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Energy Efficient Localization Technique Using Multilateration for Reduction of Spatially and Temporally Correlated Data in RFID System

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Keywords:
Collective Readers; Localization; Multilateration; RFID Systems; Spatial Redundancy; Temporal Redundancy.

Highlights:

- *Data Redundancy in Wireless Sensor Network is minimized by exploiting Spatial and Temporal Data Correlation during data transmission.*
- *A Voronai diagram-based spatio-temporal data redundancy minimization method is used by taking the idea of multilateration method.*
- *Performed the experiment by taking the synthetic data for vehicular sensor network in RFID system and compared with existing techniques to check the effectiveness of proposed method in terms of key parameters and performance measures.*

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Abstract: RFID plays a vital role in data communication in multidimensional WSNs as it collects vast amounts of redundant data. The physical phenomena constitute the correlated observations in the space domain and generate spatial correlation. Periodic observations of sensor nodes result in a temporal correlation in the data. Reducing these spatio-temporal correlations in RFID surveillance data is necessary for the smooth functioning of the network. This paper proposes a Voronoi diagram-based spatio-temporal data redundancy elimination approach for RFID systems having multiple readers so only one reader will read every RFID tag depending on the distance between the tag and the center of the Minimum Enclosing Circle of the Voronoi cell to which the reader belongs. This approach eliminates spatial redundancy in the gathered data. Reading the RFID tags at regular time intervals larger than a chosen threshold value minimized temporal redundancy. In contrast to existing methods, the proposed technique is free from any false positive and false negative errors, with no loss of data and every tag being read by only one reader. Simulation of the proposed approach also established its superiority to the existing techniques in terms of these performance parameters.

تقنية التعريف الموفرة للطاقة باستخدام تعدد الأطراف لتقليل البيانات المرتبطة مكانيًا وزمانيًا في أنظمة RFID

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الخلاصة

وتؤدي هذه الشبكة دوراً حيوياً في نقل البيانات في المذكرات الاستراتيجية المتعددة الأبعاد، إذ تجمع كميات هائلة من البيانات الزائدة. وتشكل الظواهر الفيزيائية عمليات الرصد المترابطة في مجال الفضاء وتولّد ترابطاً مكانياً. وتؤدي عمليات الرصد الدورية لعُقد الاستشعار إلى وجود ترابط زمني في البيانات. ومن الضروري الحد من هذه الارتباطات البذيئة-الزمنية في بيانات المراقبة في إطار قاعدة البيانات المرجعية الدولية من أجل سير عمل الشبكة بسلاسة. وتقترح هذه الورقة نهجاً قائماً على أساس الرسوم البيانية لإلغاء تكرار استخدام البيانات في إطار المراسلة والزمنية في نظم المعلومات الأساسية ذات القارئات المتعددة، بحيث يقوم قار واحد فقط بقراءة كل بطاقة من علامات البيانات المفردة حسب المسافة الفاصلة بين الوسم ومركز الدائرة التضمينية الدنيا لخلية فورونوي التي ينتمي إليها القارئ. وهذا النهج يقضي على التكرار المكاني في البيانات المجمعة. تُقرأ العلامات المرجعية المرجعية في فترات زمنية منتظمة أكبر من القيمة العتبية المختارة المخفضة زمنياً إلى أدنى حد. وعلى النقيض من الأساليب القائمة، فإن التقنية المقترحة خالية من أي أخطاء سلبية إيجابية وباطلة كاذبة، مع عدم فقدان البيانات وقراءة كل علامة بواسطة قارئ واحد فقط. كما أن محاكاة النهج المقترح أثبتت تفوقها على التقنيات القائمة من حيث بارامترات الأداء هذه.

الكلمات الدالة: القراءات الجمعية، الموقع، التعددية، أنظمة تحديد الهوية بموجات الراديو، التكرار المكاني، التكرار الزمني.

