Logitboost with Fisher's Linear Discriminant Classifier for Traffic Aware Resource Optimized Routing In WSN

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Abstract- One of major problem to be solved in wireless sensor networks (WSN) is to prevent network from traffic congestion without compromising the energy of sensor nodes. Network congestion directs to packet loss, and energy waste. In order to address the above said limitations, Ensemble Classification based Traffic Aware Resource Optimized Routing (EC-TAROR)technique is proposed. The EC-TARORtechniqueis presented with objective of improving routing performance to optimally utilize the resources of WSN and avoiding congestion occurrences to achieve maximum packet delivery ratio. At first, EC-TARORtechnique measures energy, bandwidth and load of sensor nodes in network. The logit boosting with FLD classifier is then employed to classify the sensor node as minimum or maximum resource utilization (i.e. energy, bandwidth and load) by constructing strong learner. After classification process, the EC-TARORtechnique performs route path discovery to choose optimal path from source node to destination. The optimal path is identified by selecting sensor node with minimum resource utilization to transmit data without loss. This helps for EC-TARORtechnique to attain traffic aware resource optimized routing in WSN. The EC-TARORtechnique conducts simulation process using metrics such as energy consumption rate, packet delivery ratio, bandwidth consumption rate and data loss rate with respect to different number of sensor nodes and data packets. The simulation result illustrates that the EC-TARORtechnique is able to improve the packet delivery ratio and lessens the energy consumption as compared to state-of-the-art-works.

Keywords: Ensemble Technique, FLD, Logit Boost, Strong Learner, Weight, WSN

I. INTRODUCTION

WSN includes diverse wireless devices with different kinds of sensors to collect information from the environment. The gathered data is broadcasted to destination using routing protocol. The objective of different routing scheme is to optimally employ the resources of WSN to attain higher throughput. Congestion in a WSN is degrades network performance and also dropsthe packet that leads to extreme energy consumption. The routing technique avoids congestion by choosing sensor nodes with sufficient buffer space to increases packet delivery ratio. Few researches works are designed for congestion control in WSN. However, the performance of conventional congestion control technique was not sufficient. Therefore, EC-TARORtechnique is developed to avoid congestion occurrences and thereby optimize the resources employment of sensor nodes in WSN.

A hop-by-hop gradient-based routing scheme was presented in [1] for uniformly distributing loads in WSN. This scheme minimizes the number of packet retransmissions and packets dropped through preventing nodes with overloaded buffers. The bandwidth consumption during routing was not solved. An adaptive cuckoo search based optimal rate adjustment (ACSRO) was introduced in [2] for congestion avoidance in WSN. The ACSRO presents better performance in terms of throughput, delay, normalized packet loss, normalized queue size, and congestion level. However, energy and bandwidth utilization rate in WSN was remained an open issue.

A congestion-aware and Traffic Load balancing Scheme (CTLS) was presented in [3] using composite metric. The CTLS provides better performance in terms of packet delivery ratio, delay, throughput, and energy consumption. The routing overhead was not solved in this scheme. A traffic-aware dynamic routing (TADR) algorithm was employed in [4] for WSN. The TADR consumes more amount of energy for data transmission.

Congestion Aware, Energy Efficient, on Demand Fuzzy Logic Based Clustering Protocol was developed in [5] for Multi-hop WSN. This protocol reduces redundant control message communication. The bandwidth utilization was not considered in this...
protocol. Enhanced Congestion Aware Routing (E-CAR) was intended in [6] in order to avoid the effect of congestion in the network. The E-CAR improves packet delivery ratio. The resource optimization was remained unaddressed in E-CAR.

An Improved Bat Algorithm was introduced in [7] for energy efficient congestion control in WSN. This algorithm enhances the throughput. However, the transmission delay in WSN was not solved. Trust Integrated Congestion Aware Energy Efficient Routing algorithm was designed in [8] for WSN. This algorithm enhances the network performance. But, the data loss rate was not considered.

A Load Balancing Optimization Algorithm was developed in [9] with application of Fuzzy Neural Networks. An Index Base Congestion aware Routing Protocol (ICRP) was intended in [10] for performing energy efficient routing. ICRP controls congestion in network. However, delivering real-time traffic such as video over a wide range of conditions was not solved in ICRP.

