Collision Mitigation algorithm for tracking of RFID based assets in Defence

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Abstract

INTRODUCTION: Asset tracking plays a crucial role in Military warehouses, deploying RFID system will be beneficial. When an RFID reader scans multiple tags in the Military warehouse, the missing tags and redundant tag problem occurs due to the signal interferences. To overcome these issues of missing tags and redundant tags, we proposed Cuckoo Search-based Clustering Protocol (CSCP) followed by linear classifier algorithm.
OBJECTIVES: The primary objective of this paper is reducing the collision problems in military warehouse
METHODS: In this paper, we propose Cuckoo Search-based Clustering Protocol (CSCP), where cluster heads delete duplicate data and sends processed data to the base station, Later the TDMA-based graph colouring technique is implemented to prevent reader collision issues in the RFID network. The Linear Classifier algorithm first separates similar data for classification, which in turn reduces the collision occurrence of missing tags and redundant tags.
CONCLUSION: In the RFID deployed military warehouse, cluster head readers are selected, and clusters are created. Readers are scheduled to read information from tags in the cluster using the TDMA-based graph coloring algorithm. The linear classifier algorithm classifies the weapon's data and filters the redundant weapon's data in RFID deployed military environment.

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1. Introduction

RFID is a technology which uses radio frequency waves for transferring data between readers and tags. Typically, the tag is attached to an object, that helps RFID system to detect, categorize and track objects. RFID is speedy, reliable and needs no physical line of sight or contact between reader and tagged item. RFID System has two components: Tag and Reader. The RFID tag has two parts such as microchip and antenna. The microchip is used to store the information and can be accessed when required and antenna is used to receive and transfer the signal from reader. The tag possesses separate serial number for each item. RFID Reader is used to scan the items containing tags. Interrogator or readers also called two-way radio transmitter – it receives the information from tags and transmits the information to the computer. There are two types of tag Active Tag and Passive Tag.

Now a day a common problem faced in Military warehouse scenario using RFID system is collision. Some weapons might not get scanned using reader which results in missing tags or else scanning the same tags repeatedly

which results in redundant tags. It will be a national issue where these conflicts among such kind of data are dangerous and can create a huge problem country wide. When the weapons get scanned through RFID reader, the reader to tag collision issue will arise in this RFID environment due to signal interference.

There are plenty of weapons which has to be scanned through RFID readers in the military warehouse environment. Each weapon is attached with tag in the military warehouse. Collision will occur in this scenario because when the readers read the information from the tag, the multiple tags respond to the reader. As many readers are involved in this scenario, the tag will also be confused to which reader it should respond. Let us consider a container of weapons which has 20 guns on it. A RFID reader is used to scan it and instead of giving data of 20 guns, it gives either less or more number of weapons because of the collision occurring between readers and tags. When this happens, it will be a national issue where these conflicts among such kind of data are dangerous and can create a huge problem country wide. To surmount these issues, Cuckoo Search based Clustering Protocol (CSCP) is proposed.

There are two types of collision
- Multiple readers to the tag collision
- Tag to tag collision

1.1 Multiple readers to the tag collision

When two or more readers send the signal simultaneously to the same tag, the tag cannot read any reader at that time, then multiple readers to tag collision occurs as shown in the Figure 1.
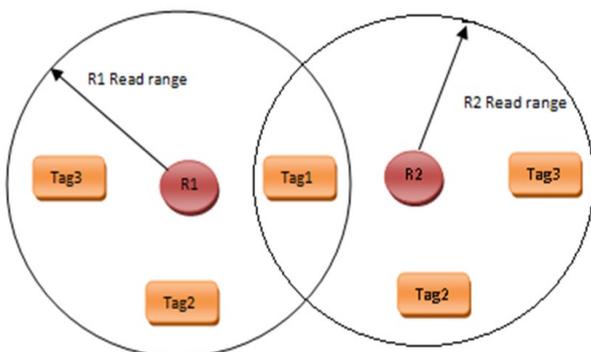

