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Energy Aware Secure Dynamic Multipath Routing using ACO with Modified Local Selection using SA

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Abstract: Security, efficiency and reliability remains to be the major requirements of a MANET. However, there exists tradeoffs in each of the requirements and not all the three can be achieved to its maximum extent. This paper uses the three-opt variant of ACO with high emphasis towards exploration. The three-opt variant operates by identifying the shortest path after every ant in the system has identified a complete path. Simulated Annealing (SA) is used to identify the best path from these available set of paths. The major concentration of this approach is to obtain an equilibrium point for best efficiency and time. Experiments were conducted using several datasets and the efficiency and randomness observed in the obtained paths revealed that the algorithm performs effectively.

Keywords: MANET, Routing, ACO, Multipath Routing, Simulated Annealing.

I. INTRODUCTION

The increase in number of mobile devices has attracted several researchers in this area. MANET is a self-configuring temporary network consisting of several mobile nodes interconnected with one another wirelessly [1, 2]. Since the interconnection is wireless, the infrastructure is not defined and the systems do not bother about regulating the traffic. Communications are usually carried out through intermediate nodes, as the range of each node is limited. Hence the basic operation of a MANET lies in nodes forwarding packets or in other words being altruistic. Since nodes in a MANET are battery constrained, maintaining the altruistic nature of nodes remains to be a huge challenge.

Routing protocols play a major role in maintaining the altruistic nature of the nodes in a MANET [3]. Unlike routing techniques for wired networks, routing in MANET is not only concerned with the distance of travel, it is also concerned with the charge contained in intermediate hops and the reliability of the nodes. Retransmission in MANET in costly, hence reliability of nodes when identifying a path is of huge importance. Further, repeated utilization of paths leads to repeated charge depletion in specific nodes, hence the routing protocol must also consider the fact that the routing protocol must perform random utilization of the entire network rather than specific nodes.

II. RELATED WORKS

Routing has been in existence since the inception of the first network. While conventional routing techniques deal with identifying shorter and efficient paths, MANET routing techniques deal with uniform energy dissipation and efficiency. This section presents some of the recent techniques dealing with MANET routing.

Swarm intelligence has been a preferred technique in the recent times for MANET routing due to the intrinsic error contained in swarm based techniques that aids in the generation of random paths rather than a single best path every time. A swarm intelligence based multipath routing technique using BAT optimization is presented in [4]. This technique proposes an ad-hoc on-demand multipath distance vector (AOMDV) routing based on the link delay observed in the network. This is an extension of the AODV [5,6] routing technique. A similar single path routing technique was proposed by Obaidat et al. in [7].

This technique is based on identifying node-disjoint paths with least delays. A multi-metric based routing technique was proposed by Khimsara et al. in [8]. This technique was proposed to ensure effective end-to-end delivery along with low retransmission rates. A similar multi-criteria based routing technique is presented by Patil et al. in [9]. This technique utilizes bandwidth, link quality, node mobility and remnant power to identify the destination node. A route split MANET routing technique was proposed by Takeuchi et al. in [10]. The usual route split algorithms result in high battery depletion, this method proposes to overcome that drawback by providing a sustainable algorithm that adapts to node faults and battery exhaustion. An agent based technique that monitors the quality parameters of nodes to facilitate routing was presented by Palaniappan et al. in [11]. This technique employs agents to monitor quality of nodes using several reliability metrics. When the demand for packet transmission occurs, these parameters are operated using Fuzzy logic to identify the best route for destination. A bi-directional routing technique that identifies the best affordable path for routing was presented by Malathi et al. in [12]. This technique has is major focus on reducing the acknowledgement overhead and eliminating malicious

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attacks. A cluster based routing technique for MANET was proposed by Singh et al. in [13]. This technique proposes an election algorithm that assigns effective nodes as cluster heads. These cluster heads transfer information between themselves to aid in the process of routing.
Major drawback with most of the routing techniques is that they do not consider the presence of selfish nodes during the process of routing. This leads to in-effective routes, hence retransmissions. The technique proposed by Thorat et al. in [14] overcomes this issue using an opportunistic routing technique. A measure to identify path goodness is proposed in this technique that considers the trustworthiness of a path prior to the transmission. A minimal energy consumption based optimized routing was presented by Havinal et al. in [15]. This technique proposes a novel routing strategy based on the mathematical and signaling properties of the MANET.

