# RFID and Wireless Sensor Networks

Dr.P.C.Jain, K.P.Vijaygopalan

**Abstract-**RFID (Radio Frequency IDentification) and Wireless sensor network (WSN) are two important wireless technologies that have wide variety of applications and provide unlimited future potentials. RFID is used to detect presence and location of objects while WSN is used to sense and monitor the environment. Integrating RFID with WSN not only provides identity and location of an object but also provides information regarding the condition of the object carrying the sensors enabled RFID tag. It can be widely used in military, environmental monitoring and forecasting, healthcare, intelligent home, intelligent transport vehicles, warehouse management, and precision agriculture. This paper presents a brief introduction of RFID, WSN, and integration of WSN and RFID, and then applications related to both RFID and WSN. This paper also discusses status of the projects on RFID technology carried out in Ubiquitous Computing group at C-DAC Noida and future projects to be taken on WSN and RFID technology.

**Keywords:** RFID, Wireless sensor, sensor network, embedded sensor, Internet of things, Wi-Fi, Bluetooth, ZigBee.

## 1. Introduction

It is now well recognised that future internet will not only connect people and data but also objects (anything). This means most of the traffic will flow between objects thus creating “the Internet of the things”. Objects connected to network could be a refrigerator connected with grocery stores, laundry machine with clothing, implanted RFID tags with medical equipments, and vehicles with stationary and moving objects. With this it appears that the computers as a dedicated device will disappear, and intelligent objects might be tagged and networked. Future Internet will be object-to-object communication rather than machine-to-machine communication. An Internet can detect and monitor changes in the physical status of connected objects through sensors and RFID in real time.

Wireless sensor network has applications in environment, disaster prevention, healthcare, home automation, intelligent transportation, precision agriculture, etc. The sensors are used to collect and transmit information about their surrounding environment. The node collects the information from a group of sensors and facilitates communication with a control center. The software helps the system in collecting and processing of large volumes of data.

RFID relates to the technique of transmitting the identification of an object in the form of a unique serial number using radio waves. The basic components of RFID technology are the tags, readers and host computer. RFID reader reads information on the tag and passes it to the host computer for analysis. RFID software helps in collection and processing the data.

WSN and RFID are complementary because they were originally designed with different objectives (RFID for identification while WSN for sensing). For these reasons integrations of WSN and RFID provides a significant improvement on monitoring. This provides the RFID to work in multi-hop to extend applications to operate in a wider area. GPS is not a realistic solution for location determination for WSN nodes since WSN operates with low complexity and with low power consumption.

This paper gives an overview of WSN and RFID Technology and their applications, which is organised as follows: Section 2 and 3discusses about WSN and wireless connectivity to WSN, section 4 and 5discusses about RFID technology and Integration of RFID and WSN, section 6 discusses various applications of WSN and RFID, section 7 discusses status of the projects on RFID technology carried out in Ubiquitous Computing group, and section 8 provides concluding remarks.

## 2. Wireless Sensor Network

WSN is one of the most rapidly evolving R&D field for microelectronics. Their applications and market potentials are increasing day-by-day. According to Frost & Sullivan, the expected market size will be approximately US$ 2billion by 2012 at a compound annual growth of 41.9%.

WSN aims to monitor and sometimes to control an environment. The system operates for periods varying from weeks to years in an autonomous way. The sensor network is composed of large number of sensor nodes that can be deployed on the ground, in the air, in vehicle, inside building [1,2]. The Sensor Node comprises of sensing (measuring), computing, and communication elements. A sink node aggregates some or all the information. Since sensor energy can not support long range communication to reach a sink, multi-hop wireless connectivity is required to forward data to the remote sink. Each of the distributed sensor nodes has the capability to collect data, process them, and route them to sink node. Router nodes are deployed in sensor field to forward data from sensor nodes to remote sink node. To support node operation, open source operating system (OS) is designed specially for WSN. It utilizes a component-based architecture that enables rapid implementation and innovation while minimizing code size as required by the memory constraints in sensor networks. It includes network protocols, distributed services, sensor drivers, and data acquisition tools. It is event driven execution model, which enables fine-grained power management, yet allowing scheduling flexibility needed for unpredictable nature of wireless communication and physical world interfaces.

