An Intelligent Heuristic Algorithm Based on Tabu Search to Enhance Open Shortest Path Protocol

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***Abstract*— Nowadays, a number of artificial intelligence search algorithms have been engaged with the problem of computer networks, especially in the area of network routing problems. Nodes in a network with many connections can be called hubs and some other nodes with fewer connections can create problems in routing messages around the network. In general, the protocol Open Shortest Path First OSPF is a link state protocol and it provides a good connection performance. However, this protocol has some drawbacks such as the determination of like weights and the increase of routing load. In this paper, an intelligent heuristic method based on the Tabu Search algorithm is proposed to find the optimal link cost/weight set and to determine the best path for the OSPF in a dynamic network. The simulation results show that other paths can be checked and selected to avoid congestion problem with the optimal path.**

***Index Terms*—Dynamic Routing; OSPF; Tabu Search.**

I. INTRODUCTION

Generally, computer networks can be constructed from a wide range of nodes (nodes and routers). The router is a device for making a routing in any network. What is a routing? It is the many jobs of finding a path in network(s). Basically, the routing algorithms are used to find the best path between two nodes, such as (source and destination nodes). The metric is used to find a better path, which is the goal of most routing algorithms such as the link state algorithm or the distance vector algorithm. Currently, many routing protocols used these algorithms as a technique to learn about available routes to build a routing table [1].

One of the simplest protocols in routing algorithms is Routing Information protocol (RIP). However, the main problems with RIP protocol is that it worked well in relatively small systems, but less well as Autonomous Systems (ASs) gets larger. RIP was replaced in 1979 by the Link-State protocol. In 1988, a new routing protocol, called Open Shortest Path First (OSPF) protocol was introduced, which became a standard protocol in 1990 [1].

In routing protocol, the communication cost, path cost or reliability can play a main role as a metric to find a better path, such as the shortest path. In the open shortest path (OSPF), the best path is determined by the link state algorithm [2]. However, the OSPF routing protocol has some drawbacks, such as the weight setting and the increasing routing load as a result to apply the shortest path first algorithm. Therefore, in this paper, we proposed to integrate Tabu Search algorithm [3, 4] which is a well-known artificial intelligence search algorithm to enhance the routing protocol and the performance of any computer network with the same environments.

This paper is organized as follow; Section II includes related works. Section III describes the Tabu search algorithm, then section IV introduces the methodology of proposed methods, followed by the experimental works. Finally, the conclusion is reported.

II. RELATED WORKS

In the literature, the shortest path routing algorithm (SPRA) is divided into two categories: the Static Routing Algorithm (SRA), and the Dynamic Routing Algorithm (DRA). Figure 1 illustrates the taxonomy of the shortest path routing algorithm.

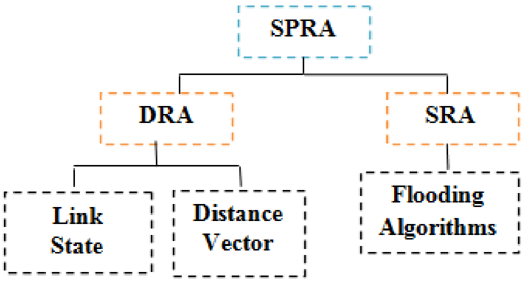

Figure 1: Taxonomy for the shortest path routing algorithms

In this paper, the Static Routing Algorithm (SRA) is beyond the focus of our study. Dynamic routing algorithm includes two mechanisms, which are the Link state and the distance vector. An example of this type is the OSPF protocol that uses weights for determining path between nodes. However, OSPF has a problem with weight setting. This problem is considered as an NP hard problem; hence, high interest has been given in such type of routing [5].

In (2012), Kok et al. proposed a new mechanism to combine a time depending on the shortest path and vehicle routing by a restricted dynamic heuristic search algorithm [6].

Jaballah and others tried to solve a problem of Time-dependent vehicle routing by proposing a new mathematical model for developing valid inequalities to strengthen them and to improve the lower bounds. The authors used meta-heuristic search and simulated annealing (SA) algorithm to make a new mathematical model for developing valid inequalities to strengthen them and to improve the lower bounds [7].

