Application of Genetic Algorithms for QoS Routing in Broadband Networks

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INTRODUCTION

The networks of today are passing through a rapid evolution and are opening a new era of Information Technology (IT). In this information age, customers are requesting an ever-increasing number of new services, and each service will generate other requirements. This large span of requirements introduces the need for flexible networks. Also, future networks are expected to support a wide range of multimedia applications which raises new challenges for the next generation broadband networks. One of the key issues is the Quality of Service (QoS) routing (Baransel, Dobosiewicz, & Gburzynski, 1995; Black, 2000; Chen & Nahrstedt, 1998; Wang, 2001). To cope with multimedia transmission, the routing algorithms must be adaptive, flexible, and intelligent (Barolli, Koyama, Yamada, & Yokoyama, 2000, 2001). Use of intelligent algorithms based on Genetic Algorithm (GA), Fuzzy Logic (FL), and Neural Networks (NN) can prove to be efficient for telecommunication networks (Douligeris, Pistillides, & Panno, 2002). As opposed to non-linear programming, GA, FL and NN use heuristic rules to find an optimal solution.

In Munemoto, Takai, and Sato,(1998), a Genetic Load Balancing Routing (GLBR) algorithm is proposed and its behavior is compared with conventional Shortest Path First (SPF) and Routing Information Protocol (RIP). The performance evaluation shows that GLBR has a better behavior than SPF and RIP. However, in Barolli, Koyama, Motegi, and Yokoyama (1999), we found that GLBR genetic operations are complicated. For this reason, we proposed a new GA-based algorithm called Adaptive Routing method based on GA (ARGA). ARGA has a faster routing decision than GLBR. But, the ARGA and GLBR use only the delay time as a parameter for routing.

In order to support multimedia communication, it is necessary to develop routing algorithms which use for routing more than one QoS metric such as throughput, delay, and loss probability (Barolli, Koyama, Suganuma, & Shiratori, 2003; Barolli, Koyama, Sawada, Suganuma, & Shiratori, 2002b; Matsumoto, Koyama, Barolli, & Cheng, 2001). However, the problem of QoS routing is difficult, because the distributed applications have very diverse QoS constraints on delay, loss ratio, and bandwidth. Also, multiple constraints make the routing problem intractable and finding a feasible route with two independent path constraints is NP-complete (Chen & Nahrstedt, 1998). In this article, we propose two GA-based routing algorithms for multimedia communication: the first one called ARGAQ uses two QoS parameters mixed into a single measure by defining a function; and the second one is based on multi-purpose optimization and is used for multiple metrics QoS routing.

USE OF GA FOR NETWORK ROUTING

The GA cycle is shown in Figure 1. First, an initial population is created as a starting point for the search. Then, the fitness of each individual is evaluated with respect to the constraints imposed by the problem. Based on each individual's fitness, a selection mechanism chooses "parents" for the crossover and mutation. The crossover operator takes two chromosomes and swaps part of their genetic information to produce new chromosomes. The mutation operator introduces new genetic structures in the

population by randomly modifying some of genes, helping the algorithm to escape from local optimum. The offspring produced by the genetic manipulation process are the next population to be evaluated. The creation-evaluation-selection-manipulation cycle repeats until a satisfactory solution to the problem is found, or some other termination criteria are met (Gen, 2000; Goldberg, 1989). The main steps of GA are as follows.

1. Supply a population P0 of N individuals (routes) and respective function values;
2. i ← 1;
3. P'i ← selection_function (Pi-1);
4. Pi ← reproduction_function (P'i);
5. Evaluate (Pi);
6. i ← i+1;
7. Repeat step 3 until termination;
8. Print out the best solution (route).

The most important factor to achieve efficient genetic operations is gene coding. In the case when GA is used for routing and the algorithm is a source-based algorithm, a node which wants to transmit the information to a destination node becomes the source node. There are different coding methods of network nodes as GA genes. A simple coding method is to map each network node to a GA gene. Another one is to transform the network in a tree network with the source node as the root of tree. After that, the tree network may be reduced in the parts where are the same routes. Then, in the reduced tree network, the tree junctions may be coded as genes.

After the crossover and mutation, the elitist model is used. Based on the elitist model, the route which has the highest fitness value in a population is left

intact in the next generation. Therefore, the best value is always kept and the routing algorithm can converge very fast to the desired value. The off-springs produced by the genetic operations are the next population to be evaluated. The genetic operations are repeated until the initialized generation size is achieved or a route with a required optimal value is found.

OUTLINE OF PREVIOUS WORK

In this section, we will explain ARGA and GLBR algorithms. In the GLBR, 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, a route between two adjacent nodes may not exist and some complicated genetic operations should be carried out to find a new route. Also, because the individuals have different size, the cross-over operations become complicated. On the other hand, in ARGA the network is expressed by a tree network and the genes are expressed by tree junctions. Thus, the routing loops can be avoided. Also, the length of each chromosome is the same and the searched routes always exist. Therefore, there is no need to check their validity (Barolli, Koyama, Yamada, Yokoyama, Suganuma, & Shiratori, 2002a). To explain this procedure, we use a small network with 8 nodes as shown in Figure 2. Node A is the source node and node H is the destination node. All routes are expressed by the network tree model shown in Figure 3. The shaded areas show the same routes from node C to H. Therefore, the network tree model of Figure 3 can be reduced as shown in Figure
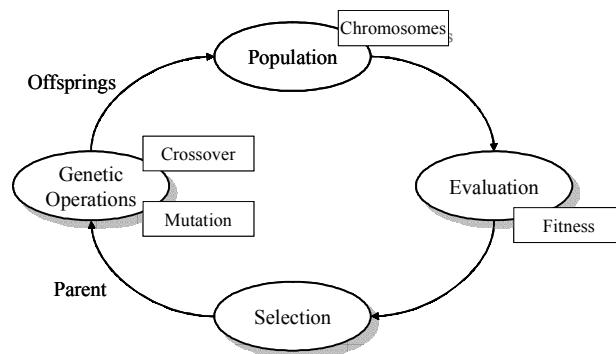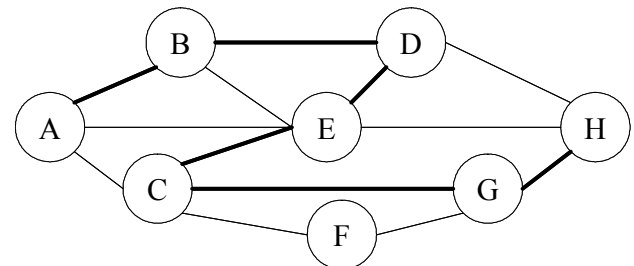
Figure 1. GA cycle

Figure 2. Network example with 8 nodes

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