

HYBRID ZIGBEE RFID FOR DETECTION OF ACTIVE TAGS AND ENERGY MINIMIZATION

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ABSTRACT

Radio Frequency Identification (RFID) is the wireless use of electromagnetic fields to transfer data for the purpose of automatically identifying and tracking tags attached to objects. These tags contain electronically stored information and each tag has a unique identification number. RFID can support automatic information tracing and management during the identification process in many fields. Minimization of energy in RFID active tags plays a vital role in RFID management system. We propose a hybrid method for energy minimization using Zigbee integrated with RFID. The combination of RFID and ZigBee can be done with a very simple set up and it can manage all the data transmissions with very few bytes. Zigbee is used because it is a low power device and operates in beacon mode. Zigbee coordinator is responsible for managing and controlling the entire system. It transmits the data received by one reader to another thus eliminating redundant tag information from all the readers. Collision among tags is minimized thus increasing the throughput of the system.

Keywords: *RFID, Zigbee, coordinator, beacon, slotted aloha, collision.*

1. INTRODUCTION

In earlier days barcode was used to track the objects using the barcode scanner. The scanner could be used to detect the objects only within 15ft. Barcodes do not possess read and write functionalities and they contain the information of only the manufacturer and the product. Barcodes have less security features than RFID; as they can be easily forged. To scan any product the barcode data should be present outside the product. The scanning waves does not penetrate through metal or liquid. If any damage on the barcode data the scanner will not be able to detect the product. The main disadvantage with the barcode is that the product and the scanner should be in line of sight and that only one product could be scanned at a particular instant of time. Multitasking is not possible under a barcode scanner. To overcome these disadvantages RFID is used which is a tagging system that uses radio frequency identification devices for tracking and detection purposes.

1.1 RFID

An RFID tagging system includes the tag, a read/write device, and a host system application for

data collection, processing, and transmission. An RFID system with components is shown in Figure: 1. An RFID tag which is also called as a transponder consists of a chip, memory and an antenna. In a basic RFID system, tags are attached to the items that are to be tracked. These tags are made out of a tiny chip called an integrated circuit (IC) which is connected to an antenna. The tag chip contains memory which stores the product's electronic product code (EPC) and other variable information so that it can be detected and read by RFID readers anywhere. The tags used in RFID environment are of three types: passive tags, active tags and semi passive tags. Passive tags are not battery powered, so they use the energy from the reader to send the data back to the reader. Active tags are battery powered and they use their own power to send the data to the reader. An RFID reader is a network connected device (fixed or mobile) with an antenna that sends power as well as data and commands to the tags. Fixed RFID reader implies to a specific interrogation zone and detects the tags which move in and out of the coverage area. Mobile RFID reader is handheld and is not operated under a specific area. The reader is mobile and detects the tag which moves in and out of its interrogation zone. RFID is a non specific short

range device which uses frequency bands to perform its operations. Nevertheless, RFID has to be compliant with local regulations (ETSI, FCC etc.) Reader queries the tags on different frequencies. The frequencies depend on the type of application that is executed. Proximity (short range) and Vicinity (long range) are two major application areas where RFID technology is used. Track and trace applications are long range or vicinity applications. This technology provides additional functionality and benefits for product authentication. Access control applications are Short range or proximity type of applications. Low frequencies (LF) : 125 kHz - 134,2 kHz are used in logistics and traceability applications. High frequencies (HF): 13.56 MHz, ultra high frequencies (UHF): 860 MHz - 960 MHz and super high frequencies (SHF) or microwave frequencies : 2.45 GHz are used in military and shipment applications.