Moreover, Huang et al. (2017) proposed a flexible path in the vehicle routing problem depending on time. A mathematical model of Huang et al. (2017) can be used to select the candidate paths depending on the situation of network congestion. However, this work has some disadvantages in general networks, when all routers need to be used between two customers [8].

Khandani [9] and Li [10] proposed some models to work in a static search. Khandani proposed a new model to solve a problem of Transmission-side diversity and routing in a static wireless network. In more than one environment, the author had some achievements in energy savings for both lines and grid network topologies. The main drawback of this work is that the model works in static environments only [9].

Li [10] proposed a graphical model to be broadcasted as a tree to minimize the cost of energy. This work is special for Energy efficient broadcast in ad hoc wireless networks. However, the author tried to prove their solution to find the shortest path in all situations and formulated the suggestion as an NP-hard problem. The proposed model was not a simple model and it did not work in dynamic situations, such as a mobility environment.

In our point of view, this area is a very interesting research area as many researchers have focused in this field and it still needs more development. Some interesting works were done with static and dynamic environments. Most of these works are focused in discounting the cost of routing discovery to find the shortest path. However, the rest of the parts of the discovery (route maintenance and sending the packets) are also very important and significantly affected the performance of routing algorithms. To improve the performance of the networks by improving the routing algorithm, there are some other that needs to improve the quality of services also.

III. TABU SEARCH ALGORITHM

Tabu Search algorithm (TS) was introduced by Glover in 1986. It is a meta-heuristic search method utilized for fining local optimal solution. TS starts by taking a potential solution and checks all neighbors for a better solution. It stops when the criterion for the best solution is met. All solutions are saved in a memory list. The visited solutions are marked as (tabu); hence, the algorithm does not repeat similar solution [3, 4].

TS has been used in many subject fields such as travelling salesman problem [11], cohesive clustering problem [12], and economic dispatch problem [13], where, it is improving successfully. Figure 2 shows the pseudo code of the Tabu Search algorithm [14].

IV. METHODOLOGY

The main focus of this work is deploying a new technique to work alongside with the internet routing protocol OSPF. In this work we have presented the availability of backup routes to be used by the OSPF protocol in case of congestion or high traffic to enhance the performance of the network.

We worked to find the optimal link cost/weight set for the OSPF in a dynamic network. A new scenario is used to improve the efficiency of the shortest path first routing algorithm in a network and the network is implemented to enhance the quality of service network. The intelligent heuristic method based on a Tabu search algorithm (IHTS) was conducted by choosing the most appropriate set of weights that provide the optimal route from the source node to the other nodes in the dynamically created network environment. The algorithm provides an automatic update of the routing tables i.e., during the run time of the system. The cost values for the links between nodes are randomly assigned and randomly changed in the network. We assumed that in case of a heavy loaded network, the nodes will be provided with more than one route to avoid congestions.

- Determine the maximum number of iteration *M*.
- Determine initial solution *Xinit*
- Define initial tabu list *T*.
- For *i*=1 to *M*
- Define neighbor set *N*.
- Define set of solution *G*.
- Find the best solution *Xbest* from *G*.
- If *F(Xbest)* > *F(Xinit)* then
- Replace *Xinit* with *Xbest*
- End if
- Update *T*
- End For

Figure 2: Pseudocode of Tabu Search algorithm [14]

The proposed network model is beneficial for a network that can be freely extended in size. Hence, the nodes in such network characterized by the availability of nodes with higher number of links compared to other nodes in the network with low degree of edges. This kind of networks is considered a power –low degree distribution [15] Ldegree, for example, node *i*.

$$Ldegree(i) \alpha\, i - z \qquad (1)$$

where: z = Exponential value decays slowly as the degree node (i) increases external force

Hence, some nodes can have a very large degree. For node i, the degree distribution (k) is:

$$Kj = \sum_{j=1}^{n} ij \qquad (2)$$

where: j = Number of connected links with node i

A. Mathematical Model

The network is created using directed weighted graph (*DW_Net*) with different network sizes (*N*). Hence, *DW_Net = (DW_Nodes,DW_Link,DW_Cost, DW_Nsize)*; where the *DW_Nodes* are the nodes that have been used during the simulation, the *DW_Link* is a set of edges (communication links between the distributed nodes) bidirectional links, The *DW_Cost* are the numerical and random values - set on links between the distributed nodes, and the *DW_Nsize* is the number of nodes in the created network as it is changeable from run to run.