Figure 1. Multiple Reader to Tag Collision

1.2 Tag to Tag Collision

Whenever the reader transmits the signal to the tag, multiple tags respond simultaneously to the reader, in which the reader gets confused and the reader finds it difficult to understand which tag to communicate as shown in Figure 2.
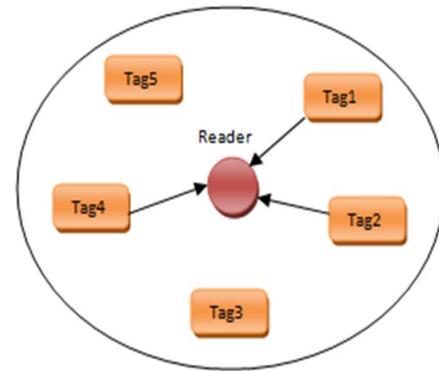

Figure 2. Tag to Tag Collision

The major problems occurring in RFID deployed military scenario is collision. The collision is caused because due to signal interference between tags and readers. The multiple readers to tag collision and tag to tag collision problem which results in missing tags and redundant tags in the military warehouse environment. When scanning the military weapons through reader, due to signal interference, the missing tags and redundant tags problems occurs. In that case, the data stored in the weapons might get missed and producing the incorrect results.

2. Existing System

RFID plays a major role in modern technology. The places where the RFID is used are defence sector, supermarkets, medical sector and in the manufacturing industries. In the RFID environment, reader should use to scanning the tags and then it can gather the information from the reader. Authors [5] proposed a method for blind people, the Bus Detection System using RFID. The main objective is to make travelling easy for blind people. The proposed system introduced two parts. Blind people recognition and communication between the bus and bus station.

Authors [6] proposed Attendance Monitoring system and Student Tracking in RFID. This system has RFID tag and Reader. In the existing system, a Student places that RFID card in the card reader. When student place RFID card, the card reader can be able to read the details of the student. The software which is responsible for monitoring the attendance is interface

Authors [7] proposed a method for Enhancement of School Children transportation safety with Attendance system in RFID based system. This project focuses on to monitor the school children of picking up and dropping off to the school and to enhance the safety of school children daily starting from home to school and school to home. It has two main units, Bus unit and School unit. The bus unit is responsible for detecting when the child comes and leaves the bus. Hence this information can be communicated with

the school unit that recognize and find which of the children did not comes and leaves the bus and gives alert message to it accordingly.

Authors [8] proposed Smart trolley using ARM processor in RFID based system. In shopping mall, after shopping our product we must stand in a long queue for billing. Hence this is not time consuming, so in ARM processor Each product has RFID tag and that trolley which they are having is RFID receiver. When customer puts that product in the trolley, the product will be stored in memory. When another product added means cost will get increased. Finally, it will be displayed in LCD by total bill calculated. To solve the collision problems, there are various existing conventional protocols such as Collecting Collision Tree (CCT) Protocol and Adaptive Couple Resolution Blocking Protocol.

2.1 Collecting Collision Tree (CCT) Protocol

A Collecting Collision Tree protocol is used to identify the tags in the RFID deployed environment using Capture Effect. One of the major benefits of RFID is the detection of multiple tags. The reader cannot completely identify tags once when capture effect happens. There are two phases in which the tags get identified. In the first phase, by adopting collecting mechanism, staying tags can be identified. In the second phase, by adopting capturing effect mechanism, arriving tags can be identified. But here the disadvantage is that, since there is no blocking technique, the staying tags and arriving tags gets collided and finally producing wrong results.

2.2 Adaptive Couple Resolution Blocking Protocol

Adaptive Couple Resolution Blocking protocol allowing persistent recognition of tags in RFID systems. CRB (Couple Resolution Blocking) method could use blocking techniques to prevent staying tags from colliding with newly arriving tags. CRB protocol adopts blocking techniques, in which it is used to prevent the occurrence of collision between the staying tags and the arriving tags. The staying tags can also re-identify successfully by using the stored data. After separate detection of the staying tags, the arriving tags are also detected. To avoid this, each identification frames are separated into the two slots. The first slot will be only the staying tags and the next slot will be the arriving tags.

3. Proposed Methodology

We proposed the Cuckoo Search-based Clustering Protocol (CSCP) protocol which emphasizes on intentionally reducing the collision problems in the military warehouse. To reduce the reader collision problems, clusters are created using the Cuckoo Search-based Clustering Protocol, accompanied by the graph coloring technique used to scheduling the readers in the cluster. The method involves clustering the big network into small clusters by selecting a cluster head among them itself using the cuckoo search algorithm. The criteria like the energy level, distance, and neighbour count of readers are considered in selecting the suitable cluster heads in the RFID military warehouse. The chosen cluster heads interact with their neighbouring RFID readers and let them know by signalling. Once the optimum cluster heads are identified and the clusters are formed, the readers interact with the tags without inference based on the TDMA based graph coloring scheduling algorithm, thereby mitigating the collision, and establishing an effective communication field within the network.

