Minimum frequency slots allocation based on the Tabu Search meta-heuristic in flexible optical network :MFSA-Tabu

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Abstract

Flexible optical networks are undoubtedly the promising solution to the exponential growth of Internet traffic. They combine flexibility with the finest granularity of optical resources. These optical networks are positioned as a better solution than conventional Wavelength Division Multiplexing (WDM) networks. However, the multiplicity of resources and the possibility of having multiple levels of modulation with the use of Orthogonal Frequency Division Multiplexing (OFDM) technology make it difficult to allocate resources to future demands. The current work aims at the judicious use of a tabu search meta-heuristic to avoid the waste of optical resources by minimizing the number of frequency slots required on each optical link. The main result is to ensure that all allocated connections are grouped under the index λ, which is the optimal value obtained by the algorithm designed.

Keywords: f*lexible optical network, frequency slot, spectrum allocation, routing, tabu search.*

1. Introduction

The lack of flexibility and the wasteful resources of the conventional optical WDM network have produced a new paradigm of important flexible optical transport networks. This new model is known as an elastic optical network (EON) or flexible optical network (FON). It is based on OFDM technology which renders operational to spectrum-sliced elastic optical path network (SLICE) architecture [1]. That architecture is composed of transponders and variable flow switches which are connected by optical fiber links. The main characteristics of this structure are the adaptability of bandwidth given by traffic and the transmission area, the incorporation of lot of subchannels in the only one super channel, and the support of incongruous flow connections [2]. The subchannel stands for the frequency slot of 12, 5 GHz bandwidth. Many frequency slots must be combined to create a unique channel in which the bandwidth is many frequency slots compose it. Moreover, it is useless to insert the guard bands between different frequency slots, creating a super channel and the use of OFDM can pave the way for the overlap of frequency spectrum allocated to the same connection.

In addition to existant constraints (continuity and non-overlapping) in WDM network, a new one appears such called contiguity constraint in this new optical network [3]. Correspondently, the strategies of Routing and Wavelengths Allocation (RWA) created for WDM networks are not adapted, and the researches have devoted themselves to the elaboration of new strategies of Routing and Spectrum Allocation called RSA. As in the RWA [4], RSA is composed of two sub problems. The first is the routing and the second is the allocation of frequency slots(subdivision of optical spectrum). In the linear topology network, RSA reduces itself only to the allocation of frequency slots. But in the mesh topology, it is useful to take into account the two sub problems. According to "half distance law" [5], it must interesting to deal with the flexibility of modulation format, then RSA becomes Routing, Modulation and Allocation of frequency Slots (RMSA)[6]. The allocation of resources follows the rule of constraints using frequency slots that stays one of serious challenges of flexible optical networks at the level of network layer. A poor allocation policy can lead to an inefficient use of frequency slots and thus this new paradigm would lose all the advantages it has on the WDM given the flexibility both in terms of sub-channel aggregation and level of the choice of the modulation formats which influences the number of subchannels [5].

This problem can be formalized as an Integer Linear Program (ILP). In the phase of network planning, where the connections are considered as permanent and having traffics flow known in advance, the objective function of the

ILP is to reduce the number of allocated frequency slots to the set of connections, or the maximization of connections links to fix exact number of frequency slots. Moreover, this difficulty is deemed NP-hard problem in the linear topology network from 4 links [6]. As for mesh topology, RSA is also NP-hard problem [7, 8].

The rest of the paper will be organized around the following sections. Section 2 deals with related work. Section 3 is devoted to the formulation of the problem. Sections 4 and 5 deal respectively with the proposed solution to effectively resolve this problem and the simulations performed to test the performance of the proposed algorithm. Then we end with a conclusion of the bibliographical references.

2. Related work

Many approaches are used in literature to solve this problem.
The first approach consists in the utilization of the exact methods of resolution. On these grounds, Branch and Bound (BB) method implemented in the solvers like CPLEX [9] is used. Nevertheless, based on the combinatorial aspect of problem, the exact methods are not adapted to the passage of large scale. Another exact method, Branch and Price [10,11] from the association of Columns Generation(CG) technique and Branch and Bound (BB) has been developed. It is a method that solves RSA in two phases. During the first phase, CG produces spectrum paths and these paths are used in the second phase by BB for the spectrum allocation. Thus, the complexity of problem is reduced and the results are obtained on average size topologies in a shorter time than the BB allows. Though these methods provide the optimal solution, they are not usable for large networks.

