A Dual Data Processing System Using Sensor Integrated RFID Middleware

I. INTRODUCTION

The evolution of sensor technology and Radio Frequency Identification (RFID) research makes possible integration [1,2] of RFID data and Sensing data using same RF tag, called Sensor Tag [3,4]. Sensor tags are, in general, characterized by RF identification, user memory and sensing information. RF capable sensor tags having user memory store sensing data to its memory and transfer that data to the reader when it is in reader interrogation area. While comparing EPCglobal [5] tag class structures [6], active tags enable a greater communication range, can be applied to metal objects, and allow easy addition of sensing modules [7, 8]. Therefore, active RFID tag can be used as sensor tag [9], enabling simultaneous id and sensing data transmission using same RF infrastructure. A large number of such tags can be deployed in cold chain management [10,11], supply chain management systems and harbor logistics systems where huge amount of sensing data is generated. Consequently, sensor tag is suitable for continuously monitoring temperature-sensitive perishables, controlling product temperature and humidity, elimination of container damage due to huge inside pressure, and automatic tracking of product location. Thus, it is possible to create a physically linked world in which every item is numbered, identified, cataloged and tracked with various sensing information. However, to provide proper system services using sensor tags, it is necessary to control and efficiently manage tags carrying id and sensing information.

Although Sensor Tag is used to acquire integrated RFID-Sensing information, the technology used in its management and control is still in its infancy. Still there is no global standard provided for RFID-Sensing data collections. In most RFID applications, heterogeneous tags such as RFID tag (only id data) and active sensor tag (RFID-sensing data) from various vendors are used and RFID reader must be able to retrieve data from these heterogeneous tags. Therefore, compatibility and interoperability become a major system concern in using Sensor Tag. Also, sensor tag must continuously store sensing information in its tag memory. But limited memory and battery power is big a challenge in system deployment. Moreover, system suffers from bulk air load while transmission of sensing data in tag memory takes place. However, faster tag collection is possible using active RFID System [12], still controlling sensor tag modes and states is important for saving tag battery power and sensing values in tag memory.

We develop an efficient Sensor integrated RFID Middleware based on EPCglobal Architecture Framework [13]. Our state-of-the-art system architecture follows standard active air interface ISO/IEC 18000-7 [14] to manage and control sensor tag, tag modes and states to store battery power with sensing information. It provides several APIs for receiving sensing queries, managing tags and readers, monitoring sensing values, reporting alarms and notifications to the users. It also provides four service types that together form core service module for an efficient dual data processing system.

In this paper, we focus on the development of efficient Sensor integrated RFID Middleware using existing standards. We analyze all the necessary standards and background technologies involved with active RFID systems, existing management architectures and related application scenarios to extract all the system requirements. The main contribution of this paper is to design efficient system architecture for sensor tag that incorporates all the management requirements to process dual data (RFID data and Sensor data) with compatibility and global interoperability of the system.

The structure of this paper is as follows. Section 2 describes lists of related works. Section 3 analyzes sensor tag application scenarios and active air interface standards to extract system requirements with some unique services. In section 4,
requirements are used as brick features to build the proposed system to its fundamental to final architecture. We conclude Section 5 with avenues for further research.

II. RELATED WORKS

A. Trend of Sensor Standard

Figure 1 shows the basic architecture of sensor, related to RFID system. From the figure shows the related ISO and IEEE standard concerned to sensor system. In the bottom layer, sensor tags carries sensing information which is read by the sensor driver (show in yellow block) and send to the processor. Finally, application can receive information using ISO/IEC 15961 commands.

![Figure 1. Basic Sensor Technology in RFID Environment](image)

The standards specify not only the tags and readers, but define methods and protocols for data processing and connectivity to IT infrastructure. The ISO/IEC 18000, Part 7, is the newly provided standard for item management using active air protocol. It possible to use the extended air protocol to manage and control of an active sensor tag.

B. Trend of Sensor Technology

Host The IEEE provides new standards for Automated Sensor Measurements. IEEE P1451.4 defines a relatively simple and straightforward mechanism by which an analog sensor can provide self-identification and calibration information through the use of an EEPROM embedded in the sensor itself shown in figure 2. This information is stored in a format known as the Transducer Electronic Data Sheet (TEDS). The TEDS contains such data as sensor identification information, sensitivity, calibration parameters, location ID, and custom user data. In order to keep the TEDS structure compact but flexible enough to handle a wide range of sensors, IEEE P1451.4 provides a collection of standard TEDS formats called templates. These templates specify how to translate the TEDS bits for a particular type of sensor.

