QoS Multicast Routing Algorithm over Hybrid Hap-Satellite Networks

F. De Rango[1], A. F. Santamaria[2], M. Tropea[1], S. Marano[1]
D.E.I.S. Department, University of Calabria, Italy, 87036
[1]e-mail:{derango, mtropea, marano}@deis.unical.it
[2]afs78@libero.it

Abstract

Emerging network applications require the delivery of packets from one or more senders to a group of receivers. For this reason QoS Multicast Routing Algorithm is a key problem for the researchers. This paper shows a QoS Multicast Genetic Algorithm (GA) that is applied to a multi-layer wireless system composed of a GEO DVB-RCS Satellite and a set of High Altitude Platforms (HAPs). This architecture permits of taking advantage of low HAP delay and wide Satellite bandwidth. The GA considers three QoS metrics that are cost, delay and bandwidth of multicast tree. The performance of GA, measured in terms of fitness, cost, delay and bandwidth, has been evaluated through simulations. In order to show the better performances of proposed algorithm a comparison between the proposed algorithm and a well known in literature genetic algorithm called Multi-objective Genetic Algorithm (MOGA) has been shown.

Keywords*:* DVB-RCS, Multicast, QoS, Genetic Algorithm.

1. INTRODUCTION

The rapid development and deployment of high-speed networks in recent years have given rise to many new distributed real-time applications such as video-conferencing, tele-teaching, video-on-demand, computer visualization, etc. In this paper, the routing problems for supporting these applications have been studied.

The goals of routing for supporting real-time applications involving audio/video traffic should be computing paths, multicast trees for multiple destinations, that satisfy the given QoS requirements managing the network resources efficiently. Many algorithms have been proposed in order to resolve the optimization problem of multicast constraints which were able to make tradeoffs between the multicast tree costs, as inter-destination delay variation, maximum and average end-to-end delay, bandwidth requirement and so on. These techniques are based on the construction of a multicast tree. Finding routes with two or more QoS parameters is a NP-hard problem. In the last years, genetic algorithm techniques are in growth [1-11].

This work describes the introduction of a new multicast QoS genetic algorithm in a wireless system composed of a multi-layer platform. It considers an architecture composed of a Geo DVB-RCS Satellite which works in cooperation with a set of HAP that are placed in a bottom layer. This hybrid system permits to take advantage of the peculiarity of both platform in terms of bandwidth and delay [12], that are the considered metrics for the QoS multicast optimization problem.

The remainder of this paper is organized as follows. The Multi-Layer Wireless System is presented in section 2. Section 3 describes the network model and problem definition. A description of Constrained Cost-Delay-Bandwidth Genetic Algorithm (CCDB-GA) and MOGA is illustrated in section 4. Simulation results are summarized in section 5 and finally conclusions are presented in section 6.

2. HYBRID HAP-SATELLITE NETWORKS

Here, a brief description of the reference architecture, that has been taken for performance studying, is provided. The experiments have been conducted over a multi-layer wireless system composed of a next-generation GEO DVB-RCS Satellite and a set of HAPs. Both of wireless platforms are considered intelligent system with On Board Processing (OBP) on the payload and both of them have the specific elements previewed by the standard [13].

Fig.1 shows all the architectural parts provided by the ETSI that, beyond the wireless body (HAP or Satellite), are the user terminal also called Return Channel Satellite Terminal (RCST), and the Network Control Center (NCC) that is the core of the structure.

The standard previews also that the transmission capability uses a Multi-Frequency Time Division Multiple Access (MF-TDMA) scheme; the capacity categories supported are: Continuous Rate Assignment (CRA), Rate Based Dynamic Capacity (RBDC), Volume Based Dynamic Capacity (VBDC), Absolute Volume Based Dynamic Capacity (AVBDC), Free Capacity Assignment (FCA); a frame structure of the duration of 47 ms and a possible use of IP packets carried via DVB/MPEG2-TS [13].

