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Ant Colony Optimization and Genetic Algorithm Integrated Load Balancing Approach for MANET

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Abstract: ***Multi-path routing in Mobile Ad Hoc Networks (MANETs) minimizes latency and ensures on-demand back-up routing to prevail over route errors. Unplanned network load degrades individual node performance, preventing instant path switch-over. This increases overloading of the nodes and henceforth resulting in drops. We propose a two-phase optimization algorithm in a hybrid manner assimilating Ant Colony Optimization (ACO) and Genetic Approach (GA) to improve load handling capacity of the nodes with improved packet delivery at the destination. Both node and path selection are favored by conditional optimization in both the phases; concentrating in minimum switch-over and higher delivery rate. Precise path and neighbor selection by improved load handling capability minimizes packet drop and control overhead.***

Index Terms: ***Optimal Cluster Head Selection, Ant Colony Optimization, Genetic Algorithms, Load balancing.***

I. INTRODUCTION

Mobile Ad Hoc Network is defined as an assortment of wireless nodes that possesses unique intrinsic attributes for facilitating information exchange. The nodes in the network are dynamic by nature that does not require any specific infrastructure; administering a central control system is tedious. Bandwidth, energy, storage and topology constraints that prevail over the network project it to be complicated. Due to the autonomous nature of the nodes, it exhibits a two-fold nature of operating as a host and a router [1]. Both the host and router behavior of the nodes intend to find transmission paths between the source and destination in a multi-hop fashion. Perhaps, routing becomes a challenging and vital task at the time of designing an adhoc network [2]. Bandwidth allocation and utilization is one of the predominant factors due to the varying topology and decentralized nature of the network [3]. The nodes communicate through wireless links that are influenced by bandwidth constraints like varying capacity, inaccuracy, interference, etc and hence the chances of congestion is most common [4].

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Handling unplanned load drains resources allocated for the network and the nodes resulting in buffer runoff, transmission delay, connectivity loses and packet drop. In other words, inappropriate load assignment and handling topples the independent nodes that reflect in network performance causing congestion and earlier depletion of other resources. Therefore, load balancing process becomes essential so as to enhance MANET performance in order to ensure seamless Quality of Service. More conveniently, an optimal or an adaptive load balancing technique is adopted for a fair load allocation [5]. Nodes participate in routing in an on-demand fashion to relay information over multi or single hops that serves as a connection between source and destination. MANET routing protocols are designed to discover and retain finest paths that requires lesser delay and network resources. Traditional routing protocols lack the ability of fair load distribution and also fail in selecting suitable alternate paths over route errors. This emphasizes the assimilation of load balancing feature with the conventional routing protocol. Moreover, the conventional routing protocols that falls either in static / dynamic category have reliability and resource utilization constraints post route failures. Multi-hop communication between source and destination does not rely on shortest path alone. Data transmission is carried out through multi-paths over the distributed nodes that become more feasible for routing [6]. Multi-path routing incorporates the trait of balancing load post route failures. Multi-path routing protocols own backup routing paths that can be swapped without a new route discovery that minimizes latency and retains network throughput.

II. RELATED WORKS

The authors in [6] proposed a queuing model based routing to handle and distribute network load. This model estimates the path capacity for handling the load before transmission so as to minimize network congestion and packet drops. Ahmad Momani et al. [7] proposed an Intelligent Paging Backoff Algorithm to minimize transmission failures. Network collisions are prevented by shifting contention window of the transmission protocol to appropriate positions in an incremental manner. A traffic management method is introduced in [8] for load balancing and dissemination that aids service discovery in anycast manner. This traffic management system improves network fault tolerance and flexibility.

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Kheirandish Fard Mohammad Amin et al. [9] proposed a congestion control mechanism to resolve MANET link failures. This congestion control is a source-destination threshold based algorithm that considers outage and trip time for addressing link dropouts. Senthil Kumaran and Sankaranarayanan [10] proposed an adaptive routing by identifying non-overloaded next neighbor paths. This routing scheme identifies congested nodes at an early stage so as to evade them from participating in routing. The authors in [11] introduced Ant Colony Optimization Algorithm for balancing network load. The authors combined the nature of the ants and swarm intelligence technique to improve network throughput and to minimize resource utilization.

