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FRUIT FRESHNESS MONITORING SYSTEM DURING TRANSPORTATION -An RFID and WSN based Monitoring System

I. Joe Louis Paul, S. Sasirekha, S. Jesu Iswarya, R. Praveen Chandru

Department of Information Technology, SSN College of Engineering, Chennai, Tamil Nadu, India
joelouisi@ssn.edu.in, sasirekhas@ssn.edu.in

ABSTRACT

In India, 104 million tons of perishable products such as fruits and vegetables are transported annually between Indian cities, out of which 100 million tons of products are transported in non-refrigerated mode. If the quality change of these products during transportation is not monitored, may incur economic loss or damage to fruits. There are many systems currently available in the literature for monitoring the perishable fruits using Radio Frequency Identification (RFID) and sensor technologies. However, these systems lack in providing a comprehensive approach taking under consideration of energy consumption and compliance with the temperatures needed to preserve foods. To overcome this issue, there is an emerging need to use and integrate the efficient technologies such as RFID and Wireless Sensor Networks (WSNs) to monitor the ripening status of fruits for preventing the damage as well as to identify and track the exact presence of damage during transportation.

In this work, the ripening status of the fruits can be determined by the amount of ethylene content (fruit ripening hormone) it produces using sensors and RFID. The uniqueness of the proposed system lies in identifying the condition of fruits in each box using RFID tag with unique identifier. This helps in tracking the fruit box depending upon its ripening status without even opening it. For achieving an efficient real-time monitoring, control and management of fruit freshness during transportation, an integration of WSN and RFID based system interfaced with Service Oriented Architecture (SOA) has been proposed in this work. This work aims to automate the fruit monitoring system by minimizing the system complexity and maintenance costs can be useful to suppliers with chain of warehouses, grocery retailers etc.

Index Terms— RFID Tag, WSN, Fruit Quality Monitoring, Cloud Data Store.

I. INTRODUCTION

Poverty is a root cause of many socio-economic problems and biggest challenge to the development of India. Being home of one-sixth of human population, the world will not be poverty-free, if India is not going to eradicate its poverty. It's pathetic when India, the one who produces in enormous amounts faces the trouble of poverty and food shortages.

Globally, one third of food created is wasted with-out human consumption, estimated as 1.6 Billion tons. It is found that food wastage amounts to USD one trillion every year. Huge amount of food gets wasted without consumption when 870 million people's stomach are not fed and hungry when they go to bed. One in eight people in global population are under-nourished during the period 2010-12 as per Food and Agriculture Organization (FAO) report of the United Nation. Highly producing countries like India waste 21 Million tons of wheat which is equal to the total consumption of Australia (food that's equal to the entire food production of some country).

In India, 40 percent of the fruits and vegetables get wasted between the cultivator and consumer. If food could be distributed efficiently, surplus can be used to feed the poor. Annually, India suffers Rs 550 billion worth fruits and vegetables as wastage due to inadequate cold storage and supply chain infrastructure, lack of food processing in agri sector. Consumer behavior and lack of communication in the supply chain say, best-before-date are considered so much seriously and people throw food even when the food is edible. This amounts to food wastage in societies according to Food and Agriculture Organization (FAO) of the United Nations. Poverty cannot be eradicated unless the produced food reaches every part and kind of people in India.

There exist business solutions for monitoring the containers and trucks; but they're not providing the entire information about the cargo, because of which they use to produce the data solely during a single or solely at the restricted points. The cold chain, from harvest to the consumer's plate, ought to be under-stood as one entity. Enhancing one link inside the cold chain is not enough to spice up the entire system.

Hence, a comprehensive approach taking under consideration of energy consumption and compliance with the temperatures needed to preserve foods is highly needed. In addition to that a lot of control, management, measuring and automation remains to be developed in this context.

Appropriated observation needs an increasing range of measurements to be performed in food supplying. Specialized observation devices promise to revolutionize the shipping and handling of a large vary of destructible merchandise giving suppliers and distributors continuous and correct readings throughout the distribution method.

The major contributions of this research work are as follows: (1) to integrate RFID and WSN technologies to monitor the ripening state of the fruits during transportation; (2) to propose an integrated automated framework as a solution for an efficient real-time monitoring of perishable fruits using Service Oriented Architecture (SOA); (3) to increase the system's agility, and lower the maintenance cost for food suppliers.

In the remainder of the paper, Section 2 narrates the background followed by Section 3 which briefs about some of the related works carried out. In Section 4, the system model of the proposed work is illustrated. Then in Section 5, the implementation steps, the test results obtained and their inferences are elaborated. Finally, Section 6 concludes.