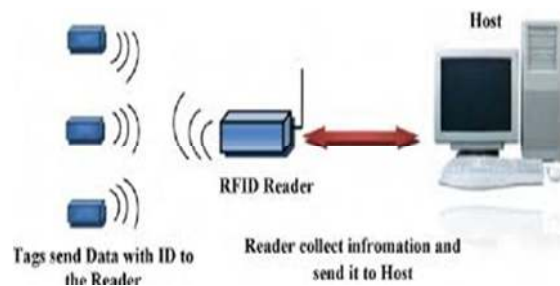


FIGURE 1: An RFID System Illustration

1.2 ZIGBEE Technology

Zigbee is a wireless communication technology which aims at providing reliable, cost-effective, low-power, wireless monitoring and tracking objects. Zigbee uses IEEE 802.15.4 as the communication standard. Zigbee is suitable for applications that require reliable low data rate within a short range. 250kbps data rate is suitable for monitoring and control systems. 40 kbps data rate is suitable for home automation systems. Zigbee can organize a network which manages 65,535 network devices with simple network ability. Zigbee is a very low-power technology as the nodes transmit data only during specific intervals of time. It provides a beacon mode of data communication which switches between active state and sleep state.

Zigbee can provide excellent peer-to-peer communication. Zigbee supports three types of

topologies for its functionality star, tree and mesh as shown in Figure 2. Star topology is the simplest one. Each device communicates with a centre device which is the hub called as the coordinator. The coordinator is responsible for communicating the message from one device to another. It performs the functions of relaying and receiving data. The main disadvantage in the star topology is that if there is a problem with the coordinator the entire network fails to function. In a tree topology the top node is the coordinator. If a sub node wants to communicate with the neighbor node it sends the data to its ancestor node which will relay back the message to the neighbor node. The disadvantage in this technique is that the data transmission causes delay in the communication if the tree consists of many nodes and sub nodes. Another flaw in the topology is that if the ancestor node fails the data transmission among the nodes will not be possible as like the star topology. To function as the mesh topology all the nodes in the network can transmit data to all the other nodes in the network. The mesh topology is faster than the tree and star topology when the network is large.

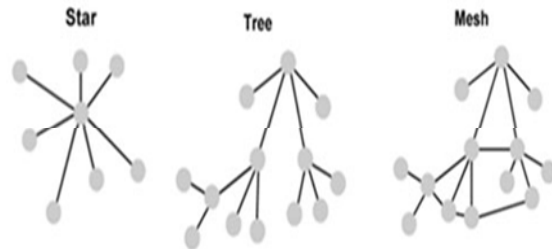


FIGURE 2: Zigbee topology models

2. HYBRID ZIGBEE – RFID

ZigBee has the advantage of supporting advanced sensor networks and RFID is suitable for low-power wireless tracking of people and objects. By combining these two technologies it is possible to create a ZigBee mesh network with integrated active RFID tracking capability one in which RFID tags within the network can communicate with each other. The combination of RFID and ZigBee has two great advantages: it can be done with a very simple set up and it can manage all the data transmissions with very few bytes. Zigbee technology can be implemented on the RFID devices as shown in Figure 3. RFID server is generally a high computing ability with external power source and large memory. All RFID readers possess large memory and microprocessor. Passive and semi passive RFID readers' power

consumption is higher when compared to Zigbee and they usually depend upon an external power source. The active readers may be powered by batteries but as they have a similar or higher power consumption level than the Zigbee devices they can still support a Zigbee module and achieve a reasonable battery life. The tags act as the zigbee end device which transmits the data. The active tags are battery powered and implemented with zigbee technology which conserves the battery life. Zigbee supports the following types of communication:

- Communication between a reader and a server
- Communication between two readers
- Communication between a reader and an active RFID tag

For a reader to server communication the server acts as the coordinator and readers as the nodes which will transmit the data to the server through routers. Topology will be a star topology in case of a reader to server communication. To enable a Reader-reader communication a hybrid mesh network is formed. The server and all the readers comprise a mesh network, in which the server acts as the coordinator, the readers will be the Zigbee routers and the active tags will act as the Zigbee end nodes. The tree structure model is used for reader to active tag communication. The tag transmits data to the reader which in turn communicates with the coordinator.

