Journal of Industrial Engineering International *Islamic Azad University, South Tehran Branch*
April 2007, Vol. 3, No. 4, 35-43

Advanced operations research techniques for multi-constraint QoS routing in internet

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Abstract

Internet Traffic has grown exponentially over last few years due to provision of multiple class services through Internet backbone. With the explosive use of Internet, contemporary Internet routers are susceptible to overloads and their services deteriorate drastically and often cause denial of services. In this paper, an analysis is made how forecasting technique, routing algorithm and Genetic algorithm can be simultaneously applied for solving a multi-constrained routing problem in Quality of service (QoS) traffic in Internet. Also, a model is suggested for solving the above-mentioned problem. Simulation results show that the throughput of the given network is enhanced by implementing the model. It can also be seen that the average delay of packets flowing through the network comes down when the proposed model is employed for the network.

Keywords: Qos; Multi-constrained routing; Congestion control; Genetic algorithm

1. Introduction

The evolution of the Internet over the last thirty years has been accompanied by the development, growth, and use of a wide variety of network applications. These applications range from text-based utilities such as file transfer, remote login, electronic mail, and network news from the early days of the Internet, to the advent of desktop videoconferencing, multimedia streaming, the World-Wide Web, and electronic commerce on today's Internet. Thus, in order to ensure the efficient content access to all the users with minimum loss rate at gateway during busy hours, speedy connectivity, and negligible packet loss with high bulk throughput is becoming of a high consideration by people dealing with internet. At present, various operations research techniques are used in routing, congestion control, scheduling problems of Internet and its performance evaluation. But, still the performance degradation of Internet traffic in the form of low throughput, high packet loss rate and long packet delay is an important problem. It was found that these problems are mainly due to the inefficiency of the conventional routing techniques to handle large volume of data traffic and the absence of efficient techniques to control congestion.

In this paper, it is illustrated how the combination of operations research techniques can be applied for multi-constraint routing problem in QoS traffic. This paper is organized as follows:

In Section 2, a brief overview of Internet, internet routing, QoS routing, forecasting technique, routing algorithm and genetic algorithm is given. This is followed by a detailed step by step description of the proposed model in Section 3. Section 4 contains the simulation results. Finally, Section 5 concludes the paper.

2. Literature review

2.1. Internet

Internet can be defined as a collection of packet switching and broadcast networks connected together via routers that use the TCP/IP network protocols to facilitate data transmission and exchange. With the

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help of Internet, computers on a network can back up their files over the network, can share resources, such as disks and printers, facilitate communications by sending and receiving e-mails, transferring files and videoconferencing etc.

Internet architecture. The internet is essentially a network of networks, and its success depends upon cooperation. Since no one person, organization or government is responsible for the Internet, cooperation among networks and computers that comprise the Internet is paramount. This cooperation is accomplished by a common set of protocols. The protocol that determines how computers connect, send, and receive information on the Internet is Transmission control protocol/Internet protocol (TCP/IP). In fact, TCP/IP consists of about 100 different protocols, and new ones are developed and added regularly. TCP permits communication between the various computers on the Internet, while IP specifies how data is routed from computer to computer.

Internet routing. The main function of the network layer is routing packets of information from the source machine to the destination machine. In most subnets, packets will require multiple hops to make the journey. The only notable exception is for broadcast networks, but even here routing is an issue if the source and destination are not in the same network. The algorithms that choose the routes and the data structures that they use are a major area of network layer design. The routing algorithm is that part of the network layer software responsible for deciding which output line an incoming packet should be transmitted on. Dijkstra's algorithm and Bellman-Ford algorithms the routing algorithms currently used in the Internet performs well for single objective routing condition. However, for multi constraint environment in QoS routing, we need some other techniques to find out the optimum routes.

2.2. QoS routing

QoS routing selects routes based on flow QoS requirements, and network resource availability. QoS routing determines feasible paths satisfying QoS requirements, while optimizing resource usage, and degrading gracefully during periods of heavy load. Constraints imposed by QoS requirements, such as bandwidth, delay, or loss, are referred to as QoS constraints, and the associated routing is referred to as QoS routing. The aim of Multi constrained routing is to find a path satisfying the required path constraints, meanwhile, the found path is optimized on another QoS metric. An example of Multi constrained routing is the delay-constrained least-cost (DCLC) routing problem, which is to find a least-cost path with bounded delay.