II. BACKGROUND

Recent developments in Information and Communications Technology enable lowering the costs, creating smart devices and processes. Remote observation might induce an applicable action to keep up quality of the shipment through, as an example, aeration or defrosting. The sensing devices need to have certain specifications such as robustness, minimal energy consumption, decent, precision, low cost, and acceptable size and shape.

Latest advances in wireless sensor technology paved the way for low cost, small sized sensors nodes that could cooperate with each other. Wireless Sensor Networks (WSNs) are used primarily for their cost-effective monitoring of application that includes sensing environmental conditions like temperature, humidness and pressure. These sensors can form a network through that they impart the information with different sensors, forward them to a gateway [1].

Sensor with limited energy cannot communicate to gateway where the information is analyzed, hence multi-hop wireless setup is needed to forward the information to and from the gateway that causes an extra overhead and interference issues [2].

Radio Frequency Identification (RFID) could be a wireless radio communication technology that's used for classification and detection of items on which they are tagged. It's a fast, easily readable and when used in real time application save time and reduce labor cost. RFID tags consist of a transponder, memory that can store data such as identification information like manufacturer, products name and environmental parameters like temperature, humidity, amount of certain gases present in the atmosphere. RFID readers which are of high frequency can read the information stored onto the tags without line of sight [3].

There are some applications where much more than identification and location by RFID is needed, where WSN can be useful for sensing. However, WSN can be used to do the required environmental sensing, identification and location remains crucial [4]. Hence, there is a need for the integration of both to effectively combine the capabilities of these technologies [5, 8].

III. RELATED WORKS

This section describes the elaborate related works as follows. Ruiz-Garcia et al., [17] mentioned that the provision of varied data technologies like Global Positioning System (GPS) and wireless information transmissions will offer higher observance data regarding fruits and vegetables transported within the cool containers. This work emphasizes on the need for the development of new intelligent based transport systems which should concern about security and food safety [9, 10].

RFID and WSN are the two essential wireless technologies that have a good variety of applications like environmental observance, security and surveillance, health care, control and management applications. In recent years, the use of RFID technology finds a new way for the transmission of sensed data automatically in a large class of WSN based applications. Though RFID tags are capable of transmitting sensor information from the limited number of sensors, it is very difficult to miniaturize and embed the complex sensors in the RFID chip. Hence, an economical general purpose multi-ID tag based sensor data transmission was proposed mainly to transmit any type of sensory data [11] using RFID tags.

Initially, RFID technology was applied only to indoor applications. Nowadays, RFID is combined with WSNs essentially to provide an improved tracking and monitoring system for outdoor applications. To integrate WSN and RFID technologies, a Non-deterministic Push-down Automata (NPDA) model based two heterogeneous u s architectures were presented in [12]. Here, the complexity of that model needs an attention.

Moreover, RFID technology is employed to notice and determine the objects that aren't simply detectable by the standard sensors. However, RFID doesn't offer any details regarding the condition of the objects. Besides, WSN provides the knowledge concerning the state of the objects and achieves multi-hop wireless communication. Hence, the integration of these two technologies can extend the overall functionality of system. Hence, the merge of these two technologies will extend the general practicality of system. The new challenges faced in integrating RFID and WSNs must be addressed further [13].

Perishable food product like vegetables, fruit, meat or fish is subject to additional risk on the cold chain. These products need of refrigerated transports. Hence, it becomes necessary to monitor and control the conditions of these products during transport and storage to ensure the quality for the consumers. Though, Van et al explored the potential use of WSNs for the observation of fruit storage and transport conditions, it consumes more time to develop, seems to be expensive in deploying sensors and it is difficult to achieve the interactions with the sensors in real-time especially in a controlled environment like a refrigerated truck [14,15].

Based on the literature survey, it is inferred that various environmental parameters such as temperature, humidity, light intensity and the toxic gases inside the cold storage container must be monitored for keeping the quality of the perishable food products in the storage. It is alleged that the quality and life time of the goods can be increased by monitoring and analyzing the environmental parameters collected from the sensor nodes deployed at the appropriate locations inside the container [16].

In addition to health and safety considerations, the customers additionally demand sort of food product with prime quality. Because, the standard of the food product is subject to a spread of risks throughout production, transport and storage lead into quality losses. Today, this is the biggest challenge faced by the food industries to meet the consumers need. Prolonging the sensible time of perishable food product could be a primary concern for the food business. The use of various wireless sensors in refrigerated vehicles to notice, establish and communicate what happens throughout the transport, observing the conditions of biodegradable items in transport was described in [17].

