International Journal of Smart Home
Vol. 10, No. 4 (2016), pp. 325-334
http://dx.doi.org/10.14257/ijsh.2016.10.4.28

Integration of RFID Network Planning with Xbee Network: A New Approach

Khalid Hasnan[1], Aftab Ahmed[1], Badrul-aisham[1], Qadir Bakhsh[1], Kamran Latif [1], and Kashif Hussain[1]

[1]Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor, Malaysia
khalid@uthm.edu.my, aftabgmik@gmail.com, aisham@uthm.edu.my, qadirquest@gmail.com, engr.kamranqureshi@gmail.com usitsoftrevised@gmail.com

Abstract

Radio Frequency Identification (RFID) is a wireless technology used for real time identification and data capture of items. It replaces the traditional barcode at retail shop, warehousing, logistics and supply chain management etc. The basic requirements for deploying RFID network are to know the number of readers needed, location of the readers and the efficient power setting for each reader. The optimal solution of RFID network planning problems can be achieved by the implementation of newly developed Multi-Colony Global Particle Swarm Optimization (MC-GPSO) algorithm, which computes objective functions scientifically. However owing to the limited transmission range of RFID reader, it can track and identify items within specified range only. A novel approach to integrate RFID network planning with XBee wireless mesh network was developed. It could enhance the communication range and visibility of items identification and tracking activity faster and accurate. It also increases the tracking activity of multiple items as compared to existing barcode technology. RFID system is able to reduce the product loss or shrinkage and bullwhip effect resulting to reduce the overall cost. It also reduces the time of data transfer in global network.

Keywords*: RFID, MC-GPSO, ZigBee, XBee*

1. Introduction

The RFID wireless communication system is used for real time identification and data collection of items [1-2]. RFID system consists of three basic components such as (1) Tag with embedded antenna (2) Reader along with antennas (3) Middleware [3]. The operating principle of RFID system is based on transmitting of radio wave signal through reader to the tagged items which is embedded with silicon chip. When the silicon chip meets the minimum threshold power to turn on. The silicon chip memory sends data back to the reader on the same RF wave through antenna [4]. The reader transmits that data to the middleware for updating data of enterprise operations [5].

Presently, the retail industry uses barcodes for identification of manufactured items and Electronic Article Surveillance (EAS) for an anti-theft mechanism at outlets to minimize the product loss or shrinkage throughout the supply chain from the point of manufacture to the end customer, but yet they fail to minimize product shrinkage across the entire retail supply chain. Most organizations focus on supply chain operations such as inventory management and distribution innovatively for competitive advantage for enterprise operations [6]. RFID system is able to collect accurate information of product identification and tracking on real time basis without human intervention [7]. RFID can easily be integrated with ZigBee wireless mesh network for increasing the node

ISSN: 1975-4094 IJSH

placement and wider the range of detection [8]. ZigBee is low cost and low power consumption network device in RFID system. RFID-ZigBee integrated system can increase the overall function and efficiency to get real time information of supply chain effectively resulting to cut the product loss (shrinkage) and bullwhip effect. The fast development of RFID technology having challenging issues of the optimal deployment of RFID network are tags coverage, interference, economic efficiency and load balance [9-10]. Due to the limited range and high cost of RFID reader the following constrained are to be considered before deploying the reader network [11-12]. (1) How many minimum readers are required to cover all tags? (2) Where to deploy these minimum readers? (3) What parameters are to be set for each reader?

The Artificial Intelligence (AI) is a branch of computer science, used for computing very complex network problems [12]; it behaves like a human intelligence in order to work multiple tasks concurrently. AI has two major branches such as Evolutionary Algorithm (EA) and Swarm Intelligence (SI) and its further developed techniques are as shown in Figure 1 [11-13].

