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Graph Coloring Based TDMA Algorithm for Scheduling the Readers in RFID Network to Avoid Reader Collision

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Abstract: RFID is the technology that reads and captures the information from the tags attached to the objects with the use of radio waves. Reader collision is an obstruction in RFID and it is also a greater disadvantage in RFID system. The existing reader anti-collision algorithms like LEACH, HEED and DCHS leads to communication overhead and increase in time and energy consumption. A graph coloring based TDMA scheduling algorithm is proposed that reduces the reader collision and improves the throughput of the readers. Every the readers in the RFID network transmit their mobility and energy level to the base station for cluster head reader selection. The base station computes the average energy level of all the readers and ranks the cluster head. The cluster head reader is ranked based on the energy level, mobility of the readers, number of tags around it and the distance to the base station. The cluster head selection process is done with the firefly algorithm followed by coloring and scheduling the readers in the RFID network. When compared with the Priority Clustering Protocol (PCP), the proposed scheme saves the energy of the readers there by reducing the data loss and increasing the network life time.

Key words: Graph coloring, RFID, reader collision, TDMA, cluster based RFID, firefly, scheduling

INTRODUCTION

RFID (Radio Frequency Identification) is an identification and tracking technology that used to identify and validate tags that are applied to any product, individual or animal and it can be grouped beneath the broad category of automatic identification technologies. RFID system consists of RFID readers and tags. The tags are normally joined to the objects and readers can read the information from tag using radio signals. Every RFID tag enable object has its individual Electronic Product Code (EPC). An RFID reader sends an encoded radio signal to read the information from the tag. The RFID tag receives the encoded radio signal and then transmits the stored information to transmitter.

There are two types of RFID tag such as read-only or read/write and does not need touch or line-of-vision to operates it research beneath a wide variety of environmental circumstances and gives a high level of data incorruptibility. It is similar in concept to bar coding. Bar code reader uses optical signals to read information from the label that is attached to object but RFID uses RF (Radio Frequency) signals to read the information from tag. The tags generally contain an electronic chip with an antenna in order to transmit the information onto the interrogator. RFID uses several radio frequencies and distinct types of tag occur with distinct communication methods and power supply sources.

MATERIALS AND METHODS

Problem definition: RFID is the use of electromagnetic waves to gather and captures the information stored on a tag attached to an item. RFID has been used in many real time applications like race timing, attendance tracking and e-Passport, etc. The reader interference problem arises while the signal of one reader interferes with the signal of the other readers. Such conflicts can consequence in collision among the reader and the tags. In this approach, the collision can be minimized by electing the cluster head, using firefly algorithm and the readers are programmed with the use of graph coloring TDMA based scheduling algorithm.

Existing system: The existing system provides scalability in the network by way of reducing most of the transmission within the distinct clusters of the network. However, it does not achieve well with the applications

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that need huge broadcasting area along with inter-cluster communication. LEACH ,HEED and DCHS are some of the three existing clustering protocols.

LEACH: Low Energy Adaptive Clustering Hierarchy (LEACH) (Batra and Kant, 2014) is one of the TDMA based MAC protocol in which most nodes send the data to cluster head and it collect and consolidate the data and forward it to the base station. LEACH attains energy efficiency by dividing the nodes into clusters. In LEACH the selected cluster head uses a TDMA based algorithm schedule and allocates time slots to each member node in the cluster for data transmission.

HEED: Hybrid Energy-Efficient Distributed clustering (HEED) (Younis and Fahmy, 2004) was designed to select the cluster head regularly depends on their residual energy. The intra-cluster "communication cost" is treated as a secondary clustering parameter to boost energy efficiency and to extend the network lifetime. For cluster head selection, HEED which uses residual energy as primary parameter and network topology feature as secondary parameter.

