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RFID System Integration and Application Examples

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1. Introduction

RFID today is the popular wireless induction system. Each RFID tag in RFID system is given a unique ID (UID). The RFID tag with memory also records the on demand information. When an independent RFID tag approaches the RFID antenna, the induction between tag and antenna happens. The information and content recorded in the tag is transmitted to the RFID antenna and translated into the computational data. Following up the data translation, the tag recognition can be completed and related applications are provided.

Due to the popularity of RFID, many applications based on the local or small area were proposed. According to the short-distance wireless signal, the RFID tag users can be monitored within the specific area. In other words, the RFID systems are generally used to be the hardware identification in many applications. Most of these applications are based on the indoor environments or be a tiny area service and independent of the existed system.

Some of the RFID systems were proposed to be used in hospital or health care (Munoz et al., 2003). Each patient is given and equipped the designed RFID tag. In addition, each patient should always wear every time and everywhere. Therefore, all the patients' current location and conditions are monitored by the hospital. Some entrance guard systems are also based on RFID system. The RFID ticket or RFID card [5-7, 12] (Pala & Inanc, 2007) is used to identify that a user is legal or not.

In addition, since the RFID tag can be used as the identification, it means that the applications which adopt software encryption as the identifications to protect the intellectual property of the applications or files can also use the RFID tag. Some researches presented that the embedding RFID can be plugged into a small device such as handheld host [1]. The handheld device users can plug in the SD or CF interface of RFID reader card. Hence, the users can scan and induct the RFID tag everywhere. Since the RFID systems are popular and ripe for distinguishing treatment of individual target [8,9], the unique characteristic or identification of RFID can be the solution of intellectual property protection. Many researches proposed the possible way to protect the intellectual property, products, or applications. In some applications [10], the RFID chips are embedded in the cap of bottle. The medicine or other objects can be differentiated between fake and true (Jian et al., 2009).

However, there are many RFID related products. To manage the RFID information from different RFID products and the communication with different applications will be the important issue.

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The remainder of this paper is organized as follows. In Section 2, the RFID system is presented. The concepts of RFID system integration are shown in Section 3. Some integration examples of RFID applications are introduced in Section 4. At last, the conclusion is given in Section 5.

2. RFID system

Generally speaking, the RFID System consists of

- At least one RFID antenna for RFID reader,
- An RFID reader,
- RFID tags.

The RFID tag is composed of two essential elements: designed antenna and an RFID chip. Some RFID tags also equip memory. According to the requirement, the RFID tag can be designed as different contours or shapes such as: card, wrist belt, button, ornament, 3D toy, tattoo, etc. Each of these RFID tags records a unique identification (UID) and finite information. The antenna of the RFID tag is designed and used to absorb the electromagnetic wave for the power supply of the RFID tag and communicate with the RFID reader. In addition, according to the size and design of the antenna, the induction distance between RFID tag and RFID reader will be limited. Based on the power of the RFID tag, three basic types of RFID tag are proposed:

- Passive RFID Tag
- Active RFID Tag
- Semi-Active RFID Tag

The Passive RFID tag is triggered when a user with the RFID tag approaches the antenna of RFID reader. Then, the information recorded in the RFID tag is transmitted through the antenna to the RFID reader. The RFID reader will parse the signal into the digital and computing content. At last, the gained content from RFID tag can be further utilized. Typical applications of passive RFID tag are tickets and guard cards.

An Active RFID Tag indicates that the tag owns a battery and can actively broadcast the information about this tag even there is no RFID reader which inducts this tag. Since there is a battery in the tag, more functions such as temperature sensing, pressure sensing, humidity sensing, etc., are embedded. The information gained from the embedded functions is transmitted actively. When the RFID reader approaches the active RFID tag, the reader can obtain the information. Typical applications of passive RFID tag are wireless sensors.

A Semi-Active RFID Tag seems an RFID tag with an on-off switch. In general, the semi-active RFID tag also equips a battery and some embedded functions. For the most part, this RFID tag works as a passive RFID tag. When an RFID reader approaches and inducts the tag, this tag is triggered. After triggered by the reader, this tag turns on the battery and executes the functions. Then, the information from the functions can be translated to the RFID reader. At last, the RFID tag turns off the battery for power saving.

In addition to three basic types of RFID tag, the frequency of RFID system used can be classified as LF (low frequency, 125~134KHz), HF (high frequency, 13.56 MHz), and UHF (ultra high frequency, 915MHz). The characteristics of these RFID systems are different. In addition to the operation frequency, the communication protocol standard may be different. Most RFID tags communicate based on the standard of ISO-14443A or ISO-15693. Some RFID tags are even designed as dual frequency tags.



