solution for traffic forwarding [14]. In our approach, the following similarity function is used to retrieve the similar cases [15, 16].

$$dis(\lambda'_i, \lambda_i) = \frac{|\lambda'_i - \lambda_i|}{\max |\lambda'_i - \lambda_i|} \quad (8)$$

$$0 \leq dis(\lambda'_i, \lambda_i) \leq 1$$

Where λ'_i, λ_i respectively stand for values of attribute in the retrieved case's situation (figures 5) and the same attribute for the new problem.

Figure 4, 5 illustrate an example of an on-line situation together with its similar cases, and the procedure essential to retrieval.

The compositional adaptation in our approach is performed through averaging the transformed values of each attribute in the solutions of the retrieved cases. The transformed value of an attribute (the i -th attribute in a solution) is determined through following expression:

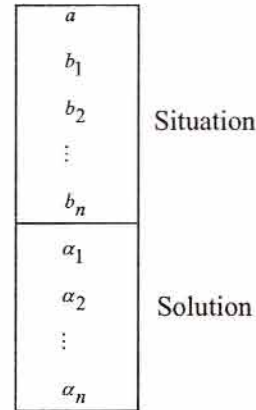


Figure 4 The case structure

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Retrieved Cases  $\leftarrow \phi$ 
for each case in case library as  $C_i$ 
     $sim_i \leftarrow sim(Newproblem, C_i)$ 
    if  $sim_i \geq threshold$  then
        Retrieved Cases  $\leftarrow Retrieved Cases \cup \{< C_i, sim_i >\}$ 
    end for

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Figure 5 Procedure essential to retrieved

$$\alpha'_i = \frac{\sum_{j=1}^L \alpha_i \rho_j}{\sum_{j=1}^L \rho_j} \quad (9)$$

Where j and i stand, for number of cases retrieved, and number of pre-assigned LSPs respectively and α_i is evaluated in the process of generating training/test set as following:

$$\alpha_i = a. \frac{spare T_i}{\sum_{i=1}^n spare T_i} \quad (10)$$

Where $n=6$ and $spare T_i$ is the spare allocated capacity for the i -th pre-assigned LSP.

As it is observed in figure 6 ($n=7$), the main abc LSP is protected by seven pre-assigned backup LSPs; $ab_1c, \dots, ab_7c$, where in formula (1), for abc LSP, m varies between 1000 & 1500 packet/second and the maximum capacity for each ab_7c LSP is mentioned in table 1.

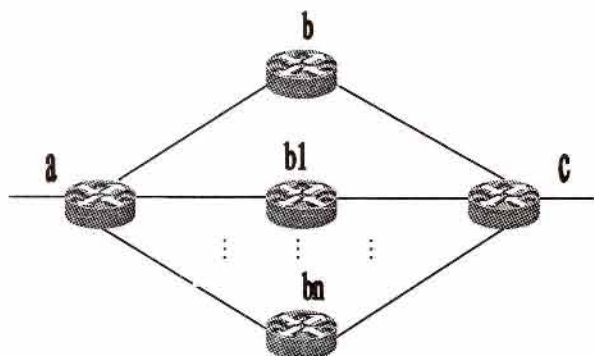


Figure 6 abc is the faulty LSP and ab_1c is the Pre-assigned Protection LSP

Table 1 PRE-ASSIGNED LSP CAPACITY (packet/sec)

LSP name	ab_1c	ab_2c	ab_3c	ab_4c	ab_5c	ab_6c	ab_7c
Capacity	500	600	700	800	900	1000	1100

All LSRs have exponential service time distribution with service rate of 3500 packet/second.

5. Experimental Result

For evaluating the CBR performance in the traffic decomposition on the basis of preserving the service quality, first of all, solve 4700 problems with 250 case number in library case. In the second step 4450 problems with 500 case number are solved and in this order, the number of problems are reduced and the number of cases in the case library are increased. The results are summarized in tables 2, 3 and 4 for 5, 6 and 7 backup LSPs respectively.

Table 2 VALUE OF EXPERIMENTAL RESULTS FOR 5 BACKUP LSPs.

Step	Train set #	Test set #	Retain #	Performance
1	250	4700	84	0.0178
2	1250	3700	1051	0.284
3	2500	2450	1032	0.421
4	3750	1200	564	0.47
5	4750	200	92	0.46

Table 3 VALUE OF EXPERIMENTAL RESULT FOR 6 BACKUP LSPs.