In order to address the above said existing issues in WSN, EC-TAROR technique is developed. The main contribution of EC-TAROR technique is formulated as,

- To improve the routing performance through resource optimization and congestion avoidances, EC-TAROR technique is proposed. The EC-TAROR technique is designed by combining logit boosting with Fisher's Linear Discriminant classifier.
- To increase the classification performance and thereby achieving resource aware optimized routing in WSN, Logitboost with FLD Classifier is introduced in EC-TAROR technique on the contrary to existing works.

The rest of paper is formulated as follows: Section 2 presents the related works. In Section 3, EC-TAROR technique is explained with helps of architecture diagram. In Section 4, Simulation settings are described and the result discussion is presented in Section 5. Section 6 depicts the conclusion of the paper.

II. RELATED WORKS

A review of different mechanisms intended for controlling congestion in WSN and their comparative study was presented in [11]. A novel congestion control protocol was presented in [12] for enhancing network lifetime and reliability of WSN. A Gradient routing protocol for LOAD-BALANCING (GLOBAL) was designed in [13] with help of gradient model to prolong network lifetime of WSN. The congestion control was not solved effectively.

Hierarchical Tree Alternative Path (HTAP) algorithm was applied in [14] for congestion control in WSN. Adaptive mechanism-based congestion control was introduced in [15] for WSN. Grid-based multipath with congestion avoidance routing protocol was presented in [16] to decrease network delay and improves throughput in WSN. This protocol reduces the packet delay and obtains better utilization for the available storage.

A fairness-aware congestion control (FACC) protocol was intended in [17]. An interference-minimized multipath routing (I2MR) protocol was presented in [18] to enhance throughput in WSN. A learning automata-based congestion avoidance scheme was introduced in [19] to get reliable data delivery in healthcare WSN. Flock-based Congestion Control (Flock-CC) mechanism was designed in [20] for balancing load in network.

III. ENSEMBLE CLASSIFICATION BASED TRAFFIC AWARE RESOURCE OPTIMIZED ROUTING TECHNIQUE

Let us consider a WSN in the form of graph structure like ‘G(Vi,Ei)’. Here ‘Vi’ indicates the number of sensor nodes in network whereas ‘Ei’ refers the links between sensor nodes.

The sensor node in WSN is represented as ‘SNi = SN1,SN2,SN3…SNn ∈ V’ that is lies within transmission range ‘r’. The following diagram depicts the routing process in simple WSN structure.

As depicted in Figure 1, data packet is transmitted to destination from source node via choosing the best route path in WSN. The best path is discovered by sending the route request (RR) and route reply (RP) messages between nodes. Due to resource constraints, increasing quality of data routing through
the resource optimization and congestion avoidance plays a considerable role in WSN.

As a result, EC-TAROR technique is designed. The EC-TAROR technique chooses the best route path between source and destination node with application of Logitboost with FLD Classifier to transmit the data packets with minimal resource utilization in WSN. On the contrary to existing works, Logitboost with FLD is employed in proposed EC-TAROR technique as it provides improved classification performance and also minimizes the time complexity to obtain traffic aware resource optimized routing in WSN. The detail processes of EC-TAROR technique is shown in below.

3.1 Resource Utilization

Measuring resource consumption of sensor node is significant in order to enhance the network performance in terms of energy, bandwidth, and packet delivery ratio. The EC-TAROR technique considers the energy and bandwidth consumption, load on node to obtain traffic aware resource optimized routing in WSN. The energy level of sensor node \( \xi_{SN_i} \) is determined as,

\[
\xi_{SN_i} = \xi_i - (\xi_T + \xi_R)
\]

(1)

From equation (1), \( \xi_i \) refers an initial energy level of node. Here, \( \xi_T \), \( \xi_R \) point outs energy consumed by sensor node to transmit and receive the data respectively. The amount of energy utilized by a sensor node \( \xi_U \) to broadcast or receive the data is computed as,

\[
\xi_U = T\xi_{SN_i} - R\xi_{SN_i}
\]

(2)

From equation (2), \( T\xi_{SN_i} \) is the total energy of a sensor node and \( R\xi_{SN_i} \) denotes residual energy level. The bandwidth utilization of sensor node is determined based on bandwidth used during data transmission. The bandwidth utilization of sensor node \( \vartheta_U \) is obtained as,

\[
\vartheta_U = \vartheta_i - R\vartheta_{SN_i}
\]

(3)

From equation (3), \( \vartheta_i \) denotes an initial bandwidth and \( R\vartheta_{SN_i} \) residual bandwidth of sensor node. Followed by, load on sensor node \( \delta_{SN_i} \) is measured as,

\[
\delta_{SN_i} = \frac{N_{DP}}{TLC}
\]

(4)

From equation (4), \( TLC \) represent total load capacity of sensor node. Here, \( N_{DP} \) represent the amount of data packets being carried by sensor node. By using the equation (2), (3), (4), EC-TAROR technique estimates the energy, bandwidth and load on sensor nodes in network.

