CHAPTER 8

CONCLUSION AND FUTURE WORK
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8.1 CONCLUSION

The present thesis entitled ‘QoS Support for One To One Routing: A Multi-Path Approach’ is a significant effort to design a routing strategy to fulfil the needs of current Internet.

In order to fulfil the desires of current scenario of Internet and to support the real time applications, we must have QoS routing mechanism in the present routing protocols. Thus the intent of the present study was to attain QoS in routing algorithms.

The basic problem of QoS routing is to find a path or paths satisfying multiple constraints. It is focused on identifying the path that will consider multiple parameters like bandwidth, delay, jitter, cost, hop count etc. instead of one.

Various source routing and distributed routing algorithms satisfying QoS were surveyed and presented in chapter-3 and chapter-6. One source routing algorithm proposed by Wang and Crowcroft in [22] was identified and described in chapter-5. This algorithm was a single path determination algorithm. An extension to this algorithm was proposed in the same chapter to identify multiple paths. The objective for multipath extension of this algorithm was to have a uniform utilization of the resources thus obtaining better QoS.

However, it was also identified that distributed QoS routing algorithms dominate source routing QoS algorithms in terms of practicality of implementation and utilization of state information.

Thus a distributed QoS routing algorithm (DRA) proposed by Chen and Nahrstedt[93] was elaborated in chapter-6 of the thesis and a multipath extension to this algorithm was proposed in chapter-7.

Hence a DQM routing algorithm was proposed that identifies multiple paths between a source and destination pair and then distributes traffic proportionally on these paths to attain QoS.
The QoS parameters that have been considered were residual bandwidth and delay. These values have been extracted from load and capacity of the links. This fully distributed approach uses only local information, stored at each node and is independent of the global information to find the paths. Every node is required to maintain the delay and residual bandwidth of its all outgoing links.

Only those multiple paths have been obtained at the destination which satisfy the given bandwidth and delay requirement. At destination these paths have again been processed to identify mutually exclusive disjoint paths. These two QoS parameters (bandwidth and delay) have been converted into one QoS value using fuzzy logic.

Based on this value, the list of calculated paths has been filtered to disjoint paths.

The objective of finding link-disjoint paths is to target an efficient load balancing scheme on the paths, for improving the performance of the network and attaining QoS. The load balancing scheme is again applying fuzzy logic on the selected disjoint paths to distribute the load efficiently.

To validate the proposed approach, the code has been developed using MATLAB and anticipated results have been obtained that verify the correctness of the proposed strategy.

The thesis has been formulated as follows-

**Chapter-1** covered the background concepts related to the present research work. A layout of whole thesis is also specified in it.

**Chapter-2** identified the need of QoS over the traditional routing paradigm ‘best effort service’ of the network.

An investigation of all possible QoS routing problem and its various promising solutions has been made in **chapter-3**. We have categorized the QoS routing algorithms presented in literature in the form of its solution category. The characterization table has been presented depicting problem solving strategy, metrics used, complexity and the basic algorithm. The
solutions related to artificial intelligence approaches – genetic algorithm and fuzzy logic to solve QoS routing problem have also been explored.

Multipath routing employs multiple parallel paths between a source and destination instead of a single best path for routing. In contrast to single path approach, multipath routing can better utilize networks resources and balance network traffic. As the objective of the present thesis is implementation of multi-path strategy to attain QoS, so a general discussion about multipath routing was done in chapter-4 followed by related work in this domain.

The possibilities of mingling multi-path and QoS was presented in chapter-5. The domains that have been covered under merging QoS with multi-path in literature are: Dijkstra algorithm, Bell-man ford algorithm, MPLS & Resource reservation. A multi-path source routing QoS algorithm was proposed in chapter-5 which was an extension of the algorithm proposed in [22]. The algorithm was based on the constraints – bandwidth and delay as they seem to be the most prominent QoS parameters. The presented multi-path algorithm is built around Dijkstra algorithm.

There has been a number of previous works and investigations that have explored related aspects of distributed routing. A characteristic evaluation of these workings was presented in chapter-6. Chapter-6 also explored a distributed routing algorithm (DRA) proposed in [22] which establish a single path between a source & destination pair that may satisfy one or more QoS constraints.

In chapter-7, the fully distributed QoS multi-path searching algorithm DQM was proposed which was an extension to DRA algorithm described in chapter-6. The proposed algorithm DQM (Distributed QoS Multiple path Searching algorithm) searches multiple paths satisfying QoS requirement, reaching from one source to one destination within a network, without loops. Firstly the algorithm obtains all the path that satisfy the QoS criteria from a source to a destination in a fully distributed fashion using only local information of resources. Here, the QoS criteria include – residual bandwidth and delay. Then at destination, these paths are refined to the mutually exclusive disjoint paths by applying fuzzy logic. The fuzzy logic has been applied to the two QoS parameters of obtained paths to get one QoS value in order to
incorporate the magnitude of both of the parameters. Those disjoint paths are selected whose QoS value is stronger than others. Using the same QoS value a load distribution scheme has also been proposed for disjoint paths. Further to verify the proposed strategy, the algorithm was implemented in MATLAB and two example networks were considered with separate runs on different input values. The results derived were found to be as per anticipated. One such case taken was verified manually for one example network and was illustrated in the chapter.

We conclude the key contributions in this Thesis as follows:-
11. Design of Multi-path QoS source routing algorithm (M-Bandwidth-Delay constrained algorithm) and its implementation in MATLAB.
14. Design of Distributed QoS Multi-path algorithm (DQM) based on local information and its implementation in MATLAB.
15. A scheme that finds disjoint paths from all available paths using fuzzy logic.

8.2 FUTURE WORK

This thesis formulated a comprehensive distributed multiple disjoint QoS paths computational strategy along with the traffic distribution scheme on the multiple paths. There are several research directions which require further investigations in the future. Some of them are pointed here:

8.2.1 Impact on organization of the network

In the proposed approach, we assumed that the topology information and current network state are known. Assumption has also been made about the domain of the network where the algorithm operates. As a result of this assumption, all the links from the source may lead to the destination. We plan to design more explorative mechanism to find the way out for this assumption. The solution remains for future work.
Another direction worthy of investigation is exploring the impact of the proposed strategy on the larger network since our study showed and illustrated network that is confined to small number of nodes.

8.2.2 Provision in Future Internet Protocol - IPv6.

One future direction of the present research work is in the context of future Internet protocol –IPv6 that has incorporated Quality of Service.

IPv6 is an enhanced version of IPv4 protocol specification. The reasons for transition from IPV6 to IPv4 are - integrate QoS, security considerations, mobility issues and increased address usage in the network domain-RFC2460[27].

As discussed, the present research work has laid a foundation for the distributed multipath QoS strategy and traffic distribution scheme. More investigations are required to study as to how the proposed approach results can be framed into message format of IPv6 [1] and how the traffic distribution among the multiple paths can be carried out in a flow [13][33].
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