Bootstrap Aggregated Mutual Dependency Ensemble Clustering and Learning Agent Based Approach to Eliminate Stale Routes in MANET

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Abstract*—Mobile Ad hoc networks deploy the network with the support of self-organizing and self-configuring mobile nodes. Due to the lack of centralization, the topological structure of the network fluctuates frequently. Preserving stable link communication to obtain reliable data transmission is the key challenge in the dynamic wireless network environment. This stimulates discrepancy on discovered route paths. To address this issue a novel approach called bootstrap aggregated mutual dependency ensemble clustering and learning agent based approach to eliminate stale routes in MANET (BAMDEC-LABA) is introduced. This algorithm is used to identify the stable link based on the metrics such as residual energy, receiving signal strength, less hop count and node behavior. Maximum dependency with less hop count route paths are classified by employing bootstrap aggregation method. Learning agent examines the node behavior and identifies the selfish and corruptive nodes using node cooperativeness and trust value. The occurrence of the link failure due to the malicious nodes intimated to all the nodes with the distribution of route error packet. The inconsistent route path is eliminated from the cache to preserve the link failure. The performance of the proposed approach is evaluated with different performance metrics such as routing overhead, packet delivery ratio, packet drop rate, and delay. When compared to state-of-the-art approaches, the proposed BAMDEC-LABA technique on an average minimizes the routing overhead by 26%, improves the packet delivery ratio by 18%, packet drop rate is considerably reduced by 68% and delay is found to be minimized by 27%. The proposed method outperforms when compared to state-of-the-art approaches.

***Index Terms*—MANET, route discovery phase, bagging ensemble clustering, route maintenance, stale route elimination, deep learning, agent-based approach**

I. Introduction

Mobile Ad hoc networks constitute self-organizing mobile nodes which are interconnected wirelessly. These wireless links are dynamic due to the mobility characteristics of MANET. Network stability is determined by the crucial factors such as link quality, node reliability, node mobility, topological changes and constrained resources. Stable and reliable connectivity between the nodes ensures the successful data transmission. A dynamic topology characteristic precedes frequent link failure, which results as inconsistent route. Inconsistent route path is defined as stale route which increases the delay in data communication.

A. Vijay Vasanth *et al*. [1] introduced a reputation-aware multi-hop routing protocol (RAMP) to enhance the routing performance. A Cache Refreshing Policy (CRP) was implemented in RAMP to achieve overall QoS factors. It provided secure and trusted access between nodes. The Modified RAMP protocol used the distributed cache update algorithm to update the cache and to avoid the issues such as lack of hearing route error message and stale route. But the designed protocol failed to carry out the cache optimization improvement in high density mobile nodes.

A novel opportunistic routing scheme with gradient forwarding algorithm for MANETs (ORGMA) proposed by Daeho Kang *et al*. which gives the opportunity to the receiver to take the decision whether or not to relay the packets. Reliability of link quality is measured in terms of SNR (Signal-to-Noise Ratio). The highest SNR value holding link is considered as the stable link for line of sight propagation. It does not experience interference. ORGMA achieves the highest packet delivery ratio but it fails to minimize the communication overhead in a densely populated network.

The following are the limitations of existing literature

1. The algorithms failed to increase the scalability
2. Malicious node status are not considered for stable link estimation
3. Communication overhead is increased even though the reliable trusted link selection carried out between the node
4. Energy constraints are not considered for the stable link selection

By considering the shortcomings in the existing literature, the occurrence of stale routes due to the selfish and corruptive nodes are eliminated to improve the scalability and reliability of data communication. This is accomplished by the proposed algorithm Bootstrap Aggregated Mutual Dependency Ensemble Clustering and Learning Agent Based Approach to Eliminate Stale

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Routes in MANET. MANET is an open space network susceptible to various internal and external attacks. Malicious nodes are one of the root causes for the link failure as well as stale route generation. The misbehaving nodes are monitored with the analysis of abnormal node communications and connectivity observation.

The main contribution of the proposed BAMDEC-LABA technique is summarized as follows,

- The BAMDEC-LABA technique is introduced for achieving the scalable and reliable routing in MANET based on route discovery and route maintenance. In route discovery, the bootstrap aggregated clustering technique is used to identify less hop count paths from the multiple paths to minimize the delay. Stable route paths are selected for data transmission based on the parameters such as residual energy and receiving signal strength to increase packet delivery ratio and to decrease the drop rate.
- A Deep Structure Learning concept is applied for analyzing the mobile node behaviors. The selfish node or other corruptive nodes are identified by the agent node based on node cooperativeness and trust level. Then the agent distributes a route error packet for minimizing the packet drop. The broken link between the nodes is removed and by selecting the alternative path from the cache to minimize the routing overhead.

The remaining sections of the paper are organized into different section. Section II depicts the related works. Section III exhibits the background details and assumptions considered for the proposed approach. Section IV discusses and illustrates the proposed BAMDEC-LABA approach with a neat diagram. In Section V, the simulation settings are given, and the proposed BAMDEC-LABA technique's efficiency is analyzed and compared with existing methods in Section VI. The results are summarized in Section VII.

