A Framework for Pre-Computated Multi-Constrained Quickest QoS Path Algorithm

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***Abstract*—The era of advance computer networks and advance communication leads the technology to new heights and the algorithms used for the routing needs to be updated side by side parallel with the advancement. This paper presents the new multi-constrained routing algorithm which gives quality of service full-fill the service level agreements with the user. Finding a multi-constrained path is a NP-complete problem, but still the presented algorithm gives the feasible path for the routing in a given polynomial time. Furthermore the performance comparison shows the best results with presented approach and existed approach.**

***Index Terms*—QoS; Multi-Constraints; NP-Complete; Performance Envelope; Reliability.**

I. Introduction

Today internet has become the bone of the social life which makes us a significant part of the worldwide communications [1]. While the internet was born the services were provided with no guarantee issue or called as best affords services [2]. But with new era, things gone advanced and internet applications needed to be fully optimized with their concern references. A major difficulty in the network applications (remote surgery, video teleconferencing, mass data transfer and video conferencing) is to ensure the optimized services over the internet. A fundamental problem that relies on many important network issues like soft-QoS, internet television, best path selection, optimization of network resources and traffic engineering, is to find the optimized shortest path that satisfies the constraints [3], [4]. For the perfect real time traffic management and QoS, the least delay, maximum capacity and reliability have particular importance. For the traffic engineering to prove the service level satisfaction, the important thing is to find the path that assures the required constrained, while at the same time optimize the network resources [5]. The algorithm for computing the online constrained shortest path can be used in many circumstances depending on the application.

We investigate three constraints as reliability, capacity and delay in optimized tuned routing [6]. The reliability defined here is the packet delivery ratio. However, the reliability constraint is not a key factor in the optimization of network resources as compared to capacity and delay. There are the numerous papers presented on the optimized routing, but very few of them have taken the multiple constraints [9-18]. A major hurdle in multi constrained routing is the time complexity and/or space complexity because finding the path based on two or more constrained is NP-complete problem [7]. One of the most discussed topics in the internet research community is the tuned and automatic configuration of the network with the constraints of reliability, capacity and delay.

Delay, reliability and capacity are needed to be satisfied in different ways means to say that delay is a time constraint, reliability depends on the path diversity and capacity is the constrained based on bandwidth. The multi-constraint multipath proposal is based on two categories. One category gives the computed various possible paths from source edge to destination and second category will combine the resources to the computed tuned path with requited constraint [8].

A. Related Work

A number of algorithms have been proposed by the authors on the QoS routing algorithms. Chin and Chen [9] proposed QPP first time and, after that Martin and Santos [10] Rosen [11] proposes extensions for QPP as computing the shortest path using transmission time for the different sub networks.

As the concept of QPP got well known by researchers, several extensions made for different applications requirements and concept of reliability made attraction by them, therefore G. Xue [12], Spysous Tragdas [13], H. Calvete [14], S. Ruzica [15], W.C. Yeh [16], YK. Lin [17], M. Khadri [18] proposed the importance of reliability with QPP.

Paper [12] proposed an algorithm which gives end to end data path which is quickest as well as reliable. In paper [13] author presents the QPP problem as most reliable data path transmission using modeling. Lin [17] gives the evaluation of system reliability for the extension of QPP. In 2012, paper [14] proposed algorithms which give QPP and reliable quickest path problem whose reliability is not lower than the given threshold. The authors of paper [15] presents the link probability model as the reliable quickest path problem which can be seen as a restricted quickest path problem. [16] paper gives a QPP path in the multi-flow networks. In paper [18] proposed a path computation using budget constraint.

For a network to be fast, pre-computation schemes are used for finding the multi-constraints QPP. No of various pre-computation schemes are proposed by the authors for the quality of service (QoS). In paper [19] QoS are achieved by pre-computation schemes with least utilization resources. Qos depends on the bottleneck capacity metric and delay metrics. Also, using pre-computation computational complexity got reduced. Paper [20] proposed the multilayer routing protocols which solve the diffServ – based QoS management for service level agreements of services (SLA). In paper [21] pre-computation used as the priori event for calculation of path in the background, hence path computation is fast and scalability got increased.

