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RESEARCH ARTICLE

# Optimizing Large-Scale RFID Networks With Energy-Efficient Dynamic Cluster Head Selection: A Performance Improvement Approach

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**ABSTRACT** This paper uses radio frequency signals for non-contact tracking and localization utilising Radio Frequency Identification (RFID) technology. The clustering approach is quite useful when dealing with large RFID readers. This method stimulates the expansion of RFID nodes without compromising the overall network performance. The Cluster Head (CH) is the most critical node in a clustered RFID system. This research presents a method for dynamically selecting the cluster head that takes the connectivity and power of each RFID reader into account. In dynamic mode, selecting a new cluster head is based on Fuzzy Logic. Based on these data, the energy level of 0.443 and centrality of 0.809 are the thresholds at which a node has a 91.8 % chance of becoming a CH. Managing massive RFID networks is also handled, with cluster numbers increasing at different intervals. The RFID network's effectiveness is determined by measuring throughput, accuracy, delay, success, and error rates. The network may accommodate up to a thousand nodes with 13 node leaders for improved capacity. The results show a 97.8 % success rate, 0.22 % accuracy, a 2.64 % error rate, and a 36.91 second latency.

**INDEX TERMS** Accuracy, cluster count, cluster head, centrality, energy, RFID, dynamic cluster head selection (DCHS), fuzzy logic.

## I. INTRODUCTION

Nowadays, RFID Technology is in the driver's seat for tracking and locating real-world objects [1], [2]. Most developed countries are running behind the RFID technology to strengthen their tracking accuracy. Currently, RFID systems are used for various tiny Tracking applications [3], [4], [5], [6]. Some of the major real-time applications of RFID systems are the Internet of Things (IoT), Supply chain management, Vehicle tracking and location Identification of an object [7], [8], [9], [10], [11]. This is particularly evident in supply Chain Management as an IoT of collaboration, advancement, adaptation to internal failure, efficiencies and synchronization is required between a PC organisation's RFID and Supply Chain Management segments. These collaborations likewise incorporate security issues and sifting [12], [13]. A fundamental prerequisite in the huge RFID frameworks is the requirement for a high throughput of reading tags. Enormous warehouses and other stockpiling administrations are accessible for putting away large numbers of RFID-embedded things. Hence, the most required of the RFID framework is to guarantee the reading of tags and retrieval of the embedded tags data [14], [15]. In an RFID network, the collision occurs when different tags

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communicate to the reader's question, all the while because all tags share a similar remote channel. Hostile to impact convention is important to offer help for various RFID tags recognizable proof [16], [17], [18].

Planning an RFID network is fundamental for building a large RFID network. The K-coverage-based deployment of the RFID reader is important for handling efficient transmission. The Plant Growth Simulation Algorithm was guaranteed for k-coverage of RFID readers [19], [20], [21]. Some of the Routing Methods are used for less energy consumption for choosing the route. When choosing the next hop for the best route of the network, the routing algorithms have an awareness of the energy density and weight of the link. As per the energy thickness and strength of the link with neighbours, it will reconstruct the topology and give an efficient route to reach the nodes [22], [23], [24], [25]. Another used the RFID scheme for channel identification rather than the Received Signal Strength Indication (RSSI) scheme. Because the RFID scheme is used for identification and the RSSI scheme is based on the signal strength of a node, which node has more signal strength (dcb). It may be considered for the channel's selection. RSSI is often used in wireless communication networks, especially when selecting a channel in wireless protocols. RSSI represents the signal strength of the received radio frequency signal. A clustering RFID system mostly focuses on the large-scale RFID Network [26], [45], [46], [47]. When huge numbers of nodes have participated in a network, the existing tracking algorithms are not guaranteed for the efficiency of the network. In this situation, the clustering mechanism guarantees the efficient routing of the RFID network and handling of the huge number of nodes [27], [28]. Moreover, the cluster network can scale up the nodes without compensating for the network efficiency. A cluster head plays a vital role in the clustering mechanism. The node's energy density and long-range distance are used to select the cluster head [29], [30], [31]. In this research, the Fuzzy Logic is proposed for selecting cluster head [32], [33], [34]. The cluster head may change dynamically based on the energy level and failure of the cluster head. The cluster head also may fail due to some physical damage. Quantum computing algorithms can optimize the selection of cluster heads and the scheduling of tag transmissions, thereby reducing power consumption and extending the battery life of RFID tags. The enhanced processing and analysis capabilities of quantum computing algorithms for data from RFID tags allow for more rapid and precise tracking and object identification. The incorporation of quantum computing can also improve RFID network security by allowing the use of more sophisticated encryption algorithms that are immune to quantum attacks. RFID networks can also benefit from the increased efficiency and scalability made possible by quantum computing algorithms, making it easier to incorporate them with other new technologies like those used in the Internet of Things [31], [35].

### A. NOVELITY

A Performance Improvement Approach introduces a pioneering methodology to enhance the efficiency of large-scale RFID networks. The key novelty lies in the dynamic selection of cluster heads, a crucial component in RFID network architecture, primarily focusing on energy efficiency. By leveraging dynamic cluster head selection, the research addresses scalability challenges inherent in large-scale deployments, aiming to improve overall network performance. This approach contributes to extending RFID device operational lifetimes through energy conservation. It presents innovative, optimized algorithms for cluster head selection, optimizing resource utilization and communication within the network. Also, this paper deals with the cluster head faults and solutions without affecting the RFID node's communication. Fuzzy logic has been proposed to solve the cluster head fault by dynamic selection of new cluster heads. For selecting a new cluster head, the energy level and deployment of the RFID nodes are considered for getting a cluster head change. The research underscores its practical applicability and potential impact on industries reliant on RFID technology, offering a comprehensive solution for advancing the sustainability and performance of large-scale RFID networks.

### B. SIGNIFICANT CONTRIBUTIONS

The main contribution of this paper is highlighted as follows:

- Simulation analysis of Energy level, Centrality and the chance of cluster head with fuzzy logic.
- Proposed a novel algorithm using fuzzy logic for handling fail of Cluster Head in RFID network. For handling Cluster Head failure, fuzzy logic is used to select a new cluster head.
- The efficiency of the fuzzy-based clustering RFID network is analyzed in various time intervals ($T_1$, $T_2$, $T_3$, $T_4$, and $T_5$) with the enhancement of nodes and increment of cluster heads.
- This research work can be supported to enhance the geography of vehicle tracking and location identification.
- This research work can also support low-cost navigation (route map) for the intelligent transportation system.

### C. ABBREVIATIONS USED

RFID - Radio Frequency Identification, CH - Cluster Head, IoT - Internet of Things, PC - Personal Computer, RSSI - Received Signal Strength Indication, HERO - Hierarchy Exponential Region Organization, PEIS - Performance Enhancement with Improved Security, GBSA - Group-Based Binary Splitting Algorithm, EL -Energy Level, CC - Cluster Count, AOMDV_SAPTV - Ad-Hoc On-Demand Multicast Distance Vector Secure Adjacent Position Trust Verification, ODBC - Optimal Distance-Based Clustering, and ITS - Intelligent Transportation System.

The rest of the paper is organized as follows: First, we presented state of the art. Section III describes a methodology for Cluster head Selection. Section IV then presents Results and Discussion. Finally, it closes with a conclusion.