4. Proposed System

The proposed protocol Cuckoo Search based Clustering Protocol ultimately alleviates the collision problems in the RFID deployed military warehouse. When the readers scan the weapons in the military warehouse, Linear Classifier algorithm will separate the data collected from the weapons. This separation can be done through hyper planes. While separating the datasets using Linear Classifier algorithm, we can solve the issue of missing tags and redundant tags.

In the huge transportation of weapons and missiles among various states and between the countries, guns and missiles are stored in the military warehouse for further processing. Linear Classifier Algorithm can be implemented to solve the problem for multiple readers to tag collision and tag to tag collision and Hill climbing approach is involved for the collision detection.

4.1 Cuckoo Search based Clustering Protocol (CSCP)

This protocol was acquired from the cuckoo birds' parasitoids, which puts its eggs in the nests of other host birds. This reduces the likelihood that the eggs are rejected and therefore improves their performance. When the host birds find that the egg is not their own, they throw away the eggs and use the same nest as home or they will construct new nests. Cuckoo birds prefer to pick a nest in which the host birds had already laid their eggs.

Cuckoo Search based Clustering Protocol is focused primarily on certain appropriate rules:

- The number of possible host nests are specified.
- Each cuckoo bird lays only one egg in the randomly selected nest.
- The nest with high quality eggs will go to the next generation.
- If the host birds find that the egg is not their own, the host bird throw away the eggs and use the same nest as home or they will construct new nests
- Normally, the food search route of a bird or animal is successful on random walks, as next movement is dependent on the present and the next position of the prey.

Concept of Cuckoo Search based Clustering Protocol (CSCP)

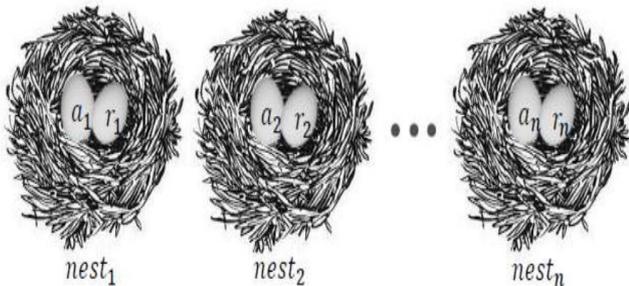Step 1. Creating population originally in n host nests, which is represented in Figure 3.

Figure 3. Readers creation and Nests

Step 2. Placing the egg (a_k', b_k') in a randomly chosen nest, which is represented in the Figure 4.
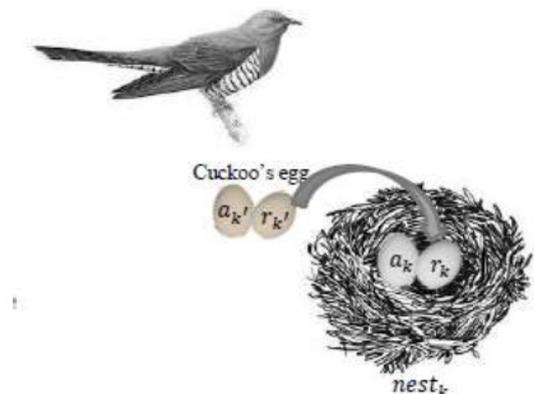

Figure 4. Placing the Egg on nest

Step 3. Evaluate the condition of the host's egg as seen in the Figure 5. with similar condition of the cuckoo bird's egg.

Figure 5. Quality Analysis of Host Bird' Egg and Cuckoo Bird' Egg

Step 4. If the egg of the host bird is not harder than the egg of the cuckoo bird, then the egg of the host bird will be replaced by the egg of cuckoo bird in k nest which can be seen in Figure 6.
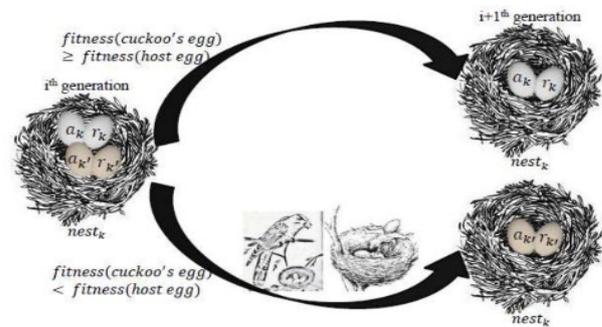

Figure 6. Host Bird's Egg Substitution

Step 5. If the host bird recognizes the egg, it destroys the nest and constructs a new nest which can be seen in Figure 7.