But these sensors based monitoring systems generate large volume of data which causes difficulty in maintaining the data introducing some additional hardware cost for implementing the same. Recent advances in RFID technology is used during this context. Wang developed a strategy for modeling the food quality degradation in terms of dynamically known food quality options by integrating with a pricing decision using RFID enabled tracking system. This system enables to maximize the food retailer's profits through the pricing approach [18].

Vergara et al proposed a solution using an RFID reader with launched gas sensing ability to observe the climacteric fruit throughout transport, storage and marketing for enhancing food logistics by considering several parameters such as wetness, temperature, intensity, ethylene, ethanol and acetaldehyde levels. The results have shown that the RFID reader may be used as a favorable tool in fruit supply [19]. The following section briefly explains the proposed work.

IV. Fruit Monitoring System

The objective of the proposed system is to monitor the quality of perishable fruits during transportation using efficient technologies like RFID and WSN. An RFID system and a WSN each exist during a network and work separately.

The combination of RFID and WSN performs within the software layer once information from each RFID tags and detector nodes is forwarded to the common center. In such eventualities, booming operation of either RFID or WSN could need help from the opposite.

For example, the RFID system provides identifycation for the WSN to seek out specific objects, and therefore the WSN provides further information, like locations and environmental conditions, for the RFID system. The advantage of merging these technologies is to design an integrated hardware and every operations and collaborations of RFID and WSN is done at the computer software layer. However, since RFID tags/ readers and device nodes are physically separated and that they work together in a similar system, it should cause some communication interference problems. This leads to overhead of programming on communications to avoid interference.

The proposed system follows a mixed architecture in which RFID tags and detector nodes are physically distinct devices however they are in an integrated network and that they work separately as shown in Fig. 1. The main advantage of such a mixed architecture is the fact that there is no need to design a hardware integrated device.

The hardware used in the proposed fruit monitoring system consists of an Arduino UNO, MIFARE Classic 1K tag, temperature sensor (LM35), CO_2 sensor (MQ-135), MFRC522 and Global Positioning System (GPS).

A. Arduino UNO

Arduino may be a single-board microcontroller, supposed to create the appliance of interactive objects or environments with a lot of accessible. The hardware consists of free open-source hardware board designed around an 8-bit Atmel Aboriginal Voices Radio (AVR) microcontroller with complementary elements to facilitate programming and incorporation into different circuits or a 32-bit Atmel Advanced RISC Machines (ARM).

B. MIFARE Classic 1K Tag

The MIFARE Classic 1K card is essentially a memory memory device, wherever the memory is split into segments and blocks with straight forward security mechanisms for access management. These cards have restricted process power because of their reliability and low value, these cards are mainly used for electronic case, access management, company ID cards, transporttation and sports stadium ticketing.

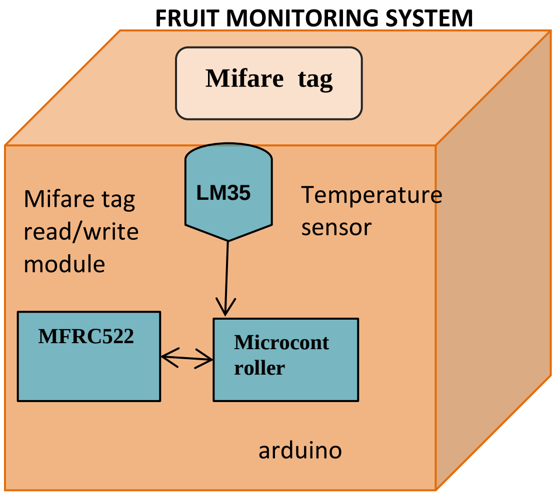

Fig. 1. Fruit Monitoring System

C, Temperature Sensor (LM35)

The LM35 series are accurate integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 also has an improvement over linear temperature sensors measured in ° Kelvin, because the user isn't needed to reckon an outsized constant voltage from its output to get convenient Centigrade scaling. The LM35 is rated to control over a −55° to +150°C temperature range.

C. CO_2 Sensor (MQ-135)

A carbon dioxide sensor or CO_2 sensor is an instrument for the measurement of carbon dioxide gas. Elevated levels of CO_2 in controlled atmosphere storage influence affect time or shelf life, fruit quality and aroma volatiles.