Radenkovic Milena and Grundy Andrew [12] proposed a unified approach of adaptive forwarding and replication method to evenly dispense load over the network. Adaptive forwarding makes use of heuristic link and resource information for load distribution. The authors in [13] proposed a queuing wait time based network traffic allocation scheme to improve load balancing precision and to minimize network delay. The traffic allocation scheme considers the wait time for every individual path that routes to the destination. Gimer Cervera el al., [14] proposed a disjoint multipath based link state routing to retain network stability that are influenced by disruption attacks. The network is stabilized against lack in topology information, flooding and multi-path load balancing. Sharma et al. [15] proposed an estimated conditional path selection technique in order to utilize bandwidth in an efficient manner. The path selection between source and destination is based on neighbors that provide maximum bandwidth. The bandwidth of the nodes is computed using detector packets generated by the source nodes. Meng et al. [16] proposed two routing protocols viz., Spatial reusability-Aware Single-path Routing (SASR) and Spatial reusability-Aware Any-path Routing (SAAR) that achieves low transmission cost and higher throughput. The dual protocols overcome the fact that routing protocols prioritize transmission cost than network throughput. Zhang J et al. [17] proposed Generalized Destination based Multipath Routing (GDMR) that is intended to discover loop-free routing paths. This routing approach achieves higher throughput similar to an explicit routing without compromise in performance over network traffic. Ahmed and Paulus [18] proposed congestion prevention and alleviating technique for wireless sensor networks to improve packet delivery ratio and to minimize energy consumption and delay. The proposed congestion prevention technique discovers paths based on utility function computed using distance, success rate and queue utilization of the forwarder. The utility function distinguishes the non-congested neighbors to establish routing path.

Gaurav Pathak and Krishan Kumar [19] proposed an AOMDV based load balancing approach for improving network throughput, minimizing delay. In this approach, the free nodes are identified prior so as to distribute load through them. Besides, the approach intends to opt paths based on the sequential load handled by the forwarders so as to identify their state. The authors in [20] proposed an ant colony optimization based load to improve MANET performance by minimizing network load. This optimization technique employs path preference computed through delay, bandwidth and next neighbor availability to select an optimal path.

Problem Definition (Consider ant based routing)

Multi-path routing improves network performance with limited routing metrics that cannot sustain for a prolonged time due to varying neighbors and distance to the destination. The so far proposed solution for the above issue optimization concentrates over one specific metric optimization . Besides, routing overhead of the network is increases due to multiple paths switch-over through the available neighbors. In these solutions, minimizing routing cost is more vital than other network metric . We propose a source-destination favoring approach by assimilating ant colony optimization with genetic approach to improve network performance, minimizing routing overhead and widening concentration over other network metrics as well.

Network Model

We consider a Mobile Ad Hoc Network with a set of N nodes that are interconnected with a wireless edge E. Let the MANET be represented using a graph G= (N, E) wherein two nodes 'i' and 'j' are said to be connected if the nodes are present within the same geographical region. The nodes in the network are grouped as clusters containing one cluster head (CH) each with few other cluster members (CM). The CH facilitated in-bound and out-bound communication to the cluster. The cluster heads are selected through a threshold determined election for which each other member of the same cluster is capable of participating. The initiating source node (S) and the destination node (D) are present in different clusters such that the CH is responsible for discerning the path between S and D.

III. ADAPTIVE DELIVERANCE AWARE LOAD BALANCING (ADA-LB) USING ASSIMILATED ANT COLONY OPTIMIZATION AND GENETIC ALGORITHM

Adaptive Deliverance Aware Load Balancing using ACO and GA assimilation is intended to levitate network performance over asymmetrical load distribution and link failures due to congestion. The proposed approach is two-fold: clustering and neighbor selection. Different from the conventional clustering approaches, the proposed CH selection process supports load balancing to a smaller extent alongside overhead suppression. The ACO-GA part facilitates delivery aware neighbor selection ensuring unbiased network load/ traffic dissemination.