B. Contribution and Usefulness of Our Work

The objective of the algorithm is that the path is chosen for the routing should be specific to application requirement so that performance parameters will not undergo any drastic effects. To so that a tuned link weight assignment algorithm has been proposed here to optimize network resources. The broad idea of proposed algorithm can be seen as a new link weight metrics formed by taking the main constraints of a network. Hence, mixed metrics give experimental tuned optimized results. In this proposed method we strict to the online constrained link assignment for better results specific to the application.

C. Organization

The rest of the paper is represented as Section II shows the network model which includes subsections of terminology and problem statements. Section III consists of an algorithm and example. Results and discussion are given in the section IV. Section V gives the conclusion of the paper.

II. Mathematical Modelling

A. Problem Statement

Let $N = (V, E, c, d, r)$ be the network where V the set of n nodes or vertices and E is is the set of m edges. The QoS parameters used are capacity $c(u, v) > 0$, delay $d(u, v) > 0$ and reliability i.e. Probability of link failure $r(u, v) \in [0, 1]$ of the edge (u, v). To transmit the σ unit's data from source to destination, we have to find the QoS path that is feasible and lies in the performance envelope.

To find a path, it is assumed that the graph is fully connected and there must be existing at least one path from the source node to the destination node problem. The quickest path problem has been given as the least delay and the link delay is given as:

$$\left[d(u, v) + \frac{\sigma}{c(u, v)}\right] \quad (1)$$

B. Pre-computation and Performance Envelope

Finding a QoS path is an NP-complete problem and also it increases extra overhead to solve the overhead problem and scalability purpose pre-computation process has been used. Also fault tolerance of the network increased because if any link failure occurs, it chooses pre-computed path itself for restoration. A number of requests that are facilitated distribution of available resources for different requests in efficient manner leads to load balancing. As the network has random traffic size and different time requirement of accomplishing the job a pre-computation process in standard network goes undergoes two parts: first part comes when an event has to be occurs, i.e. compute all paths for different set of random values and find the high performance region and keep it in the database and second part comes when event arrive. For an approximation of the optimized high performance region, we have used the statistical analysis to establish a relation between the mean-standard deviation problems and gave the bounded area between the mean and the standard deviation area.

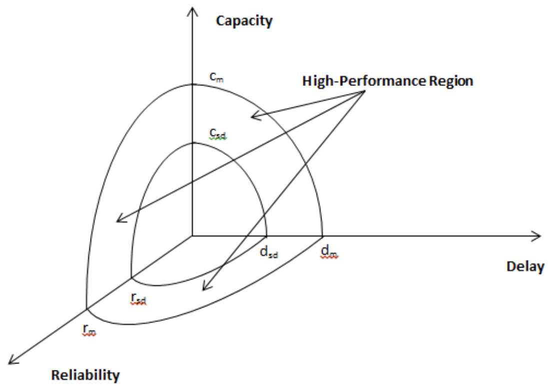

Figure 1: Performance Envelope For High Performance [22]

Pre-computation part leads to give these bounds by analyzing the random set of values for the topology to analyze the behavior of the network. Thus, by analyzing the behavior of network a tuning rule can be formed.

C. Terminology and Definitions Used

For optimized feasible path with the high performance region, we are interested with three tuple $(d(u,v), c(u,v), r(u,v))$ cost function to the Dijkstra's algorithm. The cost function for the algorithm is given as:

$$P(u, v) = -ln\left\{r(u, v)e^{\left[d(u,v)+\frac{\sigma}{c(u,v)}\right]}\right\} \quad (2)$$

$$P(u, v) = -\ln[r(u, v)] + \left[d(u, v) + \frac{\sigma}{c(u, v)}\right] \quad (3)$$

$$W(u, v) = R + \alpha L \quad (4)$$

where $r(u,v)$, $d(u,v)$, $c(u,v)$ are reliability, delay, capacity of link between u and v and σ units of data to be transmitted respectively. Tuning factor (α) depends on the application time requirement denoted by per second ($\sec^{-1}$) i.e. $\alpha = \frac{1}{T}$ where T is the tuning time in seconds.