In a network system, the network grows gradually until it reaches the value of *DW_Nsize*, which has been set for the simulation purposes. However, the operation of assigning the cost values for links between any two nodes is done before reaching the network size.

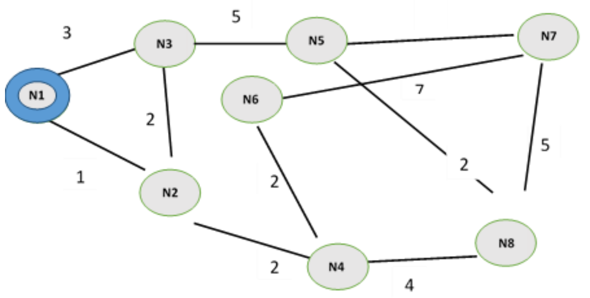

Figure 3: A network with cost values

In general, in large scale networks such as the internet, it is time consuming to find the optimal path that can lead to achieving the best route between the source and some destination node in the network [16]. This is because of the dynamic change in the cost values between the distributed nodes. Here, we are trying to show a real-world network, in which all nodes are not fully connected. However, accessing the network nodes is still active even when we have some nodes with the less number of network connections.

B. Theorem

Deploying an intelligent heuristic method based on Tabu search (IHTS) combined with the OSPF with point to point (*p-2-p*) networks. IHTS algorithm will be used to choose the optimal set of link costs (*DW_Cost*) for the network *DW_Net*. Hence, this technique avoids the paths that can lead to higher cost values and/or higher congestion in the network. The implementation of the Tabu Search gives the required flexibility to the network to have multiple pre-configured paths. Hence, in cases when the network encountered a problem such as congestion or link failure, it can check those paths to recover. Moreover, if the path with the minimum cost value has been used, the node could select other available path to reach the destination node and so on.

C. Overview of OSPF

The open shortest path routing (OSPF) is used by the Dijkstra algorithm to find the optimal path (route) from one node to any other node in the network. The common function of OSPF is that it represents the actual network as a graph and then computes the shortest path from every router to every other one.

We assume, in our work, that the process of finding the optimal path takes *t* time slot of *T*. Moving from one node to a neighbor node is taking one hop or one time slot (*t*) and it depends on the lowest path cost; that if we have more than one path that can lead to the target node. Hence, the next time slot will be *t*+1, which means that we have moved to the next node that can satisfy the optimal path. The full path will be assigned when the target node has been accessed.

V. THE HEURISTIC ALGORITHM (IHTS) WITH OSPF

Below is the representation of the proposed intelligent heuristic IHTS algorithm. The objective of the function is to find the best cost values set (*DW_Cost*) with a minimum cost path between the start node and each node in the network-satisfying the equation below.

$$Best\_DWCost\_set = \arg\min (DW\_Cost) \quad dw\_Cost \in dw_{cost}set \tag{3}$$

where: *DWCost_set* = All possible cost paths, which are available in each solution

The simple method to satisfy the objective function is to use all the *DWCost_sets* and ensure to store all the resulted sets after deploying (IHTS) in order to use them in case of having a congestion problem.

<u>Step 1:</u>

- Seeking minimum cost from source node (*i*) to all other nodes.
- Input Graph *G(S, D, C)*, *S*-start node, *D*-Destination node, *C*-Cost. paths *Vector[V]*,*V*=0
- Each node *j* is labeled with a cost value to indicate the weights between the two nodes.
- Nodes are connected by links, *L(I,j)*
- Computing the minimum cost value *Min_Cost (i, j)* which is the minimum cost recorded node *i* (the root node) to the present node *j*.
- Finding if there is any predecessor node between *i* and *j*.
- Recording the link weight from *j* to k if *L(j, k)*.
  - All nodes *k* immediately adjacent to *j*, if *d(i, j)* + *L(j, k)* < *d(i, k)*, set *d(i, k)* ← *d(i, j)* + *l(j, k)*, and set the pointer at *k* to *j*
  - Making a comparison between all available paths from *i* to *j*
  - Choosing the path with the minimum cost value (*least_Cost*).
  - Paths *Vector[V]* = *least_Cost*
  - Update *V=V+1*
  - Marking the node *j* as having been assigned with minimum cost
  - Repeating for a new *j* (next node) go to 4
  - End

