I J C T A, 9(11) 2016, pp. 5455-5466

SENSOR INTEGRATED RFID BASED POSTAL LETTER TRACKING SYSTEM

Amandeep Kaur[*] Ms. Navjyot Kaur[**] Mr. Mandeep Singh[***] and Mr. Gaurav Pushkarna[****]

Abstract: Radio frequency identification (RFID) is technology which is widely used in object tracking system. RFID system offers cheaper tags for identification of objects. The technology Wireless Sensor Networks (WSNs) are also used for object tracking. WSNs use different parameters to acquire data and provide multi-hop communication for data transfer. So, we have used integrated sensors with radio frequency identification. Integration system provides road and rail network for data processing, distribution and acquisition.

The main aim of research is to track postal letters using RFID system integrated with sensor nodes. Some sensor nodes are replaced with tags and RFID readers integrate with sensors. The tag is integrated with letter at the time of registration. Readers are used to read identification number from tag and sensors are used for sending information to base station using multi-hop communication. The work is simulated using Network Simulator version 2(NS2).

Key Words: Wireless sensor network, Radio frequency identification, Postal Letter, integration, Ad-hoc on Demand Distance Vector, Destination Sequenced Distance Vector

1. INTRODUCTION

Wireless sensor Networks (WSNs) are used in these days for many applications. WSNs are networks of low power wireless motes, cost effective devices with sensing, data processing and communication ability [1]. Sensors can be described as intelligent devices that are logically home to central sink node. Sensor devices are also known as motes [2]. Sensors are in general deployed in the high density manner and in large quantities. These distributed nodes support sensing and signal processing [3]. WSNs aims are just sensing the environment and sending data to a base station. The system operates for periods varying from weeks to years in an independent way. The sensor networks are self-possessed of enormous number of sensor nodes that can be deployed on the ground, in the air, in vehicle,inside building [4, 5].

A Wireless sensor network is used for realization of ubiquitous computing. It can be deployed in indoor and outdoor. These sensor networks can establish ad-hoc network automatically, and sensing data as per request and event driven [6]. A sensor node comprises of measuring,

[*] Department of CSE Assistant Professor Lovely Professional University, Phagwara, Punjab
Email: er.amandeep.kaur@gmail.com
[**] Department of CSE Assistant Professor Lovely Professional University, Phagwara, Punjab
Email: navjyot16.kaur@gmail.com
[***] Department of CSE Assistant Professor Lovely Professional University, Phagwara, Punjab
Email: mandeepsingh.iit@gmail.com
[****] Department of CSE Assistant Professor and Director Lovely Professional University, Phagwara, Punjab
Email: gaurav.pushkarna@gmail.com

computing, and communication elements. A sink aggregates all the information. A sensor node does not retain energy to support long assortment of communication to reach to sink, so multi –hop connectivity required to send data to the sink. Each sensor node has capabilities to collect data, process that data and route to sink node. Router nodes are used to forward data from sensor nodes to remote sink node. A single chip may be used for sensing, computing, and communication for reducing the cost and allowing deployment of large numbers of nodes [7]. Radio frequency identification (RFID) is wireless use of electromagnetic field of radio frequency to data transfer for the purpose of automatic identification of objects with a unique identification number which is stored in the attached tag [8].

Radio frequency identification (RFID) is belongs to family of Automatic Identification and Data Capture (AIDC) technologies that includes 1D and 2D bar codes. RFID uses an electronic chip usually applied to a substrate to form a label that is affixed to a product, case, pallet or other package. The information it contains may be read, recorded, or rewritten. [9]

RFID represents and wireless sensor networks are two opposite technologies and there are number of applications after integration of these technologies. RFID tags are cheaper than sensor nodes. It is beneficial to use RFID tags to replace some of the sensor nodes. It is difficult to track objects in case of wireless sensor networks. RFID technology provides some additional features to sensor network for object tracking. On the other hand, wireless sensor network provide some additional feature by which sensor provides additional capabilities to RFID tags. It basically extends the application of RFID system to embedded logic into nodes then RFID readers and tags act as intelligent interrogators and transponders.

Applications of RFID system are wider than wireless sensor networks. RFID systems are mandatory for some of the companies. It has capability of replacing and improving existing applications. RFID tags are less expensive than sensor nodes. Using RFID system can take care of positioning and identification. Wireless sensor network can use for sensing, positioning, identification and multi-hop communication. We can create different application scenario integrating RFID and wireless sensor networks. The scenario describe as follows:

(i) Integration in which wireless sensor network used for sensing and RFID is used for identification. In these types of systems both are attached to object only. These type of integration scenario are used to sense PH value, blood pressure and heart beat etc.[10]. Take a another case in which RFID tag embedded in object and wireless sensor network nodes are used for sensing object. When sensors sense the object then additional information gained from objects using sensors. In some of the cases these are used to sensing the environment [11].

