Collaborative Communication of Active RFID Tags for Warehouse Asset Management

Amenah Arooj†, Dr. Muid Mufti†† and Dr. Habibullah Jamal†††,

†Scholar of Electrical Engineering, University of Engineering & Technology, Taxila, Pakistan
††Head of Research, ID Technologies, Canada
†††Professor of Electrical Engineering, University of Engineering & Technology, Taxila, Pakistan

Summary
Radio Frequency Identification (RFID) is the wireless adhoc networking identification technology used to identify, arrange, sort, monitor people and objects upto a certain range without line of sight between reader and tag. Because of this ability, RFID technology has left behind the other identification technologies especially bar code technology in various fields. [2]
This paper discusses the working of Active RFID Tags in large warehouses, the methods to identify all containers using only one reader, the problems associated with it and the solution to the problems. Because the range of the reader is limited, so in large warehouses certain tags may not come within the range of the reader. So when an inquiry is made by these tags, it may not reach direct to the reader. For this an intermediate propagation protocol is needed which can effectively increase the range of the reader to the last unidentified tag. This methodology implies adhoc routing which have been described in this paper. In the end a secure protocol has been suggested which covers the whole scenario.
Key words:
RFID, Active Tag, Adhoc, Neighbor, Routing

1. Introduction

The RFID system is the automatic identification system which mainly consists of two components:
RFID Reader (commonly known as interrogator)
RFID Tag (commonly known as transponder) [1]
Both of them are connected to the host computer which transfers data between the RFID network and the system where databases are operating. [2]

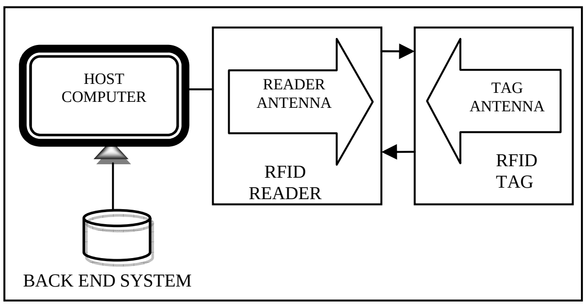


Fig. 1 A Radio Frequency Identification System [3]

Manuscript received February 5, 2011
Manuscript revised February 20, 2011

A brief description of the basic components is as under:
a) RFID Reader
An RFID reader is an object which is usually placed at the entrance of the warehouse. It also consists of an integrated circuit (IC) and an antenna for communicating with the tags. When a tag enters the read range of the reader, the tag transmits its stored data to the reader. The information received by the reader from the tag is sent back to the system through network interface [2]. In large warehouses with more than one entrance, readers are placed at each entrance and all readers can be grouped together with one back end system.
b) RFID Tag
An RFID tag is an object that is placed inside the product to be identified. It also consists of an IC and an antenna for transmitting and receiving information. In warehouses, RFID tags are implanted to the every incoming container. These tags store many kinds of information about the containers, including serial numbers, time of arrival and departures, contents of the containers, and much more. RFID tags are of three types: passive, semi passive and active.

1.1 Why Is Active Tag Used?

The status of the containers changes rapidly in a day. So it is burdensome to manage their data at every instant with a paper and a pencil. Moreover there will be greater chance of false data entry and work delay. Therefore to avoid this situation, we have used RFID system with active tags to keep the pace of the work fast and correct.
Active tags have following advantages over the passive tags:

- Active tag has its own transmitter and receiver with a power source.
- Active Tag can itself initiate transmission at any time, without being activated first by the reader because of its built-in decision-making ability.
- It can read, update and receive data from neighbor tags at distances much greater than passive tags.[1]

- Active Tag has the ability to communicate with the multiple tags simultaneously-nearly at a rate of about 50 tags per second.[4]

The read range of the reader is limited and it is not possible for a reader to communicate directly with the farthest tag. But the communication can be made possible via other tags i.e. a path is defined and the reader sends its data to the first tag within its range and then this tag sends data to the next tag and so on until it reaches the last tag. It makes a wireless adhoc network in which tags communicate with each other and with the reader.

The scope of this research paper is to design a secure routing process for the current scenario and to propose an anti collision algorithm for secure tag to tag and tag to reader communication.
In Section 2 of the paper, we describe the RFID system in a large warehouse. In Section 3, a secure Network Discovery Process by the reader and tags and the Data Communication process between the reader and last tag have been shown. In section 4, we have given a propagation delay graph and a discovery time graph for our proposed algorithm.

