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Research paper

A Quality of Service Load Balanced Stochastic Diffusion Search – TABU Search (SDSTS) Network Backbone for MANET

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Abstract

The ad hoc network can present many different problems that influence a solution which can assure a proper quality of Service (QoS). The primary goal offered by the QoS was to ensure information delivery that was better and carried out by this network with a better network resource utilization. The main objective of the QoS routing found in the Mobile Ad hoc Network (MANET) was the optimization of the utilization of network resources when satisfying some application requirements. The AOMDV (the Ad hoc On-demand Multipath Distance Vector) and its routing protocol was a multipath extension of the protocol of AODV which aims at identifying a loop-free along with a link-disjoint multipath at the time of the process of route discovery. A Stochastic Diffusion Search **(**SDS) will have a strong framework in mathematics that can describe the algorithm and its behaviour by means of investigating resource allocation, linear time complexity, minimal criteria of convergence, global optimum convergence and robustness. The TABU Search (TS) is a search strategy based on memory for guiding the method of local search in order to continue a search beyond the local optimum. For this work, there is a hybrid SDS along with the TS which is proposed for improving the QoS load balancing.

Keywords: *Quality of Service (QoS), Mobile Ad hoc Network (MANET), AOMDV (Ad hoc On-demand Multipath Distance Vector), Stochastic Diffusion Search (SDS) and Tabu Search (TS).*

1. Introduction

The Mobile Ad hoc Network (MANET) has been a mobile node collection which depends on either a fixed infrastructure of communication or any other base station for providing connectivity [1]. Every node found in the MANET will act as either a host or a router or both. In case two of the nodes have not been within the range of transmission of one another, all other nodes will be required for serving as their intermediate routers to communicate between two different nodes. The hosts are however free to be able to move around in a random fashion and this way, the topology of the network can change drastically with time. thus, routing protocols for the MANET need to be adaptive and should be able to maintain routes since the traits of the connectivity of network can change.

The designing of an efficient along with a reliable protocol for routing of these networks can be a very challenging issue [2]. For the same reason, there are several protocols in routing that are developed and this attempt at accomplishing the task in an efficient manner.

A routing based on the QoS is quite challenging in the MANETs since the nodes need to keep some up-to-date information on link status. Further, owing to the MANET and its dynamic nature, the maintenance of a precise information on the link state may be challenging. The resource which is reserved is not guaranteed as the mobility has caused a path breakage or a depletion of the power of mobile hosts. A QoS routing will first find a feasible route that is new for recovering this service. It is an agreement that provides some guaranteed services like bandwidth, packet delivery rate, delay jitter, delay and so on. The supporting of several QoS constraints can make the problem of routing NP-complete [3].

As the ad hoc networks tend to change their topology often, a new and improved system performance by means of a load balancing or a reduced end-to-end delay is achieved. This brings done route discovery and the routing overheads. An Ad hoc On-demand Multipath Distance Vector (AOMDV) based routing protocol will extend the AODV for building and also for storing various paths within the routing table. This may not always result in any new flood of the packets of route requests. As opposed to this, a source node may also choose the route available subsequently.

The existing protocols in multipath routing may not be used for route stability for carrying on multipath routing. There are several other modified versions of the AOMDV protocol for providing solutions to different problems in routing. Such protocols may resolve issues such as the problem of route cut-off, route stability and node energy efficiency.

Earlier, there were several algorithms that included the exact and the approximate algorithms proposed for addressing problems in optimization. There are certain meta-heuristic algorithms of search using framework that was population-based that have the capacity to be able to handle some high dimensional problems in optimization. The Artificial Bee Colony (ABC) and the Stochastic Diffusion Search (SDS) are some examples of this and they have an improved scheme with a good performance in a varied range of issues like the pattern recognition, neural network training, combinatorial problems in optimization, data mining, image processing and function optimization.

The TABU Search algorithm contains a certain dependence on initial solutions. There has been a good solution to help in identifying a proper solution for the solution space and a solution that is poor may reduce the speed of convergence. Generally, at the time of solving a certain problem, there are other algorithms that are used for the generation of some high-quality solutions. This solution which is from a TS that is well-designed will not strongly depend on the initial solution's quality and in case the multiple starts have been used for a TS, there could be some advantages in diversity from various initial solutions. Thus, it is not a rarity to identify randomly generated initial solutions.