(ii) Integration in which both RFID and wireless sensor network used to identification of objects. In this type of application RFID reads information from tags only after sensing object which contains RFID tags.

(iii) Integration in which RFID is used to identify objects and wireless sensor are used to find location of that object. In this sensors try to find position of object which particular object is first responder.

(iv) Integration in which RFID system is used for identification and wireless sensor networks help in multi-hop communication.

There are number of classification and architecture is defined for integration. They Include:

(i) Integration of RFID and Wireless sensor network at the application level

(ii) Integration of RFID and Wireless sensor network at data filter and collection level

(iii) Hardware integration which is responsible for collecting data from both tags and wireless sensor network by RFID readers.

(iv) Logical integration for information services that allows for a mix of RFID and wireless sensor networks.

four type of integration is defined: Integrating tags with sensors, integrating tags with wireless sensor nodes, integrating readers with wireless sensor nodes and wireless devices and a mix of RFID components and sensors [12].

2. LITERATURE SURVEY

In 2007, Xi CHEN et al. proposed a broadcasting communication protocol with high energy efficiency for large scale sensor networks with low latency based on the Small world network theory [13]. This method proposal guaranteed degree of coverage and network connectivity. It designed network to monitor an area for target detection with randomly distributed sensor network. It achieves balance between power consumption and transmission delay without solving global optimization problem.

In October 2007, Ranky P.G. discussed about "Engineering Focused Radio Frequency Identification (RFID) Model Solutions for engineering management [14]. It described that when RFID network is integrated with the factory material the accurate information can obtained and that is closed to real time environment. It includes information of factories as well as parts which are assembling at the time of shipment. Number of challenges are discussed which are occur at the time of developing mentioned system.

In 2009, Nandakumar Mysore et al. proposed to find minimum number of fixed RFID readers required for complete coverage area of irregular shape [15]. This approach used Graham's scan algorithm of computational geometry that perform for any shape of building. This model finds convex hull/polygon from given set of points. This method used for automated tracking of baggage. Irregular structure of an area also adds to signal coverage and object scanning problems.

In 2010, Yingfeng Zhang et al. proposed RFID-enabled real-time manufacturing information tracking infrastructure to capture real time data of manufacturing [16]. In this method material integrated with RFID tags and readers. This system proposed statistical methods for tracking manufacturing progress. It used to check progress of manufacturing cost, work, and inventory. This method used for extended enterprise manufacturing companies.

In 2011, Dr. V. Vaidehi et al. proposed a scheme for effective utilization of power by integrating sleep wake scheduling, clustering and tracking using Kalman filtering for object tracking [17]. This method introduces delay-less optimal shortest path routing algorithm. It used to reduce the routing delays in the cluster. A cluster head receives information from sensor nodes and send information using proposed routing algorithm. This method cannot be used for multiple object movement.

In 2011, Jian Zhang et al. proposed a dynamic clustering algorithm for target tracking [18]. This method describes local monitoring of objects in specific region of wireless sensor networks. The joint detection and decision function used for node selection. Particle filtering used for localize the target. Active nodes used to collect data from monitoring region to localize target, at that time other nodes on sleeping mode and save power consumptions.

In 2012, Wei Zhou and Selwyn Piramuthu proposed knowledge based for real time service management using RFID System [19]. This method described customer service management through analysis of service quality and service dependability. This framework incorporates

learning, simulation, and performance evaluation mechanisms. It used for decision support system. This system includes RFID reader with display, loyalty cards with RFID tag, a dynamic pricing engine that computes instant price information based on the customer's reliable status.

In 2012, Javier G.ESCRIBANO and Andrés GARCÍA proposed tracking and monitoring of physical condition of person in dangerous situation [20]. A new algorithm proposed to increase operation time and data transmission rate of the nodes in the system. This system allows finding location and state of person. It provides details of risk factors at each movement and causes of event occurrence. In this radio communication is carried out between transmission points which create a network for sending details.

In 2012, Senthamilselvi, M. and N. Devarajan proposed a distributed coverage and target tracking algorithm for wireless sensor networks [21]. It proposed a target zone detection algorithm to estimates the location of targets. In this algorithm, a border cover node included and used to determine the co-ordinates of the sensor nodes. It also used reduced energy consumption and coverage along with delay. This method determined a reduced sensor coverage for given target regions, boundary sensor nodes of given targeted region, detected target entry or movement, and also broadcast coordinates of the boundary nodes. Then reduced activated nodes activated based on the radius criteria of circular region. Faulty sensors reports arbitrary values.

