AN ENHANCED GENETIC ALGORITHM FOR DYNAMIC ROUTING IN ATM NETWORKS

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ABSTRACT

The recent advancements in the telecommunication industry have brought forth many changes in the field. One of the most important is a shift towards the wireless communication scenario. Wireless ATM is fast becoming a solution in this direction. With WATM gaining momentum it is very important that the underlying ATM network is well laid out. One of the most important research issues in the ATM scenario is the optimized usage of bandwidth. In this paper we have proposed an Enhanced Genetic Algorithm (EGA) algorithm approach based solution for optimization of bandwidth through dynamic routing in ATM network. Previous research work shows that traditional optimization heuristics result in sub-optimal solution. In this paper we have explored non-traditional optimization technique specifically EGA. The results obtained thus prove that EGA can become a potential solver algorithm for obtaining optimized bandwidth. The optimized bandwidth could mean that some attractive business applications would become feasible such as high speed LAN interconnection, teleconferencing etc. We have also performed a comparative study of the selection mechanisms in GA and listed the best selection mechanism and a new initialization technique which improves the efficiency of the EGA.

Keywords— *Asynchronous Transfer Mode (ATM), Wireless ATM (WATM), Genetic Algorithm (GA), Enhanced Genetic Algorithm (EGA).*

1. INTRODUCTION

ATM is a packet switched, connection oriented transfer mode based on asynchronous time division multiplexing. ATM is considered to reduce the complexity of the network and improve the flexibility of traffic performance [1]. In ATM, information is sent out in fixed-size cells. Each cell in ATM consists of 53 bytes. Out of these 53 bytes, 5 bytes are reserved for the header field and 48 bytes are reserved for data field. ATM is Asynchronous as the recurrence of cells sent by an individual user may not necessarily be periodic. ATM integrates the multiplexing and switching functions and allows communication between devices that operate at different speeds [2]. Different traffic types with varied traffic characteristics and different QoS requirements can co-exist with Virtual Path(VP) subnetworks within ATM network [3]. VP is basically a logical link between two nodes carrying the same type of traffic. VP networks [4, 5] are one of the best ways of utilizing the ATM networks. A large number of virtual connections are supported by a VP, as express pipes, between ATM nodes [6]. To obtain the best network performance VPs network is formulated in the form of Optimization Routing Problem (ORP) [7]. Previous research work [7, 8, 9] have concentrated on the traditional heuristic algorithms to solve the optimization problem in which calculus concepts have been used which resulted in sub-optimal solutions due to the complexity of calculus concepts [6]. In this paper we explore the meta-heuristic based optimizing technique specifically EGA also known as Memetic algorithm which can be used to optimize the ATM network [10,11,12]. There are many variations to memetic algorithm, the approach that we have used in the paper is an enhancement over Genetic Algorithm.

GA is a non-traditional based optimizing technique which can be used to optimize the ATM network. GA operations [13, 14] can be briefly described as Coding, Initialization, Evaluation, Reproduction, Crossover, Mutation and Terminating condition. GA has been used in previous studies to optimize the ATM network and also in the design of ATM network [15]. Pan

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and Wang [16] used GA for allocating bandwidth in the ATM network but the limiting factor of their work is the encoding mechanism which is very complex for large networks. An easier encoding technique in GA was proposed by Shimamoto et. al.[17] in their work the ATM networks routing based on GA but the limiting factor of their work is they have not considered the average cell delay and have only considered the average blocking probability[18]. Another limiting factor of GA based solution is the time constraint. The time required to generate solution is quite high in GA. In this paper we propose an enhanced GA approach or memetic algorithm approach, which solves the problem of quick convergence from local optima that exists in GA, to the dynamic routing problem with a new technique to populate the generation which will provide an optimal solution in reduced time along with a comparison of the various selection mechanisms. Another limitation of GA is its quick convergence from local optima. In this paper we have proposed EGA based solution to overcome the limitation of GA. Previous research work shows the implementation of Memetic algorithm to assign cell to switches in mobile cellular networks [19] and to solve Traveling Salesman Problem (TSP) [20]. Another advance version of TSP problem was solved using Memetic Algorithm [21] and also in highly multimodal problems [22]. But after extensive literature survey we realized not much research has taken place in exploring Memetic Algorithm as a potential solver. So in this paper we have explored the application of MA using EGA to bandwidth optimization problem in ATM network.

