Mingling Multipath Routing With Quality Of Service

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Abstract

The QoS issue in the Internet have become essential for the successful transmission of multimedia applications . The basic problem of QoS routing is to find a path satisfying multiple constraints. It is concerned with identifying the path that will consider multiple parameters like bandwidth, delay, cost, hopcount etc. instead of one .To provide user- or application-level Quality of Service (QoS) guarantee Multipath routing strategy can be used for the transmission of QoS sensitive traffic over the network. Multipath routing means using multiple paths instead of using single path to forward the traffic.If multiple paths are being used for the transmission of the traffic then the traffic will be redirected to the back up path if active path fails. In this way robustness can be achieved. On the other hand load balancing for communication network to avoid network congestion & optimize network throughput also requires multi paths to distribute flows . Robustness & load balancing are aspects of QoS routing . So multipath can be proved very valuable for Quality of service. This paper investigates the approaches of mingling Multipath & Quality of service. The approaches considered are based on Dijkstra algorithm, Bellman ford algorithm, Resource reservation & MPLS.

Keywords: *Multipath routing, Multiple paths, Single shortest path, Quality of Service.*

1. Introduction

In today's era of Internet ,the demand of real time multimedia applications have been increased .To fulfill this requirement, Quality of Service(QoS) factors have become necessary to be present in the network. For example, transmission of video over a computer network should be without undesirable delays and jitter and a medical image or a robot control packet may be required to be transmitted over a network with the minimum end-to-end delay. The present Internet routing mechanisms (based on the best-effort paradigm) are unlikely to provide such end to- end performance guarantees required in these applications. Here is a need of the mechanism which will consider these factors(delay ,jitter, bandwidth etc.) for the transmission. One of the components of that mechanism is QoS routing. Multipath approach can be merged into QoS Routing to catch its maximum advantage as in some situation a single path is not able to fulfill all the QoS requirements.

The benefits of provisioning multiple QoS paths are reliable QoS support and uniformly balanced network load. In addition to ground network, it is also important to provide QoS support in the presence of network failures. The approach is to take advantage of multiple alternate paths in the face of network failures. The scheme shows major improvement of fault tolerance .

In this paper, we have discussed four approaches of multipath algorithms based on QoS criteria. The approaches are based on Dijkstra , Bellman Ford ,Resource reservation & MPLS. The layout of the paper is as follows: Section 2 describes Multipath routing. Section 3 describes Quality of service. Section 4 discusses approaches of combining QoS with Multipath. Section 5 concludes the paper.

2. Multipath Routing

Unlike traditional routing schemes that route all traffic along a single path ,multipath routing strategy uses multiple paths. Single path routing may lead to unbalanced traffic distribution and congestion. It can not achieve the proper utilization of resources. In contrast to single path approach, multipath routing can better utilize network bandwidth and balance network traffic. There are two strategies for allocating traffic over available path .First is to distribute traffic among multiple paths instead of routing all the traffic along a single path. Second is to forward

traffic using only the path with the best metric and keep other discovered paths as backups that can be used in case of congestion or blocking. Thus multipath routing is an alternative to single shortest path routing to distribute load and lighten congestion in the network .

2.1Benefits of Multi path Routing

Multipath routing would offer many benefits as following-

Fault Tolerance : When multiple path are available ,traffic can move to an alternate path on the occurrence of congestion. This will lead to less delay and packet loss.

Increased Bandwidth: If multiple path exists ,an application can access more bandwidth by using multiple path simultaneously. As multipath routing has the potential to aggregate bandwidth allowing a network to support data transmission rates higher than what is possible with any one path.

Improved Reliability: If multiple path exists ,traffic can switch quickly to an alternate path when a link or router fails.

Load Balancing: By using multiple path simultaneously ,network resources can be more used by distribution of traffic among several paths . This is reverse to single shortest path routing scheme where one path is completely busy and others are under loaded . So with multipath routing load balancing can be achieved.

3 . Quality Of Service

The fundamental problem of routing in a network that provides QoS guarantee is to find a path between specified source and destination node pair that simultaneously satisfies multiple QoS Constraints such as cost, delay & reliability.