Let P is the $s - t$ path chosen from source to destination with three tuple consideration $P(s, v_1, v_2, \ldots, t)$ and protocol used to calculate the shortest path first so that it takes the smallest value of the cost first. Capacity is the bottleneck for transmission, so the value of capacity has been chosen as:

$$C(P) = \min_{(u,v)\in P} P(u, v) \quad (5)$$

Other three considerations of tuple viz. reliability, capacity, and delay are multiplicative, minimum and additive respectively.

$$R_{path} = \prod_{s}^{t} r(u, v) \quad (6)$$

$$C_{path} = \min_{(u,v)\in P} P(u, v) \quad (7)$$

$$D_{path} = \sum_{s}^{t} d(u, v) \quad (8)$$

III. Proposed Algorithm and Example

A new method of mixed metric has been shown here in this paper. The steps included in the algorithm shown below.

A. Algorithm

The algorithm online real time routing (ORTR) with the proposed approach is given as below:

Algorithm ORTR
Input: $G(V, E, c, d, r, \sigma)$ with source and sink nodes $(s - t)$
Output: A feasible optimized path

BEGIN
STEP0: Calculate $W(u, v)$ and find shortest path weight $W_{path}(s - t)$ for tuning factor α_i.
STEP1: If $W_{sd} < W_{path}(s - t) < W_{mean}$
then go to STEP2
else
go to STEP0 with tuning factor α_{i+1}
STEP2: Get the capacities of each link with in the path
If $C_{path}(s - t) < \min_{s-t} c(u, v)$
then go to STEP3
else
go to STEP0 with tuning factor α_{i+1}
STEP3: If $r_{sd} < R_{path}(s - t) < r_{mean}$
then go to STEP4
else
go to STEP0 with tuning factor α_{i+1}
STEP4: If $d_{sd} < D_{path}(s - t) < d_{mean}$
then Path is feasible and optimized QoS.
else
go to STEP0 with tuning factor α_{i+1}
END

Algorithm helps to find the feasible path in the high-performance region step by step and the Figure. 2 gives the overview of the proposed algorithm of multi-constrained quickest path problem. There are four main basis steps which give optimal QoS path which is feasible in the High performance region are given below: I step compute shortest path using Dijkstra's algorithm using given cost function and gives weight of the path. II step check path with weight if capacity full fills the condition or go to step I. The III & IV step assign the path for traffic only and only if all these four steps become true unless they will go to step I again with next tuning factor.

B. Time complexity

The proposed algorithm has been proposed based on the Dijkstra's algorithm, hence the proposed algorithm has the time complexity same as of the complexity of Dijkstra's algorithm i.e. $O(m + n\log(n))$.

C. Example

For illustration of algorithm, let's take an example of a network and find the feasible path.

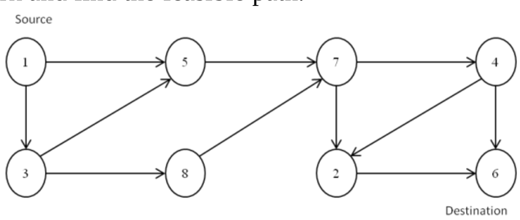

Figure 2: Network Topology

For the given topology number of nodes are 8 and the number of edges are 11 with data size (σ) of 1 Mb. Different tuning has been done according to application requirements.

In pre-computation part statistical analysis has been used to form the high-performance region. The mean and standard deviation are the bounded region for the probability scale and is inverse of natural log ($-\ln$) to get the minimum cost values of weight for the usability of Dijkstra's algorithm.

For the next part any values of reliability, capacity and delay for specific application requirement path weight are calculated using proposed algorithm and then check for the path whether it comes in the feasible region or not.

IV. Experimental Setup, Result and Discussion

In this section we will discuss about the experimental setup and result discussion. The experiment has been done on Ubuntu 15.04 and simulation part has been done using NS2 simulator. 1000 simulation for the given topology in figure 2 has been given to get the high-performance region using a random number generator.

