The future of many technologies such as video conferencing, grid computing, e-	Tương lai của nhiều công nghệ chẳng hạn như hội nghị truyền hình, điện toán

Science and peer-to-peer (P2P) will employ a massive amount of data and support for point to multipoint communication. To fortify these accommodations, the next-generation Internet will be predicated on optical networks that can provide immense amounts of bandwidth. Manycast [1-3], is a new type of communication that can fortify the point to multipoint nature of future services, in addition to fortifying generally used commu- nication types. The manycast is a generalization of the multicast communication para- digm [4]. Indeed, multicast differs from manycast in that the destinations are determined, though in manycast the destinations must be picked. Manycast is especially useful in grid/cloud computing and e-Science. In the majority of the above cases, we are regularly dealing with a prodigious amount of data.	lưới, e-Science và ngang hàng (P2P) sử dụng một lượng dữ liệu khổng lồ và có khả năng hỗ trợ truyền thông từ một điểm sang nhiều điểm. Để đáp ứng nhu cầu này, người ta dự đoán rằng Internet thế hệ tiếp theo trên các mạng quang học cần phải có băng thông lớn. Manycast [1-3] là một loại truyền thông mới có thể tăng cường bản chất một điểm đến nhiều điểm của các dịch vụ trong tương lai, cùng với việc củng cố các loại liên lạc (truyền thông) thường được sử dụng. Manycast là sự tổng quát hóa của giao thức truyền thông multicast [4]. Thực sự, multicast khác manycast ở chỗ xác định đích, mặc dù trong manycast, đích phải được chọn. Manycast đặc biệt thích hợp trong Điện toán lưới/đám mây và e-Science. Trong đa số trường hợp trên, thông thường chúng ta phải xử lý một lượng lớn dữ liệu.
In these cases, a service provider might have various servers that give an identical service. In particular, consider parallel substance conveyance in an e-Science context. e-Science regularly creates a lot of data [1] that may then be stored in different areas for either backup purposes or so that numerous exploration labs can then process it locally. We can utilize manycast to pick some subset of these locationsstorage clusters) to send this data in parallel along a light-tree set up by the network system. This issue can likewise be solved utilizing multicast rather than manycast, yet there are a few disadvantages. Rather than utilizing manycast, where the system would pick the subset of destinations for us, we can utilize multicast by picking k	[redacted]

destinations at the source. The primary disadvantage stems from the client point of view. The nodes chosen at the source may be heavily loaded or may provide a slower transfer rate than different nodes in the candidate set. Furthermore, manycast grants the freedom to choose different nodes depending on the state of the network, prompting better execution for client applications and more efficient usage of WDM networks. WDM can provide unprecedented bandwidth, reduce processing costs, and enable efficient failure handling [5,6]. An end-to-end lightpath has to be established prior to the communication between any two nodes in an optical network. A sequence of lightpath requests arrive over time with each lightpath assigned a random holding time.

These lightpaths should be set up dynamically by deciding a route across the network connecting the source to the destination and allocating a free wavelength along the path. Actual lightpaths cannot be rerouted to accommodate new lightpath requests until they are free, so some of the lightpath requests may be blocked if there are no free wavelengths along the path [7]. Therefore, finding a physical route for each lightpath demand and allocating to each route a wavelength, subject to the constraints, is known as the Routing and Wavelength Assignment (RWA) problem [8-10]. The concept of a lightpath is generalized into that of a light-tree [11], which unlike a

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lightpath, a light-tree has multiple destination nodes. Thus, a light-tree forms a tree rooted at the source node instead of the typical path created in the physical topology.

The solution to the manycast RWA problem can be either, given a fixed number of wavelengths and a set of manycast requests, to maximize the total number of manycast requests admitted (Max-RWA), or to minimize the number of wavelengths used (Min- RWA), provided that wavelength availability is sufficient to route all of the requests [12]. Given the hard computations of the linear integer program [13], we analyze the problem using metaheuristics. Our objective, given a fixed number of wavelengths, is to maximize the number of manycast requests to be established in a given session or traffic matrix.

The next section reviews the previous work completed on this topic. In Sect.3, a problem definition and formulation is given. Section 4 proposes our assignment algo- rithm EP. In Sect. 5, experimental results and a comparison between the proposed approaches is presented. Section6discusses the empirical results obtained for the suggested metaheuristics. Finally, conclusions and future work of this paper are drawn in Sect.7.

1 Previous Work

The RWA problem can be divided into two sub-problems, the path from source to

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destination - this is the routing part - and the wavelength along the path, which is the wavelength assignment part. Both of these sub-problems are NP complete [14] and tightly linked together. The manycast RWA issue is, therefore, NP complete since it contains the RWA issue as a special case.