In 2013,Dian Zhang et al. proposed transceiver free object tracking[22]. In this method, moving object used without communication device and some monitoring devices already deployed for monitoring moving objects. This method divide tracking field into different area and extra communication channels used to interaction between tracking fields. Triangular area used for communication, three nodes deployed for this purpose on the ceiling to monitor area. It uses Support Vector Regression (SVR) model to locate the object. This model is very adaptive model.

In 2013, Antonios Bouzakis and Ludger Overmeyer described about position tracking of passive RFID tags with the aid of a scanned array [23]. This method proposed RFID tag positioning system that use an array that is based on radar system. This tracking system contains a controlled reception pattern antenna array. It combined with UHF reader module. This used to track electronic shape radiation pattern of reader module. It used for warehouse applications.

In 2014, Shung Han Cho et al. presented an effective power scheduling strategy for energy efficient multiple objects identification and association [24]. Multiple objects positions decide the power level of RFID readers. The proposed model incorporated with various heterogeneous sensor networks. This system minimizes the system energy consumptions by activating the RFID readers.

In 2014, Junho Park et al. proposed data centric storage approach for distributed data regions to sensor nodes. It used to restore sensor readings in real world applications [25]. It used to process queries for specific data regions. In this method, it changes the storage for outlier data out of the entire storage. This performed according to threshold values, if range specified without threshold values, it requires change in entire storage range. The scheme resets the entire storage ranges to mitigate the variation of storage, when data generation patterns change. This model is very much suitable to preserve energy and to improve the lifetime of the sensor network.

3. THE PROPOSED MODEL

The proposed System is for real time tracking of postal letters. In order to simulate proposed model, the scenarios simulate using NS2. NS2 is a discrete event network simulator. The NS2 is

used to translate physical activities to events. Events are processed in order of their scheduled occurrences and time processes as event are processed. Using this tool, first function is region wise deployment of RFID readers and sensor. Then assign the identification number to RFID tags at the time of letter registration. Then start the distribution of letter to their respective destinations with integrated tags. At the time of movement of letter that is being sensed by sensors, their identification number is read by reader and data collection of movement is stored by sensor nodes. Multi-hop communication of sensor networks is used for sending data to the base station with the help of Ad-hoc on Demand Distance Vector (AODV) or Destination Sequenced Distance Vector (DSDV) routing algorithms. After delivery of letter to their destination, tags are removed from letter and can be reused again. Active and passive tags can be use for real time environment of letter tracking. The proposed letter tracking system is capable of getting information of letter's location using the tag information read by RFID reader. All the RFID readers integrated with sensor nodes are deployed in the route of source to destination. The RFID system coordinates with WSNs to find location of the letter and sends collected data to base station on urgent basis.

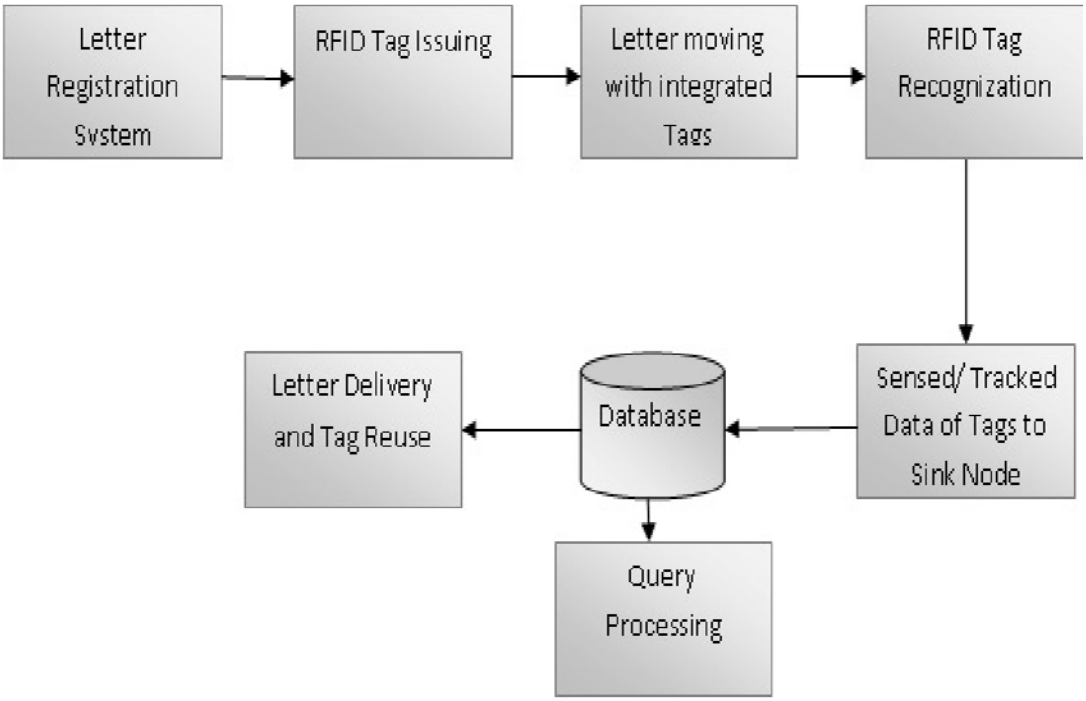

Figure 1 Proposed Sensor Integrated RFID Postal Letter Tracking Architecture

Figure 1 demonstrates, sensor integrated RFID reader architecture is proposed for postal letter tracking system. This system is used to find location of moving letter. The readers and sensor nodes perform sensing, reading tag, decision making and multi-hop communication. This system is responsible for collecting data from tags by RFID readers and transmitting data to sink using sensor nodes.