1.INTRODUCTION

In today's digital world, wireless sensor networks (WSNs) are classified as a wide range of networks constituting a huge deployment of tiny sensor nodes over the network environment [1]. Sensor nodes are scattered inside the network and observe continuous beacon signals sent and received from the network. Network topology is highly dense in nature and collects continuous and periodic observations over time dimensions [2]. These phenomena constitute spatial and temporal correlations among data. In an RFID system, the electromagnetic beacon signals are detected by the RFID readers [3]. The readers are equipped with tags associated with a unique identification number. The readers also have antennas to receive and transmit signals. RFID tags are tiny electromagnetic chips that are accountable for the recognition of objects beyond using line-of-vision, exterminating the restrictions of barcodes [4]. RFID technology is widely used in various sectors like agriculture, supply chain management, logistics, IT, healthcare, and automation due to its simplicity, low cost, and easy deployment nature. The data accusation rate is very high in the RFID system. When RFID readers and tags make consecutive observations, the data are linked in space and time because the environment has various networks [5]. Ad-hoc networks are vital in various applications, such as agriculture, military, defense, the commercial sector, and other civilian actions. Ad-hoc networks can provide a wide range of battlefield applications in terms of detection of malicious attacks, retrieving information on sensitive issues, and enemy detection [6]. Extraction of critical data and detection of network vulnerabilities are also additional tasks done by the network. Rescue and recovery operations can be coordinated to survive uninformed attacks [7]. Cloud computing works as a data warehouse to save and retrieve important data. Moving into commercial sectors, MANETs play an essential role in the IT industry, supply chain management, and traffic control systems. [8]. Retrieving important information stored on a cloud server is the basic trend in the IT sector. In MANETs, the traditional networks are based on mobile nodes. The nodes can move randomly and interact with each other wirelessly [9]. It does not require any bound infrastructure or centralized network within or outside the wireless range. The intermediate nodes act as the communication medium, including multi-hop transmission. Various routing protocols transmit the packets by choosing a track from root to target. Due to their robustness and flexibility, protocols like the distance vector routing protocol and the link state protocol can overcome geographical location and proximal infrastructure issues [10]. The Bloom filter is a probabilistic data structure that checks whether the data belongs to the set. Using hash functions, it inserts the values from the array of elements and stores them but never deletes them, generating false positive and false negative values of stored data. Storing the optimum value leads to network overhead. The bloom filter has advantages over time and space over additional data structures. The query time and storage space are static in nature in the bloom filter. The hash functions used in this filter are independent. As it stores all the data, it leads to false positive rates and false negative rates [11]. To overcome these limitations, various approaches are based on bloom filters, namely, Time Distance Bloom Filter (TDBF) [12], Time and Space Bloom Filter (TSBF) [13], Approximate Synthesis Time Interval Bloom Filter (TIBF) [14], and Compare Bloom Filter (CBF) [15] are proposed. Generating false positive and false negative values leads to major data loss [16].

1.1.Contribution

This paper proposes a Voronoi illustration based on the multilateration localization technique [17], which is error-free in terms of compression ratio [18], false positive rate [19], and false negative rate [20]. No information loss is observed in the present experiment, as all the readers forward only the redundant data generated [21]. The entire quarter of operation is a closed sector. It is assumed that the Voronoi diagram partitions the plane into small zones non-overlapping in nature. These small zones are based on some points, so each point belongs to a Voronoi cell in the diagram. The Voronoi edge is the meeting point of two Voronoi cells, and the Voronoi vertex is associated with the intersection of three Voronoi cells. The inquiry's quarter entirety is assumed to be a Voronoi diagram in a plane having different Voronoi cells with edges and vertex [22]. Multiple Voronoi cells identify multiple RFID readers, namely R_1, R_2, R_3, ... R_7. A minimum enclosing circle (MEC) can be drawn for each cell's center without overlapping with each other. A base station built in the Voronoi diagram framework can cover the entire operation area of the RFID system. Covering the entire region can limit the over-transmission of power in the network. Calculating the distance between the centers of a Voronoi cell called priori to the RFID reader reduces spatial redundancy. The reader nearer to MEC can detect it and send beacon signals from the reader. Thus, multiple readings can be avoided. Temporal redundancy can also be checked by calculating the operation time interval dependent on the considered threshold value of the application type [23]. Time Bloom Filter (TBF) is also an efficient algorithm to check for threshold values in the time interval of an operation [24]. Fig. 1 describes the scenario of multiple RFID readers in terms of a Voronoi diagram.