In this work, one model is suggested for solving the multi-constraint problem in QoS traffic. In this model, two constraints considered are the band width and the average delay of the links of a particular network. Bandwidth is expressed in Mbps and the delay in milliseconds. Bandwidth is a link constraint and the average delay is a path constraint. i.e., in the case of band width, each link is to be individually considered for optimization whereas the delay specifies the end-to-end QoS requirement for the entire path. Here, the average delay period is calculated with the help of Exponential smoothing technique of forecasting model. Routes with shortest average delay periods can be selected by using the Floyd's algorithm. A set of candidate routes having shorter average delay periods are selected with the help of Floyd's algorithm. The routes thus selected are then fed as input to the genetic algorithm used for the final optimization. It determines the routes having the maximum average bandwidth for each node pairs.

2.3. Forecasting by exponential smoothing

Using this technique, it is necessary only to retain the previous forecast figure and to know the latest actual figures.

New forecast = α (latest figures) + (1- α)(old forecast),

where 'α' is known as the smoothing constant.

The use of this technique permits the forecast to respond to recent actual events, but at the same time retain a certain amount of stability. The amount by which the new forecast responds to the latest figures, or the extent to which it is damped by the previous forecast, is, of course, determined by the size of the smoothing constant α. The size of 'α' should be carefully chosen in the light of the stability of variability of actual figures, and is normally from 0.1 to 0.3.

2.4. Shortest paths (Floyd's Algorithm)

Let $G = < N,A >$ be a directed graph; N is the set of nodes and A is the set of edges. We want to calculate the length of the shortest path between each pair of nodes. Suppose the node of G are numbered from 1 to n, so $N = \{1, 2,3,.....,n\}$ and suppose a matrix L

gives the length of each edge, with $L[i,j] \geq 0$ for all i and j, and $L[i,j] = \infty$, if the edge (i,j) does not exist.

The principle of optimality applies: if k is a node on the shortest path from i to j, then the part of the path from i to k, and part from k to j, must also be optimal. We construct a matrix D that gives the length of the shortest path between each pair of nodes. The algorithm initializes D to L, that is, to the direct distances between nodes. It then does 'n' iterations. After iteration k, D gives the length of the shortest paths that only use nodes in $\{1,2,.....,k\}$ as intermediate nodes. After n iterations, D gives the length of the shortest paths using any of the nodes in N as an intermediate node. At iteration k, the algorithm must check for each pair of nodes whether or not there exists a path from i to j passing through node k that is better than the present optimal path passing only through nodes in $\{1,2,.......,k-1\}$. The algorithm is as follows:

```
Function Floyd (L[1….n,1….n]): array[1…n,1…n]
  Array D [1…n,1…n]
  D←L
  For k←1 to n do
    For i←1 to n do
      For j←1 to n do
        D[i,j] ← min (D[i,j],D[i,k] + D[k,j])
Return D
```

2.5. Genetic Algorithm (GA)

2.5.1. Overview

In genetic algorithm, feasible results are encoded as the chromosomes (i.e. a suitable representation scheme for a possible solution). Usually, a set of chromosomes, called a population, is used in order to exploit the selection diversity. Note that each chromosome is a valid solution to the problem, and it can be good or bad-good solution has a better quality and adaptability. According to the principle of survival of the fittest, chromosomes adaptive to the environment are chosen to be duplicated by the process of reproduction. Sets of chromosomes more adaptive to environment are produced by the genetic manipulations of crossover and mutation (detailed below). The population thus evolves through generations and its average fitness is expected to improve from each generation. Eventually it will converge to an individual chromosome that is most adaptive to environment and the optimal result to the problem is obtained. Figure 1 shows this flow of simple genetic algorithm. The classical genetic algorithm has three basic operators: crossover, mutation, and reproduction. In this work, the method used for reproduction is tournament selection, the one for crossover is single-site crossover and that for mutation is shift change mutation.