Figure 2 shows proposed model scenario is being executed with the help of NS2. Letters are represented in form of tags and readers and sensors are deployed in regions. The integrated nodes read the tag data and then transfer data from source to destination post office using intermediate nodes.

The proposed sensor letter tracking system is designed and implemented using radio frequency identification and WSNs. We are demonstrated proposed system to improve the tracking and monitoring of letters. We can be deployed wireless sensor nodes/readers in post office, with post boxes and with set of points.

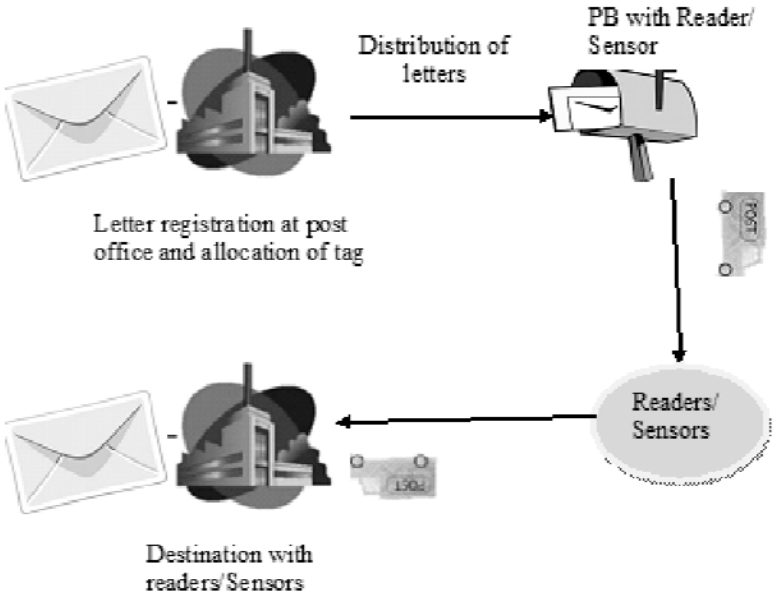

Figure 2 Proposed Postal Letter Tracking System Scenario.

3.1 Algorithm

The proposed Model approach is used to find location of Postal letters. To implement the process of letter tracking RFID system integrated with WSNs. There are different types of integrations, but in this system, we propose RFID Reader integrated with sensors. At the time of letter registration, first we issue a RFID tag with data such as postal code and address and details of that store in the RFID readers. Data of moving letter trace by sensor nodes, which are integrated with RFID Readers. The distribution of letters is performed to various post boxes according to their tag identification or region or set of points after allocation of tags to letters. We can also deploy RFID reader integrated with sensor node within the vehicle, which is used to distribute letters from one location to other. With each post box, we deploy the RFID Reader. We also deploy RFID system integrated with sensors at delivery office of Postal letters. At the time of delivery hand-held RFID reader integrated with sensor are being used and after delivery of letter removal of tag from letter. We can be used active and passive tags. If we use active tags, then these tags can use again to reduce the cost of the system. If we use passive tags, no need to remove it from letter, because these tags are less costly. Data route to the base station with the help of DSDV and AODV routing protocols. These protocols are used for Ad-hoc networking. Dynamic Frame Slotted ALOHA (DFSA) algorithm is use to adjusting the frame size and to increase the throughput of RFID systems.

The algorithm is for proposed postal letter tracking system is as follows:

1. Setup of network topology to simulate real-time Postal letter tracking.
2. Setup RFID Readers integrated with sensors at base station, Post Boxes, vehicles etc.
3. Register Letters in post office and allocate tag identification number.
4. Update details of letter integrated with tag on RFID readers.
5. Set all the readers in detect mode.

6. If Letter integrated with tag detected Then Set Reader in read mode to read the identification Number from tag and store in the memory of sensors. Else “GOTO Step 4”.
7. Location of letters is send by sensors to base stations (Source and destination post office) using multi hop communication with AODV or DSDV routing protocols.
8. Distribution of letters to their destination using hand-held RFID Readers integrated with sensors.
9. Remove tag from letter.
10. End.