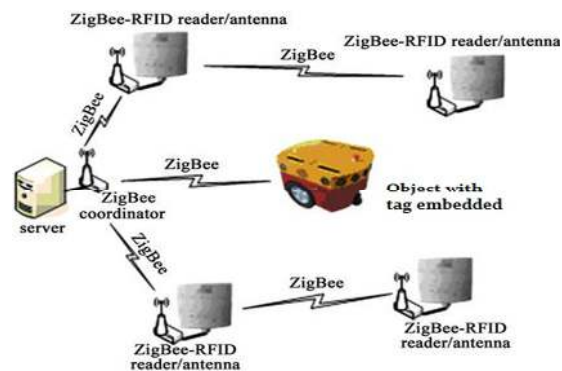


Figure 3: Fusion of Zigbee and RFID for object tracking

The data transmission speed for zigbee networks are between 20 kbps to 250 kbps and the power consumption in zigbee devices is low when compared to that of wifi and Bluetooth. The important characteristic in zigbee is multi hop communication. The readers can be at a far distance from the server and the data can be communicated to the server through multi hop technique. So not necessarily all the readers be near to the server. If

any one reader is near the server the data from all the other readers can be communicated through the multi hop technique.

3. RELATED WORK

Farhana Ahmad Poad and Widad Ismail [1] proposed active RFID system based on a switching technique between indoor and outdoor location. The effectiveness of the proposed RFID system is evaluated based on the communication protocols of reader and tag scheduling to collect multiple tags in the RFID system. It is shown that the system with TTF protocol is better than the RTF protocol in terms of data collision and average time delay while performing transmission and reception processes.

Medagliani et al [2] proposed hybrid zigbee RFID architecture which implements a deep sleep algorithm. The RFID controller is used to turn the nodes on and off thus minimizing the power of the tags used in the system. The architecture is monitored under a virtual spatial grid with the objective of at least one cell active at a particular instant of time.

Tao Li Shigang Chen et al [3] proposed efficient recognition of tags for Radio Frequency Identification (RFID) systems. It is difficult to collect all tags in a large-scale scheme from side to side using a handheld RFID reader. The person who reads has to move approximately due to the incomplete message range of tags. The focus is on the minimization of power usage of the reader.

Wen Luo et al [4] proposed Radio Frequency Identification (RFID) technologies were poised to revolutionize retail, warehouse, and supply chain management. The proposed technique is to automatically detect missing tags in a large storage space which may have to be performed frequently to catch any missing event such as theft in time. Algorithm is implemented for both energy efficiency and time efficiency. It achieves multifold reduction in both energy cost and execution time when compared to the existing algorithms. It reveals a fundamental energy-time tradeoff in missing-tag detection which can be flexibly controlled through a couple of system parameters in order to achieve desirable performance. Protocol design is extended to consider channel error under two different models. Energy/time cost will be higher in unreliable channel conditions.

Bogdan Carbutar et al.,[5] addressed three important problems associated with tag detection in RFID systems: (i) accurately detecting RFID tags in the presence of reader interference (ii) eliminating redundant tag reports by multiple readers and (iii) minimizing redundant reports from multiple readers by identifying a minimal set of readers that cover all tags present in the system.

Aslam Khan et al [6] implemented attendance monitoring system for institutional purpose using Zigbee and RFID. RFID devices are installed and the passive types of tags are used for implementation purposes. Tags are energized by RF field and based on the verification of the student the attendance is generated and stored in the database.

Zhipeng Song [9] discussed the network load balancing, saving overall energy consumption of the network, and maximizes the lifetime of the network through the Zigbee network tree routing algorithm which establishes a network layer path of energy efficiency, reliable data forwarding mechanism of formation and prolongs network lifecycle.

Boonsong et al [15] proposed the implementation of Smart Power Meter (SPM) using embedded active RFID tag with Wireless Sensor Network (WSN) for identification and monitoring of data to analyze and improve the link quality of multi-hop performance in real environment application.