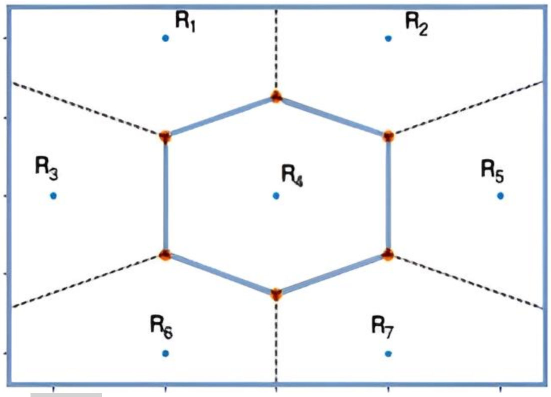

Fig. 1 Voronoi Diagram of Multiple RFID Readers.

2. BACKGROUND STUDY

2.1.Localization

Localization is a distinct capability of sensors in a sensory environment. It pertains to estimating the coordinates of tiny battery-operated sensor nodes. Anchor nodes measure the number of beacon signals transmitted according to placing coordinates. Sensor localization is vital as position information provides location accuracy for nodes in the network. Priori (the central point) needs to be known for retrieving location information to deal with holes in coverage. For a specific geographic region, the sensor location counsel needs to be queried spatially and temporally to stop the flooding in the network. In RFID systems, the readers tagged by the system calculate the time interval difference between each operation's RSS (received signal strength). High-range accuracy is achieved by implementing extra hardware equipment, which requires more energy utilization. The multiplication technique of localization can enhance network lifetime [25–31].

2.2.Multilateration

Multilateration can be defined as a localization technique that computes the separation between the sensor nodes and numerous anchor nodes in the network. These sensor nodes need to be localized based on the measured distance. Anchor nodes know their coordinates, which use the GPS concept (Global Positioning System) to retrieve location information [32]. The assumption of error-free anchor location is impractical, as in a dynamic scenario, these nodes are scattered in nature. Usually, fundamental errors occur by measuring the distance from the GPS receiver to the anchor nodes. Setting up a GPS device for every sensor node is practically impossible due to its high cost and energy-consuming features [33]. The optimal path from the beacon to the anchor nodes is sometimes blocked due to errors in signal measurement or jitter in reflecting the acoustic signal. Sensor nodes are battery-operated; hence, energy consumption for resource management in nodes is sometimes high. The iterative process between the anchor and sensor nodes can generate propagation errors, causing inaccuracies in location estimation [34]. Existing algorithms for localization use signal strength, time, and angle to locate an object. Combining these parameters can be used to calculate the distance in an RFID system. In the multilateration method, the intersection points of four or more circles are identified as the coordinates of an RFID tag and a neighboring reader in the RFID system. Increasing the number of readers [35] improves accuracy. In the triangulation method, calculations are done for three non-overlapping circles. The trigonometric equation is used to calculate the angle information between the position of a tag and its neighborhood reader [36]. In the nearest neighbor method, reference tags are arranged in a grid structure to determine the tag location. A new tag is recognized by differentiating the reference tags' wave strength from the old tags [37]. A kernel-based technique is used to detect the physical distance of the readers to identify the position of a new tag [38]. In the Bayesian inference method, the probability and recursion of signal strength are calculated to determine the coordinates of a tag [39].

2.3.Spatial Correlation

In WSNs, a huge amount of data is generated, leading to a collection of correlated data. The network is prone to various attacks in terms of security and privacy. Due to network diagnosis and geographical diversity, these correlated data generate erroneous redundant data transmission [40]. It results in bottleneck problems in the network and creates congestion in transmission. Many key areas of WSNs require opaque distribution of sensor nodes dispersed in the sensor network. In the space domain, the sensor nodes convey with neighboring nodes to persuade maximum coverage [41]. As a result, spatial correlation among data is formed. The extensive bulk of correlated data gets transmitted, generating congestion and jitter in transmission. Hence, a tremendous amount of energy is utilized in this process. In WSNs, the sensor nodes have a finite amount of power as they are battery-operated [42]. To stop depleting energy continuously among sensor nodes energy conservation is required. Multiple logging of a single transmission constitutes elevated correlation among sensor data. Exploiting spatial correlation among data can reduce the extra bug in transmission and increase overall network lifetime by conserving necessary energy [43].