<u>Step 2:</u>

- Calling update link weight state algorithm
- Re-assigning / changing randomly the weights on the links between nodes in the network
- For each node in *G*
- Choosing the *L(i,j)* update *G(i, j, new_C)* where *New_C=random(1, random_val)*
- A new routing table has been built

<u>Step3:</u>

- We used 9 solutions to find the optimal path with the minimum cost from the source node to all nodes in our simulation.

<u>Step 4:</u>

- Choosing the best solution with minimum cost value.

VI. EXPERIMENTAL WORK

In this part, we are trying to apply the suggested method for different network sizes. We have implemented the work on a complex network were number of nodes are 100,200 and 300 nodes, as shown in Table 1 and Figure 4, 5, and 6.

The table shows that the neighborhood has been kept as a constant random value. For simulation purposes, it has been set to such values. To study the effect of having different network sizes, in each of the implemented network, there are different numbers of links between the nodes as well as different cost values. The cost value of each link is to be set randomly from 1 to a constant value (*Const-Cost*) assigned for simulation purposes.

Table 1
The Experiment Setting

Network Type	Network Size	Neighborhood (R)
Network 1	100 nodes	(1-10)
Network 2	200 nodes	(1-10)
Network 3	300 nodes	(1-10)

In Table 2, the characteristics of the network are presented, network sizes (100, 200, and 300 nodes) with a number of links and the average node degree have been set depending on a probability function below.

$$Pi = ki / \sum_{j=0}^{n} kj \quad (4)$$

where: *ki* = Degree of node
j = Sum is made from all pre-existing nodes

Table 2
Characteristics of the Implemented Networks

Network Type	Network Size	No. Of Links	Average Node Degree
Network 1	100 nodes	198	1.98
Network 2	200 nodes	398	1.99
Network 3	300 nodes	792	2.64

