Selection of Appropriate Traffic of a Computer Network with Fixed Topology Using GAs

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Abstract—**This paper introduces the idea of using Genetic Algorithms as an optimization technique to select the appropriate traffic of a computer network with fixed topology. The ultimate goal in computer network design is to have a high utilization of the network resources such that low level of congestion, high throughput and minimum delay over the channels are achieved. This is why we need to minimizing the delay over the network such that the constraints on the total capacity and traffic are satisfied. On doing this, we developed a set of experiment to test the performance of GAs. We also compared our results with [1] for the ATM network. Experimental results show that our setup experiments for GAs can provide good results in solving such a problem.**

Keywords: Genetic Algorithms, Computer Networks, ATM, Traffic Assignment

1 Introduction

A computer network system consists of two main components. They are the stations or terminal and a cabling system. The nodes are represented by computers or printers and the cables could be of a type like coaxial cables, fiber optics or any other mean of communication media. Nodes normally communicate via the communication media. There exist many techniques to handle sending and receiving data over the channels. To increase the network reliability we may allow more routes between various links such that we can avoid loss of data due to congestion. There is no free lunch. This design concept leads to an increase in the cost of cabling and the need for larger bandwidth.

In [2], authors have used genetic algorithms to determine the link capacities of a network initially generated by the software called DESIGNet. A system called SIDRO based artificial intelligence techniques for topological design of packet switched networks was proposed in [3]. Simulated annealing (SA) method was also explored as a technique to find the optimal network topology [4, 5]. Many articles considered the issue of building reliable computer network that can provide a high quality of service [6]. The problem was presented as a constrained optimization problem [7]. GAs found to be successfully in handling such a problem [8, 9].

In this paper, we focus on the issue of solving the flow assignment problem which consists of determining the maximum Kilo bits per second (Kbps) that can be transmitted by each communication link of a given topological configuration. We need to make sure that 1) the quantity of information sent over the network does not overwhelm the system; 2) the link capacity is worth such that no link has a flow under a permissible range; 3) reduce the delay over the network.

2 Evolutionary Process for GAs

GA is a heuristic approach, which means it can provide an estimate of a solution not the exact one. We won't know if you get the exact solution, but that may be a minor concern. In fact, most real-life problems are like that: you estimate a solution rather than calculating it exactly. Genetic algorithms are different from other heuristic methods in several ways. The most important difference is that a GA works on a population of possible solutions, while other heuristic methods use a single solution in their iterations. Another difference is that GAs are probabilistic (stochastic), not deterministic. GAs has been successfully used to solve variety of parameter optimization problems in computer science and engineering [10, 11, 12].

Each individual in the GA population represents a possible solution to the problem. Finding individuals which are the best suggestions to our problem and combine these individuals into new individuals is an important stage of the evolutionary process. Using this method repeatedly, the population will hopefully evolve good solutions. Specifically, the elements of a GA are: selection (according to some measure of fitness), crossover (a method of reproduction, "mating" the individuals into new individuals), and mutation (adding a bit of random noise to the off-spring, changing their "genes"). The following steps illustrate the basic process in GAs:

1. **[Start]** Generate random population of n chromosomes (suitable solutions for the problem)

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2. **[Fitness]** Evaluate the fitness $g(x)$ of each chromosome x in the population.
3. **[New population]** Create a new population by repeating the following steps until the new population is complete.
   (a) **[Selection]** Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
   (b) **[Crossover]** With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.
   (c) **[Mutation]** With a mutation probability mutate new offspring at each locus (position in chromosome).
   (d) **[Accepting]** Place new offspring in a new population.
4. **[Replace]** Use new generated population for further run of algorithm.
5. **[Test]** If the end condition is satisfied stop and return the best solution in current population .
6. **[Loop]** Go to step 2.
7. **[END]**

3 Network Design Using GAs

GA have been used to solve variety of problems in computer network. In this section, we summarize some of these problems. In [13], the use of genetic algorithms for automated selection of parameters in an ad hoc networking system was presented. Authors provided an experimental study to demonstrate that the GAs can optimize various network classes under different operating conditions with a comparison against hand-tuning in a complex realistic scenario. The design of network topology is an important part of network design, since network topology is directly associated with network operational behavior, capacity, reliability, and cost [14, 15]. In [16], authors provided guidelines for network topology design using GAs. Routing in computer network using GAs was explored in many studies [17, 18, 19, 20]. Network reliability is a function of number of parameters such as connectivity, degree of each node, and average distance between any pair of nodes. Designing a highly reliable computer network using GAs was explored in [21, 7].