Step	Train set #	Test set #	Retain #	Performance
1	250	4700	134	0.042
2	1250	3700	1607	0.6308
3	2500	2450	1409	0.8342
4	3750	1200	794	0.9052
5	4750	200	126	0.9

Table 4 VALUE OF EXPERIMENTAL RESULT FOR 7 BACKUP LSPs.

Step	Train set #	Test set #	Retain #	Performance
1	250	4700	141	0.03
2	1250	3700	1881	0.5082
3	2500	2450	1772	0.7232
4	3750	1200	960	0.8
5	4750	200	158	0.79

The performance is calculated according to:

$$\text{performance} = \frac{\text{Retain case \#}}{\text{Testset \#}}$$

Where the retain case # is equal to the number of problems, having successful solutions, and satisfying conditions 1, 2 and it is finally saved as suitable cases in the case library. Figure 7 shows with 5 backup LSPs ab_1c ($i=1, \dots, 5$) and 4250 samples in the case library, the performance curve reaches its saturational characteristic point. Figure 8 shows the same feature with 6 backup LSPs ab_1c ($i=1, \dots, 6$) and 3500 samples in the case library. In figure 9, we have 7 backup LSPs and 2900 samples in the case library. The performance curve reaches its saturational characteristic point. The number of cases existing in the saturational points is the number of sufficient samples in the case library using as data base in CBR for decision making of problem solving.

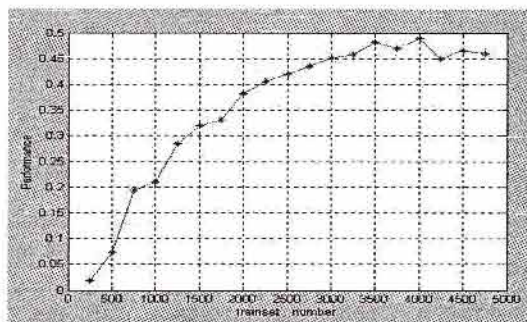


Figure 7 Performance evaluation with 5 backup LSPs

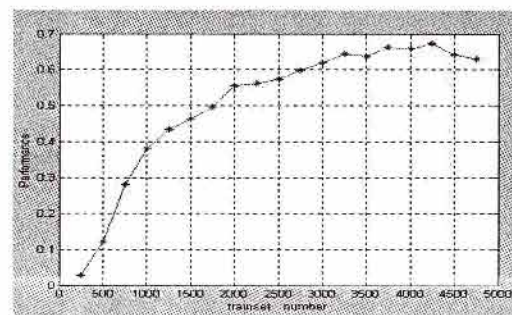


Figure 8 Performance evaluation with 6 backup LSPs

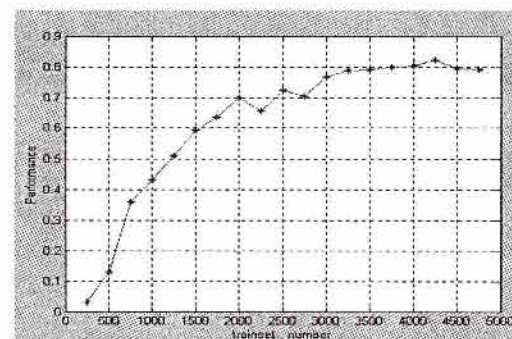


Figure 9 Performance evaluation with 7 backup LSPs

Due to limitation in accessing to experiences with high performance (negligible error) in a network environment, erroneous cases also would better be considered. In this respect, first 200 training cases were selected, to meet the first constraint (having appropriate α_i 's solved values) but do not hold sufficient QoS. Here any male performance in QoS is based on the condition that the summation of loss probability on 6 backup LSPs after splitting the faulty LSP traffic does not exceed the 3% value. Error function in our approach is defined in the following manner.

$$Error = \frac{\sum_{i=1}^m \rho_L(i)}{m} \quad (11)$$

$$\text{Where, } \rho_L(i) = \sum_{l=1}^n \rho_{loss}(i) \quad (12)$$

m is the test set number, $\rho_{loss}(i)$ is the summation of loss probability on 6 backup LSPs and n is the number of pre-assigned backup LSPs. It should be noted that the average error value obtained after considering the 200 training cases was 9.1%. As it seen from table 5 through adding the new erroneous training cases to the library, and retaining those cases with less amount of error, the average error ratio is getting decreased to the extent that after applying 22500 test cases, the library of CBR can be ended up with high performance (almost non-erroneous) cases. As it seen in figure 10, 1000 training cases is sufficient to provide cases with tolerable amount of error.