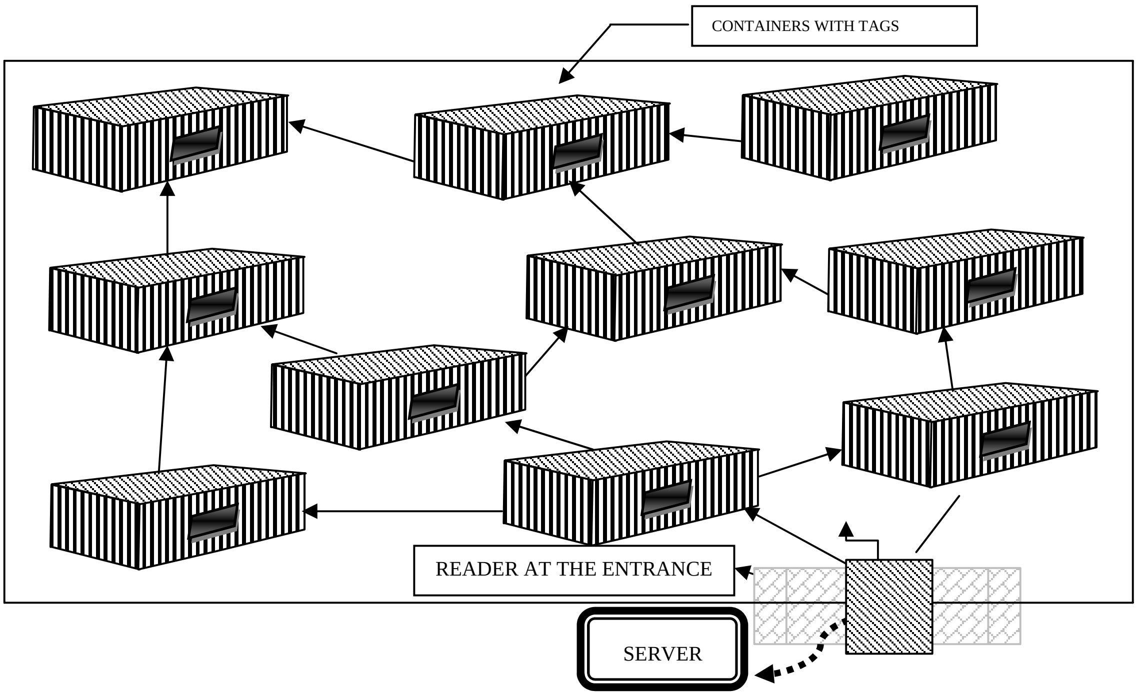


Fig. 2 Warehouse Asset Management with RFID system

2. Implementation of RFID System in a Warehouse

Consider a warehouse in which several containers are placed at farther locations. . Each container is furnished with a unique tag for information processing and all the tags are networked together with a reader which is placed at the entrance of the warehouse (Fig 2). The reader must keep the record of all tags in the warehouse so that we can get the following information about the containers:

- Time of arrival of containers
- Time of departure of containers
- Suspected Tampering in containers
- Change of status of containers (full or empty)
- Change of location of containers
- Contents of shelf

Various techniques can be used for wireless networks but in our situation the algorithm should meet the following criteria:

- Every tag in our system should keep the record of its neighbors.

- The algorithm must avoid tag to tag and tag to reader collision.

- All the tags in our network should be accessed by only one reader
- A path must be defined from the reader to the last tag such that there are minimum numbers of hops and minimum signal strength.

For simplicity, we consider 5 containers containing tags and 1 reader in the warehouse.