Incorporation of more than one objective fitness function has finally become a popular area of research. The basic idea can be found in [22]. Author "summarized and organized the information on these current multi-objective optimization approaches, emphasizing the importance of analyzing the operations research techniques in which most of them are based, in an attempt to motivate researchers to look into these mathematical programming approaches for new ways of exploiting the search capabilities of evolutionary algorithms". Recently, Telecommunication network design with parallel multi-objective evolutionary algorithms was explored [23]. A study on the QoS-based mobile multi-cast routing protocol using multi-objective genetic algorithm was presented in [24, 25]

4 Traffic Assignment Using GAs

The problem of selecting appropriate traffic of computer network can cast as a parameter estimation problem. The objective is to find a set of flow values f_i within the allowable bandwidth of each link such that the mean delay over the network is minimum.

Assume we have a computer network as presented in Figure 1. Each network link is characterized by a set of attributes which principally are the flow and the capacity. For a given link i, the flow f_i is defined as the effective quantity of information transported by this link, while its capacity C_i is a measure of the maximal quantity of information that it can transmit. Flow and capacity are both expressed in Kilo bits/s (Kbps).

The domain of search for this type of problem could be very large makes the use of expert knowledge or traditional search techniques like gradient search techniques suffer many problems [13]. Gradient search might trapped by local minimum solution. The solution provided by these techniques are most likely not the optimal one. Stochastic search algorithms can provide a better performance in solving the flow assignment problem of computer network.

5 Objective Function

In this step of the evolutionary process, the function being searched, and assigns a value to the individual member of the population upon which selection for reproduction is based. There are a large number of ways of scaling the fitness function to prevent early good (but not global) minimizations from dominating. Some selection methods require that the fitness parameters be positive numbers, and the scaling would have to take this into account.

In [26], the average packet delay in a network was defined as *the mean time taken by a packet to travel from a source node to a destination node*. This in turn results in a high quality of service. The fitness criterion considered, in this study, was also the mean delay time. Given that γ is the total traffic over the network and N is the number of link. The mean delay is computed according to Equation 1.

$$Minimize\ T = \frac{1}{\gamma}\sum_{i=1}^{N}\frac{f_i}{C_i - f_i}, \quad \gamma = \sum_{i=1}^{N} f_i \qquad (1)$$

For each of experiments. we computed the GA utilization as an indicator for the effectiveness of the developed results. As the GA utilization increases the using of the link will be better. The GA utilization is computed as follows:

$$GA - Utilization = \frac{f_i}{C_i} \tag{2}$$

6 Constraints

In solving real world problems, we must handle constraints; and our problem has two main constraints to be satisfied.

$$f_i \leq C_i \times 95\% \tag{3}$$

The maximum allowable flow values for each link were restricted not to exceed 95% of the link capacity so that we can avoid congestion.

$$Throughput(\gamma) = 0.5 \times \sum_{i=1}^{n} C_i \tag{4}$$

The throughput of the network was not allowed to go below half the sum of all capacity. Thus, we have a useful use of the network resources. We selected a simple method for constraint handling, by assign new value for the fitness function of bad chromosomes. This value is 9999 greater than the delay in the worst case.

7 Experimental Results

In this section we describe the results developed to solve the flow assignment problem using GAs. Number of examples is presented. GA is used to determine the f_i parameters for each network link i. For example, in the ATM network case, we have 14 genes to be identified. Each gene corresponds to a link and each link has a given capacity C_i. We run GA using various population sizes. The tuning parameters for GAs were selected as follows:

- The creation function was selected as a random initial function with uniform distribution.
- The initial range had a lower bounds of 1 and upper bounds is 95% of capacity of line (i.e. link).
- The selection mechanism was a stochastic uniform mechanism.
- The crossover type was a scattered function.
- The mutation type was a Gaussian function with Scale = 1 and Shrink = 1.
- The population size had a range of values which include 10, 20, 30, 40, 50, 100.
- The maximum number of generations was 1000 to allow more time for convergence.

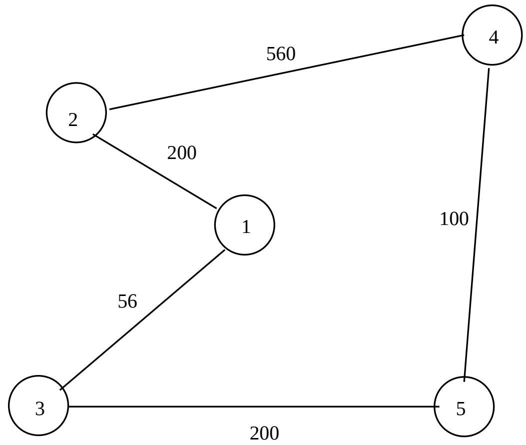

Figure 1: Network Topology of Example 1

Table 1: Link capacities and flows for each link i

Link l_i Km	Capacity C_i (Kbps)	Flow f_i (Kbps)	GA utilization f_i/C_i
1-2	200	83.4326	0.417162855
1-3	56	0.1749	3.12E-03
2-4	560	367.6124	0.656450786
3-5	200	86.5553	0.432776325
4-5	100	20.3044	0.20304354