Steps 2 to 5 should be repeated until the requirement of termination has been met.
Steps 2 to 5 should be repeated until the requirement of termination has been met.
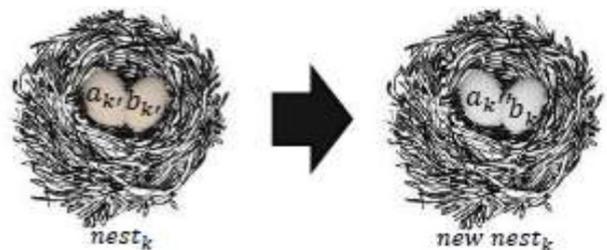

Figure 7. Building of New Nest

Cuckoo Search based Clustering Protocol

Function target f (y), while y = (y₁, y₂ .... y_d) T
Creating population originally in n host nests y_i (where i = 1,2,3...n)

While (T < Maximum creation of population) or (criteria to stop)
Choose a cuckoo bird i through Levy's random distribution
    Assess the fitness quality function F_i
Choose a nest j at random among 'n' number of host nests
  Assess the fitness quality function F_j
    While ($F_i > F_j$)
      Substituted with a new cuckoo bird's egg
    End while
The proportion of (P_a) worse nests are destroyed, and new nests are constructed through levy fights at new regions
    Maintain the optimal solutions (or nests with quality eggs).
    Rate the solutions and identify the best currently available.
End while

4.2 Cluster Head Selection and Formation

The optimal cluster heads of RFID network are selected by using CSCP which is based on the metrics such as high energy level of the stationary readers and the neighbour reader count .In this RFID deployed military warehouse, Stationary readers with high energy level and high neighbour count are chosen as the head readers for the clusters of a network. Once readers are chosen as the head readers, it then transmits the message to the neighbouring readers about its head position and the readers closest to the head readers in the network start to communicate with the head reader defining its position, address, and energy level. The neighbour readers are joined with head reader to the form the clusters.

4.3 Scheduling in the Heterogeneous RFID Network

After the cluster formation, the readers are scheduled based on an algorithm using Graph Coloring Technique to avoid the collision problems. In this algorithm, the readers are scheduled to read the information from tags without interfering adjacent readers. In this scheduling, the mobile readers are given priority to read the tags first, followed by the stationary readers read the information from tags in the cluster. Whenever the readers read the tags, the data gets transmitted to the head reader and is stored in the database with the details of the reader, its tag information, address, location, and energy level. The head reader checks the database to avoid the missing tag and redundant tag.

4.4 Collision detection in the Cluster

Once the readers are scheduled, collision can be identified through Hill Climbing Approach which consists of identification of missing tags and redundant tags. The Hill Climbing Algorithm is a local search algorithm which moves in the direction towards increasing elevation to find the peak of the mountain or to find the best solution of the problem. The hill climbing approach search the clusters until it reaches the cluster which contains maximum number of collisions. If the clusters have least number of collisions, the Hill Climbing Approach continues and moves to the neighbouring clusters. It does not mean that it is skipping the least number of collisions, once it reaches to the maximum collisions in the cluster, the collision can be identified. Then the issue of missing tags and redundant tags of the cluster is solved by using Linear Classifier algorithm.

Hill Climbing Approach

Step 1: The Hill Climbing Approach searches the clusters with highest number of collisions in the RFID deployed military warehouse environment.
Step 2: If the neighbouring clusters have least number of collisions, the Hill Climbing Approach continues its search and visits for next cluster.
Step 3: Once it reaches the cluster which has the maximum number of collisions, the hill climbing stops the searching. From Step 1 to Step 3 the steps are repeated until it detects the collisions in the clusters of the RFID network.

4.5 Classification of data in the cluster head reader

Linear Classifier Algorithm
The aim of statistical classification in the machine learning field is to use the characteristics of the object to classify the group it belongs to. This is done by a linear classification algorithm implementing a classification decision depending on the importance of a linear combination of the characteristics. Also known as feature values are the characteristics of an object and are usually provided to the computer in a vector called a feature vector. These classifiers function well for practical issues such as document classification, and more generally for problems with several features, achieving levels of accuracy comparable to non-linear classifiers while taking less time to train and use.