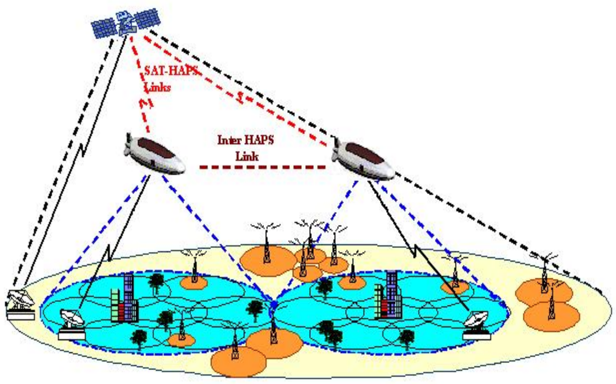

Fig. 1 System architecture.

3. NETWORK MODEL AND PROBLEM DEFINITION

A directed network graph G=(N,L) consists of a nonempty set N of |N| nodes and a set L, $L \subseteq N \times N$, of |L| links connecting pairs of nodes. Each link is associated with three QoS metric functions: cost(.), delay(.) and bandwidth(.), that have to be optimized by the algorithm.

In addition, a nonempty set V={s,d1, d2, … , dk} of terminals in G is given where $L \subseteq N$, *s* is the source node, and D={ d1, d2, … , dk} is the set of destinations.

The algorithm has to find a sub-network TG(V)=(NT,LT) of G.

Let be $P_T(s,d)$ a unique path in the tree from source s to a destination node $d \in D$. The total delay of this path is the sum of the delay of all links along such path.

Each path in the spanning tree presents the three metrics that are defined as follows:

$$Cost(P_T) = \sum_{l \in P_T(s,d)} Cost(l) \qquad (1)$$

$$Band\,(P_T) = \underset{l \in P_T(s,d)}{Min}\ Band\,(l) \qquad (2)$$

$$Delay(P_T) = \sum_{l \in P_T(s,d)} Delay(l) \qquad (3)$$

Accordingly, the tree TG(V)=(NT,LT) that is a sub-graph of G has an associated cost defined as:

$$Cost(T_G) = \sum_{l \in L_T} Cost(l) \qquad (4)$$

We can define a multicast call request in the network as a 4-tuple:

$$\mathrm{C = (s, D, Min\_Bandwidth, Max\_Delay)} \qquad (5)$$

where $s \in N$ is the source node in the multicast call, $D = (d_1, d_2, ..., d_n) \subset N$ is a set of destination nodes. The Max_Delay (MD) and Min_Bandwidth (MB) are the constraints that have to be satisfied for each source-destination pair.

Given a call C on the network G, we define a multicast tree T=(NT, LT) that respects the constraints, optimizes the tree cost and that has as radix the source s and which further satisfies the conditions $N_T \subset N$ and $L_T \subset L$, $s \in N_T$ and $D \subset N_T$, $Band(v) > MB \quad \forall v \in N_T$, $Delay(P) < MD \quad \forall p \subset T$.

If we define Set(CT) like the set of overall multicast routing trees associated to a call C, the multicast problem can be seen, in simple manner, as follows, finding a routing tree T_s so satisfy that [4]:

$$C(T_S) = \min\{Cost(T_S) : T_S \in Set(C_T)\} \qquad (6)$$

4. GENETIC ALGORITHM

The Genetic Algorithms (GAs) are used to solve an optimization problem based on the principle of evolution. In the following, two genetic algorithms are described focusing the attention on the proposed algorithm Constrained Cost-Delay-Bandwidth Genetic Algorithm (CCDB-GA). The slope of this algorithm is to perform a good tradeoff between the HAPs mesh and with low bandwidth but with also low round trip delay and the GEO Satellite that offer a great bandwidth but also a higher round trip time. To do this are implemented different QoS metrics that can help the algorithm to choose the best path. With the utilizing of penalty technique we can penalize some path that includes the satellite link for example when we serve an application that require a low delay end-to-end; but at the same way, we can reward a satellite link when an application requires a high resource of bandwidth.

4.1 CCDB-GA Description

The CCDB-GA is based on an object called chromosome which represents a possible problem solution. Another key problem is the representation of the chromosome through a right coding scheme.

