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# Multi-Constrained QoS Routing Issues in High-Speed Multimedia Networks

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***Abstract*— High- Speed Multimedia Networks (HSMN) have diverse Quality of Service (QoS) requirements. Designing QoS routing protocols that optimizes multiple QoS requirements is one of the major issues in these networks. Traditional routing algorithms are not adequate to handle QoS requirements of real-time multimedia applications. QoS Routing is defined as finding paths satisfying multiple QoS constraints. It is a Multi-Constrained Path (MCP) Problem which is a NP-complete problem that cannot be solved in polynomial time. Various heuristics and approximation algorithms have been proposed to solve multi-constrained QoS routing problems. In this paper we will discuss various QoS routing issues followed by review of some important heuristic algorithms developed to solve multi-constrained QoS routing problems.**

***Keyword*- High-Speed Multimedia Networks, QoS Routing, Real-Time, Multi-Constrained Problem, Multi-Constrained Optimization Problem.**

## I. INTRODUCTION

Traditional routing protocols were designed to provide best effort, fair delivery of service. No distinction is made in terms of the relative importance of any traffic or of the timeliness requirements of any of the traffic. This type of data delivery mechanism has provided satisfactory service to applications [1] such as e-mail, file transfers, remote login etc.

But, with the tremendous increase in traffic volume and increased usage and demand of real-time, multimedia and multicasting applications, traditional routing methods are no longer adequate [2]. These applications require certain performance guarantees from the network in terms of delay, jitter, bandwidth, packet loss etc. To ensure that these requirements are fulfilled, network must consider some parameters when transferring data. These parameters are known as QoS parameters.

Provisioning QoS is a very complex process. It requires QoS awareness at each layer of network architecture. At network layer QoS provisioning is achieved by QoS routing. QoS routing has two goals. The first goal is to find an optimal path between source and destination so that QoS requirements of an application is satisfied and second goal is to utilize the overall network resources in an efficient & optimized manner. Optimizing network resources is important so that the network can accommodate as many QoS requests as possible [3].

Real-time multimedia applications have diverse QoS requirements [4]. Each application has its own set of QoS requirements which is to be satisfied simultaneously. Individual QoS parameters may be conflicting and interdependent which makes the problem of QoS routing NP-complete that cannot be solved by simple algorithms. This type of problem is known as Multi-Constrained Path (MCP) Problems [5] which is defined as follows:

**Definition 1: Multi- Constrained Path (MCP) Problem**: Consider the network G (V, E). Each link (u, v) ε E is associated with k additive weights $w_i$ (u, v)≥ 0, i = 1 , 2… k. Given k constraints $C_i$, i = 1, 2… k, the problem is to find a path P from source node s to destination node d such that

$$w_i (P) = \Sigma\, w_i (u, v) \leq C_i \quad \text{for } i = 1, 2\ldots k \qquad (1)$$

All the paths satisfying equation (1) are said to be a feasible path. There may exist many feasible paths in the network G. Sometimes, it is desirable to find the optimal path among these feasible paths. This problem is called the Multi-Constrained Optimization Path (MCOP) Problem, which is defined as follows:

**Definition 2: Multi-Constrained Optimal Path (MCOP) Problem:** Consider a network that is represented by a directed graph G = (V, E), where V is the set of nodes and E is the set of links. Each link (u,v) € E is associated with a primary cost parameter c(u, v) and k additive QoS parameters $w_i$ (u, v)≥ 0, i = 1, 2… k. All parameters are non-negative. Given k constraints $C_i$, i = 1, 2… k,, the problem is to find a path P from a source node s to a destination node d such that

(i) $w_i (P) = \Sigma\, w_i (u, v) \leq C_i$ for i = 1, 2… k; and
(ii) $c_P = \Sigma\, c (u, v)$ is minimized over all the feasible paths satisfying (i).

Both MCP and MCOP are NP-complete problems. Various heuristics and approximation algorithms have been proposed to solve these problems.

This paper is organized as follows. Section II describes the issues/ challenges faced in provisioning QoS followed by QoS requirements of HSMN in section III. Section IV presents a brief overview of some important heuristic-based multi-constrained QoS routing algorithms.