3.2 Logitboost with FLD Classifier

Logitboost with FLD Classifier is a supervised learning technique for combining multiple base learners or classifiers to create a strong learner. Logitboost with FLD Classifier is an ensemble that constructs a set of base classifiers and then classify sensor node by taking a weight of their predictions to produce improved classification results. An ensemble of Logitboost with FLD Classifier gives more accurate classification result than a single model. In
Logitboost Classifier with FLD, the weak learner is considered as Fisher's Linear Discriminant (FLD).

FLD is employed in machine learning to discover a linear combination between features for classifying the sensor nodes into two more classes. The FLD is used as a linear classifier. The proposed technique employed FLD as base learner for handling the large number of sensor nodes in network. Classifying huge number of sensor nodes is very complex process and it needs more execution time. In order to get higher accuracy and to lessen time of node classification in WSN, proposed technique exploits FLD as base learner. The FLD performs the classification between two classes with respect to different number of sensor nodes. “SN" denotes a number of sensor nodes in WSN. In FLD, linear transformation matrix \( \varphi \) (i.e., discriminant vector) is utilized to project the sensor nodes in a network into a one dimensional subspace. The projection maximizes variance between the two classes while decreasing the variance within each class. The FLD describes a separation function as ratio of variance between the classes to the variance within the class. From that, separation function is defined as follows,

\[
sf = \frac{\sigma_b}{\sigma_w} = \frac{\varphi^T s_{b/w} \varphi}{\varphi^T s_{w/i} \varphi} \tag{5}
\]

From equation (5), \( \varphi \) indicates a separation function, \( \sigma_b \) represents variance of between the classes and \( \sigma_w \) refers a variance of within the class. Here, \( \varphi^T \) denotes a discriminant vector that projects the sensor nodes in WSN into classes according to optimal projection direction \( \varphi \). The mean value of each class is determined mathematically as,

\[
m_c = \frac{1}{n} \sum_{\text{SN} \in c} SN_i \tag{6}
\]

From equation (6), \( n \) represents a number of the sensor nodes in each class and \( m_c \) indicates a mean value of the each class. The mean value of each sensor node is determined based on energy and bandwidth utilization and residual load using below mathematical expression,

\[
m_{SN} = \frac{1}{n} \sum_{\text{SN} \in X} SN_i \tag{7}
\]

From equation (7), \( m_{SN} = \frac{1}{n} \) denotes a mean value of each sensor node, \( n \) denotes a number of sensor nodes in WSN. Here, \( X \) denotes energy and bandwidth utilization and residual load. Followed by the scatter matrix is formulated with help of the mean value of sensor nodes and classes. The scatter matrix is a covariance matrix that computed as a product of mean of the two variables. The scatter matrix is also evaluates the deviation of these variables from their particular mean value. The scatter matrix within the class is determined using below formulation,

\[
s_{w/i}(C_i) = \sum_{c=1}^{n} \sum_{SN \in c} m_{SN} (m_{SN} - m_c)^T \tag{8}
\]

From equation (8), \( s_{w/i}(C_i) \) represents a scatter matrix of within the class and \( m_{SN} \) denotes a sensor node, \( m_c \) refers a mean of the class. Here, \( T \) signifies a transpose of a matrix. In the same way, the scatter matrix between the classes is evaluated as,

\[
s_{b/w}(C_i) = \sum_{c=1}^{n} n (m_c - m_{SN}) (m_c - m_{SN})^T \tag{9}
\]

From equation (9), \( s_{b/w}(C_i) \) is a scatter matrix between the subsets, \( n \) denotes a number of sensor nodes in WSN, \( m_{SN} \) indicates a mean value of sensor nodes. The optimal projection direction \( W \) is determined as,

\[
\varphi = s_{w/i}^{-1} (m_c - m_{SN}) \tag{10}
\]

From equation (10), the optimal projection direction \( \varphi \) is identified. The determined optimal projection direction \( \varphi \) significantly classifies the sensor nodes in WSN as maximum resource utilization sensor nodes or minimum resource utilization sensor nodes. The below diagram demonstrates the node classification results based on energy and bandwidth consumption and residual load using base FLD classifier.