Table 5 VALUES OF EXPERIMENTAL RESULT

Step	Retain number	%Error	Case library
1	51	8.6	251
2	69	7.4	320
3	93	7	413
4	127	6.2	540
5	167	5.7	707
6	200	5.48	907
7	211	5.206	1118
8	218	5.2	1336
9	224	5.203	1560

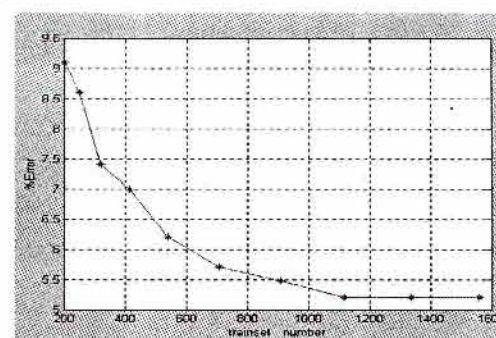


Figure 10 Error evaluation

6. Comparison with Haskin, Makam and simple-dynamic's restoration schemes

Haskin and Makam have proposed a restoration scheme applied for MPLS network [3, 17]. According to previous categorization of restoration scheme, they use a pre-assigned backup path restoration scheme as shown in figures 11, 12. In Haskin's scheme, when an original LSP L13-L35-L57-L79 is assigned, pre-assigned reverse LSP (L97-L75-L53-L31) and alternative LSP L12-L24-L46-L68-L89 is assigned as shown in figure 11.

If a fault occurs at L79, the LSR7 detects a fault and switches the traffic flows through L57 to reverse LSP L75. So the traffic flows along L13-L35-L57-L75-L53-L31, and LSR1 detects a reversed traffic, it stops transferring the traffic to L13 and transfers the traffic to an alternative LSP L12. This scheme has some advantage of having a simple architecture, but it has the shortcoming of wasting network resources and crank back thus always occurs. Ingress LSR1 must have a large-capacity buffer to queue newly incoming traffics until the reverse LSP traffic flows are restored.

As shown in figure 13 in simple-dynamic's scheme, when a main LSP (e. g. LSR1- LSR3- LSR5-LSR7-LSR9) fails, an alternative backup LSP (LSR5-LSR6-LSR8-LSR9) is established after a failure detection from a node that detected the failure to PML.

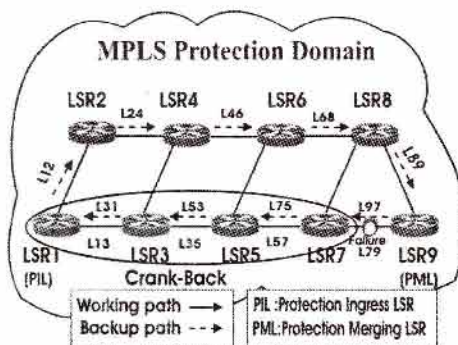


Figure 11 Haskin's scheme

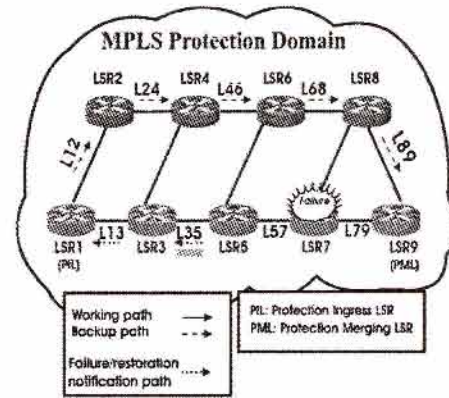


Figure 12 Makam's scheme

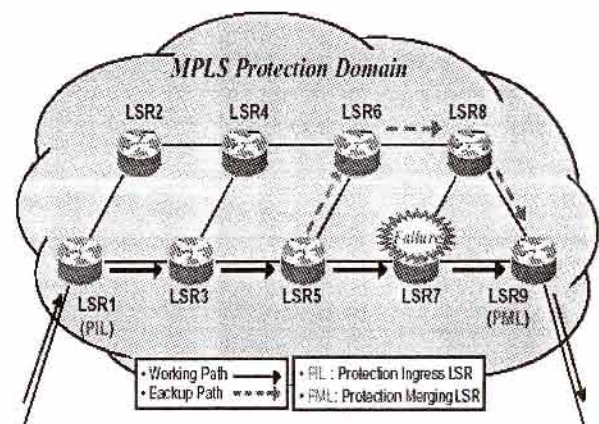


Figure 13 Simple-dynamic's scheme

This scheme has an advantage of having high resource utilization and a disadvantage of having long LSP setup time.

