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Application of RFID and Wireless Sensor Network for Optimizing the Dynamic Placement of Materials in Storage Houses

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Abstract: ***Storage houses are an important part of certain businesses. As the cost per unit of area of these storage houses is very high, it becomes very important for the businesses to optimize the placement of the different kind of materials. Some of these materials have their own environmental requirements which may not be the apt environmental conditions for other type of material. Usually separate placement zones in same storage house are created which have specific set of environmental conditioners suitable for a particular class of material. But this approach may lead to inefficient utilization of space as well as energy. And if material with a specified set of environmental requirement is placed in a zone meant for material with significantly different set of environmental requirements, it may get spoiled in very short span of time. In this paper a novel approach is presented which uses RFID and WSN to meet the challenge of optimizing the material placement with efficient utilization of space and energy thus lowering down the operational cost.***

Keywords: RFID, Wireless Sensor Networks, Inventory Management, Storage house, Condition Monitoring and Control, Decision Support Advisory

I. INTRODUCTION

Businesses have inventories. The inventory of a large business is usually stored and maintained in large storage houses. In these storage houses, depending upon the kind of business and its individual requirements, different types of materials are stored. Proper and optimized management of materials stored in storage houses is a multi-billion dollar global challenge now days. The quality check and the other parameters required for efficient storage needs strict real time monitoring. Various methods employed in the current scenario monitor entry and exit of materials, but do not take into consideration the location and placement of the containers containing these materials [11]. Each of these materials has its own level of tolerance against temperature, pressure, moisture, light and chemical activity. Besides this, certain other materials are stored in the same storage house which contributes to the moisture level and chemical activity in the storage house. Acidic material cannot be stored in one warehouse, and a flammable material cannot be stored within the vicinity of an oxidizer. During transit and storage of all these materials, such constraints pose a major challenge. Thus combination of such materials may lead to the partial/total damage of one particular class of product rendering it unusable. This could lead to huge financial loss as well as loss in social reputation of the business organization. Moreover, there is a grave chance of human fatality too. Hence separate zones are provided for storage of such materials in the storage house. Each of these zones has their own set of environmental conditioners so as to meet the requirement of a particular set of materials. But if a new set of material has to be brought in which has altogether different environmental requirement, it may not be stored in the pre-created zones. Hence there is a need to provide a virtual and logical separation without any physical partitioning. This can be achieved by configuring the settings of environmental conditioners which are strategically placed in the storage house so as to provide localized environmental zones [10]. Settings of each conditioner correspond to suitable conditions for a particular set of materials to be placed.

With the invasion of Passive RFID, inventory management has become a lot easier with low operational costs [8], [9]. Moreover, low-cost and low-power wireless sensor networks are now widely available in market.

A well devised system comprising of Passive RFID and wireless sensor network can be employed in storage houses to meet the above posed challenge with prior knowledge about the appropriate environmental conditions required for each set of materials. An Automatic Alert System (AAS) and a Decision Support Advisory (DSA) can be developed so that the person in-charge for the inventory management and material movement can make best decisions regarding the proper placement of the different materials so as to avoid any mishap. Thus a very well maintained system can be made to operate dynamically in real time, so that whenever some sort of violation takes place in terms of exceeding the defined threshold values, an alarm can be sounded off.

II. RFID TECHNOLOGY

Radio-frequency identification (RFID) is an automatic identification method, which stores and retrieves unique data using RFID tags, RFID readers, and middleware. The Electronic Product Code (EPC) standards and RFID technology assigns each entity a unique code and forms a real-time network for sharing material information as per the requirement

[6]. Application of RFID technology is found in many areas, including material management, inventory review, manufacturing automation, entrance guard control, theft detection etc.

RFID systems basically consist of three components:

i) An electronic data carrying device called a tag that is attached to the item that needs to be identified. Each razor-thin tag contains an antenna and a microchip with a capacity of at least 64 bits.

ii) A reader which communicates with the tag by using radio frequency signals. The reader powers an antenna and generates an RF field. When a tag passes through the field, the information stored on the chip in the tag is decoded by the reader and stored, sent to a server containing RFID middleware and database.

iii) A data processing system that contains information on the identified item and distributes information to other data processing systems maybe a server.