## II. LITERATURE SURVEY

The HERO (Hierarchical Exponential Region Organization) protocol deals with the issue of tracking and locating the vehicles continuously. The location data of each vehicle are successfully updated in nearby nodes, which will be conveyed throughout the city. HERO protocol rapidly monitors the movement of vehicles using their overlay organization of neighbourhood nodes and updates the area information in bordering nodes. The most extreme jumps are limited, and the query is directed and HERO certifications to meet the constant necessity with each vehicle [7]. To improve the RFID network, The Performance Enhancement with Improved Security (PEIS) technique has been updated to build security. The performance across unmistakable neighbourhood areas is planted and scattered throughout the hubs to total information dependent on item developments. To get elite and high security, the RFID strategy regulated with the PEIS system works honourably, and an individual reader goes about as a worker based on bandwidth. Also, alongside the PEIS approach is set up for upgrading the exhibition just as ensuring security highlights and the segments of a regular RFID network [26], [28], [40]. Vitruvius is a juncture that enables clients to produce ongoing applications utilizing street vehicle sensors. This will produce straightforward sensor warning applications for multi-sensor, multi-vehicle frameworks for street risks. A fuzzy logic permits streamlining the assets utilized by continuous applications that send information while keeping up quality information. This methodology is moderately high, however worthy regarding the huge upgrades accomplished in the system traffic decrease [36]. A group-based binary splitting algorithm (GBSA) for the tags impacts issues and increases the recognizable proof rate in huge-scale systems. In GBSA, tags are appropriately isolated into various subsets as per the tag cardinality assessment and the ideal grouping methodology. Suppose different tags fall into an equivalent availability and structure a subset. In that case, the adjusted parallel parting system can apply while the rest tags hold up in the line and will be recognized in the accompanying openings. The shut structure articulation of framework throughput for GBSA is utilized to assess the presentation [37]. Dependability relies upon the execution rate, which is described as utilizing an accurate numerical strategy dependent on a recursive investigative methodology, defeating the limitations of past works, which depended on simplifications. For example, registering the most extreme joint traffic that a system can process steadily, choosing the insignificant determining the ideal time slot span or the number of readers to process a given load are unique concepts in the literature on RFID [41]. There are three productive conventions for distinguishing the missing tags from the blocker-empowered RFID frameworks. The first is a group-based protocol that parts the tags set into three subsets and independently manages everyone in various manners. The subsequent convention is called impact accommodated convention, transforming some pointless crash openings into valuable singleton spaces, expanding opening accessibility and diminishing completion time. The third convention is the simultaneous missing tag recognizable proof convention that increases the time productivity of missing-occasion recognition by executing clustering and identifying the missing tags in parallel instead of in succession [14], [42].

## III. CLUSTER HEAD SELECTION

Clustering helps in organizing RFID readers into groups to improve efficiency and scalability. The density-based clustering method determines the number of clusters in the proposed RFID network. In this method, we can use density-based clustering algorithms like Density-Based Spatial Clustering of Applications with Noise (DBSCAN) to automatically determine the number of clusters. These algorithms identify clusters based on the density of RFID nodes. All the readers are grouped in the clustered RFID network and form a cluster with the cluster head (CH) by applying fuzzy logic in every network node. The CH is responsible for other cluster communication. We can scale up the RFID network by increasing the clusters and the cluster head. The selected CH should consider the energy level [38] of the node and the centrality [39] of the network as important. Among the clusters, which node has a high energy level and good centrality is treated as CH with the help of fuzzy logic. Later, the energy level of the node is decreased or failure of the CH circumstances, the CH will change dynamically based on the novel fuzzy algorithm.

Fig. 1 shows the flowchart representation of cluster head selection using fuzzy logic. In the proposed algorithm, the cluster head plays a major role between the clusters. The cluster head will take charge of communicating between neighbour clusters. While deploying the RFID nodes based on the geographical, the nodes will initially group and form the clusters. During the initial formation of the cluster, one node is designated as the cluster head, and this cluster head will change dynamically based on their energy level and centrality node locations. Which node consists of a higher energy level and centrality of locations (easy communication with other nodes) than another node? Fuzzy logic will play the main role in the selection of the CH.

CH is at fault if the CH fails to communicate with other nodes or cannot receive the signals from the tags (working as a node). Immediately, the sender node will broadcast the CH down signal to the RFID network. Afterwards, Fuzzy logic will applied to find the next cluster head for non-interrupt communication of the RFID network. The two major inputs, Energy and Centrality, are considered for new CH selection. After selecting the optimized cluster head, the new node will broadcast the Join-Req signal to all the nodes connected with

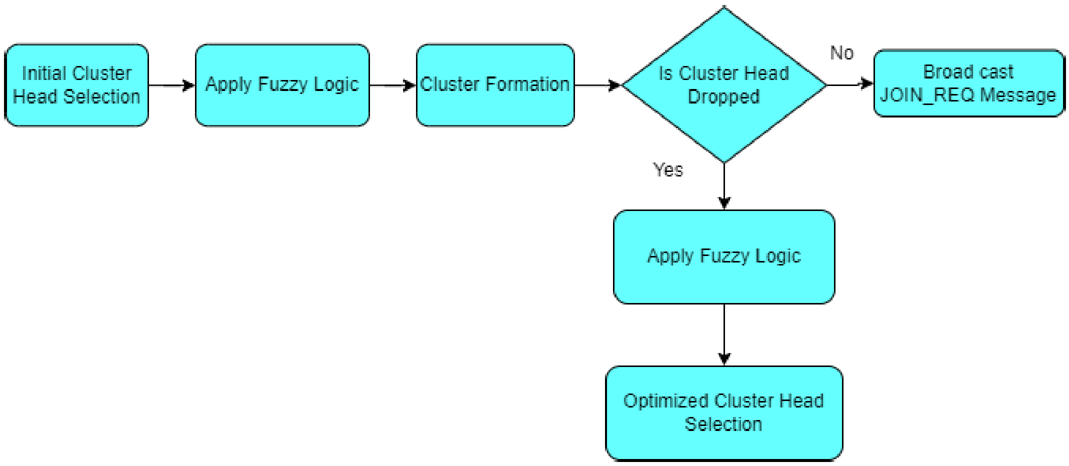


**FIGURE 1.** Flowchart representation of cluster head selection using fuzzy logic.

**TABLE 1.** Energy level variations.

| Sl.No | Energy Level (EL) | Value |
|---|---|---|
| 1 | Very High | 0.5≥ EL ≥0.45 |
| 2 | High | 0.46≥EL≥0.36 |
| 3 | Medium | 0.36≥EL≥0.25 |
| 4 | Low | 0.26≥EL≥0.15 |
| 5 | Very Low | 0.16≥EL≥0 |

this CH. Immediately, all the nodes will join with the new cluster head for non-interrupt RFID communication.

