A Network Recovery Strategy Scheme Based on Network Failure Scenarios and Topologies

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Abstract— **Network failures happen frequently. There is a need for recovery mechanisms to reduce service interruption. Recovery mechanisms' advantages and disadvantages are described extensively based on their characteristics and performances. However, it is more desirable that network recovery strategies are chosen based on failure scenarios and topologies. In this paper, we propose a recovery scheme and focus on networks whose paths and resources from source to destination nodes are computed and negotiated primarily at source nodes, Ingress Label Switched Router (LSR), which are the case for Generalized Multiprotocol Label Switching (GMPLS) networks. Choosing proper network recovery mechanisms depends on many parameters such as distance of failure from source node, degree distribution of nodes, availabilities of alternative paths, and maximum allowed-hop-count increase in alternative paths. Three recovery mechanisms: Haskin, Global and Local Protection are compared with the proposed restoration scheme. By changing parameters on appropriate ranges and by using probability of received data packet at the destination node, e.g. probability of error as one of the performance criteria, we can make a fair judgment on choosing a network strategy by considering available network parameters and topology.**

Keywords- network recovery; Global and Local Protection; Haskin; GMPLS; probability of packets received; restoration; degree distribution; Ingress and Egress LSR.

I. INTRODUCTION

In recent years, various network recovery schemes have been used in order to meet the new challenges and demands in communications markets. Since research on many aspects of network recovery and resilience has been done up to now, and the reliability of network systems has feasible applications in other areas, this trend seems to be increasing. Many network recovery mechanisms have been proposed in the literature, each of which has advantages and disadvantages. Some of these recovery schemes are very complex. Therefore, it is sometimes hard to design or even to implement them in existing network facilities and infrastructures. Many researchers have put their efforts on designing network recovery schemes which are efficient or optimal in some senses of channel capacity or time of recovery etc. Some of these schemes have remained in theory and are optimistically expected to be realized in many years to come. Despite the simple and tricky appearance of network recovery, it has a design that is closely tied to many delicate concepts and techniques in many areas. Network recovery is classified into many different types. Some of these classifications overlap very delicately with each other. Among them comprehensive works have been done on restoration, protection, dedicated, share recovery, p-cycles, tree-based recovery, etc in the sense of network resources optimization, recovery time and channel capacity [1- 5].

The aim of this paper is to show that network recovery schemes would be more efficient and useful if they are used according to current network circumstances and parameters such as link availabilities, degree distribution, working path length, location of failure with respect to length of hop count from source or destination nodes, degree of nodes, and maximum allowed increase in length of hop count of alternative paths.

Generalized Multiprotocol Label Switching (GMPLS) seems to be a promising protocol for the next generation Internet Protocol over Wavelength Division Multiplexing (IP over WDM) networks. Since path computation and resource negotiation is primarily done mostly at source node, Ingress Label Switched Router (LSR), in GMPLS networks; many traffic and LSP parameters may be negotiated at Ingress LSRs. GMPLS architecture and signaling protocol seems to be proper for the proposed restoration scheme. In this paper, we use link availability to analyze and compare the proposed recovery mechanisms on stages. In the literature, recovery path is optimized with respect to conventional criteria [6-10]. The proposed scheme requires the least signaling message either in Resource Reservation Protocol - Traffic Engineering (RSVP-TE) or Constraint-based Routing Label Distribution Protocol (CR-LDP), and Traffic Engineering (TE) information on an LSR router through the working path. Link availabilities of working and alternative paths give us an intuitive idea as to whether to include the protection tunnels or just to use restoration mechanisms in the proposed restoration scheme.

The remainder of the paper is organized as follows. The proposed recovery scheme is introduced in Section II. Mathematical model using link availability and probability of received packets at destination nodes for given recovery mechanisms and the proposed restoration are described. Section III presents the simulation results for the proposed recovery scheme. Finally, this paper is concluded in Section IV.