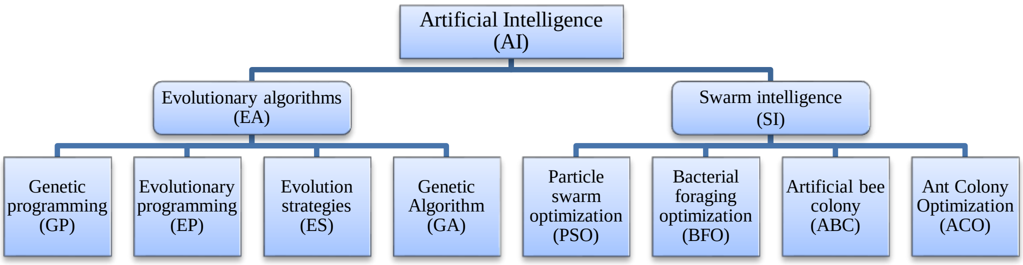


Figure 1. Artificial Intelligence and its Branches

These heuristic techniques works on the basis of nature inspired behaviour of biological and of social animals; they are searching their food collectively as self-organized with the systematic approach [10-13]. There is no centralized control to organize the agents to follow the rule to interact with the local agents and environment [9]. It is a built-in natural property for searching based approach to perform collectively. Each agent interacts with other agents locally according to the environment. The following are the basic advantages of artificial intelligence: (1) compute repeated operations according to the nature based inspiration, (2) highly efficient to explore optimal solutions in very short time, (3) flexible to solve various problems of different application areas with slight changes, (4) robust to perform in difficult, harsh and uncertain environmental conditions and (5) able to integrate with other techniques [11].

In this research it was essential to consider the criteria regarding RFID network planning, such as the coordinates of tags and interrogators were fixed as static RNP problem. On the contrary in actual practice during continuous working area, RFID tags and readers can be placed at any location. Due to the complexity of the network and cost of RFID system depends on the number of readers, so it was essential to minimize the number of readers at optimum level to achieve the target of cost effective planning of network. The Multi-Colony Global Particle Swarm Optimization (MC-GPSO) algorithm was developed to solve the RNP issues by deploying minimum number of readers to cover all tags with minimum interference between readers.

2. Concept of Particle Swarm Optimization (PSO)

The particle swarm optimization algorithm is based on social behavior of fish schooling or bird flocking. It is a population based heuristic evolutionary technique used for global optimization. PSO has two following basic mathematical equations for optimal solution.

$$V_i^d = \omega \times V_i^d + c_1 \times rand_1^d \times (pBest_i^d - x_i^d) + c_2 \times rand_2^d \times (gBest_i^d - x_i^d) \quad (1)$$

$$X_i^d = X_i^d + V_i^d \quad (2)$$

Where, d = 1, 2,……,D (dimension of the search space)
i = 1, 2…..,N (index of each reader)
In this algorithm, each particle individually moves through the problem space with a velocity. The velocity vector having speed and direction which has to be regulated on the basis of particle's previous best known (self-cognitive) and the historical best knowledge in its neighbourhood (social-influence) [9-11]. Inertia weight is an important parameter which controls the convergence by setting higher value at first and then gradually reduce toward its lower value for achieving better performance [13]. Inertia part (ω x V_i^d) is used to avoid sudden changing the velocity of readers in the search space. The cognitive part $[c_1 \times rand_1^d \times (pBest_i^d - x_i^d) + c_2 \times rand_2^d \times (gBest_i^d - x_i^d)]$ is used to represent as an external force to drag the particle to move towards better position. The social part $[c_2 \times rand_2^d \times (gBest_i^d - x_i^d)]$ is used to closely interact with each swarm and predict to plan the number of better positions in the search space [11]. c_1 and c_2 are acceleration coefficients are the learning rates which specify the proportional importance of self-cognitive and social-influence. The $rand_1$ and $rand_2$ are random numbers uniformly distributed in (0,1). In this way, the particle can move towards a promising area in the global search. PSO algorithm has advantages such as easy to apply, fast convergence, highly efficient and firm validity. Due to these advantages the algorithm has been used in wide range of application and also has provision for further improvements in future applications [10]. In first step each particles has to search its own best position in the space with respect to its previous position that is called personnel best "*pBest*" and is recorded in its memory. In second step its position is compared to the neighbour particles in their group and set their positions best fittest possible that is called local best "*lBest*", finally their position is compared to the global search among all particles existing in the search space and set their position, that position is called global best "*gBest*". This is the iteration based techniques followed by each particle in each iteration step and updates velocity and optimal best positions until meets the termination conditions. To evaluates the fitness of each reader followed by objective functions according to precedence and finds their "*pBest*" and "*gBest*" of each reader until termination conditions meets [11].

