IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 3, No 1, May 2012
ISSN (Online): 1694-0814
www.IJCSI.org

An Optimized Link Management Algorithm for Handling Link Failure in MPLS

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Abstract

This paper presents an effective solution for link failure and congestion management in MPLS networks which employs RRATE algorithm. The contributions of this work are two fold. The first is that an algorithm for link failure and congestion management in MPLS Networks is proposed. The MPLS Networks that we have used in our simulation employs RRATE algorithm for traffic engineering. Till date the performance of RRATE algorithm has been only tested on synthetic networks on idealistic conditions. Hence the algorithm does not address network link failure issues. Secondly, situations are considered where there are realistic link ups and downs occurring in a network and an efficient rerouting mechanism on link failure is suggested. The performance of the RRATE algorithm is also analyzed.

Keywords: *Delay, real time conditions, RRATE, MPLS, active networking, network processor, etc.*

1. INTRODUCTION

The growing demand for increased bandwidth in the Internet has sought new algorithms and architectures to provide a high degree of quality-of-service (QoS). Further, Traffic Engineering algorithms has to be developed in such a way that a higher priority is given to real time data processing than non real time data processing [1]. Multi Protocol Label Switching (MPLS) has recently emerged too many professionals as a solution for effective traffic engineering to handle the growing bandwidth demands [2]. MPLS is an IETF standard that is generally considered to lie between traditional definitions of Layer 2 (data link layer) and Layer 3 (network layer), and thus is often referred to as a "Layer 2.5" protocol. It merges the layer-2 information of bandwidth, latency, and utilization of network links with the control protocols used in layer-3. Internet Protocol (IP) improves and makes the exchange of IP packets simple [3], [4]. The MPLS network uses labels or tags for efficient differentiation and forwarding of packets along pre-calculated routes in the network. A label can be perceived as a header in an IP packet. The simplified representation used in the network enables the backbone networks to route the packets at high speeds. The system can also provide different quality-of-service (QoS) plans, services, and policies to the customers [5], [6].

Numerous traffic engineering algorithms are available for improving quality-of-service in MPLS networks. In our simulation [7], [8], [9], we consider the Random Races Algorithm for Traffic Engineering (RRATE) which incorporates the family of stochastic random races algorithm. This traffic engineering algorithm is a new advent in MPLS [10], [11], [12] and has been proved that the algorithm outperforms traditional traffic engineering algorithms like

1) Profile Based Routing (PBR) [18]

2) Dynamic Online Routing Algorithm (DORA) [19]

3) Iliadis and Bauers Algorithm [20]

4) Stochastic Estimator Learning Automata Routing Algorithm (SELA) [17]

Till date, the performance of the RRATE algorithm has been tested only on synthetic networks and on ideal scenario which do not consider link failures. Specifically, the contributions of this paper are listed below:

- We propose a new fast rerouting algorithm which is based on load balancing curve analysis for effective buffer management and rerouting during link failures.
- We experimentally test the performance of RRATE algorithm incorporating our proposed algorithm to handle network link failures under realistic link ups and downs scenario.

The rest of the paper is organized as follows: In section 2, we discuss the proposed rerouting algorithm. In section 3, we discuss the simulation scenario and network configurations. In section 4, we evaluate the performance of the RRATE algorithm during realistic link failures in real time traffic conditions. Finally, we summarize the paper and discuss some future work in section V

2. REROUTING ALGORITHM

A network is usually designed based on statistical and initial factors, but the network traffic conditions like load and bandwidth change with time. Network resources also change with new resource requests or configuration changes (e.g., node or link failures). The most important aspect of designing a quality of service (QoS) network is the reliability of the network, i.e., an alternate routing mechanism should be available during node or link failures [17], [18]. Hence, analyzing the performance of RRATE algorithms on synthetic networks does not give us the actual results that would be desired. Therefore, we propose a fast rerouting technique that could be implemented with the RRATE algorithm to make it more reliable and more resilient [19], [20].

The proposed rerouting algorithm identifies the node or link failure based on queue build up. It computes the alternative path by calculating the load across the different routes. The load is calculated using the following mathematical analysis. A mathematical model for efficient buffer management in the router (LSR) during link failure has been modeled and the performance analysis has been done [13], [14], [15],

[16]. The algorithm uses a load balancing curve based on greedy shaper to achieve its objective.

