Bandwidth Optimization through Dynamic Routing in ATM Networks: Genetic Algorithm & Tabu Search Approach

Susmi Routray, A. M. Sherry, and B. V. R. Reddy

Abstract—Asynchronous Transfer Mode (ATM) is widely used in telecommunications systems to send data, video and voice at a very high speed. In ATM network optimizing the bandwidth through dynamic routing is an important consideration. Previous research work shows that traditional optimization heuristics result in sub-optimal solution. In this paper we have explored non-traditional optimization technique. We propose comparison of two such algorithms - Genetic Algorithm (GA) and Tabu search (TS), based on non-traditional Optimization approach, for solving the dynamic routing problem in ATM networks which in return will optimize the 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 GA.

Keywords—Asynchronous Transfer Mode(ATM), Genetic Algorithm(GA), Tabu Search(TS).

I. 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] is 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 techniques GA and TS which can be used to optimize the ATM network [10,11,12].

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 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 a GA approach 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.

The basic concept of Tabu Search is described by Glover [19, 20] in 1989 for solving combinatorial optimization problem. It is kind of iterative search and is characterized by the use of a flexible memory. Tabu search is basically, a single solution, deterministic neighborhood search technique that uses memory - a "tabu list, to prohibit certain moves, even if they are improving. This makes tabu search a global optimizer rather than a local optimizer. The components of Tabu search algorithm are Encoding, Initial solution, Objective Function, Move operator, Definition of Neighborhood, Structure of Tabu list(s), Aspiration criteria (optional), Termination criteria. Tabu search approach has been used in ATM networks to solve the design problem [21] of the trunk group (TG) overlay in wide area ATM networks under reliability constraints to ensure the successful rerouting of the S-PVCs and also in the S-PVC network planning [22] but after extensive literature survey we realized not much research has taken place on Tabu search implementation for

dynamic routing problem in ATM network. So in this paper we have explored the same and compared it with GA.

II. 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.
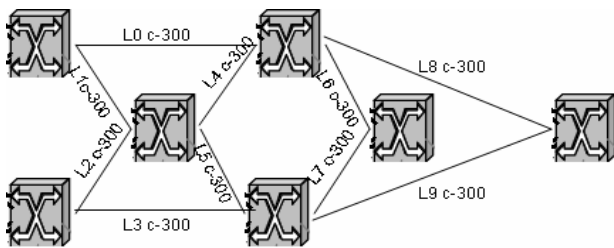

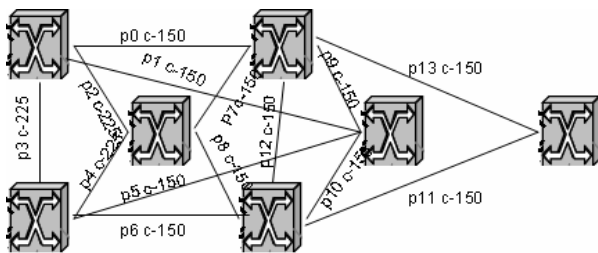Fig. 1 Network Model with Physical Link Capacity

Fig. 2 Network Model with Virtual Paths

III. 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).

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

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 VP_m in bps, N = total number of nodes in the network.

IV. 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 satisfy 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 removed 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 -Based on the fitness function parents are selected and children are produced. In this paper we have taken into consideration the roulette wheel selection, Truncation selection and Tournament selection mechanisms.

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.

Tabu Search Approach

Step 1: The inputs to the algorithm are the routes that will be obtained from the route matrix and which will constitute the configuration string. The initial CS is generated randomly and

which should satisfy the given constraints explained in the previous section.

Step 2: Set maximum number of iterations MAX, the size of the tabu list S_TABU and M_TABU is the tabu memory. Initialize the tabu list with random CS fitness values and tabu memory entries to zero.

Step 3: Randomly generate two route numbers to be swapped. Swap the routes in the CS and make an entry in the tabu memory. Those routes for which the tabu memory entry is not zero cannot be considered for swapping.

Step 4: Check for the constraint.

Step 5: Calculate fitness for the CS. If the value is already present in the list consider it tabu or enter the value in the tabu list.

Repeat step 3 to step 5 till the terminating condition is reached.

Step 6: Output the best solution (i.e., the one with the minimum cell delay) from the tabu list.

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 that is taken as the terminating condition.

We have implemented a generalized tabu search algorithm. We have not considered any aspiration criteria in this algorithm.

V. RESULTS AND DISCUSSIONS

TABLE I
TRAFFIC SPECIFICATION

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

The algorithms were applied to the network model (Fig. 2). The traffic matrix for the nodes is given in Table I 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 both GA and TS are converging to nearly same values. In TS the variation in the average cell delay is quite high across the generations as compared to GA (Fig. 3). On the basis of VP flow and utilization factors, (Table II), it can be inferred that GA is utilizing the VP's more efficiently than TS. So for the above problem according to our experimental results GA is a better option for the dynamic routing problem in ATM network.

