International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:1, No:8, 2007

Design and Bandwidth Allocation of Embedded ATM Networks using Genetic Algorithm

H. El-Madbouly

***Abstract*—**In this paper, genetic algorithm (GA) is proposed for the design of an optimization algorithm to achieve the bandwidth allocation of ATM network. In Broadband ISDN, the ATM is a high-bandwidth; fast packet switching and multiplexing technique. Using ATM it can be flexibly reconfigure the network and reassign the bandwidth to meet the requirements of all types of services. By dynamically routing the traffic and adjusting the bandwidth assignment, the average packet delay of the whole network can be reduced to a minimum. M/M/1 model can be used to analyze the performance.

***Keywords*—**Bandwidth allocation, Genetic algorithm, ATM Network, packet delay.

I. INTRODUCTION

IT is great interest of today's technology to have a network that can implement aspects of both the circuit switched and packet-switched networks. ISDN (integrated services digital networks) comes up to replace data networks and voice networks that give users an integrated service. Users need not buy multiple services for multiple needs; instead, they can obtain multiple services through a single access link.

As the optical fiber transmission and the microelectronic switching technology mature rapidly, BISDN (Broadband ISDN) which can offer transmission capacity of up to Gbits/s emerges. HDTV, video telephone, high speed data transfer, are the targeted services of this developing network. Circuit switching can no longer handle the wide range of different bit rates and traffic parameters required by the BISDN, new switching techniques have to be developed for replacement. Asynchronous transfer mode (ATM) has been proposed as the most prospective candidate. ATM is a high-bandwidth, low delay, packet-like switching (or fast-packet switching), and multiplexing technique [1].

In ATM, usable capacity (band-width) is segmented into short fixed-size information units called cells [2]. The voice service will benefit from the high speed transmission of these short cells and face only very short delays. Users can also negotiate with the network manager in the call set-up procedure and adjust the service quality so that network can accommodate as many service requirements as possible.

H. El-Madbouly is with academic of special studies, Technology department, Worker University, Alexandria-21544, Egypt (e-mail: h_elmadbouly@yahoo.com).

Thus, ATM equipment can flexibly support a wide variety of services with different information transfer rates.

In order to meet a variety of services, the ATM switches are connected with multiples of SD3 trunks via Digital Cross connect systems (DCS). One of the advantages of DCS is its ability to reconfigure a customer network dynamically. In this paper, genetic algorithm is used to conduct the dynamic network reconfiguration following trunk failures, and the reassignment of trunk capacities to applications in response to traffic changes.

Genetic algorithms, developed by john Holland, provide robust and efficient search in complex spaces. Survival of the fittest among string structures and structured yet randomized information exchanges are the basic philosophies behind these algorithms [3]. They have been applied to a variety of function optimization problems and, also, combinatorial problems such as the traveling salesman problem [4].

II. THE MODEL USED

A network with backbone facilities (i.e., number and location of DCS switches, interoffice fiber trunks, etc.) defined is shown in Fig. 1 In [6], a dynamically reconfigurable P/S network model that can be embedded into this backbone network to meet the traffic demand has been proposed. A number of express pipes installed between remote nodes through DCS's are illustrated in Fig. 2, where the broken lines denote the express pipes and the solid lines represent the local routes. Using the express pipes can reduce the number of intermediate hoes along the path and the number of packet-switching terminations. Thus, the store and forward time delay as well as the hardware cost can be substantially diminished [6].

With above network model, the network optimization problem is also formulated in (6) to minimize the average packet delay subject to the trunk capacity constraints offered by the underlying fiber trunk, two variables are considered: one is the traffic routing over the express pipes, and the other is the allocation of the bandwidth (capacity) in these pipes. In ATM nets, the buffer overflow probability at switching nodes is an important factor measuring the network quality. It is well known that buffer overflow probability is related to average trunk queue lengths, and the latter are related to the average delay. Therefore, average delay can be chosen as the indirect measure of buffer overflow probability. Also, the finite capacity of ATM switches would lead to an internal buffer overflow problem and the overflow probability is a function of the aggregate traffic transit through the switch. M/M/1 queues are used in [6] to model both of the trunk and the switch.

