Improvement of RFID Tag Detection Using Smart Antenna For Tag Based School Monitoring System

Sabira Khanam, Maliha Mahbub, Anuradha Mandal,
M. Shamim Kaiser and Shamim Al Mamun
Institute of Information Technology, Jahangirnagar University, Dhaka, Bangladesh
Email:sabira001840@gmail.com,{maliha_mila,anuradhamandal_bd}@yahoo.com,{mskaiser,sam}@juniv.edu

***Abstract*—Radio Frequency Identification (RFID) technology has attracted much attention due to its variety of applications in different fields e.g. military, sports, security, airline, inventory control, object tracking etc. Comparing to other tracking and detecting system such as barcode or smart card systems, RFID is faster and efficient. In this paper we present an efficient method of RFID tag detection for monitoring school going kids, by implementing smart antenna technology along with providing the updates to their parents. While this is an effective approach for the security and management of school going kids, we have to consider the coverage area and efficient tag detection issues. One important problem in RFID systems is to optimize the power allocation to the tag with respect to their distance from the reader which results in efficient tag detection and distance coverage. In this paper, we proposed an efficient and improved approach to fulfill these requirements for efficient tag detection. Results from mathematical analysis and extensive simulation demonstrate that our scheme shows a significant improvement over the traditional approaches of tag detection and power allocation techniques.**

I. INTRODUCTION

Our world today revolves around the mercy of internet, smart phones and advanced technologies that has lifted the wall of oblivion and blessed us with 24x7 updates on what is going on around us. In such circumstances, it is obvious that today's parents would like to be aware of their child's whereabouts, especially when they are at their school. Our proposed system is based on keeping this need in mind. It focuses on the security systems implied in schools, specially kindergarten and primary classes to ensure school going kids are safe and sound at the school premises and also helps parents and teachers monitor their kids overall performance at class. We have decided to use RFID as the tracking technology as this field is not much explored and especially not in school level in Bangladesh. RFID is used in supply chain, military, store checkouts, hospitals, inventory management and many other tracking sectors. RFID is comparatively less expensive, easy to maintain, easy to use. Therefore at school levels, RFID monitoring facilities can prove to be hugely convenient and affordable. Our on-going proposal focuses on not only the security of kids through RFID tracking but also feeding the updates of the necessary information to the parents. This also helps build interactions between school faculty and parents on their joined concerns of the student's welfare. In this paper, we have focused on increasing the coverage area of the tag, efficient power allocation and distribution to the tag, by using Smart antenna, which has shown that using Smart antenna can improve performance of the tag detection as well as the system.

II. RELATED WORKS

As tracking technology, RFID system is currently being used in many countries, in shopping malls such as Wal-Mart, general stores, hospitals, traffic monitoring etc and more recently, using RFID tags to track school going kids is also a very known application in advanced countries. However, in our country, although other security measures such as CCTV, wireless alarm system and barcode reader are used, RFID technology is not much in prevail. In some shopping malls this technology is used for tracking purposes such as Aarong and more recently it is used for car tracking by traffic police. At school level, CCTV or wireless alarm systems are used in some schools but using RFID tags and reader for monitoring students is a completely new application in this area. Thousands of companies around the world use RFID today to improve internal efficiencies. NYK Logistics uses RFID to improve the throughput of containers at its busy Long Beach, Calif., distribution center. And many other companies are using RFID for a wide variety of applications [1]. Some other related researches and works based on RFID system are given below: One proposal has been suggested to work with the attendance system using RFID technology. Here RFID tags are scanned by the reader and the tag sequences are simply matched with the stored values and showed on a GUI [2]. Another work by Herdawatie Abdul Kadir et al [3] have proposed the student monitoring system using RFID tracking to ensure the security and safety of students as well as to improve attendance data management, reduce administrative error and internal theft. Work by Ilkar Kormaz et al [4] have proposed a patient monitoring system where the RFID tag is worn by the patient as a bracelet and the assigned doctor can read the information related to the patient on his PDA. Another proposal by Mr.Tushar T. Tanpure et al [5] also has used RFID reader and tag to monitor students. As use of RFID tracking and identification has experienced a significant growth over recent years, there also have been many problems faced in this area. There have been proposals and research regarding localizing and power efficiency of tags. An analytical approach for multistage rectifiers, which provides design tradeoff and improve power efficiency [6]. While work by Kim et al. [7] estimate the direction of arrival by tracking the receive signal strength of two directional antennas depending on their orientation, the phase difference at distinct array elements is considered for direction of arrival estimation in this work. Additionally, several authors, for instance [8] propose to install multiple readers and apply reader-to-tag distance estimation to localize an RFID tag. Salonen et al. [9] show a phased array realization for blindly scanning an area with a beam.