DCHS: Distributed Cluster Head Scheduling (DCHS) algorithm (Jedda and Mouftah, 2016) was modelled to minimize the energy consumption in WSN. The main advantage of the DCHS algorithm is that it considerably reduces the communication distance among the cluster head and Cluster Nodes (CN). This approach creates the possibility of reducing the transmitting power of CH nodes which will further enhance the individual node lifetime. DCHS can be mainly used for energy aware applications in WSN. Drawbacks of existing system:

- Communication overhead
- It consumes extra energy to rebuild clusters
- DCHS protocol has occupied the residual energy of the node into account but it reduces the network life cycle

Nawaz *et al.* (2013) proposed the reader anti collision protocol in dense RFID environment". In a thick, dense domain, numerous readers are assembled to examine a typical zone for wanted scope. The widely used distributed technique based on Carrier Sense Multiple Access (CSMA) is pulse protocol. The pulse protocol is simple and requires less overhead. It effectively mitigates the reader collision problem but when pulse algorithm is compared with TDMA based approaches it lacks in efficiency and throughput. Random colors are picked by each reader in every cycle. In Pulse Distributed Color Scheme (PDCS) a probability is considered while choosing new colors for collided readers.

Alcaraz *et al.* (2013) proposed scheduling algorithm that used to identfy moving tag. The resource allocation algorithm controlling is proposed in this study and the main objective is to deduce the frame length configurations that fulfill the reliability objectives, given the velocities of the tags, the tag flow densities densities and the link budget parameters. Based on dynamic system theory, a mathematical model was proposed which allows the users to get the required configurations in order to obtain the set reliability objective. This is done to express that some configurations present multiple equilibrium points and such configurations should be avoided and so as to also define the operating boundaries of the system.

Alsalih (2013) proposed an idea about distance clustering scheme based on power for anti collision .In this study, tags within the coverage area are clustered based on transmission power of reader and their distance between the reader and tags. The proposed method aims to divide tags into clusters based on their distance to the reader and to read tags cluster by cluster. Since, the number of tags in a single cluster is less than that in the whole interrogation zone, the likelihood of a collision is reduced. Both the deterministic anti-collision and probabilistic anti-collision has been proposed. The Binary Search Tree (BST), Enhanced BST (EBST) and Query Tree (QT) are discussed in deterministic anti-collision blog to find the optimal number of clusters in the RFID network.

Eom *et al.* (2009) proposed reader anti-collision networks with mobile RFID technique to improvise colorwave, a Hierarchical Q-learning algorithm (HiQ) have been proposed. As a globally optimal solution, Q-server is used as the coordinator. The Q-server conducts the Q-learning algorithm, a form of reinforcement learning with the collision information of readers. After using the Q-learning algorithm, the resource allocation decisions is made by HiQ which is done to enhance the number of operating readers at the same time and reduce the number of reader collisions. It can get difficult to implement the Q-learning algorithm when the number of readers is large in dense RFID systems due to lots of computational load. The proposed Neighbour Friendly Reader Anti-Collision (NFRA) improves the efficiency of reader operation by enabling them to research without interference from neighbouring readers. The proposed NFRA is a reasonable protocol for dense RFID networks with mobile readers and it can be effectively applied to dynamic environments.

Ergen and Varaiya (2010) proposed "TDMA scheduling algorithms for wireless sensor networks". The scheduling problem is utilized to determine the smallest length conflict-free allotment of slots during which the packets generated at each node reach their respective destination. The conflicting node transmissions are determined based on an interference graph. In this study, the researcher proposes two centralized heuristic algorithms are proposed, one is node-based scheduling and the other algorithm is based on scheduling the levels in the routing tree before scheduling the nodes or level based scheduling. The distributed algorithm is proposed which is based on a two-stage coloring algorithm at the end of which nodes assigned the same color form a maximal non-conflicting set.

Wang *et al*. (2006) proposed "A novel solution to the reader collision problem in RFID system". The Reader Collision Problem (RCP) is considered to be the trouble spot of the system throughput and reading efficiency. The proposed novel RCP scheme-Central Cooperator (CC)-RFID improves the performance of multiple readers RFID system and also increases the reading speed and efficiency as compared to current popular RCP solutions. A novel and an enhanced RCP solution-Central Cooperator (CC)-RFID is proposed to reduce the reader collisions by sharing the tag information among adjacent readers in RFID network. In CC-RFID system, the present 'Multiple Points to Multiple Points' (MP2MP) collision problem is then converted into two 'Multiple Points to one Point' (MP2P) classical collision problems.CC-RFID simplifies the complex 'MP2MP' access problem as two 'MP2P' classical problems, making the anti-collision protocol design for RCP an easier job to accomplish.