2.5.2. Reproduction using tournament selection

Depending on the value of the objective function, individual chromosome would duplicate itself in the next generation. Usually a proportionate reproduction strategy is used in that a fitter chromosome will have a proportionally higher number of 'offsprings' in the next generation. Thus, the reproduction mechanism reflects the principle of survival of the fittest. In tournament selection, as the name suggests, tournaments are played between two solutions and the better solution is chosen and placed in a population slot. Two other solutions are picked again and another population slot is filled up with the better solution. If done systematically, each solution can be made to participate in exactly two tournaments. The best solution in a population will win both times, thereby making two copies of it in the new population. With a similar argument, the worst solution will loose in both tournaments and will be eliminated from the population. This way, any solution in a population will have zero, one, or two copies in the new population. It has been shown that the tournament selection has better convergence and computational time complexity properties compared to any other reproduction operator.

2.5.3. Single-site crossover

To apply the crossover operator, two chromosomes are randomly selected from the population. A crossover point is then randomly selected. The two chromosomes are then 'chopped' into two parts at the crossover point and they exchange their parts. The crossover operator is thus a realization of the building block hypothesis, in the hope that a better solution (chromosome) is obtained after combining the 'good' building blocks of two solutions (chromosomes). However, the crossover operation is not always applied to the selected chromosomes. The application of crossover is governed by a crossover probability, denoted by 'p_c': In each iterations (i.e. a generation) of the genetic algorithm, the crossover operator is tried N times (N is the population size) and thus, the expected number of applications of crossover is p_c N. Figure 2 shows the process of crossover.

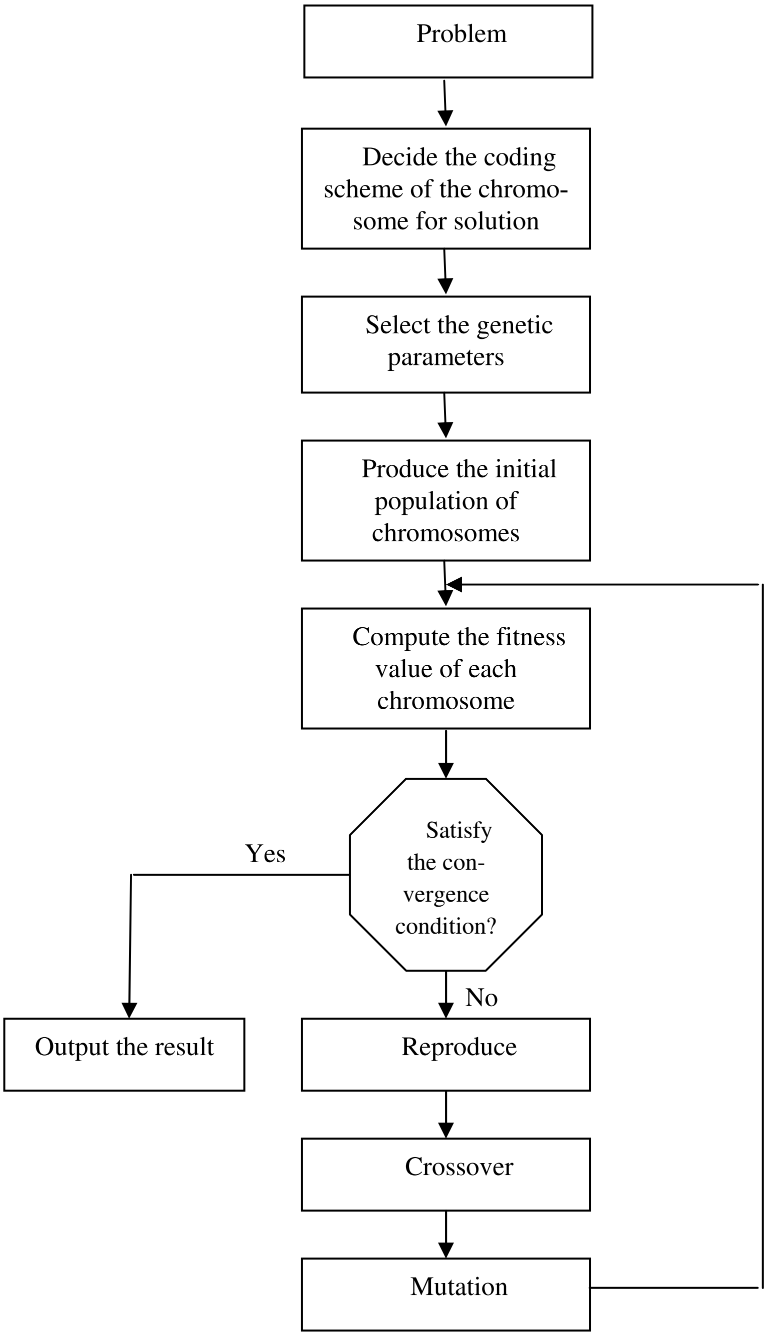

Figure 1. Flow chart of simple Genetic Algorithm.

