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Meta-Heuristic Techniques for Bandwidth Optimization through Dynamic Routing in ATM Networks

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Abstract: Asynchronous Transfer Mode (ATM) is widely used in telecommunications systems to send data, video and voice at a very high speed. ATM based B-ISDN is expected to support varied traffic with varied traffic patterns for dynamic routing for desired network performance. The average cell delay of the entire network is minimized by dynamically routing the traffic. This study proposes a HYBRID approach based on the meta-heuristic optimization techniques using Genetic Algorithm (GA) and Tabu Search (TS) for solving the dynamic routing problem in ATM networks and to optimize the bandwidth. The initialization technique is used to populate the generation to provide an optimal solution at reduced time to avoid premature convergence and efficiency improvement. The algorithm has been coded in the C language.

Key words: Asynchronous Transfer Mode (ATM), Genetic Algorithm (GA), Tabu Search (TS), dynamic routing

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. 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. Since, ATM is asynchronous, 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.

Gupta *et al*. (1993) found that different traffic types with varied traffic characteristics and different QoS requirements can co-exist with Virtual Path (VP) sub networks within ATM network .VP is basically a logical link between two nodes carrying the same type of traffic. Sato *et al*. (1990) suggest that a VP network is one of the best ways of utilizing the ATM networks. Tanterdtid *et al*. (1997) found that a large number of virtual connections are supported by a VP, as express pipes, between ATM nodes. This study explores hybrid approach based on meta-heuristic optimizing techniques GA and TS to optimize the ATM network through the algorithmic procedure.

GA has been used in previous studies to optimize the ATM network and also in the design of ATM network studied by Thompson and Bilbro (2000). Pan and Wang (1991) used GA for allocating bandwidth in the ATM network but the limiting factor of their work is the encoding mechanism that is complex for large networks. An easier encoding technique in GA proposed by Shimamoto (1993) the average cell delay has not been taken into account and has considered only the average blocking probability. Another limiting factor of GA based solution is the time constraint. The time required to generate solution is quite high in GA. In this study, GA approach has been proposed to the dynamic routing problem to populate the generation and to provide an optimal solution in reduced time.

GA and TABU approach is compared independently by Susmi *et al*. (2006). The variation in the average cell delay is quite high across generations for TABU as compared to GA and also TABU utilizes less calculation time than GA. To avoid trade off between these two, hybrid approach is used by combining features of two algorithms. Simple GA and generalized TABU search is used for hybrid approach.

Network model: In this study one fixed VP sub-network as given in Fig. 1 with 13 logical links carrying the same type of traffic with the same QoS requirement is considered. Bandwidth allocation to each VP is based on

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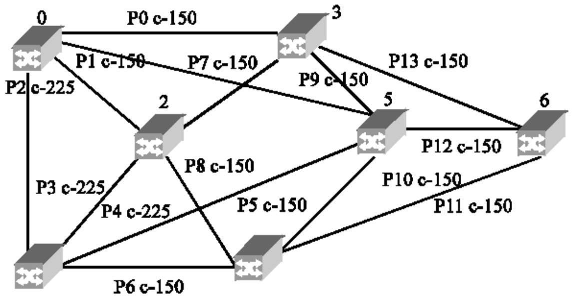

Fig. 1: Network model with virtual paths

the deterministic bandwidth allocation from the studies made by Sato and Sato (1991). The capacity allocation to each VP is done on the basis of equal distribution of physical capacity. The capacity is measured in Mbps. 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).

Objective function: Suruagy *et al*. (1989) considered the network model that is a dynamically reconfigurable network model and 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. Hence cell delay is an indirect measure of cell loss probability. The average cell delay has been considered for optimization in the objective function given by Pan and Wang (1991) in Eq.(1).

$$\text{Minimize} \quad T = 1/\lambda \sum_{m=1}^{M} Fm/Cm - Fm \qquad (1)$$

Subject to,

$$Fm < Cm \text{ for all VPm in N}$$

T = Average cell delay in sec.
M = Total number of VPs.
λ = Total external load on the network.
Fm = Total flow going through VPs in bps.
Cm = Transmission capacity of VPm in bps.
N = Total number of nodes in the network.