Quality of Service(QoS) puts some restrictions in the form of certain constraints on the path. These constraints may be 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.

By combining a set of QoS metrics in a single metric, it is possible to use existing polynomial-time path computation algorithms, such as Bellman–Ford or Dijkstra. The three basic rules are-

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
$D(pi) = \sum_{e \varepsilon pi} (d(e))$
It means delay of path is sum of all its edges.

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)
It can be represented as
$R(pi) = \prod_{e \varepsilon pi} (r(e))$
The reliability of the path is multiplication of all its edges. Multiplicative metric can be converted into additive by taking logarithm.

Concave Metric: In this metric, either we can take min value or max value among all the edges for a path. For Example- Bandwidth
It can be represented as-
$B(p) = min/max\ (b(e))$

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 60 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 .The further QoS issues have been discussed in[4].

4. Multipath Approach And Quality Of Service

The two main concerns to implement multipath routing scheme are the calculation of multiple paths and traffic distribution among multiple paths. To determine the multiple paths various k-shortest path algorithms have

been used. The k-shortest means determining not only the shortest ,but also the second, the third …….the kth shortest path (for given integer k>1).Regarding this, two different types of problems are usually considered : the unconstrained and the constrained k-shortest path problem. While in the former no restriction is considered in the definition of path. In the constrained k shortest path problem all the paths have to satisfy some condition . e.g. to be loop less and to be disjoint. A path from s to t is a loop less path, if all its nodes are different . A path is disjoint if it is link disjoint or node disjoint. Paths between a given pair of source and destination nodes in a network are called link disjoint if they have no common (i.e. overlapping) links and A pair of paths is considered node-disjoint if, besides the source and destination nodes, they have no common nodes. Node disjoint paths provide more reliability then the link disjoint paths.

In general a link-disjoint paths algorithm can be extended to a node-disjoint algorithm with the concept of node splitting, i.e. replacing one node with two nodes that are linked together via a link with zero-valued weights[15].

To find the k-shortest path, shortest path algorithms Dijkstra & Bellman-ford-Moore algorithms can be used in the generalization form [5]. The K-shortest paths are limited to defining alternate paths without consideration of QoS constraint.

So here is a need of enhancing the above mentioned algorithms to consider QoS parameters.

The main Multi path QoS approaches to provide multiple QoS paths are as follows-

4.1 Using BellMan ford algorithm-

In considering with multiple constraints, it has been noticed that the BF algorithm can potentially solve a two metric routing problem [1].It is a property of the BF algorithm that, at its h-th iteration, it identifies the optimal path between the source and each destination, among paths of at most h hops .It searches for a minimum path cost (or maximal bandwidth) in ascending order of no of hops .The cost of a path is a function of its available bandwidth i.e. the smallest available bandwidth on all links of the path, and finding a minimum cost path amounts to finding a maximum bandwidth path. However, because the BF algorithm progresses by increasing hop count, it inherently provides for the hop count of a path as a second optimization criteria.

So the result of the algorithm comes with the path that is the one with maximal available bandwidth among all the feasible paths with the minimum no of hops.

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Thus Bellman Ford is very powerful in solving most multiple constrained routing problem if the minimum hop is the main objective function. BF algorithm is also capable of solving delay ,delay jitter, loss & bandwidth constrained routing problem[2].This Bellman ford algorithm is single QoS path computation algorithm. This Single path computation algorithm has been extended to perform multiple QoS computations [3].Each of the QoS metric is manipulated in the same way as in single path algorithm by increasing hop count. The algorithm has been designed in order to improve fault tolerance & load balancing . The multiple path computation algorithm searches for maximally disjoint paths(minimally overlapped paths) so that impact of link failure is reduced & links are more evenly utilized by spreading the network load over multiple paths .In order to search for multiple alternate paths to provide fault tolerance and load balancing yet satisfying QoS constraints ,it has defined alternate paths with the following conditions –

-Satisfying given QoS constraints
-Maximally disjoint from already computed paths
-Minimizing hopcount.