The second approach is to transform the offline RSA into equivalent problem, in this way offline RSA can be considered as the problem of graph coloring [12]. It is transformed to research of chromatic number of graph. In the static case, where the matrix of traffic is known, the problem to solve is to establish all connections in using the possible minimum frequency slots. This minimum number of necessary slots for the allocation in taking into account the constraints of continuity, contiguity, and non-overlapping is the chromatic number resulting from the auxiliary graph in which the nodes are the connections. This graph is built so that two adjacent nodes represent the connections that they have at least a physical link in common. Other studies [13,14] as for them give the resolution of RSA offline through the solution of another problem equivalent, those of multiprocessor scheduling of tasks on the dedicated processors. Each connection is the task or duty where the processing time corresponded the number of frequency slots required by this connection. The number of dedicated processors to this task is the number of link on the connection path in question. Concerning to constraints of continuity, contiguity, and non-overlap, every processor runs a unique task in given time and each task must be executed simultaneous by these dedicated processors.

The third approach is composed of the heuristics and the meta-heuristics and contribute to have the approximate solution in a reasonable time. Among these heuristics, we can list the Most Subcarriers First (MSF) and Longest Path First(LPF) presented in [15], the heuristic which solve separately the routing and the allocation of frequency slots. In the same approach of separate or sequential resolution of routing and the allocation, Wang et *al* [16] propound the Shortest Path with Spectrum Reuse(SPSR) which uses the shortest disjoint paths to treat better the re-use of the frequency slots and the Balanced Load Spectrum Allocation (BLSA) that selects the least congested path. As for the meta-heuristic, a method based on genetic algorithm has been proposed in [17] and recently an approach on tabu search into detailed and exact way for the optical multicast networks demonstrated in [18]. All these approaches over-quoted share the problem in two sub problems like those of routing sometime, the modulation and the allocation. If this separation reduces the complexity of problem, it not preserves the optimality of solutions. Therefore, we propose a meta-heuristic based on tabu search that take into account the simultaneous resolution of routing, modulation, an allocation, we call this proposal MSFA-Tabu which mean Allocation of Minimum Spectrum Frequency based on Tabu search.

3. Problem formulation

3.1. Illustration of the allocation of resources

The optical spectrum of the flexible optical networks is subdivided into frequency slots. Each frequency slot is recognized by its index, an integer that the value ranges between 1 to the maximum index denoted i_{max}. Typically, i_{max} has the value of 400 assuming that the optical spectrum of width of 5 THz as well as each frequency slot is12.5GHz. The problem of routing and the spectrum allocation is illustrated in figure1. This illustration implements the respect of the constraints of continuity, contiguity, non-overlapping and the necessity of treatment a set of connections with the least possible frequency slots.

Each connection request d_i is symbolized by a triplet$\{p, \varphi(d_i), N\}$: p is a physical path which is a set of nodes belonging to this path, N is the necessary frequency slots to the connection and $\varphi(d_i)$ is the index of the first frequency slot occupied by the connection. In this small topology of network of Figure (1a) of 6 nodes, we set through 4 connections:

$d_1\{(a_2,a_3,a_4),1,2\}, d_2\{(a_1,a_2,a_3,a_4,a_5,a_6),2,1\}$ $d_3\{(a_1,a_2),5,2\}$ and $d_4\{(a_2,a_3,a_4,a_5,a_6),8,3\}$. Figure (1b) depicts four connections d_1,d_2, d_3, and d_4, however, this allocation is not executable because the connections d_1 and d_2 whose paths share the links L_2 and L_3 using currently the frequency slots of index 2. This paved the way for the violation of constraint of non-overlap. A solution would be possible in Figure (1c) if all four connections queries follow all the constraints. However, the number of frequency slots used in Figure (1c) is seven must be improved by the solution of Figure (1d), where instead of seven frequency slots as above, we use six frequency slots, moreover all the slots with index greater than 6 are available on all the links of the topology.

