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Exploring Genetic Algorithms to Solve QoS

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ABSTRACT

Today, there has been an increasing demand for real-time multimedia applications on Internet that can provide transmission of audio, video and tele-conferencing. Many of these applications have multiple quality-of-service (QoS) guarantees in terms of delay, bandwidth, transmission success ratio etc. To fulfil this demand, QoS-based network framework has been adopted. One of the key issues in the QoS framework is how to determine a feasible path that satisfies QoS requirements. In general, the problem of finding a path satisfying multiple constraints is NP-complete and finding an exact solution can be difficult. Various heuristics and approximation algorithms have been proposed in literature to solve this problem . However , the QoS path calculated by these algorithms may turn out to be invalid over the time because of dynamic nature of network conditions. Using Genetic algorithm to solve Multi constrained QoS problem, may be proved a better solution. Genetic approach makes the algorithm more robust in the case that the frequency of state information change in the network is higher than the rate of state information received at the node. In order to solve the QoS constrained routing efficiently, the scheme of routing based on a genetic algorithm (GA) has been discussed in this paper.

Keywords:- QoS, Genetic algorithm, Chromosome, Routing.

I. INTRODUCTION

There is a need to develop routing algorithm which consider more than one QoS parameter such as bandwidth, delay, cost and loss probability while finding the path to support high-speed and real-time services .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, hop count etc. instead of one.

The problem of QoS routing to find the path satisfying multiple constraints is intractable. Various heuristics and approximation algorithms have been proposed in literature to solve QoS problem .However, in implementation of multimedia network , the status information available for making routing decision changes dynamically . The heuristic and approximate routing algorithm does not provide adequate performance with imprecise state information. The effectiveness and performance of the routing algorithms can significantly be degraded by this outdated information. QoS routing is much more sensitive than non-QoS routing in terms of the accuracy of the global state. Inaccuracy can lead QoS to failure.

One of the solution may be using Genetic algorithm . The main advantage of using genetic algorithms is that the Genetic algorithm is insensitive to variations in network topologies with respect to route optimality and convergence speed. GA is a kind of parallel optimization algorithm that simulates the evolution process of a creature, and is suitable to find optimal solution in a large and complicated search space. Genetic algorithm is stochastic, not deterministic. It can automatically obtain and accumulate the knowledge about the research space, so as to control the search process adaptively, until the optimal solution is finally found [1]. GA does not need the solutions of the problem to be continuous so that it can work well for the QoS routing problem. Further, it is quite simple and robust, and very easy to be implemented . A genetic algorithm works on a population of possible solutions, while other heuristic methods use a single solution in their iterations. Thus GA is more effective and efficient than conventional heuristic and approximate algorithms in multimedia networks.

This paper explores the approach of solving QoS problem based on genetic algorithm. The layout of the paper is as follows-Section 2 gives brief description of QoS . Section 3 presents the process of genetic algorithm. Section 4 discuss the genetic algorithm for routing problem and also presents the related work of genetic algorithm in context of QoS . Section 5 concludes the paper.

II. 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 parameters.

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, number of hops, cost of links etc.

These parameters 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, number of hops metric, packet loss ratio etc. from 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 [15].-

(i) Additive Metric: The value of the constraint over the entire path is the addition of all links constituting path. For Example- delay, hop count, cost or jitter.

ii) Multiplicative Metric: Using this metric, the value for the complete path is multiplication of metric value of all its edges.

Examples are – reliability (1-lossratio) and error free Transmission (probability)

Multiplicative metric can be converted into additive by taking logarithm.

iii) Concave Metric: In this metric, either min edge value or max edge value is taken as constraint value for a path among all the edges of that path. For Example- Bandwidth

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[2][3].

III. Genetic Algorithm

Genetic Algorithm (GA) is an optimization algorithm that is based on natural selection, inspired by the theory of genetics.

It starts with an initial set of random solutions called population. Population evolve through successive iterations to obtain new and improved generation. During each iteration of the algorithm, each solution in the population are tested to see whether they give a valid solution. This testing operation is nothing but the fitness functions to achieve the objective. A new generation is formed by selection according to the fitness values. The generation undergo one or more genetic operations such as crossover and mutation. Again fitness function is applied to test its fitness. This process continues until either the solution is found or a certain termination condition is met.

The general process of GA as described by Goldberg [1] is as follows-

1**. Initialization of initial population**- The initial population is normally created randomly or based on some heuristics which is assumed to give solutions. Each individual solution in the population is called a chromosome. A chromosome is encoded form of solution that consists of several genes.

2. **Evaluation of population**-Evaluate the fitness of each chromosome on the population. The fitness is usually the value of the objective function in the optimization problem being solved.

3. **Reproduction and Selection** - In this process, chromosomes are selected to be put into new generation. A selection scheme is utilized to choose the chromosomes. The selection scheme could be proportionate selection, ranking selection, tournament selection etc, According to their fitness values, some of chromosomes are reproduced and some are eliminated in such a way that Chromosomes with higher quality i.e. higher fitness value have higher probabilities of being

selected and chromosomes having small values die off. Some of the parent chromosomes are included in the new generation so as to keep the population size constant.