The proposed scheme is to schedule the colored readers using graph coloring based TDMA algorithm in RFID network. In this scheme, the readers and tags are grouped as clusters and the cluster head is chosen using the firefly algorithm. The initial CH is elected with the parameters like the number of tags around it and the distance to the base station. Then, the firefly algorithm continues to research by electing the other readers as cluster heads. The readers are colored using the graph coloring algorithm.

The graph coloring based TDMA algorithm schedules the same colored reader at a same time to balance the energy consumption among all readers in the clusters. The same colored readers will occupy the same time slot there by reducing collision. The readers with in the clusters are scheduled withan effective time-mechanism to avoid the reader collision and to increase the scalability and robustness (Fig. 1).

Cluster formation and cluster head selection: The readers and tags are grouped as clusters to avoid the reader collision. Among several readers reading the information, one reader is initialized as the CH with the use of firefly algorithm. Base station (sink) runs the firefly algorithm to select the optimized cluster head reader

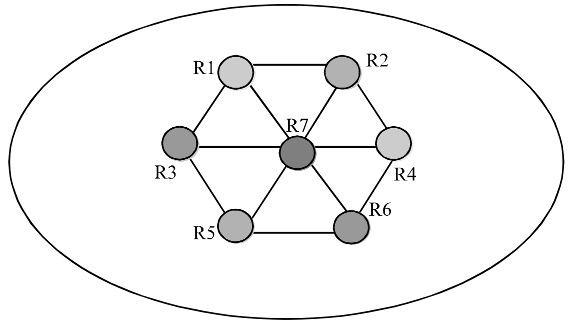

Fig. 1: Graph coloring

Fig. 2: Time slot for colored readers

among the eligible RFID readers. Figure 2 shows the cluster formation and cluster head reader selection process. Cluster head reader is selected based on energy level and mobility of the all readers in the RFID network.

The cluster head reader is in charge for collecting the data from all other readers within the cluster and sends the data to the base station. The average energy level of the readers is computed. When the present CH loses its energy, the reader whose energy level is greater than the average energy level within the cluster is chosen as the next cluster head. By this cluster formation the collision is not fully avoided there might be the chance of information loss and hence, scheduling is done to remove the reader collision and to increase the performance, efficiency and throughput of the readers.

Pseudo code; Cluster head selection using firefly algorithm:

```
Consider the mathematical function f(x), x = (x1,..., xd) T
Estimate an original population of fireflies xi (i = 1, 2,..., n)
Intensity of light Ii at xi calculated by f(xi)
When (t<MAxGeneration) describe light absorption coefficient γ
for i = 1to n, n fireflies
for j = 1to n, n fireflies
if (Ij>Ii) go firefly i in the direction of j in dimension
Stop if
Fireflies attractiveness varies with distance r via. exp [-γr]
Revise intensity of light 'li' and Estimate new solutions
Stop j
Stop i
Arrange the fireflies and then discover the present best
Stop while
```

The cluster is used for reducing RFID the reader collision and to extend the network life time. The cluster head reader selection is done using firefly algorithm as:

Algorithm; Cluster head reader selection using firefly algorithm:

1. All RFID readers (n = 1, 2, …., N) transmit their energy level to the base station
2. The base station calculates average energy level of all the readers in the RFID network and picks the eligible cluster heads
3. For each reader, calculate the distance of the reader to the base station and the tags around it
4. Assign the reader as the cluster head depends on the minimum distance of the reader to the base station
5. Order the selected cluster head and optimize the best on the criteria in step 3
6. The reader whose energy level is greater than average energy level is selected as the next cluster head reader. Whenever the cluster head reader changes, update the position of the cluster head reader
7. Repeat the step 3-5 for the successive election of readers as the cluster head

Scheduling the readers: The readers are colored using the graph coloring algorithm such that no adjacent readers are colored with the same color and this avoids the reader collision and conserves the energy for the readers. Graph coloring has significant applications to a huge variety of difficult problems involving optimization. The graph coloring concept is widely used in everyday applications like pattern matching, frequency assignment, making schedule, register allocation.

