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Proposing Bat Inspired Heuristic Algorithm for the Optimization of GMPLS Networks

Mohsin Masood, Mohamed Mostafa Fouad and Ivan Glesk

Abstract — **Introduction of modern and diverse applications in telecommunication field has raised challenges in networking area regarding efficient use of network resources and with optimizing performance. Therefore MPLS/GMPLS (Generalized multiprotocol label switching) networks were introduced to provide a better quality of service to meet users' requirements as well as to optimize network resources. GMPLS networks use traffic engineering techniques for more efficient communication within the network and help to optimize network resources. This paper proposes BAT inspired metaheuristic algorithm for selecting an efficient route in MPLS/ GMPLS networks. In our investigation we considered routing costs as an objective function with goal to minimize it. The paper uses BAT algorithm with various levels of loudness parameter. The simulation results show performance improvements in MPLS/GMPLS networks of different size.**

Keywords — **bat algorithm, GMPLS network, metaheuristic algorithms, network optimization, traffic engineering**

I. INTRODUCTION

The rapid increase of modern applications have raised the importance of using network resources more effectively and without compromising the quality of services. This can be achieved via traffic engineering (TE). In short, traffic engineering means the management of network traffic by efficient use of network resources [1]. One example of TE application is handling the massive flow of data by splitting and routing the traffic into multiple paths. Splitting the traffic into multiple routes in the network helps to avoid the congestion of individual links, minimizes the risk of packets loss, and helps with effective utilization of network resources. The routing algorithm plays a critical role in producing optimal solutions (routes) for traffic engineering in the network [1], [2]. For such purpose, a number of heuristic algorithms have been developed. The differences among them are in the complexity and performance tradeoffs [3].

Conventional IP networks face various problems while using traffic engineering (TE). However, to improve IP networks capabilities, Multiple Protocol Label Switching (MPLS) has been introduced. MPLS networks are based on label switching. The Generalized MPLS (GMPLS) is introduced as extension to MPLS to deal with different classes of interfaces. The GMPLS networks enhance the functional limitations of IP networks [2], [4], [5].

This paper presents a metaheuristic algorithm for finding optimal paths within MPLS/ GMPLS networks. The objective function is to find the minimum routing costs paths, which will use for traffic forwarding in MPLS/ GMPLS network.

II. TRAFFIC ENGINEERING IN GMPLS NETWORKS

This section describes a literature review on traffic engineering in MPLS/ GMPLS networks. Routing protocols play critical roles for optimal dissemination of data traffic within the network. MPLS/GMPLS networks effectively support traffic engineering optimization [4], [5]. MPLS/GMPLS networks are based on interior gateway protocols (intermediate system-to-intermediate system (IS-IS) and open shortest path first (OSPF). They use labels over the packets instead of IP address traditionally used in IP networks. GMPLS networks provide solutions for different switching-based technologies such as time, packets, wavelength and space switching. MPLS/GMPLS supports high performance telecommunication networks for all kind of modern applications with efficient features of (TE) [6], [7]. In MPLS/GMPLS networks, before forwarding the user traffic, virtual paths are established between source and destination routers (known as ingress and egress routers), respectively [6]. Ingress and egress routers are label edge routers (LER) as they relate to source and destination nodes. The routers in between the LERs are known as label switched routers (LSR). They forward the traffic in MPLS/GMPLS networks. The virtual paths are known as label switched paths (LSP) and are computed by routing algorithm embedded in the LERs. In MPLS/GMPLS domain, virtual connections (LSPs) are established for forwarding the user traffic from source to destination. This technique avoids the complex look-up routing table in each router which optimizes the network performance with less utilization of network resources. For modern applications, most of the service providers prefer GMPLS network based routers [6-8].

III. PROBLEM FORMULATION

To ensure the quality of service provisioning, TE must control/handle various network parameters such as packet loss, delays, link drops, congestions, network resources and so on. However, an algorithm can be deployed and use to manage those parameters and also provide a number of optimal routes as a solution for splitting traffic over multiple paths.