The contributions made in this paper are (1) Determination of tags using integration of Zigbee and RFID technology (2) minimizing battery power of active tags (3) Increase in throughput of RFID system. In this paper we propose tag determination technique using Zigbee coordinator as the parent node for transmitting the data between the readers.

4. PROPOSED METHOD

In a basic RFID system the reader identifies the tags by sending the frame size and a random number to all the tags. The tags upon receiving the frame size and random number perform hash function with the random number and the tag's ID value to compute the slot number into which the tag has to fit in. Through this slotted aloha technique the tags which form a single slot are detected by the reader. The process is iterated for the tags that are regarded under collision slots.

The other method of tag identification is the tree based protocol method in which the tags are split into a binary tree format and when the reader queries with the value, the branch of the tree that matches the reader's value is selected and the concerned tag is identified. The tree based protocol is performed when two or more tags form collision under the frame slotted aloha protocol. The two types of collision that makes the tags to be unidentifiable by the reader are the tag collision and reader collision. Tag collision occurs when two or more tags respond at the same time to the reader. Reader collision occurs when two readers attempt to read the same tag which makes the tag undetectable.

To save the battery life of active tags that participate in the tag detection process Zigbee based RFID system is proposed. The main advantage of using Zigbee in the proposed model is that it is a low power device and the Zigbee devices function under a beacon mode which transmits data when needed and goes to sleep mode thereby conserving the battery life of the devices. Active tags with Zigbee can be used up to long distances and Zigbee is a good radio standard for low power consumption.

The proposed method involves tag detection process using the Zigbee coordinator which switches on the readers sequentially and transmits the tag information collected by one reader to the other reader to reduce the redundancy of data. Proposed method is discussed in detail below.

4.1 Tag Identification and Searching

In the tag identification mechanism the two types of communication can be executed in RFID system; TTF (Tag Talks First) and RTF (Reader Talks First). Zigbee coordinator controls and manages all the devices, Routers are used to route the data between readers and the coordinator. In the TTF functional mode the tags send the data to the reader periodically. Zigbee based active tags are deployed which send the information to the Zigbee based RFID reader during beacon intervals when the tags are in active mode. During non beacon mode the tags do not transmit the data to the reader. During the RTF mode the reader transmits query to all the tags. The tags that are detected by the reader are sent to the coordinator. During both TTF and RTF modes the tag information is sent to the coordinator by placing the Zigbee node's physical

address before the tag id in the format *<zigbee node physical address, tag id>*.