In this work, the AOMDV proposed made an estimation of its bandwidth, the node delay, and the load along with a CDS-TS. This was done with the TS and the SDS algorithm which was proposed and presented in the MANET. The work that is related to the literature was reviewed in Section 2. In section 3, the methods employed were discussed. Section 4 discussed the experimental results and Section 5 concluded the work.

2. Related Works

The Quality-of-Service Multicast routing is an NP-complete problem such as the problem of the constrained Steiner tree that has different real-time applications of the multimedia in the high-speed networks. A bandwidth-delay-constrained least-cost multicast routing based algorithm that was further based on the TABU Search had been proposed by Armaghan et al [4]. Such algorithms were able to improve the speed of search and can make it a solution that is better by employing any of the neglected aspects in TABU Search and its candidate list strategy. There was an evaluation of both the performance and efficiency of these algorithms on various randomly generated work. The results of the evaluation had indicated that these proposed algorithms will be able to overcome all other currently existing memory versions of TS-based algorithms along with the heuristics as regards an average cost of the tree and its running time.

Owing to a centralized, dynamic and self-configuring nature of the MANETs there are many advantages that were identified. For supporting these multimedia applications, it may be necessary for the MANETs for having efficiency in routing and the requirements of the QoS. But, the rapid growth in diversity and number of network applications has now made it important to be able to consider end-to-end delay needs of network traffic. According to Tekaya et al [3], by means of coupling a new multipath routing protocol along with a mechanism of load balancing based on certain QoS, a new protocol known as the QLB-AOMDV (the QoS and Load Balancing AOMDV) were presented and this achieved a better load balancing. The results showed a significant improvement in the performance of the network for a multipath routing protocol and the proposed QLB-AOMDV was found to work better compared to that of the other protocols in aspects of load balance, capacity, and delay.

Allakany et al [5] further presented another new method for the least-cost QoS multicast routing based problem that was further based on the GA and the TABU Search. This was also an NP-complete problem. This proposed Genetic TABU Search algorithm (GTS) was a combination of the Genetic Algorithm and TABU Search for improving the performance of computation. In this method proposed, the multicast tree chromosomes that were represented by the coding scheme of a tree structure were used. It simplifies the operations of coding and then omits both the coding and the decoding process. There was a new initialization of the process which was based on the Prim's algorithm and this method ensured that each chromosome was a multicast tree that was reasonable without any loops. It was then compared to the currently existing algorithms and the results of simulation proved that this method that was proposed had a high convergence speed which was effective in solving problems.

Owing to their intrinsic trait of flatness, the hierarchical topology is able to achieve both the scalability and the efficiency of the wireless network. For solving such a problem, the virtual backbone network through using the Connected Dominating (CDS) Set for the wireless network was used. Recently, there was an efficient and fast construction of the CDS. A comprehensive survey of the CDS and its related problems was made by Yu et al [6] using different network models with specific applications. Finally, there were some open problems along with interesting issues that were proposed.

In order to find a high number of CDSs and become different, Shi et al [7] had identified a large number of the CDSs found in the EHN for prolonging the activity of the network. All novel problems of an investigation were NP-Complete and had proposed four different approximate algorithms. A solid theoretical analysis along with some extensive simulations was performed for evaluating these proposed algorithms. Guibas et al [8] further proposed certain algorithms for the effective maintenance of a constant-approximate minimum connected dominating set (MCDS) with a geometric graph that was under both node insertions, as well as deletions. Considering the two nodes to be adjacent in this graph, only in case they are inside a fixed and geometric distance. It is shown that the O (1)-approximate MCDS for a graph in the Rd with the n nodes are maintained in the O (log2dn) time for each node insertion or deletion. It is also shown that the $\Omega(n)$ time for each operation was necessary for the maintenance of an accurate MCDS. The lower bound will hold even for a d=1, and even for the randomized algorithms, even at the time of amortizing running time over an entire sequence of insertions or deletions or over some continuous motion. The fact that was crucial here was that one single operation could affect the whole solution and an approximate solution was affected only inside a small neighbourhood which was either inserted or deleted. For an approximate case, it is shown as to how the local changes may be computed using a few ranges of the search queries with certain bichromatic queries of the closest pair.

3. Methodology

This section further details on the AOMDV, the Connected Dominating Set, the Stochastic Diffusion Search, the TABU Search, the proposed Hybrid SDS-TABU Search (SDSTS), and the Hybrid SDS – TABU search Algorithms.