In Fig.2 a pseudo code of a generic genetic algorithm procedure is presented. In the following the different steps of the algorithm are presented.

a) Initial Population

The first step of genetic algorithm is to find an initial population that is represented by set of chromosomes. In this study, the generation of the initial population is based on the randomized Depth-First Search (DFS) Algorithm. The choice of initial population is very important because it influences the execution time of the algorithm and then its convergence.

```
Procedure: Gentic Algorithm
 Begin
  generate initial population
  While (not stop condition) do
   Begin
    Evaluate current population
    perform coding
    apply elitism model on the current population
    calculate fitness of each individual
    While (not population finishes) do
     Begin
      select 2 individuals
      perform crossover and mutation
      perform Decoding
      insert the two offspings in the new generation
     End
   End
 End
```

Fig.2 Procedure of Genetic Algorithms

b) Fitness

The fitness function is defined using the Penalty technique [3]. The fitness function considered in this paper is based on cost, delay and bandwidth constraints. It is represented by the following equation:

$$F(T(s,R)) = \frac{a}{\sum_{e \in T(s,R)} C(e)} \left(\prod_{d \in M} \phi(D(P(s,d)) - MD) \right) \cdot \left(\prod_{d \in M} \phi(MB - B(P(s,d)) \right) \qquad (7)$$

where α is a positive real coefficient, MD and MB are defined in previous section and $\phi(z)$ represents the penalty function with γ as penalty degree:

$$\phi(z) = \begin{cases} 1 & z \leq 0 \\ \gamma & z > 0 \end{cases} \qquad (8)$$

The algorithm simulates evolution through the three classic genetic phases: selection, crossover, mutation, that simulate the natural processes of biological evolution. The algorithm shows that, after a certain number of generations, the chromosomes that have an higher fitness value will emerge and it could be representing a good solution for the problem.

c) Coding

The chromosome can be represented by a string of digit inserted in a vector where the position represents the number of the node inside the network.

Chromosome coding is the first and an indispensable step of genetic algorithm, which affects not only methods of decoding and evaluation, but also the realization of selection, crossover and mutation procedures. Coding represents the core of the whole algorithm. The coding phase tries to find the manner of representing the chromosome with some well known structures like vector or matrix.

In this work the attention has been focused on Prufer Number Encoding [4]. On a complete graph with n nodes, there are n^{n-2} distinct label trees. Prufer coding provides a one-to-one correspondence between such trees and the set of all strings of n-2 digits. For more details see [4].

d) Selection

In the CCDB-GA algorithm, the elitism model is used as selection operator. This model previews, that the best chromosomes are chosen on the basis of their fitness value. In this manner they are selected and directly copied in the next population set.

In this way, chromosomes with large fitness values will survive and the convergences time are reduced

To select a parent at each chromosomes is assigned a probability that it is given by equation (9):

$$P_i = \frac{F(T_i)}{\sum_{j=1}^{pop\_size} F(T_j)} \qquad (9)$$

where pop_size is the population size [3].

e) Crossover

The crossover operation reproduces, through mathematical formulas, the natural process of genetic information exchanged between two individuals.

The chromosomes with a larger fitness values are chosen first. The chosen crossover operator is one-point crossover. A random number indicate the starting point to exchange the two chromosomes.

f) Mutation

Mutation is a mechanism to insert in the next generation a random factor therefore to improve or to get worse the goodness of the individuals. It performs a random change in the chromosome. In the CCDB-GA algorithm, the pointwise mutation technique is chosen. In this kind of mutation operator only a bit can be changed with a certain probability defined as *pm* that it is called mutation probability. The mutation procedure provides the generation of a random number that if it is lower than *pm* means that the mutation can be performed on the chromosome. Moreover the mutation permits to explore a grater region of the space of solution, so to increase the probability to find a new best solution.

g) Extensive De-Coding

After these steps a new solution is found. Now, the problem is whether the found solution is a correct spanning tree too [4].

In this case, the tree can be connected executing an extensive coding that follows these steps:

Step 1: finding links which are in the constructing tree T represented by chromosome but not in the original graph G.

Step 2: remove these links from T; the resulting graph is composed of multiple sub-trees, denoted as (T1,T2,…..,Tp).