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In this paper, MPLS/ GMPLS network is represented in the form of a graph. In the graph, links are edges and routers are vertices. In the network at ingress router, traffic requests are received. Ingress router uses routing algorithm for the computation of a path or a label switched path (LSP) from ingress to egress routers.

We have proposed an algorithm which is used for optimal path calculation in the network. The algorithm uses routing costs as an objective function for path computation, and provide path as a solution with a minimum routing costs. Furthermore, the algorithm is implemented on a different number of nodes as well as scenarios. The annotations for a graph, edges and vertices are as follows: $G = (V, E)$, V is a set of vertices such as $[v = 1,2, 3,\dots, V]$ and E is set of edges $[e = 1, 2, 3,\dots, E]$, respectively.

IV. PROPOSED METHODOLOGY

To enhance the network performance and effective use of network resources, a number of optimization-based techniques have been proposed. These techniques could be either SWARM based or Bioinspired-based. This paper proposes heuristic based algorithm known as BAT algorithm for enhancing the performance of MPLS/GMPLS networks.

A. The BAT Algorithm (BA)

In 2010, X. Yang [9] introduced bio-inspired metaheuristic method known as the Bat algorithm (BA) for solving optimization problems in various applications. This algorithm was inspired by ways how bats search for they prey (a solution) in *n*-dimensional search area. Each bat individually evaluates the updated solutions with a given fitness function. Searching nature of bats for feasible solution is highly dependent on two parameters known as the *pulse rate*(r) and *loudness*(A). *Pulse rate*(r) and *loudness*(A) represent the echolocation processing of bats which they use to find the solution (prey) from a distance and then they attack. The Bat algorithm is modeled in such a way that virtual bats are considered as potential candidates for searching the best solution in searching space [9], [10].

During a searching process using the Bat algorithm, the movement of each bat(i) updates its velocity(v_i^t) and position(x_i^t) in *n*-dimension searching area at each t^{th} iteration according to following equations [9], [10], [11]:

$$f_i = f_{min} + \beta\,(f_{max} + f_{min}) \tag{1}$$

$$v_i^t = v_i^{t-1} + f_i\,(x_i - x^{best}) \tag{2}$$

$$x_i^t = x_i + v_i^t \tag{3}$$

Where t represents the iteration during algorithm processing stage, f_i denotes initial frequency used by a bat for its echolocation process while f_{min} and f_{max} are minimum and maximum frequencies, respectively used for algorithm. β represents a number which is randomly taken within the limits [0,1]. Whereas, x^{best} represents the best position with the best fitness value, also known as current global best position (solution). However, this global best position is achieved by comparing all solutions provided by n bats. After updating velocity(v_i^t) and position(x_i^t) of each bat during the iteration, each i_{th} bat takes the random walk (step) to produce its local best solution around the current best solution if it fulfills the condition $rand > puls\ rate\,(r)$. The local best solution is produced according to following equation [9-11]:

$$x_{i,local}^t = x_i + \varepsilon < A_i^t \tag{4}$$

Where, $x_{i,local}^t$ represents the local best solution, $\varepsilon \in [-1,1]$ is a random number vector and A_i^t represents the computed value of average loudness of all bats in present iteration. At the starting stage of the algorithm, A_i^t is set to be a random value but this value will update with each iteration. Maximum loudness value(A_{max}) and minimum loudness value(A_{min}) are used to calculate average loudness value(A_i^t) during each iteration. A_{max} and A_{min} are set to be a constant value during the initialization stage of this algorithm.

Each bat's local best position$(x_{i,local}^t)$ with its fitness function is compared with the previous fitness function. If the new solution is better than the previous one then the bat updates its *loudness*(A) and *pulse rate*(r) parameters according to equations [9-11]:

$$A_i^{t+1} = \alpha A_i^t \tag{5}$$

$$r_i^{t+1} = r_i^0\,[1 - e^{-\gamma t}] \tag{6}$$

Where α and γ are constants from an interval [0,1]. If the bat is approaching its prey (optimal solution) it's *loudness* parameter (A) will decrease while the *pulse rate*(r) will increase.