II. Related Works

Meena Rao *et al*. [2] implemented a K-means cluster formation firefly cluster head selection based MAC routing protocol (KF-MAC) for data packet transmission with minimum energy consumption. The node sending the data from source to destination KF-MAC (K-means cluster formation firefly cluster head selection based MAC routing) protocol reduces the attention of QoS. The transmission of data in the network nodes and TDMA was based on MAC routing communication. However, data packet forwarding was not improved with minimum delay. P. Tamilselvi *et al*. designed a Routing Algorithm to Eliminate Stale Routes (RAESR) [4] in MANET, for better data transmission. The designed RAESR did not consider the node's energy and obtained signal power. Amir Tavizi *et al*. developed a Reliable Energy-Aware Multicast Ad hoc On-demand Distance Vector (REA-MAODV) routing protocol using multicast Tree [5]. However, the protocol failed to comprehend the criteria such as energy and hop counts for data transmission. M. Malathi *et al.* introduced a Power-Efficient Reliable Routing Protocol [6] ensures data transmission while minimizing route failure. The machine learning technique was not used for accurate data transmission. Anbarasan M. *et al*. developed a Reliable Path Selection based routing protocol (RPS-LEACH) [7] for improving data communication. But the node behavior was not analyzed for efficient path selection. Mina Ghafouri Vaighan *et al*. established a Stable and more Reliable efficient Multicast Routing Protocol in [8] for Multi-Path quality of service (SR-MQMR). But there was no reduction in routing overhead. Bander H et.al built a protocol that is both reliable and energy efficient responsible for distance and remaining energy in [9] using the clustering approach to provide better performance. But the delay output was not reduced. Cai *et al*. implemented an Evolutionary Self-Cooperative Confidence (ESCT) approach [10] to detect the various attacks. The proposed scheme increases network scalability and guarantees routing performance, but it does not address the packet loss rate. Alamgir Naushad *et al*. established a Dynamic Link Connectivity (DLC) [11] approach to improve link stability between neighboring nodes. The path stability of randomly deployed network nodes within the cluster was not assessed. Masood Ahmad *et al*. reported a different cluster-based algorithm [12] to reduce the routing table size. However, the algorithm was unable to create stable and balanced clusters. For the route selection process from source to destination, O. S. Gnana Prakasi *et al*. constructed a Decision Tree-based Routing Protocol (DTRP) [13]. The link's reliability was not improved in order to increase transmission. Naghma Khatoon *et al*. [14] developed a clustering algorithm for data transmission using a multi-agent stochastic parallel search technique of particle swarm optimization. The algorithm failed to improve multi-hop routing efficiency. Bin Yanga *et al*. provided an effective routing protocol [15] for increasing the packet distribution ratio and reducing energy consumption. The protocol was not considered reliability in data transmission. To improve the efficiency of service-aware route selection Dipika Sarkar *et al*. [16] developed an improved Ant-Colony Optimization Ad hoc On Demand Vector (ACO-AODV) protocol. The link reliability was not measured and it failed to consider the distance and received signal strength. Jinke Huang *et al*. constructed a new clustering algorithm [17] to improve the cluster's stability for large-scale mobile ad hoc networks. But the reliability of the data transmission was not improved. Yong Qiang *et al*. proposed Reliable Ant Colony algorithm for packet transmission and throughput in dual channel systems. The output of the collision rate remained unaddressed. For selecting the route path with the fewest hop counts, Gaurav Singal *et al*. [19] implemented a Mobility Prediction with Connection Stability based Multicast routing protocol. The multiple connection stability metrics were not taken into account when it came to improve network performance. Dinesh Chander *et al*. implemented, a tree-based multicast routing protocol [20] was used to create a Cross-Layer Multicast Routing (CLMR) technique for establishing highly stable links.

To improve the network performance, the secure routing was not used.

By implementing a new technique called BAMDEC-LABA, the major issues in the existing literature are addressed.

III. Background

This section exhibits the underlined concept involved in the proposed approach.

Cluster:

It is the process of grouping of similar objects based on some characteristics.

Bootstrap aggregation:

It is an ensemble machine learning algorithm designed to perform statistical classification and regression in an improved accuracy. In BAMDEC-LABA bagging is employed to classify the route paths based on the hop count and to obtain the less hop count route path from the classified result. The reason behind to apply machine learning algorithm is, when improving the scalability of the network in terms of node density numerous numbers of paths established from the source to destination. Traditional algorithm takes too long time to accomplish the classification whereas bagging takes less time to obtain the result.

Mutual Information dependency:

An information and probability theory concept called Mutual information dependency is used to measure the dependency between the two variables. It is applied in the proposed approach to find the dependency of the connectivity between the centroid node and the route path nodes.

IV. Proposed Methodology

An ensemble clustering-based deep learning concept is applied for improving the scalable and reliable data transmission in MANET with minimum packet drop due to the selfish or other corrupted nodes in the network. The proposed Bootstrap Aggregated Mutual Dependency Ensemble Cluster and Learning Agent Based Approach in MANET (BAMDEC-LABA) use the bootstrap aggregation clustering technique to find the route paths with minimum error. While selecting the efficient route, scalability and reliability are the important parameters in MANET due to dynamic network topology.

The network scalability is achieved by the different parameters such as node density, stable links between the nodes, and connections between the nodes. The node density is the number of nodes participates in the data transmission. Reliability in data communication is defined as the data transmission is guaranteed to reach their destination and the data are not corrupted by the other misbehaving node. Based on these parameters, the BAMDEC-LABA technique is designed.