Figure 3 shows the output of FLD classifier. The base FLD classifier classifies sensor node as minimum resource utilization or maximum resource utilization by discovering optimal projection direction. As demonstrated in Figure 3, yellow color represents the minimum resource utilization nodes whereas red color denotes the maximum resource utilization nodes in WSN.
with FLD, an ensemble of weak learner are combined them into a final strong learner to obtain the higher classification results. The performance of FLD is improved by applying logitboost ensemble technique. The below diagram shows the flow processes of Logitboost with FLD Classifier.

Figure 4 presents the block diagram of Logitboost with FLD Classifier for improving classification performance of sensor node in WSN with minimal time complexity. As shown in Figure 4, Logitboost with FLD Classifier at first estimates energy, bandwidth and load of each sensor node in WSN. Then, Logitboost with FLD Classifier creates ‘n’ number of base FLD results for each sensor node. Next, Logit boosting Ensemble technique applied to increase the performance of FLD Classifier where all base learners are combined into stronger learner based on error rate.

![Flow Processes of Logitboost with FLD Classifier](image)

Finally, stronger learner effectively classifies the sensor nodes as minimum resource utilization or maximum resource utilization with higher accuracy and lower time to obtain higher quality of data transmission in WSN.

Let us consider ‘n’ number of base FLD results of sensor node is represented as ‘FLD$_{b1}$, FLD$_{b2}$,...FLD$_{bn}’$. The Logitboost with FLD Classifier initializes the weight value ‘$\omega$’ to each base classifier. Then, logit loss (i.e. error) is determined for each base learner with help of below mathematical expression,

$$Err = \sum_{b=1}^{n} \log(1 + \exp(\gamma_i^b FLD_{b_i})) \quad (11)$$

From equation (11), $Err$ represents an error of the base FLD classifier. Subsequently the weight of all base learners is updated. The weight of base learner is higher when the sensor nodes are incorrectly classified. In the same manner, weight of base learner is lower when the sensor nodes are correctly classified. From that the weight is updated for all base FLD classifier based on determined error value.

The output of strong learner is a summation of base FLD classifiers which is formulated mathematically as,

$$f = \sum_{b=1}^{n} FLD_{b_i} \quad (12)$$

From equation (12), ‘$f$’ indicates a strong learner output and ‘FLD$_{b_i}$’ denotes a base learner output. With assists of measured weight value, weight of all base learners are updated as,

$$f = \sum_{b=1}^{n} \omega_i FLD_{b_i} \quad (13)$$

From equation (13), $\omega_i$ denotes an updated weight of the base learner ‘FLD$_{b_i}$’. Followed by, Logit boosting technique chooses the base learner with minimum weight value as strong learner using below,

$$f = \arg \min \omega_i FLD_{b_i} \quad (14)$$

From equation (14), strong learner output is obtained. The output of final strong learner enhances the classification accuracy of sensor node as minimum resource utilization or maximum resource utilization with minimum time. The algorithmic processes of Logitboost with FLD Classifier are shown in below.

<table>
<thead>
<tr>
<th>Input:</th>
<th>Number of Sensor Nodes‘SN$_1$, SN$_2$, SN$_3$ ... SN$_n$’, Data Packets ‘DP$_1$, DP$_2$, DP$_3$ ... DP$_n’’.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output:</td>
<td>Traffic Aware Resource Optimized Routing In WSN</td>
</tr>
<tr>
<td>Step 1: Begin</td>
<td>// Base FLD classifier</td>
</tr>
<tr>
<td>Step 2:</td>
<td>For each sensor node‘SN$_i’’</td>
</tr>
<tr>
<td>Step 3:</td>
<td>Determine energy consumption using (2)</td>
</tr>
<tr>
<td>Step 4:</td>
<td>Compute bandwidth utilization using (3)</td>
</tr>
<tr>
<td>Step 5:</td>
<td>Find load on sensor node using (4)</td>
</tr>
<tr>
<td>Step 6:</td>
<td>Define class separation function ‘$s_f$’ using (5)</td>
</tr>
<tr>
<td>Step 7:</td>
<td>Compute mean value of each class$m_c$ using (6)</td>
</tr>
<tr>
<td>Step 8:</td>
<td>Mean value of each sensor nodem$_{SN}$ using (7)</td>
</tr>
<tr>
<td>Step 9:</td>
<td>Compute ‘$s_{b/u}$’ and ‘$s_{w/i}$’ using (8) and (9)</td>
</tr>
<tr>
<td>Step 10:</td>
<td>Find optimal projection direction‘$\varphi$’ to classify</td>
</tr>
</tbody>
</table>
sensor nodes using (10)