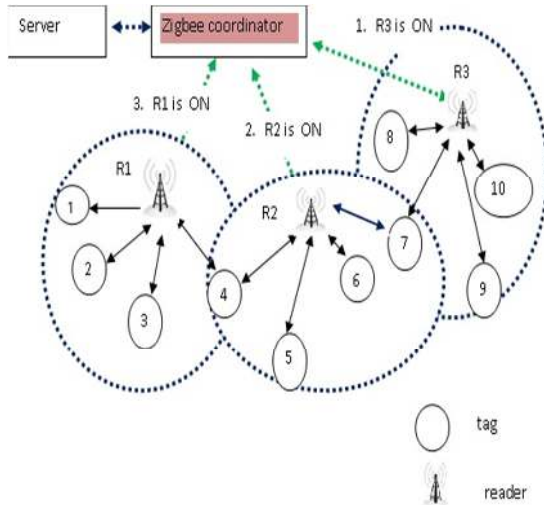


Figure 4: Tag detection in Zigbee based RFID network

The zigbee coordinator is responsible for the network formation. It issues requests to all devices for network formation. Zigbee devices respond to the request, discover the network and joins. Consider in Figure 4, the tags {t1,t2,t3,t4} are in the vicinity of reader R1; tags {t4,t5,t6,t7} under R2 and tags {7,8,9,10} under coverage area of R3. The coordinator sequentially switches the readers to ON state to perform tag collection process. Consider the Figure 4 for tag detection model. The coordinator activates reader R3 to perform tag collection. Reader R3 performs tag collection process by executing slotted aloha protocol and sends the coordinator the details of the tag identified by attaching the corresponding Zigbee node's physical address before each of the tags present in the slot. In the next iteration coordinator activates reader R2. The coordinator sends the tag details collected by R3 to R2 through the router. Tag 7 is in the vicinity of both reader R3 and R2. Since Tag 7 is already detected by R3, it will not be detected by reader R2. So R2 replies with the tag details of {4,5,6} to the coordinator. The same process is repeated when the coordinator activates reader R3. R3 returns to the coordinator the tag values of {1,2,3} only and ignores {4} as it was already detected by R2. In the proposed model reader to reader communication is executed through the coordinator which follows a tree like topology function. The coordinator sends to the server the tags collected the readers. By checking up with the database of the server the tags that are not identified

can be known. Since beacon type of operation is involved in tag monitoring under Zigbee network the battery life of the active tags are conserved which corresponds to energy efficiency. The algorithm for tag detection is given below. Table 1 shows the notations in the algorithm. Figure 5 represents the flowchart for the tag detection process.

Table 1: Notations used in the algorithm.

Notations	Meaning
N	Total number of readers
Id	Tag unique identification number
F	Frame size generated by the reader
R	Random number generated by the reader
H(.)	Hash function

Algorithm for tag detection

- 1.a: coordinator forms the network formation process. Coordinator issues commands to all the devices to join the network.
- 1.b: coordinator switches the readers to 'ON' state to perform tag detection.
- 2: **for** readers $\leftarrow 1$ to n **do**
 while (tag mode \neq sleep)
 Reader receives the tag information
- 3: Reader returns the tag detected information to the coordinator in the format *<zigbee node physical address, tagId>*
- 4: coordinator activates the next reader and sends the tag information received by the previous reader
- 5: Reader checks the information of tags received
- 6: If the incoming tag id matches with the information sent by the coordinator it is ignored
- 7: Else the tag information is stored in the reader's database
- 8: Steps 2 to 7 is carried out for all the readers in the network
- 9: coordinator performs aggregation of the tag details which is then updated onto the server.

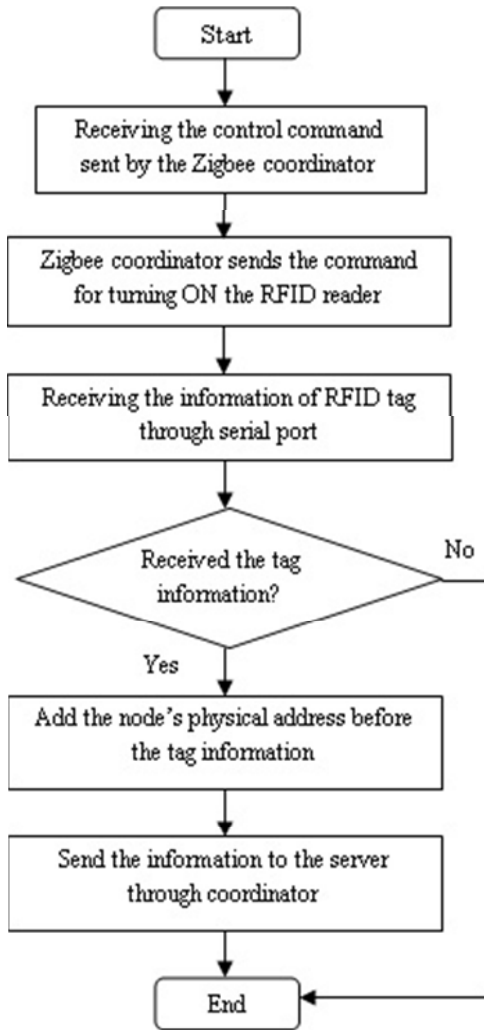


Figure 5: Flowchart for Zigbee based RFID tag detection

4.2 Energy Efficient Tradeoff

Since active tags are used in the proposed system model it consumes battery power. But through the beacon mode of periodical tag responding to the reader the battery power of the active tags can be consumed which leads to long battery life. The residual energy for each zigbee node active tags is calculated by :

$$Er(t) = Ei - Ec(t) \tag{1}$$

Equation (1) implies that the residual energy can be calculated with idle time and energy consumed during data transmission and receiving the input from the reader during a time period (t). Ei is during the tag idle state and Ec(t) is the battery power consumed during data transfer.