This ensures convergence-free routes to the destination despite varying network load, preventing earlier packet drop and re-transmissions.

The proposed ACA-LB for MANETs includes two phases:

- Optimal Cluster Head Selection and
- Precise Path Selection for unbiased Load Distribution

A. Optimal Cluster Head Selection

The optimality in cluster head selection is achieved by distributing network load in a fair manner.

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The primary work of CH selection is to retain cluster stability despite uneven load distribution and to minimize the number of autonomous node communication. Therefore, the CH selection concentrates in three factors that are to be satisfied by the candidate node namely: Multipath routing, effective load handling and minimizing the exchange of multiple control messages.

Cluster head is elected based on maximization function HS_{max} that considers the neighbor's contribution and interaction quality (I_q). The prime condition for a node to participate in CH selection process is that the node must possess more than one E. As the number of neighbors is higher, the contribution of that neighbor is high. The contribution factor of a neighbor (c_f) is computed using equation (1)

$$c_f = \frac{1}{count(ni)}, \sum_{nj \in N, ni \neq nj} [d(ni, nj) \leq R_n] \quad (1)$$

Where, $d(ni, nj)$ is the distance between the nodes ni and nj and R_n is the transmission range.

Similarly the interaction quality for the maximization function is computed using equation (2)

$$I_q = hc * NH_r + (1 - d) * NH_t \quad (2)$$

where, hc is the hop count, NH_r is HELLO packets generated for 'r' number of transmissions, and NH_t is the count of HELLO packets generated at a particular time 't'.

Once the above factors are computed for a candidate node (CN), the maximization function for determining a new CH is given as represented in (3)

$$HS_{max} = \max \{CN_1(c_f, I_q), CN_2(c_f, I_q), \dots, CN_n(c_f, I_q)\} \quad (3)$$

The CN that satisfies (3) becomes the authoritative cluster head. After the CH selection process is absolute, it concentrates in balancing load among the paths available. For a basic load balancing process, the CH first analyzes the individual load of its cluster members. The load of a cluster member (L_{CM}) is approximated using equation (4)

$$L_{CM} = \sum_{i=1}^{r} \frac{d_s(i)}{t(i)} + \frac{BU(i)}{BL} \quad (4)$$

Where, $d_s(i)$ is the i^{th} data transmission, time of the same transmission, $BU(i)$ is the buffer utilization in i^{th} transmission and BL is the buffer length.

The CH then splits the incoming load over the available 'm' paths. The head initiates multipath relaying outside the cluster. Let L_m denote the load observed over a path 'm', then the load arrival factor ∇L_{af} is given by equation (5).

$$\nabla L_{af} = \sum_{i=1}^{k} L_m, k \in m \quad (5)$$

Load distribution in an unbiased manner is governed by the CH internally; load balancing over external non-cluster nodes is administered using ant colony optimization.

B. Ant Colony Optimization

Ant Colony Optimization intends to improve load balancing over the non-cluster nodes that are distributed outside the cluster. The CH identifies the available neighbors outside the cluster through its CM that is listed in the second position at the time of head selection. The CH initiates ant population in order to visit each node present in all the 'm' paths to reach the destination. The ants update the pheromone of $e \in E$ associated with the nodes; it has visited at the lapse of each traversal. The node with higher load handling capacity retains higher pheromone. CH then assembles all the transmissions through a single path by integrating the lesser pheromone ants with the higher pheromone concentration ants. After each transmission, the load of each node is computed followed by their individual pheromone update. The load of each path node is computed using equation (4) other than cluster members.

The probability that an ant 'a' visits an adjacent node 'j' immediate after node 'i' is computed using equation (6)

$$\rho_{ij}^{d}(t) = \frac{[\varphi_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum_{j \in N}[\varphi_{ij}(t)]^{\alpha}.[\emptyset_{ij}]^{\beta}} \quad (6)$$

Where,

φ_{ij} represents the pheromone absorption in an edge $e \in E$ between node 'i' and 'j', $\emptyset_{ij}$ is the heuristic value considered for ∇L_{af}.