// Applying logit boosting technique

Step 11: Initialize weight 'ω' to all base learner 'FLD\_b_i'

Step 12: For each base learner

Step 13: Measure error rate 'Err' using (11)

Step 14: Update the weight of base learner using (13)

Step 15: End for

Step 16: Choose base learner with minimum weight value as strong learner using (14)

Step 17: Strong learner classify the sensor nodes in network as maximum or minimum resource utilization

Step 18: Perform route discovery by selecting sensor nodes with minimum resource utilization to transmit data using RR and RP messages

Step 19: End

Step 20: End

Algorithm 1 Logitboost with FLD Classifier

Algorithm 1 portrays the step by step processes of Logitboost with FLD Classifier to perform traffic aware resource optimized routing in WSN. The Logitboost with FLD Classifier at first determines energy, bandwidth and load for all sensor nodes in WSN. After that, Logitboost with FLD Classifier formulates 'n' number of base FLD learner results for each sensor node. Next, Logitboost with FLD Classifier initializes weight to all base learners and subsequently error rate is estimated for each base learner result. Then, Logitboost with FLD Classifier updates the weight of base learners. Finally, Logitboost with FLD Classifier selects base learner with minimum weight value as strong learner. This strong learner classifies the sensor nodes as minimum resource utilization or maximum resource utilization with higher precision and minimal time as compared to state-of-the-art works. After completing classification process, EC-TARORtechnique carried out route path discover where sensor node with minimum resource utilization (energy, bandwidth and load) is selected between source and destination to successfully broadcast data without any traffic. Thus, EC-TARORtechnique attains improved performance for traffic aware resource optimized routing in WSN.

IV. SIMULATION SETTINGS

The EC-TARORtechnique is implemented in NS-2 simulator with network area of 100m * 100m to evaluate the proposed performance. The EC-TARORtechnique used Dynamic Source Routing (DSR) as routing protocol for simulation work. The simulation parameters are depicted in Table 1.

<table>
<thead>
<tr>
<th>Table 1 Simulation Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulation factor</strong></td>
</tr>
<tr>
<td>Simulator</td>
</tr>
<tr>
<td>Network area</td>
</tr>
<tr>
<td>Protocol</td>
</tr>
<tr>
<td>Transmission range</td>
</tr>
<tr>
<td>Number of Sensor Nodes</td>
</tr>
<tr>
<td>Number of Data Packets</td>
</tr>
<tr>
<td>Data packet Size (KB)</td>
</tr>
<tr>
<td>Simulation time</td>
</tr>
<tr>
<td>Pause time</td>
</tr>
</tbody>
</table>

The efficacy of EC-TARORtechnique is estimated in terms of energy consumption, bandwidth utilization rate and packet delivery ratio and packet loss rate. The performance of proposed technique is compared with existing hop-by-hop gradient-based routing scheme [1] and adaptive cuckoo search based optimal rate adjustment (ACSRO) [2].

V. RESULT AND DISCUSSIONS

In this section, the result analysis of EC-TARORtechnique is presented. The performance result of EC-TARORs compared with hop-by-hop gradient-based routing scheme [1] and adaptive cuckoo search based optimal rate adjustment (ACSRO) [2] respectively using following metrics with the assist of tables and graphs.