Fig. 1. Procedure of RFID System.

In addition, there are different antenna sizes of these RFID systems. Due to the power and size of RFID antenna, the induction distance between antenna and tag changes. Generally speaking, most RFID applications adopt the suitable frequency according to the required induction distance of the application.

	Low Frequency	High Frequency	Ultra High Frequency
Induction Distance	<2 Feet	<3 Feet	<10~30 Feet
Normal Application	Keyless entry	Smart Card	Electronic Toll Collection
Data Rate	Low ←-----→High		
Tag Size	Large←-----→Small		
Performance Near Metal / Liquids	Better←-----→Worse		

Table 1. The characteristics of different RFID systems

RFID reader is the basic element of the RFID system. All induction and parsing are made by the RFID reader. An RFID reader is composed of at least one antenna and a microprocessor. The RFID reader uses the antenna to send the radio frequency wave for inducting and communicating with the RFID tag. The antenna also receives the radio frequency wave from the RFID tag. The size and contour of the antenna affects the distance of communication range and accuracy.

Although the RFID reader owns a microprocessor, most applications are based on the integration of several systems which the RFID reader may not manage independently. Therefore, most RFID readers provide some I/O port for integration or communication with other systems. Some RFID readers provide the RS-232 serial port as the I/O (especially output) port for other hardware or system. Some RFID readers with more powerful processor supply the TCP/IP protocol or Internet access (RJ45). Some readers only give the USB connection for end applications or hardware.

According to the procedure of the RFID utilization, the RFID applications can be defined and divided into three types: 1) emphasis on standard objects with fixed RFID utilization procedure, 2) emphasis on defined and specific area with defined RFID utilization procedure, and 3) emphasis on third party applications or services based on RFID induction.

3. Integration

Since the RFID reader may not manage independently, to integrate with other systems or embedded in an existed applications becomes an important issue. First, the application designer has to know that the integration of the application is based on the software, hardware, or both. If the application is a new system, the RFID system can be embedded in initially. However, if the RFID system is integrated with the existed system, to define and decide the interface for integration is important. In this section, the integration mentioned is based on the existed systems or applications though the new applications also applicable.

According to the communication interface of the RFID reader, hardware and software communication is available. Even the microprocessor of the RFID reader is not powerful, general logic computing based on electric circuit can be implemented. By controlling the voltage of the circuit, the primary circuit can implement the On/Off action or signal. After receiving the signal from the circuit combined with the RFID reader, mechanical action can be realized such as door locking or opening.

In addition to the simple On/Off signal, further information may be required for the applications. Corresponding to the RFID reader selected, simple circuit, RS-232, USB, or RJ45 Internet access can be used.

3.1 Simple circuit for RFID system integration

Most hardware for simple mechanical control or action is based on the designed circuit. According to the requirement or action of the machine, some mechanical actions are triggered when receiving an On/Off signal. The reader of the RFID system equips the control circuit such as the MOSFET of simple IC control circuit. Sometimes the under-controlled applications or systems only need a trigger signal. In other words, the reader of the RFID system provides only an electric wire for signal transmission.

In this type of integration, the RFID system acts as a signal sender. When the reader of RFID system inducts the RFID tags, the reader determines that the inducted RFID tag is the pre-defined (Ex: legal, valid, permitted, etc.) tag or not. If the inducted RFID tag is the pre-defined RFID tag, the RFID reader sends the control signal to trigger the hardware or mechanical action such as unfasten the lock of door, open a lock gate, etc. In other words, the RFID system is the active controller of the integrated system. The integrated system will act based on the decision of the RFID system.

3.2 RS-232 for RFID system integration

RS-232 serial port is the general communication interface. Most appliances or computers support the communication based on RS-232 (D-sub). The RS-232 (EIA232) consists of DTE device (Data Terminal Equipment, usually a computer or terminal) and DCE device (Data Circuit-terminating Equipment, usually a terminal or receiver such as a modem). By sending the control signal, two devices can connect each other vial RS-232 connection. In addition, according to the standard of the RS-232 communication, the reader of RFID system can 1)

send the pre-defined command via RS-232 to drive the machine or systems, or 2) send the emulated signal as the command to drive the systems.

In this type of integration, to implement the RS-232 interface of the RFID reader, the RFID system has to equip at least one of the two functions: a simple electric wire for simple action of driven systems or a simple computing unit (or IC chip) for serial port control and command ordering.