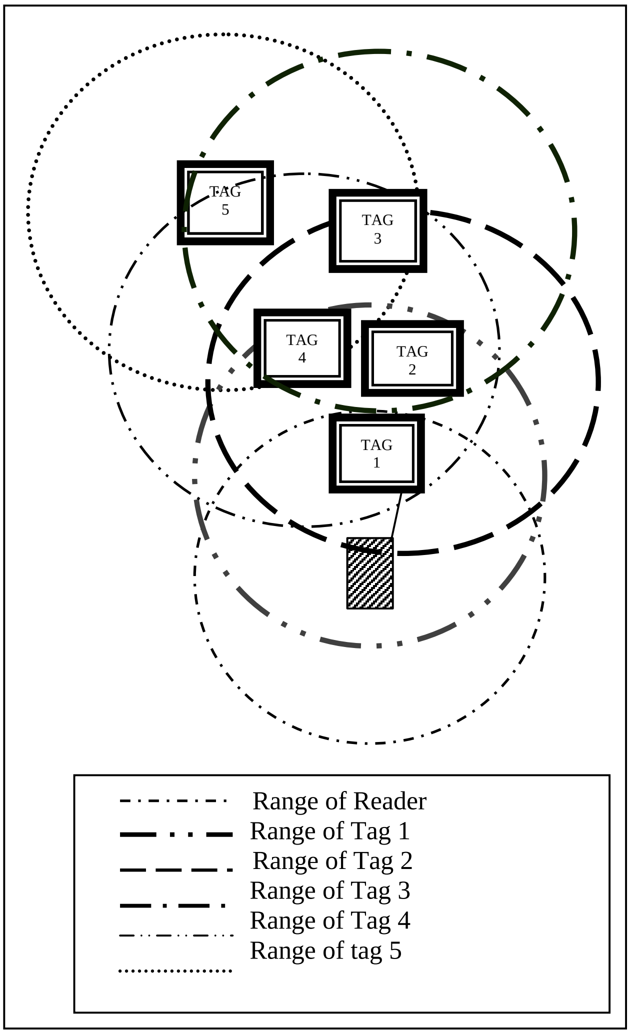


Fig. 3 Proposed RFID Adhoc Network for long distance communication

The reader and tags make an adhoc network with each other. Let the farthest is Tag 5 and there is no direct path between reader and Tag 5. Tag 1 comes in the communication range of the reader (Neighbors) (Fig 3). So it can be considered as a subnet in which reader can only communicate with its neighbors directly. Likewise Tag 2 and Tag 4 come within the range of Tag 1 so Tag1 can communicate with Tag 2 and Tag 4 only. Similarly, Tag 4 communicates with Tag 2, 3 &5 and makes an adhoc network. It can be considered as a big network divided into subnets like the case of master – slave network. In Fig 3 the subnets (neighbors in the communication range) of the reader and every tag are shown by dotted circles. The network can be simply drawn as shown in Fig 4. This figure shows the possibilities of communication between tags and readers with reference to Fig 3.

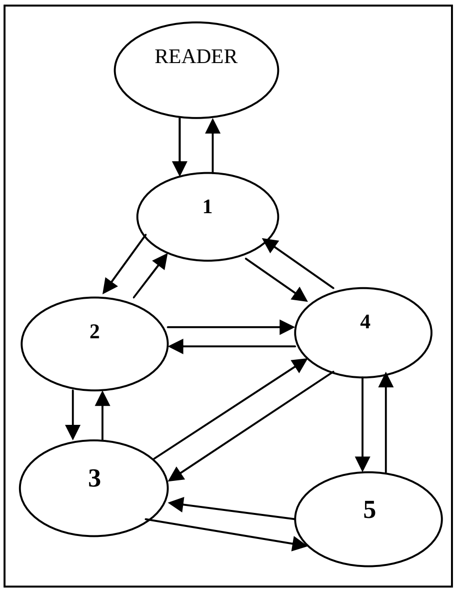


Fig 4 Network with all tags and their neighbors

3. Proposed Models for Network Discovery & Data Communication Processes

3.1 Network Discovery Process

The Reader initiates the communication by sending a Broadcast Inquiry message (BC Inquiry). Only Tag 1 is in its vicinity so it responds the BC Inquiry message with an ID packet after waiting for random time (Fig 5a). The reader then responds with Ack packet. The readers then sends discovery packet (DISC) to Tag 1 after certain time slot to allow it discover its neighbors. Therefore it sends BC Inquiry to detect its neighbors. Tag 2 and Tag 4 will respond to Tag 1 with ID packets after random times. Tag 1 will respond back with an ACK packet. Tag 1 sends this information through neighborhood (NB) packet to the reader. The reader will generate a routing table for tag 1 by sending it a routing table packet (ROUTE). Tag 1 responds back by an ACK packet. The reader then initiates the neighborhood discovery of Tag 2 and Tag 4 by sending a DISC packet which first hops to Tag 1 and then it hops to Tag 2 and 4 at different instants.