This paper uses the bat algorithm to find the minimum routing costs path(s) for the traffic in MPLS/ GMPLS network.

B. Routing Cost Fitness Function in GMPLS Networks

In networks, for traffic flow, service providers assign link cost per unit of data packet/traffic. Similarly, in MPLS/GMPLS networks, LSP (label switched path) is a path that is used for traffic flow. Each path is a summation of connected links within the GMPLS network domain. This can be explained by the given expression as [12]:

$$RC_t^l = \sum R_l\, l_t \tag{7}$$

Where, RC_t^l represents the total routing cost of the path of the traffic while R_l is the routing cost of each link used in the path. l_t represents the link used for traffic in the path. The objective function for the algorithm is to find the route/ path as an optimal solution that uses the 'minimal total routing costs'. The objective function of the total routing costs is represented as[12]:

$$\sum_{t \epsilon Tset} \sum_{l \epsilon\, Lset} RC_t^l x_t^{LSP} \tag{8}$$

Where, traffic t is a member of a traffic set (T_{set}). x_t^{LSP} represents the flow of traffic over the computed LSP(path).

V. USED APPROACH

To apply the proposed method, the above bat algorithm was implemented using the MATLAB tool. The Bat algorithm was implemented for five different cases, having various levels of maximum loudness value(A_{max}) and minimum loudness value(A_{min}). The maximum and minimum loudness levels for each case are: $A_{min} = 0$ and $A_{max} = 3$ for BAT-1, $A_{min} = 0$ and $A_{max} = 5$ for BAT-2, $A_{min} = 0$ and $A_{max} = 7$ for BAT-3, $A_{min} = 0$ and $A_{max} = 9$ for BAT-4 and $A_{min} = 0$ and $A_{max} = 11$ for BAT-5. BAT-1 to BAT-5 are implemented on 20, 50 and 80 nodes GMPLS network. The purpose of using various loudness levels of the BAT algorithm is to study the change in convergence activity of this algorithm as well as to evaluate the algorithm performance for the various network sizes.

VI. OBTAINED RESULTS AND ANALYSIS

The simulated results for each case (BAT-1 to BAT-5), implemented over 20, 50 and 80 nodes networks are shown in Fig. 1, Fig. 2 and Fig. 3, respectively. The figures show a performance analysis of each bat algorithm (BAT-1 to BAT-5) in the form of convergence. We run each bat algorithm (BAT-1 to BAT-5) 100 times for the 20, 50 and 80 nodes networks. The related results are represented in table 1, table 2 and table 3, respectively. We analyze the collected data focusing on three parameters: the mean, standard deviation and minimum routing costs objective function. Minimum routing costs function provides the minimum routing costs path as the optimal solution after running the algorithm 100 times. The mean provides information on how much the average value of the minimum routing costs has been achieved by the algorithm. The standard deviation shows how the results (optimal solutions) deviate from the mean.

Fig. 1 represents the analysis results of bat algorithm cases (BAT-1 to BAT-5) on 20 nodes size MPLS/ GMPLS network. Similarly, Fig. 2 for 50 and Fig. 3 for 80 nodes size network.

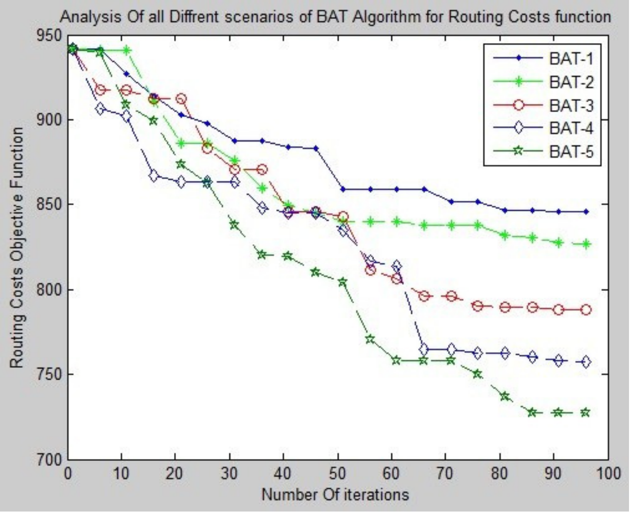

Fig. 1. Analysis of BAT algorithm with different scenarios for 20 nodes GMPLS networks