$$Ec(t) = Ec TX(t) + Ec RX(t) + Ei idle(t) + Ec sleep(t) \tag{2}$$

Energy consumed is calculated using equation (2). Ec TX(t) is the battery power consumed to transfer the tag data to the reader during the time period (t). Ec RX(t) is the battery power spent by the tag to receive the signal from the reader. Ei idle(t) represents the battery power during the tag idle state at the time period (t) and the Ec sleep(t) is the energy consumed during sleep state of the tag.

$$Ec(t) \approx KTX + KRX * t = Ktot * t \tag{3}$$

KTX – power consumed during data transmission
KRX- power consumed during reception of readers query. Using equation (3) in (1)

$$Er(t) \approx Ei - Ktot * t \tag{4}$$

Thus the final residual energy is given by the power used in transmission and reception of data to and from the reader at time t.

5. ADVANTAGES OF ZIGBEE WITH RFID

- i. Power consumption of zigbee devices is less when compared to that of wifi and Bluetooth
- ii. Multi hop routing is implemented with zigbee networks so that all the devices need not be near to the server. Only one device can communicate with the server.
- iii. Zigbee enables RFID to integrate with a wireless sensor network.
- iv. Zigbee RFID integration provides low data rate and a secure network.
- v. Using Zigbee wireless RFID system can be established with greater flexibility.

6. RESULTS AND DISCUSSIONS

We have conducted the implementation of tag detection with only RFID and then using the hybrid model (Zigbee+RFID). The results obtained from RFID and the proposed model are compared and discussed below. The experimental setup values that were assigned during the implementation of the proposed protocol is shown in Table 2.

Table 2: Experimental setup values

Parameter	Values
Number of tags	500
Length of original ID	96 bit
Number of readers	4
Reader communication range	14 m
No of slots in a read cycle	10
Tag velocity	2m/sec
Reader -> Tag Request packet size	88 bits
Tag -> Reader Response packet size	80 bits
Beacon duration	5 sec

Table 3 shows the power consumption values that were obtained after experimenting with different frequencies. Figure 6 represents the frequency and power consumption during transmission mode for RFID and hybrid technology. Power consumption of devices increases with the increase in frequency. But since zigbee is a low power device power consumption in the hybrid model increases when compared to that of RFID.

Table 3: Frequency Vs Power consumption TX mode

Frequency(MHz)	Power consumption (mA)	
	RFID	Zigbee + RFID
856	19	23
889	21	26
912	24	31
935	28	36
968	32	39

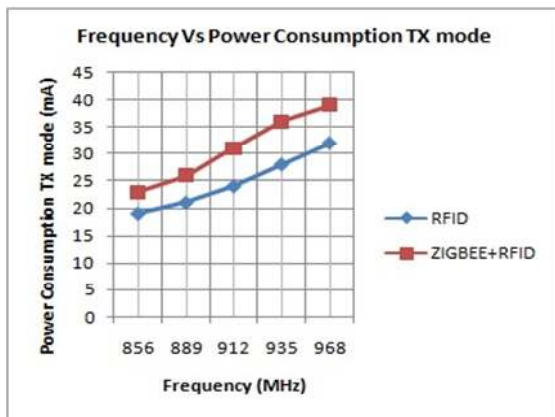


Figure 6: shows the frequency and the power consumption for RFID and hybrid model

Table 4 depicts the energy efficiency values in percentage by increasing the number of tags in RFID environment. The graph in Figure 7

represents the number of tags used for experimentation purpose and their energy efficiency. Energy efficiency is the goal to reduce the amount of energy consumed during tag detection. Active tags are used for experimental purpose. Active tags are battery powered tags which use their own power supply for data transmission and reception of signal from the reader. Zigbee uses beacon mode for data transfer and the battery power of active tags are conserved and this results to longer battery life. Thus the energy efficiency is higher in the proposed model when compared to that of RFID systems.