### A. ENERGY

The first input of the fuzzy set is energy. The reader's energy is significant for selecting the cluster head. The required energy of the node is given as [38]

$$E_r \leq E_t - E_c, \tag{1}$$

where $E_r$ is the required energy, $E_c$ represents consumption energy, and $E_t$ is the total energy. The consumption energy $E_c$ is calculated as the consumption energy of every transmission ($E_{ci}$) and idle ($E_i$).

$$E_c = E_{ci} + E_i \tag{2}$$

where $E_{ci} = E_{ti}(t_r)$. Similarly, we can write [38]

$$E_{ti}(t_r) = \sum_{i=0}^{n} Vol(t_i)Cur(t_i)\Delta t \tag{3}$$

where

$$Cur_{idle} = \frac{\sum_{i=0}^{n} \omega(t_i)\Delta t}{T_{idle}} \tag{4}$$

$E_{ti}$- Energy consumption of Individual Transmission, $T_r$- transmission time, $Vol(t_i)$-transmission voltage, $Cur(t_i)$-transmission current, $\Delta t$- sampling time interval. The expression in (2) is used for the total energy consumption of the RFID node. The expression in (3) calculates the $E_c$ of every transmission. Similarly, (4) analyses the non-transmission (idle) energy depletion. $Cur_{idle}$- current consumption when the node is idle. $\omega(t_i)$- Idle current when time $t_i$. $\Delta t$- sampling time interval. $T_{idle}$ -total idle time when the node is not involved in any transmission. $n$ – total count of sampling while $T_{idle}$. Table 1 deals with the energy level of the parameters and the energy level variations dispersed among the attributes. In this work, the trapezoidal member function leads to play with every attribute and the initial energy value is achieved as 0.5.

The principal parameter, very low, accomplishes 0 to 0.15; the low parameter accomplishes 0.16 to 0.25; medium level parameter accomplishes 0.26 to 0.35; the high-level parameter accomplishes 0.36 to 0.45, and the very high parameter accomplishes 0.46 to 0.5 energy esteems individually.

### B. CENTRALITY

The second input of the fuzzy set is centrality. The Centrality is considered from the adjacent node distance for selecting the cluster head. The expression that is used to calculate the local indicators of the cluster node [39]

$$L_i = \sum_{j=1}^{n} \frac{x_{ij}y_j}{y_i\bar{y}_i} + \frac{y_i}{\bar{y}_i}, \tag{5}$$

where $L_i$ is denoted as local indication, $x_{ij}$, $y_j$ are indicated as adjacent nodes; $y_i$ is indicated as degree of directly connected neighbour node and $\bar{y}_i$ indicates as average degree of Global indicator. Here, the global indicator can be defined as

$$G_i = \sum_{j=1}^{n} P_{ij}, \tag{6}$$

where $G_i$ is denoted as global indicator, and $P_{ij}$ represents node pair. To find the pair nodes in the cluster, the expression can be used is

$$P_{ij} = \frac{1}{D_{ij}} \in [0, 1] \tag{7}$$

where $D_{ij}$ denotes the distance between $i$ and $j$. Similarly,

$$\omega_0 = \sum_{i<j\in G}^{n} P_{ij} \tag{8}$$

here, $\omega_0$ is denoted by all the nodes in the topology in isolation. Another case

$$\omega_i = \sum_{j<k\in G}^{n} \omega_{jk}^{i} \tag{9}$$

where $\omega_i$ is denoted as node isolation in a topology after the destruction of the node. For emergence indication of the node, we can write

$$E_i = \frac{\omega_i - \omega_0}{\omega_i}, \tag{10}$$

where $E_i$ is denoted as an emergence indication. Equations (8), (9) and (10) will used to find the isolated nodes in the topology and the isolated after destruction of the node. The expression (11) and (12) is calculated as the centrality indication of the individual nodes involved in the RFID network.

$$C_i = L_i \times G_i \times E_i, \tag{11}$$

where $C_i$ can be defined as

$$C_i = \left(\sum_{j=1}^{n} \frac{x_{ij}y_j}{y_i\bar{y}_i} + \frac{y_i}{\bar{y}_i}\right) \times \left(\sum_{j=1}^{n} P_{ij}\right) \times \left(\frac{\omega_i - \omega_0}{\omega_i}\right) \tag{12}$$

here, $C_i$ is denoted as a centrality indication of a node. The proposed clustering mechanism processes an opportunity that exhibits the chosen node to be picked as a CH, using fuzzy if-then standards. Table 2 shows the centrality levels for discovering the cluster head. Three attributes are utilized in this fuzzy set: Far, Adequate, and Close. If the values are between 0 to 30%, it is connected as the neighbour node is far from the cluster head. On the off chance that the values are between 31% to 70%, it is implied that the neighbour node is situated in an adequate area. If the values are between 71% to 100%, it means that the neighbour node is close to the cluster head.

**TABLE 2.** Centrality levels.

| Sl.No | Level | Percentage |
|---|---|---|
| 1 | Far | 0%≥C≥30% |
| 2 | Adequate | 31%≥C≥70% |
| 3 | Close | 71%≥C≥100% |

**TABLE 3.** Chance of cluster head parameters variations.

| Sl.No | Percentage | Chance (nu) |
|---|---|---|
| 1 | 0 to 20 | Very Low (0≥ $\nu$ ≥0.20) |
| 2 | 21 to 40 | Low (0.21≥ $\nu$ ≥0.40) |
| 3 | 41 to 60 | Medium (0.41≥ $\nu$ ≥0.60) |
| 4 | 61 to 80 | High (0.61≥ $\nu$ ≥=0.80) |
| 5 | 81 to 100 | Very High (0.81≥ $\nu$ ≥1) |

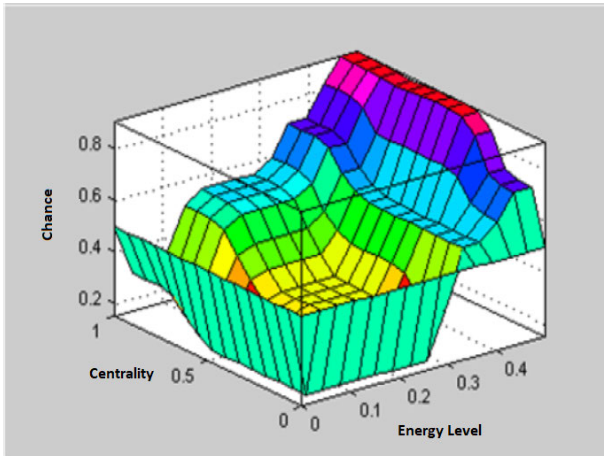


**FIGURE 2.** Cluster head selection probability.

**TABLE 4.** Chance of cluster head.

| Sl.No | Energy Level | Centrality | Chance |
|---|---|---|---|
| 1 | 0.443 | 0.809 | 0.9180 |
| 2 | 0.447 | 0.768 | 0.812 |
| 3 | 0.351 | 0.736 | 0.7644 |
| 4 | 0.250 | 0.910 | 0.6876 |
| 5 | 0.259 | 0.264 | 0.6100 |
| 6 | 0.0482 | 0.809 | 0.5340 |
| 7 | 0.278 | 0.500 | 0.4572 |
| 8 | 0.250 | 0.500 | 0.3804 |
| 9 | 0.0757 | 0.500 | 0.2268 |
| 10 | 0.0711 | 0.336 | 0.1500 |

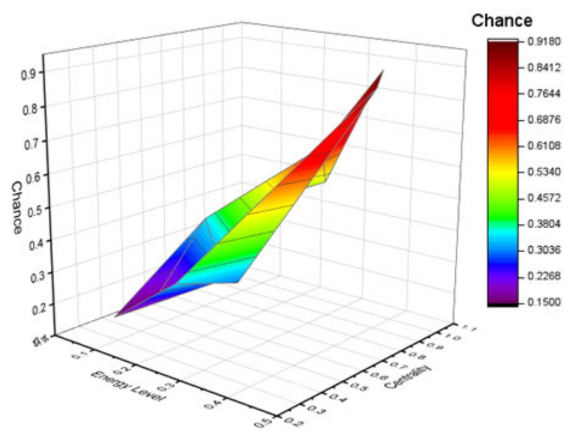


**FIGURE 3.** Results to chance of cluster head.

## C. CHANCE OF CLUSTER HEAD (CH)

This section determines the probabilities of forming cluster heads based on the energy and the centrality. Five attributes (Very High, High, Medium, Low, and Very Low) determine the chance of a node becoming a CH. Table 3 shows the possible values of a node becoming a cluster head based on the five attributes as mentioned above. The trapezoidal member function is utilized for dealing with the parameters. The potential outcomes of the cluster head extension are somewhere in the range of 0 and 1.