RFID tags can be classified as active tags which have their own internal power source and can be used to power any ICs that generate the outgoing signal, and the passive tags in which the power to read the tags comes from the reader, rather than from a battery within the tag. The tags used in this approach are essentially passive RFID tags due to their lower cost and easy implementation. Each material container is tagged with passive RFID tags by the manufacturer and the corresponding entry is stored in a shared database for further access by stakeholders.

III. WIRELESS SENSOR AND ACTUATOR NETWORK

Low power, wireless network based sensor modules are widely available in the market. Usually IEEE 802.15.4 forms the basis of such low power network of sensor nodes. IEEE 802.15.4 also provides the data communication channel for many control devices like air humidifiers/dryers, air coolers/heaters and various types of motors. The form factor of wireless nodes is very small and hence can be placed conveniently almost anywhere. These nodes eventually form a complete network called as wireless sensor and actuator network. Sensor nodes senses various physical parameters of the environment like temperature, humidity and pH level and then relays the data in digital form to a predetermined storage or computational server. A sensor node may include at more than one sensor and actuator thus enabling multi-faceted data collection [1]. The computational server processes the data from sensors and gives appropriate command to wireless actuators thus enabling an automatic control action.

IV. OPERATION

The RFID system along with wireless sensor nodes helps in identification of the parameters related to a particular material and the existing environmental conditions of the storage house required in this approach [3],[4]. The parameters taken into consideration here are moisture, temperature and pH value. The moisture, temperature and pH requirement of materials stored varies according to the type of the material. The threshold values of moisture, temperature and pH level of each material is already stored in the shared database and is usually provided by the manufacturer. Fig 1 shows the strategic layout of assembly of different sensors/actuators and RFID readers placed in the storage house.

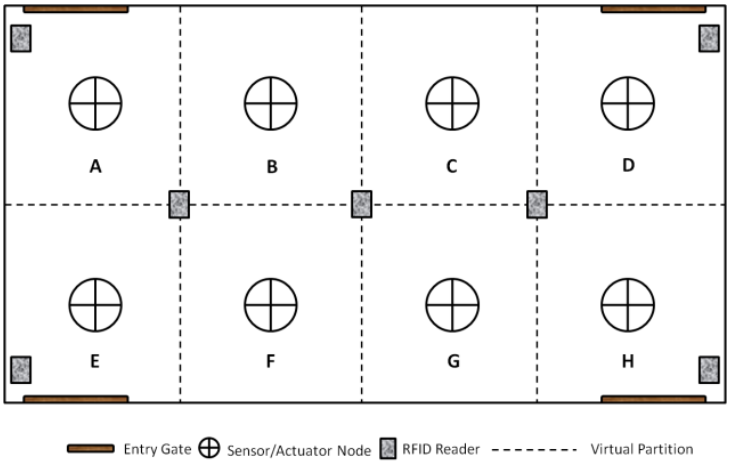

Fig 1: Layout of storage house with strategic placement of Sensors and RFID readers

Fig 2 shows the block diagram of the system. The storage place is equipped with strategically placed wireless sensor assembly nodes which consist of temperature sensor, moisture sensor and pH level sensor and wireless module. This assembly senses the physical parameters and actuators which perform the necessary action to regulate the conditions. The strategic placement of the actuators in the defined storage place is necessary so as to provide a localized environmental zone. The actuators are used to control and regulate the temperature, moisture and pH level of the area surrounding it or which is within its range. The containers storing a particular material are equipped with RFID tags. The RFID Readers are also placed at strategic places such as entry gates, exit gates and within the storage area. The RFID readers relay the tag data to DSAS through low power wireless network [7]. When the containers enter the storage house, RFID readers read the tag data and relay it to the DSAS. The DSAS has a RFID middleware running on it as well a database. Middleware filters the tag data and store it in a database. These containers are then identified on the basis of the type which it is storing i.e. whether it is acidic, inflammable, nuclear etc. and the corresponding threshold data is retrieved

from the manufacturer's database and stored in local database [5]. Then a feature vector is formed. Most of the times each material has a unique feature vector which corresponds to the threshold values of moisture, temperature and pH required by it during its storage period. The conditions required by materials already stored in the storage houses are also retrieved from the local database and the corresponding feature vectors are formed. The feature vector of incoming material and feature vectors of material already stored are compared and then an appropriate localized zone is identified and the settings of actuators is done in correspondence with the conditions required the material to be placed. These actuators maintain the condition required by the materials in such a way that the threshold values of moisture, temp and pH level are satisfied. Thus the proper placement of material is done. The localized zone is chosen in such a way that the nearby localized zones contribute to its environmental conditions instead of posing a negative impact on its localized environment.