2. ROUTING PROBLEM DESCRIPTION AND NETWORK MODEL

The ATM network model that we have considered in the paper is taken as a graph [18] G(N,L) . N represents switching nodes and L represents physical link, connecting each node [17]. Lij is the link between node i and j. The second order graph $G_L(N,P)$ where P represents the logical path connection. In this paper a sample network with seven switching nodes and ten physical links is considered in Fig.1. A pair of node is connected by one logical link by sharing the capacities of physical links connecting the nodes. The path created by connecting two nodes is bidirectional therefore the capacity requirement is the sum of the traffic demand in both directions and total paths will be N (N-1)/2. In this paper we have considered one VP sub-network (Fig.2.) carrying the same type of traffic with the same QoS requirement and also the VP sub-network is considered to be fixed. We have considered fourteen logical links in this paper. Bandwidth allocation to each VP is based on the deterministic bandwidth allocation [23]. The capacity allocation to each VP is done on the basis of equal distribution of physical capacity. The capacity is measured in Mbps.

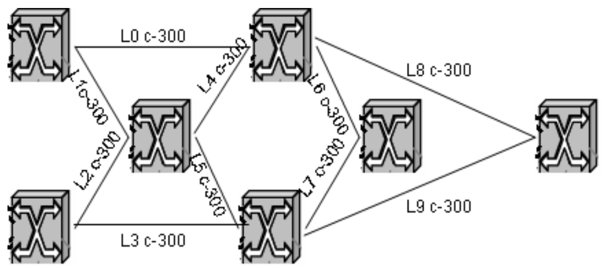

Fig.1. Network Model with Physical Link Capacity

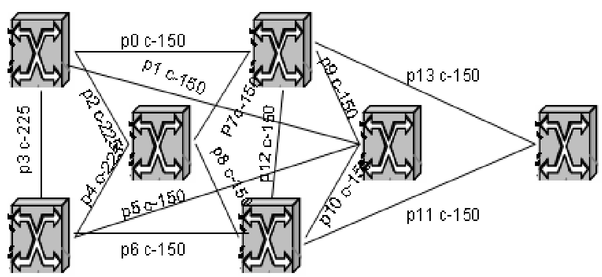

Fig.2. Network Model with Virtual Paths

3. OBJECTIVE FUNCTION

The network model that has been considered is a dynamically reconfigurable network model [24] that can be embedded into the backbone network to meet the traffic demand. In ATM networks to measure the network quality, buffer overflow probability is an important consideration. Buffer overflow probability is related to the average queue length and it is in turn related to the average cell delay[16]. Hence cell delay is an indirect measure of cell loss probability. Therefore average cell delay has been considered to be optimized in the objective function[16] given in (1).

Minimize

$$T = \frac{1}{\lambda} \sum_{m=1}^{M} \frac{f_m}{c_m - f_m} \quad (1)$$

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subject to, $f_m <= c_m$ for all VP_m in N, where, M = total number of VPs, λ = total external load on the network, f_m = total flow going through VPs in bps, c_m = Transmission capacity of VPm in bps, N = total number of nodes in the network

4. METHODOLOGY

Genetic Algorithm Approach

Encoding Mechanism: Network configuration has been encoded based on the multi-parameter encoding mechanism [17]. Route table are created for all pairs of node combination. The entries in the route table, corresponds to the virtual paths included between pair of nodes. In the proposed algorithm each route is identified by a route number which is in accordance to the row number in the route table and these constitutes the configuration strings.

Steps involved in Genetic algorithm:

Step1: Initialization - The very first step in GA is initialization. The routes are selected randomly from the route table. Between each pair of nodes a route is selected from the route table and that forms the configuration string (CS). A pool of all CS that satisfies the given constraint is maintained. The size of the pool is fixed which is greater than the population size and as new strings are generated the older strings are replaced by the newer ones. If in any generation, the population falls short of the size defined, the strings are chosen randomly from the CS pool.

Step 2: Evaluation - Based on the objective function the fitness of the CS are calculated. In this paper we are minimizing the average cell delay.

Step 3: Selection Mechanism: The selection (reproduction) operator is intended to improve the average quality of the population by giving the high-quality chromosomes a better chance to get copied into the next generation [14], [15]. The selection thereby focuses on the exploration on promising regions in the solution space. Selection pressure characterizes the selection schemes. It is defined as the ratio of the probability of selection of the best chromosome in the population to that of an average chromosome. Hence, a high selection pressure results in the population's reaching equilibrium very quickly, but it inevitably sacrifices genetic diversity (i.e., convergence to a suboptimal solution). The selection techniques used in GA for the above problem are the roulette wheel selection, Truncation selection and Tournament selection mechanisms.