A. Results

The scale used in the performance envelope for reliability is $-\ln$ for the capacity it is in Mbps and for the delay its seconds. The region boundaries are bounded in the statistical parameters. The 1000 random simulations have been made to decide the high-performance envelope regions. For different tuning factors different high-performance regions have been found. Hence, for an online traffic demand data (σ) find the high-performance region corresponding to the tuning factor.

Table 1
High Performance Envelope for Figure 2 with Tuning Factor 1

Constraint	Reliability	Delay	Capacity	Weight
Mean	1.45826	14.9	1.733	32.39
S.D.	1.201	6.419588	1.582628	28.53873858

For the tuning factor 0.00625 and 0.025 the performance bound is given in Table 2 and 3.

Table 2
High Performance Envelope for Figure 2 with Tuning Factor 0.025

Constraint	Reliability	Delay	Capacity	Weight
Mean	3.718454876	15.1	2.028	711.238
S.D.	3.282	6.454112	1.396009	221.7036

Table 3
High Performance Envelope for Figure 2 with Tuning Factor 0.00625

Constraint	Reliability	Delay	Capacity	Weight
Mean	3.764035	15.1	2.028	2726.72
S.D.	3.327	6.454112	1.396009	860.1086

Now take any random set of values taken for different values of tuning factor the path given directly for the tuning factor 1, 0.025 and 0.00625. According to the occurrence of the random values, these tuned paths can be applied directly as these paths came under high performance region.

Table 4
High performance path with different tuning time

Tuning Time	160	40	1
Best Path	0..4..6..1..5	0..2..7..6..3..1..5	0..2..7..6..3..1..5

In the next part performance analysis has been made with existing approaches. The main performance factors are compared with existing approaches and the proposed approach.

B. *Performance analysis*

For the performance analysis the main factors taken for proposed approach and MRTDPT [13] algorithms without pre-computation are average throughput, average delay, packet delivery ratio and instantaneous throughput.

1. Average Throughput is the rate (bits/time unit) at which bits transferred between sources to sink for a longer time period. Instantaneous throughput is the rate at a given point in time.

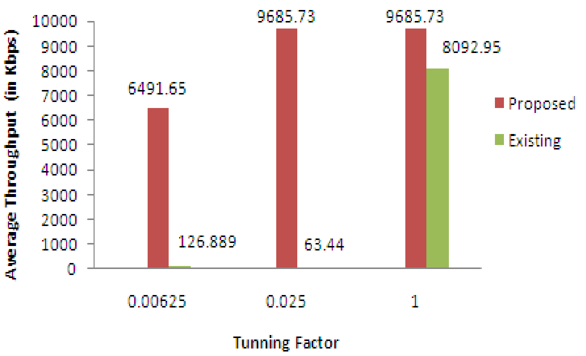

Figure 3: Average throughput for the all tuning factor

2. Average Delay is the parameter which represents an average delay and indicates how much time it has been taken by the packet to travel from source to destination and measured in seconds.

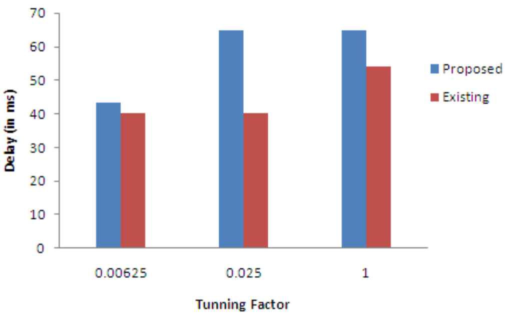

Figure 4: Average delay for the all tuning factor

3. Average packet delivery ratio is calculated by dividing the number of packets received by sink through the number of packets originated from the source. This specifies that rate of packet loss in the network, which leads to limit the throughput of the network.