This paper [10] presents an algorithm for redundant reader elimination for directional antenna. It uses a radio propagation model and also accounts for loss due to multipath fading to model communication between a reader and a tag. Very recently, Nikitin et al. [11] published a comparison of different techniques of DOA estimation by utilizing a phase difference. They propose to exploit a phase difference of a) multiple consecutive measurements of a moving tag (time domain), b) multiple consecutive measurements of a static tag with different carrier frequencies (frequency domain), and c) multiple receive antennas (spatial domain). Here, this proposal focuses on the improvement of tag detection and coverage area and our proposed application field for this is the school monitoring application. We have provided the possible scenarios for installation of RFID system in school and possible interface views for web page and mobile apps which are used for giving updates.

III. Objective

As it has been noticed that most parents are worried about their kids security while they are in school, the objective of this system must be to relieve them by updating the status of their kids while entering, exiting and when they are in school premises. As well as for more efficient power allocation and more coverage area for reader, use of smart antenna has been proposed. Goals are include:

- Ensure security in school:
  - Providing RFID tags to students
  - Installing RFID readers in school premises
- Android app to notify parents
  - Notifications of entrance end exit of student
  - Notification if student is missing within the coverage area.
- Interactive web page design
  - Attendance, class performance and extra-curricular performance grade of students
- Increasing the coverage area of RFID reader for efficient power allocation to tags
  - Using smart antenna in RFID reader
  - Using Adaptive algorithm to optimize power distribution.

IV. System Model

A. Proposed System

Radio frequency identification or RFID, is a generic term for technologies that use radio waves to automatically identify people or objects. There are several methods for such identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). This antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers [12]. An RFID system consists of a tag, which is made up of a microchip with an antenna, and an interrogator or reader with an antenna. The reader sends out electromagnetic waves. The tag antenna is tuned to receive these waves. A passive RFID tag draws power from field created by the reader and uses it to power the microchip's circuits. The chip then modulates the waves that the tag sends back to the reader and the reader converts the new waves into digital data. Why RFID- Although there are other security systems that prevail in our country such as bar code, we have chosen RFID because it serves our core purpose which is not only the security, but also to ensure parents of their kid's whereabouts and delivering updates on them. Barcode system is comparatively inexpensive and less complex system than RFID, but there are some issues with barcodes which can be overcome by using RFID instead. The optical nature of barcode requires labels to be 'seen' by lasers. This line-of-site property is often a bottleneck especially when we are tracking people, not objects. RFID technology enables tag reading from a greater distance, even in harsh environments. In addition, the information imprinted on a barcode is fixed and cannot be changed. RFID tags on the other hand have electronic memory similar to what is in your computer to store information about the inventory or equipment. This information can be dynamically updated. Although RFID system is costly, it has better coverage area, robust system, reliable in tough environments. Our proposed system is concerned with school environment, where RFID is clearly more convenient and fulfills most of the requirements. The architecture of proposed system is illustrated as follows.

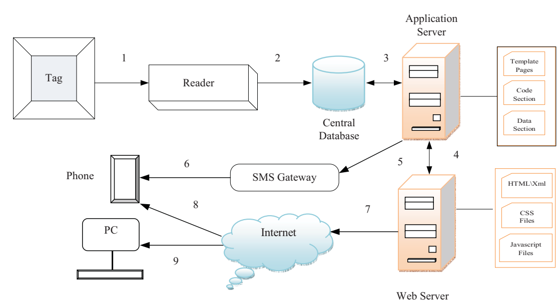

Fig. 1. System Design

Figure. 1(1)The tag is detected by the reader within its vicinity. (2)The information fed by the reader is interpreted and processed in the central database. (3) The processed information of corresponding tags is sent to the application server. (4)The information is also stored in the web server and vice versa. (5) The updates and related information are sent to the SMS gateway. (6) The information is sent to the phone through the SMS gateway. The app in the phone provides updates and notifications to the user. (7) The same updates, information and other factoids are available on the web page over the internet from the web server. (8) The information of the web page will be available on the phone. (9) The web page will also show information to PC as well.