CMOS chipsets optimized for WSN are key to its commercialization success. Sensing, computing, and communication can now be performed on a single chip, further reducing the cost and allowing deployment of large numbers of nodes. Advances in MEMS (Micro electro-mechanical system) technology will produce sensors that are even more capable and versatile and yet are tiny enough to fit inside a $1mm^3$ space. Available MEMS include pressure, temperature, humidity, strain gauge, and various piezo and capacitive transducers for proximity, position, velocity, and acceleration and vibration measurements.

One of the current R&D challenge is to develop low power communication with low cost on-node processing and self-organizing connectivity/protocols. Another critical challenge is limited power supply (battery life). Power efficiency in WSN can be accomplished in three ways: low duty cycle operation, local/in-network processing to reduce data volume (transmission time), and multi-hop networking to reduce requirement for long range transmission since signal path loss is an inverse exponent with range or distance.

The applications are varied. Ships, aircraft, and building can ‘self detect’ structural faults; earthquake-oriented sensors in building can locate potential survivors; tsunami-alerting sensors may be set up along the extensive coastal lines. Sensors can be used in battlefield for reconnaissance and surveillance. This is only a potential list of ever-increasing applications in this area.

## 3. Wireless Connectivity

The major advantage of wireless connectivity over wire connections is that they offer more desirable features like easy installation, easy accessibility, enhanced user friendliness, and easy adding new devices to existing networks. Wi-Fi (IEEE802.11WLAN) can support many devices (max. 128) within one network, can transmit data up to 30m distance, needs more power, and cost is more than Bluetooth or ZigBee [3]. Bluetooth was developed as a wireless protocol for short-range communication in WPAN (Wireless personal area network) as a cable replacement for mobile devices. Bluetooth (IEEE802.15.1 WPAN) tends to be utilized for lower-end, cheaper product that works on low power and enables data up to the rate of 1Mb/s. Its range is only 10m and it supports up to 8 devices. The search for cheaper system opened the door for new standard called ZigBee Standard [4,5]. The name of ZigBee has come from domestic Honey **Bee**, which uses **Zig**zag type of dance to communicate important information like food to other hive members. ZigBee is a software standard that sits on top of the IEEE802.15.4 low data rate wireless standard. ZigBee wireless technology specifies the network, security, and application layers and the IEEE802.15.4 specifies physical (PHY) and media Access Control (MAC) layers. IEEE802.15.4 operates in 2.4GHz ISM band and support data rate up to 250kb/s at the ranges from 10 to 70m. ZigBee is designed to complement Bluetooth and Wi-Fi. It allows large number of nodes (more than 65,000). The network layer organizes and provides routing over a multi-hop network, specifying different network topologies. Network layer facilitate an end-to-end data transmission from source to sink via potential relaying nodes. The application layer provides a framework for distributed application development and communication. Application layer deals with data gathering, information processing, etc. A hybrid star-mesh topology implemented in ZigBee provides robust and versatile communication network with low power consumption and low latency. Hierarchical topology aims at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. ZigBee is a low power network which can operate for years on a pair of AA batteries, short time delay (from the sleep state to wakeup state requires 15ms and to connect to a network needs 30ms), highly secure network since it uses Advanced Encryption standard (AES-128bit) for encryption and authentication. ZigBee could be used in light switches, heating, ventilation, air-conditioning, electrical, gas, and water metering, irrigation, industrial plants, medical devices, and environmental monitoring. The WSN could be either IP based or non-IP based protocols. The 6LowPAN (IPv6 based low power WPAN) standard (IPv6 over 802.15.4) is developed within IETF and represents an Internet standard protocol for WSN adapting IPv6 as a network and therefore enable to standardize the IP applications to work. 6LowPAN has been developed in conjunction with ZigBee standard. In this process each sensor node will be provided IPv6 address and they will be directly connected to IP network.