The results in Fig. 1, 2 and 3, show that the bat algorithm has higher convergence for higher A_{max} values. For example, in Fig. 1: BAT-5, having highest $A_{max} = 11$ value, has a higher convergence towards the optimal solution compare to BAT-4, BAT-3, BAT-2 and BAT-1. Similarly. BAT-4 has a higher convergence than BAT-3 and BAT- 3 has a higher convergence than BAT-2 and BAT-2 has a higher convergence towards the optimal solution than BAT-1.

Furthermore, BAT-5, having the maximum A_{max} value, gives the best solution (the minimum routing costs path) when compare to BAT-4, BAT-3, BAT-2, and BAT-1. Similar results are shown in Fig. 2 and Fig. 3.

From Fig. 1, 2 and 3, we can conclude that when the A_{max} value increases, the algorithm converges faster and provides the optimal solution compare to the lower A_{max} values for 20, 50 and 80 nodes MPLS/GMPLS networks.

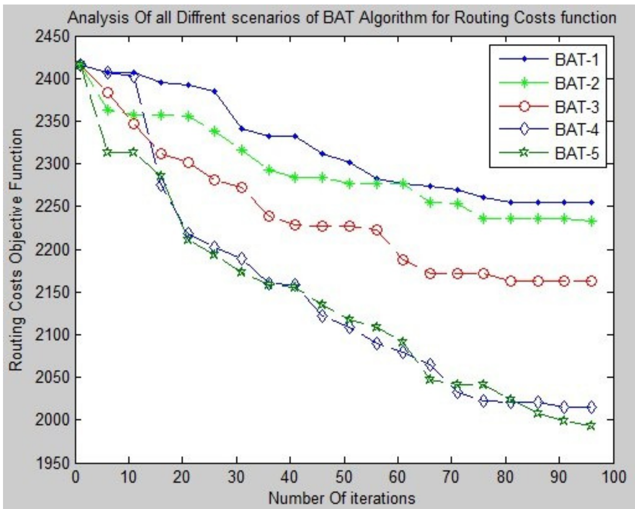

Fig. 2. Analysis of BAT algorithm with different scenarios for 50 nodes GMPLS networks

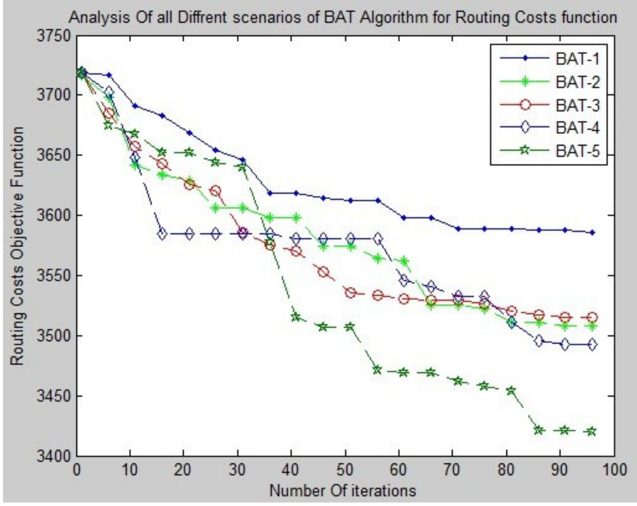

Fig. 3. Analysis of BAT algorithm with different scenarios for 80 nodes GMPLS networks