Manycast is a special type of multicast communication, in which, from a single source, we must reach a set of destination nodes. These destination nodes are to be selected instead of being given. In fact, there are many previous works that investigate the multicast dilemma. This static multicast RWA is studied in numerous pieces of research [15,16] targeting the objective of minimizing the blocking probability. Manycast is also a generalization ofunicast where the message needs to be delivered to any one of the group. Indeed, there is a wealth of recent work [8,10,17-19] that proposes a genetic algorithm and an evolutionary programming to solve RWA problem in the unicast case. While in the manycast case, in numerous previous works, the manycast problem is first presented as quorumcast [2, 20,21]. In quorumcast, messages are sent to a subset of destinations (quorum pool), which are selected from a set. Charbonneau and Vokkarane [1,12] propose three heuristics to solve the manycast problem. The objective was to minimize the number of wavelengths required to satisfy all of the manycast requests. In our previous work [3], we propose and compare two metaheuristics, tabu search algorithm and genetic algorithm to solve the static manycast RWA problem by maximizing

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the number of manycast request established for a given number of wavelengths. In the work [22], an ILP and several heuristics are introduced for solving multi-resource manycast in mesh networks. Few studies, however, tackle the manycast service over optical burst-switched (OBS) networks [23-25]

Let a network be represented as a graph *G(V,* E), where *V* denotes the set of network nodes and *E* represents the set of unidirectional fibers. Assume that lightpath requests are unidirectional, each carrying *W* wavelengths. A manycast request is represented as $MR\{s, D_c, k\}$ where s, D_c, k denote the source, the set of candidate destination nodes, and $k<$ ID$_c$l = m is the number of destination nodes needed to reach out of m. If we change the parameters to $k = m = 1$ in the manycast request, we can also perform unicast [1]. Therefore, any algorithm that solves the static manycast RWA problem, in general, should adhere to these following constraints:

1. *Wavelength Continuity Constraint:* The wavelength continuity constraint indicates that a specific request for a source-destination pair should follow a single light- path [26].

2. *Wavelength Conflict Constraint:* The wavelength conflict constraint affirms that a wavelength might be utilized just once per fiber. In this manner no two

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signals can cross along the same wavelength in a specihc fiber [7].

Let be the number of all lightpaths in G. Let *R* — (/?,) be the vector that contains the request number to which a lightpath belongs. Let N_R be the number of all requests in G. Let *multiplicity(n)* be the number of connection requests desired to be set up for one request. Let */}* be the sum of all utilized traffic by all requests, as follow:
i.e., djj = 1 if lightpaths *i* and *j* share a physical link, otherwise *dịį* = 0. Let $T = (T_i)$ be the 1 xN_r**vector, i.e.,** T_i = A, VA e {1,2... W} if the wavelength A is assigned to the lightpath-tree i, otherwise T = 0. Let *p* **-(Pi)bethe** 1 $xN_{ư}$ vector, i.e., P_i = A, VA e {1,2... W} if the wavelength A is allocated to the lightpath i, otherwise P_i = 0. Let *iỷTịíữVỈ* e {1, 2... N_R}, otherwise *(p* — 0.

Our problem can be math-
ematically formulated as follows:

Ns *ifd*$_w$*=l,i^j^P^P*$_1$
Vi,ý6{1,2,...*N*$_r$*}* **(1)**
maximize: *F = f(é) = Ỵ' á* such as
ứ
yậ,<J3,\/i$_e$*ụ,2...*
N$_R$*}* (2)
i=

In constraint (1), wavelengths assigned mus
such that no two lightpaths that share a phys
link, belonging to different requests, or use
same wavelength on that link.

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In constraint (2), the sum 2 *ậị* of the elements of *P* that are different from zero, cannot,under any circumstance, surpass the number p.

2 Our Proposed Metaheuristics

Previous research offers a variety of solutions, from simple to complex metaheuristic algorithms for solving the RWA complication. Here, we extend the same Evolutionary Programming (EP) presented in [8,10,19] based on a backtracking approach but this time we utilize it to solve the Static Manycast RWA problem.

4.1 Evolutionary Programming (EP)

The EP is a stochastic optimization procedure that can be applied to a range of difficult combinatorial problems. It's relatively similar to Genetic Algorithm since both them emulate the procedure of natural evolution in order to solve combinatorial optimization problems. For this purpose, EP exploits a myriad of techniques inspired by natural evolution such as selection, mutation, and replacement so that it can create the best near- solutions to optimization issues. Compared with GA, EP has no crossover operator even though it also has the mutation function. The key concepts of the EP explained below:

Initial Population: In this phase, each gene in a chromosome solution represents one of the paths generated through a

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backtracking algorithm so that we can investigate all the possible candidate paths between the source and the destination pairs. These candi- date solutions are called chromosomes which take, in our case, the form of bit strings. Each bit position in the chromosome has W possible values. During this step, we initi- alize the variables that will be used namely: k, D_c, n, P, P_{max} and F_{max}.

