Exploring Issues for QoS Based Routing Algorithms

Dr. Shuchita Upadhyaya[1]
[1] Department Of Computer Science And Applications, Kurukshetra University ,Kurukshetra

Gaytri Dhingra[2]
[2]GVM Institute Of Technology And Management, M.D. University , Sonipat

Abstract— The Internet is growing at an astonishing rate, nearly doubling its enormous size every year. There is an increasing demand for using real time multimedia applications over the Internet. One of the challenging issues in exchanging multimedia information over a network is how to determine a feasible path that satisfies all the requirements of multimedia applications. Thus there is a need for routing mechanism which are able to satisfy requirement of both real time traffic and efficient management of network resources . Quality of service routing is one of these components . QoS(Quality of service) routing provides guarantee of service to the receiver. The main problem to be solved by QoS routing algorithm is multi constrained path problem. In general, The multi constrained path problem is NP-complete that cannot be exactly solved in polynomial time. So various types of heuristic and approximate algorithms have been presented in literature to solve this problem .This paper discusses main approaches used to reduce QoS routing algorithms complexity and to improve overall network performance.

Keywords: Quality Of Service Routing, Heuristic, Approximate, Exact.

I. INTRODUCTION

Quality of Service (QoS) routing has as main objective the selection of paths that satisfy the requirement of traffic in the network while contributing to improve network resource utilization. The QoS requirements are specified in terms of certain constraints e.g desired bandwidth, delay, variation in delay experienced by receiver(jitter),packet loss that can be tolerated, no of hops, cost of links etc.

QoS Constraints are represented in the form of metrics. One metric for each constraint is to be specified like bandwidth metric, jitter(variation in delay) metric, delay metric, no of hops metric, packet loss ratio etc. for one node to all other nodes in the network. Metric for a complete path with respect to each parameter is determined by the composition rules of metrics. The three basic rules are[21].-

i) Additive Metric: The value of that constraint for a path is the addition of all links constituting path. For Example- delay, hop count, cost, jitter.

It can be represented as

$$D(p_i) = \sum_{e \varepsilon p_i} (d(e))$$

It means delay of path is sum of all its edges.

ii) Multiplicative Metric: Using this metric, The value for the complete path is multiplication of all its edges . Examples are – reliability(1-lossratio) and error free Transmission (probability)

This can be represented as

$$R(p_i) = \prod_{e \varepsilon p_i} (r(e))$$

The reliability of the path is multiplication of all its edges. Multiplicative metric can be converted into additive by taking logarithm.

iii) Concave Metric: In this metric, either we can take min value or max value among all the edges for a path. For Example- Bandwidth

$$B(p)=\min/\max (b(e))$$

For a complete path, the constraints may be required either as a constrained form or in a optimization form. In constrained form, some condition is put on constraint value e.g. Choose that path only which has delay less than or equal to 50 ms. The path obeying the condition is called feasible. On the other hand optimization refers to path having minimum or maximum value for a constraint e.g. Choose the path that has minimum delay among all the paths. This path is called optimal path [1].

Based on these forms QoS routing is broadly classified into two categories .MCP Routing (Multiple constrained path) and MCOP Routing (Multiple constrained optimal path).Where In MCP ,the target is to find the feasible path satisfying multiple constraints, where as MCOP is a special case of MCP problem in which feasible path is found according to one of the constraints. Then from those optimal path is computed according to other constraint .Restricted Shortest Path (RSP) is a type of MCOP problem. Among the entire MCP problems RSP has received most attention.

A widely studied case of Restricted Shortest Path problem group is DCLC (Delay Constrained least cost).

In this paper, we discuss various techniques to solve the QoS routing problem and put a light on various factors that can make the solutions better. We have covered only unicast algorithms.

The layout of paper is as follows: section II discusses the techniques to solve NP-complete problem, exact algorithms are discussed in section III, and section IV provides summary and conclusion.