3.1 Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV)

The primary concept of the AOMDV was to compute multiple paths that are loop-free for every route discovery. Using multiple redundant paths, the protocol will switch routes to other paths at the time the previous one fails. The route discovery will be initiated only at the time all paths to a certain destination fail. It has to be noted that the link disjoint paths will be sufficient for this purpose and are used for multipath routing to reduce overheads as opposed to load balancing. In the case of the latter, all node-disjoint paths will be even more useful since switching to another node may be guaranteed for avoiding a congested node. The link-disjoint paths, have some common nodes and as their disjoint nature is stricter compared to the others, they use this hoping to identify alternate routes within the network [9]. As per figure 1, the routing table entries and their structure of the AOMDV have been depicted.

Destination
Sequence number
Advertised_hopcount
Expiration_timeout
Route_list

Figure 1: Structure of routing table entries for AOMDV [9]

A basic structure in the entry of the routing table of the AOMDV has been depicted in Figure 1. To this, there are two differences: (i) a hop count will be replaced by the advertised hop count found in the AOMDV (ii) the subsequent hop will be replaced by a route list. A route list was just the list of the subsequent hops and the hop counts that correspond to various paths to a destination. This advertised hop count will represent the maximum hop counts for the multiple paths as long as there are a strict update of routes where the update is followed. Every routing table entry will have one expiration timeout that is common irrespective of the actual number of the paths to their destination. In case none of these paths have been used until such time the timeout expires, all paths will be invalidated and the hop count that is advertised will be reinitialized. The primary idea behind the AOMDV was the computation of multiple paths at the time of the process of route discovery for the contending of link failure. At the time the AOMDV creates the multiple paths which are between the source node and the destination node, there are only some path-based metrics selected to transmit data. The path that reaches the destination node first will be selected for a primary path and the others will be the ones that are alternate. This way, it is easy to create a data transmission path.

3.2. Connected Dominating Set (CDS)

The Dominating Set which is DS denotes a subset of the nodes in a way in which every node is in the DS or has a neighbour in the DS. There is a Connected Dominating Set CDS which is the connected DS, and there is also another path between two nodes not using nodes which are not present in the CDS. The CDS is considered to be an ideal choice for the backbone. It can be quite favourable to have some nodes within the CDS and this is called the problem of Minimum CDS.
The connected and dominating set for graph *G* is a set *D* of the vertices with two different properties:

1. A node in the *D* may reach another node in the *D* by the path which entirely remains within *D*. Which means *D* will induce the connected subgraph of *G*.
2. Each vertex in the *G* will belong to the *D* or will be adjacent to the vertex in *D*. Which means *D* remains the dominating set of that of *G*.

There is also a minimum connected dominating set for the graph *G* which is a new connected dominating set having a probability that is the smallest among cardinality among connected dominating sets of the *G*. This connected domination number which is for *G* denotes the vertices within its minimum connected dominating set.

3.3. Stochastic Diffusion Search (SDS)

A Stochastic Diffusion Search (SDS), denotes a multi-agent global search along with an optimization of the swarm intelligence based on iterated interactions among agents [10]. Once the SDS is considered within a broader context of the natural swarms, there is a high-level description of algorithms that are presented as a search metaphor which is driven by their social interactions. This will be followed by the example of one trivial 'string search' and its application for illustrating their entire core algorithmic processes through which the SDS will operate. After this, the behaviour of SDS is analysed and the actual possibility of embedding various strategies in a novel manner wherein the SDS can deal with the costly objective functions is also investigated. Lastly, there are many hybrid algorithms of the SDS that are reviewed and all issue that is related to the SDS will be presented.
An SDS algorithm will start a search or an optimization by means of initializing the population such as the miners in the case of a metaphor of a mining game. For any SDS search, every agent will maintain a new hypothesis h, which will define a possible solution to this problem. In the case of an analogy of the mining game, the agent hypothesis will identify a hill. Once the initialization is complete, there are two phases that are followed:

- The Test Phase (such as testing the availability of gold) ·
- The Diffusion Phase (such as the congregation and the exchange of information)

In the case of a test phase, the SDS will check if the agent hypothesis has been successful or not by means of performing a new partial evaluation and then returning the independent of domain Boolean value. After this, a contingent based on the employed strategy and its successful hypotheses will diffuse across this population based on potentially good solutions in the entire population. For the test phase, every agent will perform a function of partial evaluation which is the pFE, a function of the hypothesis of the agent; pFE=f(h). For the mining game, a partial evaluation of the function will entail the mining of a region chosen randomly on the hill defined by the hypothesis of the agent (as opposed to the mining of all of the regions in the hill). in the case of the diffusion phase, every agent will recruit one more agent for the purpose of interaction and their communication of hypotheses.