3. Identification and Formulation of Objective Functions of RFID Network Planning

In this research the following three objective functions of RNP has been solved such coverage, interference and number of readers described as follows.

3.1. Coverage

The very important and basic objective function of all RFID systems is the entire tags coverage in specified area. It has been achieved by placing the RFID readers at the center of each cluster of the tags in the working area. If the signal power received at the tags higher than the minimum required power level "threshold power" is -10dBm, the contact between reader and tags has to be established [13]. Tags coverage has formulated as the sum of the difference between the actual powers received by each tag to the required power. The mathematical equation of tags coverage is as follows.

$$Coverage = \sum_{i=1}^{NT} (P_{tagi} - P_{req}) \quad (3)$$

P_{tagi} = Actual received power at each tag "i"
P_{req} = required threshold power = -10dBm

NT =Number of tags in working area

By Friis transmission equation power at each tag can calculate by the following equation [10].

$$P_{tag} = P_{reader} \times G_{tag} \times G_{reader} \times \left(\frac{\lambda}{4\pi d}\right)^2 \quad (4)$$

$$Coverage = \sum_{i=1}^{NT} [P_{readeri} + G_{tagi} + G_{readeri} + 20 \log_{10} (\frac{0.026}{\sqrt{(x_i - a_i)^2 + (y_i - b_i)^2}}) + 10)] \quad (5)$$

3.2 Interference

The interference between RFID readers took place at the area of thick populated readers environment where the interrogation range of each reader overlap to the other reader interrogation range, in this scenario each reader attempt to read the similar tags at the same time, as a consequence unaffordable level of misinterpret to be happened [11]. The interference can be reduced by changing the positions of readers away from each other and variation of radiated power. The interference can be solved by the following formula [13].

$$\text{Interference} = \sum_{i=1}^{N_{max}-1} \sum_{j=i+1}^{N_{max}} [d(R_i, R_j) - (r_i + r_j)] \quad (6)$$

N_{max} is the total available number of readers, "d" is distance between readers, R_i is the position of ith reader, R_j is the position of jth reader, r_i is the interrogation range of ith reader and r_j is the interrogation range of jth reader.

3.3. Number of Readers

The number of readers in the working area of RF network, it needs to reduce the number of readers because its cost is too high, if greater the number of readers higher is the overall cost of the system. So it was necessary to figure out how much extra readers were deployed at initial stage which were no more to be useful and must be removed from the network using multi-colony global particle swarm optimization (MC-GPOS) algorithm. This objective function can be solved by the following formula [11].

$$N_{req} = N_{max} - N_{extra} \quad (7)$$

N_{req} is the number of required readers, N_{max} is the number of available readers and N_{extra} is the number of extra readers.

4. RFID Reader Representation by Coding

The coding translates the variable parameters of reader representation. It indicates the number of readers deployed in the network and their locations and radiated power of each reader. In this research each reader is represented as D = $3N_{max}$, multidimensional real number vector. N_{max} is maximum number of available readers which was deployed in the network at initial stage. By the representation of readers coding as the vector $2N_{max}$ is denoted the coordinates x_i^r, y_i^r of each ith reader and the vector $1N_{max}$ denoted as radiated power p_i^r of each ith reader which decide the interrogation range of each reader. To consider the above vector notations then the entire ith reader notation in the whole swarm is denoted as;

$$X_i = [x_i^1, y_i^1, p_i^1, x_i^2, y_i^2, p_i^2, \dots \dots .. x_i^{N\,max}, y_i^{N\,max}, p_i^{N\,max}] \quad (8)$$

(x_i^r, y_i^r) are the coordinates and (p_i^r) is radiated power of each reader "r"

Where [r = 1, 2,…….., N_{max}]