The network is organized in an undirected graphical model $G_{ud} = (V, E)$, where the number of mobile nodes (i.e. node density) $\{mn_1, mn_2, \cdots, mn_n\}$ are represented in V and is distributed in a $n \times n$ squared circumstances and communicate through a transmission range 't_r'. E represents a link between the mobile nodes in a network. Fig. 1 shows the undirected graphical model of the MANET where the source node S represents source and destination node is D. The valuable intermediate nodes are $N_1, N_2, \cdots, N_n$, used to identify the available path from source to destination for improving the link connectivity and reliable data transmission.

With the above system model, the proposed BAMDEC-LABA technique is designed. Fig. 2 depicts the architecture of the proposed BAMDEC-LABA.

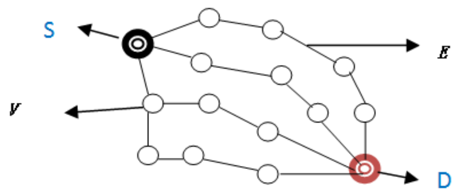

Fig. 1. Undirected graphical model.

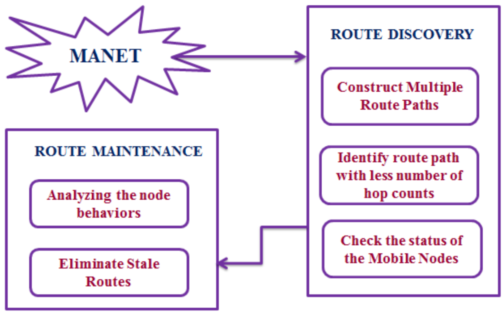

Fig. 2. Flow process of proposed BAMDEC-LABA technique.

A. Bootstrap Aggregated Mutual Dependency Clustering for Route Path Discovery

Initially, the proposed BAMDEC-LABA performs route path discovery in MANET to ensure efficient data transmission. The neighboring nodes are identified through the distance measure. The coordination of the mobile node in the two-dimensional space is denoted as (u_1, v_1), (u_2, v_2). The distance D_{mn} between the mobile nodes are mathematically calculated as,

$$D_{mn} = \sqrt{(u_2 - u_1)^2 + (v_2 - v_1)^2} \tag{1}$$

After that, multiple route paths are established between the source and destination via neighboring nodes. The multiple route paths between the source and destination are established by transmitting route request r_{req} and route reply r_{rep}. The source node transmits the route request r_{req} to the destination via intermediate nodes. The route path information is stored in the route cache. From that, the route path having less number of hop counts are identified by applying bootstrap aggregated mutual dependency clustering technique. Bootstrap aggregating, also known as bagging, is a machine learning ensemble technique to improve the stability and accuracy in the statistical clustering process. This, in turn, reduces over fitting. Over fitting is the error. The clustering results have higher stability than the individual ones. Therefore, the bagging technique is computationally more efficient than boosting. The structure of the bootstrap aggregated clustering is shown in Fig. 3.

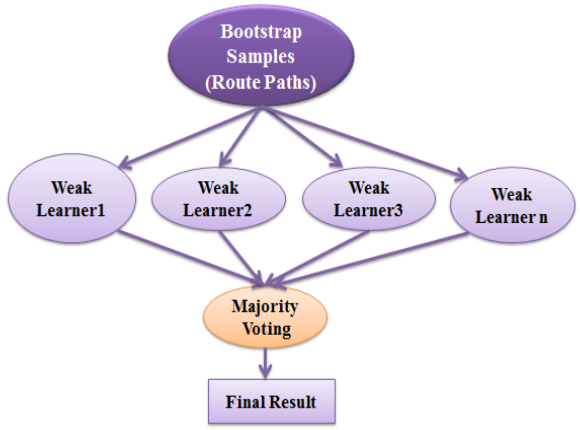

Fig. 3. Structure of bootstrap aggregated clustering.

The bootstrap aggregated clustering technique groups the route path based on the hop counts in the routing paths. The bagging ensemble considers a bootstrap sample as the training set. Here multiple route paths and its hop counts are considered as the samples. Bootstrap aggregated clustering group the route paths based on the similar hop counts in the routing path. According to that grouping, 'm' numbers of weak learners are constructed. The weak learners are represented as w_1, w_2, ···, w_m.. To identify the dependency between the route paths bagging ensemble employs mutual informative clustering as a weak learner. The weak learner initially defines the number of clusters f_1, f_2, ···, f_m and cluster centroid v_1, v_2, ···, v_m. Dependency between the paths and cluster centroid is measured using mutual information dependency.

$$M_d\left(s_1, s_2, \cdots, s_n \mid v_j\right) = \sum_{i=1}^{n}\sum_{j=1}^{m} p\left(s_i, v_j\right)\log_2\left[\frac{p(s_i, v_j)}{p(s_i)\,p(v_j)}\right] \quad (2)$$

where M_d denotes mutual dependence between the samples s_i and the cluster and the cluster centroid v_j, $p(s_i, v_j)$ denotes a joint probability distribution, $p(s_i)$ and $p(v_j)$ represents a marginal probability.

$$h_i = \arg\max M_d(s_i, v_j) \quad (3)$$

where h_i denotes an output of the weak learner, and $M_d(s_i, v_j)$ denotes a mutual dependence between the route path and cluster centroid.

Maximum dependency between the route path and the cluster centroid is identified. The hop count of the route paths which has maximum dependency are compared to obtain the less hop count route path. The less hop count path classification is considered as the weak learners result. Weak learner results are inaccurate, because of the misclassification. So the entire weak learner results are combined and to make a strong one. The strong clustering results are obtained as follows,

$$W = \sum_{i=1}^{m} h_i(s) \quad (4)$$

where W denotes strong clustering results, and $h_i(s)$ represents the output of the weak learners.