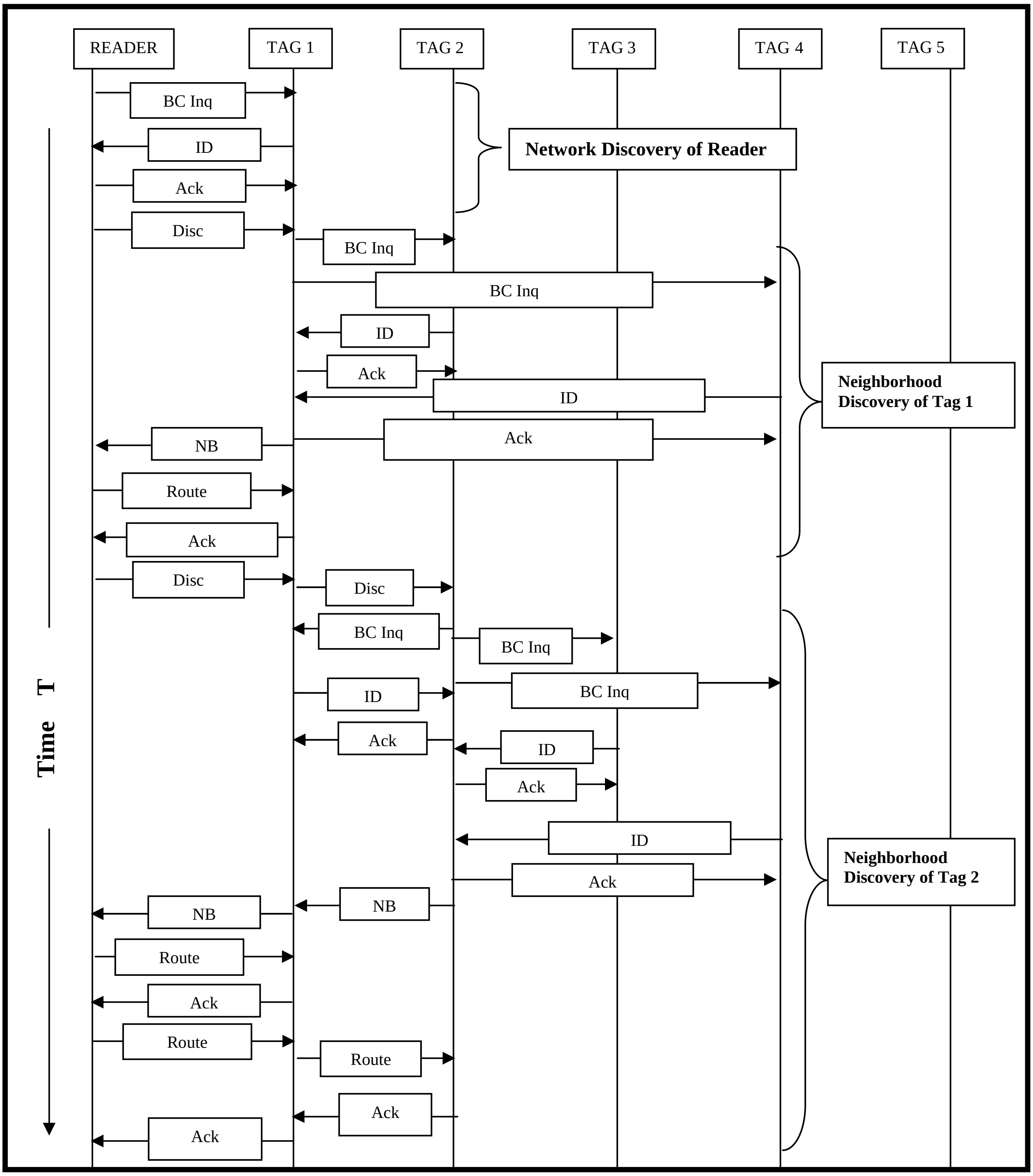


Fig 5a Network Discovery process (Packet Exchange Sequence)

Let Tag 2 starts discovering it neighbors first by sending a BC Inquiry message. Tag 1, 3 & 4 respond by their ID packets at random slots. Tag 2 will acknowledge them at random times one by one. Then Tag 2 sends its neighbors' information to tag 1 by NB packets and then tag 1 sends it to the Reader.