**Algorithm 1** Dynamic Cluster Head Selection

```
Input:
ERN: N- Network
n - node (participant in N)
C − {c|c CH candidate participant}
p- how many times to be a CH
Chance (n)- chance to become a Cluster Head
m- cluster count
t- threshold value for ClusterHead
output:
Cluster Head (n)- node n's ClusterHead
if Cluster Head (n) = n then
    function:
    broadcast(d, data,); // d- distance
    send(D, data);// D- destination
    fuzzy logic(Eresidual, EexpResidual);
    Initialization:
    chance (n) ← fuzzy(E_residual,E_expResidual);
    is Cluster Head (n) = not true;
    p ← 0
    Main
    if p = [size of(N) / m] then
      ;// for all cluster round computation
      is Cluster Head (n) = not true;
      t ← 1
    else
      t ← [m / size of(N)]
    end if
    if (rand(0,1)>t) then
      Cluster Head (n)←n;
      chance (n) ← fuzzy(E_residual,E_expResidual);
      broadcast(chance (n), C);
      receiving CH Message;
      For each c ∈ C
      if (chance (n)<chance(c)) then
        Cluster Head (n)←c;
        'Is Cluster Head (n)← false;
        Broadcast(failure-message, C)
      else
        Is Cluster Head (n)← true;'p ← p + 1
      end if
    end if
    if (is Cluster Head (na) ==true) then
      broadcast(CH-Message, CV)
      On receiving JOIN-REQ message;
    else
      CH-Message reception is; Send
      (JOIN-REQ CH(n))
    end if
end if
```

The phonetic parameters for this fuzzy set are very high, high, medium, low and very low. A trapezoidal member function can be utilized for the parameters. The two information sources factors frame fuzzy guidelines like Energy and Centrality. One output variable (chance) is utilized to discover the Cluster Head. Figure 2 shows the result of the fuzzy set rules with the two inputs (Energy level and centrality) and a single output (chance) for cluster head selection. Normally, it is the 3D view of the data presented in Table 4. Table 4 shows the experimental output of the fuzzy set rules with the two input sources (Energy level and centrality) and a single output (chance). Here, the complete initial energy level is 0.5, the total probability of the centrality is 0 to 1, and the total probability of the node getting the chance of cluster head is 0 to 1.

From Table 4 (Sl. no 1), the situation of a node gets a high chance of cluster head. It details the energy level is 0.443, centrality is 0.809, and the chance of the cluster head is 0.9180. Sl.no 1 to 3 has a high chance of becoming a cluster head. Table 4 (Sl. no 4) represents the situation of a node that gets a medium chance of cluster head. It details the energy level is 0.25, centrality is 0.91, and the chance of the cluster head is 0.6876. Table 4 (Sl.no 10) represents the situation in which a node gets a low chance of cluster head. It details the energy level is 0.0711, centrality is 0.336, and the chance of the cluster head is 0.15. Sl.no 5 to 10 gets a low chance of becoming a cluster head. In our proposed method, we have used the centrality value, which represents the strength of the signal received by an RFID reader, as a metric for selecting the cluster head. The reader with the strongest centrality value can be chosen as the cluster head, ensuring reliable communication. Figure 3 detailed the cluster head chances in various levels of energy and centrality. The remaining table details the node getting the chance of the cluster head. While broadcasting the CH candidate message, every node collects and holds it.

If the probability is more noteworthy than other communicated nodes, the selected node communicates a Cluster Head message, implying that the selected node is chosen as the Cluster Head (CH). If the node doesn't get the message, the node with very high energy and close centrality is its Cluster Head and transmits a join request message to ask to the head.

**TABLE 5. Experimental initials.**

| Sl.No | Parameters | Value(max) |
|---|---|---|
| 1 | Initial Energy in Joule | 0.5 |
| 2 | Cluster Count (CC) | 13 |
| 3 | Total No. of Nodes | 1000 |
| 4 | Max iteration | 10x5 |
| 5 | Transmission range | 100meter |
| 6 | Field dimension | 100meter x 100meter |

## IV. RESULTS AND DISCUSSIONS

The proposed clustering mechanism using a fuzzy logic method is implemented for simulation results. Table 5 shows the simulation settings. The initial energy of each node is 0.5 joule. The total number of nodes that can be accumulated