    If the classifier's input vector is a real vector, the output score will be

$$y = f(\vec{w} \cdot \vec{x}) = f\left(\sum_j w_j x_j\right).$$

Where there is a real weight vector and f is a function which converts the dot product $\vec{w}$ of the two vectors into the expected outcome. The weight vector is acquired from a collection of labelled training samples. Sometimes f is a threshold function that maps all values beyond a certain threshold to the first class, as well as all other values to the second class; for example,

$$f(\mathbf{x}) = \begin{cases} 1 & \text{if } \mathbf{w} \cdot \mathbf{x} > T, \\ 0 & \text{otherwise} \end{cases}$$

In this situation, any number of linear classifiers will properly distinguish the solid and empty dots. They are properly identified by H1 (blue) as is by H2 (red). H2 may be called "better" in the sense that it is also the furthest out of both. H3 (green) fails to identify the dots correctly. A more complex f could give the likelihood that an element belongs to some class. One can imagine the operation of a linear classifier as splitting a high-dimensional input space with a hyper - plane for a two-class classification problem: all points on one side of the hyper plane are classified as "yes," while the others are classified as "no". A linear classifier has been used in circumstances in which speed of the categorization speed is a problem because it is often the quickest classifier, particularly when $\vec{x}$ becomes sparse.

After the Data aggregation, Linear Classifier Algorithm separates data which are similar in the cluster head reader; later hyper plane technique is implemented for classifying and for grouping the data in their respective classes. With this there are no chances of missing tags and redundant tags, hence collision can be minimized. The hyper planes technique has been explained in the Figure 8.
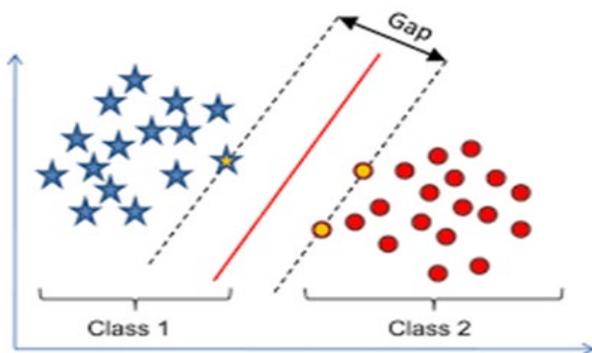

Figure 8. Hyperplanes technique

Formula for Linear Classifier in Military Weapons
$Y = f(tc.x_g) = f(\sum_j tc_j.xg_j)$

$Y = f(tc.x_b) = f(\sum_j tc_j.xb_j)$

$Y = f(tc.x_m) = f(\sum_j tc_j.xm_j)$

Where f represents Threshold Function which maps 1st class, 2nd class
tc = Total Amount of weapons
x_g = Number of Guns
x_b = Number of Bullets
x_m = Number of Missiles

$(\vec{tc}.\vec{xg})$ = Total number of guns read by the reader

$(\vec{tc}.\vec{xb})$ = Total number of bullets read by the reader

$(\vec{tc}.\vec{xm})$ = Total number of missiles read by the reader

$f(\sum_j tc_j.xg_j)$ = Total number of guns read and classified

$f(\sum_j tc_j.xb_j)$ = Total number of bullets read and classified
$f(\sum_j tc_j.xm_j)$ = Total number of missiles read and classified

5. Implementation and Performance Evaluation

The Network Simulator (NS-3) is used to develop and implement the RFID network environment. The simulator executes the Cuckoo Search-based Clustering Protocol (CSCP) for cluster head selection and cluster creation. This prevents the cluster breakage problem by mitigating the movement of the member readers and by increasing the reading performance of the network. There are different categories of readers namely mobile readers, fixed readers and handheld readers in the heterogeneous RFID deployed military warehouse. The cluster head reader schedules the member readers to record the data from the tags and to transmit the data to the cluster head reader in the cluster. Cluster head reader aggregates the collected data before forwarding it to the base station. Once the cluster is formed, collision can be identified through Hill Climbing approach. The Linear Classifier algorithm classifies the data in the cluster head reader to filter the duplicate data from the RFID network. Our simulation results are evaluated with respect to several parameters including the collision rate, successful read tags, energy efficiency and computation time. The simulation parameters of Cuckoo Search based Clustering Protocol (CSCP) are defined in Table 1.