4. **Perform crossover**. This process allows two chromosomes to exchange information and produce two new chromosomes. Firstly, the parent chromosomes are selected randomly from the generation. Then the Crossover operator combines sub parts of two parent chromosomes and produces off spring that contains some parts of both the parent. These new chromosomes are returned to the generation.

5. **Perform mutation**-
This is performed to the new chromosomes produced by crossover. This operation is the random change of some elements /gene in a chromosome. Each gene will be considered for mutation with a certain probability.
Steps 2 to 5 are repeated until a chromosome is found for the objective function or the termination condition is met.

The performance of GA is based on efficient representation, evaluation of fitness function and other parameters like size of population, rate of crossover, mutation and the strength of selection. Genetic algorithms are capable to discover optimal or near optimal solution depending on the selection function.
Thus, a genetic algorithm has five basic requirements for its process as follows-

1. An encoding method, that is a genetic representation of solutions to the problem i.e. chromosome.
2. A way to create an initial population of chromosome.
3. An evaluation function to test the solutions in terms of their fitness.
4. A selection mechanism
5. The genetic operators - crossover and mutation that helps in reproduction.

IV. Genetic algorithm for QoS routing problem

GA is fit for network model to find the optimal path. In order to use Genetic Algorithms for networking applications, the chromosome consists of the network parameters as the genes of the chromosomes.

For instance ,in context of network routing problem i.e. to find the best path in the network , a possible chromosome would be a string consisting of the various nodes that constitute the paths between source and destination . In this, the source and the destination nodes are sure to participate in every generation. Other nodes or the genes become a part of the chromosome if they find an optimal path between the source and destination. The fitness function can be the criteria chosen to evaluate the path according to the objective of the problem . For example - If the objective is to minimize the route delay between source and destination, then the fitness function will compute the route delays of all paths in the generation and return the minimum delay path between source to destination. In case of QoS routing problem, the evaluation function will check more than one QoS parameters.

Using Genetic algorithm to solve QoS routing problem is not a new concept. Many of the researchers have successfully implemented this concept. There are various algorithms presented in literature to resolve QoS routing problem with genetic algorithm. These algorithms are varying in terms of encoding , evaluation of fitness function, size of population, rate of crossover & mutation , length of chromosome ,selection mechanism and the number/type of QoS parameters considered . Some of the work has been explored here-

Chang [4] presents a genetic algorithmic approach to the shortest path routing problem. Variable-length chromosomes have been employed. This algorithm displays a much better quality of solution and a much higher rate of convergence than other shortest path algorithms. This paper also develops a population-sizing equation that facilitates a solution with desired quality for the proposed GA.

Inagaki [5] proposed an algorithm that can find not only shortest route but also semi- shortest routes. This can search for semi-optimal routes by comparing each possible solution in the search process using the feature of a genetic algorithm. The algorithm employs fixed (deterministic) length chromosomes. The chromosomes in the algorithm are sequences of integers and each gene represents a node ID that is selected randomly from the set of nodes connected with the node.

In [6],Munetomo proposed a GA-based routing algorithm i.e. Genetic Routing algorithm with Migrations (GRM) which employs genetic operator to generate alternate paths that can be quickly used in the case of link failures. The GRM employs a source routing approach in order to effectively utilize the similarity among routes in a routing table. In the proposed algorithm, the algorithm chromosome is encoded as a list of node IDs that are on the path from the source node to the destination node. Since different paths can have different number of nodes, the chromosomes are of variable length. This algorithm employs crossover, mutation and migration genetic operators in generating the next generation of solutions. As an initial route, a default route is generated by using the Dijkstra's shortest path algorithm based on a hop count metric. Alternative routes in a routing table are generated by applying genetic operators such as mutation and crossover. The genetic operators are invoked at a specified probability after every evaluation of weight values. Migration is performed to exchange routes among nodes. After migration, the migrated string is modified by deletion/addition operators.

In [7], a GA based routing algorithm which uses two QoS parameters for routing. The proposed method is called ARGAQ method. In ARGAQ method two parameters: the Delay Time (DT) and Transmission Success Rate (TSR) are considered as QoS parameters. The DT means the time it takes a packet to go from one node to another one. The TSR is the rate of packets transmitted correctly without losses. The packet loss may be caused by the overflow in the queue or from the network trouble. The ARGAQ method is a source-based routing mechanism. ARGAQ provides only an approximate approach to QoS routing as it computes path subject to single mixed metric T, which is the ratio of Delay Time and Transmission Success Ratio.

In [8], a multi-purpose optimization method for QoS routing based on GA has been proposed. The proposed method is a source-based routing method and has a flexible and adaptive behaviour.