For each weak clustering result, the generalization error is calculated to predict the accurate clustering results. The error is calculated as follows:

$$E_{h_i} = E_x - E_p \quad (5)$$

where E_{h_i} denotes a generalization error of weak learner, E_x is the expected error, E_p denotes an observed error.

By applying the Borda count voting method, the weak learners are arranged in an ascending order based on the generalization error.

$$E_{h_1} \le E_{h_2} \le E_{h_3} \le \ldots \le E_{h_n} \quad (6)$$

Then the Borda count voting method takes the weak learner results which have minimum generalization error to the final results. From the clustering results, the votes of samples in the weak learner with a minimum error are counted and identify the majority to be elected.

$$W = \arg_m \max t\left(s_i\right) \quad (7)$$

where W denotes strong clustering results, $\arg_m \max$ denotes an argument of the maximum function to find the majority vote(t) of the samples (i.e. route paths) whose decision known to the mth weak learner.

Finally, the bootstrap aggregating ensemble technique provides the majority of the samples as final results hence it improves the clustering accuracy and minimizes the error. In this way, the clusters with lesser hop counts are identified among the available paths. Then the clusters with less number of hop counts are stored in the route cache and eliminate the other clusters.

To obtain the stable route path, status of the mobile nodes is checked by measuring the residual energy and the receiving signal strength. The unit measurement of energy is Joule (J). The residual energy is measured as the difference between the total energy and the consumed energy.

$$E_{\text{residual}} = \left(E_{\text{total}} - E_{\text{consumed}}\right) \quad (8)$$

The received signal strength of the node is computed using a given formula,

$$S_r = S_t \frac{g_t g_r l_t^2 l_r^2}{D^4} \quad (9)$$

where S_r represents a received signal strength of the mobile node, S_t is a transmitted signal power of the mobile node, The transmitter and receiver antenna gain are represented as g_t and g_r, l_t^2 is a transmitter antenna height, l_r^2 denotes a receiver antenna height, and D denotes a distance between transmitter and receiver.

According to the remaining energy and signal strength, the valuable nodes in the selected route paths are identified for seamless data transmission.

The node which has greater residual energy and the received signal power than the threshold is said to be a valuable node. Otherwise, the mobile nodes are said to be invaluable nodes. With the number of valuable mobile nodes, the routes are selected and stored in route cache and other nodes are removed. In this way, the best route path with more valuable nodes is chosen for data packet transmission. The algorithm of bootstrap aggregated mutual dependency ensemble clustering-based route discovery is explained as follows:

Input *: Mobile nodes* $mn_1, mn_2, mn_3 \ldots mn_n$
Output *: Route path discovery*

Begin
1. *For each* mn_i
2. *Identify the neighboring nodes with minimum distance*
3. *Construct route paths from Source S to Destination D*
4. *End for*
5. *For each identified route* r_i
6. *Construct 'm' number of weak learners*
7. *Initialize the number of clusters and cluster centroid* $v_1, v_2, \cdots, v_m$
8. *For each centroid* v_i
9. *For each route path* s_i
10. *Measure mutual dependence* $M_d(s_i, v_j)$
11. *Find* $\arg\max M_d(s_i, v_j)$
12. *Obtain weak learner results* '$h_i(s)$'
13. *End for*
14. *End for*
15. *Combine all weak learners* $W = \sum_{i=1}^{m} h_i(s)$
16. *For each* $h_i(s)$
17. *Calculate generalization error* E_{h_i}
18. *Arrange the weak learners with ascending order*
19. *Select the weak learners with minimum error*
20. *Identify the majority votes of the samples* $\arg_m \max t(s_i)$
21. *Obtain strong clustering results*
22. *End for*
23. *End for*
24. *Store the route paths with less number of hop counts to cache*
25. *For each selected* r_i
26. *For each* mn_i *in* r_i
27. *Calculate the signal strength* s_r *and residual energy* $E_{residual}$
28. *if* $((E_{resudial} > T_E$ *(*T_E *Threshold of Energy) && (*$S_r > T_S$ *(Threshold Receiving Signal Strength) then*
29. *valuablemobile node*
30. *else*
31. *invaluable node*
32. *else if*
33. *Select the route with more valuable nodes in the route-cache*
34. *End for*
35. *End for*

End

Algorithm 1. Route discovery process.

B. Learning Agent Based Stale Route Elimination

The learning agent based approach is applied to perform the stale route elimination by finding the link failure due to the selfish node and the corruptive node in the route path. Learning agent based approach is analyzing the node's behaviors using different layers. Each node in one layer is connected to the next successive layer. Fig. 4 illustrate the learning agent based approach with different layers.

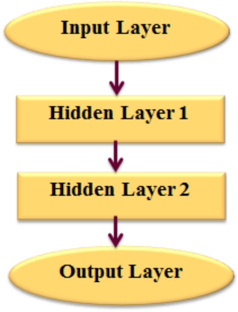

Fig. 4. Learning agent based approach.