The algorithm searches for multiple maximally disjoint paths (i.e with the least overlap with each other) such that the failure of a link in any of the paths will still leave (with high probability) one or more of the other paths operational

Based on this algorithm [13] has presented the multiple QoS path algorithm with some enhancements for maximally disjoint paths i.e PDMA (partially disjoint multiple QoS path algorithm with multiple iteration)and also presented fully disjoint multiple QoS path algorithm (FDMA).

4.2 Using Dijkstra Algorithm

Dijkstra algorithm can generate a minimum hop path that can accommodate the required bandwidth and also has maximum bandwidth. But it requires some modification in order to be able to calculate the minimum hop path computation as it does not search for a minimum path cost in ascending order of no of hops as Bellman-Ford does. The modification required for supporting them is straightforward. Firstly on a graph from which all edges, whose available bandwidth is less than that requested by the flow triggering the computation, have been removed. This can be performed either through a pre-processing step, or while running the algorithm by checking the available

bandwidth value for any edge that is being considered. Another modification to a standard Dijkstra based minimum hop count path computation, is that the list of equal cost next (previous) hops which is maintained as the algorithm proceeds, needs to be sorted according to available bandwidth. This is to allow selection of the minimum hop path with maximum available bandwidth. Alternatively, the algorithm could also be modified to, only keep among equal hop count paths the one with maximum available bandwidth. This would essentially amount to considering a cost that is function of both hop count and available bandwidth[1].

Bellman ford algorithm used in computing k shortest paths ignores equal hop multiple count but equal hop multiple paths impairs the performance of routing protocol if the link state information is inaccurate

[6][9] have presented a bandwidth constrained multipath routing algorithm based on Dijkstra . Besides specifying the optimality criteria that define the best paths , it has also described the construction & selection strategies for multiple paths. The path construction is performed each time link state information becomes available , while the path selection is performed for each connection request .

This algorithm is based on k best one to one non loop less paths. It has modified the algorithm to find k one to all loop less paths instead of one to one non loop less paths. The algorithm generates k paths that are either shortest in terms of number of hops(hop based) or widest in terms of bottleneck bandwidth(bandwidth based).It has considered 2 metrics bandwidth & hop count. It has developed 2 categories of k-shortest algorithms-hop based & bandwidth based & five selection algorithms. It has concluded that hop based algorithm outperforms the bandwidth based one. It has also presented five path selection schemes as Best-K-Widest(BKW),Random-K-Widest(RKW),Shortest-K-widest(SKW),Best-K-Shortest(BKS),Widest-K-Shortest(WKS).

4.3 Using Resource Reservation

In order to use the network resources efficiently, bandwidth reservations are made to ensure high probability of data arrival to its destinations.

Bandwidth reservation means If certain amount of bandwidth is reserved for a program and then when the program accesses the network, up to that much bandwidth is guaranteed to be available to the program.

By reserving bandwidth, it is possible to provide reasonable levels of QoS. The idea is to identify traffic flows, which are streams of packets (voice, video, file transfers, and so on) going to the same destination IP address and port number. Reservations are negotiated with each network device along a route to a destination. If each device has resources to support the flow, a reserved path is set up.

[16] has presented a QoS routing algorithm in which the QoS constraint is specified by bandwidth guarantee. Therefore, the goal of QoS routing algorithm is to find the best path with sufficient bandwidth. Here the best path as the path with least cost. To find the least cost path, the algorithm can run either Dijkstra or Bellman-Ford shortest path algorithm.

[11] has presented a family of algorithms that route and reserve resources along parallel sub routes i.e. fast algorithm ,slow algorithm super fast algorithms.

[12] has presented a framework in which bandwidth can be reserved on the communications links, and, once reserved, is guaranteed for the required time period. The algorithms finds multi paths, consisting of possibly overlapping paths, based on the available bandwidths on various links of the network. It considers delay as a second consideration criteria. It has presented the algorithms based on two problems. The first problem requires that a message of finite length be transmitted from s to d within r units of time. The second problem requires that a sequential message of r units be transmitted at a rate of n such that maximum time difference between two units received out of order is no more than q.