Sometimes, the connection between RFID system and the controlled machine will add the middleware (or hardware). The command from the RFID system via RS-232 connection can be translated to the digital signal.

3.3 USB and internet access for RFID system integration

For most integration with the existed applications or systems, a host PC (Computer) is the main platform for all information management. Due to the computing ability and the easy maintenance, many applications provide service and control other systems based on PCs. In addition, most applications today consist of different software, applications and database. To integrate the RFID system with the existed applications or systems, a main platform for dealing with all requirements and messages are needed. According to the hardware of the computer, the RFID reader can connect to the PC via USB port or RJ45 Internet connection.

When the RFID reader connects to the PC via the USB connection, the information from the RFID tag can be transmitted to the PC directly. Since the computing ability and processing performance are better than the RFID reader, the applications which gain the information from the RFID reader can enhance the functions or capabilities of the services. The control signal, function executing, or further information management can be done by the applications.

If the RFID system communicates with the integrated systems via Internet, the RFID reader has at least the network component and sufficient centre processing unit for information computing. The RFID system works as a network device belongs to the platform. In other words, the RFID system works independently. The Internet access is only for data and information transmission.

No matter communication based on USB port or network connection, the RFID system is just the role of information gathering. The main platform which manages all information, defines the corresponding actions, and gaining service from the third party applications, is independent from the RFID system. In this case, the RFID system is selected for replacing some identification procedure of the existed systems.

4. Example of RFID system integration

The characteristic of the RFID system is to identify the RFID tag and exchange the information with the RFID tag. If an application needs no identification, to integrate the RFID system becomes useless. Therefore, to recognize whether an application or a system needs for RFID system integration or not is the first important thing. Then, considering the object served by the applications, to select the suitable RFID system is an important issue. The object can be the human, animals or goods. Most objects follow pre-defined action functions or fixed procedures when served by applications. Only the procedure which is used to identify and differentiate the objects can be replaced by the RFID system. Therefore, based on different frequency of RFID system, different size of RFID tags, and different way

for integrations, there are different integrated systems and applications. In this section, some integrated systems are introduced.

4.1 Guard system

In opposition to creating new execution or service environment, there were many existed systems or applications such as guard system or application deployed. Since these existed systems or applications run for a long time and present the stability themselves, to include the original systems or applications can reduce the time for stability testing and cost of new infrastructure establishment.

In this section, a realistic application for parking guarding (Jian et al. (a), 2008) is presented. Via using the proposed system, the main contributions are:

1. the efficiency of management can be improved,
2. the is modular and can be embedded in other similar parking system and hardware without additional re-modification,
3. the procedure of passing the Inlet & Outlet can be simplified via using RFID,
4. the costs of the real construction for the proposed system can be decreased and estimated.

The RFID System, original gate hardware, and other business management system colored blue in the framework are independent.