B. Work flow of tag detection

The work flow of proposed system is illustrated as follows. The Figure. 2 shows the work process of the detection of tag by reader and processing of the information in the server. Step

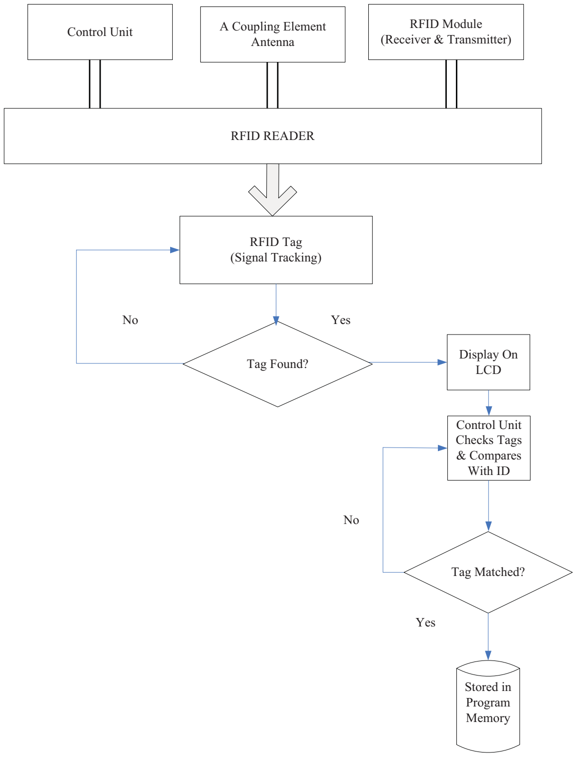

Fig. 2. Work flow of tag detection

1: RFID reader tracks the signal from the tag. Step 2: If tag is found, then notification is showed on LCD.Step3: Otherwise, go to step 1.Step 4: Control unit of reader checks tags and compares with stored value. Step 5: If tag is matched, then value is stored in program memory of central database. Step 6: Otherwise go to step 4.

C. RFID system part

This proposal is focuses on showing that the performance level of RFID reader/tag could be improved with smart antennas instead of the regular antennas. The major components of RFID system are:

- Tags- an object consisting of a microchip and antenna that is attached to the product or people and contains a serial number to define it.
- Antenna- it is responsible for the transmission of information between the reader and tag using radio waves.
- Reader- a scanning device that uses the antenna to recognize the tags that are in its vicinity.
- Middleware- it is a communication interface to interpret and process data being fed by the readers into information.
- Backend database- a repository of information, which is designed specific to the application. Figure. 1

RFID frequency range RFID systems use many different frequencies, but generally the most common are low- (around

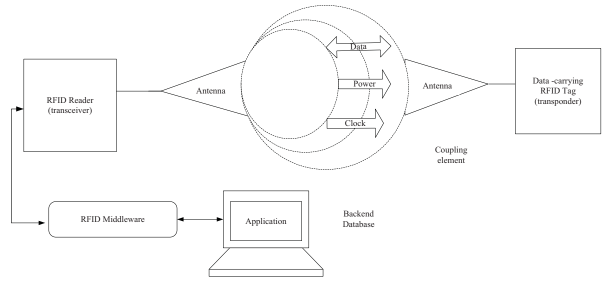

Fig. 3. Main components of an RFID system.[1L.A.Burdet,RFID Multiple Access Methods,ETHZurich 2004.]

125 KHz), high- (13.56 MHz) and ultra-high frequency, or UHF (850-900 MHz).Microwave (2.45 GHz) is also used in some applications. Radio waves behave differently at different frequency, so you have to choose the right frequency for the right application. In our case we have considered 13.56 MHz (high) frequency for calculations. Here, a possible scenario of RFID monitoring coupled with the smart phone is given. Figure. 4 according to the proposal of the system, the tracking information which is detected and verified by RFID reader is stored in a central database and then the required data(data corresponding to particular student) is sent to the smart phone via SMS gateway. Thus a notification message is shown to the phone informing the presence or absence of the student to the parent.