The IEEE 1451.4 standard reduces the time and challenges associated with sensor configuration. The standard establishes a universally accepted method of giving sensors plug-and-play capability, similar to the plug-and-play capability of a USB mouse and your computer. IEEE 1451.4 defines a mechanism for adding self-describing behavior to sensors with an analog signal interface. This mixed-mode interface combines the traditional analog sensor signal with a low-cost serial digital link to access a transducer electronic data sheet (TEDS) embedded in the sensor.

![Figure 2. Smart TEDS Sensor with Embedded TEDS EEPROM](image)

C. Active Tag Memory Accessing Mechanism

Active RFID Reader uses Active Air Interface to access tag memory of an active tag. There are two ways to access the tag memory: (1) implementing reader commands following ISO/IEC 15961 [16] and 15962 [17], (2) implementing RF-interface commands based on ISO/IEC 18000-7. Fig. 3 depicts the basic components of active reader and how it accesses active tag memory data by using active air interface. Command/Response Unit of an active reader receives the request from host and converts the request to ISO/IEC 18000-7 air interface commands. Finally, reader uses tag driver to access the data stored in the tag memory.

![Figure 3. Active Reader and Active Tag Communication](image)

D. Sensor Applications

1) Humidity Logging:

Products within the global supply chain are continuously subjected to humidity resulting from ambient and/or artificial levels of environmental conditioning. Certain items may be susceptible to reduced, excessive, ambient or acute moisture conditions, resulting in premature product degradation, damage or loss. Cold chain products including produce, pharmaceuticals and biologics may require humidity conditioning to be maintained within tight tolerances. Sensors affixed to product packaging or transportation vehicles could provide logging or alert functionality to communicate excursions or sustained environmental conditions. Data collected from humidity sensors may be correlated to psychometric charts or linear data sets to chart humidity histories.

2) Tamper Proofing:

Tamper proofing refers to methods used for hinder, deter and/or detect unauthorized access to a sealed system. RFID
tags can be used as e-seals, which can be read automatically at desired control points. Mechanical structure of the tag can provide means for hinder tampering while electrical functionality provides tamper-evident. At the same time the e-seal can incorporate the unique ID of item (for example transport item). This is yet another use case for a sensor enabled RFID tag. In this case the sensor is basically one bit sensor (on/off). If an RFID tag is equipped with a battery (i.e., semi-passive or active tag).

2) Shock detection of valuable goods:

Temperature is not the only the environmental parameters that it is worth monitoring along the distribution chain. In some cases, especially for valuable goods, the sensitivity is related more to the handling conditions, which expose the product to risk of damage or malfunctioning, than to spoilage due to temperature abuse. Among the others, in particular the following valuable goods:

- Avionics products
- Sensitive computers or electronic devices
- Aerospace components
- Military equipments
- Ammunition

These may require the use of sensor-enabled tags equipped with shock sensors to guarantee product’s integrity. Improper handling events such as impacts, drops, inclination and flipping can inadvertently occur not only during shipping but also during the storage phase. Again, the use of a UHF RFID shock-enabled tag allows the review of the shipping and handling log contextually with standard inventory operation and contributes to the control of product’s integrity without the need of a direct inspection.

III. SPECIFICATION REQUIREMENTS

A. Enhanced Active Air Interface

ISO/IEC18000-7 [14] defines a way of request and response format among Readers and Tags. They are of two types, Interrogator-to-Tag commands and Tag-to-Interrogator message response. The former is used as a request from the reader to the tag issued by the application and the latter is a response to the reader tag which is eventually sent as a reply message to the user application. The standard defines a table of command codes for the interrogator which could further be divided into 5 broad categories such as

(a) Tag State (Unlock, Sleep, Sleep All But etc.)
(b) Tag Mode (Beep ON/OFF)
(c) Tag Security (Set Password, Set Password protect etc.)
(d) Tag Memory (Table create/read/write/update, Table query/get data etc.)
(e) Tag Information (User ID, Model Number, Tag Collection etc.)

The tag battery status is provided by Tag-to-Interrogator response message. The battery low status massage is sent by setting (“1”) the service bit in the status field. An active sensor tag requires more status information such as tag memory status and threshold status. Therefore, service bit should provide extended tag status information shown in Fig. 5. Despite the existing interface commands defined by ISO/IEC18000-7, the system requires additional air interface commands such as Logging ON/OFF, Sensing ON/OFF, Flash bit ON/OFF, Set Sensing Threshold, Set Alarm condition, Set Interval Time, Clear Sensing Memory, Tag Reboot etc. to act active tag as an active sensor tag.