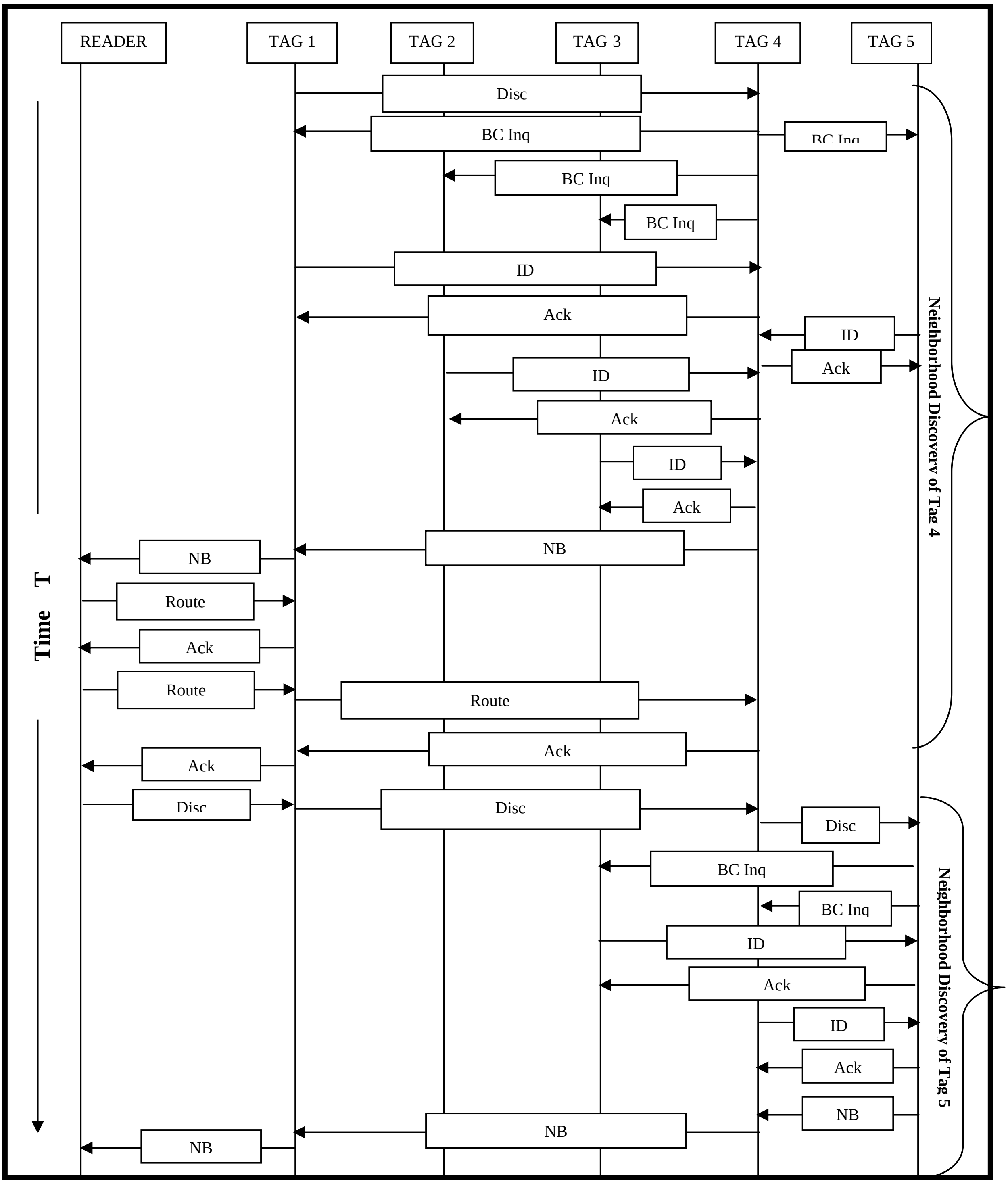


Fig 5b Network Discovery process (Packet Exchange Sequence)

Likewise all the Tags discover their neighbour until it reaches the last Tag 5. The process is completed with all Tags having upgraded routing tables and Reader with all its neighbors' details.

This process is like a centralized communication process in which every node sends its neighbors details to the Reader. The Reader will look up its routing table for shortest path if it wants to send any data to the farthest Tag. Fig 5a shows the network discovery process of the Reader and the neighborhood discovery process of Tags 1& 2. Fig 5b shows the neighborhood discovery process of Tags 4& 5.

During neighborhood discovery process, there is always a chance that the two or more Tags respond at the same time i.e. the random expected value of time for two tags becomes same. This causes a collision due to duplication of data. Fig 6 shows that Tag 2 and 4 are responding in the same random time slot.