2.4.Temporal Correlation

Different sectors of WSN applications include video surveillance, event tracking, habitat monitoring, and defense requisite sensor nodes to operate at regular time intervals. This occasional engagement characteristic of sensor data channeling yields the troupe of interrelated data in numerous timestamps at a specific time [44]. Between each successive occurrence of events, temporal correlation among data is formed due to physical phenomena between each successive occurrence of events. The level of correlation is hanging on the type of occurrences in a multidimensional sensor environment [45].

2.5.Bloom Filter

The bloom filter is a type of data structure based on the probability of events. It detects the existence of some component in the set. The array of a set of elements is mapped by the hash functions. The result of hash function mapping returns 1 for non-redundant data and 0 for redundant data. First, the gain is set to 0, and eventually, it is increased to 1. The fixed-size array is always mapped by independent hash functions. It comprises a constant dimension array and unconventional hash functions directed to the substances of the array [46]. To test the existence of a newly arrived value in a set, the optimal value is initially set to be 0. The value increases to 1 when different values start arriving in the set. In the RFID system, the tags are inputted into the set and mapped to hash functions to check existing redundant values. The newly arrived tags are identified as redundant or non-redundant depending on the hash function values, either 0 or 1 [47]. All information about the incoming data is stored in the bloom filter by taking advantage of the independent hash function in terms of time and space. For this reason, the bloom filter is more efficient than other data structures. In the view of the system privacy and security, the conventional bloom filter never overloads the network by adding all the information to the system [48].

3.RELATED WORK

A data filtering approach has been proposed by [49], which eliminates data redundancy in small-scale environments. WSNs and MANETs, being large-scale networks, are prone to bottleneck problems in the network due to redundancy in data transmission. Traditional RFID systems store data in a warehouse, depending on various applications. A query-based system can access the data based on the kind of implementation. For such situations, a window-based filtering method is suitable, which can enhance performance in large-scale environments [50]. These window-based procedures work on a fraction of the information set, depending on the various attributes of a specific window. The effectiveness of these algorithms depends on selecting attributes for the concerned window and the window's size [51]. Tremendous work has been done to eliminate redundancy. To match the RFID data characteristics, some pipeline-based frameworks were designed [52]. Data cleansing using the pipeline method is time-consuming and sometimes results in inaccurate results. To eradicate this limitation, finite-state machine models were proposed by [53]. This method avoids spatial redundancy by integrating the area of operation into several states. In the machine learning area, RFID data stream filtering is based on dynamic Bayesian networks (DBNs) [54]. In DBNs, the network relates the variables to each other over a consecutive time interval. State space models, such as the Kalman filter [55] and the Markov model [56], are extensively used in data mining domains. Recent research includes a Bloom filter-based filtering approach. The Bloom filter uses a hash function, which takes input and results in a unique fixed-size identifier to identify the input value. The bloom filter technique is appropriate for real-time applications with dynamic data streams [57]. Table 1 presents a summary of the related works in a tabular form below:

Table 1 Summarized Related Works.

Authors Year	Title	Techniques Used	Findings
Jeffery et al. [49]	Adaptive cleaning for RFID data streams.	CQL Smoothing Filter to Correct for Dropped Readings.	SMURF technique is proposed, which is the first declarative, adaptive smoothing filter for RFID data cleaning which does not require the application to set a smoothing window size. It automatically adapts its window size based on the characteristics of the underlying data stream.
Guoqiong et al. [50]	Approximately Filtering Redundant Data for Uncertain RFID Data Streams	A sliding window model based on the block Technique.	A Probabilistic Synthesis Bloom Filter (PSBF) for filtering the temporal redundant events in the RFID streams, calculating the existential probabilities of the tagged objects.
Rui et al. [51]	Filtering Redundant RFID Data Based on Sliding Windows	A random decay strategy is proposed for deleting the expiration elements.	The filter extends the one-dimension array in the standard bloom filter to a two-dimension array.
Hu et al. [52]	A dynamic path data cleaning algorithm based on constraints for RFID data cleaning	A constraint-based data-cleaning algorithm, using self-restraint and user-specified constraints, can guide the data-cleaning process.	It proposes a redundancy deleting algorithm by setting a time tolerance threshold, cleaning the data redundancy, and reducing the data, avoiding data cleaning processes.
Derakhshan et al. [53]	RFID Data Management: Challenges and Opportunities	Low-level data processing consists of data cleaning and data aggregation.	One primary Role is to process a stream of simple events generated during the interaction between readers and tagged objects.
Xu et al. [54]	An improved SMURF scheme for cleaning RFID data	Improved SMRUF follows two steps: Step 1-dynamic tag consideration, Step 2- influence of data redundancy.	Improved scheme as compared to dynamic sliding window.
Ma et al. [55]	Fusion of RSS and Phase Shift Using the Kalman Filter for RFID Tracking	A new RFID tracking method that fuses the RSS and phase shift together to predict the instant position of a mobile target.	The Kalman filter is utilized afterward to enhance the position estimation by combining the rough location estimation and the instant velocity.
Ye et al. [56]	A hidden Markov model combined with RFID-based sensors for accurate vehicle route prediction	It builds the probabilistic model by observing the driver's habits from a map database involving RFID information.	It first computes the shortest path from the starting point to the destination point, and then, some redundant data can be filtered through this path.
Xie et al. [57]	Hash Adaptive Bloom Filter	A new Hash Adaptive Bloom Filter (HABF) that supports the customization of hash functions for keys.	The key idea of HABF is to customize the hash functions for positive keys (elements are in the set) to avoid negative keys with high cost and pack customized hash functions into a lightweight data structure named Hash-Expressor.