Figure 14 shows the experiment network for 3 mentioned schemes.

Each link has a bandwidth 1Mbps, a delay of 10ms.

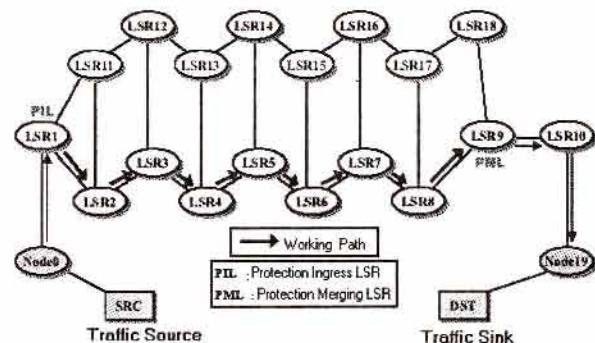


Figure 14 MPLS experiment network

Figure 15 compares the number of dropped packets of 3 schemes while failed LSR moves from $LSR2 \rightarrow LSR8$. It shows that Haskin's scheme has no problem. Because of the delivery time of notification message in Makam's scheme, number of dropped packets increases more in proportion to the distance between PIL and a failed node. Also because of the setup time of a backup LSP, the number of dropped packets in simple-dynamic's scheme increases more in proportion to the distance between a failed node and PML.

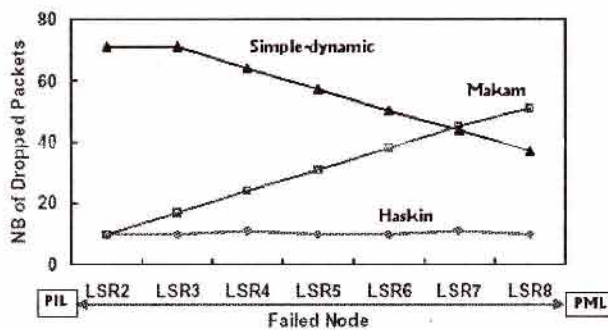


Figure 15 Performance evaluation

Figure 16 shows that Makam's and simple-dynamic schemes have no reordered problem, but in Haskin's scheme, during the switchover time from BP to WP after recovery of a failed node, the number of reordered packets increases more in proportion to the distance between PIL and a failed node. Table 6 compares the 4 restoration schemes.

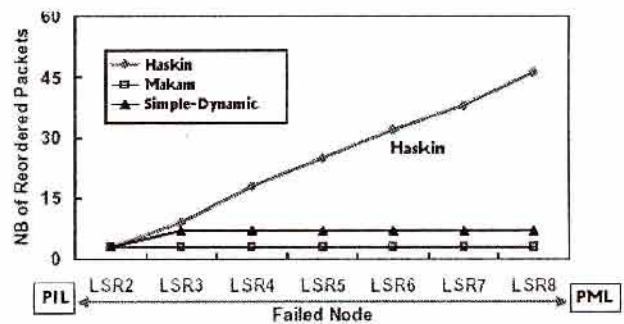


Figure 16 Performance evaluation

Table 6 The Comparison of Restoration Schemes

	Proposed scheme	Haskin's scheme	Makam's scheme	Simple-dynamic scheme
Restoration start point	Ingress LSR	Preceding node of faulty link	Ingress LSR	Preceding node of faulty link
Fault detection	In-band	In-band	In-band	In-band
Alternative LSP	Pre-assigned	Pre-assigned	Pre-assigned	Dynamic
Band width reservation	No	Yes	Yes	No
Packet loss problem	Occurs because of the message delivery time	No	Occurs because of message delivery time	Occurs because of the setup time of a backup LSP
Packet reordering problem	Occurs during the traffic splitting over pre-assigned LSPs	Occurs during the traffic switch over time from BP to WP after the recovery of the failure	No	No

7. Conclusion Remarks

The fault in the MPLS causes serious problems such as a massive data loss and degradation of service quality.

In this paper, it was shown that CBR can have an effective role in forwarding the traffic of a faulty link on a number of pre-assigned LSPs. The efficiency of this approach was then demonstrated via using a randomly selected set of faulty LSPs in terms of cases (together with their corresponding LSPs), calculating the expected traffic for each LSP, and then deriving the related QoS by simulation for these solutions satisfying the capacity constraints. As it was shown in the paper, using CBR, we may reach a number of cases in the case library, which can guarantee a high performance for the forwarded traffics with respect to LSPs capacity constraint. It was also seen that, for this number of cases, the average total loss probability becomes quite low; a fact that makes CBR quite promising for traffic forwarding Purposes in networks. According to the derived results and figures 7, 8 and 9 we find that by increasing the number of pre-assigned backup LSPs, the number of cases in saturational characteristic points on the performance curve are reduced. In another words, the number of sufficient cases in the case library for problem solving are reduced, which is due to increasing network resources by increasing number of backup LSPs.