**TABLE 6. Performance analysis.**

| Sl. No | No.of Nodes | CC | No. of Tags | Success Rate | Error Rate | Accuracy | Throughput | Delay |
|---|---|---|---|---|---|---|---|---|
| 1 | 200 (at time $T_1$) | 3 | 20 | 199 | 1 | 99.50 | 74.35 | 0.2677 |
| 2 | | | 40 | 199 | 1 | 99.50 | 75.09 | 0.2650 |
| 3 | | | 60 | 198 | 2 | 99.00 | 75.89 | 0.2609 |
| 4 | | | 80 | 198 | 2 | 99.00 | 74.93 | 0.2642 |
| 5 | | | 100 | 197 | 3 | 98.50 | 76.87 | 0.2563 |
| 6 | | | 120 | 197 | 3 | 98.50 | 80.92 | 0.2434 |
| 7 | | | 140 | 196 | 4 | 98.00 | 79.95 | 0.2451 |
| 8 | | | 160 | 196 | 4 | 98.00 | 79.88 | 0.2453 |
| 9 | | | 180 | 195 | 5 | 97.50 | 78.83 | 0.2474 |
| 10 | | | 200 | 195 | 5 | 97.50 | 78.78 | 0.2475 |
| 11 | 400 (at time $T_2$ | 5 | 40 | 399 | 1 | 99.75 | 26.02 | 1.5329 |
| 12 | | | 80 | 398 | 2 | 99.50 | 25.70 | 1.5484 |
| 13 | | | 120 | 397 | 3 | 99.25 | 24.57 | 1.6157 |
| 14 | | | 160 | 396 | 4 | 99.00 | 26.06 | 1.5191 |
| 15 | | | 200 | 395 | 5 | 98.75 | 25.92 | 1.5238 |
| 16 | | | 240 | 395 | 5 | 98.75 | 25.19 | 1.5676 |
| 17 | | | 280 | 394 | 6 | 98.50 | 23.57 | 1.6712 |
| 18 | | | 320 | 393 | 7 | 98.25 | 23.37 | 1.6812 |
| 19 | | | 360 | 392 | 8 | 98.00 | 22.30 | 1.7578 |
| 20 | | | 400 | 391 | 9 | 97.75 | 22.05 | 1.6254 |
| 21 | 600 (at time T3) | 8 | 60 | 598 | 2 | 99.66 | 6.77 | 8.8292 |
| 22 | | | 120 | 597 | 3 | 99.50 | 7.74 | 7.7053 |
| 23 | | | 180 | 596 | 4 | 99.33 | 9.07 | 6.5647 |
| 24 | | | 240 | 594 | 6 | 99.00 | 7.96 | 7.4543 |
| 25 | | | 300 | 593 | 7 | 98.83 | 7.02 | 8.4440 |
| 26 | | | 360 | 592 | 8 | 98.66 | 8.91 | 6.6399 |
| 27 | | | 420 | 590 | 10 | 98.33 | 8.05 | 7.3253 |
| 28 | | | 480 | 589 | 11 | 98.16 | 7.15 | 8.2430 |
| 29 | | | 540 | 588 | 12 | 98.00 | 6.38 | 9.2238 |
| 30 | | | 600 | 586 | 14 | 97.66 | 7.56 | 7.7242 |
| 31 | 800 (at time $T_4$) | 10 | 80 | 798 | 2 | 99.75 | 5.06 | 15.7546 |
| 32 | | | 160 | 796 | 4 | 99.50 | 4.95 | 16.0733 |
| 33 | | | 240 | 795 | 5 | 99.37 | 4.58 | 17.3308 |
| 34 | | | 320 | 793 | 7 | 99.12 | 5.33 | 14.8769 |
| 35 | | | 400 | 791 | 9 | 98.87 | 5.12 | 15.4470 |
| 36 | | | 480 | 790 | 10 | 98.75 | 4.89 | 16.1246 |
| 37 | | | 560 | 788 | 12 | 98.50 | 5.06 | 15.5516 |
| 38 | | | 640 | 786 | 14 | 98.25 | 5.09 | 15.4362 |
| 39 | | | 720 | 785 | 15 | 98.12 | 5.02 | 15.6126 |
| 40 | | | 800 | 783 | 17 | 97.87 | 4.88 | 16.0315 |
| 41 | 1000 (at time $T_5$) | 13 | 100 | 997 | 3 | 99.70 | 2.96 | 33.6246 |
| 42 | | | 200 | 995 | 5 | 99.50 | 2.87 | 34.6612 |
| 43 | | | 300 | 993 | 7 | 99.30 | 2.73 | 36.2911 |
| 44 | | | 400 | 991 | 9 | 99.10 | 2.72 | 36.4178 |
| 45 | | | 500 | 989 | 11 | 98.90 | 2.76 | 35.7254 |
| 46 | | | 600 | 987 | 13 | 98.70 | 2.85 | 34.5259 |
| 47 | | | 700 | 984 | 16 | 98.40 | 2.96 | 33.1966 |
| 48 | | | 800 | 982 | 18 | 98.20 | 2.88 | 34.0043 |
| 49 | | | 900 | 980 | 20 | 98.00 | 2.70 | 36.2103 |
| 50 | | | 1000 | 978 | 22 | 97.80 | 2.64 | 36.9139 |

in a network is 1000 based on the field dimensions of $100m \times 100m$. The transmission range of each tag is 100 meters (super high-frequency active tags). The number of cluster heads in the RFID network is 13 when the node count reaches 1000. Also, the cluster headcount will increase for every iteration based on the RFID node count raise. The total number of iterations of this proposed work is $10 \times 5$.

### A. PERFORMANCE ANALYSIS

This section clarified the test consequences of the proposed fuzzy-based clustering mechanism strategy. The network can be developed here by including more readers (nodes). The clusters are expanded by expanding the tags and readers. The different recreation inputs are given for the various iterations, and diverse simulation results are obtained. The capacity of the proposed strategy has been quantitatively evaluated using different performance measures such as Success Rate, Error Rate, Accuracy, Throughput, and Delay. Table 6 shows the deep analysis of the simulated output of the fuzzy-based clustering mechanism. Table 6 also shows the performance of the Clustered RFID network using Fuzzy Logic. The various network parameters were used to analyze the RFID network with different time intervals ($T_1$, $T_2$, $T_3$, $T_4$, and $T_5$).

### B. AT TIME $T_1$

The complete number of nodes in the network is 200, with cluster count 3 (CC). At the point when the quantity of tags count will build, the Success rate of the network will diminish, and the error rate is the converse corresponding to the success rate. The accuracy of the network is exceptionally high at time T1. The throughput esteem is investigated depending on the tags engaged with the network. Right now, throughput depends on the Success Rate and The Error rate. At the point when the network is scaled up, the delay of the network will increase. The augmentation of the error rate (tag count decrement is comprehended) will mirror the delay, too. Figure 4 shows a detailed performance evaluation of the RFID network when the 200 nodes with 3 cluster counts are associated with the network at time $T_1$. At the point when 200 nodes engaged with an RFID network with cluster count 3, the presentation of the network was breaking down dependent on the tags submitted in the network at a specific time. If the tag count is 20, the network makes the success rate of the network 199, and the error rate is 1. The accuracy of the network is accomplished 99.5%, the network's throughput is 74.35, and the delay is 0.2677 sec. At the point when enhancing the tags count from 20 to 40 with 200 nodes RFID network, the success rate, error rate, and accuracy are the same, yet the throughput is expanded to 75.09, and delay is diminished to 0.2650 given the network stays stable condition. Again, increase the tags count from 40 to 80, the success rate is 198, the error rate is 2, and the accuracy of the network is 99%. The throughput of the network is 74.93, and the delay is 0.2642. Again, adding the tags count from 80 to 160, the success rate of the network is 196 error rate is 4, and accuracy is 98% throughput of the network is 79.88, and the delay is 0.2453. While expanding the tags count, the network used full usage of the cluster count. When the tags count came to 200 for 200 nodes, the network made a success rate of 195, an error rate of 5, and an accuracy is 97.5%. The throughput of the network is 78.78, and the delay is 0.2475.

### C. AT TIME $T_2$

The total number of nodes in the network will be upgraded from 200 to 400 with cluster head 5. The success rate will diminish when the tags count is expanded. The error rate is a converse proportionality of the success rate. The accuracy of the network at time T2 is high because of the augmentation of the cluster headcount. The throughput is determined according to time $T_1$; likewise, the worth is diminished when the reader and tags count increment. The delay of the network will increment for the augmentation of the reader and tags. Figure 5 details the performance of the RFID network when the 400 nodes with 5 cluster counts are engaged with the network at time $T_2$. The tags come to up to 200. The network's success rate is 395, the error rate is 5, the accuracy is 98.75%, the throughput is 25.92, and the delay is 1.5238 sec. at the point when 320 tags upgrade the network, the network responds with a success rate of 393 and an error rate of 7. The accuracy of the network is diminished to 98.25%, throughput will diminish to 23.37, and the delay of the network is 1.6812 sec. Again, expanding the tags count from 320 to 400 with a similar cluster count, the network gives the success rate of 391, and the error rate will be 9. The accuracy of the network is decreased to 97.75%. The throughput of the network is expanded due to the error rate augmented. The network accomplishes a throughput of 24.05, and the delay is 1.6254 sec, dependent on the augmentation of the error rate.