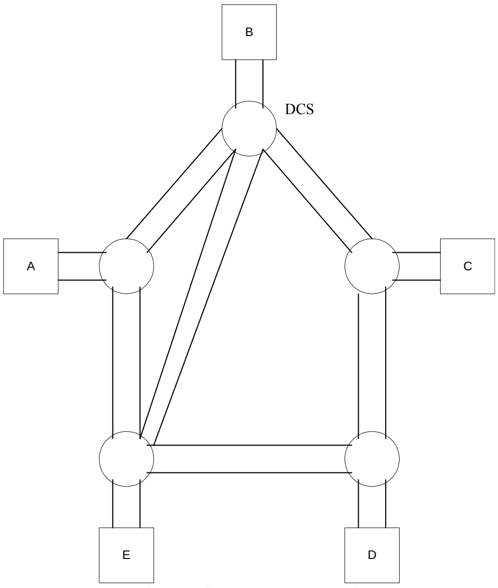

Fig. 1 The ATM Network

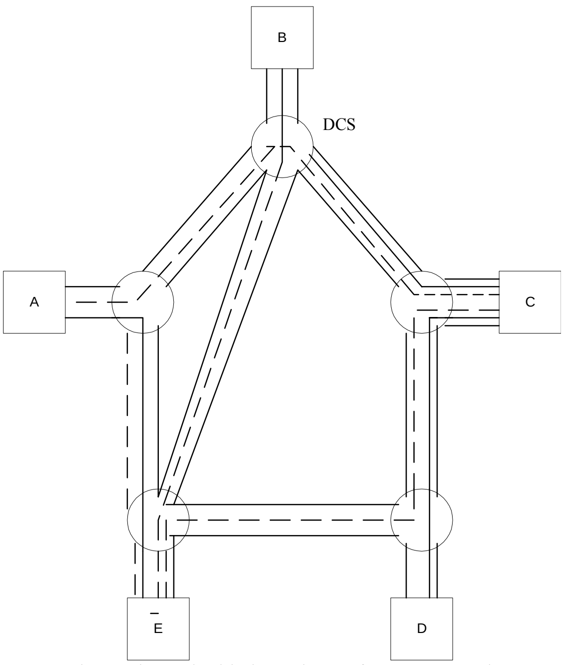

Fig. 2 The embedded topology of ATM network

A commodity com (i,j) is defined as a flow of packets offered by i and destined for j. The total number of commodities of the network is denoted by Q. If the average offered flow of commodity k is r_k and $1/\mu$ denote the average packet length, the average arrival rate will be

$$\lambda = \mu \sum_{k=1}^{Q} r_k$$

In addition, each ATM switch is modeled as two nodes of infinite capacity joined by a link of capacity C_m. Let M represent the sum of the number of embedded links and fm be the flow on the m, the total average packet delay can be written as

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

The goal is to minimize the average packet delay under the fixed trunk capacity constraints, or more precisely, to choose traffic flow routing over the embedded links and allocate the embedded link bandwidth so that:

(1) the average packet delay is minimized.
(2) the aggregate bandwidth of all paths using the trunk cannot exceed the capacity of this trunk.
(3) the flow on each path must not exceed the bandwidth. of this path.
(4) the total flow of each commodity carried on all the paths must be equal to the commodity offered by its source.

The cost function T is not a convex function with respect to both C_m and f_m, and thus, it may have more than one local minimum [7].

In the backbone network shown in Fig. 2, there is having 4 possible paths: A-F-G-H-I-D, A-F-G-J-I-D, A-F-J-I-D, and A-F-J-G-H-l-D existing between nodes A and D. The traffic between them may choose one or more of these four paths to go through. The capacities of each link are multiples of a basic data rate channel such as 150 Mbit/s. Each link with which the path or paths associated will allocate all or partial of its capacities to this path or these paths according to the traffic amount on the paths.

For example, if traffic flows go through the path A links 1, 2 and 3 are used. Part of the capacities in links 1 or 2 or 3 has to be assigned to this path.

Since only the total traffic between nodes is concerned here, we define traffic *traf(i,j)* as the combination of both commodities *com(i,j)* and *com(j,i)* and use it to describe the state of the network.