III.OUR APPROACH

Multipath routing has been used to incorporate higher levels of reliability in the packet delivery process in an ad-hoc network. But in battery constrained networks like MANETs, multipath routing by duplicating the packets is not an affordable approach. This approaches incorporates dynamicity and enhanced security in the routing process by utilizing multiple paths to transmit a single message rather than utilize one path for one entire message.
The process of identifying multiple paths using ACO [16, 17] is performed in two phases (Fig.1). The first phase uses ACO to identify several paths and the next phase uses Simulated Annealing to identify several best paths from the set of paths identified by ACO. On transmission initiation, the message is obtained and divided into nr packets. Each of the nr packets needs to be transmitted through a different route to the destination.

A. ACO based Path Identification

Network construction is performed on traffic initiation. Every traffic initiation triggers new network construction. Since MANETs are considered to be ad-hoc in nature, this process ensures that the dynamic nature of the MANET is incorporated into the algorithm and older routes are not used ensuring reliable deliveries. Modified Ant Colony Optimization, using Simulated Annealing for the final selection of multiple paths is used in this approach.
ACO operates by initializing the ants in the network. The number of paths identified in the last stage is equal to the number of ants contained in the ant system. In order to identify the most effective paths, the number of ants is set to nr^2, where nr is the number of packets to be transmitted. All the ants are initially placed on the source node. This marks the beginning of the ant movement.

The probability of an ant to select a node is given by,

$$p_{ij}(t) = \frac{[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum_{j=1}^{n}[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}$$

where τ_{ij} is the pheromone intensity in the edge ij and η_{ij} is the visibility range of the edge ij. α and β are the weights provided to the pheromone trial and the visibility respectively.

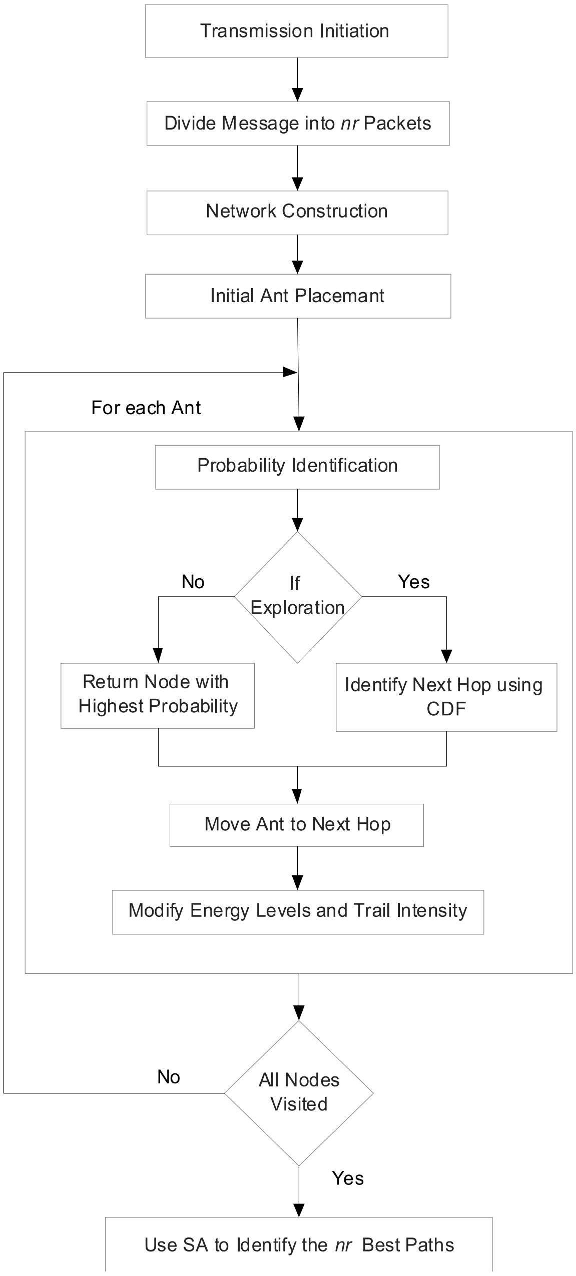

Fig.1. Multipath Routing using ACO with Modified Local Selection using SA – Architecture

After the identification of probability values, the best node for movement is identified depending on the random coefficient depicting exploration or exploitation [18]. The exploration and exploitation levels (q0) are initialized by the user during the network initialization phase. This approach initializes the q0 value to 0.3 representing 70% probability for exploration and 30% probability for exploitation. The process of exploration is carried out using Cumulative Distributive Function (CDF) [19]. CDF of a real values variable X is the probability that X will take values less than or equal to x. Here x lies in the closed interval, hence

$$P(a < X \leq b) = F_X(b) - F_X(a)$$

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When the random co-efficient is set to exploitation, the node with the highest probability is selected as the next hop node.