Step 3: finding a link in the graph G; this link can connect two sub-tree Ti e Tj.

Step 4: repeat step 3, until all the sub-trees form an entire tree.

Now, a sub-tree T of the original graph G has been created.

4.2 MOGA Description

MOGA is a well known genetic algorithm that is based on a Multi-objective Optimization Principle (MOP). MOGA, previews genetic operation, as crossover and mutation, similar to CCDB-GA algorithm, but it assigns fitness through two steps that are Pareto ranking and density calculation (denoted with C).The rank of a certain individual corresponds to the sum of individuals in the current population by which it is dominated. For details see [1]. An important issue in MOGA is how to take a measure to preserve population diversity. Differently from CCDB-GA, where is used a penalty function and the principle of elitism, in MOGA to penalize individuals is used an entropy-based strategy. For details see [1,2]. The final form of the fitness function, where has been found a trade-off between rank and density, is:

$$fitness_i = rank_i * \exp(C_i) \qquad (10)$$

Due to the more complexity function to determinate the fitness values in the MOGA algorithm, the CCDBA-GA has a minor complexity. In fact, more paths must be found in the MOGA to assign the Fitness values to each chromosome and for this more cycle are needed.

This complexity influences the execution time and for this reason in the next session is shown the differences in terms of execution time between the two algorithms. In these terms the CCDB-GA results better than MOGA.

5 SIMULATION RESULTS

Extensive simulation experiments have been conducted, in the multi-layer wireless HAP/Satellite system, to evaluate and compare performances of the proposed algorithm and the existing considered algorithm. A simulator built in C++ has been utilized for the study having the capability of giving by input many initial parameters, as shown in the Table 1.

TABLE I
SIMULATION PARAMETERS

Topology Parameters	Value	
Total Network Nodes	20 – 40 – 60 - 80	
Algorithm Parameters	Value	
Mutation Probability	0.7	
Crossover Probability	0.5	
Number of Generation	100	
Minimum Bandwidth	300 kb/s	
Max Delay End-to-End	200 – 300 – 400 ms	
Start population	10 – 20 – 30 trees	
Network Parameters	Value	
Medium Access Protocol	MF-TDMA	
Target Burst Loss Probability (ε)	0.01	
Atomic Channel (Slot)	32 kbit/s	
Return/Forward Channel's Trama	47 ms	
RCST Typology	D (2048 kbit/s)	
Max Number of Source fro RCST	16	
	Satellite Value	HAP Value
Round Trip Time	540 ms	0.1 ms
Return Channel's Slots	1400	469
Forward Channel's Slots	4000	469

5.1 CCDB-GA performance evaluation

The three metrics, on which the proposed algorithm is based are cost, delay and bandwidth. Two metrics (cost and delay) are additive metrics, and they are correlated between them in fact the algorithm has to find a valid trade-off between cost and delay in respect of the required constraints. In the simulative campaign, the proposed algorithm behaviour in respect to the change of the delay constraints, has been shown. Different simulations have been conducted changing the delay bound from 200 ms, that represents a hard constraints, to 400 ms, that gives enough free degrees to the algorithm giving it the possibility of choosing the best path utilizing also the satellite links.

Fig. 3 and Fig.4 show the cost and delay tree values. In particular, it is possible to note that the delay constraints are respected. The algorithm finds the better solution trying to satisfy the bandwidth constraints and optimizing the cost.

In Fig.5, instead, the bandwidth curves are shown. It is possible to note that the algorithm can utilize a wide bandwidth with high delay bounds, while the bandwidth value has to decrease drastically with a lower delay values. This is due to the fact that with low delay the algorithm can not choice paths that include satellite links and then it is forced to choice only HAP paths that are characterized by lower delay but lower bandwidth too. However, as it is possible to view in Fig. 5, the bandwidth constraints are respected because they are under the imposed value of 300 Kb/s.