In our optimization problem, we need to select the traffic paths and allocate the capacity of link (i.e., bandwidth) to them such that the average packet delay in (1) is minimized. Thus, the system variables C_m (the capacity of the m^{th} embedded link) and fm (the traffic volume going through the m^{th} embedded link) have to be coded into strings, so that each string can represent the network features entirely and, by decoding the string, the network delay T can be easily computed to guide the search. Let S be one of the strings used to describe a M-node network and

$S=(S_{01}, S_{02}, \ldots, S_{ij}, S_{M-1,M})$

The value of S is determined according to the value of *traf(i,j)*, links included in the embedded path between nodes i, and the link capacity assigned to this path.

International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:1, No:8, 2007

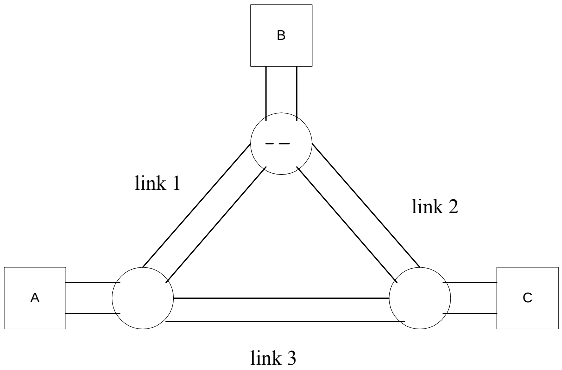

Fig. 3 A three-node ATM network

In a simple example shown in Fig.3, S = (S_{AB}, S_{AC}, S_{BC}). There are two embedded paths existing between A and B which occupy part of link *i* and link2 +link3, respectively. If the capacity of each link is three and *traf (A,B)* is two, then the value of can be determined by the following table:

TABLE I
DECISION TABLE FOR THE VALUE OF STRING ELEMENT

S_{AB}	Channel allocated to emb. Path 1	Channel allocated to emb. Path 2	Traffic going through emb. Path 1	Traffic going through emb. Path 2
0	0	2	0	2
1	1	2	0	2
2	2	2	0	2
3	3	2	0	2
4	0	3	0	2
5	1	3	0	2

.
.
.

III. THE ALGORITHM

Step 1. Initialization of the strings

The first generation of strings are created randomly except that all the constraints must be satisfied, i.e., the traffic on all links that compose one embedded path is consistent, the traffic on each link must not exceed the bandwidth of this link and the sum of the capacities assigned to all the embedded paths going through this link cannot exceed the capacity of this link.

Step 2. Evaluation of the strings

The average packet delay of network is found for each siring by using (1).

Step 3. Reproduction

According to its delay value, we decide the survival of a string. The string with shorter delay will have more offspring in the next generation. Thus, good strings survive and bad strings die off.

Step 4. Crossover

Randomly choose two strings as parents, and randomly pick up a Site fl the strings. Exchange all elements of father and mother before the Site and remain the rest unmoved. Two children are born.

Step 5. Checking constraints

Illegitimate new string that does not satisfy the constraints mentioned before is created through the crossover. Grant it with a very large delay and expect it dying out in the next reproduction. Go to step 2 and repeat the procedures.

IV. SIMULATION RESULTS

Simulation is conducted on the network with 5 nodes and 6 links illustrated in Fig. 1. Each link is assigned with an ID number as shown in Table II. The link capacity is 40 and node capacity is 60. There are 32 possible embedded paths existing in this network. The traffic requirements are given in Table III.

With 10 elements in each siring, a population of 80 strings is created in each generation. These 80 strings describe 80 net work configurations, and there are 80 delay values associated with them. The shortest delay among them improves in every generation throughout the simulation.

TABLE II
LINK ID ASSIGNMENT

	A	B	C	D	E
A	-	0	-	-	4
B	0	-	1	-	5
C	0	1	-	2	-
D	-	-	2	-	3
E	4	5	-	3	-

TABLE III
TRAFFIC REQUIREMENTS

	A	B	C	D	E
A	-	3	3	1	4
B	3	-	4	0	6
C	3	4	-	5	1
D	1	0	5	-	2
E	4	6	1	2	-

In the initial population, shortest packet delay is 0.364169. The shortest packet delay drops to 0.271230 in the 20th generation and a 25.5% improvement is obtained. The shortest and the average delay in each of the 20 generations are shown in Fig. 4.