Fig. 4. Possible scenario of RFID monitoring systems with smart phone

D. Smart antenna

A smart antenna consists of several antenna elements, whose signal is processed adaptively in order to exploit the spatial domain of the mobile radio channel. This system can automatically change the directionality of its radiation patterns in response to its signal environment. In actual, antennas are not smart antenna, systems are smart [13]. Figure. 5 Beam forming is the method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired and nullifying the pattern of the targets/mobiles which are undesired/interfering targets. Compared with traditional Omni-directional and sectorized antennas, smart-antenna systems can provide-greater coverage area for each cell site, better rejection of co-channel interference, reduced multipath interference via increased directionality, location information for emergency situations [15].

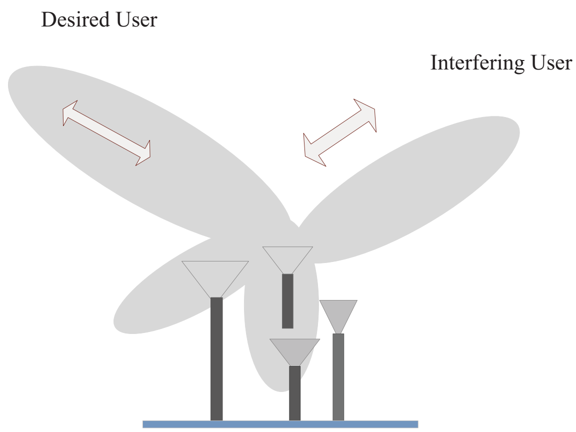

Fig. 5. Smart Antenna System-Beam Forming

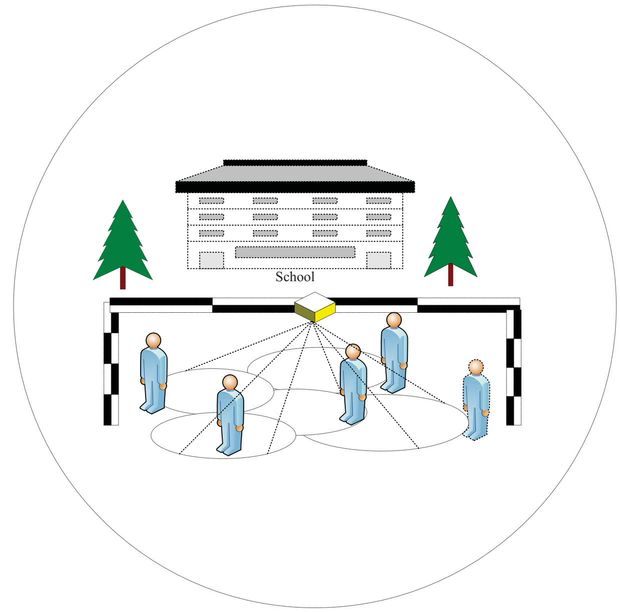

Fig. 6. Scenario of RFID monitoring systems with smart antenna

E. Implementation of smart antenna for proposed system

- Duplicate tag reporting by several reader antennas within same area
- Reader-to-tag interference which occurs when more than one reader try to read the same tag simultaneously.
- Optimal tag coverage problem which arises due to variable locations of tags within the antenna overage area.
- Efficient power consumption and distribution between reader antennas to tag.

As stated earlier, the optimal solution to these problems that we have worked is to imply a smart antenna which uses adaptive algorithm to calculate the relative distance between reader and tag and uses this calculation to determine the direction of beams or radiation pattern.

Figure. 6 scenario demonstrates the application of smart antenna in the RFID reader which uses adaptive algorithm to calculate the relative distance between reader and tag and uses this calculation to determine the direction of beams or radiation pattern. As a result, power allocation to the tags can be done based on the relative distances of the students from the reader within the coverage area. If we propose the use a smart antenna rather than a regular antenna in the reader, than instead of providing the same magnitude of power to all tags within its coverage area, the power would be allocated according to the relative distances of the tags (students) from the reader. This could lead to a significant improvement in the performance of our system in terms of power loss, increased coverage area; reduce repeated tag detection, faster detection and performance. As we have stated earlier, use of smart antenna in the reader would also reduce the cost of installing multiple readers for the school area and provide wider area of coverage. Here we have presented the theoretical idea of using smart antenna to our system. For the calculation and simulation, we have used some formula and testing models. The details of testing and simulation techniques are illustrated next.