7.1 Network Example 1

A computer network system consists of five nodes is presents in Figure 1 and [8]. Our goal is to find the best flow f_i which minimize the over all network delay using GAs. GA is used to determine the f_i parameters for each network link i. In this case, we have 5 genes to be identified. Each gene corresponds to a link and each link has a maximum capacity C_i. This chromosome can be presented as follows:

f_1	f_2	$\ldots\ldots$	f_5

The proposed capacity and the computed flow for each link of the computer network are given in Table 1. In Figure 2, we show the convergence process of the GA over various population sizes. The average GA utilization for network 1 was 0.3425. The best computed delay found with population size 100 was 6.5356.

7.2 Network Example 2

In Figure 3, we show another computer network example [8]. The network has six nodes with seven connections. We run GAs, with the given set of tuning parameters presented in Section 7, and computed the best flow f_i which minimize the overall network delay using GAs. The proposed capacity and the computed flow for each link of the computer network are given in Table 2. In Figure 4,

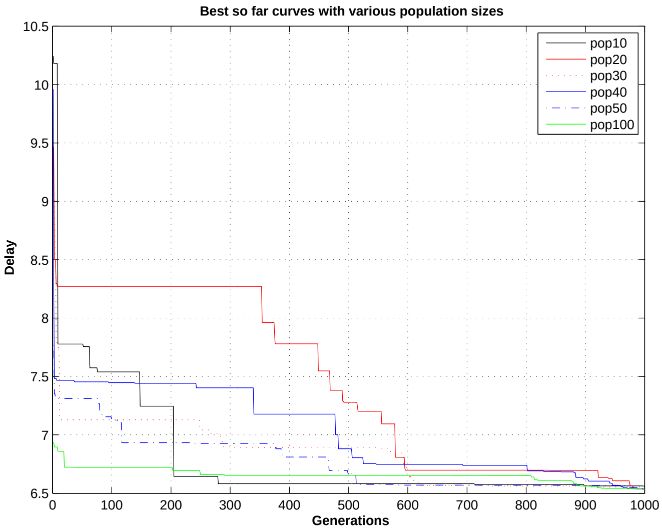

Figure 2: Best so far curve, delay (T), after each generation (iteration) for Network 1

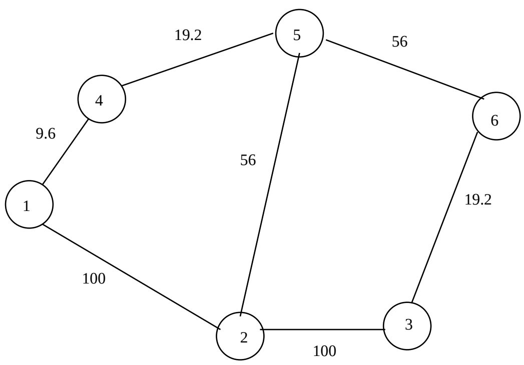

Figure 3: Network Topology of Example 2

Table 2: Link capacities and flows for each link i

Link l_i Km	Capacity C_i (Kbps)	Flow f_i (Kbps)	GA Utilization f_i/C_i
1-2	100	60.7983	0.60798279
1-4	9.6	0.0023	0.000240115
2-3	100	61.7052	0.61705172
2-5	56	26.4545	0.472401214
3-6	19.2	1.8217	0.094879323
4-5	19.2	1.7429	0.090774568
5-6	56	27.4767	0.490654625

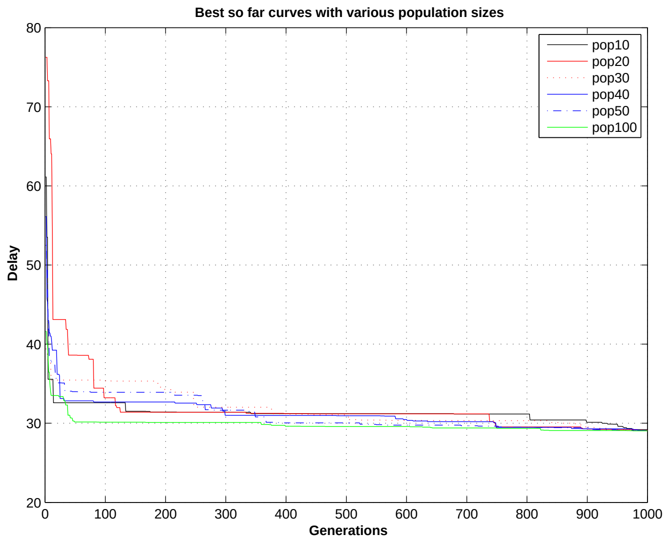

Figure 4: Best so far curve, delay (T), after each generation (iteration) for Network 2

we show the convergence process of the GA over various population sizes. The capacity of each link C_i and the computed flow f_i using GAs are given as indicated in Table 2 and the average GA utilization is 0.3391. The best computed delay found with population size 100 was 29.0320.