### D. AT TIME $T_3$

At the point when 600 nodes are associated with an RFID network with 8 cluster counts, the tags count compasses to 300, the success rate of the network is 593, and the error rate of the network is 7. Right now network will give 98.83% accuracy, and the network's throughput is 7.02. The delay of the network is 8.4440sec. At the point when the network is upgraded by 480, the network can make 589 progress rates, and the error rate is 11. At this express, the network gives 98.16% accuracy. Be that as it may, the throughput will expand from 7.02 to 7.15. At the most punctual 420 tags engaged with the network, the throughput is based on the error rate count of 10. The delay of the network accomplishes 8.2430 sec. At the point when the network improved from 480 to 600 tags, the network made 586 success rates, and the error rate was 14. The accuracy of the network is 97.66%, yet the throughput will increment from 7.15 to 7.56. The delay of the network is 7.7242sec. Figure 6 shows the detailed performance of the RFID network when the network contains 600 nodes with 8 cluster counts.

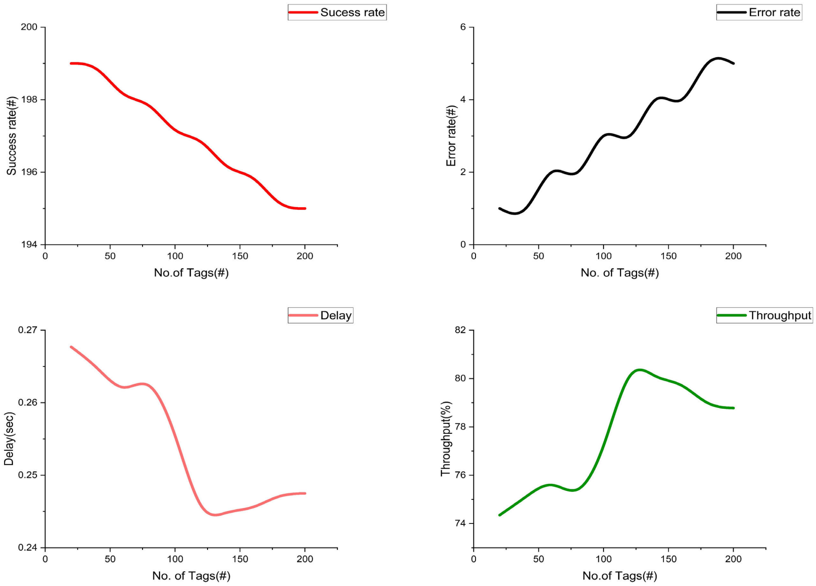


**FIGURE 4.** Upto 200 nodes with 3 CC (at time $T_1$).

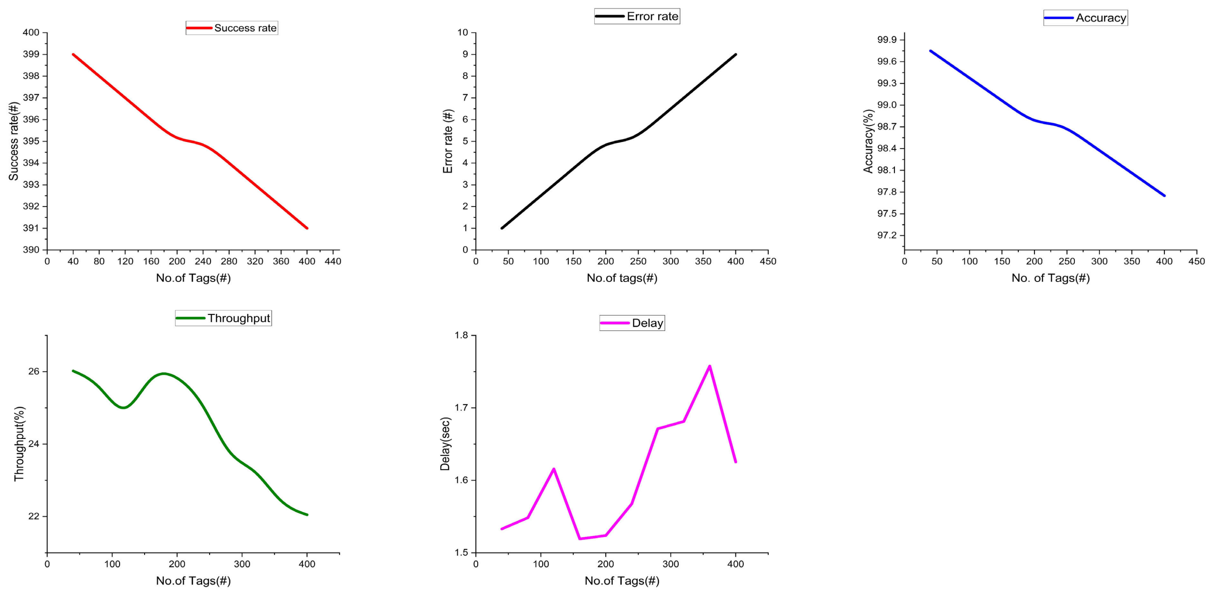


**FIGURE 5.** Upto 400 nodes with 5 CC (at time $T_2$).

### E. AT TIME $T_4$

When 800 nodes are engaged with an RFID network with a 10 cluster count, the tags count arrives at 400, the success rate of the network is 791, and the error rate of the network is 9. At this express, the network will give 98.87% accuracy. The network's throughput is 5.12, and the delay is 15.4470 sec. When we upgrade the network from 400 to 640 tags, the network gives 98.25% accuracy, throughput is 5.09, and the delay is 15.4362sec. The success rate and error rate are 786 and 14 individually. The tags count will increment from 640 to 720. The network responds with a success rate of 785, and the error rate is 15. At this express, the accuracy of the network is 98.12%, throughput is 5.02, and the delay of the network is 15.6126 sec. at the point when the tags count compasses to 800, the network makes the progress rate 783 and error rate 17. The accuracy of the network is 97.87%, throughput is 4.88, and the delay is 16.0315 sec. Figure 7 shows the detailed performance of the RFID network when the network contains 800 nodes with 10 cluster counts.

### F. AT TIME $T_5$: AT TIME $T_5$:

At the point when 1000 nodes are associated with an RFID network with 13 cluster counts, at this state, 100 tags are imparted at once in a network, and it will be responded with a success rate of 997 and an error rate of 3. The network accomplishes 99.70% accuracy, throughput is 2.96, and the delay is