Table 4: No. of tags Vs Energy Efficiency

No of tags	Energy Efficiency %	
	RFID	Zigbee + RFID
35	0.15	0.17
75	0.142	0.171
100	0.16	0.18
200	0.17	0.19
300	0.18	0.194
500	0.184	0.198

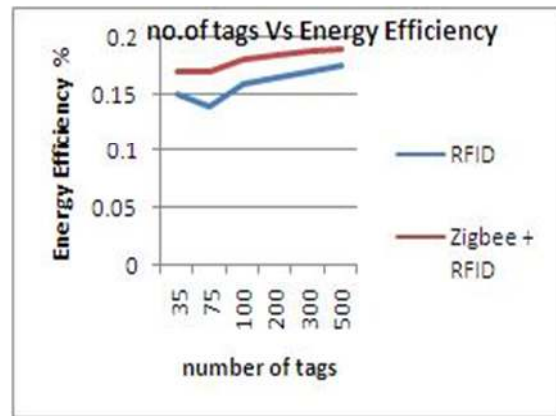


Figure 7: indicates energy efficiency values for the tags in the network

Latency is the round trip time taken to receive the radio signal from the reader and to transmit the data back to the reader. Equation (5) denotes the calculation of latency time.

$$Latency (ms) = N [Duration of a read cycle + (Duration of a single slot * no. of slots)] \quad (5)$$

N - Number of interrogation cycles

During implementation the duration of read cycle was 1.43 ms and duration of a single slot was 0.13 ms.

Since zigbee is a multi hop technology each node sends the data to the coordinator through the

zigbee routers which are nearby. The data collected by the reader is forwarded to the nearby router which transmits it hop by hop to the coordinator and then to the server. Hence the proposed model encounters delay and moreover during each iteration the coordinator has to communicate the data collected by the previous reader to the next reader. Thus the execution time also increases with the increase in delay as shown in Figure 8 with the results tabulated in Table 5.

Table 5: Read Range Vs Latency

Read range (m)	Latency (ms)	
	RFID	Zigbee + RFID
0.7	96	99
0.9	88	97
5	82	90
11	80	87
12	62	70
14	59	63

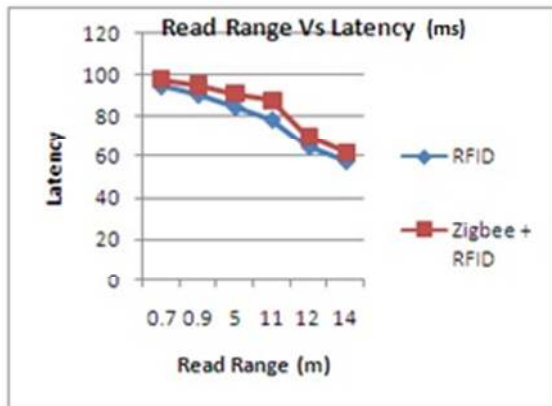


Figure 8: depicts the read range of tags and latency measure

To summarize the results section the proposed hybrid model outperforms the tag detection techniques which uses RFID through power consumption and energy efficiency of the system. However collision ratio and its detection techniques are considered as a future work.

7. CONCLUSION AND FUTURE WORK

Tag detection process using zigbee technology integrated with RFID has been proposed. Since Zigbee is a low power device that functions under beacon mode it can be used to save the battery life of active tags thus leading to energy trade off. Also since the coordinator sends the tag information collected by one reader to the next reader collision among the tags could be avoided and redundant data to the coordinator can be ignored. The

proposed method encounters increase in execution time during tag detection process as the tag details collected by one reader are sent by the coordinator to the next reader to perform tag collection. The future work is to focus on tag detection with minimized execution time and to address the collision among tags if any.