4.PROPOSED METHOD

4.1.Definition

Each RFID data is represented as [tag_id, reader_id, time, RSS] a four tuple. Here, tag_id is the unique identification of an RFID tag. The reader_id is the unique attribute of an RFID reader. Data acquisition time is denoted as time. RSS is the received signal strength, defined as the distance function between the tag and reader of RFID [58]. Here, D denotes the stream of RFID data such that d_1 〖,d〗 _2 〖 ,......,d〗 _i, where d_i denotes the i^th data. For a specific time, redundancy occurs when a tag is read by its allocated reader multiple times. The first reading of an RFID tag is non-redundant, and the rest are redundant data. With the increase of time, the frequency of redundant data also increases. It generates temporal redundancy. Spatial redundancy originates when a tag reclines within the detection zone of multiple readers [59]. It is assumed that in data stream D, the execution time of observation is T. Suppose there are two RFID tag data, a and b, such that a.tag_id=b.tag_id, a.reader_id≠b.reader_id, b.time-a.time=ω(threshold value), then data b is taken as spatially redundant data. More than one reader detects a single object concurrently. Hence, only one reader registers itself with the concerned tag, depending on the tagid. The rest of the tag data will be considered redundant [60]. To detect temporal redundancy, It can be considered that the total time of execution of events as Tin data set D. Suppose there are two tag values a and b in the set D such that a.tag_id=b.tag_id, b.time-a.time=τ(threshold value), a.reader_id=b.reader_id, then data is taken as temporally redundant data. Multiple detection of a tag by the reader within the same time interval generates redundant data. The prompted arrived data becomes non-redundant, and the rest is redundant.

4.2.Assumptions

This experiment considers an indoor zone in a closed environment. The interrogation area is divided into various Voronoi cells according to placing RFID tags. The RFID readers can interact with each other with respect to the central server, depending on the readers' connection. There are n numbers of readers inside the Voronoi diagram where each cell is non-overlapping in nature. According to the study's assumption, there are n numbers of Voronoi cells with respect to the number of readers. The readers in the Voronoi cell have no coverage holes with respect to the Voronoi cells. The Minimum Enclosing Circle (MEC) of each Voronoi cell is identified after integrating the whole region of operation into small, non-overlapping zones. The identified tags dynamically change their position, generating multiple locations for a single reader. The change in tags' position with respect to time requires multiple readings from a single reader, which generates redundant data. The appropriate information to process the universal inventory of RFID tags depends on the server quality type [61,62]. The network has optimum storage capability and high computational potential to store adequate data from the RFID stream. An RFID reader is arranged at the entrance of the operation field to keep track of newly arrived RFID data. The time complexity for the execution of dividing the interrogation zone into several cells is O(n^2).

The following steps simplify the proposed method:

Step 1: A newly arrived tag registers itself at the entrance of the interrogation zone.

Step 2: Succeeding a methodical respite of time T, beacon signals are being transmitted to RFID tags from the readers.