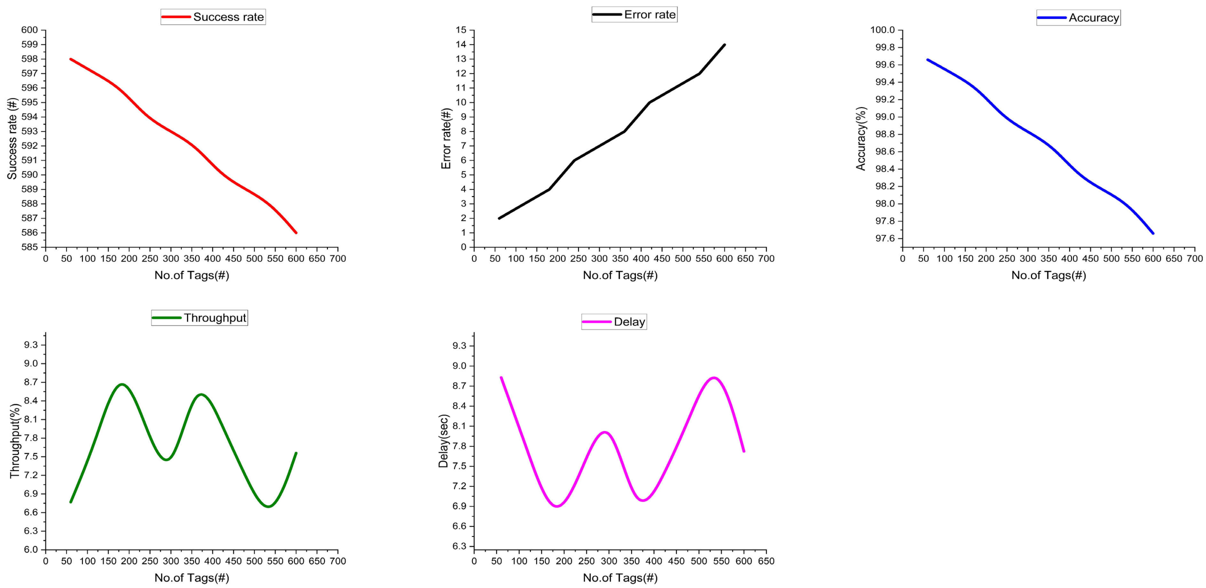


**FIGURE 6.** Upto 600 nodes with 8 CC (at time $T_3$).

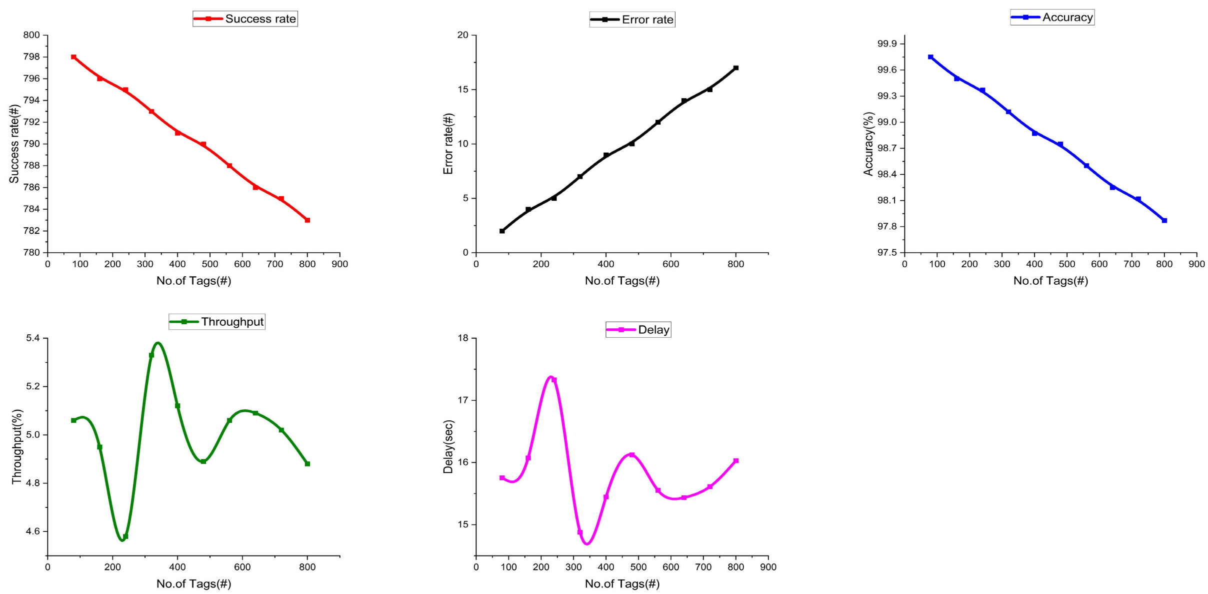


**FIGURE 7.** Upto 800 nodes with 10 CC (at time $T_4$).

33.6246sec. The tags count will increment from 100 to 400, the network accomplishes 99.10% accuracy, throughput is 2.72, and the delay of the network is 36.4178 sec. The success rate and error rate of the network are 991 and 9, respectively. The tags count arrives at 800. The network will give a success rate of 982, and the error rate is 18. At this express, the network accomplishes 98.20% accuracy; the throughput of the network is 2.88, and the delay is 34.0043 sec. Under the full load transmission (1000 nodes and 1000 tags contribution), the network accomplishes 97.80% accuracy; the success rate and the error rate of the network are 978 and 22. At this express, the network's throughput is 2.64, and the delay of the network is 36.9139 sec. Figure 8 shows the detailed performance of the RFID network when the network involves 1000 nodes with 13 cluster counts.

From the investigation, the fuzzy-based clustered system is suitable for enhancing the RFID network, and the performance of the RFID network is tremendously increased. This fuzzy-based network will give 97.8% accuracy at all-time evaluation. The augmentation of the cluster count is assisted with improving the effectiveness of the RFID network. It can be concluded that when the readers and tags

**TABLE 7. Comparative analysis of proposed method with AOMDV_SAPTV and ODBC.**

| Parameters | Tags count(#) | AOMDV_SAPTV | ODBC | Proposed Method |
|---|---|---|---|---|
| Success rate (%) | 1 | 99.7 | 99.8 | 100 |
| | 10 | 98.6 | 99.2 | 99.8 |
| | 100 | 97.3 | 98.6 | 98.6 |
| | 1000 | 64.3 | 66.4 | 97.8 |
| | 10000 | 4.2 | 23.2 | 42.8 |
| Error rate (%) | 1000 | 12.2 | 4.3 | 2.8 |
| | 2000 | 25.3 | 8.4 | 6.4 |
| | 3000 | 36.1 | 13.2 | 12.4 |
| | 4000 | 48.2 | 17.8 | 16.8 |
| | 5000 | 60.4 | 27.4 | 24.6 |
| Delay (seconds) | 1000 | 4.8 | 4.3 | 2.2 |
| | 2000 | 6.7 | 6.2 | 4.8 |
| | 3000 | 11.2 | 10.4 | 8.2 |
| | 4000 | 15.9 | 15.2 | 12.8 |
| | 5000 | 27.3 | 21.1 | 18.2 |
| Throughput (%) | 1000 | 93.4 | 95.3 | 98.2 |
| | 2000 | 83.8 | 85.9 | 90.8 |
| | 3000 | 68.8 | 69.1 | 80.2 |
| | 4000 | 51.4 | 57.2 | 64.6 |
| | 5000 | 29.7 | 27.2 | 40.2 |
| Accuracy (%) | 32 | 80.9 | 92.4 | 100 |
| | 128 | 61.8 | 87.4 | 94.6 |
| | 512 | 23.2 | 56.8 | 68.3 |
| | 2048 | 11.3 | 19.2 | 42.8 |
| | 8192 | 4.2 | 9.4 | 24.2 |