4.1 Parameters Setting

The parameter was set as the N_{max} =10 Number of RFID reader initially deployed, the Radiated power range of reader at each tag (P_{tag}) is 0.1 to 2 watt (20 to 33 dBm), this variation was directly proportional to the circular range of radiated power of reader from its centre. The minimum threshold power of tags (T_{tag}) is -10 dBm. The minimum threshold power of readers (T_{reader}) is - 70 dBm. The power gain of tag antenna (Gtag) is 3.9 dBi and the power gain of reader antenna (G_{reader}) is 7.3 dBi. Inertia weight (ω) is 0.9 to 0.4 and acceleration coefficients were set as c1 = c2 = 2.0. Operating frequency of reader was set as UHF 915 MHz and the number of iteration was set as 15000.

4.2 Application of MC-GPSO

At the start of the MC-GPSO algorithm, each individual reader in the swarm initializes its velocity first, within the limit of [Vmin ,Vmax] and positions were uniformly distributed in random numbers as [Xmin , Xmax], where Xmin is the lower bound and Xmax is the upper bound of the readers position. The PSO population comprised on "N" number of reader in "D" dimensional search space, so each reader has velocity vector Vi = [Vi^1, Vi^2, ……, Vi^D], position vector X_i = [x_i^1, x_i^2, ……., x_i^D] and pervious best position vectors pBesti = [$pBesti^1$, $pBesti^2$,…,$pBesti^D$] and global best position vector gBest = [$gBesti^1$, $gBesti^2$,…,$gBesti^D$]. In this process the velocity and position of each reader is randomly initialized in the search space according to the coordinates (x_i^r, y_i^r). p_i^r is radiated power within the transmission range of each reader (r = 1, 2,…….., N_{max}). At first instance all readers "N_{max}" were deployed in the working area for RFID network planning. At the initial stage the availability of all readers in the network represented by a vector as switch on position (1, 1,……..,1). Those readers meets the objective functions is remain switched on, otherwise it is switched off. The switched off readers are represented by the vector (0, 0,….0).

4.3. Operating Procedure of MC-GPSO

The step by step operating procedure of multi-colony particle swarm optimization (MC-GPSO) is described as follows.

Step1. Randomly initialize the velocity and position of each reader.

Step2. Evaluate the fitness of each reader according to the objective functions by using equation (5), (6) and (7) in each swarm and then record the "pBest" of each reader. Then calculate the "gBest" in each swarm.

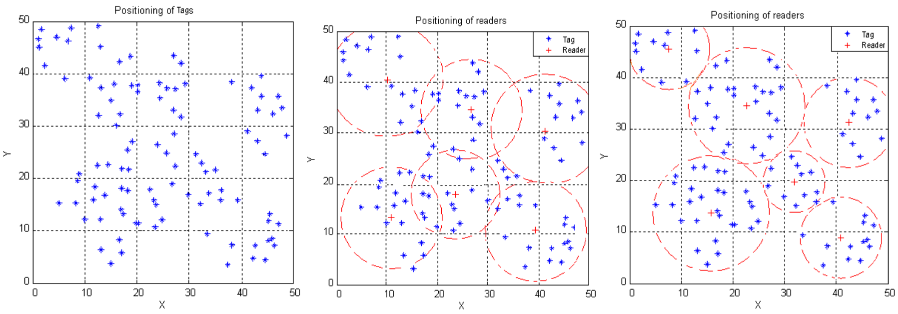
Step3. Update the position and velocity of all readers by using equations (1) and (2). If the updated position and velocity of each reader is better than the previous best, then new best position fixed as current best position, otherwise kept as the previous best.

Step4. Evaluate the fitness value of each reader and compare with the previous best fitness position and velocity on the basis of recorded knowledge and then update each reader position according to the global position in each group.

Step5. If the fitness value achieved so far as global best and maximum iteration has been completed and global best position achieved, then go to the next step as stop operation else go to step3.