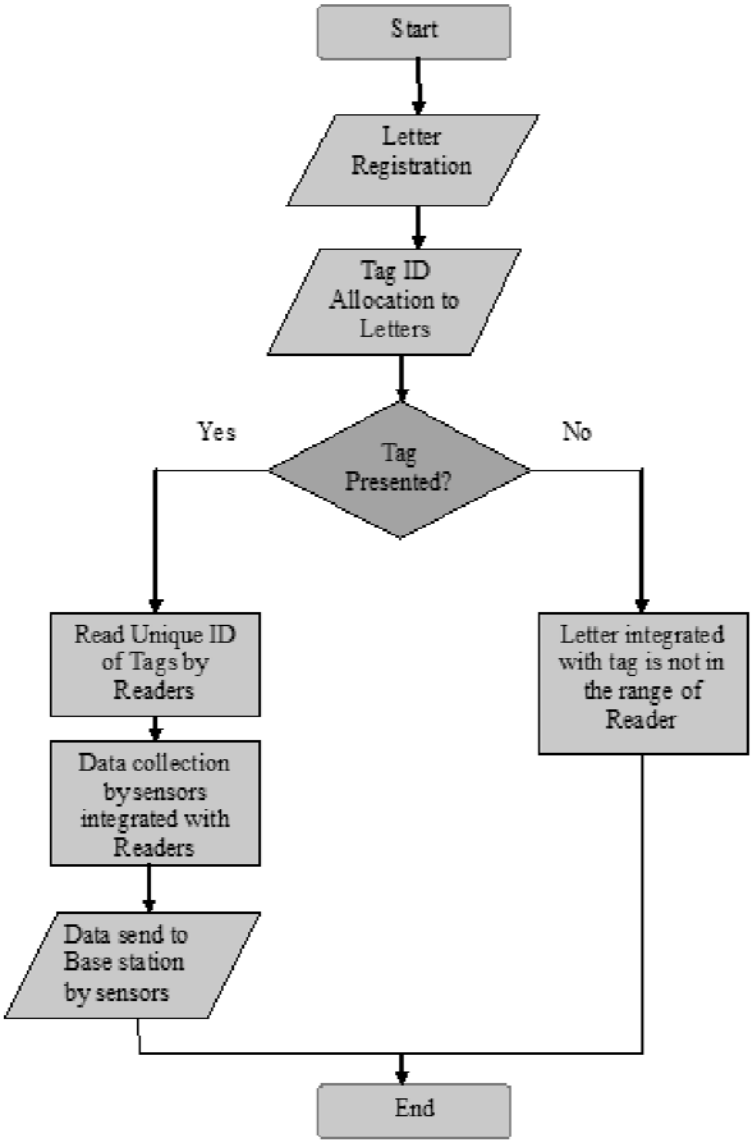

Figure 3 Flow Diagram of Postal Letter Tracking System

4. IMPLEMENTATION DETAILS

In most of the cases RFID system is used for object tracking of various products. Multi-hop communication is not possible in case of RFID System, and range of RFID tags limited to

centimeters [26]. In object tracking system, researchers used RFID system with Geographical Information System (GIS*)* to find appropriate location of objects. There are various techniques of object tracking system have been proposed, which are discussed in chapter 2 that shown effective results.

The current research work is different from the previous models:

(i) The tracking of letter is performed using RFID readers integrated with sensors. The tracking of postal letter is performed using Network Simulator version 2 (NS2). The tool performs for node creation, topology creation and simulation using network animator (NAM).

(ii) Data obtained from the trace file generated after simulation process to find the location of the letter. The trace file is not in readable form, so data from the trace file extracted using awk(interpreted programming language).

Implementation of proposed system for postal letter tracking system has three phases; first phase is configuration of RFID system and sensors, second phase to simulate the movement of tags, last phase to find location of letters using NS2. The three phases performed using random topology based scenario.

(a) ***Phase 1: Network simulation:*** In random topology based scenario, we setup three nodes as readers/sensors, the node 0 is represented as PO1/reader/sensor, node 4 is represented as PO2/reader/sensor, and node 2 is represented as PO3/reader/sensor. Nodes 1, 3, 5 are labeled as tags and labeled tags act as letters. First function is placement or setup position of letter (tag) 3 and 5 at PO2/reader/sensor and letter(tag) 1 at PO2/reader/sensor, the initial locations of letters are operated as source.

(b) ***Phase 2: Movement of letter(integrated with tag):*** Figure 4 demonstrates movement of letters with integrated tags. The figure shows movement of letters with integrated tags 3,5 from PO2 to PO3 and movement of letter integrated with tag 1 from PO3 to PO1.The location of movement is recorded by PO3/reader, when the letter integrated with tag is entered in the region of reader3. The data is read by reader and transmit using sensors to the base stations. DSDV protocol is used to communicate information between sensors.