F. Tag Power Allocation Technique

There are various propagation models which are used to define the path loss pattern such as free space propagation, Okumara, Hata models, Longley-Rice Model. For analysis used PCS extension of Hata model. The PCS extension of Hata model provides necessary correctional factors and considers multipath propagation and consists of parameter within the range well suited for our work [15]. Hata model is one of the most appropriate a path loss model which formulates the path loss provided by Okumara model. The formula used for path loss equations 1, 2, 3 are given here.

$$\begin{aligned} L(dB) = 46.3 + 33.9 \log f_c - 13.82 \log h_{te} - a(h_{re}) \\ + (44.9 - 6.55 \log h_{te}) \log d \end{aligned} \tag{1}$$

$$a(h_{re}) = (1.1 \log f_c - 0.7) h_{re} - (1.5 \log f_c - 0.8) dB \tag{2}$$

$$P_r = P_t - L \tag{3}$$

Where, L path loss ,h_{re} is receiver antenna height (tag height), h_{te} is transmitter antenna height (reader height) ,f_c is reader frequency ,d is T-R separation distance(reader coverage area), P_r received power , P_t transmitted power, $a_{(h_{re})}$ receiver antenna correction factor. We have used waterfill algorithm for the intelligent power allocations to the corresponding receiver tag based on their T-R separation distance to compensate for the received power impairments. The optimal strategy is to 'pour energy' (allocate energy on each channel). In channels with lower effective noise level, more energy will be allocated [16].

Application of Adaptive Power Control Algorithm

For dealing with varying distances of the tags and the power transmitted to them based on the calculations of the distance to determine the received power of the tag, we have used Adaptive Power Control Algorithm. An adaptive algorithm or basically adaptive control system is an intelligent system where the information about a system is obtained while the process is still operating (run time) and based on the refreshed information, special interventions or adaptations are made to fulfill the control goal [17]. An adaptive control algorithm fulfills this goal by parameter estimation based on recently received data or inputs. In our case, we have worked with waterfill algorithm, which is a common adaptive power control algorithm [18].

This section focuses on the derivation of radiation (beam) propagation pattern that could be used for smart antenna propagation using appropriate path loss model and the calculation using adapted parameters for the model. The next section includes the graph, result and simulation for our proposed system improvement analysis.

V. Result and Discussion of Coverage

A. Table of parameters

Here lists of all parameters we have used are noted with respective units.

TABLE I. Parameter Table

Parameter	Value	Unite
RFID reader frequency	433	MHz
Transmitter Antenna Height	10	Meter
Receiver Antenna Height	2	Meter
Reader Sensitivity	-95	dBm
Tx Power	1	Watt
Rx Power	Tx-Path loss	dBm
Path loss	110	dB
T-R Separation Distance	500	Meter
CM	0	dBm

We have used PCS extension of Hata model for the calculations with the above given parameters. The simulation and result with test cases are given below.

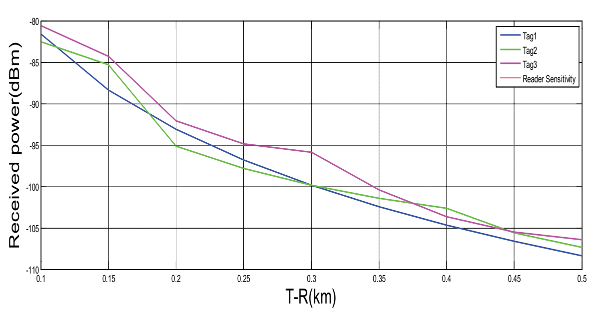

Fig. 7. Received power vs T-R separation distance.

Figure. 7 graph shows the graphical evolution of received power of for different tags against the T-R separation distance using the PCS extension of Hata model. We have considered three tags here with different distances from the reader. The reader sensitivity is -95 dBm. So, only the values above this level are acceptable. In case of f_c= 433 MHz, h_{te}= 10 m,

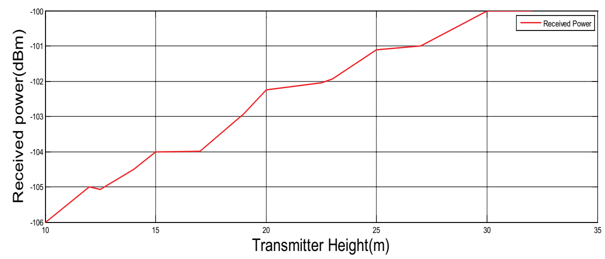

Fig. 8. Received power vs Transmitter height

d=.5 km, h_{re}=2 m We have found, a(h_{re})= 1.087 dB, $L(dB)$ = 109.225 dB, P_r= -106.225 dBm.