## 4. RFID Technology

RFID is an effective automatic identification technology for variety of objects. The most important functionality of RFID is the ability to track the location of the tagged item [6,7,8]. RFID Technologies comprises tags, reader, and host computer. The tag has an identification number and a memory that stores additional data such as manufacturer, product type, and environmental details such as temperature, humidity, etc of an object. In RFID applications, the tags are attached or embedded into objects that are to be identified or tracked. The tag may be passive with no battery or active with Read/Write function, wider communication range, and independent power supply. A passive tag reflects the RF signal transmitted to it from reader. The active tag enables higher signal strength and extends communication range up to 100-200m. Active RFID tag is capable of two-way communication where a passive tag is read only. RFID reader is able to read and/or write data to tags via wireless transmission. RFID communication is single hop, and there is no communication among RFID tags. RFID reader reads information on the tag and passes it to host computer for further analysis. RFID middleware helps in collection and processing of the data. RFID reader broadcasts to all tags within range, select a particular tag for communication, and exchange information with the selected tag. This process is quite complex when large numbers of tags are within range or when two or more readers overlap. Additional collision avoidance techniques are needed to ensure that communication is organized in structured way so as to allow all tags to participate in this process. Two types of anti-collision techniques are used. One is reservation based (TDMA/FDMA/ CDMA) which guarantees collision-free communication, while other is contention based (Slotted ALOHA/CSMA) which works in decentralized fashion but collision occurs some times. RFID uses backscatter technique and operates in UHF band between 865-956MHz. It allows range between 3-4m using 30cm long reader antenna and 10cm long tag antenna.

RFID has been widely applied in supply chain tracking, retail stock management, tracking library books, parking access control, airlines luggage tracking, electronic security keys in cars, automatic toll collection, theft prevention, and healthcare.

## 5. Integration of RFID with WSN

The basic idea of integration of RFID with WSN is to connect the RFID reader to an RF transceiver, which has routing function and can forward information to and from other readers [9,10,11]. Users are able to read tags from distance 100-200m that is well beyond normal range of readers. Integration of RFID and WSN can provide RFID to work in multi-hop to extend application of RFID to operate in a wider area. The integrated WSN node consists of an RFID reader, an RF transceiver, and micro-controller that coordinate different components in the node. The micro-controller is also used to control the RFID reader and other components which go to sleep mode when they are idle. Integrated tags with WSN can communicate with other tags and form a multiple loop network. Each integrated node transmits not only its unique ID number but also details of its sensed data to all other nodes. The integrated tag listens to the RFID reader radio of neighboring nodes. If some channel activity is detected, the tag awakes the sensor to listen to the channel and then receive data through the RF sensor radio, otherwise nodes can stay in sleeping status. To wakeup the node, a wakeup signal is sent. RFID radio uses much less energy than the RF sensor radio. RFID tag’s features can be added or integrated with sensor nodes such as commercially available MICA motes [12].

Combining RFID reader enabled cell phones and RFID sensor tags in a cellular network or the Internet, the consumers will be able to read any RFID sensor tag in almost any application. Information of RFID tag can be downloaded to cell phone from a remote database for some applications. When you stroll around a super market with RFID reader enabled mobile phone, you can receive information about any product and buy only what you need. RFID Technology enables mobile phone handsets to make payment once credit card information is embedded into cell phone.

## 6. Applications

WSN can be widely used in military, environmental monitoring and forecasting, healthcare, intelligent home, intelligent transport vehicles, warehouse management, precision agriculture, etc. With the in-depth study and broadly application of sensor networks, it will gradually enter into all areas of human life.

### 6.1 Air Pollution Monitoring

Air pollution may be defined as the presence of contaminants or pollutant substances in the air that interfere with human health or welfare or produce other harmful environmental effects. These pollutant substances result from vehicle emissions, industrial emissions, and volatile organic compounds. The WHO states that 2.4 million people die each year because of air pollution. ZigBee based WSN nodes may be spread in the area for pollution monitoring. Sensor nodes will send monitoring data to the sink node through ZigBee module. The sink node provides intelligence to a sensor node. Its main purpose is to control the sensing parts and execute the communication protocols and the data processing algorithms [13,14]. The Sink node sends data to the host computer. The RFID tag on sensor nodes sends location of each monitoring node. These data are read by host computer. Based on these monitoring data and the node location data coupled with related air pollution model, host computer can do spatial analysis, simulate temporal and special instructions of the air pollution monitoring area, and then carry out air quality assessment and decision support. In environmental monitoring system it is essential to support the frequent updates for reacting promptly against disaster. Frequent data transmission makes the batteries of sensor nodes to go out rapidly. In general, sensor nodes are always in a sleeping mode. When it is time for wakeup, the particular sensor wakeup and sends the measured data to the sensor network control system. After data transmission the sensor node sleeps again and waits for the next awake time. The initial sampling rate is low if there is no pollution. If system recognizes the indication of air pollution after checking the observed condition, sampling rate is increased continuously till the pollution gradient start behaving negative. Control node controls sampling rate, network status check, and communication control. When air pollution is above critical level and dangerous, the system will start providing alarm. The dangerous level threshold varies depending on the area such as a school, a factory, or an apartment. The types of sensors needed for measuring air pollution are temperature, humidity, dust, carbon dioxide, carbon monoxide, hydrogen sulphide, air pressure, wind direction, wind speed, altitude sensors, etc.