This unique RFID and WSN system tracks the physical location and environmental condition 24 hours a day, 7 days a week. Once the materials are entered into the storage house, the wireless sensors and actuators maintain the environmental condition of localized zone at every instant of time.

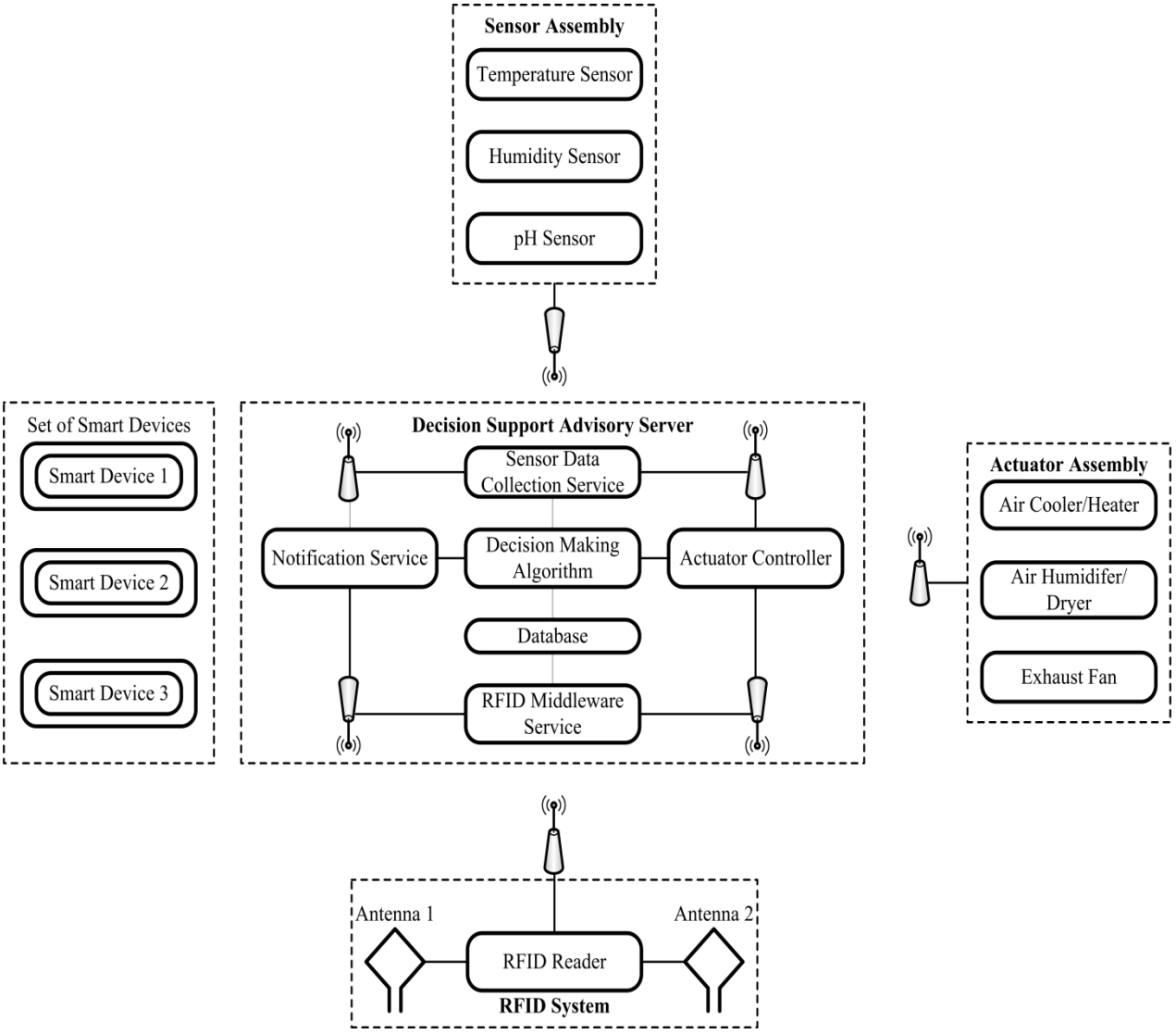

Fig. 2: Block Diagram of the System

Let us suppose material M1, material M2, material M3 have corresponding feature vectors as follows:-