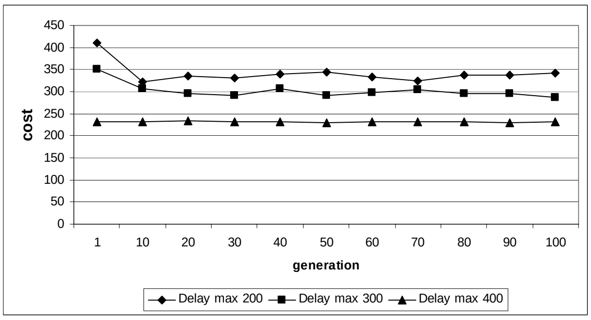

Fig. 3 Cost values of CCDB-GA vs generation

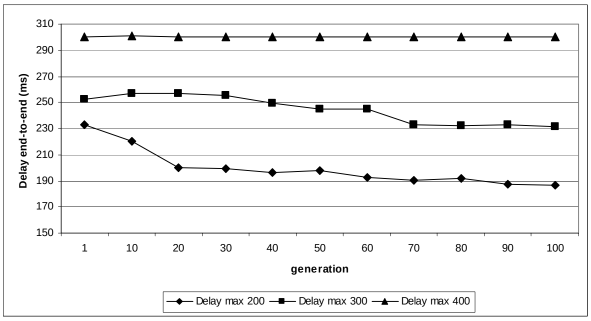

Fig. 4 Delay values of CCDB-GA vs generation

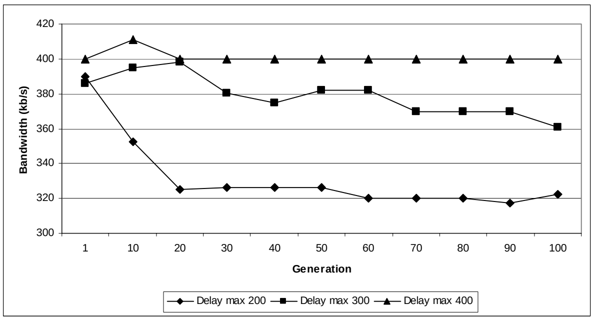

Fig. 5 Bandwidth values of CCDB-GA vs generation

5.2 CCDB-GA vs MOGA performance evaluation

To demonstrate the good performance of proposed algorithm a comparison with MOGA is performed. The comparison has been done about the cost and delay indexes.

Fig. 6 and Fig. 7 show the curve about cost and delay compared between the two algorithms. The optimization of the two metrics tries to find a trade-off between them. It is possible to observe that MOGA can decrease its cost because its delay is always constant, instead for the case of CCDB-GA the convergence is reached after a trade-off between their values of costs and delays.

Finally, Fig. 8 shows a comparison between the computing times of the two algorithms in order to reach the optimal solution. It is possible to view that the CCDB-GA algorithm needs of less time to find the optimal solution.