3.4. TABU Search (TS) Algorithm

The TABU Search had been proposed initially by Fred W. Glover in the year 1986 where several ideas that were suggested even before the 60s were borrowed and formalized in the year 1989. These two articles are simply called the 'TABU Search' which proposed most of the principles of TABU search that were known currently. The method was at first introduced for overcoming local optima produced at the time the local methods of search or the traditional algorithms were used.
For the purpose of avoiding the local minimum, there was a TABU list that was constructed wherein there were forbidden moves that were listed. The list also consisted of information which forbade search from it returning to a solution visited earlier. In this algorithm, a solution was generated and this was a TABU for a particular number.
The advantages of a TABU Search:

- Using of TABU list
- It may be applied to the discrete and the continuous spaces of the solution.
- It is a meta-heuristic guiding the process of local search for exploring its solution space beyond the local optimality
- In the case of the larger and more challenging problems, the TABU search has solutions that surpass all ideal solutions found in other approaches.

4. Hybrid SDS – TABU Search (SDSTS) Algorithm

On the basis of a simple interaction among agents, the SDS was a multi-agent optimization and global search algorithm. The actual process by which the SDS duly allocates the resources was demonstrated by means of presenting an SDS description of a high level as a social metaphor. For solving a best-fit recognition of pattern along with the matching patterns, the SDS has also introduced another novel approach. It has a very strong mathematical framework compared to the other algorithms that are inspired by nature and the framework was used for the purpose of delineating the algorithm's behaviour, allocation of its resources, robustness, minimal criteria of convergence, convergence to the global optimum and so on [11].

Firstly, there is a population which is initialized at the time the SDS starts an optimization or a search. Each agent will maintain a hypothesis h and this will be used to define a probable solution to any problem. Both the test and the diffusion phase will be the two phases following initialization. In that of the former, there is a partial hypothesis which is evaluated by agents returning to a Boolean value. This way, the SDS will check if the agent hypothesis was successful and the information relating to solutions which are potentially good, will spread across the whole agent population. Each agent within the test phase will perform a partial function evaluation or the pFE. This will represent a function of a hypothesis of an agent pFE = f (h). Each agent within the diffusion phase will recruit one more agent to interact and have the potential of communication of hypothesis.

Normally, in most of these search algorithms, it may be a major challenge to ensure optimal solutions exist. The next challenge was either the local minimum or the maximum. The work will strive towards the improvisation of the performance of the TS and its candidate solutions. If there are not more good solutions, the SDS provides diversity to the candidate solutions of the TS. The SDS will work with their best solutions and also provide a wide range of results for the TABU search candidate solution. This was done by means of interchanging all old solutions in the TABU list with the new SDS solutions. The method of iterative examination will accept unaltered moves from the i to the j in V* (i.e. f (j) > f (i)). The SDS further aids in the avoidance of a local minimum. This new version was suggested to be even more strong and heuristic and helps in reduction of the problem of local minimum and in obtaining an optimal solution. The TABU SDS suggested has been given as per figure 2.

This SDSTABU has the steps below:

- Step 1: Choosing an initial solution i in the S. Set the i* =i and the k=0.
- Step 2: Set the k=k+1 and generate subset V* of the solution in N (i, k).
- Step 3: Choosing the best j in the V* and then set i = j.
- Step 4: Selection of the best subset from the N (i, k) and add in B.
- Step 5: In case the best solution cannot be obtained then call for the SDS having the best subset from its TABU-list.
- Step 6: Selection of best solutions from an SDS output and add it to the TABU list.
- Step 7: In case the stopping state is duly met stop or go to Step 2.