Roulette-wheel Selection - In roulette wheel selection individuals are assigned a probability of being selected based on their fitness, pi = fi / Σfj, Where pi is the probability that individual i will be selected, fi is the fitness of individual i, and Σfj represents the sum of the fitness of all individuals in the population. Similar to using a roulette wheel, fitness of an individual is represented as proportionate slice of wheel. Wheel is then spun and the slice underneath the wheel when it stops determines which individual becomes a parent.

Truncation Selection - In truncation selection m parents are allowed to breed c offspring, out of which fittest m are used as parent in the next generation.

Tournament Selection - In tournament selection q individuals are randomly selected from the population, the best of the q individuals is returned as a parent. Selection Pressure increases as q is increased and decreases as q is decreased.

Step 4: Crossover - We have considered single point crossover in this paper. Two strings are selected from the parent string and a point is selected randomly. From that point onwards the strings are interchanged.

Step 5: Mutation - We have considered mutation rate of 0.5% in this algorithm.

Repeat Step 2 – Step 5 till the terminating condition is reached.

Terminating Condition

Terminating condition can be taken when average fitness is almost equal to the maximum fitness or the algorithm can be repeated for a fixed number of generations. Out of the two conditions whichever is reached first has been taken as the terminating condition.

Enhanced GA approach to Bandwidth Allocation

Memetic algorithm has been motivated by Dawkins' concept of meme. Meme is a unit of information that reproduces itself while people exchange ideas. Therefore, Memetic algorithms are termed as population based heuristic search techniques based on cultural evolution to solve combinatorial optimization problem. Genetic algorithms are based on evolution of genes. GA does not take into consideration the learning generated by cultural evolution. One of the

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limitations in GA based technique is quick convergence from local optima. Memetic algorithm can be used to overcome this limitation. One variation of memetic algorithm integrates GA with local search technique and has been termed as Enhanced GA. Enhanced GAs can be used in combination with genetic algorithms and local search algorithms to generate better solutions to optimization problems. The local search algorithm that has been considered in this paper is Hill climbing algorithm. In hill climbing the basic idea is to always head towards a state which is better than the current one. If such states are available, the algorithm searches for those states and if there are no such states available then the algorithm terminates. Pseudocode for Enhanced GA is given below:

```
pop = makeRandomPopulation
perform local search
while (not done)
        foreach p in pop
        p.fitness = evaluate(p)
        for i = 1 to size(pop) by 2
        ## select parents for reproduction
        parent1, parent2] = select two random
        solutions from
        pop
        [child1, child2] = crossover (parent1,
        parent2)
        mutate child1, child2
        replace old population with new
        population
        perform local search
```

Hill-climbing Algorithm (local search)
1. Let X := initial config
2. Let E := Eval(X)
3. Let i = random move from the moveset
4. Let Ei := Eval(move(X,i))
5. If E < Ei then
X := move(X,i)
E := Ei
6. Goto 3 till terminating condition is reached

Initial Population Generation: Initial population is generated and then local search technique namely Hill Climbing algorithm is used to generate the initial solution string.

5. RESULTS AND DISCUSSIONS

ATM Nodes	0	1	2	3	4	5	6
0	0	20	10	20	10	20	10
1	12	0	13	40	12	16	14
2	13	16	0	15	11	20	12
3	10	15	14	0	18	8	16
4	15	18	12	10	0	16	10
5	10	20	10	20	10	0	15
6	12	18	15	18	15	18	18

Table 1 Traffic specification

The algorithms were applied to the network model (Fig. 2). The traffic matrix for the nodes is given in Table1 has been considered for the evaluation of the algorithms and the flow capacities have also been listed in the network model. The algorithms were programmed in the C language.

Comparison of the algorithms on the basis of our experimental results shows that EGA performs better than GA (Fig. 5). The best result obtained by GA is 6.16µsec and with MA is 5.77 µsec. So, for the above problem according to our experimental results Enhanced GA is a better option for the dynamic routing problem in ATM network.