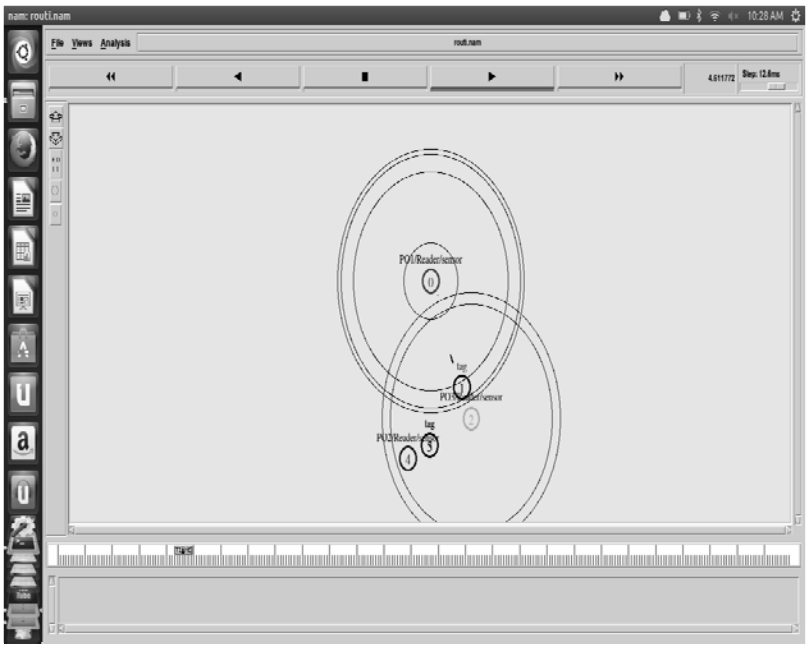

Figure 4 Depicts Movement of Letter(tag) for Random Topology based Scenario

(c) ***Phase 3:*** **Location of letter:** Figure 5 depicts final destination of the letter (tag). Final location of letters (tag) communicates with the help of AODV or DSDV routing protocols. Overall scenario is represented using random topology. Existing wireless sensor nodes are used for communication and deployed RFID system readers with sensor nodes. Data is read by readers and send through sensors to all the locations from source to destination with multi-hop communication. FTP is used for sending message from one location to another.