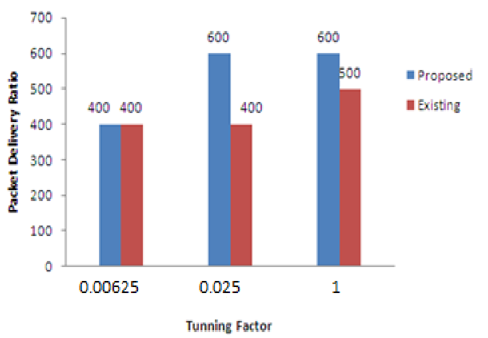

Figure 5: Average delay for the all tuning factor

4. Instantaneous throughput is the throughput at a particular time instant for the different tuning factor with proposed pre-computed approach and existing MRTDPT algorithm without pre-computation.

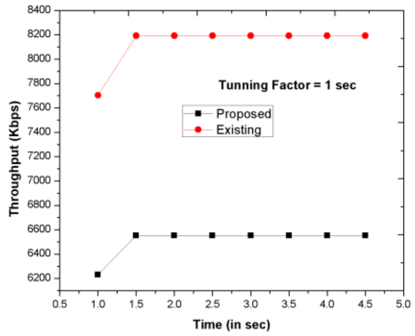

Figure 6: Instantaneous throughput for the tuning time 1sec.

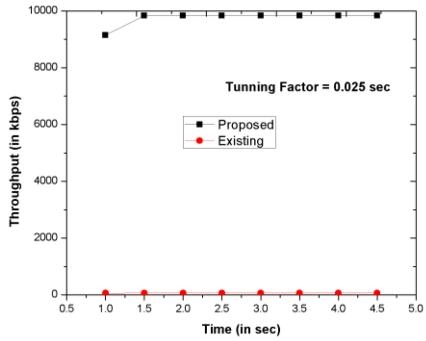

Figure 7: Instantaneous throughput for the tuning time 40 sec.

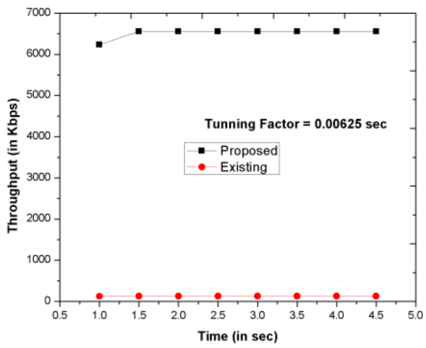

Figure 8: Instantaneous Throughput For The Tuning Time 160 sec.

C. *Discussion*

For the performance parameter average throughput in Figure 3 shows a high difference with the conventional approach and the proposed approach. The average throughput shows high variability and for initial tuning factor, it is less, but sufficient as compared to existing approaches. As tuning factor increased variability in average throughput goes decreases.

The proposed approach is based on pre-computation, so the average delay is little bit higher than the existing approach given in Figure 4. But pre-computation gives least overhead so it can be used where very less information required by the path selection algorithm.

In case of the average packet delivery ratio (PDR) the proposed algorithm gives high PDR. As for initial tuning factor, it gives the same PDR as the existing algorithm so it does not make any difference at low tuning factors and as a tuning factor got increased the PDR got increased impressively as shown in Figure 5.

For the Figures 6, 7 and 8, the instantaneous throughput of both approached shows that for conventional approach has low throughput as compared to the proposed algorithm because in proposed scheme pre-computation has been used hence it has higher throughput than the existing approach.

V. CONCLUSION AND FUTURE WORK

In this paper a new multi-constrained routing algorithm has been proposed which gives quality of service full-filled the service level agreements with the user using performance envelope. As finding a multi-constrained QoS path is an NP-complete problem, but still the presented algorithm (ORTR) gives the feasible path for the routing in a given polynomial time same as Dijkstra's algorithm. Using pre-computation scheme, it has very low overhead and useful for online services. Also the performance comparison of ORTR algorithm shows the best results with existing approaches. In future this work can be extended the random generator of topologies using a topology generator and verify the performance region also random number generation for three tuples can be done using Monte-Carlo method which gives the exactness of the proposed algorithm.

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