MATERIALS AND METHODS

Hybrid genetic-tabu approach

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

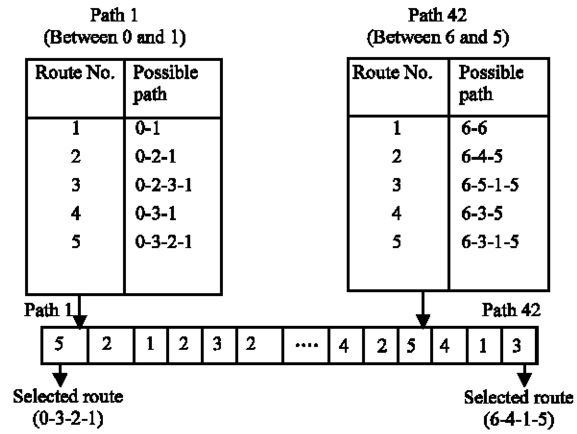

Fig. 2: An example of configuration string

Steps involved in algorithm

Step 1: 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) as shown in Fig. 2. 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. 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 and the average cell delay is minimized.

Step 3: Selection: Based on the fitness function, parents are sorted out in the current population.

Step 4: N best individuals from current population are copied to a temporary population. From this temporary population, two individuals are randomly selected and then mated using single point crossover.

Step 5: After restoring the feasibility, the child is improved by TABU Search algorithm which is explained from step 6 to step 10.

Step 6: 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 7: Randomly generate 2 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 8: Check for the constraint.

Step 9: 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 7-9 till the maximum number of iterations is reached.

Step 10: Output the best solution (i.e., the one with the minimum cell delay) from the Tabu list.

Step 11: If the improved individual is better than the worst one of the temporary population, it is added to the current population and replaces the oldest individual. Otherwise, it is rejected.

Step 2-11 are repeated 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 or the algorithm reaches a pre-threshold value. Out of these conditions whichever is reached first has been taken as the terminating condition. The flowchart for the hybrid algorithm is shown in Fig. 3.

Hybrid approach

```
P = Initial population
While not stop do
  For each cs in P
    cs.fitness = evaluate (cs)
    TP=N best individuals of P
    (P1, P2)=Parents (TP)
    S=Crossover (P1, P2)
    S=Tabu Search(S, no of iterations)
    P=Add population(S, P)
End while
```

Tabu approach

```
Input: Feasible configuration string S0, no of iterations L.
Output: New feasible configuration S
S=S0
For i=0 to L do
Choose the best authorized move
Update the tabu memory with the chosen move
Perform the chosen move in S
Update the tabu list with S.
End for
```