A Tabu list [20] is maintained for each ant to store the currently selected node. The process of node selection is continued until the destination node is reached. Tabu list corresponding to the ants contain the complete path identified by each of the ants. After completion of a complete cycle, nr^2 paths can be obtained from the Ant System.

B. Simulated Annealing based Path Shortlisting

Modified ACO identifies several paths from the list of paths generated by the ants. Simulated Annealing (SA) is used for this purpose. Simulated Annealing [21] is a probabilistic technique for providing an approximate global optimum of a given function. It is a metaheuristic approach that provides approximate global optimization on a large search space. In this approach, simulated annealing is used to identify the best nr paths from the available nr^2 paths obtained from the ants.

Simulated Annealing(bestPath,pathList,totalPaths)

1. Let s = bestPath
2. For k = 1 through totalPaths :

a. T ← pathList[k]

b. Pick a random path s_{new}

c. If $P(E(s), E(s_{new}), T) \geq$ random(0, 1), move to the new state:

- s ← s_{new}

3. Output: the final best path s

P(e,e',T) was defined as 1 if e' < e and exp(-(e'-e)/T) otherwise.

This process is repeated nr times to identify a path for each packet. These paths are not expected to be disjoint. Some repeating paths might also be present in the path list. This is accepted, as only a few near optimal paths can be identified and selecting the worst path is usually not recommended. Further, this property has also been observed to reduce the randomization level and increase the path reuse levels. However since the size of the packet transmitted through the defined paths are low (less than transferring the entire message), the reuse is compensated by reduced energy depletion rates.

IV. COMPARATIVE STUDY

A comparison was carried out between Hybrid ACO [23], Energy Aware ACO [22] and Multipath ACO in terms of distance travelled and time taken to identify the paths. Figures 2, 3 and 4 shows the distance taken by each of the algorithms when applied on networks with 30, 50 and 100 nodes.

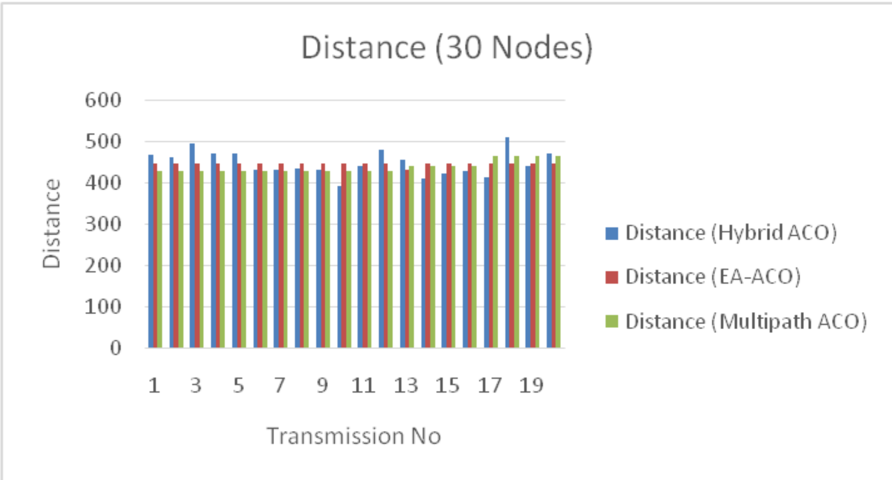

Fig. 2. Distance (30 Nodes)

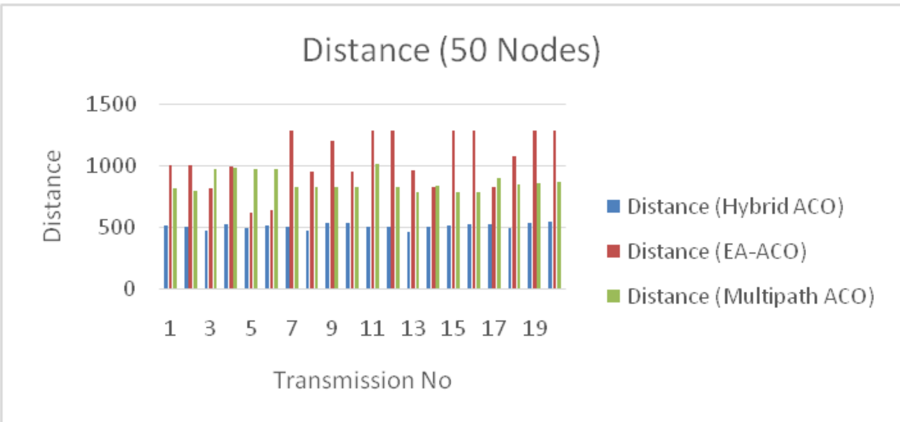

Fig. 3. Distance (50 Nodes)