5.1 Measure of Energy Consumption Rate

In EC-TARORtechnique, the Energy Consumption Rate (ECR) determines energy utilized to transmit data to destination node from source node. The energy consumption is measured as product of energy used by a single sensor node for data transmission and total number of sensor nodes in WSN. The energy consumption is determined in terms Joules (J) and mathematically obtained as,

\[ ECR = n \times E_{SSN} \]

From equation (15), ‘n’ is total number of sensor nodes and ‘E_{SSN}’ is the energy employed by a single node for reliable data delivery. While energy
consumption is lower, the technique is said to be more effective.

**Sample calculation:**

- **Hop-by-hop gradient-based routing scheme:** energy utilized by a single node to broadcast data is 0.89 and the total number of sensor nodes is 50. Then energy consumption rate is obtained as,
  \[ EC = 0.89 \times 50 = 45 \text{J} \]
- **ACSRO:** energy used by a single sensor node to transmit data is 0.57 and the total number of sensor nodes is 50. Then energy consumption rate is measured as,
  \[ EC = 0.57 \times 50 = 29 \text{J} \]
- **EC-TAROR:** energy consumed by a single sensor node for data transmission data is 0.5 and the total number of sensor nodes is 50. Then energy consumption is measured as follows,
  \[ EC = 0.5 \times 50 = 25 \text{J} \]

The EC-TAROR technique is implemented in NS-2 simulator using different number of sensor nodes in the range of 50-500 in order to determine the amount of energy consumed for data packet transmission in WSN.

![Figure 5 Performance Result of Energy Consumption versus Number of Sensor Nodes](image)

Figure 5 depicts the performance result analysis of energy consumption versus diverse numbers of sensor nodes in the range of 50-500 using three methods namely Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] and EC-TAROR technique. As shown in the figure, energy consumption using proposed EC-TAROR technique is lower when compared to existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. This is due to application of Logitboost with FLD Classifier in proposed EC-TAROR technique. With the algorithmic processes of Logitboost with FLD Classifier, EC-TAROR technique finds the minimum resource utilization (i.e. energy, bandwidth and minimum load) sensor nodes for routing data packets to destination from source node in network. Besides, EC-TAROR technique avoids the additional amount of energy utilization for data retransmission due to traffic or congestion occurs. This helps for EC-TAROR technique to use minimum amount of energy for reliable data delivery in WSN. Hence, EC-TAROR technique decreases the energy consumption by 35% and 13% as compared to conventional Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] respectively.

### 5.2 Measure of Bandwidth Utilization Rate

In EC-TAROR technique, Bandwidth Utilization Rate (\( BUR \)) is estimated as the average rate of successful data transfer from one point to another within a network in a specific amount of time. The bandwidth utilization rate is measured in terms of bits per second (bps) and mathematically evaluated as,

\[
BUR = \frac{\text{average rate of successful data transfer}}{\text{time}} \tag{16}
\]

From equation (16), bandwidth utilization rate is estimated. While bandwidth consumption is higher, the technique is said to be more effective.

**Sample calculation:**

- **Hop-by-hop gradient-based routing scheme:** the average rate of successful data transfer is 79 bits for a given amount of time (second) when considering 10 KB data packet size. Then bandwidth utilization rate is evaluated as,
  \[ BUR = 79 \text{ bps} \]
- **ACSRO:** the average rate of successful data transfer is 85 bits for a given amount of time (second) when taking 10 KB data packet size. Then bandwidth utilization rate is measured as,
  \[ BUR = 85 \text{ bps} \]
- **EC-TAROR:** the average rate of successful data transfer is 104 bits for a given amount of time

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of time (second) when employing 10 KB size of data packet. Then bandwidth utilization rate is determined as,

\[ BUR = 104 \text{ bps} \]

In order to evaluate the bandwidth utilization rate, EC-TARORtechniques implemented in NS-2 simulator using various sizes of data packets in the range of 10-100 KB. The simulation result of bandwidth utilization rate using EC-TARORtechniques compared against with existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. When employing 60KB data packet for conducting simulation work, EC-TARORtechnique gets 185 bps bandwidth utilization rate whereas Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] obtains 125 bps and 146 bps respectively. From these results, it is clear that the bandwidth utilization rate using EC-TARORtechnique is higher as compared to other existing methods [1], [2]. The comparative result of bandwidth utilization rate is shown in below.