II. TECHNIQUES

In general, MCP and MCOP both are NP-complete in nature that can not be exactly solved in polynomial time. Here the idea is to find the solution that will complete in polynomial time .Hence the objective is to find the technique to reduce the computational complexity. To implement these technique, well known shortest path algorithms e.g. Dijkstra, Bellman-Ford algorithms have been used by most of the researchers. Since these algorithms only deal with single weight so these algorithms have been extended or modified to consider multiple constraints for solving QoS routing problem. In general, the techniques to solve NP-complete problem are Parameterization, Restriction, Heuristic, Approximation and Randomization.

A Parameterization

When certain parameters of input are fixed, then the solution can be found. The problem of path selection subject to multiple additive or multiplicative constraints is known to be NP-complete. But if one of constraints is concave and other is additive / multiplicative then problem can be solved in polynomial time. Concave metric is usually dealt with a preprocessing step called topology filtering where all links that do not satisfy constraints are pruned [20].

In general, QoS Constraints are independent and a well known result is that finding a path with (independent) delay & delay-jitter is NP-complete. But in practice these bounds are not independent but the functions of reserved bandwidth. So the problem of finding a path satisfying bandwidth, delay, delay-jitter and buffer-space constraints can be simplified by taking this relationship into consideration[14].

B. Restriction

The problem can be solved in polynomial time, if the structure of input are restricted .If the QOS metrics are real number or unbounded integer then their complexity is NP-Complete, If the metrics take bounded integer then their complexity is polynomial. Chen's algorithm [2] reduced the problem into simpler by converting real weight to integer weight and then applied extended Bellman-Ford and Dijkstra algorithms.

In literature, it has also been suggested that there may exist classes of graphs in which QOS routing is not NP-complete. Also when all the nodes have degree 2 , it can be solved in polynomial time ,irrespective of link weights[19].

C. Heuristic

A heuristic algorithm does not try to find the perfect solution but an approximate solution where the time or resources are limited. It is free from providing good run times and with provably good or optimal solution quality. Many Researchers have proposed heuristic algorithms which reduces the computational time but do not provide guarantee to find a feasible path even if exist .To find a heuristic, one major method used in literature is metric composition. Metric composition may be- Linear, Non-linear, lagrange relaxation composition.

The combination of additive metrics using Linear composition has been proposed in [3][8].The link weights are computed through linear energy function, where each energy function is weighted sum of the link metrics. This approach prevents provisioning the guarantee of considering all the constraints.

The second approach is lagrange relaxation technique. The basic idea is to first combine the two weights in terms of a parameter α to form an aggregate weight $w=w1+ \alpha w2$, then Dijkstra or Bellman-Ford algorithm is used to find the shortest path [10] [11].This approach overcomes the problem of linear composition. These algorithms are having very low time complexity.

The weights can be combined to form a single weight by using non-linear composition [5][13] . This approach can be applied to the metrics that are not correlated. Non –linear length function give higher success rate to find the feasible path than linear function. Korkmaz [13] proposed an algorithm H_MCOP that runs dijkstra algorithm twice: one in reverse direction with a linear cost function and second in forward direction with non linear cost function.

D. Approximation

Approximation algorithms are those heuristic that additionally provide some bounds on error. Ideally, the approximation is optimal up to a small constant factor. An approximation algorithm always returns a solution for a given input whose cost is within some additive or multiplicative factor of the cost of the optimal solution.

The approximate algorithm for MCP problem presented in literature delivers solution with in arbitrarily specified precisionε. An algorithm is said to be ε-optimal if it returns a path whose cost is at most $(1+\varepsilon)$ times the cost of optimal path where $\varepsilon>0$. The complexity of ε-approximate solutions depends on the actual value of link weights ,size of network and $1/ \varepsilon$.These solutions are defined by first finding the lower and upper bound values. For that scaling, rounding and then approximate testing is performed [7][16].

E. Randomization

The concept behind randomization is to make random decision during the execution of algorithm. The concept of randomness is used to avoid unforeseen traps when searching for a feasible path. These algorithms are simple and easy to implement but fail with some small probability.