The load handling capacity of the nodes ceases with respect to increase in time, for which the ceasing pheromone absorption is estimated using equation (7)

$$\varphi_{ij} = (1 - \partial) * \varphi_{ij} + \sum_{a=1}^{m} \Delta\varphi_{ij}^{a} \quad (7)$$

Where,

$(1 - \partial)$ is a pheromone decrease constant, $\Delta\varphi_{ij}^{a}$ is the pheromone measure observed in the edge e that is revised by the ant a.

The ants are trained such that it reaches the destination through the higher pheromone absorbed path nodes. The turnout of the CH ACO part is given as an input for further optimization using genetic approach.

Congruent Analysis

Case 1: If the Destination is present within a cluster

Consider a network as illustrated in Figure 1. Node 13 is the destination and it is present within a cluster. The ants are initiated from node 5, traversing in the below paths:

In this case, the pheromone update is considered from both the ant paths, converging at node 11 (CH). A single path communication between 11 and 13 (Destination Node) is enough so as to retain pheromone concentration. Due to convergence, a single ant is enough for traversing.

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Through two ant paths are prescribed by node 5, the mean pheromone for node 11 (CH) is considered and therefore, the single ant is selected based on another constraint like distance factor or delay. Fore-hop pheromone consideration is less feasible as the ants would not have marked their backtracking.

This congruency minimizes recursive tracking of the converging paths (Similar to the path between 11 and 13).

$5 \rightarrow 7 \rightarrow 10 \rightarrow 11 - 13$ and

$5 \rightarrow 8 \rightarrow 6 \rightarrow 9 \rightarrow 11 \rightarrow 13$

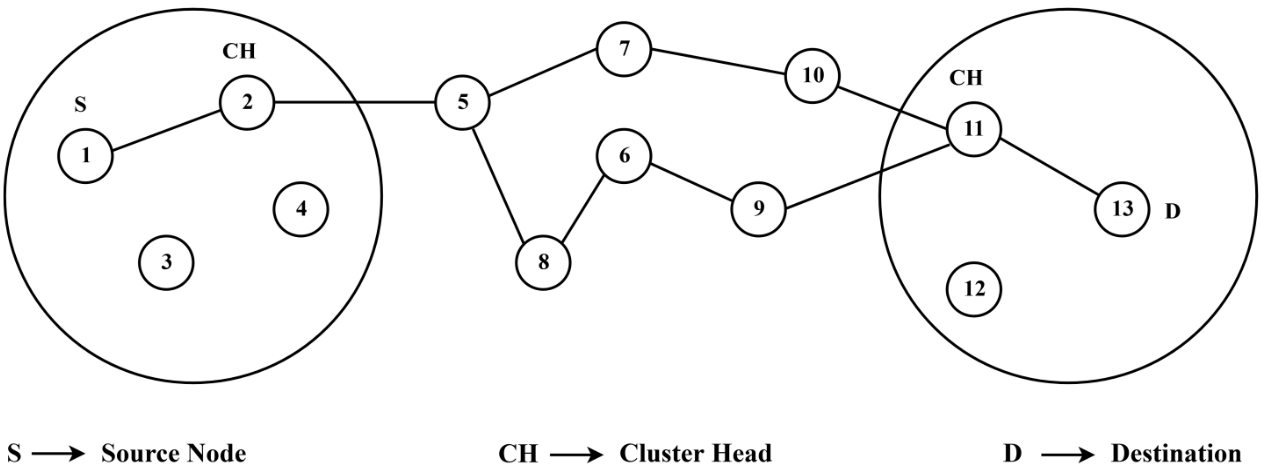

Figure 1. Destination within a Cluster

Case 2: If the Destination is present outside the cluster.