A load balancing curve is a shaper that delays the input bits in a buffer, whenever sending a bit would violate the constraint σ, but outputs them as soon as possible.

A load balancing curve with a shaping curve σ delays events of an input event stream, so that the output event stream has σ as an upper arrival curve, and it outputs all events as soon as possible. Consider a load balancing curve with shaping curve σ, which is sub-additive and with $\sigma(0) = 0$. Assume that the shaper buffer is empty at time 0, and that it is large enough so that there is no event loss. The input event trace R to such a load balancing curve, the output event trace R' is given by:

$R' = R \otimes \sigma$ --------- (1)

In practice, a load balancing curve with a shaping $\sigma(\Delta) = \min_{\forall i} \{b_i + r_i \Delta\}$ with $\sigma(0) = 0$ can be implemented using a cascade of leaky buckets. Every leaky bucket has a bucket size bi and a leaking rate ri, and the leaky buckets are arranged with decreasing leaking rate within the cascade. Initially all buckets are empty. A token is generated, at the arrival of event in the leaky bucket stage. Once the token is generated, the algorithm checks for the space in the bucket. When the bucket has space, the token is dropped into the bucket and the event is forwarded to the next stage. Otherwise, the event has to wait until the bucket is emptied.

Assume an event stream that can be modeled as an abstract event stream with arrival curves [αu, αl] serves as input to a load balancing curve with a sub-additive shaping curve σ with $\sigma(0) = 0$. Then, the output of the load balancing curve is an event stream that can be modeled as an abstract event stream with arrival curves.

$\alpha^{u'}_{GS} = \alpha^{u} \otimes \sigma$ --------- (2)
$\alpha^{l'}_{GS} = \alpha^{l} \otimes (\sigma \,\overline{\oslash}\, \sigma)$ --------- (3)

Further, the maximum delay and the maximum backlog at the load balancing curve are bounded by

$d_{max,GS} = \mathrm{Del}(\alpha^{u}, \sigma)$ --------- (4)
$b_{max,GS} = \mathrm{Buf}(\alpha^{u}, \sigma)$ --------- (5)

To prove (2) we use the fact that $R \,\overline{\oslash}\, R$ is the minimum upper arrival curve of a cumulative function R, and used the properties

$$(f \oslash g) \oslash h = f \oslash (g \oslash h)$$
$$(f \otimes g) \oslash h \leq f \otimes (g \oslash h)$$

Where the min-plus convolution $\otimes$, min-plus deconvolution $\oslash$, and max-plus deconvolution $\overline{\oslash}$ of *f* and *g* are defined as:

$$(f \otimes g)(\Delta) = \inf_{0 \leq \lambda \leq \Delta} \{f(\Delta-\lambda) + g(\lambda)\}$$
$$(f \oslash g)(\Delta) = \sup_{\lambda \geq 0} \{f(\Delta+\lambda) - g(\lambda)\}$$
$$(f \,\overline{\oslash}\, g)(\Delta) = \inf_{\lambda \geq 0} \{f(\Delta+\lambda) - g(\lambda)\}$$

We can then compute

$$\begin{aligned} R' \oslash R' &= (R \otimes \sigma) \oslash (R \otimes \sigma) \\ &= ((R \otimes \sigma) \oslash R) \otimes \sigma \\ &= ((\sigma \otimes R) \oslash R) \oslash \sigma \\ &\leq (\sigma \otimes (R \oslash R)) \oslash \sigma \\ &\leq (\sigma \otimes \alpha^{u}) \oslash \sigma \\ &= (\alpha^{u} \otimes \sigma) \oslash \sigma \\ &= \alpha^{u} \otimes \sigma \end{aligned}$$

To prove (3), the fact that $R \,\overline{\oslash}\, R$ is an input event stream, so that the output event stream has σ as an upper arrival curve, and it outputs all events as soon is the maximum lower arrival curve of a cumulative function R. We can then compute,

$$\begin{aligned} R' \,\overline{\oslash}\, R' &= (R \otimes \sigma) \,\overline{\oslash}\, (R \otimes \sigma) \\ &= \inf_{\lambda \geq 0} \sup_{0 \leq v \leq \lambda} \inf_{v \leq u \leq v + \mu} \{R(u) - R(v) + \sigma(\mu + \lambda - u) - \sigma(\lambda - v)\} \end{aligned}$$