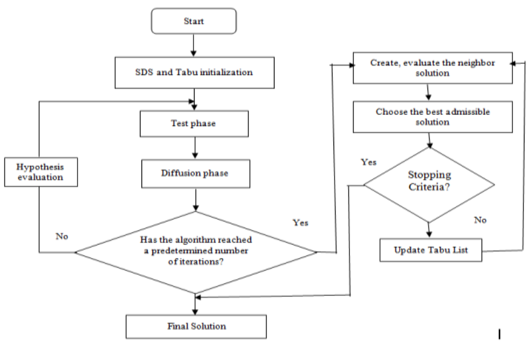

Figure 2: Flowchart for proposed hybrid SDS with TABU Search Algorithm

5. Results and Discussion

In this work, the AOMDV, CDS - TABU QoS and Hybrid SDS - TABU methods are used. Table 1 shows the parameter of TABU Search Algorithm. The average packet loss, average end to end delay, jitter, and control packet overhead as shown in tables 1 to 4 and figures 3 to 6.

Table 1: Parameters of TABU Search (TS) Algorithm

Length of Tabu List	96
Maximum number of iteration	200
Updating factor	0.3
Perturbation strength	[4 – 15]
TABU Length	10
Length of Candidate Lists	48

Table 1: Average Packet Loss

Number of nodes	AOMDV	CDS-Tabu QoS	Hybrid SDS - Tabu
100	12.32	11.8	11.4
200	13.44	12.8	12.1
300	16.88	15.9	14.9
400	17.26	16	15.6
500	19.76	18.6	17.9

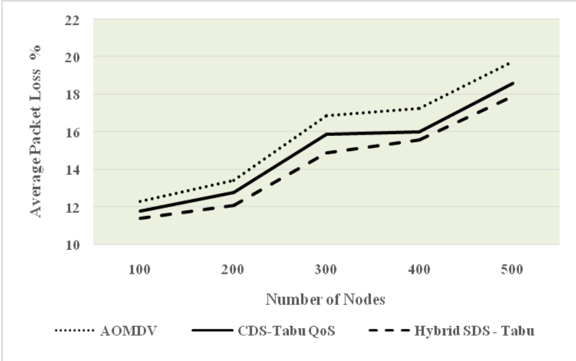

Figure 3: Average Packet Loss

From the figure 3, it can be observed that the Hybrid SDS - Tabu has lower average packet loss by 7.76%, by 10.5%, by 12.5%, by 10.1% and by 9.9% for 100. 200. 300, 400 and 500 number of nodes respectively than AOMDV. Similarly the Hybrid SDS - Tabu has lower average packet loss by 3.45%, by 5.6%, by 6.5%, by 2.5% and by 3.84% for 100. 200. 300, 400 and 500 number of nodes respectively than CDS – Tabu QoS.

Table 2: Average End to End Delay

Number of nodes	AOMD V	CDS-Tabu QoS	Hybrid SDS using - Tabu
100	0.0232	0.0216	0.0206
200	0.0289	0.027	0.0258
300	0.0365	0.0339	0.0323
400	0.0389	0.0366	0.0352
500	0.0437	0.0413	0.0392

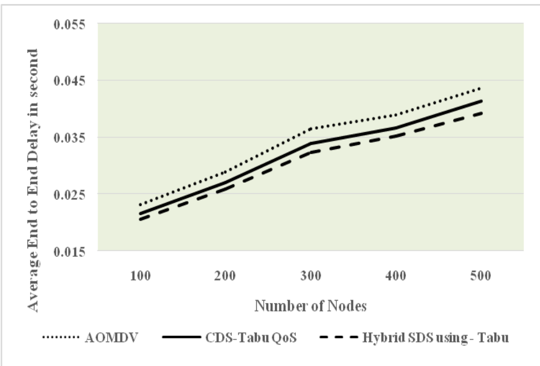

Figure 4: Average End to End Delay

From the figure 4, it can be observed that the Hybrid SDS – TABU has lower average end to end delay by 11.9%, by 11.3%, by 12.2%, by 9.99% and by 10.86% for 100, 200, 300, 400 and 500 number of nodes respectively than AOMDV. Similarly the Hybrid SDS - Tabu has lower average end to end delay by 4.74%, by

4.55%, by 4.83%, by 3.89% and by 5.22% for 100, 200, 300, 400 and 500 number of nodes respectively than CDS – Tabu QoS.