D. MFRC522

The MFRC522 could be an extremely integrated reader/writer IC for contactless communication at 13.56 MHz. The MFRC522 reader supports ISO/IEC 14443 A/MIFARE mode. The MFRC522's internal transmi - tter is ready to drive a reader/writer antenna designed to interact with ISO/IEC 14443A/MIFARE cards and conditions like temperature, humidness and pressure. These sensors can form a network through that they impart the information with different sensors, forward them to a gateway [1]. Transponders without further active electronic equipment. The MFRC522 transmission module supports the Read/Write mode for ISO/IEC 14443 A/MIFARE at varied transfer speeds and modulation protocols. The receiver module provides a strong and economical implementation for demodulating and cryptography signals from ISO/IEC 14443 A/MIFARE compatible cards and transponders.

E. Global Positioning System (GPS)

The Global Positioning System (GPS) could be a space-based satellite navigation system that has location and time data altogether weather, anyplace on or close to the world wherever there's a clear line of sight to four or a lot of GPS satellites. The system provides essential capabilities to military, civil, and industrial users round the world.

F. RFID Middleware with SOA

One of the basic functions provided by RFID middleware is the device monitoring and management. RFID middleware extracts the data from the readers, filters and aggregates the data and then sends to the enterprise system. RFID middleware bridges the MIF ARE tags with the application software at the back end and manages the data exchange between these two. However, RFID middleware is limited to support reconfiguration. Hence, a SOA based integrated frame work has been proposed in this work mainly the enterprise applications can invoke the services provided by RFID middleware across services interface layer. This framework enables the transformation of the proposed system into a set of linked services which can be accessed over a network when needed. Applying SOA can further minimize the system complexity by reducing the coupling between devices and external software and ease the integration between middleware and applications [20, 23]. Hence, the suppliers or warehouse operators can perform the following tasks easily and quickly:

1) to monitor the ripening status of the fruits during transportation for preventing the damage.
2) to identify and track the exact presence of damage during transportation.
3) to determine the appropriate temperature that needs to preserve the fruits during transportation.
4) to fix the rate dynamically based on the quality of the fruits.

V. Experimental Results

MIFARE tags are loaded with the product information such type of Fruit, Quantity, Manufacturer's name and all extra information required to identify the box. Each MIFARE tags consist of unique ID which can be used to track the status of box distinctively. Readings from Temperature, co2 and o2 sensors such as temperature inside a box, respiration rate, oxygen level respectively are sensed. These readings are written onto the MIFARE tag using MFRC522 read/write module so that high end RFID readers could read them without line of sight. These data are periodically updated into the database from the high end RFD reader. Using various Evaluation results the status of the fruit is determined. GPS is used to track the current location of the truck during transportation. Alert could be made to the nearest warehouse or retailer when the required storage condition varies that affects the shelf life of products.

Figure 2 represents the result after reading and writing data onto the MIFARE TAG after authentication.

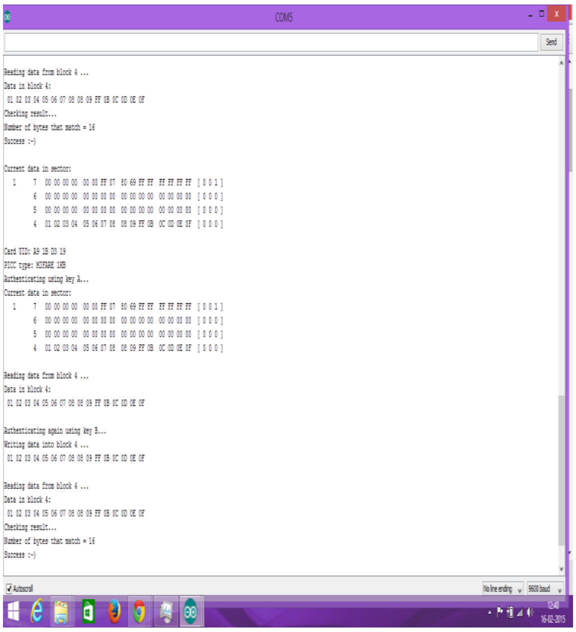

Fig. 2. Reading and Writing onto MIFARE Tag

Figure 3 represents the results of sensor data such as environmental parameters that are written onto to the MIFARE tag.