In Fig. 1, the seven readers are colored using graph coloring algorithm. R1 is colored with the maroon and its adjacent readers R2 and R3 are colored with green and blue. This process is repeated until all the readers are colored based on the concept of graph coloring.

The graph coloring based TDMA algorithm schedules the same colored readers in the same slots as given in Fig. 2 where R1 and R4 are arranged in maroon color slot as they are colored in same color. Similarly other colored readers are arranged in their respective colored slots. The energy consumption of the readers reduced and the reader can read the information at a faster rate.

Graph coloring based TDMA scheduling algorithm: Collision is not completely avoided in cluster formation. To further filter the collision and schedule the colored readers using graph coloring based TDMA scheduling algorithm.

Graph coloring is used for coloring the readers with the minimum number of colors such that no neighboring readers are colored with the same color and this helps in avoiding the reader collision. The transmission among the reader and the tag is also done and dissimilar time slots are generated based on the number of readers used.

The TDMA allocates different time slots for the readers to read the information from the tags in the cluster and to send their energy information and data to their cluster head, then it transmits the data to the server. The same colored readers will occupy the same time slot, since, the same colored readers are scheduled at the same time and this avoids the delay of readers getting the data from RFID tags.

RESULTS AND DISCUSSION

Performance measurements: The performance of the scheduling algorithm is measured with various parameters like throughput, Packet Delivery Ratio (PDR), end-to-end delay and energy consumption. Threshold energy is set for the cluster in the cluster network. This energy is set to compare the energy of the readers among the different readers in the clusters to set the next CH (Fig. 3-5).

Throughput: Throughput is the measure of how fast the reader can read the data's from the tags in the network with respect to the bandwidth. It is defined as the number

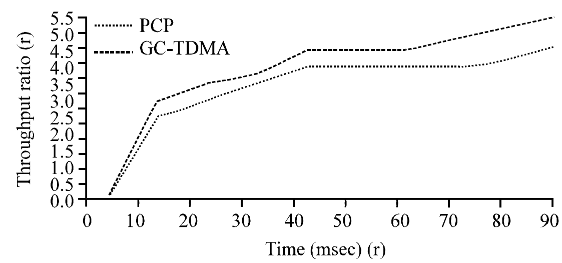

Fig. 3: Throughput performance graph

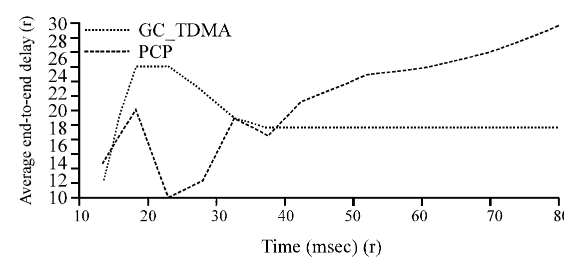

Fig. 4: Average end to end delay performance graph

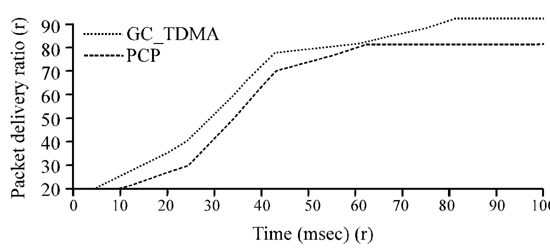

Fig. 5: Packet delivery ratio performance graph

of tags read every second. Figure 5 shows that, the graph coloring based TDMA scheduling algorithm has better throughput because the readers are colored using the

Table 1: Throughput comparison

Time (msec)	GC-TDMA	PCP
10	0.030	0.025
20	0.035	0.030
30	0.038	0.035
40	0.045	0.040
50	0.045	0.040

Table 2: Average end to end delay comparison

Time (msec)	GC-TDMA	PCP
10	0.012	0.014
15	0.025	0.020
20	0.025	0.010
25	0.022	0.012
30	0.019	0.019

Table 3: Packet delivery ratio comparison

Time (msec)	GC_TDMA	PCP
10	0.030	0.022
20	0.040	0.030
30	0.060	0.050
40	0.078	0.070
50	0.080	0.075

Table 4: Energy comparison

Time (msec)	GC_TDMA	PCP
10	0.015	0.023
20	0.040	0.071
30	0.065	0.072
40	0.066	0.072
50	0.066	0.072

concept of graph coloring and identical colored RFID readers are scheduled in the same time and at the same slot. Figure 3 shows the throughput performance graph respective to the values in Table 1.