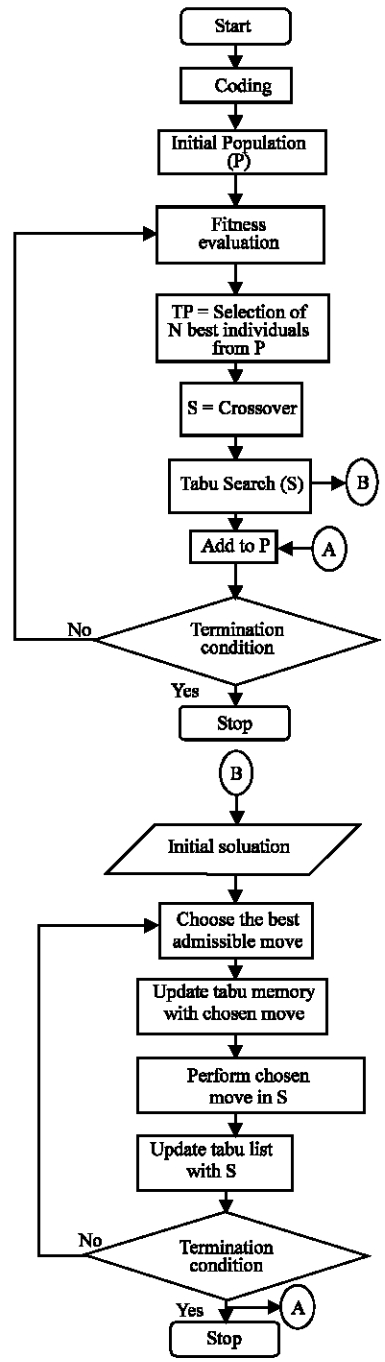

Fig. 3: Flowchart for hybrid genetic Tabu approach

RESULTS AND DISCUSSION

The traffic matrix for the nodes Table 1 has been considered for the evaluation of the algorithms and the flow capacities have also been listed in the network model. The algorithm is coded in the C language on an IBM/PC Compatible system.

Table 1: Traffic specification (Average offered flow of Commodity)

ATM source nodes	ATM destination 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	0

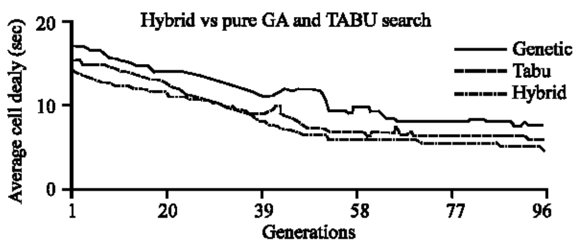

Fig. 4: Comparison chart of average cell delay using GA, TABU independently and HYBRID approach

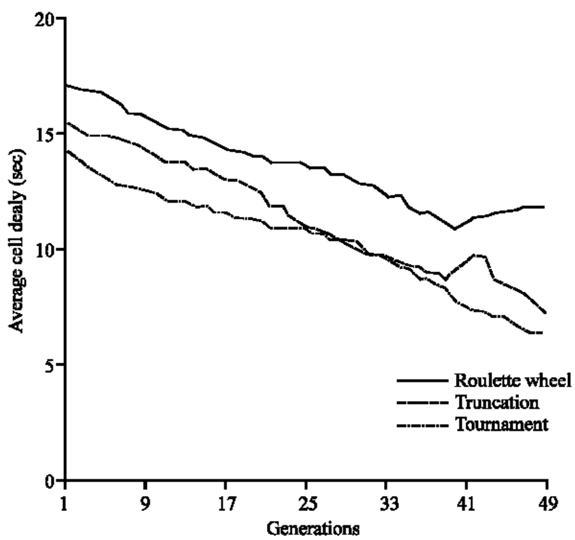

Fig. 5: Comparison of different selection mechanisms

The performance of the network is determined by the bandwidth utilization factor of the network based on the traffic specification. The Fig. 4 shows the comparison results of proposed hybrid algorithm with independent GA and TS algorithm. The average cell delay is minimized along the generations in the proposed algorithm compared to independent GA and TS. The hybrid approach gives the average cell delay of 4.88 sec whereas the pure GA gives the average cell delay of 6.12 sec and the pure TS gives the average cell delay of 7.8 sec for 100 generations.

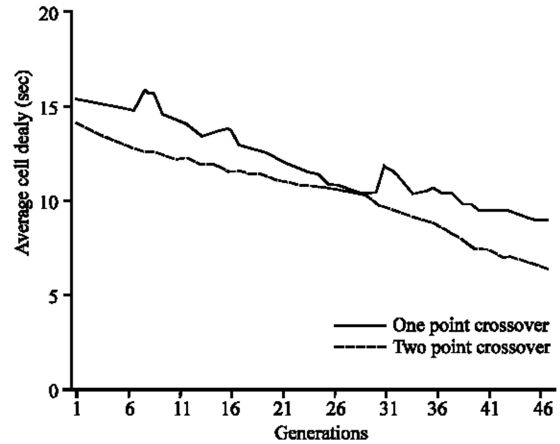

Fig. 6: Comparison of different crossover operators

The network performance have been analyzed using the proposed algorithm with different selection mechanism such as roulette wheel selection, truncation selection and tournament selection for the strings to get reproduced in the genetic operations. The various selection methods selects the best strings based on their fitness value to survive in the next generations. The Fig. 5 shows the comparison results.