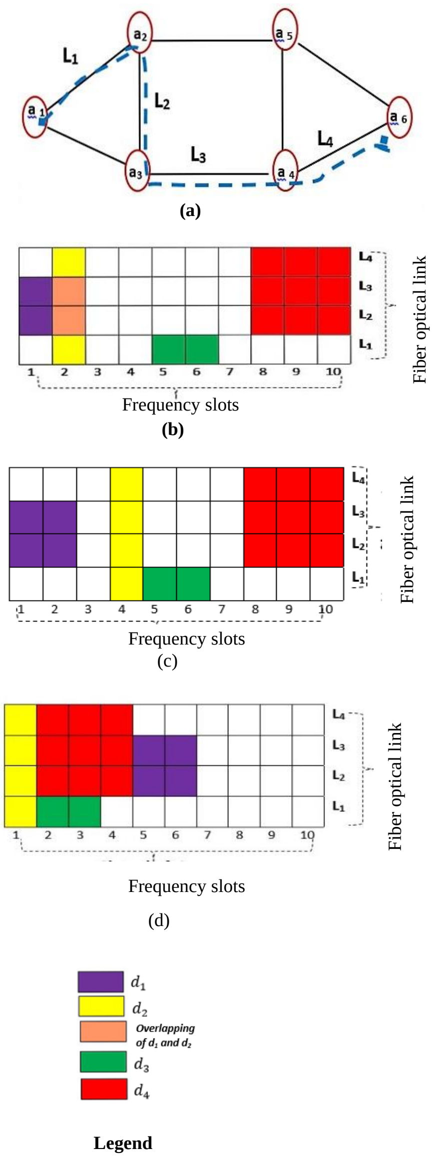

Figure 1: (a) smaller network of 6 nodes, (b) use of frequency slots of path(a_1,a_2,a_3,a_4,a_6) (c) & (d) practical solutions of allocation.

In this illustration, the maximal index is limited at 10. To the allocation of resources of four connections requests, we require at least 6 frequency slots and the allocation of figure (1d) which help us to apply 6 frequency slots, the highest index used on one of the links is not exceeded 6. In the section 2.2, We provide an ILP model of the resources allocation.

3.2. Illustration of the allocation of resources

In this section, we formulate the problem of spectrum resources allocation for static traffic as an integer leaner program. The formulation we propose has as input a set of connections whose traffic is known and a network topology represented by a graph. The output of our model is to give each connection a physical path and a band of frequency slots so that two connections whose physical paths have a common link do not overlap. This ILP is inspired by the "Link-path" model [19] which is based on the use of links and physical paths of the network topology. This choice makes it possible to simplify the search for the optimal results by providing as input of the model in addition to the topology of the network and the connections, the set of admissible physical paths. A description of variables and parameters of pattern is explained in the table1.

Table 1: Description of variables and parameters

Symbol		**Description**
G(V, E)	:	A graph represents a flexible optical network with nodes in set V and edges in set E.
e	:	$e \in E$: link of fiber
s_i	:	A frequency slot with index i
S	:	Set of frequency slots
$\mathfrak{D}$	:	Set of all permanent connections
d_i	:	A particular connection of $\mathfrak{D}$
P(d_i)	:	Set of physical paths of demand d_i
P($\mathfrak{D}$)	:	Set of all physical paths $\mathrm{P}(\mathfrak{D}) = \bigcup_{d_i \in \mathfrak{D}} \mathrm{P}(d_i)$
p_i	:	A particular physical path in P($\mathfrak{D}$)
$\mid p_i \mid$	:	Number of link e in physical path p_i
$x_{p,p'}$	:	Boolean variable equals to 1 if physical paths p and p' share at least one edge, else it is 0
$x_{p,p',e}$	:	Boolean variable equals to 1 if physical paths p and p' share the same edge e, else it is 0
$x_{p,e}$	:	Boolean variable equals to 1 if physical path p used edge e, else it is 0
$x_{p,i}$	:	Boolean variable equals to 1 if physical path p use frequency slot s_i in one edge, else it is 0

We have below, the ILP defined by the objective function (1.1) and the constraints to follow (1.2),(1.3),(1.4),(1.5), (1.6) ,and (1.7).