4.4 Algorithms for MPLS

Multi-Protocol Label Switching (MPLS) networks do routing based on connections . QoS routing and traffic engineering goals are normally achieved by finding optimal or near-optimal explicit routing MPLS algorithms .The MPLS can provide fast packet forwarding .It is a new internet technology that is rapidly emerging as a core technology for next generation networks . MPLS uses a technique known as label switching to forward the data through the network. Multi-protocol label switching (MPLS) has many attractive features. First of all, the MPLS can create easily an explicit-route label switched path as needed and it can easily map traffic trunks that consist of traffic flows with similar characteristics of traffic requirements.

[10]Proposed two multipath constrained based routing algorithms using MPLS. The algorithms proposed in this paper find multiple LSPs between ingress and an egress LSR satisfying a given bandwidth constraint. When there is

no single path through the network satisfying a whole bandwidth constraint, the suggested algorithms divide the bandwidth constraint into two or more sub-constraints and find a constrained path for each sub-constraint. First, the algorithms calculate the least-cost path between source and destination, and allocate the path bandwidth (minimum bandwidth of all links along the path) to that path. Next, it calculate the next shortest path through the network after removing links having no available bandwidth and allocate the path bandwidth to that path. The process is continued until it can allocate the whole bandwidth constraint to the successive shortest paths. If a single path satisfies the whole bandwidth constraint, there is no need to balance the traffic load. However, if there are multiple paths the traffic load should be partitioned optimally for mapping to multiple paths.

[14] proposed a new constraint based routing algorithm for MPLS networks. It has used bandwidth & delay constraint. In this algorithm the best path is selected based on Best –fit strategy. In step1, the algorithm eliminates all the links with bandwidth value less than the bandwidth constraint. In step2 ,it finds the path with delay value less than (or equal to) delay constraint value. In step3 , if the path with minimum hop count is used, the minimum of network resources are consumed. In step 4, the load is distributed & balanced. The best fit load balancing strategy selects path from all feasible paths which has the nearest bandwidth value to the bandwidth constraint value.

[17] proposed a localized proportional routing approach where each source node collects information about the traffic originating from itself and computes proportions based solely on this local information. Global schemes have to gather system wide traffic metrics and thus slower to react to changes. Localized schemes , on the other hand use only local information and thus can adapt to change faster. It has assumed that flow from source to destination arrive randomly with a Poisson distribution and their holding times are exponentially distributed. The algorithm has used the strategy equalization of blocking probabilities (ebp) of candidates paths. This ebp strategy requires only path level information.: the amount of offered load and the corresponding blocking probability. The objective of ebp strategy is to find a set of proportions such that flow blocking probabilities on all the candidate paths are equalized. The strategy can be implemented using the following procedure to compute new proportions in each iteration .First, the current average blocking probability is computed. Then the proportion of load onto a path is decreased if its current blocking probabilities higher than the average and increased if lower than the average. When we talk about path selection, the algorithm selects the candidate paths of a pair that do not share bottle neck links .In this way of path selection, the blocking probability can be reduced. To judge the goodness of paths, It has introduced the notion of width for a set of paths, which is defined as the maximum flow carriable by paths in the set. The amount of flow carriable by a link is given by its average available bandwidth. So the width of a set of paths can be computed given the average available bandwidth information about each link in the network. Based on the notion of width of a path set, the algorithm proposed a path selection procedure that adds a new candidate path only if its inclusion increases the width. It deletes an existing candidate path if its exclusion does not decrease the total width. So this proportional routing scheme yields higher throughput with lower overhead.

5. Conclusion

The multiple paths are utilized in parallel making the entire network system less prone to network failure. Multipath approach can be used as an architecture for implementing quality of service by aggregation of flows. In connection oriented networks with QoS guarantees ,they reduce blocking probabilities. By provisioning multiple QoS paths, the network system can provide backup paths when one or more paths are detected as corrupted. Besides, the spreading of network traffic over the provisioned multiple QoS paths favors even network resource utilization

There are various ways to combine QoS and Multi path approach. This combination should be further enhanced for the current need of the Internet applications .

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