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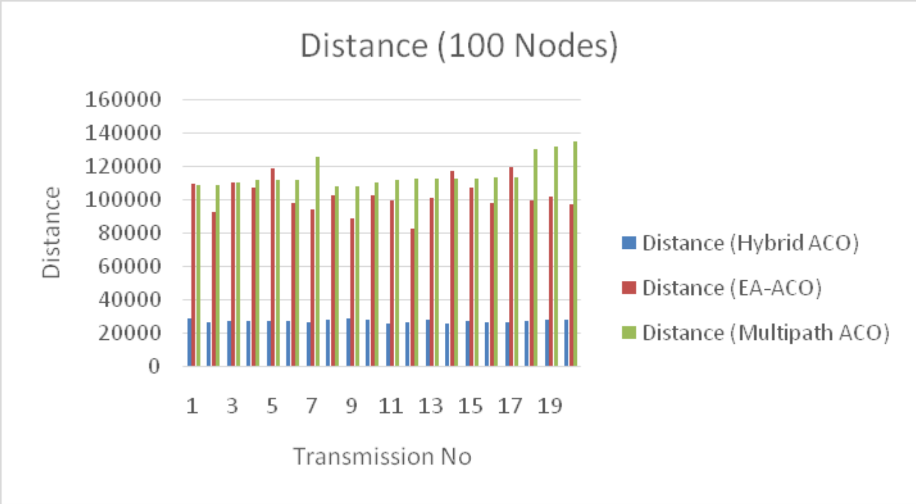

Fig 4. Distance (100 Nodes)

Fig. 2, using 30 nodes does not exhibit much difference in terms of distance covered. It could be observed from the Fig. 3 and 4 that when the number of nodes are increased, the difference exhibited is obvious. In the graph exhibiting 100 nodes, it could be observed that hybrid ACO exhibits effective and reduced distances. An analysis of all the three graphs shows that hybrid ACO performs best in identifying the shortest routes, followed by multipath ACO. The highest route distances are observed in EA-ACO.

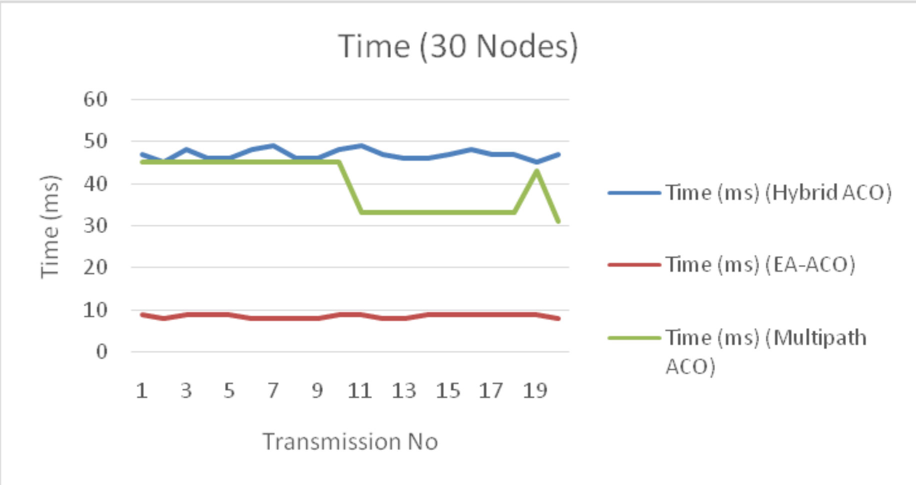

Fig. 5. Time (30 Nodes)