Objective function

Minimize

$$Z = \sum_{s \in S} x_s \quad (1.1)$$

Constraints

$$\sum_{p \in \mathrm{P(d)}} x_{dp} = 1 \quad (1.2)$$

$$\sum_{e \in p} \sum_{i} x_{p_{e,i}} = |p| \times N \quad (1.3)$$

$$\forall \ p, p' \in P(\mathfrak{D}), p \neq p', e \in E: x_{p,p'} \leq \sum_{e} x_{p,p',e} \quad (1.4)$$

$$\forall \ p, p' \in P(\mathfrak{D}), p \neq p', e \in E: x_{p,p',e} \leq \ x_{p,e} \quad (1.5)$$

$$\forall \ p, p' \in P(\mathfrak{D}), p \neq p', e \in E: x_{p,p',e} \leq \ x_{p',e} \quad (1.6)$$

$$\forall \ p, p' \in P(\mathfrak{D}), p \neq p', s_i \in S: x_{p,i} + x_{p',i} + x_{p,p'} \leq \ 2 \quad (1.7)$$

The objective function (1.1) counts the number of frequency slots allocated to a set of connections. The objective is therefore for a set of connections whose traffic flow, sources and destinations are known, as is the case for the network planning phase to be able to establish them while involving the fewest Frequency slots as much as possible. As the values of the boolean variable x_s indicate, it is a question of minimizing the number of frequency slots used at least once by a connection on one of the links of the network. the constraint (1.2) foists that each connection must borrow the single physical path to convey its queries. And so, on this path one must be able to create an optical channel whose bandwidth must be able to transmit the traffic of this connection. It should be noticed that the bandwidth consists of a set of frequency slot. This number of frequency slots constituting the bandwidth depends on the rate of the connection (C in Gb/s) and the transmission distance which imposes the choice of a modulation format, as shown in formula (2).

$$N = \left\lceil \frac{C}{M \times F_{slot}} \right\rceil \quad (2)$$

$M \times F_{slot}$represents the capacity of a frequency slot in Gb/s. $M\ (b\ /\ s\ /\ Hz)$ is the modulation level in bits per second and represents the efficiency of the selected modulation format. $F_{slot}$is the bandwidth of a frequency slot in GHz. M can take the values 1, 2, 3 or 4 depends on the modulation format is BPSK, QPSK, 8-QAM or 16-QAM [20]. The constraint (1.3) expresses the constraint of contiguity and continuity of each of N frequency slots allocated to a connection. To each link e of path p of the connection, the same N frequency slots must be available. The constraints (1.4), (1.5), (1.6) and (1.7) express the constraint of non-overlap; two different connections must exploit successively the same frequency slot if their physical paths have the common links. $x_{p,p'}$ is a boolean variable equals 1 if that physical paths p and p' have in common at least one link. Its value is determined by the constraints (1.4), (1.5) and (1.6). This problem of combinatorial optimization is reputed as NP-Hard problem because it arises from the extension that is itself NP-Hard [4]. As a result, the problem of coloring, and multiprocessor scheduling on the processor dedicated to queries [13,14] are all NP-Hard problems.

In order to achieve the goal of minimizing the number of frequency slots used for processing a set of known connection requests in the network, a λ metric which represents the maximum frequency slot index used on the links of the network is defined. It is necessary to distinguish this metric λ from the maximum index of the frequency slots (i_{max}), since all the frequency slots are not necessarily used in an allocation process. Assuming that in the planning phase there are sufficient resources, the initial value of λ must be able to process all the connection requests d_i of the set $\mathfrak{D}$. For this purpose, the initial value of the metric λ must be the smallest between the index μ of the last frequency slot allocated on an optical link assuming that all the connections use this link and the maximum index of slots of frequency denoted i_{max} . The index μ is obtained by the formula (3.1)

$$\mu = \sum_{i=1}^{m} N_i + (\mathrm{m} - 1) \times BG \quad (3.1)$$

Where m is the number of connections requests and each connection request requires a spectrum band of width N_i frequency slots. Each of connections have the bands of frequency slots that have been separated by a guard band BG composed of frequency slots left over in avoiding the interferences. However, the maximum index of frequency slots used initially is the smallest value between μ and i_{max} (formula (3.2).

$$\lambda = Inf\ \{\ \mu\ , i_{max}\} \quad (3.2)$$

The minimization of the number of frequency slots used at least once amounts to minimizing the metric λ , because the spectrum allocation is processed in the way that all the used frequency slots have their index included in the interval $[1, \lambda\,]$. Any frequency slot with index greater than λ is unoccupied and it is entirely available on all the links of network topology in the same way as the example of Figure 2. In Figure 2, the maximum index λ equals 6, occupied frequency slots have got indices in $[1{,}6\,]$. The slots of larger indices than 6, that is to say $i \in \{7{,}8{,}9{,}10\}$ stay available on all links in the network topology. It should be noted that here $i_{max} = 10$.