B. Analysis of Existing vendors and Projects

There are various vendors and several existing projects who introduce about the RFID-sensing integration. Alien user manual for Nano-scanner Reader provides host protocol extension for battery powered backscatter tags. The extended protocol commands are of five categories. These are Masks, Tags, Memory, Sensors and Logging. But the protocol defines “Get SensorValue” which is the only and very limited command for sensing data retrieval. Savi introduced ISO 18000-7 compliant active RFID tag with environmental sensor capability in an intention to increase global interoperability of their product. Tag’s sensors monitor and log the environmental conditions, both temperature and humidity, of assets and their contents during transport and while in storage. If the collected data rises above or falls below the user-configured range, the tag sends a real-time alarm to an RFID reader, and the alarm is escalated via a web application, cell phone or email notification, allowing it to be addressed immediately before spoilage or damage occurs. Likewise, Intelleflex introduces InfoSure tags operating as EPC Class 3 sensor-based passive tags. The tag supports 64K of user memory, and condition-monitoring sensors, especially used for temperature monitoring. Although various types of sensor tags exist from vendors, the management of tag and solution for integrated RFID-sensing data retrieval is still in its infancy.

The BRIDGE [15], is an ongoing pilot project that describes an abstract overview of the integration of multiple sensors with a single RFID tag. It specifies a common platform for sensor-enabled RFID tags [6]. BRIDGE focuses strictly on sensor functionality while access control and battery support are omitted. The approach considers development within ISO and EPC Global, but the scope is narrower than those bodies propose. The project focuses on UHF tags based on EPCClass1.
Gen2 and the air interface is adopted by ISO into 18000-6C standard. BRIDGE is built on passive communication. Therefore, it becomes impossible for tag to send asynchronous notification or alarm message to the interrogator unless interrogator initiates the communication.

C. Required Services and APIs

An efficient tag management system should provide various services for configuring tag, controlling its modes and states, managing device and data, handling events and processing queries, report generation and data storage. Table I shows the required service types and their description. An efficient management must also provide API for those services.

<table>
<thead>
<tr>
<th>Types of Services</th>
<th>Description</th>
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<tbody>
<tr>
<td>Tag Command and Control Services (TCCS)</td>
<td>Provides service for tag configuration, tag mood and state control.</td>
</tr>
<tr>
<td>Device and Data Management Services (DDMS)</td>
<td>Provides services for active reader and tag device management with tag data services.</td>
</tr>
<tr>
<td>Event and Query Processing Services (EQPS)</td>
<td>Listens to the events, handles events happened and process registered queries.</td>
</tr>
<tr>
<td>Data Storage and Output Services (DSOS)</td>
<td>Stores sensing data in data base, generate reports and sends to the users.</td>
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### IV. System Architecture Development

#### A. Our Approach

Sensor tag attached with a container can provide sensing information of the container as well as other necessary information such as lot code, company name, source and destination location information. To provide safe container monitoring in harbor logistics, we attach sensor tag with each container in the harbor shown in figure 5.

![Figure 5. Sensor Tag Attached with container](image)

We also deploy a number of RFID readers to read sensing data from the tag. RFID reader (safe-Reader) continuously monitors sensing information of the container (safe-Container) and delivers to the system (safe-System).

#### B. Fundamental Architecture

The overview the system where sensor tag attached with items is shown in figure 6. Active Reader reads sensing information from tag memory and send to the Sensor Integrated RFID System. The application user sends requests and system replies to the intended users.

![Figure 6. Sensor Tag Attached with container](image)

The Middleware composed of three main components. i) Active Sensor Tag – Create active communication with Reader and Stores sensing information in the tag memory. ii) Active Reader – Uses Active Air interface for communication with the tag and reads tag memory data. iii) It stores and Manages tag, reader and tag data. The Application users issue queries to the system and replies intended user for those queries.

#### C. Safe Container Monitoring in Yard

We attach more than one sensor tags with each of the safe-Container to prepare a safe container yard (shown in Figure 7). E-seal tag is attached at the container door and light sensitive tag is attached inside the container to check the light illumination inside the container. This is particularly useful for security while container door is opened. Determining illumination value inside the containers helps safe-System decide whether container door is opened or not. Additional temperature and pressure sensor is attached to get container temperature and pressure information. A safe-Reader continuously retrieves all sensing information, and a safe-System checks the sensing information and notifies unwanted sensing events to the safe-Application.