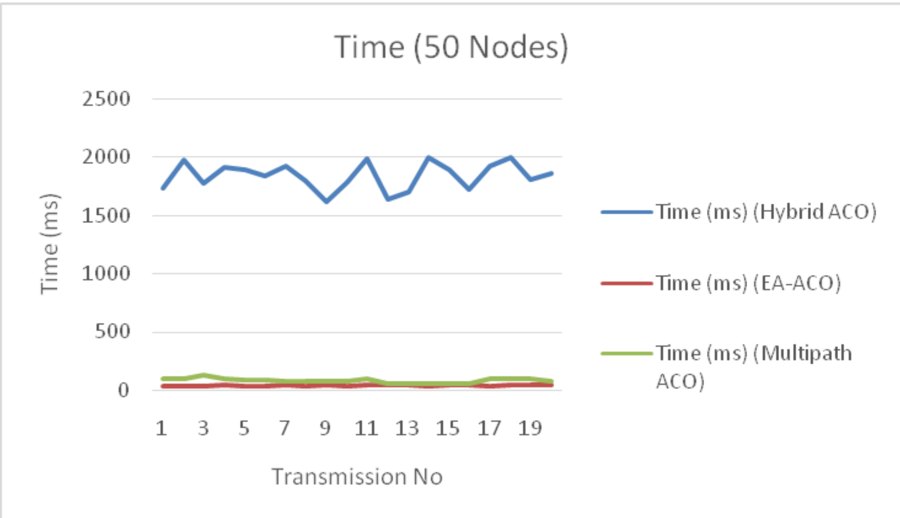

Fig. 6. Time (50 Nodes)

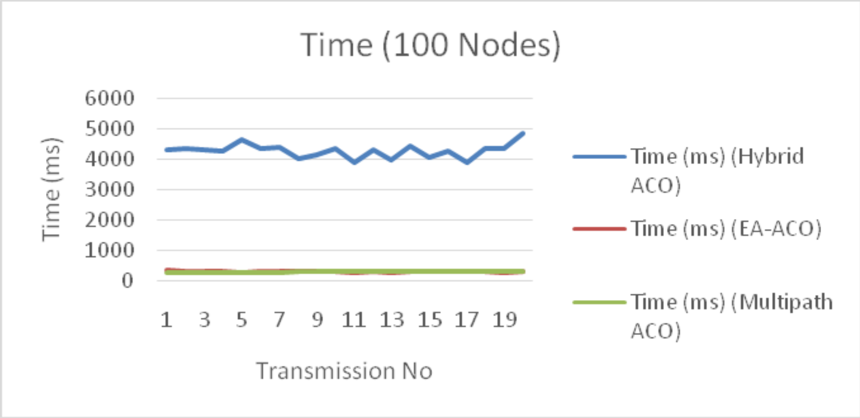

Fig. 7. Time (100 Nodes)

Fig.5,6,7 show the time taken for the route identification phase, when considering 30, 50 and 100 nodes. It could be observed from the figures that EA-ACO consumes the least time, followed closely by multipath ACO. Effective time scalability was observed in EA-ACO and Multipath ACO, while hybrid ACO exhibits very high time increase when the network size is increased.

Hence it could be concluded that hybrid ACO is efficient in terms of identifying the best routing paths but lacks in terms of time scalability, while EA-ACO is efficient in terms of time but provides routing paths that are very inefficient. A balance was obtained in the multipath ACO that provides multiple effective routing paths better than EA-ACO in almost the same time. Though the trade off in distance is reduced when compared to EA-ACO, the high distance levels are attributed to the necessity for multiple paths rather than one single path. Further, since the packet is distributed in multiple paths, energy depletion is also uniform, hence leading to a longer network lifetime.

V. RESULTS AND DISCUSSION

The following results describe the efficiency of the multipath routing strategy in terms of randomness obtained, the path reuse levels and number of nodes used for constructing paths.