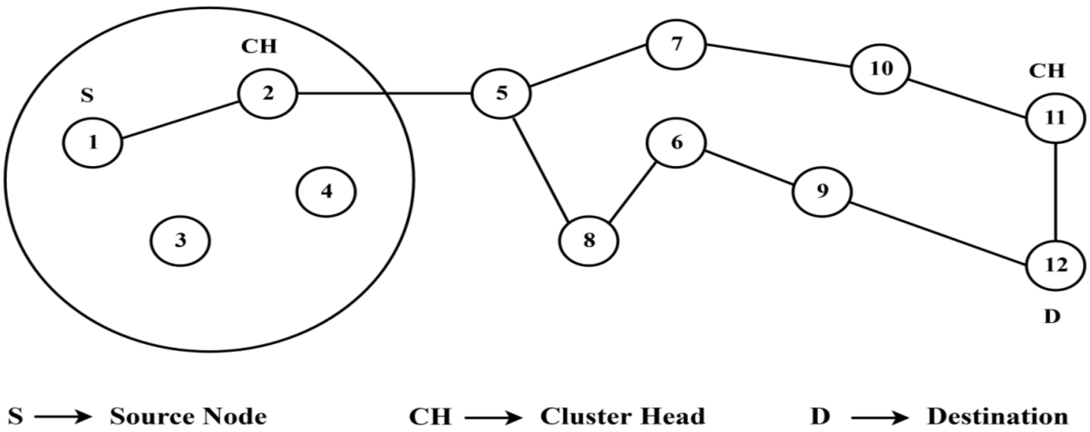

Figure 2. Destination is present outside the cluster

Consider the Destination node (12) is present outside the cluster as in Figure 2. In this case, node 5 (outside the cluster) generates two paths as below:

$5 \rightarrow 7 \rightarrow 10 \rightarrow 11 - 12$ and

$5 \rightarrow 8 \rightarrow 6 \rightarrow 9 \rightarrow 12$

Unlike in Figure 1, the convergence (at Node 11) is not formed and hence the ants are analyzed independently for their pheromone concentration. This case follows the conventional pheromone update process of ACO.

C.Precise Path Selection for unbiased Load Distribution

Precise path selection phase intends to improve efficiency in load distribution over the available path nodes. The path selection is facilitated using genetic approach so as to retain load balancing throughout the communication. The genetic approach follows pheromone generation and fitness verification post initialization.

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The instigating parents are decided in the initialization phase of GA. GA operates on the output of ACO considering it as its initial population. Two parents that are capable of generating further offspring are selected from the first two apex of ACO. Let $\{a_1, a_2, \ldots, a_n\}$ represent the set of ants that tour in multi-path in order to update the pheromone of its path nodes. Two ants that possess the higher pheromone from the other set are selected as the parents. Unlike the conventional ACO, the ants after second higher pheromone are allowed to migrate towards the higher pheromone ants. The initiating parents hold independent paths as a result of ACO and hence the paths are evaluated for their fitness. The fitness of the children is estimated based on their packet delivered at the destination node. The fitness of packet delivery $f(P_{dr})$ is computed as given in (8)

$$f(P_{dr}) = \prod_{i=S}^{D+h-1}(1 - P_L) \qquad (8)$$

Where, h is the hop count between source S and destination D and P_L is the packet loss factor. The packet delivery factor at the destination node is further estimated to check the consistency of the transmission through the current paths. Packet delivery at the destination (D_{pd}) is computed using equation (9)

$$D_{pd} = \frac{P_R}{P_T} \qquad (9)$$

Where, P_R and P_T are the count of packets received at the destination and packets transmitted to the destination, respectively.

Routing is influenced by many factors, and hence there may be some difference between (8) and (9). If the difference is vast, then the parent nodes generate a new set of offspring through cross-over and mutation process. Cross-over and mutation results in generating further optimal paths through their newly generated offspring. The initial parental chromosome resultant set has a dual probability of producing optimal result or sub-optimal result. Besides, all the resultant set chromosomes cannot be deployed for relaying packets to the destination as it causes additional routing overhead. In such cases, the fitness function based on packet delivery is computer (Equation (8)) along with its validation using equation (9). Over each offspring generation, the previous load is distributed among the available offspring ensuring improved packet deliverance.

The steps for path selection are as follows:

Step1: The CH initiates route discovery to the destination through the available nodes outside the cluster.