	Request	Slot 1	Slot 2	Comments
T1		ID1		No Collision
T2			ID2,ID4	Collision

Fig 6 Two or more tags transmitting in the same time slot

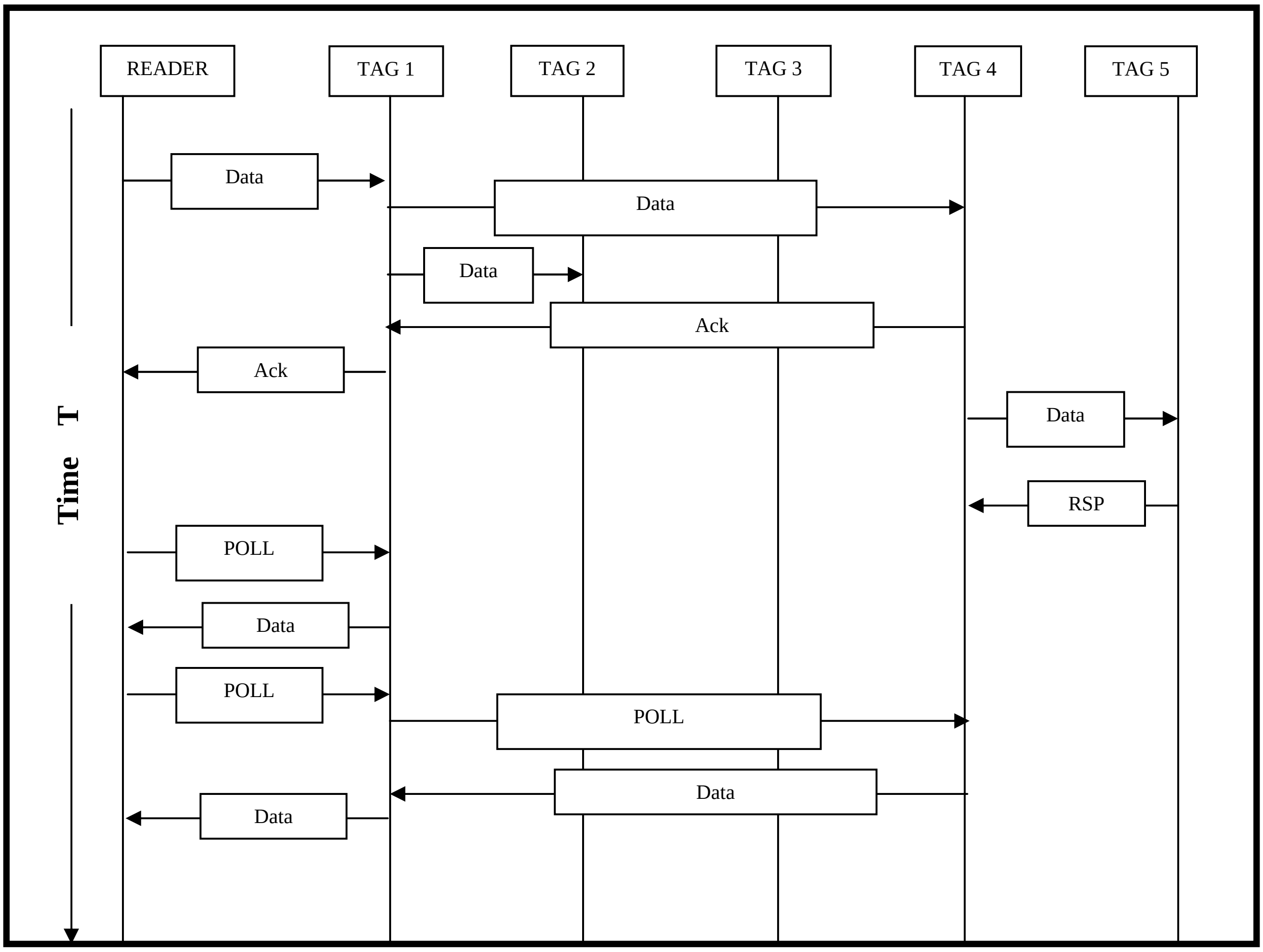


Fig 7 Data Communication Process

Wen-Tzu Chen suggested anti collision for RFID tags by allocating random frame length for every request. The tags which fail to respond or collide in the first neighborhood discovery cycle, will respond in the next cycle [5]. Won-Ju Yoon provides an improved tag collection method for active RFID systems based on ISO/IEC 18000-7 standard. [6]. Björn Nilsson suggested a dynamic back-off algorithm thereby reducing the tag energy consumption and read-out delays. [7]