### 6.2 Healthcare

Sensor networks can track patients, doctors, and medical instruments, monitor patient’s physiological data and control the drug administration, track and monitor inside the hospital.

WSN in-home and nursing home can provide continuous medical monitoring, medical data access, and emergency communication to the linking hospital, thus providing physiological and environmental data. Focus of healthcare is shifting from treatment to prevention that also at home [15]. This type of monitoring helps in detecting abnormal situation where the computer can alert the concerned medical personnal. The medical sensor network system normally integrates heterogeneous devices, some wearable on the patient and some placed inside the patient’s room. This includes pressure sensor, oriental sensor, RFID tags, floor sensor, environmental sensor, dust sensor, etc.

Body sensor network comprises tiny portable devices equipped with a variety of sensors such as heart rate, temperature, oximeter, and accelerometer, and perform biophysical monitoring, patient identification, location detection, and other desired tasks. They support fall detection, unconsciousness detection, vital sign monitoring and dietary/exercise monitoring. The nodes are small in size to be worn comfortably for a long time; the energy consumption should be optimized so that battery is not required to be exchanged regularly. They may use 'kinetic' recharging. A backbone network connects PDAs, PCs, and database servers to the sensor network that provide richer interfaces with historical data, in real time. These systems are also capable of monitoring the health status of individuals who perform very high risk jobs such as soldiers in battle field, firefighters, and underground mineworkers.
RFID can eliminate inefficient, long manual searches for assets (surgical equipment, wheel chairs, oxygen cylinders, etc.) and can maintain up to-date equipments status. This results in significant labor saving, improved efficiency, and good return on investment. Doctors and medical staff can immediately identifies a patient with handheld palmtop reader and provide current information to the system of the patient. There is no mix up with medication or any treatment that the patient should get.

**6.3 Precision Agriculture**
WSN can be used to detect soil moisture to let the irrigation system know where to irrigate [16]. It helps in maximising crop yield and improves profits. Irrigation system requires wind speed and direction, temperature, water level, humidity sensors.

**6.4 Glacier Dynamics**
Use of WSN becomes beneficial in remote areas, where manual observation would be extremely tedious if not impossible. To monitor glacier dynamics and subsequent climate change, sensors are buried 60m in the surface of glacier and are able to record information about temperature, pressure, and movement within glacier and of the sediments at its base [17]. The information from various scattered sensors inside the glacier is wirelessly transmitted to a sink node located on top of the glacier using RF. The information then travel over cellular network from sink node to server at the research institute for continual monitoring of glacier behavior.

**6.5 Structural Health Monitoring**
Strain-gauge sensors embedded into machines and structures enable condition-based maintenance of these assets. The corresponding WSN indicates damage when problem occurs in the structure, thereby reducing the cost of maintenance and preventing catastrophic failures.
Structure gauge sensors can be suitably sealed from the environment and are spot-welded to the surface of the bridge steel support structure. They operate in low power sampling (6Hz). The movement of the train increases the strain on the rail, which is detected by these sensors. The system starts sampling at a much higher rate. The strain waveform is logged into local flash memory of WSN, from where it is transferred to engineer's office for analysis. This event driven data collection method reduces the power requirement by a factor of 30 as compared to the continuous operation model.