In [12] firstly, the algorithm computes shortest path from every node u to destination and then Randomized BFS discovers nodes where there is a chance to go destination.

In [15] firstly, prune all the links satisfying one constraint and then make the list of candidate paths satisfying second constraint and then selects one path from computed candidate paths.

Randomized algorithm can balance network load, prevent performance degradation and improve service performance of entire network.

III. EXACT ALGORITHM

Some researches in literature have also proposed exact algorithms instead of defining approximate or heuristic algorithm. The exact algorithm of MCP problem is possible because-

- NP-complete behavior seems only to occur in specially constructed graph, which are unlikely to occur in realistic communication networks.
- There exist exact algorithms that are equally complex as heuristic and they do not induce NP-complete behavior.
- By simply restricting the no of paths explored, the complexity can be decreased at the expose of possibly loosing exactness.[17]

The exact algorithms are SAMCRA (self adaptive multiple constraints routing algorithm)[17], TAMCRA (Tunable accuracy multiple constraints routing algorithm) [4].
TAMCRA and SAMCRA are based on three fundamental concepts.

A. Non- linear path length measure:

The non linear length functions in more efficient than linear length function, as the curved lines match the constraints boundaries much better than straight lines.

B. K-Shortest Path Approach:

K-shortest path approaches returns not only shortest path to given destination but also second shortest, third shortest.....Kth shortest path.

C. Principal of Non Dominance:

A path P2 is said to be dominated by a path P1, if at least one of the weight of path p1 is less than the path p2.Exact algorithms only considers non-dominated paths .

A fourth concept has been added in SAMCRA i.e. Look ahead concept. Look ahead concept proposes to compute the shortest path tree rooted at destination. So the lowest value from destination to a node is stored in the queue of that node n. By using this information the set of possible path can further be limited.

IV. SUMMARY AND CONCLUSION

QoS routing is key network function for the transmission and distribution of multimedia applications across future high speed networks. The main objective of QoS routing is the selection of paths that satisfy the requirements of traffic in the networks. The main problem to be solved by QoS routing algorithm is multi constrained path problem. QoS based routing subject to multiple additive constraints is NP-complete problem that cannot be exactly solved in polynomial time. So mostly heuristics algorithm were proposed for NP-complete problem which close to optimal results and reducing the complexity of path computation problem. Heuristic either imposes relationships among the link metrics to reduce the complexity of the problem which may limit the general applicability of the heuristic or too costly in terms of execution time to be applicable to large networks. The best algorithm is H_MCOP algorithm. H_MCOP can outperform almost all known heuristic algorithms in terms of success ratio of finding feasible solution. The success ratio of H_MCOP is actually very close to that of an exact algorithm.

Approximate Algorithms are very efficient but having very high time complexities. Unfortunately, in practical cases, the running time of these methods for sufficiently small ε will be worse which makes these results rather theoretical.

Randomized algorithms are useful when networks are having inaccurate or dynamic state. Randomized algorithm can balance network load, prevent performance degradation and improve service performance of entire network but some times fail with small probability.

This MCP selection problem is not NP-complete in strong sense. The NP-completeness of MCP problem depends on underlying topology, link weights, value of constraints. So exact algorithm have also been proposed by researchers. Thus the future researches should focus to differentiate the cases for which the complexity is polynomial so that exact algorithms may be refined further.