4.4 Simulation Results

The scenario of the working area was set as $(50\text{m} \times 50\text{m})$ and 100 numbers of tags are randomly distributed in working space as shown in Figure 2 (a). After plotting of tags (as blue star "*"), the 10 number of RFID readers was initialized and distributed in order to cover all the tags. The coordinates of readers is shown as red plus sign (+) and their interrogation range as red dotted line circle. The 6 number of RFID readers was covered all the tags in the defined space as shown in Figure 2 (b). The unnecessary number of readers was removed from the space by skip reader operator used in MC-GPSO algorithm. Those readers which covers all the tags, its interrogation zone was overlapped and interrogates the same tags concurrently, due to the overlapping of interrogation zone between each reader; the interference occurred that effects the misread of tags which decreases the QoS in the network. The interference was reduced by adjusting the distance between readers as to take away from each other also regulates their interrogation power with consideration of the tags coverage until minimum or no interference occurred. As a result the minimum interference was achieved as shown in Figure 2 (c). After deploying the optimal number of RFID readers in specified area, the RFID readers are connected to the number of XBee devices for increasing the data transmission range to the main server. In this research the cost effective RFID reader is used f as a proof of concept.



(a) (b) (c)

Figure 2. Deployment of Tags and Readers in Working Space (a) (b) and (c)

5. RFID Reader Connection and Testing

The RFID reader connects according to the following circuit diagram as shown in the Figure 3. The RFID reader connected with Universal Asynchronous Receiver/Transmitter (UART) to RS232 Converter (URS232A). The female wire connector of URS232A have two wire sets, one of them is RJ11 connector (male) which was used for the RFID reader for data transmission and other one have USB connector used for getting 5V power supply from breadboard power stick 5V 3V3 (BPS-5-3) through Breakout USB A female (BB-USB-AR). The breadboard power stick 5V 3V3 was used to receive power from adapter 12V 2A and the adapter got power from external power source normally used as 240 V.

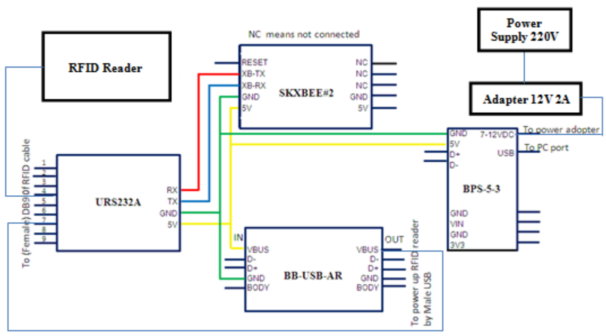


Figure 3. Circuit Diagram of RFID Reader and Xbee Device

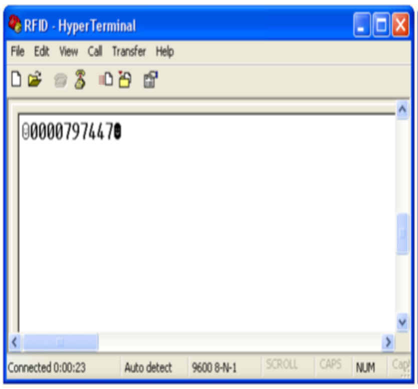


Figure 4. Tag ID

RFID-IDR-232N is a plug and play RFID reader. It was designed as low cost solution and is used for reading 125 KHz passive tags. It is worked on 9600 data transmission rate (bits/second), The USB connector is only used for getting 5V power. The RFID reader has ability to detect the tag at 2cm reading range, 0.1s response time and 12 bytes of data received like "□0003274177□".

The hardware connection must be setup before use RFID-IDR-232N. Then the HyperTerminal (software) is opened and used for testing of hardware. COM is selected from the list and configured as follows:

Bits per second = 9600, Data bits = 8, Parity = None, Stop bits = 1, Flow control = None

RFID-IDR-232N is ready to use and it indicates the tag's ID as shown in Figure 4. RFID-IDR-232N can easily connect with Xbee nodes for more distant communication. The XBee connection and communication described in detail in the next section.