There are a number of advantages to using CBR in our restoration scheme. When the relationship between the case attributes and the solution or outcome is not understood well enough to represent it in rules, or when the ratio of cases that are "exceptions to the rule" is high, rule-based system become impractical. CBR is especially useful in such situations because it models the exceptions and the novel

case CBR is also useful in explaining or justifying a solution. Also, in cases that there is no possibility of using the experiences successfully and having exact cases is not possible due to any reasons, using erroneous cases as the initial case sets and applying the proposed adaptation method for composing the solutions, is a suitable alternative.

8. Reference

- [1] R. Guerin, D. Williams, A. orda, "QoS Routing Mechanisms and OSPF Extensions" Proceedings of Globecom 1997.
- [2] D. Awudche, J. Malcom, J. Agogbua, M. O'Dell and J. MC Manus "Requirements for Traffic Engineering over MPLS", Request for comments: 2072, September 1999.
- [3] D. Haskin and R. Krishnan, "A Method for Setting an Alternative Label Switched Paths to Handle Fast Reroute", Internet Draft <draft-haskin-mpls-reroute-50.txt>, May 2001.
- [4] V. Sharma, B. crane, S. Makam, K. Owens, C. Huange, F. Hellstrand, J. Weil, L. Andersson, B. Jamoussi, B. Cain, Seyhan Civanlar and A. Chiu, "A Framework for MPLS -Based Recovery", Internet Draft <draft-ietf-mpls-recovery-frmwkr-02.txt>, May 2002.
- [5] K. Kompella and D. Awduche, "Notes on Path Computation in Constraint-Based Routing", Internet Draft <draft-kompella-te-pathcomp-00.txt>, Jan. 2001
- [6] D. Haskin, R. Krishnan "Extensions to RSVP to Handle Establishment of Alternate Label-Switched Paths for fast Re-Route", Internet Draft <draft-Krishnan-mpls-reroute-revp ext-01.txt> 1999

- [7] W. Leland, M. Taqqu, W. Willinger and D. Wilson, "On the Self-Similar Nature of Ethernet traffic (Extended Version)," IEEE/ACM Transactions on Networking, Vol.2, PP. 1-5, 1994
- [8] V. Paxson and S. Floyd, "Wide-Area Traffic: the Failure of Poisson Modeling", Proceeding of ACM Sigcomm' 94, PP. 257-268, 1994
- [9] J. Beran, R. Sherman, M. S. Taqqu, and W. Willinger, "Long-Rang Dependence in Variable Bit Rate Video Traffic," IEEE Transactions on Communications, Vol.43, PP. 1566-1579, 1995.
- [10] I. Norros, "Studies on a Model for Connectionless Traffic, based on Fractional Brownian Motion," Conference on Applied Probability in Engineering, Computer and Communication Science, Paris, June 1993
- [11] A. Dana, A. Khadem-Zadeh, K. Badie and S. Valace, "A Method for LSP Restoration in IP Networks based on MPLS," in Proc. 7th Annual CSI Computer Society of Iran Conference, PP. 439-477, Feb. 2002
- [12] A. Aamodt, E. Plaza, "Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches," AI Communications, 7(1), PP. 39-59, 1994
- [13] M. Lenz, B. Bartsch-sport, H. D. Burkhard, S. Wess, "Case-Based Reasoning Technology: from Foundations to Applications," Springer-Verlag, Berlin Heidelberg, 1998.
- [14] K. Borner, "Structural Similarity as a Guidance in Case-Based Design," in Topics in Case-Based Reasoning EWCBR 94, PP. 197-208, 1994.
- [15] R. Lopez de Mantaras, "A Distance-Based Attribute Selection Measure for Decision Tree Induction," Machine Learning, 6:81-92, 1991
- [16] E. Plaza, "Case as terms: A Feature Term Approach to the Structural used Representation of Cases," In M. Veloso and A. Aamodt, Editors, Case-Based Reasoning, ICCBR-95, Number 1010 in Lecture Note in Artificial Intelligence, PP. 265-276, Springer-Verlag, 1995.
- [17] S.Makam, V. Sharma, "Protection/Restoration of MPLS Network," Draft-Makam-Mpls-Protection-00.Txt, 1999.