REFERENCES

[1] S. Chen , K. Nahrstedt, “An overview of quality-of-service routing for the next generation high-speed networks: Problems and solutions”, IEEE Network, vol. 12, no. 6, pp. 64–79, Nov-Dec 1998.
[2] S. Chen and K. Nahrstedt, “On finding multi-constrained paths”, in Proceedings of the ICC ’98 Conference. IEEE, 1998, pp. 874 –879.
[3] Y.Cui,J.Wu ,”Pre computation for multi constrained QoS routing in high speed networks”, Proceedings in IEEE infocom
.[4] H. De Neve and P. Van Mieghem, “TAMCRA: A Tunable Accuracy Multiple Constraints Routing Algorithm”, Com-puter Communications, 2000, vol. 23, pp. 667-679.
[5] L. Guo and I.Matta, “Search space reduction in QoS routing”, in Proceedings of the 19th IEEE International Conference on Distributed ComputingSystems. IEEE, May 1999, pp. 142 – 149.
[6] R. Guerin and A. Orda, “QoS routing in networks with inaccurate information: Theory and algorithms”, IEEE/ACM Transactions on Networking, vol. 7, no. 3, pp. 350 –364, June 1999.
[7] R. Hassin, “Approximation schemes for the restricted shortest path problem”, Mathematics of Operations Research, vol. 17, no. 1, pp. 36–42,1992.
[8] J. M. Jaffe, “Algorithms for finding paths with multiple constraints”, Networks, vol. 14, pp. 95–116, 1984.
[9] W..Jianxin,W.Weiping,c.jianer ,”A Randomized Qos Routing algorithm on networks with inaccurate Link state information “ Communication Technology proceedings 2000.
[10] A. Juttner, B. Szviatovszki, I. Mecs, and Z. Rajko, “Lagrange relaxation based method for the QoS routing problem,” in Proc. IEEE INFOCOM, vol. 2, Apr. 2001, pp. 859–868.
[11] T. Korkmaz, M. Krunz, and S. Tragoudas, “An efficient algorithm for finding a path subject to two additive constraints”, in Proceedings of the ACM SIGMETRICS ’00 Conference, June 2000, vol. 1, pp. 318–327.

[12] T. Korkmaz and M. Krunz, "A randomized algorithm for finding a path subject to multiple QoS constraints", in Proceedings of the IEEE GLOBECOM '99 Conference - Symposium on Global Internet: Application andTechnology, Dec. 1999, vol. 3, pp. 1694 – 1698.
[13] T. Korkmaz and M. Krunz, "Multi-Constrained Optimal Path Selection", IEEE INFOCOM 2001.
[14] Q.Ma and P.Steenkiste, "Quality of service routing with performance guarantees". Proc. Of 4th Int. IFIP workshop on QOS May 1997.
[15] H-k.Park, y.Heo , "A Fast randomized Qos routing algorithm "
[16] S. Vutukury and J. J. Garcia-Luna-Aceves,"A simple approximation to minimum-delay routing", in Proc. ACM SIGCOMM'99, Boston, MA, Aug. 1999, pp. 227–238.
[17] P.Van.Miegham and F.A.Kupier, "Concepts of Exact QoS routing algorithms",IEEE/ACM Transaction on networking , vol.12,no.5 ,oct. 2004.
[18] R. Widyono, "The design and evaluation of routing algorithms for real time channels", Tech. Rep. TR-94-024, University of California at Berkeley & International Computer Science Institute, June 1994.
[19] Z. Wang, "On the complexity of quality of service routing, " Information Processing Letters, vol. 69, no. 3, pp. 111–114, 1999.
[20] Z. Wang and J. Crowcroft, "Quality-of-Service Routing for Supporting Multimedia Applications", IEEE JSAC, vol. 14, no. 7, pp. 1228-1234, September, 1996.
[21] X. Xiao and L. M. Ni," Internet QoS: A big picture", IEEE Network, vol.13, no. 2, pp. 8–18, March-April 1999.

AUTHORS PROFILE

Dr. Shuchita Upadhyaya
Is an associate professor in the Department of Computer Science and applications in Kurukshetra University, India. She is Ph.D. in Computer Science and application. Her area Of specialization is Computer Network. She has published more than 35 research papers in various national and international Journals. She is having 22 years of teaching and research experience.

Gaytri Dhingra
Is a Lecturer in GVM Institute of Technology and Management , Sonipat, India.She has done MCA , M.Phil. Now she is pursuing Ph.D. from the department of Computer Science and applications, Kurukshetra University. She is having more than 8 years of teaching experience
.