From the comparison results, it is shown that the average cell delay of tournament selection mechanism gives the better value of 6.35 sec compared to roulette wheel selection which gives 7.28 sec of cell delay and truncation selection gives 8.86 sec of cell delay.

The network performance have been analyzed using the proposed algorithm with different crossover operators such as single point crossover and two point crossover operator for the strings to get mated in the mating pool. The various crossover operators produce new offspring in the mating pool to make the strings survive in the next generations. The Fig. 6 shows the comparison results.

From the comparison results, it is observed that the average cell delay of single point crossover operator gives the better value of 6.35 sec compared to 2 point crossover operator which gives 9.0 sec of cell delay. On the basis of VP flow and utilization factors, from the Table 2, it can be inferred that hybrid is utilizing the VP's more efficiently than GA and TS. The best virtual path network specifications are given in Table 3. The optimum results is obtained by tournament selection.

Table 2: Flow and utilization table

		Hybrid		Genetic		Tabu	
Vp No.	Capacity (Bits per Second)	Flow (Bits per Second	Utilization Factor (Flow/Capacity)	Flow (Bits per Second	Utilization Factor (Flow/Capacity)	Flow (Bits per Second	Utilization Factor (Flow/Capacity)
0	150	107	0.71	97	0.64	30	0.20
1	150	89	0.59	84	0.56	20	0.13
2	225	93	0.62	129	0.57	48	0.21
3	225	119	0.79	124	0.55	32	0.14
4	225	80	0.53	109	0.48	84	0.37
5	150	102	0.68	63	0.42	46	0.30
6	150	125	0.83	110	0.73	30	0.20
7	150	119	0.79	98	0.65	112	0.74
8	150	108	0.72	96	0.64	106	0.70
9	150	74	0.49	51	0.34	28	0.18
10	150	87	0.58	42	0.28	56	0.37
11	150	68	0.45	30	0.20	20	0.13
12	150	89	0.59	60	0.40	30	0.2
13	150	57	0.38	30	0.20	20	0.13
	Average		0.62		0.47		0.28

Table 3: The best virtual path specification

Source-destination	Paths taken	Source-destination	Paths taken
0-1	p1,p5	3-4	p0,p1,p10
0-2	p2	3-5	p2,p3,p5,p7
0-3	p2,p4,p5,p9	3-6	p9,p12
0-4	p3,p4,p8	4-0	p0,p10,p9
0-5	p2,p7,p9	4-1	p4,p8
0-6	p1,p12	4-2	p2,p1,p10
1-0	p2,p6,p8	4-3	p0,p2,p6
1-2	p5,p7,p9	4-5	p1,p2,p8
1-3	p0,p3	4-6	p11
1-4	p4,p7,p9,p10	5-0	p8,p4,p10
1-5	p4,p7,p9	5-1	p2,p1,p4
1-6	p5,p10,p11	5-2	p6,p4,p10
2-0	p0,p7	5-3	p0,p1
2-1	p3,p7,p0	5-4	p5,p6
2-3	p10,p8,p9	5-6	p9,p13
2-4	p2,p3,p4,p8	6-0	p0,p13
2-5	p10,p8	6-2	p7,p13
2-6	p8,p11	6-3	p13
3-0	p4,p3,p7	6-4	p5,p6,p12
3-1	p5,p9	6-5	p12
3-2	p0,p2		

CONCLUSION

In this study, hybrid approach based on Genetic Algorithm and Tabu search is proposed for dynamic routing problem in ATM network. The simulation results show that hybrid approach gives the better average cell delay than pure GA and pure TABU by obtaining the optimized bandwidth. Future research can be carried by parallel GA with reactive Tabu search for solving routing problem.

Acronyms:

ATM = Asynchronous Transfer Mode.
CS = Configuration String.
GA = Genetic Algorithm.
B-ISDN = Broadband Integrated Services Digital Network.
QoS = Quality of Service.
S-PVC = Soft-Permanent Virtual Connections.
TG = Trunk Group.
ITU-T = International Telecommunication Union-Telecommunications.
TS = Tabu Search.
VC = Virtual Circuit.
VPI = Virtual Path Identifier.
VP = Virtual Path.

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