TABLE II
FLOW AND UTILIZATION TABLE FOR GENETIC AND TABU SEARCH ROUTING ALGORITHM

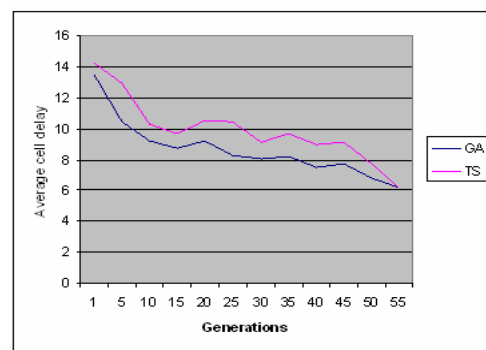| VP No.	Capacity	Tabu - Flow	Tabu - Utilization	GA-Flow	GA-Utilization
0	150	30	0.2	97	0.64
1	150	20	0.13	84	0.56
2	225	48	0.21	129	0.57
3	225	32	0.14	124	0.55
4	225	84	0.37	109	0.48
5	150	46	0.30	63	0.42
6	150	30	0.2	110	0.73
7	150	112	0.74	98	0.65
8	150	106	0.7	96	0.64
9	150	28	0.18	51	0.34
10	150	56	0.37	42	0.28
11	150	20	0.13	30	0.2
12	150	30	0.2	60	0.4
13	150	20	0.13	30	0.2
			Avg. 0.28		Avg. 0.47

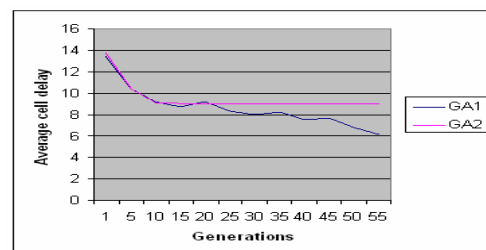Fig. 3 Comparison chart for average cell delay using Genetic Algorithm(GA) and Tabu search algorithm(TS)

Fig. 4 Comparison chart for average cell delay using Genetic Algorithm without implementing the new initialization technique (GA1) and Genetic Algorithm with new initialization technique (GA2)
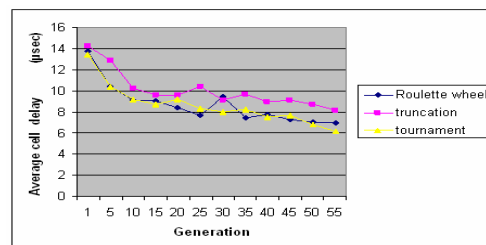
Fig. 5 Comparison chart for average cell delay using different selection mechanisms in GA

It was observed (Fig. 4) 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. In our experimental result we have shown the result for the 55 generations which proves that the string does not converge prematurely.

Results of comparison (Fig. 5) proves 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. The average cell delay that was observed by the tournament selection is 6.16µsec. The comparison results of delay variation between average cell delay and minimum cell delay using tournament selection in GA also shows that the variation is not very high and the variation is more or less consistent (Fig. 6).
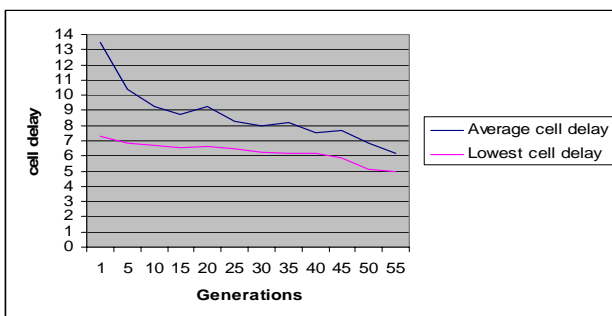

Fig. 6 Comparison chart for delay variation between average cell delay and minimum cell delay using tournament selection in GA

VI. CONCLUSION

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 generalized Tabu search algorithm to dynamically route the ATM network traffic. Our experimental results show that Genetic algorithm is a better option to solve the dynamic routing in ATM network problem. 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 the tournament selection method gives the best average cell delay which is 6.16µsec, according to the experimental network model. Thus optimized bandwidth is achieved. For future work hybrid approach can be considered for the routing problem.

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Susmi Routray received MCA degree from Barkatullah University Bhopal, India and currently pursuing a Ph.D. degree from University School of Information Technology, Indraprastha University, Delhi, India. She is currently holding the position of Assistant Professor at IMT Ghaziabad, India. She has been contributing papers in national and international conferences. Her research interests include ATM, Wireless ATM, Mobile and Wireless Communication, Operating Systems and Computer Algorithm.

A. M. Sherry is a Ph.D., M.Sc.(Gold Medalist), M.Tech.-Computer Science from IIT Kharagpur, India. He is currently holding the position of Professor at IMT Ghaziabad, India. His Specialization is in the field of Computer Networks, inter-networking technologies and wireless communications. He has more than 15 years experience in teaching and research. He has published over 25 papers in international/national journals and conferences. He is an Information Technology Consultant of National Hydroelectric Power Corporation Ltd. (A Govt. of India Enterprise) and a Member of the Task Force for strengthening of Information Technology Application in Ministry of Power, Government of India.

B. V. R. Reddy received his B.E(E.C.E) from Andhara University, Waltair(A.P), M.E(E.C.E) from University of Roorkee, Roorkee(U.P) and Ph.D(E.C.E)from Kurukshetra University,Kurukshetra (Haryana),India He is currently holding the position of Professor in the University School of Information Technology, Indraprastha University, Delhi. He is a member of various professional bodies like ISTE, IE and IETE. He has many research publications to his credit. His teaching and research interests include semiconductor devices and circuits particularly using microwave and optical devices, microwave and optical communications, computer communication networks.