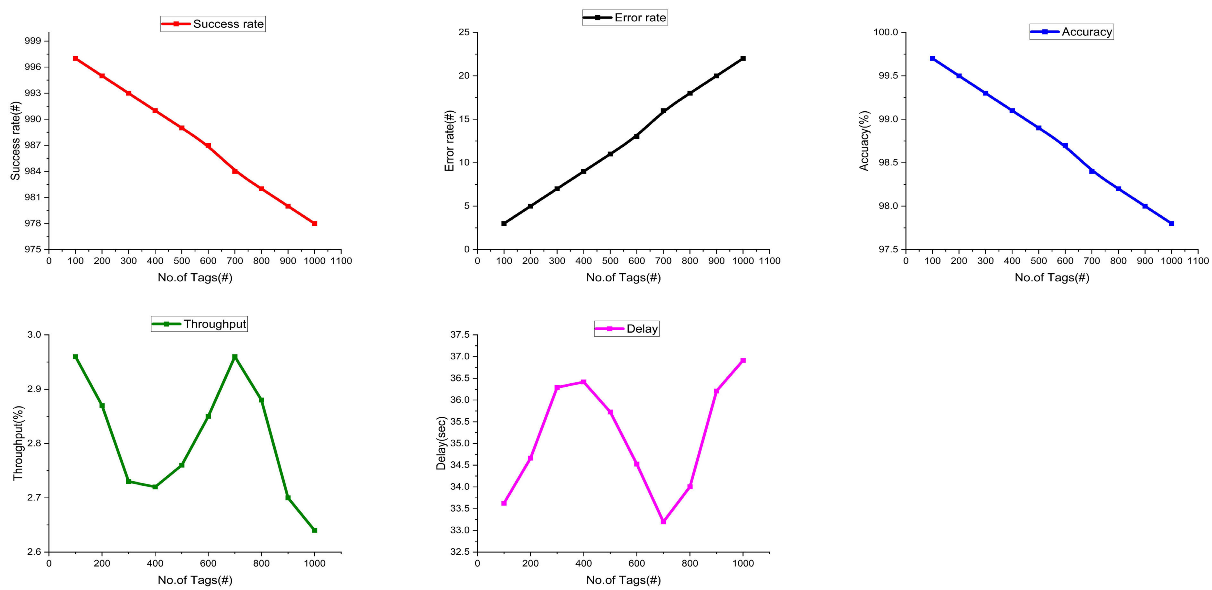


**FIGURE 8. Upto 1000 nodes with 13 CC (at time $T_5$).**

count expand, the cluster count should increase to keep up the presentation of the RFID network.

Table 7 represents the comparative analysis of the proposed fuzzy-based methodology with ad-hoc on-demand multicast distance vector secure adjacent position trust verification (AOMDV_SAPTV) and optimal distance-based clustering (ODBC). The results are analysed with five iterations, and with every iteration, more tags can be added to the network

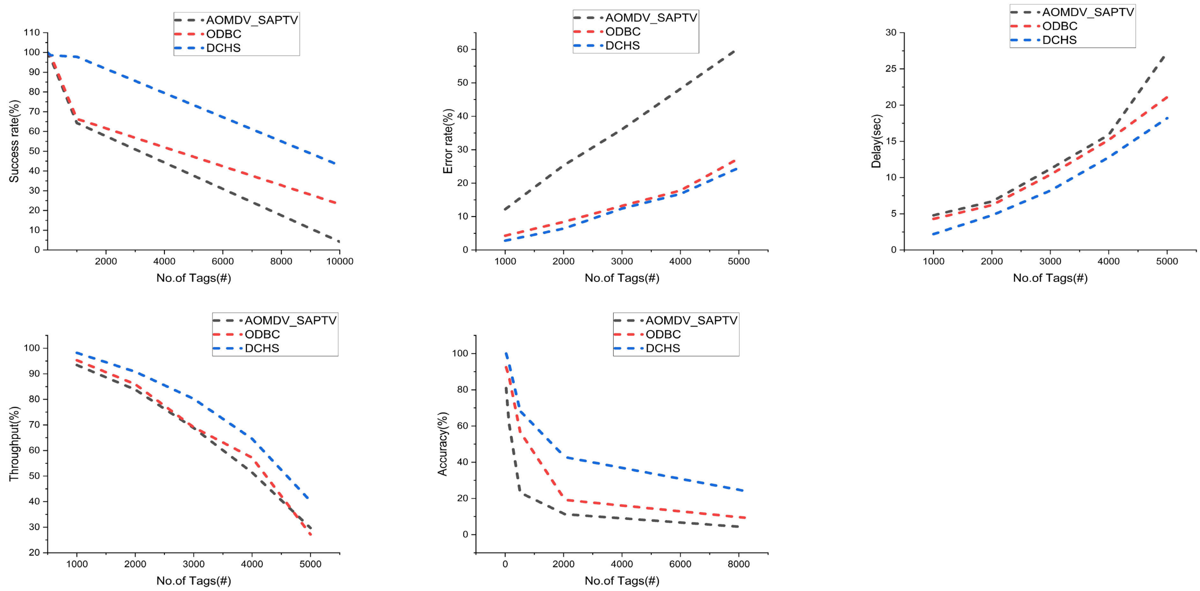


**FIGURE 9.** Comparision between AOMDV_SAPTV, ODBC and DCHS.

with a single cluster. For analysing accuracy, the tags count will increase based on $x^i$. Here $x = 2$ and $i = 5, 7, 9, 11$. The proposed method has better accuracy among the three protocols than the other (AOMDV_SAPTV and ODBC) methods. The proposed cluster-based RFID network has given 94.6% when 128 tags participate. Other methods can be achieved 61.8% and 87.4%, respectively. At the same time, the proposed method's error rate was 2.8% when 1000 tags participated in the network. The other two methods, AOMDV_SAPTV, were achieved at 12.2%, and ODBC was achieved at 4.3%. While analysing the network's delay, the proposed method has achieved a 2.2 delay in seconds, and the other two methods, AOMDV_SAPTV, were 4.8 seconds and 4.3 seconds, respectively. The proposed method had less delay than the other two methods. For throughput analysis, AOMDV_SAPTV has supported 93.4% throughput, ODBC supported 95.3% throughput, and the proposed method has supported 98.2 % throughput. The success rate of the proposed method is 97.8 %, AOMDV_SAPTV achieved at 64.3%, and ODBC at 66.4% while 1000 tags participated in the network. The tags count may be increased by $k^i$. Here $k = 10$ and $i = 0, 1, 2, 3, \ldots$ etc. As mentioned in the table among the existing methodologies [43], [44], the proposed method's performance is better regarding success rate, error rate, delay, accuracy, and throughput. Figure 9 represents the comparative analysis of the DCHS fuzzy-based methodology with AOMDV_SAPTV and ODBC.

## V. CONCLUSION

In this research work, the performance of the fuzzy-based clustered RFID network is analyzed when adding readers with various time intervals enlarges the network. Various network attributes analyze the efficiency of the RFID network. The parameters are success rate, error rate, accuracy, throughput, and delay. The proposed algorithm uses fuzzy-based dynamic cluster head selection to improve the efficiency of the large RFID network. When the network is enhanced with a huge number of readers (1000 nodes) and the cluster head count=13, the success rate=97.8%, Error rate=0.22%, Accuracy=97.80%, throughput=2.64% and delay=36.9139 sec. At the end of the research, it will be concluded by enhancing the number of clusters and cluster heads, the performance of the RFID network will tremendously increase.

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