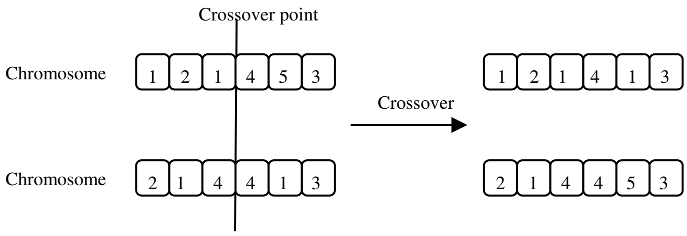

Figure 2. Single-site crossover.

2.5.4. Shift change mutation

To apply the mutation operator, a chromosome is randomly selected from the population. A mutation point is then randomly selected. The gene at the mutation point is then randomly perturbed. For example, if the chromosome is a binary bit string, the bit at the mutation point is flipped. The mutation operator is used as a means to escape from local minima in that the mutated chromosome, which may have a worse quality, can possibly lead to new search direction in the solution space. Such an escaping strategy is important and is implemented in many modern optimization search techniques such as Tabu search and simulated annealing. Similar to the crossover operator, the application of the mutation operator is governed by a mutation probability, denoted p_m. In each generation, the mutation operator is also tried N times and thus, the expected number of mutated chromosomes is p_m N. Figure 3 shows the process of mutation.

2.5.5. Parameters selection

(i) Population Size (N)

This parameter critically affects the efficiency and solution quality of the genetic algorithm. If N is too small, and thus, insufficient samples are provided (i.e. solution diversity is low), then the genetic evolution will be degenerated or no useful result can be obtained; if N is too large, then the amount of computation time needed may exceed a tolerable limit, and, more importantly, time of convergence could be prolonged.

(ii) Crossover Probability (p_c)

This parameter controls the frequency of the crossover operation (note that 0, p_c , 1). If p_c is too large, then the structure of a high quality solution could be prematurely destroyed; if p_c is too small, then the searching efficiency can be very low. Generally, p_c is chosen between 0.5 and 0.8 .

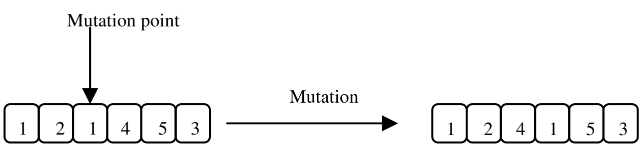

Figure 3. Shift change mutation

(iii) Mutation Probability (p_m)

This parameter (note that 0, p_m , 1) is a critical factor in extending the diversity of the population (hence, helping the optimization search to escape from local optima). If pm is too small, then new gene segment could not be induced (and hence, it is difficult to escape from local optima); if pm is too big, then the genetic evolution degenerates into a random local search. Generally, p_m is often chosen between 0.001 and 0.1.

3. Optimization of multi-constraint routing problem in QoS traffic

3.1. Model

Calculation of average delay. Average delay of a particular link is the average of the sum of transmission delay, waiting time and the servicing time of packets at the leading router. Since transmission delay is very small, it is not considered for the calculation of average delay. By applying exponential smoothing, the average delay is obtained as,

$$D = \alpha d + (1-\alpha)D_p, \tag{1}$$

where, D is the forecasted average delay, d is the present delay period, D_p is the average delay of past case and α is the smoothing constant whose value lies between .01 and .30.

Determination of candidate routes. Candidate routes are determined with the help of Floyd's algorithm. It is more general than Dijkstra's algorithm because it determines the shortest route between any two nodes in the network. The algorithm represents an n-node network as a square matrix with n rows and n columns.