The routes with maximum valuable nodes are given as input to the input layer and it is passed to the hidden layers. In that layer, node behaviors are analyzed and identify the selfish nodes or other corruptive nodes. A selfish node is one of a malicious node that affects communication. A selfish behavior is defined as a mobile node that does not send data to other mobile nodes in a network. The corruptive node modifies or corrupts the content of the data being processed. These kinds of misbehaviors nodes in the route path are identified for improving the reliability of data transmission.

As a result, the behavior of the neurons in the $X(t)$ input layer is represented as follows

$$X(t) = \sum_{i=1}^{n} x_i \; w_1 + b_j \tag{10}$$

From (10), the input layer combines the input x_i with weights w_1 and bias term b_j. Here, $X(t)$ indicates neuron activity in input layer at a time t' and w_1 denotes weights between the input and the next successive layer. After that the inputs are transfered into the next successive layer which is used to analyze the node features.

1) Agent based selfish node identification

Using the agent-based method, the selfish node in MANET is detected while transmitting data packets from source to destination along the selected route line. The intermediate mobile nodes act as misbehavior like selfish node, corruptive node and it stops the data forwarding to other mobile nodes. Therefore, the stale route is identified and removed from the route cache using the agent-based approach. The agent-based approach uses external agents to monitor the communication behavior of the mobile nodes. These agents are not contributing to communication. They only monitor the mobile nodes and capture the node status based on the communication behavior of these nodes. Initially, the agents are placed in the network to cover the region and the nodes. After that, the mobile agent starts monitoring the nodes in their region. Then the node cooperation communication is analyzed by the mobile agent. The cooperativeness of the mobile node is measured based on the activities performed by the node while communicating with other nodes in the network. Each node in the network knew the information about the network and they cooperate with the other nodes for better communication. The misbehavior nodes did not cooperate with the other nodes for data transmission.

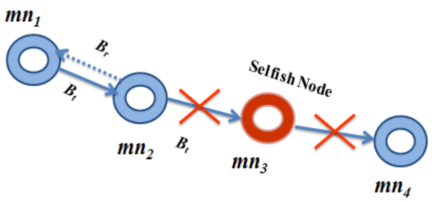

Fig.5. Mobile node cooperation.

Fig. 5 illustrates the mobile nodes mn_1, mn_2, mn_3, mn_4, in MANET. Every node sends a beacon message to the other nodes at instance of time t.

$$mn_i \overset{B_t}{\Rightarrow} mn_j \tag{11}$$

where B_t represents the transmission of beacon message from node mn_i to mn_j.

After receiving the beacon message, the mobile node sends the reply message (B_r) to the node mn_i.

$$mn_i \overset{B_r}{\Leftarrow} mn_j \tag{12}$$

If the node mn_j did not send any reply message at a particular time interval to the other node, then mn_j does not cooperate with other nodes at a time t and it stops the data forwarding to other nodes. If the node did not reply to the beacon message, then the agent node finds it as the suspicious node. The Fig. 5 shows that intermediate node act as a selfish node and discarded the incoming data.

2) Agent based corruptive node identification

The trust level of each mobile node is monitored in order to assess the internal malicious node.

$$T_n = \frac{P_{\text{forward}} - P_{\text{drop}}}{P_{\text{received}}} \tag{13}$$

where T_n represents the node trust level, P_{forward} indicates a data packet being forwarded, P_{drop} indicates a data packet lost, and P_{received} represents data packet received by the mobile node.

In that layer, the agent node finds the selfish node by the cooperative communications and the corruptive node by trust level. Then the trust level is higher than the threshold is said to be a normal node otherwise the node is said to a corruptive node it drops the more packets. In this way, the communication features are analysed by these agent nodes. The result of the first hidden layer is passed to the next hidden layer. In the next successive layer, the selfish node and corruptive node cause the link failure and it only aware of the mobile agent node. The failure link is called a stale route. So the mobile agent's nodes distribute a route error R_{err} messages to all the other nodes within the covered region. The route error packet comprises the information of the broken link. Followed by, all the mobile nodes in the network receive the information's about the broken link. The output of hidden layers at a time t is given below.

$$h(t) = w_1\ x_i + w_2\ h_{(t-1)} \tag{14}$$

where $h(t)$ denotes a hidden layer output, here $h(t-1)$ represents the result from the first hidden layer and w_2 denotes hidden layer weight, w_1 denotes a weight between input and hidden layers x_i indicates the input.

The output layer then receives the results obtained from the hidden layer. At the output layer, the failure link is removed from the route cache and another stable alternative route is selected with the efficient node data communication.

$$Y(t) = w_3 h(t) \tag{15}$$

where $Y(t)$ represents the output of deep learning, w_3 represents the adjustable weights between layer 3 and layer 4, and $h(t)$ denotes an output layer 2, i.e. hidden layers.

Based on this analysis, the learning agent based approach effectively performs the stale route elimination due to the misbehaving nodes. The algorithmic process of a learning agent based approach is described as follows,

Input: Number of routes paths in caches $r_1, r_2, \cdots, r_n$
Output: Eliminate the stale route and improve the data transmission

Begin
Give r_i to input layer $X(t)$ with the weight w_1
Transform input into first hidden layer $h(t)$
For each route r_i in cache
For node mn_i and node mn_j
Measure node cooperativeness
Measure trust level T_n
If (node has better cooperativeness) then
Node i said to normal node
Node mn_i and node mn_j connected at time 't'
Link is stable
Eelse
Node i said to selfish node
Node mn_i and node mn_j not-connected at time 't'
Link is not stable
End if
If (T_n (Node Trust level)> th(Threshold)) then
Node is said to a normal node at time 't'. Link is stable
Else if
Node is said to a corruptive node at time 't'. Link is unstable
End if
Mobile agent distribute r_{err} message to all the nodes at the second hidden layer
Remove the stale route from route cache at the output layer
Select an alternativeneighboring route Perform efficient data transmission
End for
End for
End

Algorithm 2. Learning agent based stale route elimination.