## II. QOS ISSUES IN HSMN

Existing network routing protocols are inefficient to handle QoS provisioning in HSMN. QoS routing is complex. Some of the major issues that make provisioning QoS in high-speed networks difficult are discussed below:

i) *Diverse QoS requirements*: Real time multimedia applications have diverse QoS requirements which make the routing problem intractable. Optimizing two or more than two QoS parameters is proved to be NP-complete.
ii) *Uncertainty*: Network is dynamic in nature. As the network grows in size it becomes difficult to gather up-to-date state information. Routing with this uncertain or imprecise information affects the performance of routing algorithm. Therefore, routing algorithm developed for larger networks should take the information impreciseness into consideration.
iii) *Performance Optimization*: The network is supposed to carry both QoS traffic and best-effort traffic. It is difficult to find the best operating point for both types of traffic. The routing algorithm developed should be such that the throughput of best-effort traffic should not suffer.
iv) *Scalability*: The QoS routing algorithm being designed should be such that its performance does not degrade when the network grows in size.
v) *High Overhead*: Traditional routing algorithms only consider hop count as a metric to select routes. But selecting routes with more than one metric will lead to an increase in computational and communicational cost. More time will be needed to setup a connection and more state information will be required to be maintained at each node thereby increasing both the costs. Therefore, routing algorithm developed should aim at minimizing these two costs.

## III. QoS Requirements In HSMN

Every application has certain service requirements from the network. These requirements are called its expected Quality of Service (QoS) [6]. QoS in multimedia networks can be defined from two perspectives: timeliness and reliability. By timeliness we mean delivery of data within some specified time interval i.e., QoS parameters measured are delay, jitter, throughput etc. Reliability means delivery of accurate data with minimum packet loss.

Each link in the network is associated with multiple QoS parameters. The value of metric over the complete path is determined by following QoS composition rules [7]:

i) *Additive Metrics*: The QoS value of the path is equal to sum of the corresponding weights of the links along the path. Mathematically, it can be represented as:

$$D(p) = d(i,j) + d(j,k) + \ldots + d(l,m) + d(m,n) \quad ..(2)$$

where d(i,j) denotes the QoS parameter associated with each link (i, j) and p = <i, j, k, ...., n> is path. Delay, jitter, hop count are additive QoS parameters.

ii) *Multiplicative Metrics*: The QoS value of the path is equal to multiplication of the corresponding weights of the links along the path. Mathematically, it can be represented as:

$$D(p) = d(i,j) \times d(j,k) \times \ldots \times d(l,m) \times d(m,n) \quad ..(3)$$

where d(i,j) denotes the QoS parameter associated with each link (i, j) and p = <i, j, k, ...., n> is path. Reliability, packet loss are multiplicative QoS metrics.

iii) *Concave Metrics*: The QoS value of the path is the minimum (or maximum) of link weights along the path. Mathematically, it can be represented as:

$$D(p) = \min \text{ or } \max \{d(i,j), d(j,k), \ldots, d(l,m), d(m,n)\} \quad ..(4)$$

where d(i,j) denotes the QoS parameter associated with each link (i, j) and p = <i, j, k, ...., n> is path. Bandwidth is an example of concave metric.

Constraints having multiplicative metrics can be easily converted into additive by taking logarithm. Constraints having concave metrics can be easily dealt with by pruning all links that do not satisfy the constraints. Finding path satisfying two or more than two additive QoS metrics is complex and proved to be NP-complete [8].

## IV. QoS Routing Protocols

QoS routing is defined as finding feasible paths that satisfy all the QoS parameters simultaneously. It is a multi-constrained path problem which is NP-complete [9]. Researchers have proposed many heuristics and approximation algorithms to solve this problem. We have done an extensive study of heuristic algorithms developed so far to solve QoS based MCP problem. Some of the important heuristic algorithms are described below:

*Chen et al [10]*: Proposed a heuristic algorithm that reduces the NP-complete problem into simpler one by scaling down k-1 link metrics which can be solved in polynomial time. The sub-problem is then solved using either extended Dijkstra's shortest path algorithm (EDSP) or extended Bellman-Ford algorithm (EBF) w.r.t. single metric with the condition that all the k-1 scaled metrics are within the constraints. They showed that the solution of the simpler problem will be the solution of the original problem. The time complexity of the algorithm is $O(x^2V^2)$ when EDSP is used and $O(xVE)$ when EBF is used. Here, V is the set of nodes in the network and E is the set of links connecting these nodes. x is the parameter defined by the algorithm which determines the performance and overhead of the algorithm. Larger the value of x, larger is the probability of finding solution to the problem. But the algorithm becomes computationally expensive, which is not feasible for real-time multimedia applications.

*Neve et al [11]*: Proposed a heuristic algorithm, TAMCRA, Tunable Accuracy Multiple Constraints Routing Algorithm. The algorithm is based on three fundamental concepts: a non-linear cost function, k-shortest path algorithm and the principle of non-dominance. k denotes the number of shortest paths that can be stored at each node. The time complexity of the algorithm is $O(kV\log(kV) + k^3mE)$. In TAMCRA, k is pre-defined and fixed. So there is a possibility that end-to-end shortest path is never found. Also the non-dominated paths found may not be feasible.