Step 3: If there are two data elements, namely, a and b, such that a∈D, b∈D in set D. If a.tag_id=b.tag_id, a.reader_id=b.reader_idand b.time≥a.time, then it checks for temporal redundancy in set D. If b.time-a.time≤ω, data b is taken as a redundant value and hence relinquished. Otherwise, the data is considered as non-redundant data and can be transmitted.

Step 4: The RFID readers calculate their distance from the tag and communicate the measured value to the central server of the network from the RSS measurement of the tag or the round-stumble hamper.

Step 5: More than three readers detect an RFID tag; the multilateration method calculates the placed coordinates of the sensed tag with respect to the central server. The obtained orientation of that tag depends on the interval between the midpoint of the MEC of the Voronoi cell and the sensed RFID tag.

Step 6: When less than three readers detect an RFID tag, the RFID reader having the least distance from the tag registers itself with the tag. The central server calculates the least distance, and the identified tag, registered with the reader, belongs to the MEC of the Voronoi diagram.

Step 7: Other RFID readers contemplate the data as redundant and hence repudiate it.

4.3.Schematic Representation of Proposed Method

The schematic presentation of the proposed method describes the step used to develop the proposed algorithm, displayed in Fig. 2.

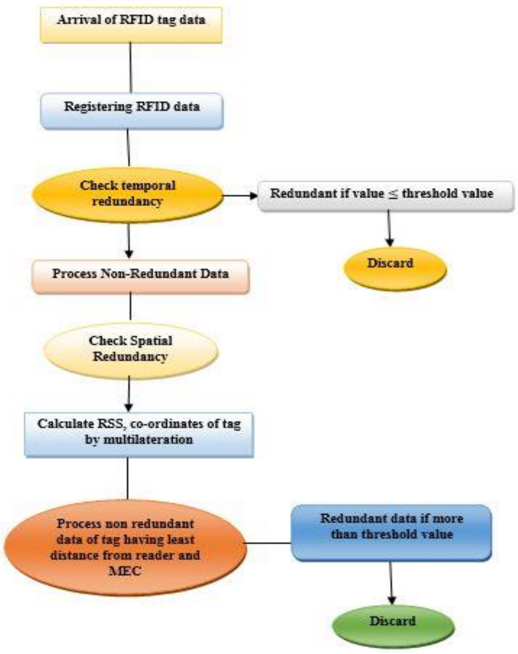

Fig. 2 Schematic Representation of the Proposed Algorithm.

5.PROPOSED ALGORITHM

- ***Algorithm 1**: Resolving Temporal Redundancy*

```
  $Input: RFID\ data\ A: a.tag_{id}, a.reader_{id}, a.time, a.RSS$
  $Output: Streamlined\ list\ Y\ of\ RFID\ data$
      $Count(Y) = length(Y);$
      $for\ i = 1\ to\ Coun\_Y\ do$
```

```
        if $a.tag_{id} == Y[i].tag_{id}$ then
            /*
            Temporal Redundancy Checking
            if $(a.reader_{id} = Y[i].reader_{id})\&(Y[i].time) - a.time \leq \tau)$ then
                Discard redundant RFID data a;
            /* Spatial Redundancy Checking
            else if $(a.reader_{id} \neq Y[i].reader_{id})\& (Y[i].time - a.time \leq \omega)$then
                Place a , Y[i] in a discrete set M;
                /* Identification of Spatial Redundancy
                Discard Y[i] from Y
        else
            Insert a as a new data in Y
            /* RFID data is considered to be non − redundant
```