Algorithm 2 describes the learning agent -based stale routes elimination in MANET for reliable data transmission. The learning agent based approach uses multiple layers for learning the input and provides the best output. The mobile node behaviors are analyzed in the two hidden layers based on the node cooperation and trust level to select the stable route and remove the unstable route from the route cache. As a result, the stable route between the mobile nodes is used for enhancing reliable data transmission in MANET.

V. Simulation Setup

The simulation is carried out using the proposed BAMDEC-LABA technique and existing methods RAMP [1], KF-MAC [2], ORGMA [3], are implemented using NS2.34 network simulator. Totally 500 mobile nodes are distributed in a squared area (1100m×1100m) in MANET. The supported mobility model is Random Waypoint model. The mobile nodes are moved in the speed varied from 0m/s to 20m/s. The simulation time is set as 300s. The Dynamic Source Routing (DSR) protocol is used for performing the scalable and reliable routing in MANET. The simulation parameters with the values are listed in Table I.

TABLE I: SIMULATION PARAMETERS

Simulation parameters	Values
Network Simulator	NS2.34
Simulation area	1100m × 1100m
Number of mobile nodes	50,100,150,200,250,300, 350,400,450,500
Number of data packets	25,50,75,100,125,150,175, 200,225,250
Mobility model	Random Waypoint model
Nodes speed	0m/s – 20 m/s
Simulation time	300sec
Routing Protocol	DSR
Number of runs	10

VI. Performance Evaluation

This section discusses the simulation output of the proposed BAMDEC-LABA technique and existing methods RAMP [1], KF-MAC [2], ORGMA [3] through various parameters such as routing overhead, packet delivery ratio, packet drop rate, and Delay. With the aid of tabulation and graphical illustrations, the output of various metrics using proposed and current methods is examined.

A. Routing Overhead

The time it takes to route data packets from source to destination is referred to as routing overhead. When comparing the BAMDEC-LABA to other techniques, the obtained results shows that routing overhead is reduced using the BAMDEC-LABA. The results are plotted in the graph as shown in Fig. 6. It shows the convergence plot of routing overhead with regard to 250 data packets sent from the source location. The findings demonstrate the routing overhead is minimal using proposed BAMDEC-LABA. This is because of applying the mutual dependency bootstrap aggregation based clustering technique. With the implementation of bootstrap aggregation instead of storing all the available paths in the cache, only maximum dependent less hop count paths and stable paths stored in the cache. Due to that the route cache entries are reduced. In case of link failure, alternative route paths captured from the cache. This reduces the reroute discovery time. Stale routes are eliminated from the cache with the help of learning agent notification. In the simulation environment BAMDEC-LABA technique takes 17ms to route 25 data packets. However, the time is taken to route the data packets using RAMP [1], KF-MAC [2], and ORGMA [3], was found to be '33ms', 29ms, and 26ms. From this, it is inferred that the BAMDEC-LABA technique minimizes the routing overhead. The average of ten results shows that the BAMDEC-LABA technique minimizes the routing overhead by 32%, 25%, 20%.

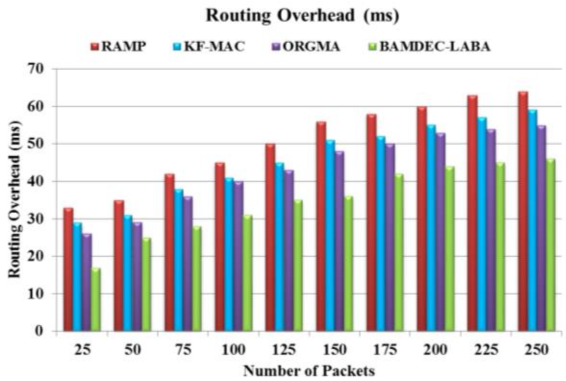

Fig. 6. Routing overhead.

B. Packet Delivery Ratio

Fig. 7 depicts the graphical representation of the packet delivery ratio. The packet delivery ratio is calculated by dividing the number of correctly received packets by the total number of data packets. It is inferred from the Fig. 7 that the packet delivery ratio is found to be higher using the BAMDEC-LABA when compared with other existing strategies. This is due to the incorporation of both clustering and deep learning concepts. Clustering method identifies the route paths with maximum dependency and minimum hop counts based on the majority votes. Maximum dependency provides the strong connectivity link between the centroid node and nodes in the route path. Stable link is ranked based on the parameters such as residual energy and receiving signal strength. Learning agent approach detects the abnormal communicating nodes such as selfish nodes and corruptive nodes. This helps to know in advance about the link failures. These links are considered as the inconsistent routes and are eliminated from the cache.