On evaluating this formula separately for $0 \leq u \leq v$, for $v \leq u \leq v + \mu$ and for $v + \mu \leq u \leq \lambda + \mu$, we get

$$\begin{aligned} (R \otimes \sigma) \,\overline{\oslash}\, (R \otimes \sigma) &\geq \min\{(R \,\overline{\oslash}\, R) \otimes (\sigma \,\overline{\oslash}\, \sigma), (R \,\overline{\oslash}\, R), (\sigma \,\overline{\oslash}\, \sigma)\} \\ &= (R \,\overline{\oslash}\, R) \otimes (\sigma \,\overline{\oslash}\, \sigma) \end{aligned}$$

$$\begin{aligned} d(t) &= \inf\{\tau \geq 0 : R(t) \leq R'(t + \tau)\} \\ &= \inf\{\tau \geq 0 : 0 \leq \inf_{0 \leq u \leq t + \tau} \sigma(t + \tau - u) + R(u) - R(t)\}\} \end{aligned}$$

$$\begin{aligned} b(t) &= R(t) - R'(t) \\ &= R(t) - (\sigma \otimes R)(t) \\ &= \sup_{0 \leq u \leq t} \{R(t) - R(u) - \sigma(t - u)\} \end{aligned}$$

Relations (2) and (3) can now be used as internal relations of an abstract load balancing curve, and (4) and (5) can be used to analyze delay guarantees and buffer requirements of load balancing curves in a performance model.

The proposed algorithm is now implemented with RRATE algorithm to handle link failure and to improve the reliability of the network.

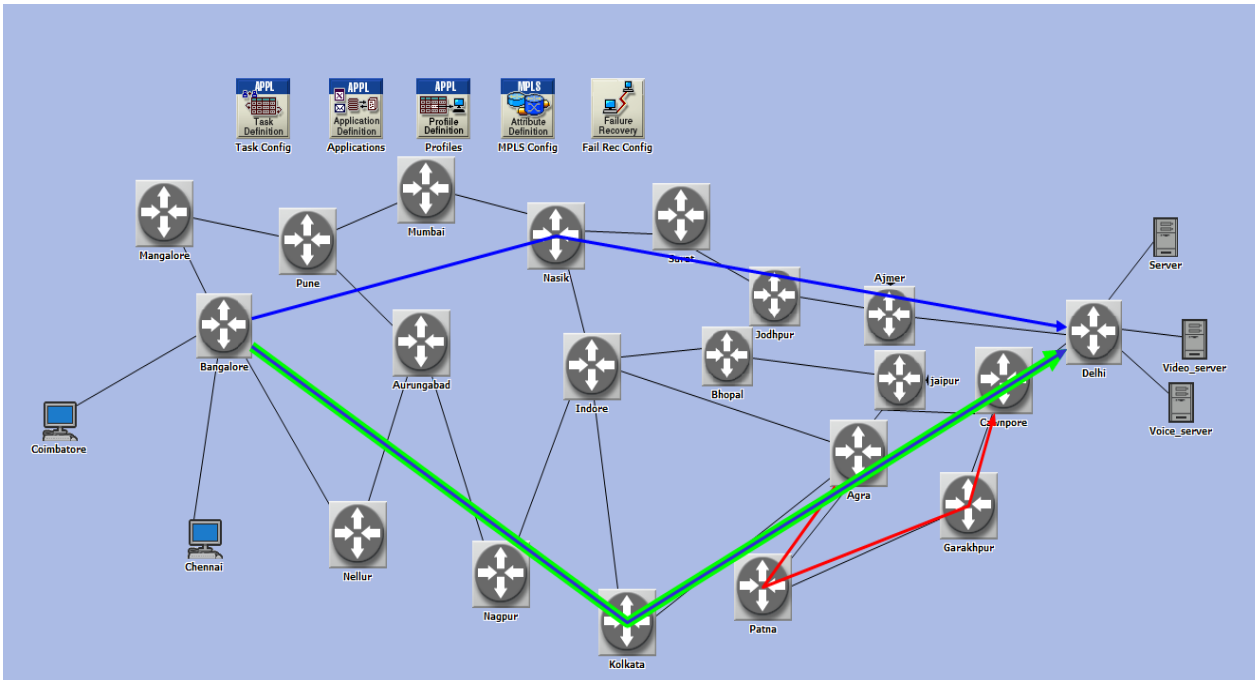
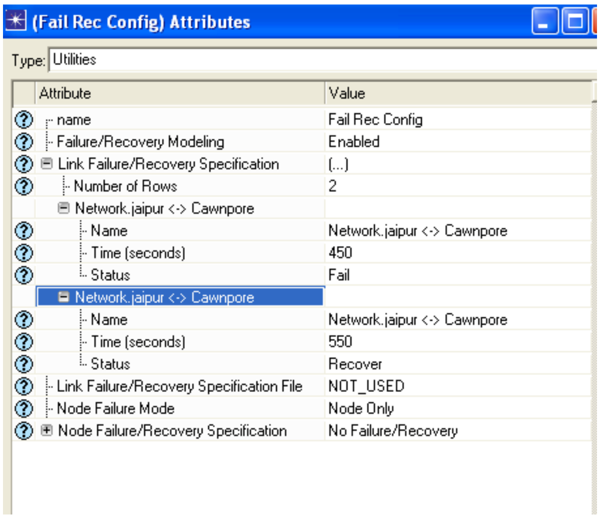