- ***Algorithm 2**: Resolving Spatial Redundancy*

```
Input : List M of RFID data with $i^{th}$ data as
$< M[i].tag_{id}, M[i].reader_{id}, M[i].time , M[i].RSS >$, Centers of MECs of Voronai Cells $C_1 C_2, .., C_n$
Output : Updated Values of RFID data after redundancy elimination where,
Count K = length(k); $t_{id} = K[i].tag_{id}$;
Evaluate the RFID tag coordinates using M[i].time, M[i].RSS values
    if Count_M > 2 then
        for i = 1 to Count_M do
            Evaluate distance $l_i$ between the center $C_i$ of MEC of Voronai cell of RFID reader $K[i].reader_{id}$
            and the tag $t_{id}$
        for i = 2 to Count_M do
            if $\min\_l > l_i$ then
                $\min\_l = l_i$;
                $\min\_index = i$;
        /*
        Tag data id being registered with recognised RFID reader
        $n.tag_{id} = t_{id}$;
        $n.reader_{id} = M[\min\_index].reader_{id}$;
        $n.time = M[\min\_index].time$;
        $n.RSS = M[\min\_index].RSS$;
        Include n to list Y;
    else
        /*for Count_M = 2
        for i = 1 to Count_M do
            Evaluate distance $l_i$ between RFID reader$M[i].reader_{id}$ ang tag $t_{id}$
        if $l_1 > l_2$ then
            $n.tag_{id} = t_{id}$;
            $n.reader_{id} = M[2].reader_{id}$;
            $n.time = M[2].time$;
            $n.RSS = M[2].RSS$;
        else
            $n.tag_{id} = t_{id}$:
            $n.reader_{id} = M[1].reader_{id}$;
            $n.time = M[1].time$;
            $n.RSS = M[1].RSS$;
        Include n to list Y;
```

5.1 Complexity Analysis

The algorithm is executed at regular intervals on a central server. There are two steps to reduce redundancy: Step 1. temporal redundancy reduction, and Step 2. spatial redundancy elimination. The result is then used to update a global list of RFID data. Before the algorithm execution, the interrogation zone is partitioned into non-overlapping Voronoi cells, and the central server identifies each cell's minimum enclosing circle (MEC). The centers of these MECs are denoted as C_1, C_2,..., C_n. These centers are provided as input to Algorithm 2. It is assumed that the execution time of the algorithm is very small, ensuring that during its execution, a tag's position remains unchanged. Algorithm 1 involves checking the temporal redundancy of newly received RFID data and then calling Algorithm 2 to resolve spatial redundancy. Here are some key points regarding the time complexity of each step: Temporal redundancy reduction in Algorithm 1: The newly received RFID data is checked against the global list Y, which has a maximum length of nn (assuming active tags in the system). Checking for temporal redundancy in Y would take O(n) time complexity, as the worst case would involve iterating through the entire list. *Algorithm 2 for spatial redundancy elimination:* Determining the coordinates of an RFID tag takes constant time. If an RFID tag has been identified by zreaders simultaneously and z>2, the algorithm computes the distance between the RFID tag and the center of the MEC of each of the z Voronoi cells. Computing the distance for each reader takes O(z)time complexity, as it needs to be done for all z readers. Next, the algorithm computes the minimum z distance, taking O(z) time complexity. For z=2, the total computation takes constant time, as there are only two distances to compare. Hence, the worst-case time complexity of Algorithm 2 can be computed as O(n(z+z))≈O(n(2z))≈O(n^2), considering the maximum possible value of z being n.

6.EXPERIMENTAL RESULTS AND PERFORMANCE EVALUATION

The present experiment used synthetic data from the Cooja Simulator [63]. Three datasets are considered: Data set 1, Data set 2, and Data set 3. The details of the data generation of 3 given methods are explained in Table 2 below:

Table 2 Data Generation of Proposed Filter, TDBF, and TBF.

Algorithm	Data set 1	Data set 2	Data set 3
Proposed Filter	3.000	2.750	2.000
TDBF [12]	3.000	2.600	1.800
TBF [24]	3.000	2.700	1.900

The experiment uses synthetic data randomly generated from the Cooja simulator. Simulation results of MATLAB are represented in the form of bar graphs in Fig. 3. The algorithm’s effectiveness shows the best result compared with the existing two algorithms, i.e., TDBF [12] and TBF [24], by taking three datasets. The score of TBF, TDBF, and the proposed Algorithm in terms of Compression Rate, False Positive, and False Negative are displayed in Table 3.