Table 3:Jitter

Number of nodes	AOMDV	CDS-Tabu QoS	Hybrid SDS using - Tabu
100	0.00022	0.00013	0.00009
200	0.00006	0.00009	0.00018
300	0.00035	0.00001	0.00003
400	0.0003	0.00023	0.00029
500	0.00033	0.00007	0.00003

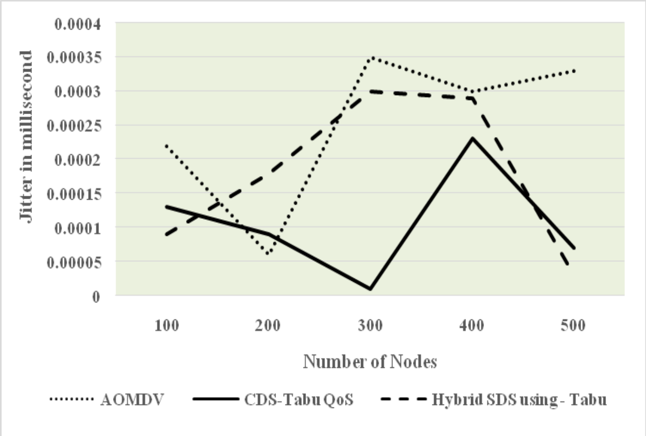

Figure 5: Jitter

From the figure 5, it can be observed that the Hybrid SDS – TABU has lower average end to end delay by 83.9%, increased by 100%, lowered by 15.4%, increased by 3.39% and lowered by 166.7% for 100, 200, 300, 400 and 500 number of nodes respectively than AOMDV. Similarly the Hybrid SDS - Tabu has lower average end to end delay by 36.4%, increased by 66.7%, lowered by 187.1%, increased by 23.08% and lowered by 80% for 100, 200, 300, 400 and 500 number of nodes respectively than CDS – Tabu QoS.

Table 4: Control Packet Overhead

Number of nodes	AOMDV	CDS-Tabu QoS	Hybrid SDS using - Tabu
100	7.71	4.89	5.58
200	6.56	5.13	7.12
300	8.84	8.29	5.99
400	6.79	7.5	7.34
500	12.39	10.45	6.77

From the figure 6, it can be observed that the Hybrid SDS – TABU has lower average end to end delay by 32.1%, increased by 8.2%, by lowered 38.44%, by increased 7.8% and by lowered 58.7% for 100, 200, 300, 400 and 500 number of nodes respectively than AOMDV. Similarly the Hybrid SDS - Tabu has higher average end to end delay by 13.5%, by 32.5%, by 32.3%, lowered by 2.2% and lowered by 42.7% for 100, 200, 300, 400 and 500 number of nodes respectively than CDS – Tabu QoS

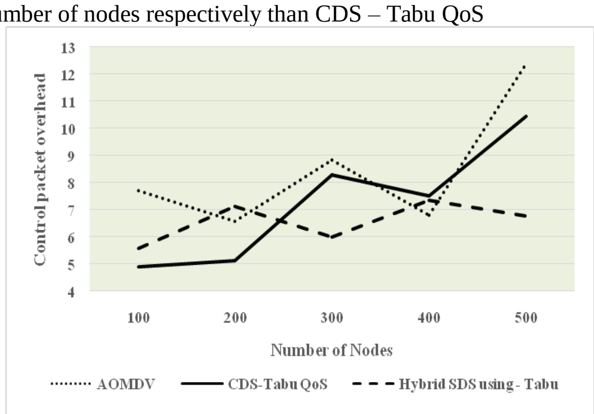

Figure 6: Control Packet Overhead

6. Conclusion

The actual quality of service is very challenging to be achieved in the case of ad hoc networks and also in their other wired counterparts as the wireless bandwidth was shared between their adjacent nodes where the changes to topology are unpredictable. The primary objective of that of the QoS routing in the MANET was the optimization of the utilization of network resources at the same time satisfying the requirements of the application. The TS also has the capacity to escape from the local optimum. The results have proved that this Hybrid SDS - TABU has an average packet loss that was lower by about 7.76%, 10.5%, 12.5%, 10.1% and 9.9% for the 100, 200, 300, 400 and the 500 number of nodes compared to the AOMDV. Likewise, a Hybrid SDS - TABU has an average packet loss that is lower by about 3.45%, 5.6%, 6.5%, 2.5% and about 3.84% for the 100, 200, 300, 400 and the 500 number of nodes compared to the CDS – TABU QoS.

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