Fig 1. Simulation setup

3. SIMULATION SCENARIO

Fig 1 illustrates the simulation setup. Traffic has been configured from clients located at Chennai and Coimbatore trying to establish a communication with servers located at Delhi. This Scenario illustrates the use of RRATE-TE to configure LSPs (Fig 2) dynamically and uses the proposed algorithm to handle link failure. All links are OC3 links. MPLS has been configured in the network. Two Primary Dynamic LSPs are configured from Bangalore to Delhi via Kolkata. Routers are configured with RRATE-TE for setting up LSPs. Link between "Jaipur to Cawnpore" fails at time 450 seconds (Fig 2). Simulation is carried out for 900 seconds.



Type: Utilities

Attribute	Value
name	Fail Rec Config
Failure/Recovery Modeling	Enabled
Link Failure/Recovery Specification	(...)
Number of Rows	2
Network.jaipur <-> Cawnpore	
Name	Network.jaipur <-> Cawnpore
Time (seconds)	450
Status	Fail
Network.jaipur <-> Cawnpore	
Name	Network.jaipur <-> Cawnpore
Time (seconds)	550
Status	Recover
Link Failure/Recovery Specification File	NOT_USED
Node Failure Mode	Node Only
Node Failure/Recovery Specification	No Failure/Recovery

Fig. 2 RRATE-TE configuration

4. RESULTS

Reroute time: Time taken to switch traffic away from failed LSP. This statistic is the difference between the time when LSP actually failed and the time when the Ingress LER or the Point of Local Recovery (PLR), switches the traffic away from failed LSP.

Fig 3 illustrates that the algorithm takes 30ms to reroute the traffic through Agra-Pune-Garakhpur-Cawnpore. When primary route fails, the entire traffic has been totally rerouted through the alternate path computed by the algorithm.