*Miegham et al [12]*: Proposed an algorithm called SAMCRA, Self Adaptive Multi Constraint Routing Algorithm. The algorithm is based on the same three principles and has the same time complexity as TAMCRA. The only difference between the two algorithms is that in SAMCRA, k is not fixed so all possible paths between source and destination is found and stored at each node. The value of k at each node differs. In worst case, the value of k increases exponentially.

*Korkmaz et al [13]:* Proposed H_MCOP, a heuristic based algorithm which solves both MCP as well as MCOP problems with time complexity O(VlogV + mE), where V is the number of nodes in the network, E is the set of links connecting nodes and m is the number of constraints. This heuristic attempts to find a feasible path for any number of constraints while simultaneously minimizing a path length function. It uses the same non-linear cost function as used in SAMCRA and TAMCRA to find feasible paths. To find optimal path H_MCOP minimizes the primary cost function. H_MCOP always find a path from source to destination either by minimizing the non-linear cost function or minimizing the primary cost function so H_MCOP can be seen to be implemented as single-objective algorithm.

*Liu et al [14]:* Proposed an algorithm for MCOP problem that finds first K-multi-constrained shortest paths that are within the constraints. The paths are calculated using linear path cost function which is same as that of Jaffe's algorithm [15]. The algorithm works by storing the paths that are within the constraints and pruning all those paths that do not satisfy the constraints and hence the algorithm is termed as A*-Prune algorithm. The algorithm proposed to provide an exact solution to the problem but the technique that is being used is heuristic in nature.

*Xin Yuan [16]:* Proposed two polynomial-time heuristics, the limited granularity heuristic (LGH) with time complexity $O(V^K E)$ and the limited path heuristic (LPH) with time complexity $O(V^2 lgV)$, where V is the set of nodes in the network and E is the set of links connecting these nodes. Both the algorithm uses variations of Extended Bellman-Ford algorithm to solve general k-constrained QoS routing problem. The two heuristics are being compared and is concluded that though both the algorithms are efficient in solving two-constrained QoS routing problem[17] and k-constrained QoS routing problem, limited granularity heuristic algorithm is inefficient when k becomes greater than 3. It requires more resources than the limited path heuristic algorithm as the value of K increases.

*Khadivi et al [18]:* Proposed algorithm that deals with solving MCP problem using a single mixed metric. The method takes into account variations of the link weights in performing path selection. The algorithm operates as a modified version of Dijkstra's shortest path algorithm. The complexity of the algorithm is $O(KV^2)$, where V is the number of nodes in the network. Although mixed metric method discards potentially useful information, the overall complexity of the algorithm is reduced.

*Sen et al [19]*: Proposed a K-approximation algorithm with time complexity O (KE + V log V), which uses a single auxiliary edge weight to compute a shortest path from source to destination. Here V is the number of nodes in the network and E is the set of link connecting these nodes. The edge weight is calculated as maximum of all K edge weights divided by W, a constant value. The edge weight is computed locally at each node and the shortest path is computed using either Dijkstra's algorithm or Bellman's Ford Algorithm. The algorithm is best implemented in hop-by-hop networking environment. They have also proposed two Fully Polynomial Time Approximation Schemes (FPTAS) for two slightly different versions of the problem. But to implement these two FPTAS in current networking environment some modifications will be necessary. The main focus of the algorithm is on the accuracy of the solution. Computational Complexity of the algorithm is very high.

## V. CONCLUSION

QoS routing is a MCP problem which is NP-complete. To solve this problem researchers have proposed many heuristic-based algorithms. In this paper we have discussed few important heuristic-based routing algorithms. Table I summarizes algorithms discussed in this paper.

From our study and Table I, we conclude that though these algorithms are providing solutions for multi- constrained QoS routing problem, the main limitation is that these algorithms are using extended forms of shortest path algorithms such as Dijkstra's algorithm or Bellman-Ford algorithm to find QoS-based paths. Shortest path algorithms calculate path based only on single metric and rest k-1 metrics are approximated, reducing the problem to single objective MCP problem.

The path selected using single metric does not necessarily guarantee that the path have the sufficient resources to meet the desired QoS requirements of the application. Moreover, these algorithms are computationally expensive and not suitable for larger networks. Further, these algorithms are heuristic-based and hence are problem-specific. So an algorithm used to solve one problem might not be used to solve another problem.