Table 1. CSCP simulation parameters

PARAMETER	VALUE

RFID network area	1000 x 1000 sq. meters
Base station location at	(800,800)
Quantity of Mobile readers	10
Quantity of Fixed readers	10
Quantity of Handheld readers	10
Quantity of Tags	60
Transmitting power	12.910 watts
Receiving power	11.081 watts
Residual energy of the reader	150 joules
Tag Length	14 bytes
Sleep power	0.00214 watts
Routing protocol	AODV Protocol
Number of clusters K = kopt	5 % of total nodes
Total simulation period	800 seconds

Figure 9. Collision Rate vs. Number of Clusters

5.1 Collision Rate

The below Figure 9 explains the total collision rate with respect to Cluster while implementing CSCP'S (Cuckoo Search based Clustering Protocol). The collision rate is less when compared to CCT and ACRB. By comparing these protocols, CSCP is giving an average result of 0.41. In the first stage of ACRB, staying tags will be identified and in the second stage, arriving tags will be identified. However even after implementing blocking technique in the ACRB protocol, collision occurs between the staying tags and the arriving tags. When reader sends the signal to the staying tags during the first stage, if there were more than one tag having same frame number, ID, it starts responding simultaneously to the reader, this causes collision hence collision rate gets increased. In CCT, blocking technique is not implemented; hence there are more chances of staying tags and the arriving tags getting collided. The Linear Classifier algorithm classifies the similar data and filters the redundant data in the cluster head reader, this produces low collision rate compared to existing protocols of CCT and ACRB.
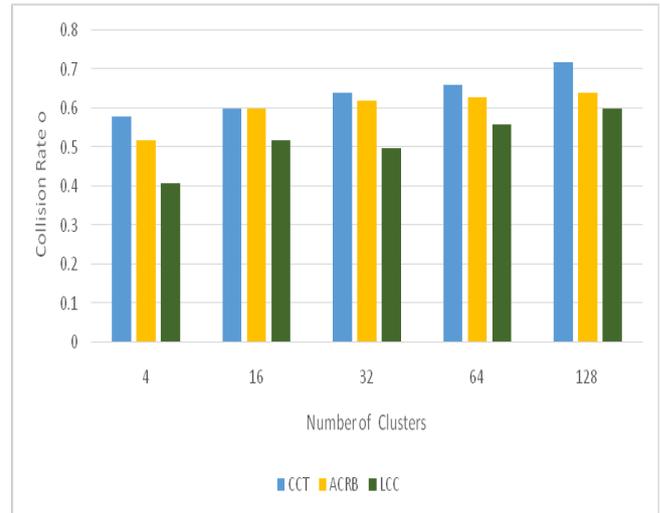
5.2 Successfully Read Tags

The graph in Figure 10. indicates the number of tags read successfully by the reader. This implies the throughput of proposed protocol CSCP is greater than CCT and ACRB. As the collision rate of the system reduces, the amount of the tag identified gets improved which leads to the improved throughput of system. The system throughput is retained as 0.6 to 0.63, even if the number of clusters increases.
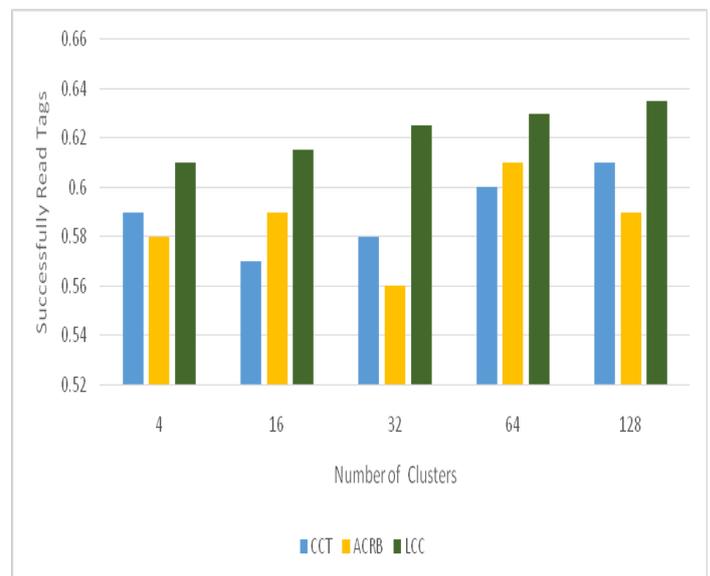