![Figure 7. Safe Container Yard in Harbor](image)

#### D. 3-Layer Middleware Architecture

Fig. 8 shows the detailed block diagram of Middleware architecture for efficient processing of dual (RFID-Sensing) data. It is 3-layer architecture:
A. Capture Layer (Common Reader Framework)

B. Service Layer (Core Engine Layer)
   i. Tag Command and Control Service Module (TCCS)
   ii. Device and Data Management Service Module (DDMS)
   iii. Event and Query Processing Service Module (EQPS)
   iv. Data Storage and Output Service Module (DSOS)

C. Application Layer (Web Service Layer).

The Capture Layer receives RFID-Sensing (dual data) from the tag and sends to the Processing Layer while Processing Layer replies user queries and generates alarms to the Application Layer.

A. Capture Layer

Capture Layer is the bottom layer of the architecture. It provides common reader interface for both active and passive reader types. Active Reader Layer is used for capturing streaming RFID-Sensing data from active sensor tag while Passive Reader Layer is used to read passive RFID tag data. Captured event is dispatched by Message dispatcher and sent to the Service layer for further processing.

B. Service Layer

Service Layer is the core of Sensor Integrated RFID Middleware. This layer provides 4 types of services required by the application which are described as follows-

1) Tag Command and Control Service Module (TCCS): The TCCS module is an integrated Command and Control Module. The command module receives the tag setting commands from the users. This Module usually receives three types of commands such as setting tag device (configuring tag id, tag EPC binding, tag source and destination etc.), tag alarm setting (configuring alarm conditions) and query setting. Users can issue the four types of queries by using command modules. Mainly, *tag status query* sends the tag battery status, tag memory status and threshold status of the tag. The *conditional sensing query* helps user issue query about the tag *Entry* and *Exit* temperature in a warehouse.

The control module facilitates users to control the tag according to the user requirements. Tag state, mode and alarm are controlled by this module. Note that, alarm setting sets alarm conditions and the alarm control can activate and deactivate the tag alarms set by the users. Moreover, a *command and control switch* is used to change the commands among the two modules.

2) Device and Data Management Service Module (DDMS): The DDMS module is designed only to store and manage the commands that are set by the user. It follows the command module in TCCS and stores the tag configurations, alarm conditions and Query storages.

![Figure 8. The 3-Layer Architecture of Dual Data Processing System](image-url)
3) **Event and Query Processor Service Module (EQPS):**

The EQPS module contains two modules, *a*) Event Handler and *b*) Query Processor. The Event Handler module listens to the alarm events generated by the active sensor tag. Tag can generate auto alarms according to the alarm conditions set by the user. This module listens and detects the type of alarm generated by the system depending on the message type. After detection, the processor module is called to take proper action for the alarm detected. Likewise, the Query Processor module parses the queries and executes according to the conditions specified by the user.

4) **Data Storage and Output Service Module (DSOS):**

Sensor reports are generated by the DSOS Module and send the generated reports to the corresponding user in response to the query issued by that user. It stores the integrated data that is read from the sensor tag to the RFID-SensingDB. Moreover, our Middleware provides three types of Loggers (TCP Logger, HTTP Logger, and File Logger) to log the users accessed asynchronously to the middleware.

### C. Application Layer

Application Layer is the top layer of the Middleware architecture which provides four API(s) to the users. Command and Query is sent by using Tag Configuration API and Sensing Query API. The other two APIs are used for synchronous and asynchronous sensor data reporting to the user. Sensing Data Report API is used to send synchronous reporting for user query and Sensing Alarm Notification API sends alarm notification to the user asynchronously if any alarm event occurs.

### V. CONCLUSION

Active RFID tag integrated with sensing module can serve as active sensor tag. The advantage of using active sensor tag is that it provides greater communication range, long battery life and fastest tag data collection. However, sensor tag differs from active tag in several ways, because it continuously senses and stores sensing values in its tag memory. Although, ISO provides standard for active tag communication, it is insufficient to provide all the services required by sensor tag application. In this paper, we analyze the sensor tag applications and existing global standards to extract requirements and necessary features for efficient sensor tag management. Our proposed Sensor Integrated RFID Middleware is based on EPCglobal Standard Architecture Framework and ISO/IEC 18000-7 active air interface standard that provides compatibility and global interoperability of the system. We proposed four types of core management modules which are namely: Tag Command and Control Services (TCCS), Device and Data Management Services (DDMS), Event and Query Processing Services (EQPS), and Data Storage and Output Services (DSOS). Here, we only consider about tag device and tag data management but our tag management does not consider about sensor tag locations. Our future research work lies on providing integrated RFID-Sensing-Location management services using existing standards.

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### REFERENCES