REFERENCES:

- [1] Farhana Ahmad Poad and Widad Ismail, “An Active Integrated Zigbee RFID System with GPS Functionalities for Location Monitoring Utilizing Wireless Sensor Network and GSM Communication Platform”, *Transactions on Engineering Technologies*, Springer, 2015, pp. 495-506.
- [2] Medagliani, G. Ferrari, M. Marastoni, “Hybrid Zigbee–RFID Networks for Energy Saving and Lifetime Maximization”, *Electric Power Energy Research*, Vol. 54, No. 2, 2010, pp. 101-111.
- [3] Tao Li Shigang Chen and Yibei Ling “Efficient Protocols for Identifying the Missing Tags in a Large RFID System”, *IEEE/ACM transactions on networking*, vol-1, pp no.35, 2013.
- [4] Wen Lou, Shigang Chen, Yan Qiao and Tao Li “Missing-Tag Detection and Energy-Time Tradeoff in Large-Scale RFID Systems with Unreliable Channels” *IEEE/ACM transactions on networking*, June 11-14, 2012.
- [5] Bogdan crabiner, Murali Krishna Ramanathan, Mehmet Koyukuk, Suresh Jonathan and Ananth Grama “Efficient Tag Detection in RFID Systems” *ACM Transaction on Networking*, vol-3, pp no.37, 2010.
- [6] Aslam Khan, Akshay Patil, Viral Shah and Mansi Kambli, “Attendance Monitoring System Using ZigBee and RFID”, *International Journal For Research In Emerging Science And Technology*, Volume-2, Issue-2, 2015.
- [7] Yanmin Zhu, Wenchao Jiang, Qian Zhang, Haibing Guan “Energy-Efficient Identification in Large-Scale RFID Systems with Handheld Reader”, *IEEE Transactions On Parallel And Distributed Systems*, vol-25, pp no.5 May 2014.
- [8] Yuanqing Zheng and Mo Li “Fast Tag Searching Protocol for Large-Scale RFID Systems”, *IEEE/ACM Transactions On Networking*, vol-21, ppno.3 June 2013.
- [9] Zhipeng song, “ZigBee Network Tree Routing Algorithm based on Energy Balance”,

- International Journal of Smart Home, Vol 9, No 4, 2015, pp 85-96.
- [10] Yuhao Wang, Yi Liu, Henry Leung, Rongling Chena and an Li “A Multi-Bit Identification Protocol for RFID Tag Reading”, *IEEE Sensors Journal*, vol-13 pp no.10 October 2013.
- [11] Chenglong Shao, Taekyung Kim, Jieun Yu, Jihoon Choi and Wonjun Lee “ProTaR: Probabilistic Tag Retardation for Missing Tag Identification Large- Scale RFID Systems” *IEEE Transactions on Industrial Informatics*, August 31,2014.
- [12] S.Srinivasa Rao, E. G. Rajan , K. Lalkishore, “ASAF ALOHA Protocol for Dense RFID Systems”, *Wireless Communications*, 66:667–681, Springer, 2012.
- [13] Karsten Fyhn, “Fast Capture - Recapture Approach for Mitigating the Problem of Missing RFID Tags”, *IEEE Transactions On Mobile Computing*, Vol. 11, No. 3, March 2012.
- [14] S. Schneegans, P. Vorst and A. Zell, “Using the RFID snapshots for mobile robot self-localization,” in *Proc. of the European Conf. on Mobile Robots (ECMR)*, Freiburg, Germany, 2007.
- [15] W.Bonsong, W.Ismail, “Multi-hop Performance of Smart Power Meter Using Embedded Active RFID with Wireless Sensor Network”, International conference on robotics, vision, signal processing and power applications, pp 547-554, 2016.