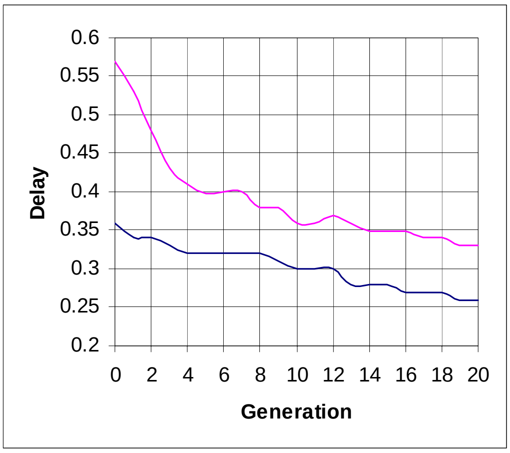

Fig. 4 The shortest and the average delay in 20 generations

Since *T* is an unconvex cost function, more than one local minimum exist. The simulation program has been run 30 times to locate better network configurations that yield a shorter delay. The best network configuration as listed in Table 4 is found in run 28, and the associated delay is 0.239196. The first three rows in Table IV show that all the traffic between nodes A and B is allocated to embedded path 1 which occupies a bandwidth of 10 on each of link 4 and 5. However, the traffic between nodes B and C is divided into two parts: three quarters of it uses embedded path 15 and the rest uses embedded path 16.

TABLE IV
THE BEST NETWORK CONFIGURATION

Emb. path	Link 0 1 2 3 4 5	Source node	Destination node	traffic	Band width
0	1*****	0	1	0	0
1	****11	0	1	3	10
2	*1111*	0	1	0	0
3	11****	0	2	0	0
4	1*11*1	0	2	3	8
5	*1**11	0	2	0	0
6	**111*	0	2	0	0
7	111***	0	3	1	3
8	1**1*1	0	3	0	0
9	***11*	0	3	0	0
10	*11*11	0	3	0	0
11	1111**	0	4	0	0
12	1****1	0	4	2	7
13	****1*	0	4	2	7
14	1*111*	1	2	0	0
15	*1****	1	2	3	11
16	**11*1	1	2	1	3
17	1**11*	0	0	0	0
18	*11***	0	0	0	0
19	***1*1	0	0	0	0
20	1***1*	1	4	6	12
21	*111**	1	4	0	0
22	*****1	1	4	0	0
23	11*11*	2	3	0	0
24	*1*1*1	2	3	0	0
25	**1***	2	3	5	13
26	11**1*	2	4	1	3
27	*1***1	2	4	0	0
28	**11**	2	4	0	0
29	111*1*	3	4	2	7
30	*11*11	3	4	0	0
31	***1**	3	4	0	0

V. CONCLUSION

In this paper, we have developed an algorithm to manage the bandwidth allocation and the traffic routing in the ATM network. The simulation results show that a substantial delay improvement (41.8%) can be achieved within 30 iterations.

REFERENCES

[1] William Stallings, Integrated Services Digital Networks (ISDNJ) Computer Society Press, 1998.
[2] S.E. Minzer, "Broadband ISDN and Asynchronous Transfer Mode (ATM)," IEEE Communications Magazine, pp.17- 57, September 1998.
[3] D.E. Goldberg, Genetic Algorithms in search Optimization and Machine Learning, Addison-Wesley Publishing Company INC., 1989.
[4] J. Grefenstette, R. Gopal, B. Rosmaita, D.V. Gucht, "Genetic Algorithms for the Traveling Salesman Problem," Proceeding of an International Conference on Genetic Algorithms and Their Application, pp.160-168. 1995.
[5] Goldberg, "Genetic Algorithms and Rule Learning in Dynamic System Control," Proceeding of an International Conference on Genetic Algorithms and Their Application, pp.8-15, 2000.
[6] J.A.S. Monteiro and R. Pazos, "Topology Design and Bandwidth Allocation in ATM Nets," IEEE Journal on Selected Areas in Communications, Vol. 7, No. 8, pp. 1253- 1262, October 1999.
[7] Hong P. and Wang I. "The bandwidth allocation of ATM through genetic algorithm" GOLBECOM 91, pp 4.4.1-4.4.5, 1991.