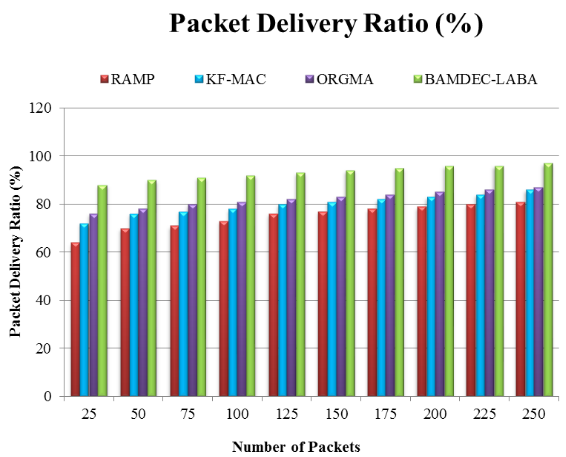

Fig. 7. Packet delivery ratio.

The simulation results of the packet delivery ratio based on the number of data packets taken in the range from 25 to 250 as shown in graphical illustration. By applying the BAMDEC-LABA technique, '22' number of data packets are received and the delivery ratio is 88%. In addition, '16', '18' and 19 data packets received and the delivery ratio is 64%, 72%, 76% by applying RAMP [1], KF-MAC [2] and ORGMA [3]. From this analysis, that the packet delivery ratio is better using the BANDEC-LABA technique than the other routing techniques. The ten results of the packet delivery ratio using various routing techniques are obtained and graphical illustration is shown in fig. 7. When compared to RAMP [1], KF-MAC [2] and ORGMA [3] the average of ten results proves that the packet delivery ratio is improved by 25%, 17%, and 13%, using BAMDEC-LABA.

C. Packet Drop Rate

It measures the number of packets dropped due to misbehaving nodes. Fig. 8 illustrate the simulation results of a packet drop rate with respect to the number of data packets When compared to existing routing methods, the BAMDEC-LABA technique reduces packet drop rate. This is due to the deep learning agent based stale route elimination.

The behaviour of the intermediate nodes in the route paths are deeply analysed in the hidden layers. The node with better cooperativeness and a highly trusted node are selected for data transmission to minimize the packet drop. Furthermore, when a connection failure due to the misbehaving node, the agent node sends an error message to all nodes involved in the data transmission.The data packets are then transmitted using the other alternative stable link. This, in turn, minimizes the packet drop at the destination end. The packet drop rate of BAMDEC-LABA technique is considerably reduced by 74%, 67%, and 63%, when compared to RAMP [1], KF-MAC [2], and ORGMA [3] as shown in Fig. 8.

D. Delay

It calculates packet arrival time delay. The convergence graph in Fig.9 shows that as the number of data packet increases, the end to end delay increases as well, but the BAMDEC-LABA approach, in comparison to the other methods, minimizes the delay.

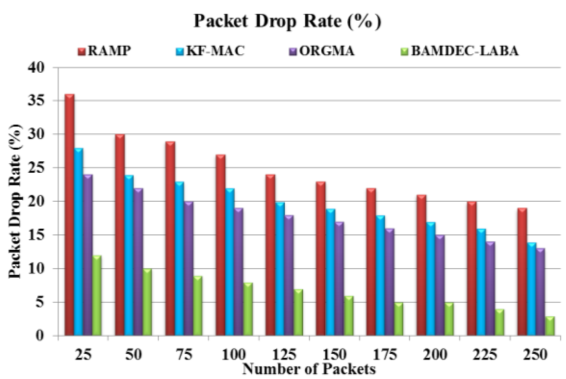

Fig. 8. Packet drop rate

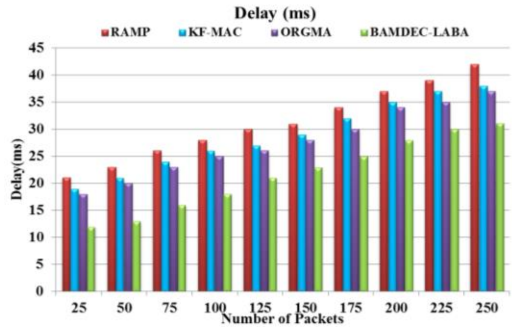

Fig. 9. Delay.

This is because of applying the agent based stale route elimination in MANET. The agent node identifies the link failure and distributes error messages to other nodes. Subsequently, the broken link is removed and selects other stable routes and performs the data transmission. Therefore, the data transmission is improved and minimizes the routing end to end delay. The delay of BAMDEC-LABA technique is found to be minimized by 32%, 26% and 23% as compared to RAMP [1], KF-MAC [2], ORGMA [3] depicted in Fig. 9.

VII. CONCLUSION

An efficient approach called BAMDEC-LABA for improving the scalable and reliable data transmission by eliminating the stale routes in MANET. This contribution is achieved by applying two techniques namely clustering and deep learning concept. Initially, the bootstrap aggregated mutual dependency clustering technique is applied for finding the route paths based on the number of hop counts between source and destination nodes. The path with lesser hop counts is selected for routing to minimize the routing overhead. After that, the deep learning is applied to eliminate the stale route due to the selfish nodes and other misbehaving nodes and select an alternative route based on the cooperativeness and trust level. This, in turn, ensures reliable data transmission with minimum packet loss. The simulation is run with different routing strategies and different parameters such as routing overhead, packet delivery ratio, packet drop rate, and delay. The performance results obtained show that the BAMDEC-LABA decreases the routing overhead, delay, packet drop and increase the successful packet delivery ratio than the existing contemporary strategies and state-of-the-art methods. Reliability is carried out only through the node behavior but the security is unaddressed. In Future, in order to further reduce routing overhead and to improve packet delivery ratio, we plan to achieve the stale route elimination and stable link communication by considering the security threats using artificial intelligence methods.