The objective function is given by:

$$\text{Min } z = \sum D_{ij} X_{ij} \qquad i, j = 1,2,\ldots\ldots,N, \tag{2}$$

where, D_{ij} is the delay period in each link, X_{ij} is the route selection parameter and N is the number of nodes. X_{ij} is equal to zero if link i-j is not included an is one otherwise.

Optimization by Genetic Algorithm. In this model, tournament selection is used for reproduction, single site crossover operator is for crossover and shift change mutation operator is used for the mutation.

Here, the objective or fitness function is:

$$\text{Max} \quad z = \sum \frac{B_{ij} X_{ij}}{n}, \tag{3}$$

where B_{ij} represents the band width of each links, and n is the number of links in the path.

Each chromosome represents a combination of candidate routes for a pair of nodes. From that initial population, reproduction ,crossover and mutation are carried out for determining the optimum paths for each pair of nodes.

3.2. Procedure

Step 1. All kinds of data in the problem such as number of nodes in the network, number of links, average delay of each links, bandwidth of each links, smoothing constant (α) and the controlling parameters such as cross over and mutation probability and the number of chromosomes in the group are given as the input.

Step 2. With the help of exponential smoothing technique, the average delays of each links are forecasted and these values are used for further calculations.

Step 3. At least three shortest delay routes called the candidate routes are found out for each node pairs in the network by using Floyd's algorithm. These candidate routes are numbered as 1, 2,3,… for each node pairs. Thus a set of candidate routes are created for each node pairs.

Step 4. The average bandwidth of the candidate routes are calculated. Average bandwidth represents the fitness value of the objective function. The objective of final optimization using GA is to determine the paths having maximum average bandwidth.

Step 5. The initial population for GA is created based on the value of population size. Here, a chromosome represents a combination of candidate routes. One candidate route is randomly selected from each set of candidate routes and the combination of these newly selected candidate routes represents a chromosome. The number of genes in the chromosome is equal to the number of node pairs present in the network. i.e. if there are 5 nodes, then there are 20 node pairs and the number of genes in the chromosomes is also 20.

Step 6. Reproduction is carried out using Tournament selection.

Step 7. Single site crossover is carried out after checking out the cross over probability.

Step 8. Shift change mutation is performed only after checking out the mutation probability.

Step 9. Steps 6-7 are repeated as many times as equal to the number of generations. Then the calculation is stopped and the final combination of routes for the entire network is obtained.

Step 10. Steps 2-9 are repeated after a certain period so as to update the network conditions.

4. Simulation results

In order to investigate the effectiveness of the proposed model, extensive computer simulations have been performed using MATLAB software. The below mentioned network (Figure 4) has been used for the analysis. Service times of each nodes are calculated based on the link weight, bandwidth. Packet flow from node1 to all other nodes is considered for the analysis. Packets arrive at node1 randomly based on uniform distribution. Packet length is assumed to be constant for a particular time period. Queuing policy at each router is FIFO. Simulation tests for the existing models and the proposed model are conducted. At first the performance of the network is analyzed by sending packets through the routes selected by existing models. Then the packets are sent through the routes selected by the proposed model and the performance is evaluated.

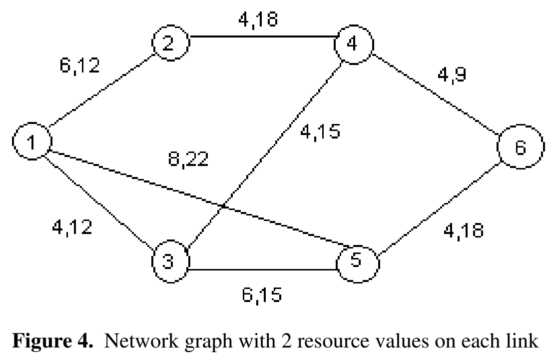

Figure 4. Network graph with 2 resource values on each link (Bandwidth in Mbps, delay in ms).