**TABLE 2 TABULATION FOR BANDWIDTH UTILIZATION RATE**

<table>
<thead>
<tr>
<th>Data packet Size (KB)</th>
<th>Hop-by-hop gradient-based routing scheme</th>
<th>ACSRO</th>
<th>EC-TAROR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>79</td>
<td>85</td>
<td>104</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
<td>98</td>
<td>127</td>
</tr>
<tr>
<td>30</td>
<td>99</td>
<td>105</td>
<td>136</td>
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<tr>
<td>40</td>
<td>107</td>
<td>121</td>
<td>148</td>
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<tr>
<td>50</td>
<td>120</td>
<td>133</td>
<td>170</td>
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<td>60</td>
<td>125</td>
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<td>70</td>
<td>132</td>
<td>158</td>
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<td>80</td>
<td>140</td>
<td>183</td>
<td>240</td>
</tr>
<tr>
<td>90</td>
<td>145</td>
<td>188</td>
<td>245</td>
</tr>
<tr>
<td>100</td>
<td>200</td>
<td>240</td>
<td>289</td>
</tr>
</tbody>
</table>

Table 2 depicts the performance result analysis of bandwidth utilization rate versus varied numbers of data packets size in the range of 10-100 KB using three methods namely Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] and EC-TARORtechnique. As presented in the table, bandwidth utilization rate using proposed EC-TARORtechnique is higher when compared to existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. This is because of application of Logitboost with FLD Classifier in proposed EC-TARORtechnique. By using Logitboost with FLD Classifier, EC-TARORtechnique accurately identifies the maximum and minimum resource utilization nodes in network through performing classification. The EC-TARORtechnique picks sensor nodes which takes minimum amount of resources (i.e. energy, bandwidth and minimum load) for effective data transmission in WSN. The selected best sensor nodes during route discovery process increases average rate of successful data transfer from one point to another within a network in a specific amount of time as compared to existing techniques. Therefore, EC-TARORtechnique improves the bandwidth utilization rate by 49 % and 28 % as compared to conventional Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] respectively.

### 5.3 Measure of Packet Delivery Ratio

In EC-TARORtechnique, packet delivery ratio ‘PDR’ evaluates ratio of number of data packets that are successfully transmitted in a particular amount of time. The packet delivery ratio is evaluated in terms of packets per second (pps) and mathematically obtained as,

\[ PDR = \frac{NST_{DP}}{NST_{time}} \]  

From the equation (17), the packet delivery ratio ‘PDR’ is measured where NST\(_{DP}\) denotes number of data packets successfully transmitted. While packet delivery ratio is higher, the technique is said to be more effective.

**Sample calculation:**

- **Hop-by-hop gradient-based routing scheme:** the number of data packets successfully transmitted is 9 for a given amount of time (second) when considering 10 data packets as input. Then packet delivery ratio is computed as,
  \[ PDR = 9 \text{ pps} \]

- **ACSRO:** the number of data packets successfully transmitted is 7 for a given amount of time (second) when employing 10 data packets as input. Then packet delivery ratio is measured as,
  \[ PDR = 7 \text{ pps} \]

- **EC-TAROR:** the number of data packets successfully transmitted is 6 for a given amount of time (second) when taking 10
In order to determine the packet delivery ratio, EC-TARORTechnique is implemented in NS-2 simulator using different number of data packets in the range of 10-100. The simulation result of packet delivery ratio using EC-TARORTechnique is compared against with existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. When taking 70 data packet for simulation work, EC-TARORTechnique attains 68 pps packet delivery ratio whereas Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] gets 57 pps and 54 pps respectively. Thus, it is significant that the packet delivery ratio using EC-TARORTechnique is higher as compared to other existing methods [1], [2]. The comparative result of packet delivery ratio is demonstrated in below.

![Figure 6 Performance Result of Packet Delivery Ratio versus Number of Data Packets](image)

Figure 6 depicts the performance result analysis of packet delivery ratio versus diverse numbers of data packets in the range of 10-100 using three methods namely Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] and EC-TARORTechnique. As depicted in the figure, packet delivery ratio using proposed EC-TARORTechnique is higher when compared to existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. This is owing to application of Logitboost with FLD Classifier in proposed EC-TARORTechnique. With the assists of Logitboost with FLD Classifier, EC-TARORTechnique discovers the optimal path between source and destination through picking minimum resource utilization nodes. The selected optimal path avoids data loss due to link failure and also controls congestions over a network. This helps for EC-TARORTechnique to successfully transmit data to destination node with minimum loss rate compared to existing works. As a result, EC-TARORTechnique enhances the packet delivery ratio by 33% and 17% as compared to conventional Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] respectively.