### 6.6 Smart Digital Home

Various dedicated sensors for temperature, humidity, fire, smoke, gas, glass-break, and motion can be installed in the smart digital home to detect abnormal condition, they send a message to control node which can raise alarm signal and alert the user. The gas, fire, smoke sensors can be placed in kitchen; glass-break sensors can be installed in various windows/ doors; temperature, fire, humidity sensors can be placed in other areas of a house. A camera and microphone can be installed at the door. Thus, when bell rings the user can see the person outside and can interact without opening the door. The network can be made intelligent by programming actions to be taken. When fire sensor detects fire, sprinklers turn ON, and when theft is detected, police are automatically called. One can use the home network to monitor babies, elderly, and pets

By Clubbing ZigBee home network with GSM network cell phone can be used to control the home network from remote location via Internet. With this one can switch on/off the AC, water heater, lights, microwave oven , and any other connected appliances while on move. In GSM controlled home network, central control node of the local network at home is empowered by a GSM interface. Home network reduces the stress level of a user making things easier and more manageable.

## 7. National RFID Programme

National RFID Programme was a project sponsored by the Department of Information Technology, Government of India to popularize the usage of RFID Technology in different applications in the country. This is a multi-institutional project involving C-DAC, Noida, IIT, Kanpur and SAMEER, Mumbai. As part of this, C-DAC, Noida was to integrate a few real-life systems of national importance, primarily for a technology demonstration. Presently, Department of Posts (DoP) is using a barcode-based system to track the speed-post bags. Articles are placed in bags, which are tied with labels having barcodes. Barcode scanners are used to scan these bags at important transit points en-route viz. Speed Post Centres (SPC) and Transit Mail Offices (TMO). The SpeedNet System of DoP brings this information to a centralised server that provides the tracking information of articles over its website.

We have so far taken following three important projects under this initiative:

a) Speed Post Parcel Tracking System for Department of Posts
b) People Management system for tracking of employees / students movement and their attendance
c) Development of low cost UHF RFID Reader

These are further described in the following sub-sections:

### 7.1 Speed Post Parcel Tracking System for Department of Posts

The usage of Radio Frequency Identification (RFID) technology in place of barcode scanning was proposed as a solution to eliminate the problems associated with the manual operation.

Department of Information Technology (DIT), Government of India, has sponsored this project. The project work started in 2007. Presently, the first phase of the implementation involving 75 Post Offices in three cities of Delhi, Chennai and Mumbai is in operation. The introduction of RFID technology in these offices has not disturbed their existing workflow, but aided and improved their efficiency of operation. Fixed RFID readers are installed in the SPC at strategic locations where the RFID tagged speed post bags could be tracked. The Post Offices do not have any RFID systems other than the tags [18,19]. When the speed post bag is being prepared in a Post Office for dispatch to the destination through the concerned SPC, an RFID tag with barcode label is attached to the bag. The operator then enters the relevant details like source, destination, bar code number, etc in the computer system using the SpeedNet software developed by Department of Posts. The data-uploader software developed by CDAC, which runs in the SpeedNet computer, sends out the relevant data to the database server hosted in CDAC and NIC. The database servers store all necessary information of the speed post bags and keep track of it as and when it moves through the transmission chain. When the speed post bag is dispatched from Post Office through mail van reaches the other SPC, the bag and the attached RFID tag are detected by the RFID reader installed in SPC. This information is instantly sent to the server thus updating its current status in the server. Handheld mobile RFID readers are used to detect speed post bags which do not reach the vicinity of the fixed RFID readers. Wi-Fi network is used to communicate handheld RFID reader information to the computer. The tracking is done using the barcode number labeled on the RFID tag. Introduction of RFID system in the SPC has reduced a lot of manual work for the postal staff. The manual system of entering the weight of the speed post bags has now been completely automated. As soon as the bag is put on the electronic weighing machine, the weight is detected and sent to the computer and recorded in the system. The delivery chart preparation also is now done by the computer which has relieved the postal staff from manual entry.

The system was installed in the three cities in August, 2009 and was under trial for a period of three months. Necessary training was also imparted to the concerned officers in the three cities to use the system. The systems were then handed over to Department of Posts and they are now in a position to use the system independently without any help from CDAC. Now the systems are in regular use at Department of Posts. Based on the success of this project, Department of Posts is now planning to extend the system to another three cities of Kolkata, Hyderabad and Bangalore.

### 7.2 People Management System

In conventional application of RFID for attendance management, an HF based passive sensors are used to mark the attendance and additionally to allow the gate to open. In the world of Ubiquitous Computing and smart spaces, we look for systems which operate unobstrusively. This is possible only with UHF passive tags having a detection range of a few feet. The UHF based system was developed in C-DAC, Noida as a part of National RFID Programme and the same has been well received and is in operation for more than 18 months now [20].