3.2 Data Communication Process

In the Data communication process the reader looks for the entry of Tag 5 in its routing table. There is no direct path entry as the destination is through intermediate nodes. The Routing table shows that the path to the destination is through Tag 1. So it transmits DATA packet to its

immediate neighbor Tag 1 and search for routing table entry there.
Again there will be no entry and DATA packet will be transmitted to neighbors of Tag 1 i.e Tag 2 & Tag 4after random time. As Tag 4 has direct address entry of Tag 5 so Tag 4 responds back with Ack packet to Tag 1.Tag 1 forwards Ack packet to the Reader. Then Tag 4 sends DATA to Tag 5. The process continues until the DATA packet reaches Tag 5 which respond to the least hop path i.e. Reader-Tag1-Tag4-Tag5 with response (RSP) packet. Now the reader polls each tag of the least hop path. First it polls Tag 1 with POLL packet which responds with an empty DATA packet. Then it polls Tag4 via Tag 1 with the POLL packets. Tag 4 embeds RSP from Tag 5 in the payload of its DATA packet and sends it to the reader via Tag 1. Fig 7 shows the data transfer process as explained above.

4. Mathematical Approach for the Proposed Model and Results

Let N be the number of Tags to be discovered in the warehouse. Suppose X be the time slot for which each hop waits for response from the neighbors and Y be the Expected Random Time slot in which neighbors responds. Then the total time required by the nodes to discover their neighbors is given in Eq 1:

$$Z_0 = (N * X) + Y \quad (1)$$

The Expected value for uniform distribution is taken as maximum i.e. the mean of minimum (x) and maximum values (y) of time as in Eq 2:

$$Y = (x + y)/2 \quad (2)$$

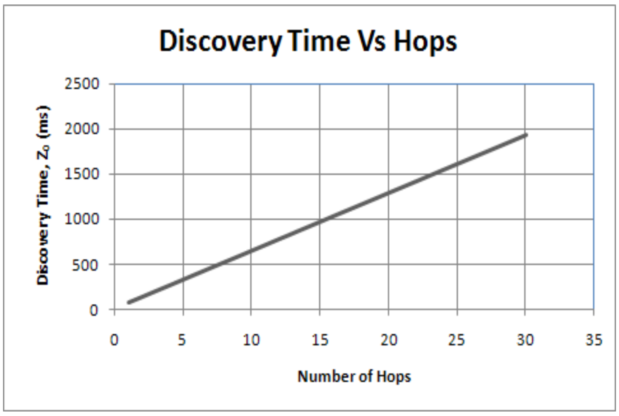


Fig 8 Graph between Discovery time and Hops

Fig 8 shows the relation of discovery time with the number of hops. A time slot of 64ms is considered for simulation for each hop. So the total discovery time for one hop is the sum of total slot time and the response time of the neighbors.
When all hops in the network complete their neighbor discovery process, then the data starts to propagate through the shortest possible path. The flow of data in the calculated shortest path anti collision network increases with the number of hops. Referring to fig 6, if data propagation time for 1 hop is taken as 4ms then the graph of time taken from 1 hop to 100 hops is almost proportionally increased as shown in the following graph.

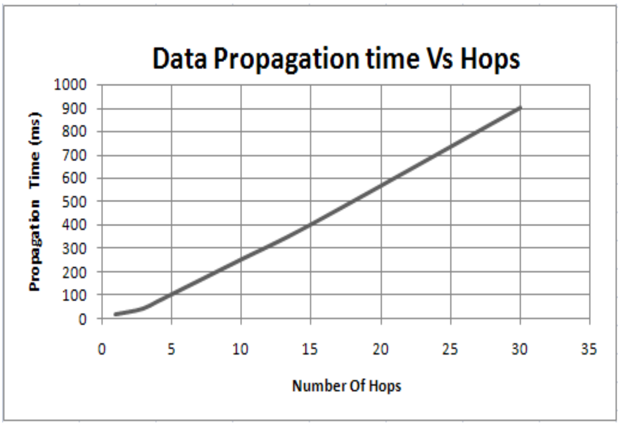


Fig 9 Graph between Data Propagation time and Hops

The Effective Throughput of our network can be calculated by taking into account the processing delay of each hop and the time to propagate the data through the hops. If data packet size is D bytes, data propagation time (as calculated above) is T1 and Node processing delay is X, then the effective throughput can be formulated as Eq 3:

$$Throughput = (D * 8)/(T1 + X) \quad (3)$$

The simulation results are shown in Fig 10.The throughput decreases gradually with the increase of data propagation time. This verifies that throughput will be better if number of hops and thus propagation time will be less.