II. PROPOSED RECOVERY SCHEME

When link/node failure happens, the transmitted traffic by network can be classified into two time events during the recovery processes. The recovery process is named regarding to these two time events as "recovery stages". Parts of traffic may be transmitted during the two recovery stages. In the first stage, the dispatched data may be rerouted at PSL (path switching LSR) or intermediate nodes as long as notifying signaling message do not reach the Ingress LSR. In the second stage, after notification of failure at Ingress LSR, part of the data is rerouted to a secondary path. These paths are computed by Ingress LSP to Egress LSR. These paths could be optimized according to the criteria of routing protocols and TE information. In figure 1 shows failure in primary path. This section focuses on the first recovery stage.

A. First Recovery Stage

In this stage, it is assumed that each LSR for sake of generality has a random degree with a uniform distribution of $d \sim (0, D)$, and each LSR with degree d has alternative paths with random maximum allowed increase in hop count of m for each path. Due to Quality of Service (QoS) and Service Level Agreements (SLAs), we suppose that m is the discrete random variable with the uniform distribution of $m \sim (0, M)$. We suppose that data are received at Egress LSR in the destination node. (figure 1)

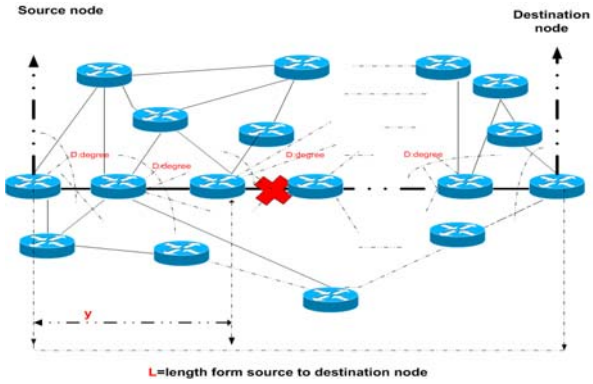

Figure 1. Network with a Single-Failure in Working Path.

The probability of packets received at Egress node LSR is as follows:

$$\begin{aligned} &P_{\text{received at destination}} = \\ &P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y}.P_{Y=y} + P_{\text{received}\,|\,\text{send}\ \text{at}\,Y\le y\text{-}1}.P_{Y\le y-1} \\ &= p.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y} + q.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y\text{-}1}.P_{Y=y-1} \\ &+ q.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y\text{-}2}.P_{Y=y-2} \\ &\quad\vdots \\ &\cdots + q.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y\text{-}k}.P_{Y=y-k} \\ &\quad\vdots \\ &\cdots + q.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=1}.P_{Y=1} \\ &+ q.P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=0}.P_{Y=0} \end{aligned} \quad (1)$$

where y is the distance from Ingress LSR to penultimate LSR, LSR before node/link suffered from failure, as shown in figure1. p is the probability of rerouting packets at a given router. q is the probability that packets cannot be rerouted at the given router, q = 1 - p.

By solving Equation (1), it will be as follows:

$$P_{\text{received at destination}} = \sum_{k=0}^{y} P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y-k} \cdot p.q^{k} \quad (2)$$

According to the above probability, it should be noted that network traffic is supposed to be balanced, p and q assumed to be the same for every LSR. Since in the proposed scheme we have no prior knowledge of p and q, we assume the maximum entropy where p = q = 1/2 is chosen. By this assumption, Equation (2) will be:

$$P_{\text{received at destination}} = \frac{1}{2}\sum_{k=0}^{y} P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y-k} \cdot \left(\frac{1}{2}\right)^{k} \quad (3)$$

Suppose that LSR at (y - k) has d paths to Egress LSR. However, it is possible that more than one path can be assumed for each outgoing link from a given LSR. In this case, we can deal with them as individual logical degrees. If an outgoing link from LSR has n path, we can deal this as n links with one path. However, if we are reluctant to do so, the equations might undergo minor changes. They will be as follows:

$$P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y-k} = \frac{\sum_{i=1}^{d_k} P_{\text{send}\,|\,\text{path}\,l}}{d_k} = \frac{\sum_{i=1}^{d_k} A^{\text{length}\ _{path l}}}{d_k} \quad (4)$$

where d_k is the number of degree of k^{th} LSR and A is the link availability [11].