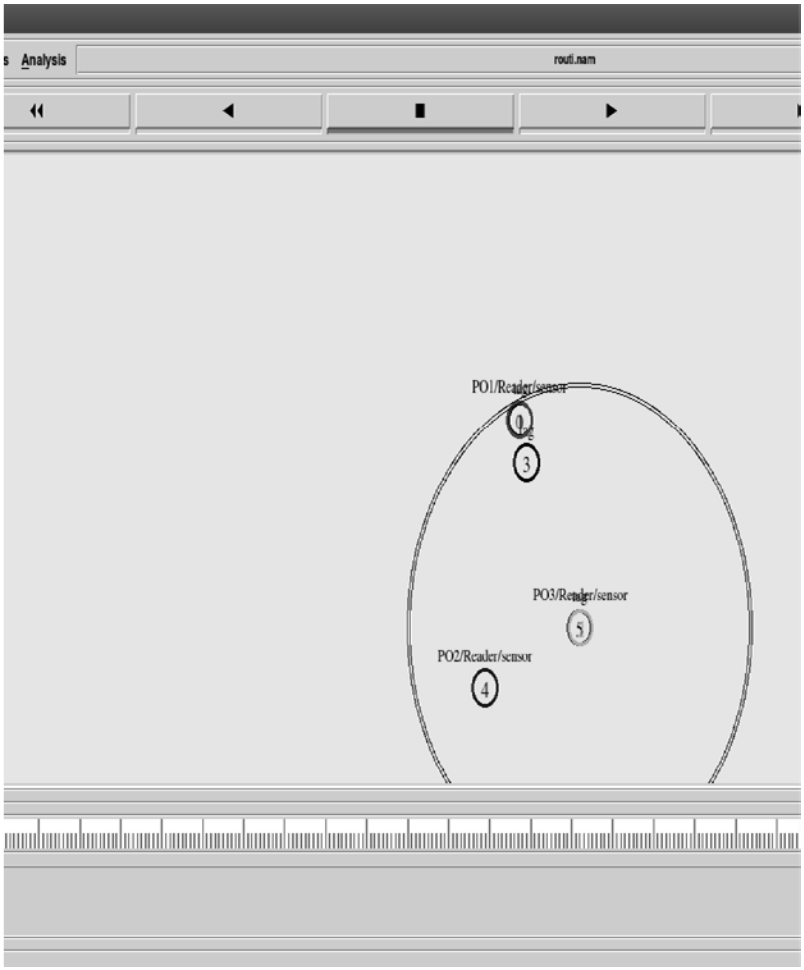

Figure 5 Locations of Letter (tag) for Random Topology based Scenario

5. RESULTS AND ANALYSIS

To find accurate locations of tracked letters play a very important role in real life monitoring and tracking of postal letter. Figure 6 depicts that few locations of the letter integrated with tags 1, 3, 5 are tracked and monitored for random topology based scenario. Letter integrated with tag 5 reached at destination at time 13.466181090. The result shows the locations of movement letters integrated with tags. The location of letter integrated with tag is verified according to the regions or field defined for readers. When letter enters into the new region, then details of tag is read by reader and transmits to the base stations through sensor nodes. New region range is identified and verified a new location of letter. Probability distribution of read count at one position in existing system is 0.099.

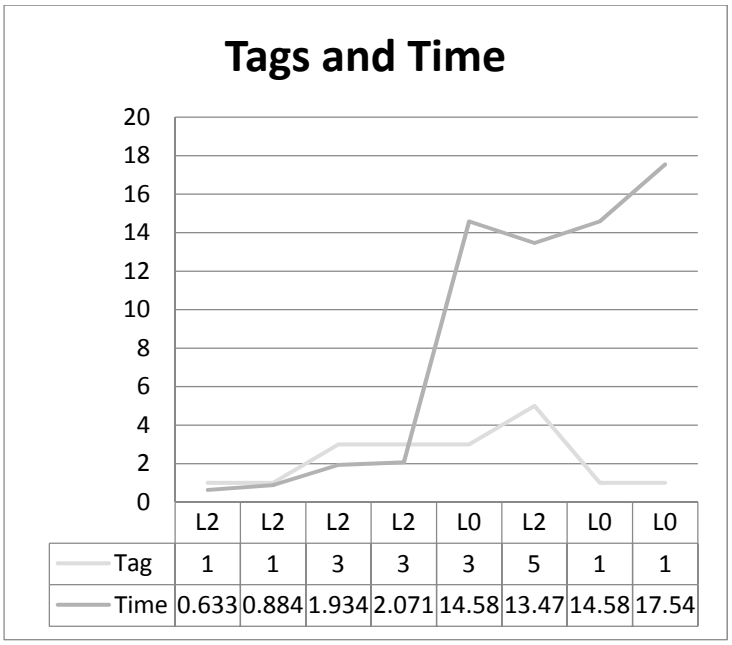

Figure 6 Time and Location for Tags in Random Topology based Scenario

6. CONCLUSION

RFID system and WSNs, both of the systems are used to tracking and monitoring of objects. To find appropriate location identification of object, it is important area of research in the field of object tracking system. Mostly static nodes are used for the WSNs, which is not good fit for tracking of object. Sensor networks can perform for multi-hop communication with limited energy consumptions. In RFID system usually single hop communication is used, and tags can move with attached object. There are two types of tags: active, passive. Active tags are used more power consumption for monitor and record sensor input. Passive tags can be used to reduce to energy consumption. So, individual system is not suitable for object tracking. The integration of RFID system with sensor nodes provides improved performance of object tracking system in term of scalability, portability and expandability.

A postal letter tracking system is able to reduce region non detection problems of sensors. This system is able to find location of letters for real time systems. It transfers information of monitoring details to base stations with multi-hop communication and also reduced visibility problem of RFID tag data. In random topology based scenario, random topology is used to implement the process, this system showcase the multi-hop communication between sensor nodes to update the data at base station as per letter movement details tracked by readers.

References

[1] M. Welsh, D. Malan, B. Duncan, T. Fulford-Jones, S. Moulton, “Wireless Sensor Networks for Emergency Medical Care” Presented at GE Global Research Conference, Harward University and Bosten University School of Medicine, Boston, MA, Mar 2004.

[2] Deshpade, Carlos Guestrin, Samuel R. Madden, Joseph M. Hellerstein, Wei Hong, “Model-Driven Data Acquisition in Sensor Networks” Proceedings of the 30th international conference on very Large Data Bases, pp. 588-599, 2004.

[3] R. Nowak, U. Mitra, “Boundary Estimation in Sensor Networks: Theory and Methods”, Proceeding of the 2nd workshop on information processing in sensor Networks (IPSN’03), Palo Alto, CA, April 2003.

[4] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "A Survey on Wireless Sensor Network", IEEE Communication Magazine, vol.40, pp. 102-114, Augest 2002.

[5] D. Cutler, D. Estrin, M. Srivastva, "Overview of Sensor Networks", IEEE Computer,Vol.37, no.8, pp. 41-49, 2004.

[6] Bonhyun Koo, Kyusuk Han, James J. Park, Taeshik Shon, "Design and Implementation of a Wireless Sensor Network Architecture using Smart Mobile Devices., Published online Springer Science+ Business Media, LLC, July 2011.