While in PCP, all readers in cluster based RFID network is given priority to identify tags in order, this decreases the speed of the readers to read the data's from tags. The results indicate that graph coloring based TDMA increased thereby showing considerable performance improvement. Table 1 given shows the throughput comparison.

Average end to end delay: Table 2 given shows the average end to end delay comparison for both graph coloring based TDMA schedule and PCP. The average time occupied by a data packet to reach the destination. It also includes the lag produced by route detection process and the queue in data packet transmission. Only the data packets that successfully transported to destinations that counted.

Before selecting the cluster head, the readers find difficult to read the data's from the tags and there by increasing the delay, after coloring the readers and scheduling the colored readers in the same time slot it is easy for the readers to read the information from tags with the minimum delay.

In PCP it takes time for prioritizing the readers for identifying the tags in sequence and optimizing the sequence of readers, this increases the delay for the readers to read the data's from tags.

Packet delivery ratio: Packet delivery ratio is the ratio number of packets that are effectively transported to a destination compared to the number of packets that have been sent by sender.

The packet delivery ratio clearly defines the collision avoidance. The collision is minimized by the cluster formation followed by the graph coloring based TDMA schedule there by reducing the energy and time consumption. While in PCP, since, more time and energy is spend on prioritizing the readers for identifying the tags the collision is not fully avoided there is a chance of data loss. Table 3 shows the packet delivery ratio comparison.

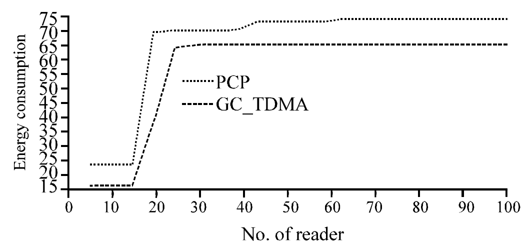

Fig. 6: Energy consumption performance graph

Energy consumption: Collision occurs when the signal of one reader interfere with the signal of other reader. This results in increased energy consumption of the readers. In order to overcome this problem and to stabilize the energy consumption, readers are grouped as clusters and the cluster head is selected using the firefly algorithm followed by graph coloring based TDMA schedule. The Table 4 shows the energy consumption of both graph coloring based TDMA and PCP.

The PCP increases the energy consumption to prioritize the readers for identifying the tags and increases the time consumption for optimizing the sequence of readers (Fig. 6).

CONCLUSION

Reader collision is one of an obstruction for the proliferation of the RFID. To overcome this hindrance, the readers are scheduled in the cluster based RFID is implemented in-order to improve the throughput and efficiency. The proposed scheme has been processed in three phases, the first phase deals with selection of the cluster using the dragonfly algorithm, hence by this phase end-to-end delay of the reader's transmission to the base station is reduced but collision is not completely avoided.

The second phase is about graph coloring concept of the readers. To minimize the collision and increase the energy efficiency of the readers, the readers are colored using the graph coloring algorithm. Using graph coloring based TDMA scheduling algorithm the readers are scheduled to avoid collision and packet loss. The third phase deals with measuring the performance of scheduled readers in the cluster based RFID network through various parameters like throughput, energy consumption, average end-to-end delay and packet delivery ratio. The performance of the graph coloring based TDMA schedule is compared with the reader anti-collision Priority Clustering Protocol (PCP). The Graph coloring based TDMA scheduling algorithm performs better for the above mentioned parameters as compared to PCP.

RECOMMENDATION

The further development on the proposed scheme includes improving the security in the network through various encryption and decryption techniques. Future research will be focused to avoid collision between the readers and mobile devices and increase the read range of mobile devices.

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