Figure. 8 graph shows the graphical evolution of received power for different tags against transmitter height using the PCS extension of Hata model. As the transmitter antenna height increases, the received power of tag antenna increases simultaneously. In this case f_c= 433 MHz, h_{te}= 10 m, d=.5 km, h_{re}=2 m We have found, a(h_{re})= 1.087 dB, $L(dB)$ = 109.225 dB, P_r= -106.225 dBm.

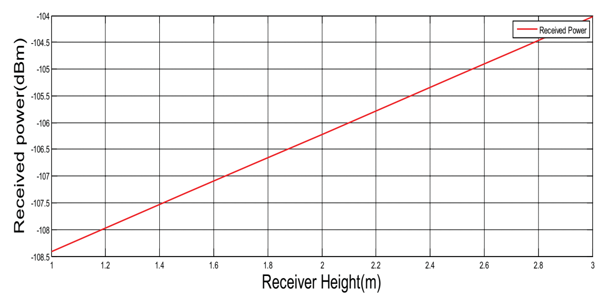

Fig. 9. Received power vs Receiver height

Figure. 9 graph shows the graphical evolution of received power for different tags against receiver height using the PCS extension of Hata model. As the transmitter antenna height increases, the received power of tag antenna increases simultaneously. Here we found a straight line.

In this case f_c= 433 MHz, h_{te}= 10 m, d=.5 km, h_{re}=1m We have found, a(h_{re})= -1.1 dB, $L(dB)$ = 111.41 dB, P_r= -108.41 dBm.

Water filling Algorithm Here we are using Water filling algorithm to distribute 1 W (1W= 3dBm) power to three tags where the power is arbitrarily divided into these three tags eventually providing the farthest tag with the maximum received power. The following graphs show significant improvement over the graph using non adaptive approach.

Figure. 10 graph represents the graphical improvement of all three tags using Adaptive algorithm over the non adaptive approach. This demonstrates the improvement of distance coverage of all three tags we have taken as test cases using adaptive approach show an effective improvement over non adaptive approach.

This section includes the graph, result and simulation for our proposed system improvement analysis. Our simulation

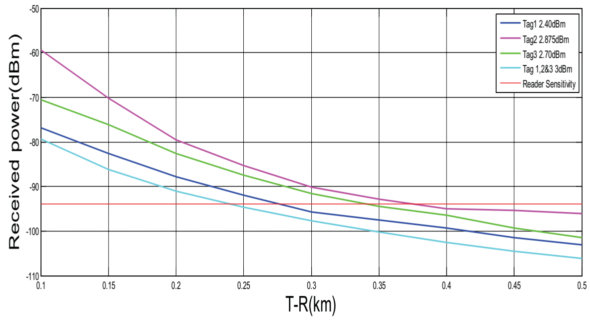

Fig. 10. Received power vs T-R(km) using Adaptive Algorithm for All Tags (fc=433 MHz)

graph clearly shows the significant improvement of the coverage area of all the test tags using adaptive algorithm against the non-adaptive approach of power allocation.

VI. Conclusion

The research is conducted based on the need of an effective and easy monitoring system for school going kids and it has identified and explained the key reasons and benefits of RFID technology in this regard. The proposal that we have presented here that show an efficient and systematic way of using RFID tracking applications coupled with smart phone technologies to fulfill the key security and monitoring purposes. In order to optimize the proposal, this paper investigated the effects of variable localization of RFID tags from reader and power loss, inefficiency and distance constraints caused due to equal power allocations to the tags. As an improvement to the situation, we have proposed implementation of adaptive algorithm which could estimate the variable distances of tag from the reader and distribute power to tags based on this calculation. As per our simulations and results, it can be inferred that using adaptive power control algorithm by implementing Smart Antenna in RFID system could result in an overall improvement of the system. In the long run, with reducing the number of reader by using smart antenna and increasing coverage area, several other sectors will be hopefully able to leverage the benefits of RFID technology and smart antenna using adaptive algorithm.

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