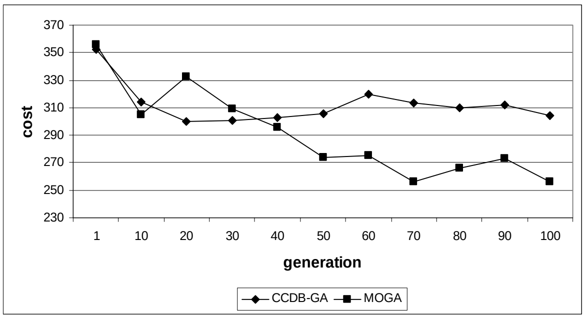

Fig. 6 CCDB-GA vs MOGA cost

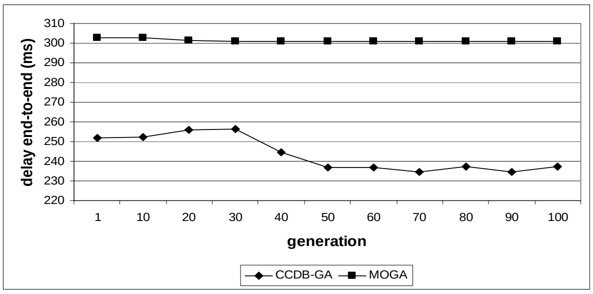

Fig. 7 CCDB-GA vs MOGA delay end-to-end

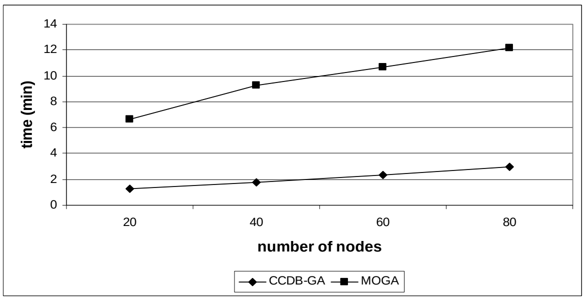

Fig. 8 CCDB-GA vs MOGA computing time

6. CONCLUSION

In this work, it has been conducted a study of a new genetic algorithm which has been called Constrained Cost-Delay-Bandwidth Genetic Algorithm (CCDB-GA). This algorithm has been implemented in a multi-layer wireless system composed of a Satellite and a mesh of HAP. Many simulations have been carried out in order to validate the algorithm and in order to show the good performance in a similar hybrid architecture. Metrics have been graphed in order to verify the solution found by the algorithm. Finally this proposed algorithm has been compared with another genetic algorithm known in literature and called MOGA. The comparison has shown that the CCDB-GA algorithm performs better than MOGA and its performances are better in terms of simulation time. Moreover we can take advantage of the technique of the penalty, implemented in the CCDB-GA, in order to use in the best way the hybrid satellite-hap net. In particular the algorithm can be set on the application type basis that it wishes to serve.

REFERENCES

[1] X. Cui, Chuang Lin, Yaya Wei "A multiobjective Model for QoS Multicast Routing based on Genetic Algorithm", proc of ICCNMC'03

[2] X.X. Cui,M. Li and T.J. Fang, "Study of population diversity of multiobjective evolutionary algorithm based on immune and entropy principles" in Proc. 2001 Evolu. Compu., May, 2001, pp 1316-1321

[3] A.T.Haghighat, K.Faez, M.Dehghan, A.Mowlaci, Y.Ghahremani, "Efficient Multicast Routing with Multiple QoS Constraints Based on Genetic Algorithm," Proc. of the 15th Int. Conf. on Computer Communication, Mumbai, India, pp.181-192, 2002.

[4] L.Chen, Z.Y.Yang, Z.Q.Xu, "A Degree-Delay-Constrained Genetic Algorithm for Multicast Routing Tree," Proc. of 4th Int.Conf on Comp. and Inf. Technology (CIT'04), 2004.

[5] R.H.Hwang, W.Y.Do, S.C.Yang, "Multicast Routing Based on Genetic Algorithms," Journal of Information Science and Engineering, issue 16, pp.885-901, 2000.

[6] Y.L.Feng, Z.W.Yu, Y.Pan, "Heuristic Genetic Algorithm for Degree-Constrained Multicast Routing Problem," Proc. of 3rd Int.Conf.on Machne Learning and Cybernetics, Shangai, 26-29 Aug, 2004.

[7] Q. Zhu, M. Parsa, J.J. Garcia-Luna-Aceves, "A Source-Based Algorithm for Delay-Constrained Minimum-Cost Multicast", 1995 IEEE, pp.337-385.

[8] A. Koyama, T. Nishie, J. Arai, L. Barolli, "A New Quality of Service Multicast Routing Protocol Based on Gentic Algorithm" ICPADS 2005.

[9] H.T. Tran, R.J Harris, "Solving QoS Multicast Routing with Genetic Algorithms", IEEE ICICS 2003

[10] C.W. Ahn, R.S. Ramakrishna, "Elitism-Based Compact Genetic Algorithms", IEEE Transactions on Evolutionary Computation, vol.7, no.4, August 2003

[11] L.H. Sahasrabuddhe, B. Mukherjee, "Multicast Routing Algorithms and Protocols: A Tutorial", IEEE Network 2000

[12] F. De Rango, M.Tropea, S.Marano, "Integrated Services on High Altitude Platform: Receiver Driven Smart Selection of HAP-Geo SatelliteWireless Access Segment and Performance Evaluation," to appear on Int. Journ. Of Wireless Information Networks, 2006.

[13] ETSI EN 301 790 V 1.3.1 (2003-03): "Digital Video Broadcasting (DVB); Interaction channel for satellite distribution systems".