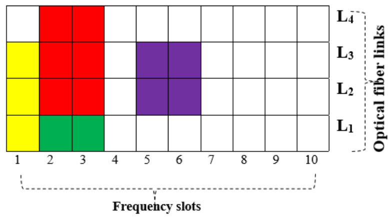

Figure 2: illustration of notions of i_{max} and the metric λ

In the following section, we propose spectrum allocation based on the Tabu search algorithm with the aim to improve significantly the value of λ until some finite iteration or some feasible solution occur. Our proposal deals simultaneously with the route and available frequency slots chosen.

4.Proposal : AMSF-Tabu

4.1. Meta-heuristic of Tabu search

The method Tabu [21] proposed by F. Glover, in1986, is an iterative meta-heuristic. From its initial solution, it engenders the new solutions in order to improve the value of objective function of optimization problem. Each solution denoted Γ leads to a set of neighboring solutions denoted $N(\Gamma)$.

To deal with the allocation resources made by Tabu meta-heuristic, we proceed as follows. For a set of the connection queries: $\mathfrak{D} = \{d_1, d_2, d_3, \ldots\ldots, d_m\}$, we associate with each request of connection $d_i \in \mathfrak{D}$ a triplet$(P_i, \varphi(d_1), N_i)$. The solution to this set of connections, $\mathfrak{D}$ is a set of triplets denoted as follow by Γ:
$\Gamma = \{(P_1, \varphi(d_1), N_1), (P_2, \varphi(d_2), N_2). \ldots (P_m, \varphi(d_m), N_m)\}$. Below are some definitions for a resource allocation solution.

Definition 1: degree of conflict of connection request
The degree of conflict of connection request d_i denoted $Conf(d_i)$ corresponds to the number of connections requests in a set Γ whose paths have shared at least one link with the path of d_i.

Definition 2: cost of a solution Γ
The cost of a solution Γ denoted $C(\Gamma)$ is the sum of the conflicting degrees of each of the connection requests of solution Γ. This cost is indicated by formula (4):

$$C(\Gamma) = \sum_{i=1}^{m} Conf(d_i) \qquad (4)$$

Definition 3: Solution feasible
A solution Γ is said to be feasible if its cost is zero: $C(\Gamma) = 0$

Definition 4: solution unfeasible
A solution Γ is said to be unfeasible if its cost is non-zero: $C(\Gamma) \neq 0$

4.2. How our proposal works

The idea is to minimize the λ metric, the maximum frequency slot index used on network links. Indeed, we explain the initial value λ given to Formula (3.2) previously in Section 2.2. This value of λ must be improved by decrementing it by 1 iteratively whenever a feasible allocation solution is found by the Tabu search process. That is to say if we find a solution Γ whose allocated frequency slots have indices which are in the interval $[1, \lambda]$ and of zero cost, the process starts again with a new value of λ which is the previous value Decremented by 1.This process must be reached the number of iterations previously set or its impossibility at the end of some iteration to improve λ because the process has not the feasible solution in slots index$[1, \lambda]$.

In this procedure to each connection, we determine the k-shorter paths according to the Yen algorithm [22]. In addition to this, the other mechanisms intervene in its operation. There are the procedures of construction of the initial solution Γ_{ini} , the construction of neighboring solution Γ denoted$N(\Gamma)$, the updating of conflicting list, and the rules of Tabu search. These procedures are pinpointed in the section 3.3.

4.3. Description of Mechanisms of Solutions

- Construction of Initial Solution Γ_{ini}

To construct the initial solution, we attribute to each connection query one of its k-shorter paths in a random manner. The k-shorter paths are calculated with the Yen algorithm [22]. However, the choice of one of k-shorter paths given to connection d_i that operates during the construction of the solution. From the path length, we compute the number of frequency slots N_i according to the appropriate modulation format in Formula (2). Finally, for each connection request $\boldsymbol{d_i}$, the index of the first occupied slot $\boldsymbol{\varphi(d_i)}$ is chosen randomly in the interval $[\mathbf{1}, \boldsymbol{\lambda}]$**.** Thus, defining the band of spectrum allocated to $\boldsymbol{d_i}$.