[9] presents a genetic algorithm to solve the MCP problem subject to transmission delay and transmission success ratio. Three key design problems are investigated for this new algorithm, i.e., how to encode the problem in genetic representation, how to avoid the illegal chromosomes in the process of population initialization and genetic operation, and how to design effective genetic operator. Gene structure (GS) has been proposed to deal with the first problem, and the gene structure algorithm (GSA) to generate the GS. Based on the GS chromosome initialization and mutation operator are given to solve the last two problems. In the process of evolution, there is no need to check and repair the illegal chromosomes. The mutation operator based on the GS is the unique genetic operator used in the evolution to search all potential solutions, which simplifies the genetic operation. Consequently, the proposed GA can search the solution space in a very effective and efficient manner.

[10] proposes a dynamic routing method based on a Genetic Algorithm. A new string structure and genetic operations suitable for network problems is proposed, and an optimization method that uses past solutions as the initial data for new searches is also proposed. These techniques dramatically improve the efficiency and convergence speed of the Genetic Algorithm.

In [11], the genes are put in a chromosome in the same order the nodes form the communication route, so the chromosomes have different size. If genetic operations are chosen randomly, the new offsprings of a population may be unsuitable individual populations. As a result, a communication route between two adjacent nodes may not exist and some complicated genetic operations should be carried out in order to find a new communication route. Also, because the individuals of a population have different sizes, the crossover operations are complicated. Moreover, the number of searching iterations has been decreased by using the past routing patterns as a part of the initial data for new searches. The proposed method is therefore useful for dynamic routing control during traffic fluctuations.

In [12], Barolli proposed an adaptive routing method based on GA (ARGA) subject to one additive metric (i.e., TD). In this method, the network is expressed as a tree network and the tree junctions represent the genes. The chromosomes in the algorithm have the fixed length. Genetic operators (i.e., crossover and mutation) are carried out on the tree junctions.

[13] proposed a robust GA-based QoS routing algorithm for the general k-constrained MCP routing problem. The proposed algorithm is also able to produce multiple feasible paths and this enables the algorithm to become more robust in the case that the actual state

information in the network has changed since the last state information update received by the router. If the first feasible path found turns out to be no longer feasible, there are other alternative paths that can be tried without having to execute a new routing computation. This will increase the success of finding a feasible path that can fulfil a particular QoS requirements. Variable length chromosomes have been used in this algorithm. Each chromosome consists of a sequence of nodes that are in the path from sender to receiver.

In [14],Multi-constraint QoS Unicast Routing Using Genetic Algorithm (MURUGA), which incorporates multiple constraints required by multimedia applications to find the feasible path satisfying the constraint requirement has been proposed. In this paper, a study of the existing GA based QoS routing algorithms has been done. The drawback in all these existing algorithms has been the consideration of single or single mixed constraint while computing the feasible path. MURUGA satisfies multiple additive constraints for finding a feasible route. MURUGA is a source based QoS routing algorithm and uses a tree structure for gene coding. The chromosome is initialized based on the chromosome structure. The population initialization based on the chromosome structure can generate chromosomes without loops. This algorithm adopts a heuristic nonlinear fitness function which uses the upper bound of the QoS constraints to evaluate chromosomes. This fitness function makes the routing algorithm select a feasible route quickly. However, crossover may generate chromosomes with routing loops. Checking and repairing function are needed to deal with illegal chromosomes (chromosomes with loops).

Based on these works, the generalized approach of executing routing problem through genetic algorithm can be outlined as-

1. For initial population, generate the possible paths from source to destination. The chromosomes that represent paths from a source to destination selected randomly among all the valid routes. These valid routes can be collected by route table or calculated by some method.

The representation of path in chromosome can be done by either a suitable encoding in the form of string or directly in the sequence of nodes.

2. A "fitness" is calculated for each chromosome .The fitness is a value of the objective function for the network configuration. The objective function may be any function that can check two or more QoS requirements. If the quality of one routing path is better than others according to the requirement then its fitness function would have a better value.

3. According to their fitness values, some of paths are reproduced and some are eliminated.

4. The crossover and mutation operators are performed on paths to generate new paths. For example- select two possible paths and perform crossover to generate a new sequence of paths . This may lead to invalid paths i,e. the paths having loops . So some mechanism should be provisioned to avoid illegal paths.

This process will continue until a optimal path is found or termination condition is met.

V. CONCLUSION

The traditional routing method is inadequate for the successful transmission of networked multimedia applications as these applications require quality parameters to be present in the network like strict delay & bandwidth guarantee etc. To support these applications, it is important for the network to provide Quality-of Service (QoS) guarantee. One of the key technology to provide QoS guarantees is QoS routing. QoS routing means to find a path that satisfy multiple constraints of QoS like delay, jitter, bandwidth, cost, hopcount etc.

It is well known that Multi-constrained problem is NP-complete. Heuristic and approximate algorithms for Multi-constrained problem are not effective in dynamic network environment for real-time applications when the state information of the network is out of date. Genetic algorithm are very good at solving optimization problems . Since solving an NPcomplete QoS routing problem is similar to solving an optimization problem, therefore it is possible to apply genetic algorithm to this problem. This paper has explored this possibility i.e. how to solve a QoS routing problem with genetic algorithm. Our future work will focus on to develop a QoS routing algorithm based on genetic approach.

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