	M1	M2	M3
Moisture	60	45	35
Temp	28	30	33
pH	6	6	7

As given the moisture requirement of material M1 is more than material M2. Thus material M2 needs to be placed far away from material M2. The M1 material is placed in localized zone A. Air Moisturizer/Dryer system, air Heating/Cooling system are configured with corresponding threshold values which then based on the sensor data keeps on regulating the environmental parameters. Material M2 is placed in localized zone B where air dryer and air heater are configured with the corresponding values. As the localized zone B also gets affected by the localized zone A, the sensors in zone B keep on sensing the conditions and regulate the moisture and temperature of localized zone B by automatically triggering the air dryer and air heater ON at appropriate moments.. The requirement of material M3 lies in between M1 and M2 .Thus the location of M3 will be neither be in area of high moisture nor in area of low moisture. Hence it is placed in localized zone G. Thus the strategic placement of these materials requires the optimization of distance between the materials with the help of certain distance optimization algorithm taking into the consideration the effect of nearby localized zones. The storage house manager or the incharge person gets all the recommendations from the DSAS on his mobile smart device and then he dispatches material into the storage house. The material then with RFID tags gives the information of their presence to the RFID readers, which in collaboration with the data from the sensors helps in placing the materials in their optimized positions [6]. The further influx of materials will go through the same procedure and gets placed in an appropriate localized zone where the respective nodes then adjust the temp, moisture and pH of the environment.

V. WORK FLOW

The whole process can be summarized in a form of a precise work flow. Following assumptions are considered

i) Each object to be stored is tagged (RFID)

ii) Database contains a map where each UID (tag data) is mapped with its temperature sensitivity, moisture sensitivity and pH sensitivity.

iii) User has a mobile smart handheld device that contains an application which connects to DSA Server through wireless network.

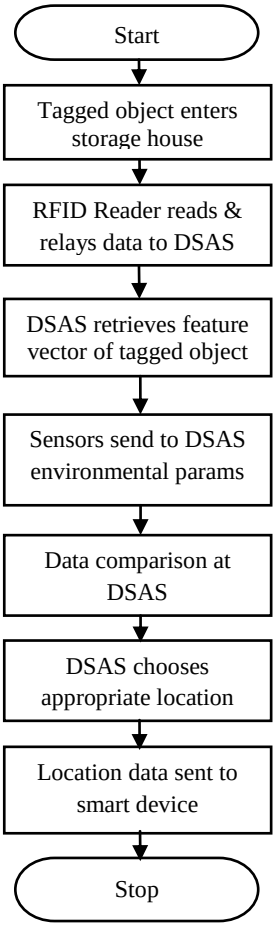

Fig 3: Flow chart of the process

Extensive care is taken so that the nodes do not interfere with each other's data and while data is relayed, collision is avoided by usage of IEEE 802.15.4 based network. If any abnormal situation occurs, like rise in temperature, moisture and pH level above a certain threshold, an alarm is triggered that alerts the emergency responders to take immediate action. This necessitates the development of decision support advisory (DSA) which takes the important and necessary decisions regarding the placement optimization and error correction if any. The data which is sent to the central database helps the responders to take decision regarding the placement of the materials in order to optimize the area of the storage

house and tracks the movement of the material within the storage house. The responder is facilitated with a hand held device which maybe a smart phone, in order to direct the entry of materials in their localised zones.

The data which is processed by the nodes is further transmitted to the central data base and server. The end user can access data and other parameters in real time. The databases can be searched on the basis of storage conditions, storage contents, shelf life etc. This data is continuously updated and monitored.

VI. CONCLUSION

The proposed design by integration of Wireless Sensor Networks and RFID Technology can be used for efficient storage management. The placing of the materials in their localised zones can be done by using a line follower robot. The DSAS can directly provide the location coordinates and necessary directions to the robot and thus placing the material in accordance with the idea behind to optimize the area utilization.

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