TABLE I. HEURISTIC BASED QoS ROUTING ALGORITHMS

| ***Algorithm*** | ***Time Complexity*** | ***Metric Selection*** | ***Scalability*** | ***Routing Strategy*** |
|---|---|---|---|---|
| Chen et al | $O(x^2V^2)$ (EDSP) & O(xVE) (EBF) | Single | Nil | Source |
| Neve et al | $O(kVlog(kV) + k^3mE)$ | Single | Nil | Source |
| Miegham et al | $O(kVlog(kV) + k^3mE)$. | Single | Nil | Source |
| Korkmaz et al | O(VlogV+ mE) | Single | Nil | Source |
| Liu et al | $O(Kd^2(hKlog(K d)))$ | Single | Nil | Source |
| Xin Yuan | $O(V^2lgV)$ (LPH) & $O(V^kE)$ (LGH) | Single | Nil | Source |
| Khadivi et al | $O(K V^2)$ | Single | Nil | Source |
| Sen et al | O(KE + V log V) | Single | Nil | Hop-by-Hop |

Developing a routing algorithm satisfying multiple QoS requirements simultaneously with minimal computational complexity is thus an important research problem. Evolutionary Algorithms are found to be an effective and powerful approach to solve multi-constraint QoS routing problem in HSMN. As a future work, we plan to investigate evolutionary approaches that can be used to solve multi-constrained QoS routing problems and carry out simulation experiments to evaluate their performances.

## REFERENCES


[1] W. Stallings, *High-Speed Networks and Internets: Performance and Quality of Service*, PHI, 2008.

[2] Z.Wang and J.Crowcroft, " Quality-of-Service Routing for Supporting Multimedia Applications", *IEEE Journal on Selected Areas in Communications*, vol. 14, n. 7, pp. 1228-1234, 1996.

[3] M. Curado, E. Monteiro, F. Kuipers, P. Van Mieghem, et.al, "Research Challenges in QoS Routing", *Computer Communication*, vol 29, Issue 5, Pages 563-581, 2006.

[4] S.Chen and K.Nahrstedt, "An Overview of Quality-of-Service Routing for the Next Generation High-Speed Network: Problems and Solutions", *IEEE Network, Special Issue on Transmission and Distribution of Digital Video*, vol. 12, No. 6, pp. 64-79, 1998.

[5] F. Kuipers, P. Van Mieghem, T. Korkmaz and M. Krunz, "An Overview of Constraint-Based Path Selection Algorithms for QoS Routing", *IEEE Communications Magazine*, Vol.40, No.12, 2002.

[6] Monika Jena, Julie D. Abraham, "QoS Provisioning issues in Wireless Multimedia Sensor Networks", *IJITKM*, vol. 3, No. 1, pp. 79-82, , 2010.

[7] D. Ghosh, V. Sarangan, R. Acharya, "Quality-of-Service Routing in IP Networks", *IEEE Transactions on Multimedia*, vol. 3, issue 2, pp. 200–208, 2001.

[8] E.Crawley et al, *A Framework for QoS routing in the Internet*, Internet-draft., 1996.

[9] M.R. Garey and D.S. Johnson, *Computers and Intractability: A Guide to the Theory of NP-completeness*, Freeman, San Francisco, 1979.

[10] S. Chen, K. Nahrstedt, "On Finding Multi-Constrained Path", *IEEE International Conference on Communications*, Vol 2, pp 874-879, 1998.

[11] H.De.Neve and P.Van Mieghem, "TAMCRA: A Tunable Accuracy Multiple Constraints Routing Algorithm", *Computer Communication*, vol. 23, pp. 667-679, 2000.

[12] P. Mieghem and F. A. Kuipers, "Concepts of Exact Quality of Service Algorithms", *IEEE/ACM Transaction on Networking*, 12(5):851–864, 2004.

[13] Korkmaz and Krunz, "Multi-constrained Optimal Path Selection", *20th Annual Joint Conference of the IEEE Computer and Communication Societies* vol. 2, pp. 834-843, 2001.

[14] G.Liu, K.G. Ramakrishnan, "A* Prune: An Algorithm for Finding K Shortest Paths subject to Multiple Constraints", *Proc. INFOCOM 2001*, Anchorage, AK, pp. 743-49, 2001.

[15] J.M. Jaffe, "Algorithms for finding. paths with multiple constraints", *Networks*, vol. 14, pp. 95- 116, 1984.

[16] Xin Yuan, "Heuristics Algorithms for Multiconstrained Quality-of-Service Routing", *IEEE/ ACM Transactions on Networking*, vol. 10, issue 2, pp. 244-256, 2002.

[17] X. Yuan, "On the Extended Bellman–Ford Algorithm to Solve Two–Constrained Quality of Service Routing Problems", *Eighth International Conference on Computer Communications and Networks (IC3N'99)*, Boston, Massachusetts, 1999.

[18] P.Khadivi, S.Samavi, T.D.Todd, H.Saidi, "Multi-constraint QoS routing using a new single mixed metric", *IEEE International Conference on Communications*, Vol 4, pp 2042-2046, 2004.

[19] Guoling Xue, Arunahba Sen, W.Zhang, J.Tang, K. Thulasiraman, "Finding a Path Subject to Many Additive QoS Constraints", *IEEE/ ACM Transactions on Networking*, Vol 15, No. 1, 2007.