The system is presently being extended to monitor the movement of students in Academic Campus and tracking of their presence in important locations like Library, Laboratories, Cafeteria etc. It is also used in the cafeteria management system wherein the employee/student receiving the food is automatically identified by the reader and the cost thereof is directly billed to his/her account.

### 7.3 Development of Low Cost UHF RFID Reader

Another important development initiative under the National RFID Programme was Development of Low Cost UHF RFID Reader. [21]. The low cost UHF RFID reader is designed using high speed ICs, RFID chip, passive and active electronics components. A 32 bit microcontroller is used to control reader function like reading, writing of tags, adjust

power gain etc. UHF RFID reader is planned with three modules viz. power supply, microcontroller and transceiver. These are designed and developed from initial stage i.e. from drawing schematic of circuit, and development of Gerber data using artwork generation.
Figure 1 gives the various hardware modules that constitute both the readers.

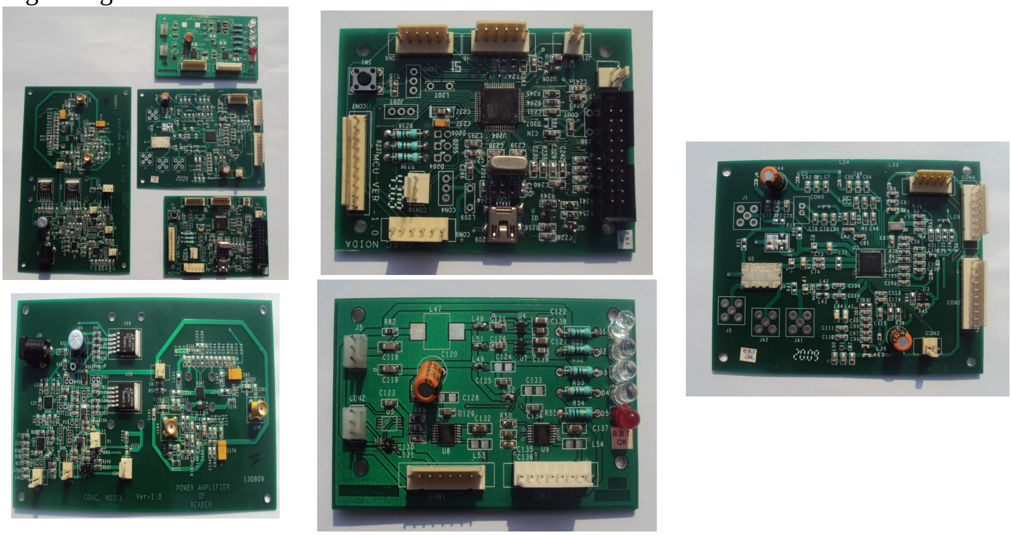

**Fig.1:** Hardware Modules that constitute the readers Figure 1: Hardware Modules that constitute the readers

Both the above reader units use the antenae developed by SAMEER, Mumbai. This is a very low cost implementation of the sensor elements. The units have been tested out extensively and have been successfully integrated in the system for tracking postal parcels in Mumbai, for the past six months.

## 8. Conclusion

In the field of electronics, information technology, and communication system, advancement in technology creates the sprawling effect of increasing consumer expectations. The consumers are looking for the systems that are cheap, consume less power, and having high level of security and safety features. As health and environmental sensors become smaller and more geared toward home and community use WSN for remote data collection is slowly becoming the order of the day. Currently a variety of health sensors can remotely monitor cardiac information, respiratory data, blood pressure, temperature, and several other important vital signs. Environmental sensors can monitor temperature, humidity, pollutants, and other factors in a home, industry, or school environment. Prices of sensors are likely to drop in a fashion similar to that of Cell Phones.
The use of semi-passive or active RFID technology in combination with WSN has a promising future since reading range becomes much larger. It opens up a large number of applications in which it is important to sense environmental conditions to obtain additional information about surrounding objects. An efficient and robust collision-free scheduler for both WSN and RFID network will help in this proliferation.