[7] P.C. Jain, K.P. Vijaygopalan, "RFID and Wireless Sensor Networks" Proceedings of ASCNT – 2010, CDAC, Noida, India, pp. 1 – 11, 2010.

[8] K. Domdouzis, B. Kumar, C. Anumba, "Radio-Frequency Identification (RFID) Applications: A Brief Introduction", Advanced Engineering Informatics, ELSEVIER, vol 21, no. 4, pp. 350–355, 2007.

[9] "An article on RFID in Packaging Digest", 2014. [http://www.packagingdigest.com/rfid]

[10] H. Deng , "Design of Sensor-Embedded Radio Frequency Identification (SE-RFID) Systems", Proc. IEEE Int'l. Conf. Mechatronics and Automation, pp. 792–796, June 2006.

[11] H. Yang, S.-H.Yang, "RFID Sensor Networks, Network Architectures to Integrate RFID, Sensor and WSN", Measurement and Control, vol. 40, pp. 56–59, 2007.

[12] Hai Liu, M. Bolic, A. Nayak, I. Stojmenovic, "Taxonomy and Challenges of the Integration of RFID and Wireless Sensor Networks", Network, IEEE, vol.22, no.6, pp.26-35, November-December 2008.

[13] Xi Chen, Qianchuan Zhao, Xiaohong Guan, "Energy-Efficient Sensing Coverage and Communication for Wireless Sensor Networks", Springer Science + Business Media, LLC, February 2007.

[14] P. G. Ranky, "Engineering Management-Focused Radio Frequency Identification (RFID) Model Solutions", Engineering Management Review, IEEE , vol.35, no.2, pp.20-30, Second Quarter 2007.

[15] Nandakumar Mysore, Prakash Nenavat, Rasmi S. Unnithan, Ravi Mulukutla, Shrisha Rao, "An Efficient Algorithm for RFID Reader Positioning for Coverage of Irregularly-Shaped Areas", Published in Automation Science and Engineering Bangalore, 5th Annual IEEE Conference, August 2009.

[16] Yingfeng Zhang, Pingyu Jiang, George Huang, Ting Qu, Guanghui Zhou, Jun Hong, "RFID-enabled Real-Time Manufacturing Information Tracking Infrastructure for Extended Enterprises", Published online in Springer, November 2010.

[17] V. Vaidehi, M. Sandhya, J. Karthika, S. Azhagarasan, "Power Optimization for Object Detection and Tracking in Wireless Sensor Networks", IEEE-International Conference on Recent Trends in Information Technology, June 2011.

[18] Jian Zhang, Chengdong Wu, Peng Ji, Tianbao Wang, "A Noble Target Tracking Algorithm Based on Dynamic Clustering for Wireless Sensor Network", Work is supported by National Nature Science Foundation under Grant 60874103, IEEE, 2011.

[19] Wei Zhou, Selwyn Piramuthu, "Consumer Preference and Service Quality Management with RFID", Springer Science+Business Media, February 2012.

[20] Javier G. Escribano, Andres Garcia, "Human Condition Monitoring in Hazardous Locations using Pervasive RFID sensor tags and energy-efficient wireless networks", Published online in Journal of Zhejiang University-SCIENCE C, Springer-Verlag Berlin, Heidelberg, June 2012.

[21] M. Senthamilselvi, N. Devarajan, "A Distributed Coverage and Target Tracking Algorithm for Wireless Sensor Networks", Journal of Computer Science, 2012.

[22] Dian Zhang, Yunhuai Liu, Xiaonan Guo, Lionel M. Ni, "RASS: A Real-Time, Accurate, and Scalable System for Tracking Transceiver-Free Objects", Parallel and distributed systems, IEEE transactions, vol. 24, no. 5, May 2013.

[23] Antonios Bouzakis, Ludger Overmeyer, "Position Tracking for Passive UHF RFID Tags with the Aid of a Scanned Array", Published online in International Journal Wireless Information Networks, Springer, June 2013.

[24] Shung Han Cho, Kyung Hoon Kim, and Sangjin Hong, "Effective Object Identification and Association by Varying Coverage Through RFID Power Control", Journal of computer science and technology, Springer Science + Business Media, LLC & Science Press, China, January 2014.

[25] Junho Park, Dongook Seong, Hyunju Kim, Kisoon Park, Byoungyup Lee, Jaesoo Yoo , "A Data-Centric Storage Scheme for High Storage Utilization in Wireless Sensor Networks", Springer Science+Business Media, New York, February 2014.

[26] A. Mason, A. Shaw, A.I. Al-Shamma'a ,T. Welsby, "RFID and Wireless Sensor Network Integration for Intelligent Asset Tracking Systems" ,General Engineering Research Institute (GERI), Liverpool John Moores University, Liverpool, L3 3AF, April 2006.