Step2: The ants initiate forward walk to reach the destination node.

Step3: On reaching the destination, the ants backtrack their path with pheromone update. The pheromone update is computed using $\varphi_{ij} = (1 - \partial) * \varphi_{ij} + \sum_{a=1}^{m} \Delta\varphi_{ij}^{a}$

Step4: The pheromone of the node is computed based on load arrival factor using $\nabla L_{af} = \sum_{i=1}^{k} L_m, k \in m$

Step5: The resulting solution of ACO is given as input for GA process.

Step6: Using GA, the initial chromosome is generated to identify the path with higher deliverance rate.

Step7: When the number of initial population ceases, the initial chromosome generates new population that satisfies $f(P_{dr}) = \prod_{i=S}^{D+h-1}(1 - P_L)$ and $D_{pd} = \frac{P_R}{P_T}$.

Step8: Repeat through step 5 until the final solution is reached.

IV. SIMULATION REULTS

The performance of the proposed ADA-LB is assessed through extensive simulations carried out using Network Simulator 1. The proposed approach is compared between ant based multipath backbone routing (A-MBR)[20] and TALB-AOMDV [19] for the trailing metrics: Throughput, delay, Packet Delivery Ratio and overhead. The simulation setup is given in table 1.

Table1. Simulation setup

Parameters	Value
Network Region	1000 X 1000
Number of Nodes	100
Mobility	10-30 m/s
Transmission Range	250m
MAC	802.11
Simulation Time	360s

Throughput

The throughput metric of the proposed ADA-LB is compared with A-MBR and TALB-AOMDV (Refer Figure 3). The proposed ADA-LB distributes load over selective nodes that do not undergo the issue of overloading.

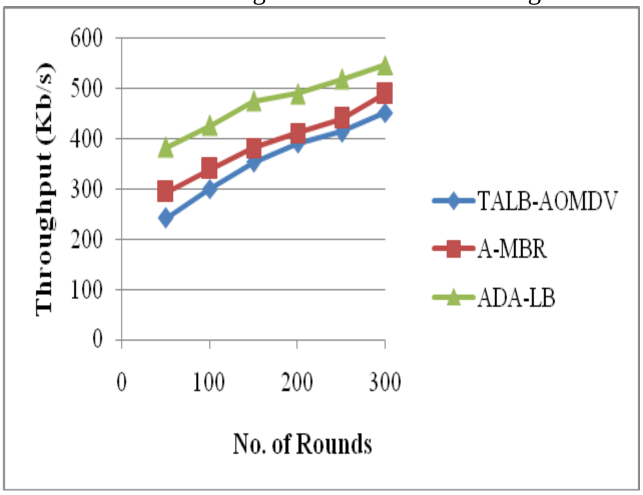

Figure 3. Throughput Comparison

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ACO phase ensures traffic free neighbor selection to handle the entire load dispatched from the source. As the transmission is favored in multi-path with precise neighbor selection, number of packets transferred is high, improving network throughput.

End-to-End Delay

Figure 4 illustrates the comparison of end-to-end delay, compared between ADA-LB and other existing approaches.

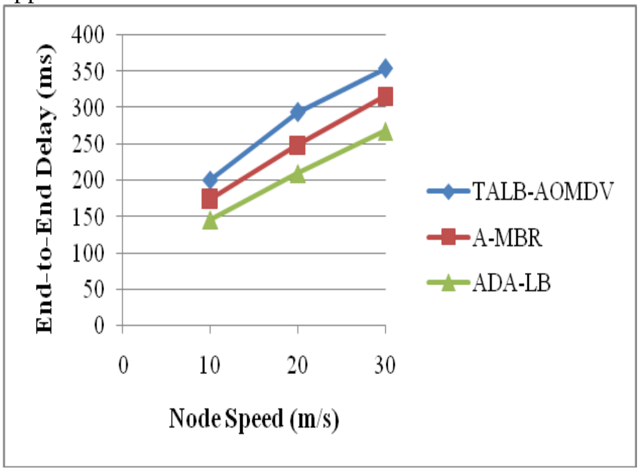

Figure 4. End-to-End Delay Comparison

This multi-path routing process minimizes delay by assigning independent load free nodes for concurrent transmission. Unlike the other methods, path selection and packet deliverance are preserved throughout the transmission, ensuring lesser number of retransmissions and drops. Minimized drop and retransmissions ensures lesser delay in the proposed ADA-LB.