- Construction of Neighboring Solution $\mathbf{N}(\Gamma)$

First, we create the conflict list denoted Ω. This list is composed of connection requests d_i belonging Γ so that degree of conflict $Conf(d_i) > 0$. Next, we show the connection requests belonging to conflict list Ω as the header of list. This header of list is called d_t and finally we generate a neighboring solution Γ' by attributing a new value $(P_t, \varphi(d_t), N_t)$ to the header list d_t. The new values d_t are chosen randomly (P_t and ,$\varphi(d_t)$). The other connection requests Γ remain unchanged. Thus, in Neighboring solution set Γ' we have d_t with its new values and the other connections requests of set Γ.

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- The Updating of Conflict Lists Ω

We begin with the creation of an auxiliary list denoted Θ composed of connections d_i de Γ which are in conflict with the head of list d_t, that is to say $\Theta = \{d_i \in \Gamma /, \ P_i \cap P_t \neq \emptyset\}$. Next, to each connection of Θ, we calculate the degree of conflict $Conf(d_i)$ compared to Γ'. If $Conf(d_i) = 0$, then we remove d_i from the conflict list Ω. Furthermore, if $Conf(Cd_t) = 0$ compared to Γ', we must remove d_t from conflict list and choose another in random way.

- Rule of Tabu Search

There are two rules: the Tabu Rule (RT) and the Aspiration Rule (RA).

Tabu Rule: Tabu list is used to record the heads of list from conflicting list in avoiding the solutions have already checked. This rule wants to label a solution that leads to the head of Tabu list. Thus, this labeled cannot be selected as the next usual solution.

Aspiration Rule: This rule is used to interrupt the Tabu rule when a better solution appears among the labeled solutions. For a given iteration, if the cost of the labeled solution is better than the cost of solutions of all the previous iterations, the Tabu label is removed by this rule.

This pseudo-code algorithm depicts how the different mechanisms intervene in our method.

***Algorithm: Pseudo** code of minimum λ search Tabu algorithm*

Begin
Calculate the initial number of slot index λ with the formula (3.2)
Solution =feasible
***When**(solution equal to feasible)*
  Build the initial solution Γ_{ini} ;
  Create the list LC from Γ_{ini}
  $\Gamma = \Gamma_{ini}$; NbIt=0 ;// Number of iteration
  ***When** $(C(\Gamma) \neq 0$ and $NbIt \neq NbItMax)$*
    R_t = head of list from conflict list LC ;
    Build $N(\Gamma)$ based on R_t;
    Apply the rule RT and RA to find the best $C(\Gamma')$ for each $\Gamma' \in N(\Gamma)$;
    $\Gamma = \Gamma'$;
    Update the list LC ; Tabu List and NbIt ;
  End while
  If $C(\Gamma) = 0$
    Solution = feasible;
    $\lambda = \lambda - 1$;
  If not solution =unfeasible
End while
$\lambda = \lambda + 1$;
End

5.Simulation and discussion of results

To test the performance of MSFA-Tabu, we can use the network topologies of figure 2. The topology (a) is a smaller network (6 knots and 9 bidirectional links). As for the topology (b), it represents NSFNET topology networks (14 knots and 22 bidirectional links) used to simulate most of done works on the flexible optical networks. Finally, the last topology using to our experiment, is the topology of Ivoirian backbone network (28 knots and 46 bidirectional links).

The first is consisted of comparing the MSFA-Tabu with the exact method *Branch and Bound* implemented in IBM ILOG CPLEX 12.6.

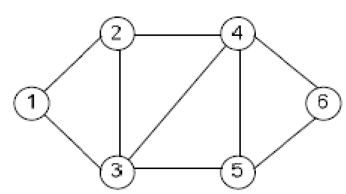
For this, we have considered four scenarios in which each one corresponds to a value of S. S is the greater value of contiguous frequency slots allocated to the connections of scenario S. For each of four scenarios, we generate randomly 20 connections requests in which the allocated frequency slots are dispatching uniformly in a set$\{1; \dots; S\}$; with $S \in \{10; 15; 20; 25\}$. The values of λ and T (running time) recorded in Table 1 demonstrates the entire part of the average obtained after 15 runs. It is useful to mention that, the maximum number of iterations for MSFA-Tabu has been fixed at 100. Regarding the k shortest paths, we have maintained the number at 3.