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHOR CONTRIBUTIONS

P. Tamilselvi conducted the research, carried out the experimental analysis and drafted the original paper. T. N.

Ravi assisted in the development, written the review of literature and edited the paper. All authors had approved the final version.

REFERENCES

[1] V. Vasanth, K. Venkatachalapathy, T. P. Latchoumi, L. Parthiban, T. Sowmia, and V. OhmPrakash, "An efficient cache refreshing policy to improve QoS in MANET through RAMP," in *Proc. Second International Conference on Computational Intelligence and Informatics in Intelligent Systems and Computing*, 2018, pp. 369-381.

[2] M. Rao and N. Singh, "Energy efficient QoS aware hierarchical KF-MAC routing protocol in MANET," *Wireless Personal Communications*, Springer, vol. 101, no. 2, pp. 635–648, 2018.

[3] D. Kang, H. S. Kim, C. Joo, and S. Bahk, "ORGMA: Reliable opportunistic routing with gradient forwarding for MANETs," *Computer Networks, Elsevier*, vol. 131, pp. 52-64, Feb. 2018.

[4] P. Tamilselvi and T. N. Ravi, "Routing algorithm to eliminate stale routes (RAESR) in mobile ad hoc networks," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 12, pp. 4503-4509, 2019.

[5] A. Tavizi and A. Ghaffari, "Tree-based reliable and energy-aware multicast routing protocol for mobile ad hoc networks," *Journal of Supercomputing*, Springer, vol. 74, pp. 6310-6332, Aug. 2018.

[6] M. Malathi and S. Jayashri, "Robust against route failure using power proficient reliable routing in MANET," *Alexandria Engineering Journal*, Elsevier, vol. 57, no. 1, pp. 11-21, 2018.

[7] M. Anbarasan, S. Prakash, M. Anand, and A. Antonidoss, "Improving performance in mobile ad hoc networks by reliable path selection routing using RPS-LEACH," *Concurrency and Computation: Practice and Experience, Wiley*, vol. 31, no. 7, pp. 1-11, 2019.

[8] M. G. Vaighan and M. A. J. Jamali, "A multipath QoS multicast routing protocol based on link stability and route reliability in mobile ad-hoc networks," *Journal of Ambient Intelligence and Humanized Computing*, Springer, vol. 10, no. 1, pp. 107-123, 2019.

[9] B. H. AlQarni and A. S. AlMogren, "Reliable and energy efficient protocol for MANET multicasting," *Journal of Computer Networks and Communications*, vol. 2016, pp. 1-13, May 2016.

[10] R. J. Cai, X. J. Li, and P. H. J. Chong, "An evolutionary self-cooperative trust scheme against routing disruptions in MANETs," *IEEE Trans. on Mobile Computing*, vol. 18, no. 1, pp. 42-55, 2019.

[11] A. Naushad, G. Abbas, Z. H. Abbas, L. Jiao, and F. Muhammad, "A novel dynamic link connectivity strategy using hello messaging for maintaining link stability in MANETs," *Wireless Communications and Mobile Computing*, vol. 2018, pp. 1-23, Dec. 2018.

[12] M. Ahmad, A. Hameed, A. A. Ikram, and I. Wahid, "State-of-the-art clustering schemes in mobile ad hoc networks: Objectives, challenges, and future directions," *IEEE Access*, vol. 7, pp. 17067-170681, Jan. 2019.

[13] O. S. G. Prakasi and P. Varalakshmi, "Decision tree-based routing protocol (DTRP) for reliable path in MANET," *Wireless Personal Communications*, vol. 109, pp. 257-270, May 2019.

[14] N. Khatoon and Amritanjali, "Mobility aware energy efficient clustering for MANET: A bio-inspired approach with particle swarm optimization," *Wireless Communications and Mobile Computing*, vol. 2017, pp. 1-12, Nov. 2017.

[15] B. Yanga, Z. Wu, Y. Shen, and X. Jiang, "Packet delivery ratio and energy consumption in multicast end-to-end delay-tolerant MANETs with power control," *Computer Networks*, vol. 161, pp. 150-161, Oct. 2019.

[16] D. Sarkar, S. Choudhury, and A. Majumder, "Enhanced-ant-AODV for optimal route selection in mobile ad-hoc network," *Journal of King Saud University - Computer and Information Sciences*, vol. 32, no. 10, pp. 1-16, 2018.

[17] J. Huang, X. Fan, X. Xiang, M. Wan, Z. Zhuo, and Y. Yang, "A clustering routing protocol for mobile Ad hoc networks," *Mathematical Problems in Engineering*, vol. 2016, pp. 1-10, Apr. 2016.

[18] Y. Q. Li, Z. Wang, Q. W. Wang, Q. G. Fan, and B. S. Chen, "Reliable ant colony routing algorithm for dual-channel mobile Ad hoc networks," *Wireless Communications and Mobile Computing*, vol. 2018, May 2018.

[19] G. Singal, V. Laxmi, and M. S. G. V. Rao, "Moralism: mobility prediction with link stability based multicast routing protocol in MANETs," *Wireless Networks*, vol. 23, no. 3, pp. 663-679, 2017.

[20] D. Chander and R. Kumar, "QoS enabled cross-layer multicast routing over mobile ad hoc networks," *Procedia Computer Science*, vol. 125, pp. 215-227, 2018.

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