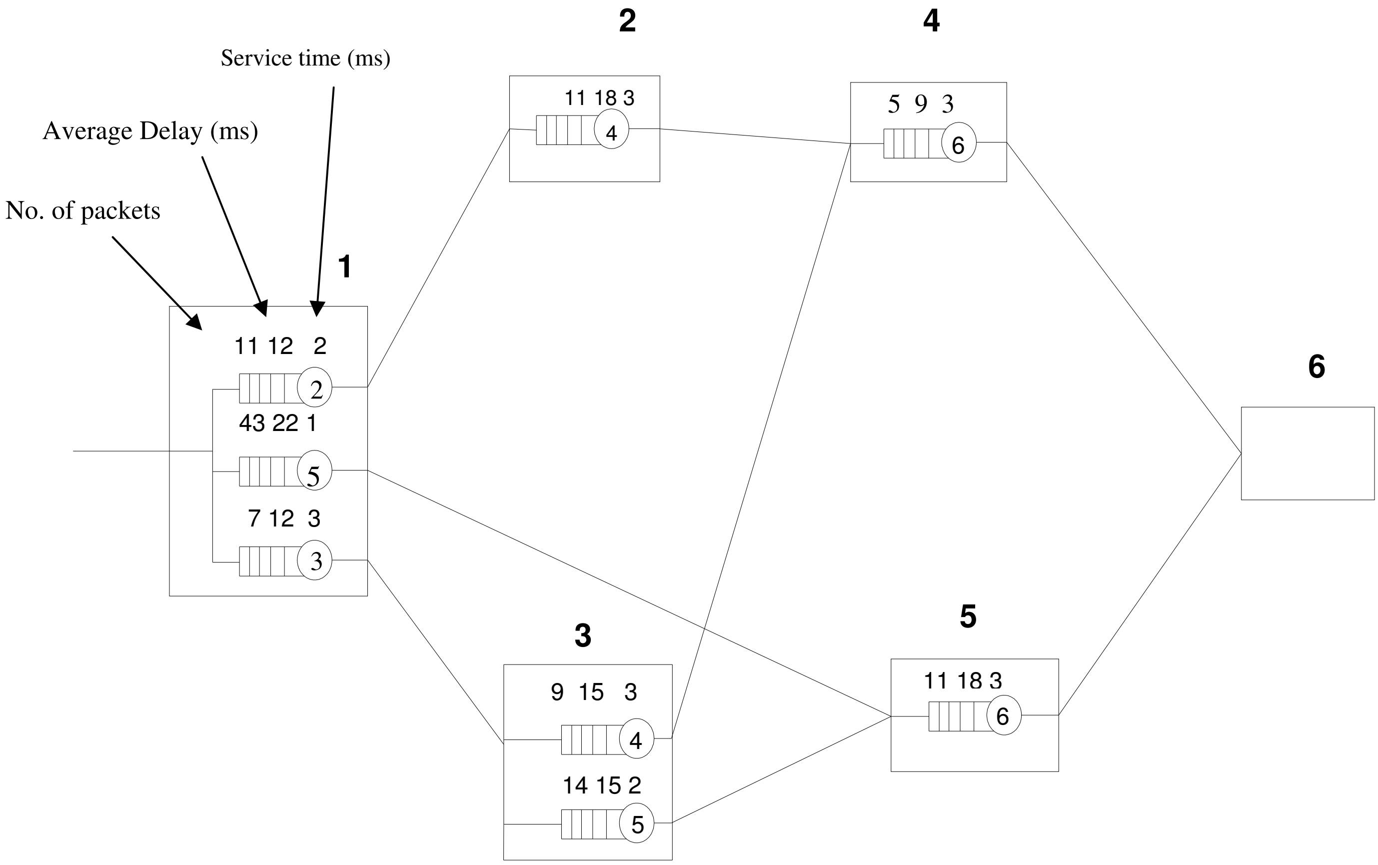

Figure 5. Queuing model of the network.