Table 1 : Difference between MSFA-Tabu an Exact method B &B

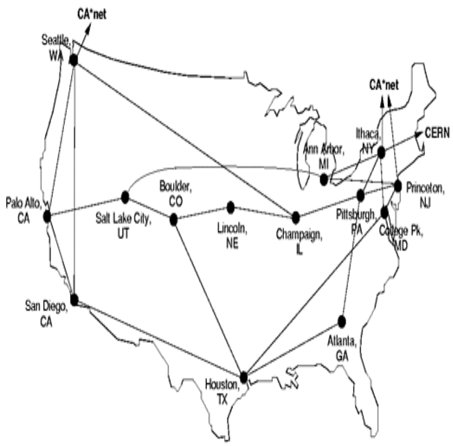
Scenario	*B&B*		*MSFA-Tabu*
	λ	T (s)	difference (%)
10	35,03	689	5.62%
15	47,45	1307	5.91%
20	54,60	8265	5.75%
25	59,5	13128	5.89 %

The analysis of the data in the table shows that the difference between the optimal results of the exact method and the results obtained by the MSFA-Tabu meta-heuristic is of the order of 5.79%. Concerning the computation time, it is of the order of millisecond for the MSFA-Tabu whereas for the Branch and Bound which gives optimal results, the time of obtaining the results is on average of the order 1 h 30 min thus, we observe a certain stability of results got by **MSFA-Tabu with an error rate of** 5.79 % but time of calculation is better than those *B& B*.

In the following, we carry out comparative between the AMSF-Tabu and other heuristic using NFSNET topology networks.

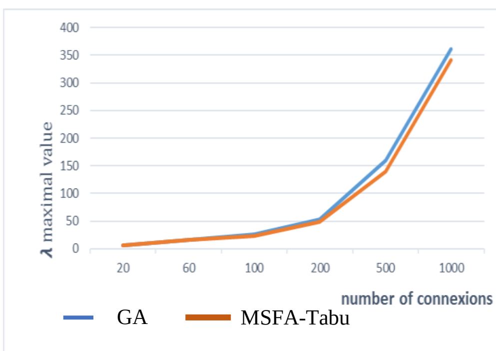


(a)

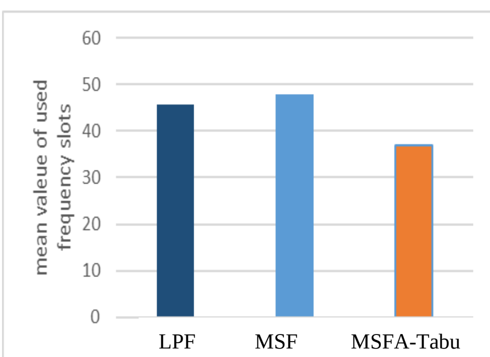


(b)

Figure 2: (a) Smaller network of six knots, (b) NSFNET topology



(a)



(b)

Figure 3: (a) maximum index of frequency slots depending on number of requests. (b) Average number of frequency slots according.

The material used is 2.16 GHz (Dual core) processor PC. It has 4 GB RAM. These codes have been implemented with Java under Eclipse. To the second experiment, we use the maximum iterative number at 100. Also, we consider the requests where the capacities vary between 20 GB/s and 100 GB/s. First, we have made the comparison of MSFA-Tabu with another meta-heuristic based on genetic algorithm and indicated in [9]. The criterion of performance is the maximum index of slot of frequency minimum required on each link. Figure 3 illustrates the results. From 20 to 200 requests, the two methods have almost the same maximum of frequency slots. However, over 200 queries as shown in Figure 3(a), our method the MSFA-Tabu provides the better result than genetic method. In the second illustrated by Figure 3(b), we begin with the comparison of our method with two other heuristics the MSF and the LPF [2]. The criterion of comparison stays the average number of frequency slots allocated to 100 requests where the capacities balance between 20 GB/s and 100 GB/s. It appears that that MSFA-Tabu gives the best result as indicated by Figure 3(b), the average number of slots of frequency used to this one is smaller than the number obtained with two other heuristics.

CONCLUSION

In this paper we proposed an approach to reduce the number of frequency slots necessary to allocate to a query instance in the planning phase of a flexible optical network. This tabu search based approach allows for effective results compared to other methods such as the genetic algorithm approach and other heuristics. Our approach contributes to the optimal use of flexible optical network resources. It based on the simultaneous resolution of the routing and the allocation makes it possible to park the connections to be planned in a range of slots of frequency delimited by the maximum index of slots of frequency used λ. And this guarantees the operator of the existence of a contiguous and continuous range of frequency slots available for future connections.

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