### 5.4 Measure of Data Loss Rate

In EC-TARORTechnique, data loss rate is measured as the ratio of number of data packets dropped to the total number of data packets received. The data loss rate is determined in terms of percentage (%) and formulated as,

\[
DLR = \frac{N_{DPP}}{N_{RDP}} \times 100
\]  

From equation (18), data loss rate is estimated with respect to various number of data packets taken as input. Here, \(N_{DPP}\) points out the number of dropped data packets in which \(N_{RDP}\) indicates number of received data packets by a sensor node. While data loss rate is lower, the technique is said to be more effectual.

#### Sample calculation:

- **Hop-by-hop gradient-based routing scheme**: the number of data packets dropped is 4 and the total number of data packets is 10. Then data loss rate is estimated as,

\[
DLR = \frac{4}{10} \times 100 = 40 \%
\]

- **ACSRO**: the number of data packet dropped is 3 and the total number of data packets is 10. Then data loss rate is obtained as,

\[
DLR = \frac{3}{10} \times 100 = 30 \%
\]

- **EC-TAROR**: the number of data packets dropped is 2 and the total number of data packets is 10. Then data loss rate is determined as,

\[
DLR = \frac{2}{10} \times 100 = 20 \%
\]

EC-TARORTechnique is implemented in NS-2 simulator by considering dissimilar number of data packets in the range of 10-100 to measure loss rate during data transmission in WSN. The simulation result of data loss rate using EC-TARORTechnique is compared against with existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. When assuming 80 data packet for accomplishing simulation process, EC-TARORTechnique acquires 15% data loss rate whereas Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] obtains 28% and 26% respectively. Thus, it is descriptive that the data loss rate using EC-TARORTechnique is lower as compared to other existing methods.
compared to other existing methods [1], [2]. The comparative result of data loss rate is described in below.

**Table 3 Tabulation for Data Loss Rate**

<table>
<thead>
<tr>
<th>Number of Data Packets</th>
<th>Data Loss Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hop-by-hop gradient-based routing scheme</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>30</td>
<td>37</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>50</td>
<td>38</td>
</tr>
<tr>
<td>60</td>
<td>33</td>
</tr>
<tr>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>28</td>
</tr>
<tr>
<td>90</td>
<td>26</td>
</tr>
<tr>
<td>100</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 3 depicts the performance result analysis of data loss rate versus various numbers of data packets in the range of 10-100 using three methods namely Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] and EC-TAROR technique. As exposed in the table, data loss rate using proposed EC-TAROR technique is lower when compared to existing Hop-by-hop gradient-based routing scheme [1] and ACSRO [2]. This is because of usage of Logitboost with FLD classifier in proposed EC-TAROR technique. This Logitboost with FLD classifier enhances the classification performance to classify sensor nodes in network. This classification results helps for EC-TAROR technique to discover the best path for transmitting data in WSN. The chosen optimal path reduces data loss because of link failure and also preserves network from congestion occur. This assists for EC-TAROR technique to obtain minimum packet loss during transmission as compared to existing works. As a result, EC-TAROR technique minimizes the data loss rate by 48% and 30% as compared to conventional Hop-by-hop gradient-based routing scheme [1] and ACSRO [2] respectively.

VI. CONCLUSION

An effective EC-TAROR technique is developed with key goal of increasing routing performance to optimize the resources utilization and avoiding traffic occurrences in WSN. The goal of EC-TAROR technique is attained by design of logit boosting with FLD classifier. The proposed logit boosting with FLD classifier improves classification result by designing strong learner to classify the sensor node in network with higher accuracy. After completing classification process, the EC-TAROR technique determines best path from source node to destination by sending RR and RP massages between neighbouring nodes in WSN. The EC-TAROR technique finds best path via choosing sensor node with minimum resource utilization to broadcast data without loss. This supports for EC-TAROR technique to achieve traffic aware resource optimized routing in WSN. The effectiveness of EC-TAROR technique is estimated in terms of energy consumption rate, packet delivery ratio, bandwidth consumption rate and data loss rate and compared with two state-of-the-art works. The simulation result proves that EC-TAROR technique provides better performance with an improvement of packet delivery ratio and minimization of energy consumption as compared to the state-of-the-art works.

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