Sensors will result in an explosive increase in data flows when networks become more ubiquitous. This increase in the number of sensors operating around us will result in an exposition. This will be the area of concern and also a number of new data mining tools would be required to be developed, which will help us in extraction of relevant information from the voluminous data.
RFID and WSN technology are the measures for the future of Ubiquitous Computing. The field is still in its infancy and along with the demand of the applications, we are definitely to see the allround improvement in the sensing, transmission and detection, networking, control theory, software, and middleware.

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## References

|1| I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "A survey on wireless sensor network", IEEE Communication Magazine, Vol.40, Aug.,2002, pp 102-114

|2| D. Cutler, D. Estrin, M. Srivastva, "Overview of sensor networks", IEEE Computer, Vol.37, no.8, pp41-49, 2004

|3| N. Baker, "ZigBee and Bluetooth - strength and weakness for industrial applications", Computer control Eng. Vol.16, pp 20-25, 2005

|4| P.Baroconti, P. pillai, V.W.C. Choose, S. Chessa, A. Golta,Y.F. Hu, "Wireless sensor networks: A survey on the state-of-the-art and the IEEE802.15.4 and ZigBee standard", Computer Communication, Vol.30, pp 1655-1695, 2007

|5| ZigBee specifications, Chapter 2, Document 053474r13, Dec. 2006

|6| Klaus Finkenzeller, RF ID Handbook, Wiley, II Ed., April 2003

|7| L. Suhong, J.K. Visich, M.K. Basheer, C. Zhang, "Radio frequency identification technology: Applications, technical challenges and strategies", Sensor Review, Vol. 23, pp 193-202, 2006

|8| C. Jechlitschek, "A survey paper on radio frequenct identification (RFID) trends", http://www.cse.wustl.edu/~jain/cse574-06/rfid.htm

|9| R. Want, "Enabling ubiquitous sensing with RFID", IEEE computer, Vol.37, no.4, pp 84-86, 2004

|10| L.T. Sanchez, T. Lopez, H. Daeyoung, 'Wireless sensor network and RFID integration for context aware services", Tech. Report, Auto-ID Labs white paper series, 2008

|11| C. Englund, H. Wallin, "RFID in wireless sensor network", Tech. Report, Dept. of Signals & systems, Chalmers Univ. of Technology, Sweden, 2004, pp 1-69

|12| MICA, web site Crossbow Technology, http://www.xbow.com, accessed 15 Jan, 2010

|13| K. Martinez, J.K. Hart, R. Ong, "Environmental sensor networks", IEEE Computer, Vol. 37, no.8 pp 50-56, 2004

|14| Y.J. Jung, Y.K. Lee, D.G. Lee, K.H. Ryn, S. Nittel, “ Air pollution monitoring systems based on geo-sensor network”, ARRS, Boston, 2008, pp 1-5
|15| M. Adnane, Z. jing, S. Choi, H. Jang, “Detecting specific health related events using integrated sensor system for vital sign monitoring, Sensors, Vol.9, pp 6897-6912, 2009
|16| L.R. Garcia, L Lunadei, P. Baneiro, J.I. Robla, “A review of wireless sensor technologies and applications in agriculture and food industry: state-of-the-art and current trends”, Sensors, Vol.9, pp 4728-4750, 2009
|17| J.K., Hart, J. Rose, “Approaches to the study of glacier bed deformation”, Quatenary International, Vol.86, pp 45-58, 2001
|18| D. Lakshmi, M. Kumar, “A pilot project for postal parcel tracking using UHF RFID tags”, Proceed. Of ASCNT-08, C-DAC, Noida, pp 28-33, Feb., 2008
|19| R. Agarwal, S. Bajaj, Anita Gupta, R. Sharma, A. Mittal, “ Gap analysis and business process reengineering for speed post bag tracking system for department of post”, Proceed. of ASCNT-09, C-DAC, Noida, pp 2o4-214, March., 2009
|20| [20] Sourish Behera, Rajesh Kushwaha, “ RFID based people management system”, Proceed. of ASCNT-09, C-DAC, Noida, pp 227-234, March, 2009
|21| [21] Lalit Kumar, Chandan Maity, Arivendu Bhardwaj, Adarsh Pillai, H.P. Srivastava, Rakesh Kumar, “ Design and development of low cost UHF Reader”, Proceed. of ASCNT-09, C-DAC, Noida, pp 215-222, March, 2009

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