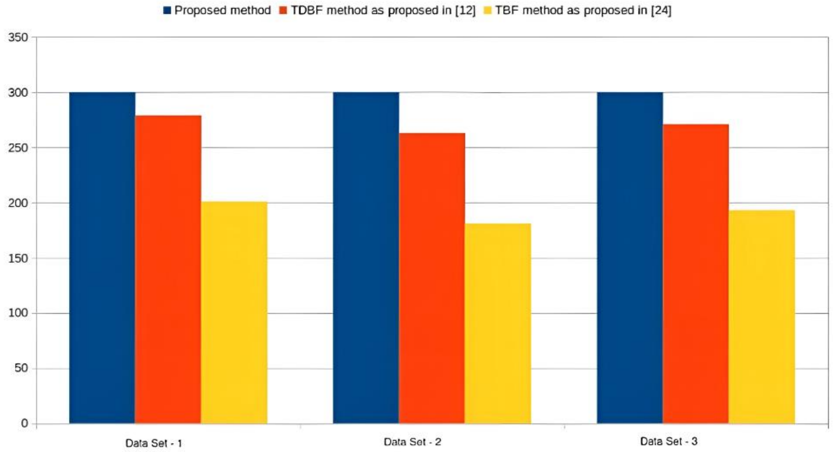

Fig. 3 Results of an Experiment Showing the Active Tags of Three Algorithms.

Table 3 Comparison of Performance of TBF, TDBF, and Proposed Algorithm.

Algorithms	Compression Rate (CR)	False Positive (FP)	False Negative (FN)	Score
TBF [24]	978.6	0	9786	144.9
TDBF [12]	33.5	0	292	0.03
Proposed Algorithm	296.5	0	33	5.2

6.1.Discussion

The present experiment is based on the parameters compression ratio, false positive rate, and false negative rate. Each parameter and its significance in evaluating the proposed algorithm's performance in a dynamic situation is broken down as detailed below:

- **Compression Ratio:** The compression ratio is calculated by dividing the total number of tags collected per minute by the number of tags registered after redundancy removal. A higher compression ratio indicates that more data have been identified as redundant and filtered out by the algorithm, which implies efficient data compression and reduced storage or transmission resources required. However, it is important to strike a balance because excessive data compression may result in the loss of important information. Therefore, finding a compression ratio that achieves a good trade-off between data reduction and preservation of crucial data is required.
- **False Positive Rate:** False positive refers to the incorrect identification of RFID tag data as redundant when it is not redundant. In other words, the algorithm mistakenly filters out useful data. The false positive rate measures the frequency of such errors in the system. When false positive rate arises, it differentiates the data redundancy scenario in the algorithm. It eventually fixes a parameter to check the effectiveness of checking of non-redundant and redundant data. Decreasing the false positive errors secure the non-removal of important data in the execution process.
- **False Negative Rate:** Eventually, the false negative occurs when the processing algorithm is unable to recognize the important data in RFID system and treats it as a non-redundant data. Such type of identification is harmful for system as it may lead to network overhead due to gathering of unwanted redundant data treated as non-redundant. Once the false negative rate is higher it will accumulate system overhead and starts burdening the system which results in low network performance and high system overhead [63].

6.2.Experimental Results

Our demonstration is performed for dynamic scenario. We have taken 10,000 synthetically generated random data for our experiment. These data are generated using COOJA Simulator. We have generated the data for 300 actively present tags in a dynamic environment for vehicular sensor network. For comparison, we have evaluated the performance of our proposed algorithm with two existing algorithms namely TBF and TDBF. From the performance evaluation of our experiment, it is clearly visible from the Fig. 3 is that our proposed algorithm outperforms the existing algorithms in terms of Compression Rate. Our algorithm is free from false positive rate and false negative rate. Our algorithm perfectly identifies all the 300 tags taken into consideration. The findings in our experiment show the effectiveness of our proposed algorithm as compared to other existing algorithms.

7.CONCLUSION

In this work, we focus on development of a localization method to reduce the spatial and temporal correlation in data transmission in Wireless Sensor Network for RFID systems with multiple readers. By adhering the multilateration method, the system filters out the unwanted redundant data from the data transmission process. Our proposed algorithm is free from any type of false positive rates and false negative rates. For the sufficient time and desired distance between the tag and the readers the algorithm executes step by step process to employ the filtration process of data redundancy. To minimize the spatial redundancy the Voronai diagram-based approach is taken into consideration. Also, the temporal redundancy is eliminated by employing the idea of dividing the area of interrogation into non-overlapping areas. The distance between the minimum enclosing circle of the concerned Voronai cell and the tag decide the reading of particular tag associated with it. Hence, eliminated spatial and temporal redundancy with identification of total number of tags taken into consideration for the experiment. In future work, our proposed algorithm will be used in a multidimensional environment for checking its effectiveness for lossless data transmission in Wireless Sensor Networks.

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