Since length of a path from k^{th} LSR to Egress LSR is $l-(y-k)+m_i$, we can rewrite Equation (4) as follows:

$$P_{\text{received}\,|\,\text{send}\ \text{at}\,Y=y-k} = \frac{\sum_{i=l}^{d_k} A^{\,l-(y-k)+m_i}}{d_k} \quad (5)$$

By using Equation (2) and (5), the probability of packets received at Egress node LSR can be worked out:

$$P_{\text{received at destination}} = A^{l-y}\sum_{k=0}^{y} A^{k}.p.q^{k}.\frac{\sum_{i=1}^{d_k} A^{m_i}}{d_k} \quad (6)$$

The equation for Global Protection will be as follows:

$$P_{\text{received at destination}} = A^{l}.\frac{\sum_{i=1}^{d_k} A^{m_i}}{d_k} \quad (7)$$

The equation for Local Protection will be as follows:

$$P_{\text{received at destination}} = \frac{A^{l-y}\sum_{k=0}^{y} A^{k} \cdot \frac{\sum_{i=1}^{d_k} A^{m_i}}{d_k}}{y} \quad (8)$$

The equation for Haskin Protection will be as follows:

$$P_{\text{received at destination}} = \frac{\frac{\sum_{i=1}^{d_k} A^{m_i}}{d_k} \cdot \sum_{k=0}^{y} A^{l+k}}{y} \quad (9)$$

B. Second Recovery Stage

In this Stage, one simple idea is to minimize the combination of functions such as number of hop counts, propagation delay of network links, bandwidth consumption, and maximum link usage for unicast transmission either by linear optimization or meta-heuristic algorithms such as in references [10] and [12-14].

III. SIMULATION AND RESULT

In this section, we will compare the proposed restoration scheme with the three recovery mechanisms: Haskin, Global and Local Protection. All parameters are fixed except y which varies over a range of values. By using Equations (6)-(9), we can obtain useful simulation result which can indicate the efficiency of the proposed scheme in various strategies on failure scenarios and network topologies through a dense or sparse with changing d for each LSR. The parameter y is varied. The other parameters (A, D and M) are fixed for the three link availabilities as A=0.9, D=2, and M=5.

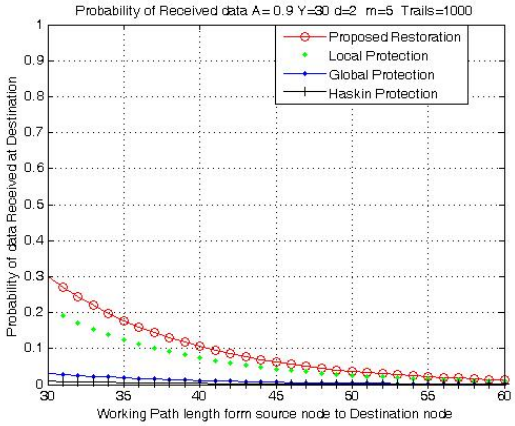

Figure 2. Probability of packets received for the working path lengths.

Figure 2 shows the probability of packets received for the working path lengths. It can be seen that the proposed restoration scheme performs more efficient than the other three recovery mechanisms: Haskin, Global and Local Protection.

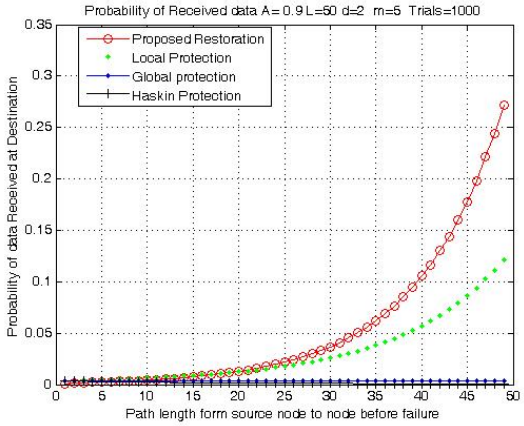

Figure 3. Probability of packets received for path lengths before failure.

Figure 3 shows the probability of packets received for the path lengths from source node to node before failure. The Local Protection mechanism has higher probability than the Global and Haskin Protection mechanisms. However, the proposed restoration scheme has the highest received packets probability for Y > 25.