6. XBee Module Connection and Communication

XBee devices are used for wireless communication and real time data transmitting. In any network minimum two devices are needed to setup for communication. In this research there were two sets of XBee wireless devices; one was directly connected to the laptop by USB connector. It was configured as coordinator and other set of XBee configured as an end device was remotely fixed on breadboard according to circuit diagram as shown in Figure 3. XBee was getting power of 3.3V from breadboard which actually interface with Breadboard Power Stick 5V 3V3 (BPS-5-3). This set of SKXBee, was remotely connected to the RFID reader according to the circuit diagram as shown in Figure 3. The working principle of XBee mesh network begins by sending radio wave signal of coordinator to the receiver, the receiver will response signal back to the coordinator along with information collected from RFID readers. Then coordinator communicates that collected data to the computer system in to the database connectivity at LabVIEW platform.

7. RFID-XBee Operating Module

The RFID-XBee operating module works according to the following diagram as shown in the Figure 5. It needs the system tools, devices and software as system requirements. The required software has been installed and configured with hardware components according to the diagram are shown in Figure 6. The database connectivity program has also been developed in LabVIEW platform in combination with Microsoft Access database. The RFID-XBee operating module is explained as follows:

The operating activity of RFID-XBee module begins with the selection of COM port first into the computer for detecting the XBee coordinator, which is connected with computer by USB connector. Camera was selected for live video operation and set all the parameters for data transmission rate according to the design requirement of RFID-XBee setup. Run the LabVIEW program for identification activity, it activates the database and XBee coordinator. The XBee coordinator transmits the forward signal to the XBee end device. The remotely RFID reader identifies and collects the data of tagged items and transmits wirelessly to the XBee end device which is connected with RFID reader according to the circuit diagram as shown in the Figure 3. The remotely XBee end device receives a signal from XBee coordinator, it immediately transmits the collected data to the XBee coordinator through radio wave signal on real-time basis. The XBee coordinator transmits collected data to the LabVIEW software, then it forwards that data to the Microsoft Access database through LabVIEW database connectivity operation.

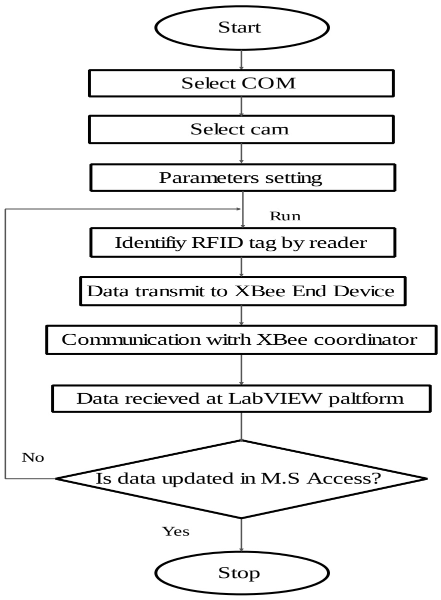


Figure 5. RFID-XBee Operating Module

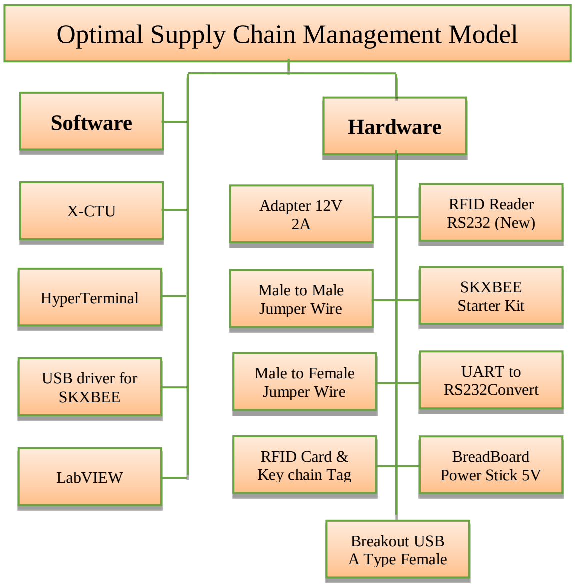


Figure 6. Optimal Supply Chain Management Model

Finally the data is recorded, updated and saved in Microsoft Access database. Then stop operation.