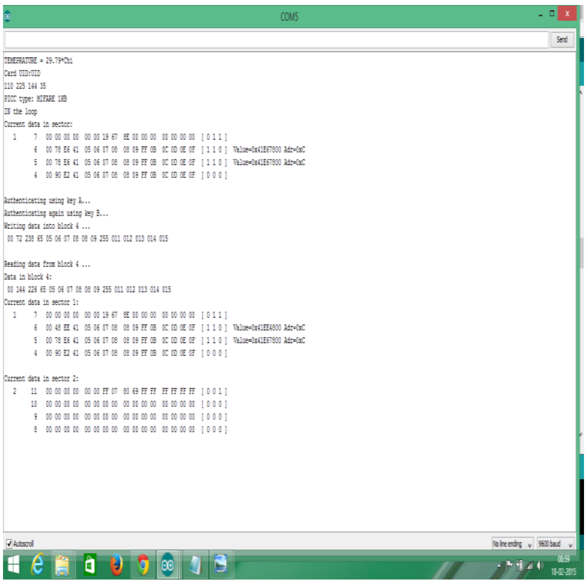

Fig. 3. Readings from sensor Written into MIFARE Tag

Figure 4 represents the results of GPS latitude and longitude reading required to trace the current location

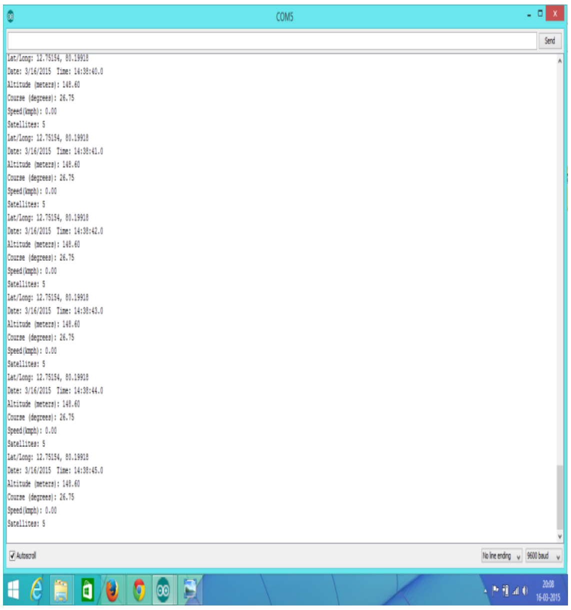

Fig. 4. GPS Latitude and Longitude Readings

Respiration rates are typically expressed as weight or volume of gas induced or consumed per kilo fresh or contemporary weight of product per hour. For example: mg CO2/kg-h (i.e. per weight unit contemporary weight, hour); or cubic centimeter CO2/kg-h (i.e. per weight unit contemporary weight, hour) or ul C2H4/ kg.hr (i.e. per weight unit contemporary weight, hour).

The sample data of evaluation results which are used to determine the status of fruits are as follows. Table I contains the data about CO_2 and Ethylene (C_2H_4) production for mango at various temperature ranges.

TABLE I. CO_2 AND ETHYLENE PRODUCTION FOR MANGO AT VARIOUS TEMPERATURES

Temperature	ml CO_2/kg·hr	ul C_2H_4/kg·hr
10°C (50°F)	12-16	0.1-0.5
13°C (55°F)	15-22	0.2-1.0
15°C (59°F)	19-28	0.3-4.0
20°C (68°F)	35-80	0.5-8.0

Table II contains the data about CO_2 and Ethylene production for apple at various temperature ranges.

TABLE II. CO_2 AND ETHYLENE PRODUCTION FOR APPLE AT VARIOUS TEMPERATURES

Temperature	ml CO_2/kg·hr	ul C_2H_4/kg·hr
0°C (32°F)	2-5	1-10
5°C (41°F)	3-7	2-20
10°C (50°F)	5-10	5-40
20°C (68°F)	12-25	20-125

From these sample data,optimum storage conditions for some fruits are evaluated so that they could be transported beyond 2 weeks or more without affecting shelf life as given in Table III.

TABLE -III: CONTROLLED ATMOSPHERE FOR STORAGE BEYOND 2 WEEKS OR MORE

Fruits and Vegetables	Storage Temperature (C)	O_2 Level (%)	CO_2 Level (%)
Apple	0-5	1-2	0-3
Apricot	0-5	0-3	0-3
Grapes	0-5	2-6	1-3
Mango	10-15	5-10	0-10
Orange	5-10	5-10	0-5
Tomatoes	12-20	3-5	2-3

Any variations in this optimum storage conditions will create an alert to another retailer nearby with the help of Sensors, RFID readers and GPS.

VI. CONCLUSION

This proposed work monitors the quality and shelf life of fruits during transportation which can be useful for customers and retailers using efficient technologies like RFID and WSN. It also has add-on features like identifying the particular box in which the fruits are perished using unique ID, GPS tracking to deliver the products to the nearby warehouse and monitoring various environmental parameters which are responsible for prolonging the shelf life of fruits during transportation. Appropriate pricing model depends upon the status of the fruit could be adopted rather than by sell-before-date.

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