[redacted]

Selection: In this step, the chromosomes of the next generation are selected from the current population by evaluating all the chromosomes using a fitness function choosing the best individual.

Mutation: In this stage, the operator randomly inverts some of the bits in a chromo- some, which is considered as a random mutation of the new pool. Thus, some randomly chosen elements of the vector *P* (P contains the best-found solution in terms of the allocated wavelength to the chosen paths for a manycast request) containing the value Ằ, which represents the wavelength that the lightpath will use, will be randomly changed by a different value of the wavelength L In this step, the generated chromosome replaces itself regardless of the fitness function. This concept is shown in Fig.1. More details about EP can be found in [4, 6,17-19,27, 28]. The main working steps of our proposed EP are shown in the general flow (Fig. 2).

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4.2 Genetic Algorithm (GA)

The GA is a search technique originally invented by [29] and used in computing to

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find true or approximate solutions to optimization and search problems. Indeed, this meta- heuristic belongs to the larger class of evolutionary algorithms, which is inspired on process of natural selection and is routinely used to generate useful solutions. Genetic algorithms use biologically-derived techniques such as inheritance, mutation, natural selection, and crossover (or recombination). More details about GA can be found in [3, 4, 6, 17-19, 27-30]. The main working steps of the proposed GA done in our previous work [3] are shown in this following general flow (Fig. 3):

4.3 Backtracking Algorithm

In the work [8,10,19] the authors propose a backtracking algorithm for routing unicastdemands. This algorithm can extend to the manycast case if a path search is done for every destination one-by-one. Using this method, we have the capacity to investigate all of the possible candidate paths between the source and the destination pairs of the trees. All research in this paper focuses on the extension of the work done on static unicast RWA problems by utilizing the backtracking algorithm. Previous studies focus on k-shortest path [5,31], which is widely used in the literature to find alternative paths. Hence, by using the backtracking approach, our initial search space will contain not only the k-shortest paths between each source-destination pair, but also all of the possible candidate lightpaths. More details about backtracking can be found in

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[3,8,10,19].

3 Discussion

In small destination sets EP largely performs better than GA. This out-performance goes up to 24 % improvement over GA, in terms of a solution. However, GA run times are very low compared to the EP approach. GA has shown it can perform better than EP by up to 5 %, especially for large destination sets. This can be related to the crossover site utilized by GA which maintains diversity in the resolution space. Related to the wave- length variation, the results are somewhat predictable, since it is easier for small size manycast requests to be nearly accepted, most notably when the wavelength number is large. In contrast, large size requests often require much of the network resources, in turn many requests could not be satisfied.

Regarding the fairness issue, we observe that GA achieves better fairness among the manycast groups in terms of satisfying all the groups of connections whereas the EP have shown low fairness, specifically when the manycast group increases. For the wave- length reuse issue, we notice that the probability of the re-use of existing wavelength is higher only if the frequency of occurrence of a common physical link is very low, seeing that lately the number of wavelengths increases, so this wavelength reuse problem will be nonexistent.

Our proposed Genetic Algorithm and Evolutionary Programming approaches a

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satisfactory solution. Our performance evaluation of 90 tests confirms that, although much research attempts to solve the multicast RWA problem, only a few studies try to deal with the manycast RWA issue. It is, therefore, important to develop more, new metaheuristics for solving the manycast RWA problem.

4 Conclusion and Future Work

In this paper we implement and compare two metaheuristic strategies to solve the static manycast RWA problem, with a special focus on maximizing the number of manycast requests established for a given number of wavelengths. The problem was studied for the static case only. We propose two metaheuristics to compute the approximated solutions, in which GA works better when the destination set are larger. This is when we increase the destination set. EP has shown good performances for small destination sets. The routing sub-problem is solved using a backtracking algorithm. The proposed GA and EP in this paper are applicable to a real NSF network. A relevant comparison, counting the performance and the time included, is made between the two metaheuristics, making a total of 90 experiments. The time spent by EP, on average, is three times higher than GA.

This work can be extended by using both splitting capabilities and wavelength converters as we have only considered networks without them. The dynamic manycast problem can be considered for future work for the manycast issue over wavelength-routed networks. The dynamic

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manycast complication is especially important for serv- ices that are related to cloud computing and grid networks, where multiple resources are required. Our work concentrates on NSF networks only. Further research on more meta- heuristics in more irregular and more realistic topologies should be conducted. Furtherstudy can be conducted with broadcasting Communications where many-to-manysessions run simultaneously.	[redacted]