8. Conclusion

The application of MC-GPSO algorithm is used for optimal result of objective functions of RNP including minimum number of readers are used for tags coverage in working area with minimum interference. The novel approach of integration of RNP with XBee network has been achieved for the benefits of optimum supply chain management. It could enhance the overall functionality of items identification and tracking activity in real time. This system increases communication range and visibility of items. RFID-XBee network also increases speed and accuracy of service in supply chain. It is able to reduce the product loss or shrinkage and bullwhip effect resulting to reduce the overall cost. The system is more efficient as compared to existing barcode technology. This network can be enhanced in future applications to expand the business.

Acknowledgements

This research supported by the Postgraduate Incentive Research Grant under Vot. No.1156. The authors would like to thank the Universiti Tun Hussein Onn Malaysia (UTHM) for financially supporting of this research.

References

[1] A. Ahmed, K. Hasnan, B. Aisham and Q. Bakhsh, "Integration of Value Stream Mapping with RFID, WSN and ZigBee Network", Applied Mechanics and Materials, no. 465-466, **(2014)**, pp. 769–773
[2] K. Hasnan, A. Ahmed, W. Sani and Q. Bakhsh, "Optimization of RFID real-time locating system", Australian Journal of Basic and Applied Sciences, vol. 8, no. 4, **(2014)**, pp. 662–668.
[3] K. Hasnan, A. Ahmed, B. Aisham and Q.Bakhsh, "Study of RFID application with Zigbee Network in Supply Chain Management", 2nd International Conference on Mechanical, Automotive and Aerospace Engineering (ICMAAE 2013), **(2013)**.
[4] Z. Asif, "Integrating the supply chain with RFID: A technical and business analysis", Communications of the Association for Information, vol. 15, **(2005)**, pp. 393–427.
[5] A. Ahmed, K. Hasnan, B. Aisham and Q. Bakhsh, "Impact of RFID and Xbee Communication Network on Supply Chain Management", Applied Mechanics and Materials, vol. 660, no. 9, **(2014)**, pp. 83–987.
[6] S. Pradhan, G. Lyon and I.Robertson, "RFID and sensing in the supply chain: challenges and opportunities", HP Laboratories Palo Alto, **(2005)**, pp. 1-11.
[7] N. Zarokostas, P. D. Dimitropoulos and J.Soldatos, "RFID Middleware Design for Enhancing Traceability in the Supply Chain Management", 2007 IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications, **(2007)**, pp. 1–5.
[8] S. A. Elshayeb, K. Bin Hasnan and C. Y. Yen, "RFID technology and Zigbee networking in improving supply chain traceability", International Conference on Instrumentation, Communication, Information Technology, and Biomedical Engineering, **(2009)**, pp. 1–3.
[9] H. Chen, Y. Zhu, K. Hu and T. Ku, "RFID network planning using a multi-swarm optimizer", Journal of Network and Computer Applications, vol. 34, no. 3, **(2011)**, pp. 888–901.
[10] H. Feng and J. Qi, "Optimal RFID networks planning using a hybrid evolutionary algorithm and swarm intelligence with multi-community population structure", 14th International Conference on Advanced Communication Technology (ICACT), **(2012)**, pp.1063–1068
[11] Y. Gong, M. Shen and J. Zhang, "Optimizing RFID Network Planning by Using a Particle Swarm Optimization Algorithm With Redundant Reader Elimination", IEEE Transactions on Industrial Informatics, vol. 8, no. 4, **(2012)**, pp. 900–912.
[12] L. Ma, H. Chen, K. Hu and Y. Zhu, "Hierarchical artificial bee colony algorithm for RFID network planning optimization", TheScientificWorldJournal, **(2014)**, pp. 1–21.
[13] H. Chen, Y. Zhu, K. Hu and T. Ku, "Dynamic RFID Network Optimization Using a Self-adaptive Bacterial Foraging Algorithm", International Journal of Artificial Intelligence, vol. 7, no.11, **(2011)**, pp. 219–231.