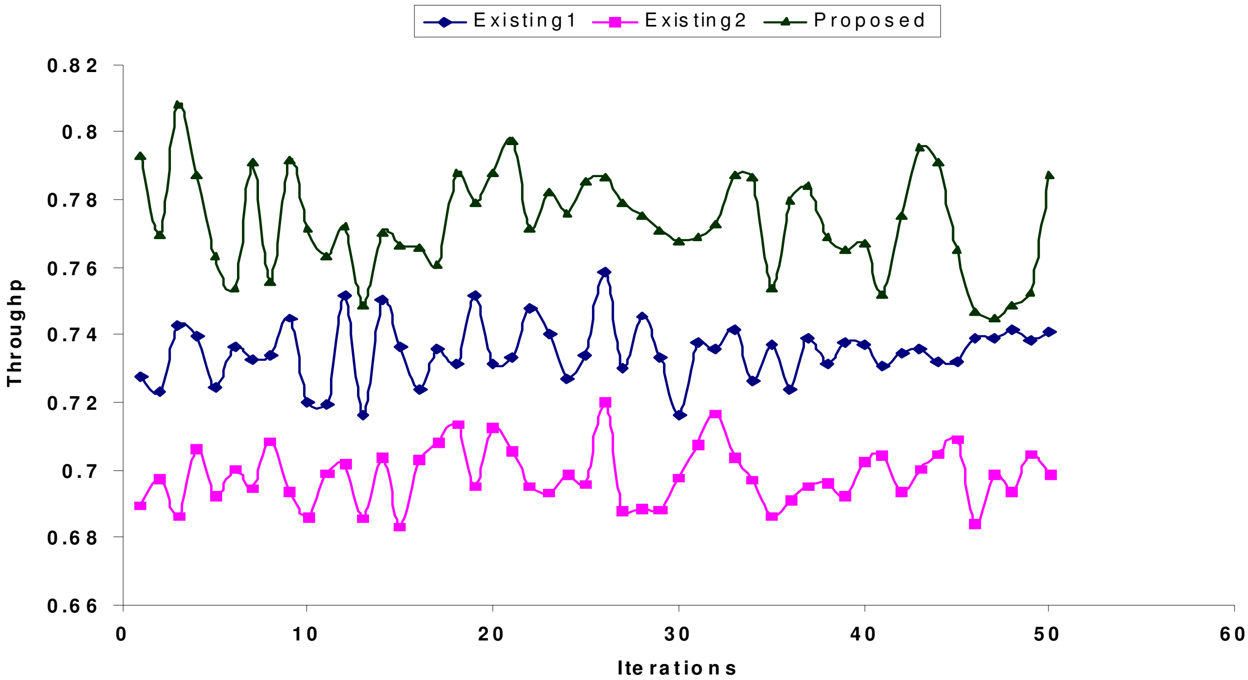

Figure 6. Results of Throughput.