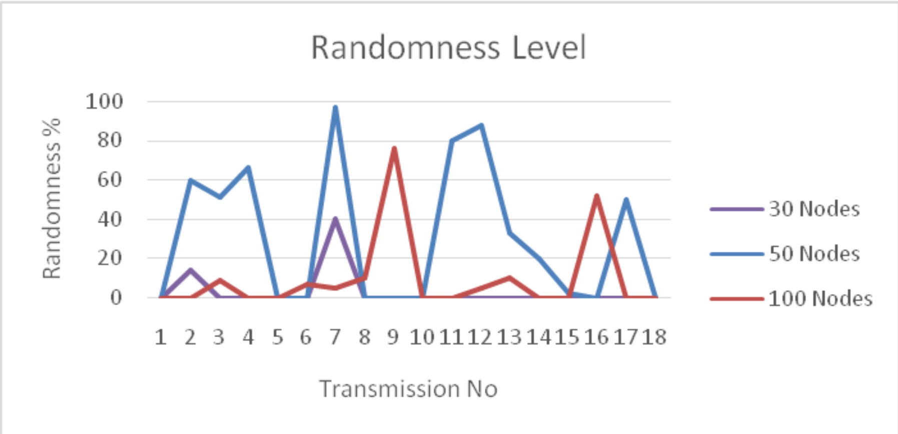

Fig. 8. Randomness Level

Fig. 8 shows the randomness levels obtained in networks of 30, 50 and 100 nodes. It could be observed that the network with 30 nodes exhibit low randomness levels, while the other networks of 50 and 100 nodes exhibit high randomness levels. It could be observed that a maximum randomness level of 98% was observed, exhibiting several disjoint paths for the same source-destination pair. It could also be observed that several paths exhibit low randomness levels and some even exhibit 0% randomness level. This is attributed to the use of SA for obtaining multiple paths in a single ant cycle. Since the same path has the probability of getting selected multiple times, a reduction in the randomness levels can be observed. Since these path transfer only a part of the message and not the entire message, this considered to a tolerable reuse level.

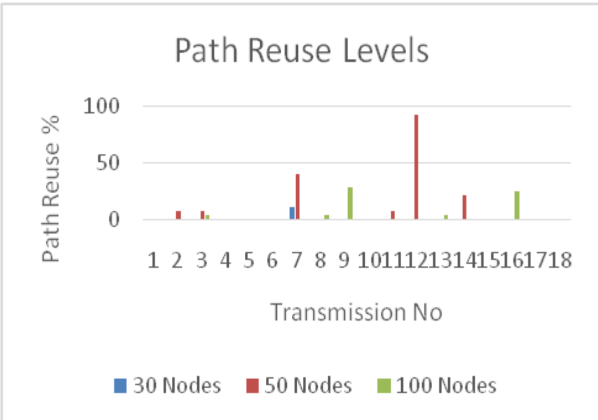

Fig. 9. Path Reuse Levels

Fig. 9 represents the path reuse levels. It could be observed that several transmissions exhibit zero path reuse exhibiting effective dispersion of routes. Several other transmissions exhibit a moderate reuse levels <20%, a few transmissions exhibit a moderate reuse level of 30% to 40% and one transmission exhibit a very high reuse level of 91%. The moderate to high reuse levels are attributed to the requirement of efficiency in the path selection process. The tradeoff for efficiency is provided in the form of path reuse. However, since high reuse levels have an occurrence probability of 0.2, this becomes an acceptable tradeoff. A similar tradeoff can be observed in figure 10, exhibiting the % of nodes used for constructing paths. Very low usage levels are observed, while the rare occurrence of high usage levels is attributed to the tradeoff for path efficiency.

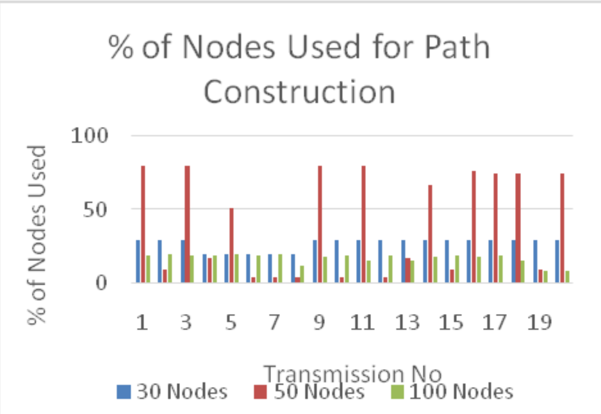

Fig. 10. % of Nodes Used for Path Construction

VI. CONCLUSION

The previous contributions [22, 23] provided by the authors had their concentration on either efficiency or time, trading off one for another. This approach tries to balance the tradeoff by providing quicker and multiple solutions with moderate efficiency. It was observed from the results that the time and efficiency tradeoffs were well maintained by this approach. The randomness levels achieved in path selection and the node reuse levels were found to be good and the effective tradeoffs observed in these categories were discussed. The proposed contributions does not consider traffic type during transmissions. It considers the entire traffic as being a single type and hence delay sensitive packets might experience problems. Hence our future contributions will deal with accounting the type of traffic, such that packets that are delay sensitive occupy faster routes when compared to throughput sensitive packets.

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