Figure 10. Successfully Read Tags vs. Number of Clusters

5.3 Energy Efficiency

Energy consumption is power depleted when the reader receives the data from tags and transmit the data to cluster

heads. The below Figure 11. shows energy efficiency between proposed protocol and existing conventional protocols such as CCT and ACRB. When the proposed protocol CSCP is compared with the existing conventional protocols, it consumes less battery life because stationary readers with high energy level are chosen as cluster head readers to mitigate the unstable clustering.
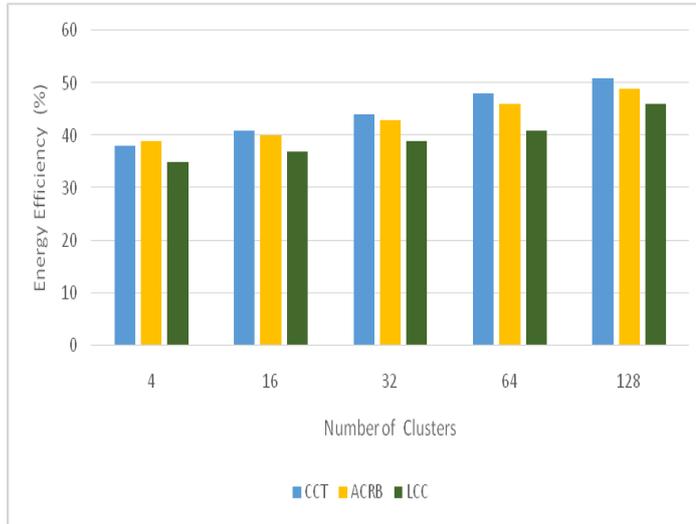

Figure 11. Energy Efficiency vs. Number of Clusters

5.4 Computation Time

It based on the number of clusters, readers, and tags in the RFID network. In the CCT protocol, collecting collision mechanism in the first stage is to detect the staying tags and adopting capturing effect in the second stage is to detect the arriving tags for reducing collisions. The cons in ACRB is However the blocking technique is involved in the ACRB protocol, collision that causes between the staying tags and the arriving tags. The proposed protocol overcomes the issue by identifying tags in the proper way; CSCP classifies and separates similar objects towards separate side. This CSCP executed in step by step, in that manner there is no chances to get collision occurrence of tags and the execution time is low when compared to CCT and ACRB as shown in the Figure 12.
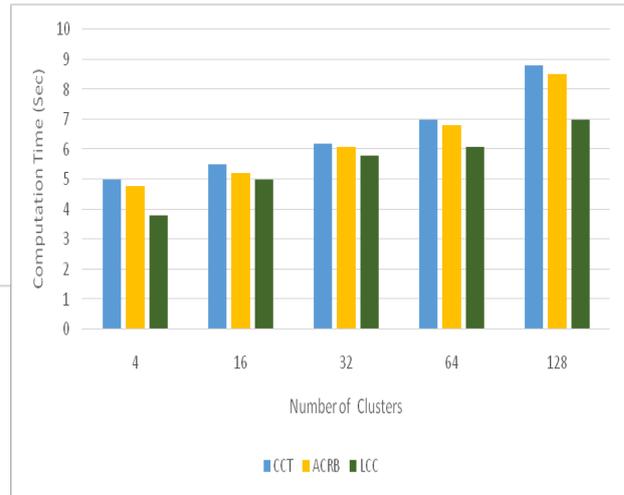

Figure 12. Computation Time vs Number of Clusters

6. Conclusion

The main aim of this paper is to mitigate the collision problems in the RFID deployed military warehouse environment by using the proposed protocol called Cuckoo Search based Clustering Protocol (CSCP). In the RFID deployed military warehouse, cluster head readers are selected, and clusters are created. Readers are scheduled to read information from tags in the cluster using the TDMA-based graph coloring algorithm. The linear classifier algorithm classifies the weapon's data and filters the redundant weapon's data in RFID deployed military environment. Simulation results of the CSCP shows better performance in terms of collision rate, successfully read tags, energy efficiency and computation of the reader compared with existing protocols such as CCT and ACRB protocol.

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