Packet Delivery Ratio

The comparison of packet delivery ratio between TALB-AOMDV, A-MBR and ADA-LB is illustrated in Figure 5. The GA process assimilated with ACO ensures proper packet delivery at the destination by its fitness function.

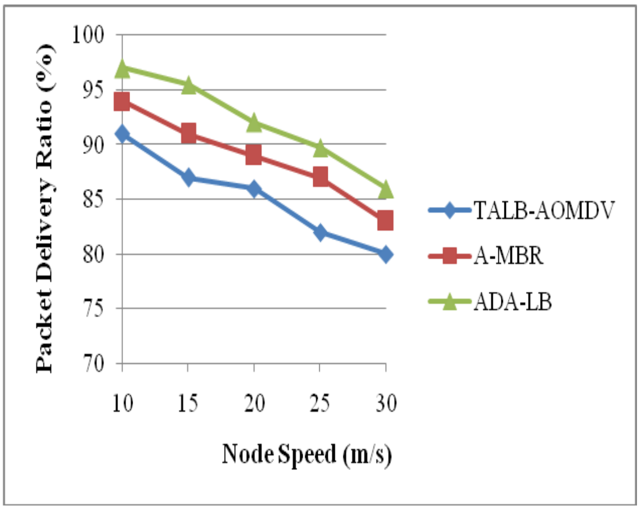

Figure 5. Packet Delivery Ratio Comparison

The packet delivery at the destination is properly ensured through traffic free nodes that ensure maximum packet handling. These factors are intended to improve the packet delivery ratio of the proposed ADA-LB

Control Overhead

Control overhead comparison between TALB-AOMDV, A-MBR and ADA-LB is illustrated in Figure 6. The number of neighbors that are swapped due to routing errors and transmission faults are less in the proposed approach. Neighbor selection is precise over the available nodes that satisfies load handling and ensures higher packet deliverance at the destination.

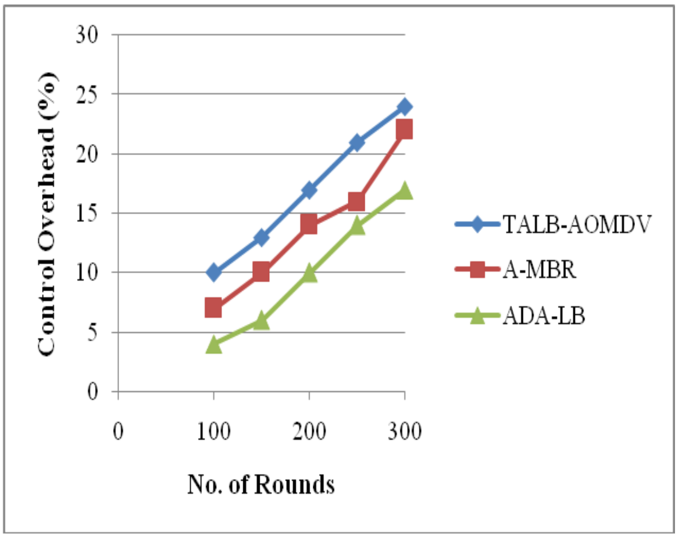

Figure 6. Control Overhead Comparison

V. CONCLUSION

In this manuscript, we propose a two-phase optimization approach assimilating ant colony optimization and genetic algorithm for improving the load balancing capability of the network. The process is carried out by identifying defined load handling nodes using ACO at the initial state. Genetic approach is used to select optimal path that guarantees maximum packet deliverance at the destination through its fitness. This improves the transmission quality minimizing drops due to unplanned load dispatched at the source. The integrated process helps to improve network performance in terms of throughput, delay, packet delivery ratio and overhead.

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