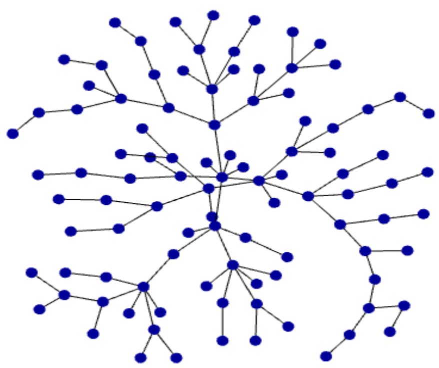

Figure 4: Network 1 - 100 nodes

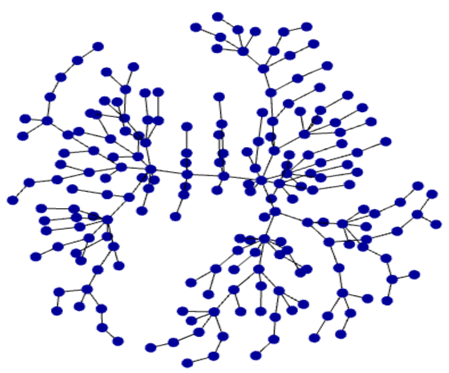

Figure 5: Network 2 - 200 nodes

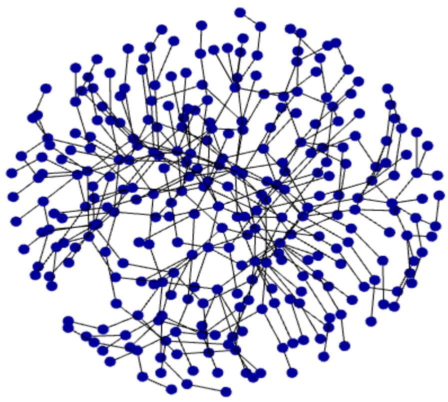

Figure 6: Network 3 - 300 nodes

We implemented two models: (model1: the standard OSPF algorithm called only (OSPF) and our proposed model 2: IHST). This purpose of this experiment is to compare and evaluate our work against the other work in literature, specifically the standard OSPF algorithm, which has been investigated in [17], in experimental work, Figure 7, 8 and 9 show the experimental results from the two models using different network sizes (100, 200, and 300) with random number of links for each node in the implemented networks. Figure 7 illustrates a network with 100 nodes, where the results from the two models are shown. It is noticeable that, IHST model can offer a number of alternative paths (from 1-9) starting from the first node (source) to the last node (destination). Moreover, it can redirect the OSPF to select and follow the optimal alternative path to be used whenever the OSPF model encountered a problem such as, link failure or over loaded path. This demonstrates that the idea of adding intelligence heuristic algorithm to network can add extra efficiency to the network functionality and enhance the network performance. The same scenario is applicable to Figure 8 and 9, when bigger network sizes 200 nodes and 300 nodes were used respectively.

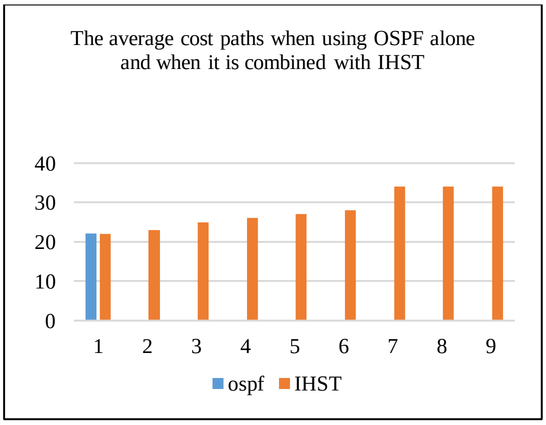

Figure 7: Network 1 - 100 nodes

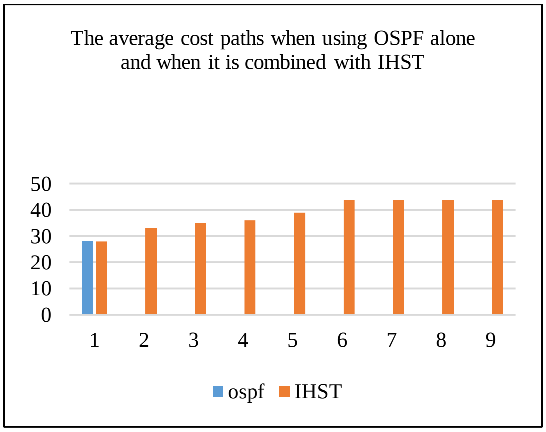

Figure 8: Network 2 - 200 nodes

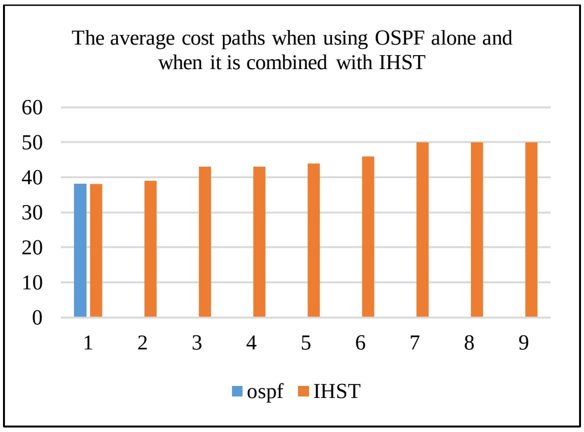

Figure 9: Network 3 - 300 nodes

VII. Conclusion

Our aim in this work is to provide the OSPF with a set of alternative paths. The resulted paths can be used as an optional choice to be taken if the OSPF protocol wanted to follow a different path instead of keeping its current path that may encounter high traffic. This work provides a preliminary results for our heuristic method based on Tabu search combined with the OSPF algorithm that can provide multiple paths to be used when there is a congestion problem in the network. The future work is to add the calculations for the time consumed in IHST and less consumption time period in case of congestion problems.

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