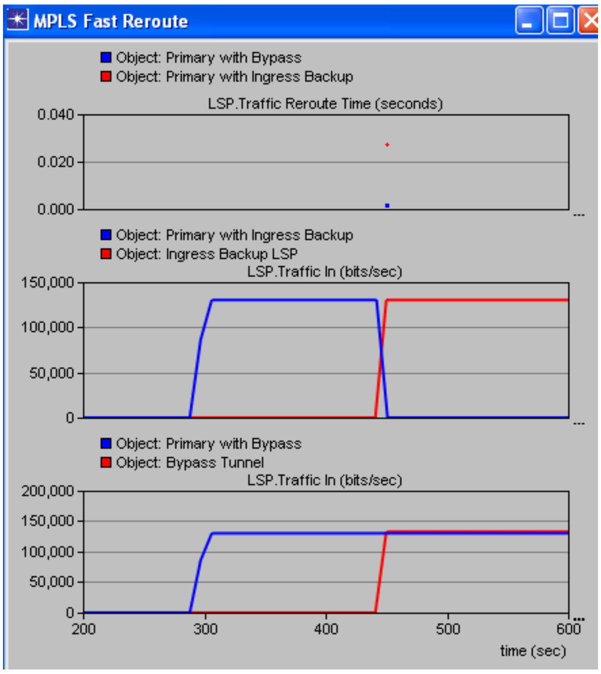


Fig 3 LSP traffic

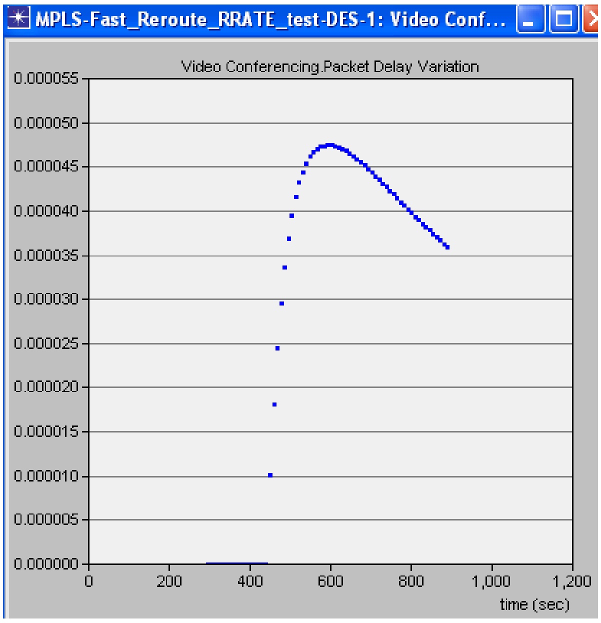


Fig 4 Packet Delay Variation for Video packets

The packet delay variation experienced by the video packets is explained in Fig 4. It may be noted that the delay at 450 seconds increases to maximum due to link failure and decreases as soon as the rerouting takes place.

The quality of reconstructed voice signals to verify the QoS of the algorithm is also analyzed. The MOS and Jitter value from Fig 5 indicates that the QoS of reconstructed signal does not degrade after rerouting.

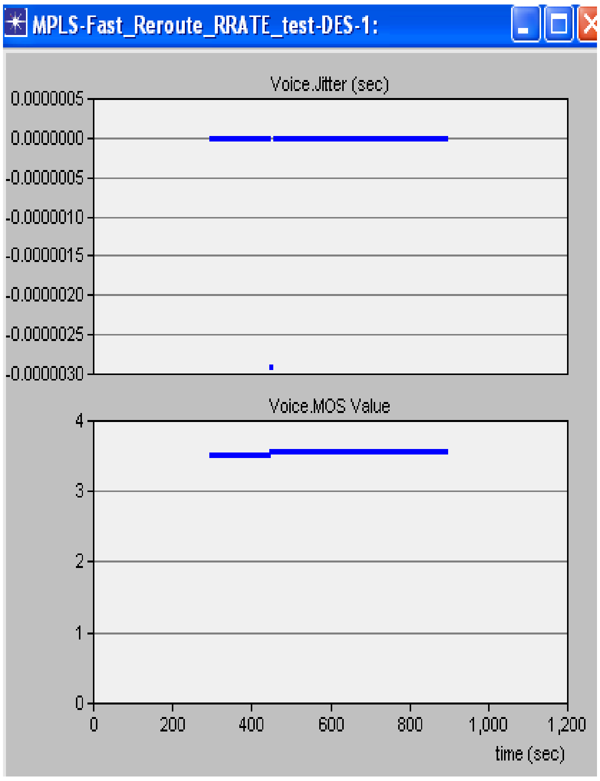


Fig 5 MOS and Jitter for voice packets

5. CONCLUSION

In this paper, the proposed rerouting algorithm uses the concepts of Greedy shapers. This algorithm used with RRATE and experimentally verified its performance. Analysis results indicate that the QoS factor have been maintained in both voice and video applications.

As future work, this algorithm will be implemented in network processor and it would be interesting to see how the algorithm performs under real time traffic conditions.

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