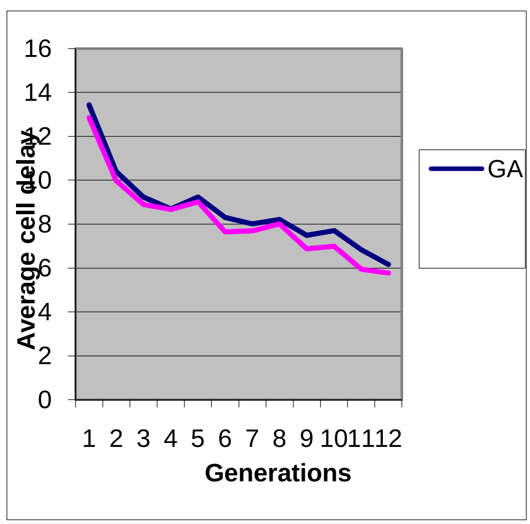

Fig.5. Comparison chart for average cell delay using Genetic Algorithm (GA) and Enhanced Genetic Algorithm (EGA).

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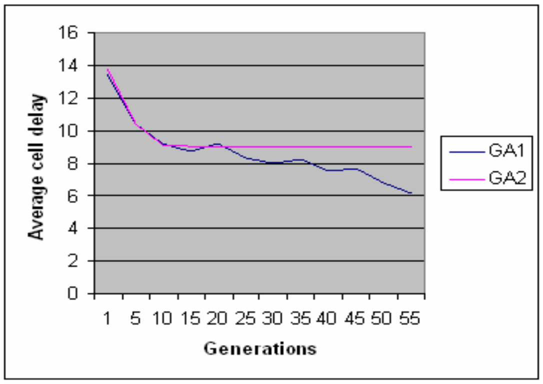

Fig.6. Comparison chart for average cell delay using Genetic Algorithm without implementing the new initialization technique (GA1) and Genetic Algorithm with new initialization technique (GA2).

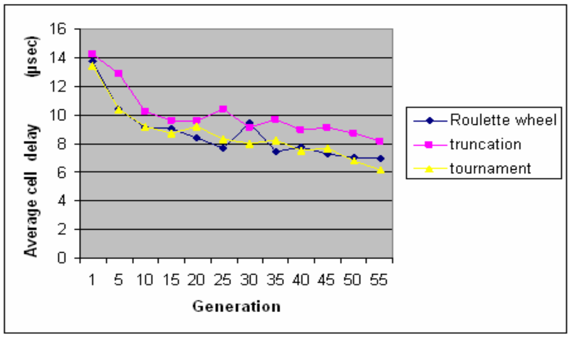

Fig.7. Comparison chart for average cell delay using different selection mechanisms in GA

On the basis of new Initialization method:

It was observed (Fig. 6) that by using the new technique that has been described, genetic routing algorithm gives an optimal results and the fitness value does not converge to a constant value. Earlier without the implementation of the technique it was observed that after a few initial generations the GA string started to converge to a constant value in which the population became almost identical. After implementing the new technique it was observed that the strings did not converge to same value prematurely but successful runs were possible till the desired number of generations.

On the basis of the selection mechanism:
Results of comparison (Fig 7) prove that out of the three mechanisms the tournament selection mechanisms gives much better result than the roulette wheel and truncation selection methods. The experimental results are shown in the graph. In case of truncation selection it was observed, the average cell delay was quite high and the variations in the cell delay was also quite high throughout the generations. In case of roulette wheel selection it was observed, the variation was not high throughout the generations but the average cell delay was more than the tournament selection method. Roulette wheel selection, as observed, gave better results than the truncation selection. In case of tournament selection it was observed, the variations were within acceptable limit and the average cell delay was better than the roulette wheel and truncation selection methods. After having incorporated tournament selection in the base GA algorithm and then implementing it in the MA the average cell delay was noted as 5.77 µsec.

6. CONCLUSIONS

The future ATM based broadband integrated service digital network is expected to support varied traffic with varied traffic patterns, so dynamic routing is an important factor for desired network performance. In this paper we have compared Genetic algorithm and Enhanced Genetic algorithm to dynamically route the ATM network traffic. Our experimental results show that EGA is a better option to solve the dynamic routing problem in ATM network. Also the results obtained by implementing the new initialization technique in GA shows that the configuration string does not converge to a consistent value prematurely as a result the solution obtained is optimal and the amount of time required by the algorithm, to generate an optimal solution, is also reduced. We have also presented a comparison of the selection techniques in GA. Our experimental results show that EGA gives best average cell delay which is 5.77 µsec, according to the experimental network model. Thus optimized bandwidth is achieved. For future work EGA approach can be considered for the bandwidth optimization in wireless ATM network.

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