7.3 ATM Network Problem

Asynchronous Transfer Mode (ATM) is widely used in telecommunications systems to send data, video and voice at a very high speed 5. In ATM network optimizing the bandwidth through dynamic routing is an important consideration. Previous research work shows that traditional and non-traditional optimization results provide non-optimal and optimal solutions, respectively [1]. In Figure 6, we show the convergence process of the GA over various population sizes, and the best computed delay found with population size 100 was 11.868. The capacity of each link C_i and the computed flow f_i using GAs are given as indicated in Table 3 and the average GA utilization is compared with [1] results are shown in Table 4. The computed results in our case based the pro-

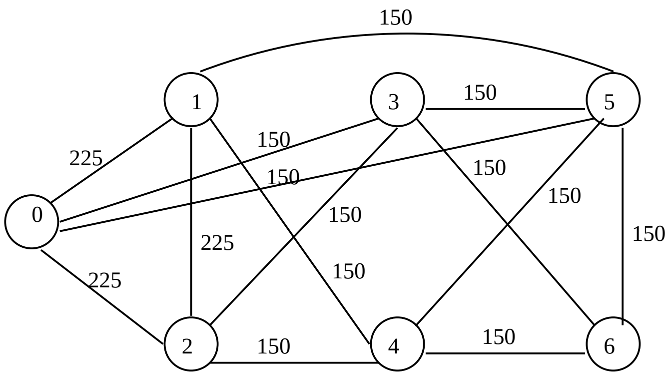

Figure 5: ATM network system [1]

Table 3: Link capacities and flows for each link i

Link l_i Km	Capacity C_i (Kbps)	Flow f_i (Kbps)	GA Utilization f_i/C_i
0-3	150	69.4739	0.463159513
0-5	150	70.9088	0.47272544
0-2	225	130.6314	0.580584
0-1	225	129.7433	0.576637022
1-2	225	124.6960	0.554204489
1-5	150	69.5712	0.46380788
1-4	150	70.3698	0.469131747
2-3	150	68.6439	0.457626007
2-4	150	71.1738	0.47449174
3-5	150	73.8224	0.492149627
5-4	150	70.9437	0.47295818
4-6	150	72.5397	0.483597947
5-6	150	70.3153	0.4687686
3-6	150	69.7105	0.464736573

posed tuning parameters was much better in reducing the delay over the network.

8 Conclusions and Future Work

In this paper we proposed the use of GA as an optimization technique to assign an optimal traffic for a computer network. A fixed network topology and pre-assigned capacity were used. GA was used to find the optimal values of the flow f_i such that the network delay time is minimum. We plan to extend our work to consider the design of a computer network topology which not only minimizes the delay time but also the cost over the computer network at the same time. This is a challenging multi-objective optimization problem in computer network.

Table 4: Solution provided by our method and [1]

	Delay	GA Utilization
Our proposed solution	11.868	0.4924
Solution in [1]	14.088	0.47

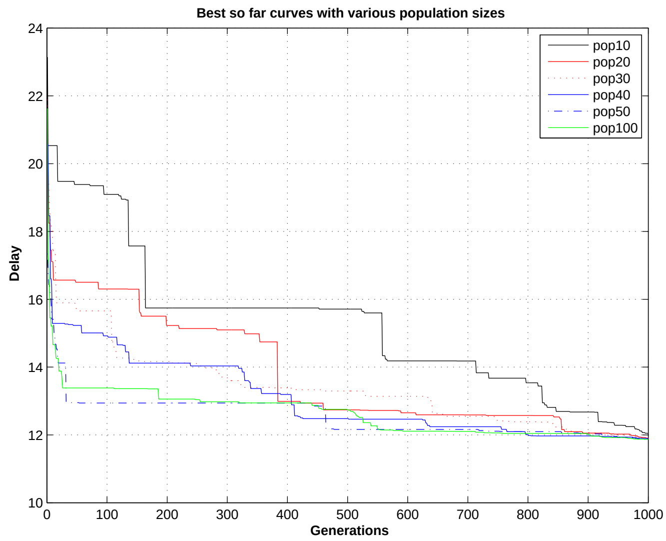

Figure 6: Best so far curve, delay (T) after each generation for the ATM network

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