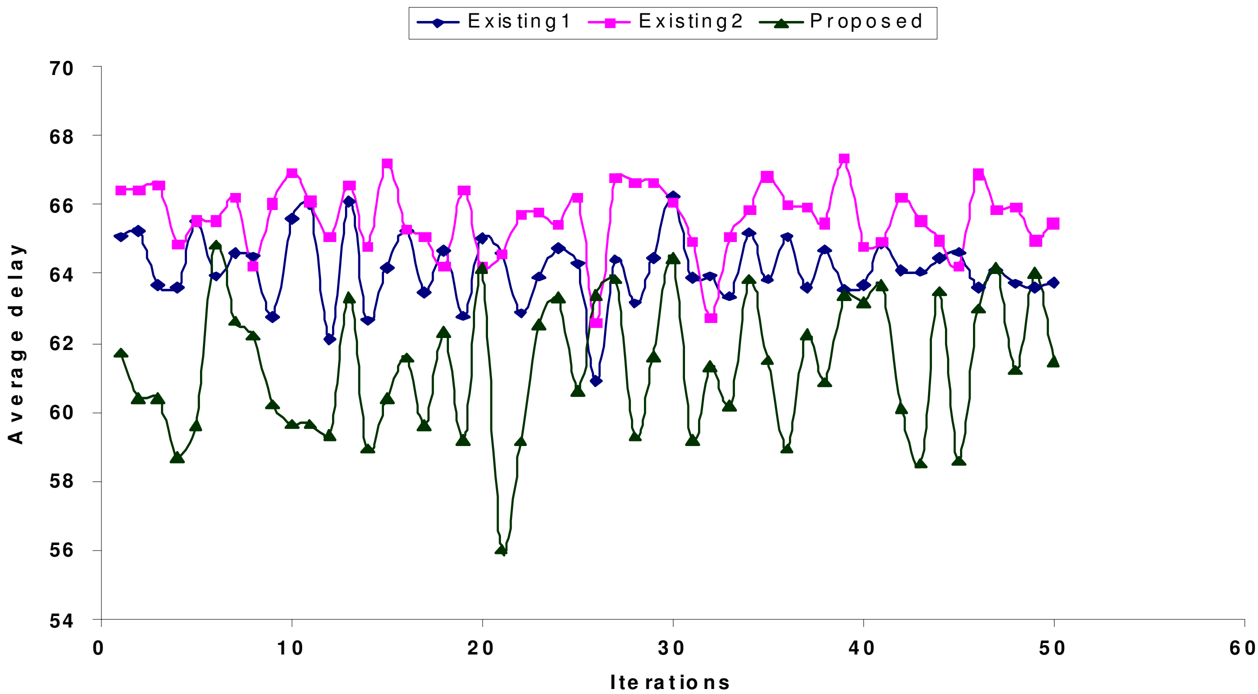

Figure 7. Results of average delay.

In the first existing model (Existing1), optimum routes are selected with the help of Dijkstra's algorithm by considering only one factor, the average delay and in the second existing model (Existing 2), average bandwidth is taken in to consideration. Meanwhile, in the proposed model, routes are selected based on the constraints, average delay and bandwidth. i.e., two factors are taken in to consideration for the purpose of routing. In the proposed model, the objective is to maximise the average bandwidth for a route subjected to the condition, average delay for the route is minimum. Routes with minimum average delay periods are determined with the help of Floyd's algorithm. Three candidate routes are selected for each node pairs. These routes are considered as the chromosomes of Genetic algorithm and the optimum routes for the network are obtained from GA.

4.1. Performance parameters used

Throughput and the average delay of packets are the parameters considered for the performance analysis of the existing models and the proposed model. Throughput is the ratio of the number of packets reached in the destination nodes to the number of packets sent from the source node. Average delay is the average of the transmission delays of all the packets that reached their destinations. A queuing model of the given network is shown in the Figure 5.

4.2. Results

The simulation results are shown in the Figures 6 and 7. We can see that the average delay/packets is less in the case of proposed model as compared to the existing models. Throughput is higher in the case of proposed model as compared to the existing models.

5. Conclusion

O.R. techniques which are currently used in Internet make use of the conventional algorithms based on certain assumptions which are irrelevant now. Certain suggestions are made by the researchers to solve the existing problems in the field of congestion control and routing. But most of them are based on ATM network configuration which constitutes only a small portion of the TCP/IP based Internet. In this paper, one model is proposed for the optimization of routing in a multi-constrained QoS environment. This model is developed for TCP/IP based Internet. Simulation results show that the model is efficient and effective in handling the problems of congestion control and routing as compared to the existing model. However, further research woks can be carried out in the field of active queue management and multi constrained routing in TCP/IP based Internet with the help of advanced techniques such as ANN, Neuro fuzzy, Ant colony optimization etc.

Acknowledgment

The authors would like to thank Mr. Sajeevkumar, CDAC for his helpful feedback.

References

[1] Cui, Y., Xu K. and Wu, J., 2003, Optimal QoS routing based on extended simulated annealing. *Lecture notes in computer science,*553-562.

[2] Greenlaw, R. and Hepp, E., 2000, *Fundamentals of the Internet and the World Wide Web*, McGraw-Hill.

[3] Lin, X., Kwok, Y. and Lau, V. K. N., 2003, A genetic algorithm based approach to route selection and capacity flow assignment. *Computer Communications,* 26, 961-974.

[4] Murarka, P. D., 2000, *Internet and web page design*. 1st edition, BPB publications.

[5] Pitsillides, A. and Sekercioglu, A., 1999, *Book CI Congestion Control.*

[6] Ryu, R., Rump, C. and Qiao, C., 2003, Advances in internet congestion control. *IEEE Communications Surveys and Tutorials*, 5(1), 28-39.

[7] Stallings, W., 2002, *High Speed Networks and Internet.* 2nd edition, Pearson education.

[8] Taha, H. A., 2002, *Operations Research.* 7th edition, Prentice-Hall.

[9] Younis, O. and Fahmy, S., 2003, Constraint-based routing in the internet: Basic principles and recent research. *IEEE Communications Surveys and Tutorials*, 5(3).