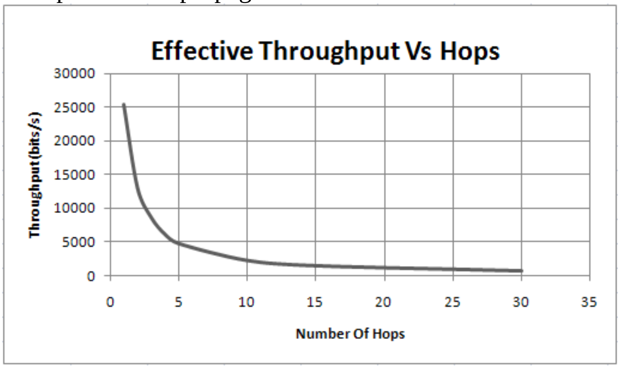


Fig 10 Graph between Effective Throughput and Hops

5. Conclusion

We have proposed the way of discovering long distant tags with one reader, thus enhancing Active RFID system capabilities. Also a secure data communication process is proposed. We have calculated the discovery time and the propagation time of the data from reader to last tag. In the end the throughput of the proposed network has been shown in the graph.

Acknowledgment

We would like to thank ID technologies Canada for providing us the platform to compile our results.

References

[1] K. Finkenzeller, RFID Handbook, 2nd ed., John Wiley & Sons, 2003.

[2] V. Daniel Hunt, Albert Puglia, Mike Puglia, "RFID-A Guide to Radio Frequency Identification", A John Wiley & Sons, Inc., Publication 2007

[3] Ted Philips, Tom Karygiannis, Rich Kuhn, "Security Standards for the RFID Market", Vol. 3, Issue 6, IEEE Security & Privacy Journal, Nov-Dec 2005, Pages(s) 85-89

[4] http://availabletechnologies.pnl.gov/

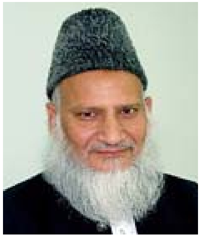
[5] Wen-Tzu Chen, "An Accurate Tag Estimate Method for Improving the Performance of an RFID Anticollision Algorithm Based on Dynamic Frame Length ALOHA", IEEE Transactions on Automation Science and Engineering, Vol. 6, No. 1, January 2009

[6] Won-Ju Yoon, Sang-Hwa Chung, Seong-Joon Lee, and Young-Sik Moon, "Design and Implementation of an Active RFID System for Fast Tag Collection" IEEE Seventh International Conference on Computer and Information Technology 2007 page(s): 961-966

[7] Björn Nilsson, Lars Bengtsson, Bertil Svensson, "Selecting Back-Off Algorithm in Active RFID CSMA/CA Based Medium-Access Protocols" IEEE International Symposium on Industrial Embedded Systems, 2008. SIES 2008. Page (s): 265-270

Amenah Arooj received the BS degree in Electrical Engineering from University of Engineering & Technology, Taxila Pakistan in 2006 .Now she is a student of MS (Electronics Engineering) in UET Taxila, Pakistan. During studies her major subjects of interest include computer networks, digital signal processing, wireless communication and information theory and source coding.

Dr. Muid Mufti received his PhD and MS degrees in Electrical/Computer Engineering from Georgia Institute of Technology, Atlanta USA in 1995 and 1993 respectively. In 1998, he remained as Post Doctorate Research fellow in Georgia Institute of Technology. He served as Manager R & D for MathTech Pakistan Pvt Limited in 2000-2001.Currently, he is associated with ID Technologies Canada. His areas of interests are Wireless Communication, Image Processing, Embedded Systems, Testing, Verification and Simulation.



Dr. Habibullah Jamal did his B.Sc. (EE) from University of Engineering and Technology, Lahore, Pakistan in 1974. He earned his MSc. and Ph.D degrees both in Elect. Engg. from University of Toronto, Canada, in 1979 and 1982 respectively. Dr Jamal has served academia throughout his professional career. Presently he is Professor, Electrical Engineering Department, University of Engineering and Technology Taxila, Pakistan. He is recipient of 9th Pakistan Education Forum, National Education Award 2003 and National Book Council of Pakistan Award 1991. He is a Fellow/Senior Member of many professional bodies including IEEE, USA. His research interests include; Signal Processing, the design of Microelectronic Circuits and development of Novel Computer architectures for Telecommunication.