Table 1 shows the data analysis for the bat algorithm cases BAT-1 to BAT-5 for 20 nodes MPLS/GMPLS network with parameters: mean, standard deviation and minimum routing costs as being the optimal solutions. The data in table 1 shows that BAT-1 has the worst obtained solution (the minimum routing costs path 623.90) which is higher compare to BAT-5 with minimum routing costs path 291.52, being the best minimum routing costs path solution. Similarly, BAT-2 has better minimum routing costs (486.24) compare to BAT-1; BAT-3 has better minimum routing cost of 427.17 than BAT-2, and BAT-4 has better minimum routing costs of 337.66 than BAT-3. Similarly, mean value of BAT-5 is 624.88, which is the minimum value compare to BAT-4, BAT-3, BAT-2, and BAT-1. Similarly, BAT-1 with 792.41 mean value, has the maximum mean value compare to BAT-2, BAT-3, BAT-4, and BAT-5. While the standard deviation value of BAT-1 is 71.99 which is minimum value obtained if compared to BAT-2, Bat-3, BAT-4 and BAT-5. BAT-5 has maximum standard deviation value of 119.07. These results show that when the algorithm is run for multiple times for BAT-1 to BAT-5 then BAT-5 maximum A_{max} provides the best solution for minimum routing cost as well as for minimum mean value. Also the standard deviation of BAT-5 will be higher. In other words, the best solution (a minimum routing costs) will be produced by the bat algorithm when we maximize the A_{max} value. But running algorithm for multiple times having maximum A_{max} will result deviation from the mean. This means difference increase between solutions obtained each time.

Similar findings have been observed in table 2 and table 3 for 50 and 80 nodes MPLS/ GMPLS networks.

TABLE 1: ANALYSIS OF BAT ALGORITHM FOR 20 NODES NETWORK

20 Nodes MPLS/GMPLS network					
	BAT-1	**BAT-2**	**BAT-3**	**BAT-4**	**BAT-5**
Mean	792.41	742.43	710.12	645.74	624.88
Standard Deviation	71.99	75.07	94.47	103.71	119.07
Minimum Routing	623.90	486.24	427.17	337.66	291.52

TABLE 2: ANALYSIS OF BAT ALGORITHM FOR 50 NODES NETWORK

50 Nodes MPLS/GMPLS network					
Mean	2173.1	2110.2	2057.1	1979.1	1924.2
Standard Deviation	136.0	151.9	158.2	177.1	187.6
Minimum Routing	1858.9	1685.8	1590.0	1434.6	1059.5

TABLE 3: ANALYSIS OF BAT ALGORITHM FOR 80 NODES NETWORK

80 Nodes MPLS/GMPLS network					
Mean	3601.9	3482.5	3464.1	3314.7	3273.7
Standard Deviation	145.9	165.0	190.3	200.2	213.76
Minimum Routing	3158	3008	2940	2854	2673.6

VII. CONCLUSION

The paper has investigated the so-called Bat algorithm using different values of A_{max} in a GMPLS networks with a varying number of nodes. Our simulation results are shown in Fig. 1 Fig. 2, Fig. 3 and table 1, table 2 and table 3. From our investigations we can conclude that the bat algorithm can offer optimal solutions (routes having minimum routing cost) for the MPLS/GMPLS network. Furthermore, our results show that the bat algorithm with minimum A_{max} value converges slowly. We found that it is better to increase A_{max} parameter to achieve a higher convergence leading to 'best solution'. We also found that when the difference between A_{max} and A_{min} increases, the value of average loudness (A_i^t) for the bat 'random searching step' enhances the algorithm performance (its convergence). Our results shown in table 1, 2 and 3 also reveal that when we run the bat algorithm for each given case 100 times and increase the A_{max} value, better results are obtained in a form of minimum routing costs path. Although the Bat algorithm is stochastic in its nature, the standard deviation values are very close to the mean values with minimum A_{max} parameter value, which means most of the searched optimal solutions are very close to the average.

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