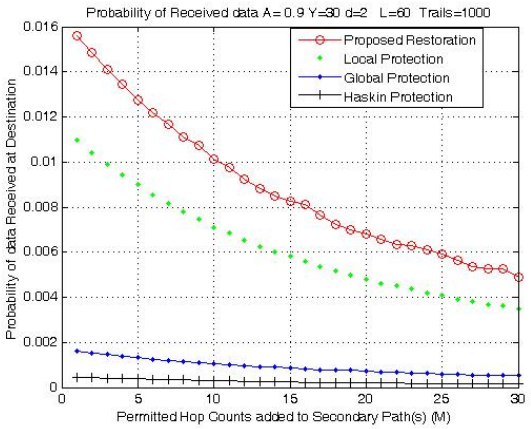

Figure 4. Probability of packets received when a permitted hop counts added to secondary path.

In figure 4, we change the value of M from 0 up to M=y/2 and we keep the other parameters fixed. It shows also that the proposed restoration scheme has the highest received packet probability and the Local Protection mechanism has a higher probability than the Global and Haskin Protection mechanisms.

Figure 5 shows the probability of packets received with a range of degree distribution of nodes. It can be seen that the proposed restoration scheme outperforms the other three recovery mechanisms: Haskin, Global and Local Protection.

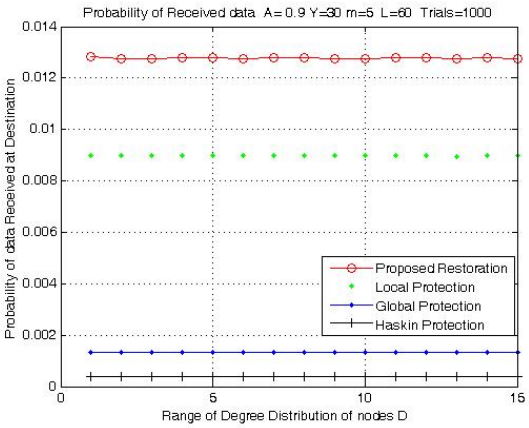

Figure 5. Probability of packets received with a range of degree distribution of nodes.

Figure 6 shows that the proposed restoration scheme outperforms the three recovery mechanisms when the link availability is low. However, Haskin, Global and Local Protection recovery mechanisms perform better when the link availability become high.

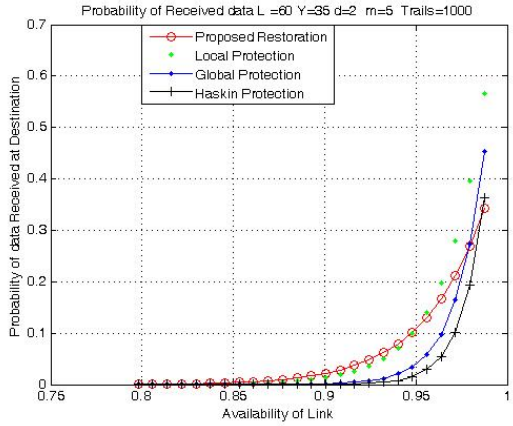

Figure 6. Probability of packets received with link availability.

IV. CONCLUSIONS

This paper proposes a recovery scheme. A mathematical model using link availability and probability of packets received at destination nodes for given recovery mechanisms and the proposed restoration are described. The three recovery mechanisms: Haskin, Global and Local Protection are compared with the proposed scheme. Simulation results show that the proposed restoration scheme is more efficient in the most cases. The Local Protection mechanism outperforms the Global and Haskin Protection mechanisms. However, it may not be optimum in long path to provide local protection paths and tunnels for each LSR. It can be seen that types of recovery schemes can vary based on value of existing parameters. It is shown that type of recovery can be decided based on node's degree, maximum allowed hop count, remaining distance to destination, path length, and link availability.

Future work can be carried out by assuming a degree and maximum allowed increase hop count M other than uniform which is the case in this paper. We can get a clearer view if recovery time, jitter and required capacity of each mechanism can be obtained or given. A network where distributions of links availability are not uniform throughout the network can be designed.

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