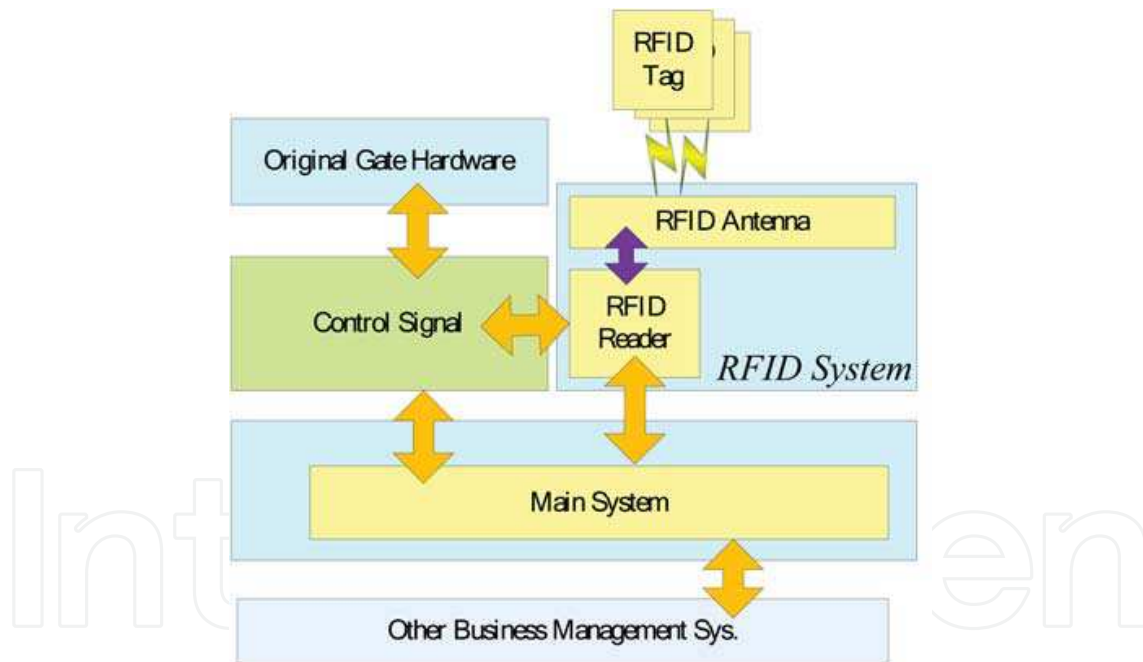


Fig. 2. The framework of modular RFID embedded parking guard system.

These independent systems are the already existed systems. Each existed systems can independently and individually work. For example, the lane gate management can be controlled by the manual operation or parking ticket machine without RFID. It means that these independent sub-systems can be substituted. The gate hardware can be the product of any possible company. There are also many RFID hardware providers. Moreover, to suitably manage and monitor the parking place, the manager may need the attendance information of different users according to each business application. Hence, different type hardware or products need the general interface to communicate with the main

management system. In this example, the Main System provides the middleware software and hardware for the interaction.

In the presented system, the RFID antennas and reader are deployed at the gate. In addition, the RFID tags are placed in the car. Considering the practicability, the RFID System should overcome the accuracy affection of weather and sunshade-paster of car, and the RFID tag type. To increase the usability of the proposed system, the UHF type of RFID tag in this paper is selected. When a user's car approaches the gate, the induction and communication between RFID tag inside the car and antenna of RFID System is automatically established. Then the reader of RFID System translates the signal information to the digital content.

If there is no further action or information required, the RFID system can send a signal to the gate directly. In other words, even without the Main System, the RFID system can communicate and control the gate (Ex. Via wire, simple circuit integration) directly.

If the information from the RFID tag is required by other systems or applications such as database, the information will be sent to the Main System first. In this case, the Main System communicates with the hardware of gate via RS-232 link (RS-232 for RFID Integration). The ADAM digital I/O module as the middleware to construct the computing_commands / voltage_signal module is selected. ADAM-4520 is the RS-232/RS-485 converter module that communicates with host PC via RS-232 link. The digital computing command from the host PC is converted into the RS-485 type data stream. Then, the converted data is inputted to the module ADAM-4050. The output DATA+ of ADAM-4520 is connected to the DATA+ of ADAM-4050 and also is the DATA-. In addition to hardware, a software program is executed. This program is designed corresponding to ADAM. The program sends the commands from host PC to the ADAM via RS-232. Then, to command the gate hardware, the voltage_signals are sent from the data output, DO0, DO1, DO4, and DO5 of ADAM-4050 to the gate hardware.

To really replace/join the original control hardware, four states of the lane gate should be known first: 1. Inlet gate open, 2. Inlet gate close, 3. Outlet gate open, and 4. Outlet gate close. Hence, to match the control requests of these four states, four individual voltage-controlled IO hardware such as: 1) InletGate_open, 2) OutletGate_open, 3) Expansion_1, and 4) Expansion_2 are defined. The InletGate_open is used to transmit a voltage signal to open the inlet gate. The OutletGate_open is used to transmit a voltage signal to open the outlet gate. Considering the real gate controller, most gates are closed after counting down an on demand time period. In other words, the control IO for closing the gate can be needless.

To control the original and existed gate hardware, the four individual voltage-controlled IO hardware are linked. If the InletGate_open which connected to the DO0 of the ADAM-4050 is set a signal with the voltage 12V, the inlet fence of the gate is opened. After 6 seconds counting down the inlet fence of the gate closes automatically. The OutletGate_open which connected to the DO4 of the ADAM-4050 controls the outlet fence of the gate and opens it when is set a signal with voltage 12V. In addition, the Expansion_1 and Expansion_2 are connected to the DO1 and DO5 of the ADAM-4050 individually. If the Expansion_1 is set a signal with voltage 12V once, the counter which counts and presents the total number of current available parking space subtract 1. In opposition to Expansion_1, the Expansion_2 is set a signal with voltage 12V once to add 1 from the current total number of available parking space. When a valid car approaches the inlet gate, the Main System sends commands to set the DO0 and DO1 a signal with voltage 12V.

In addition, the communication between the database (other business management system) and Main System is based on Ethernet or Java server socket. The connection between ADAM and Main System on server PC is RS-232.

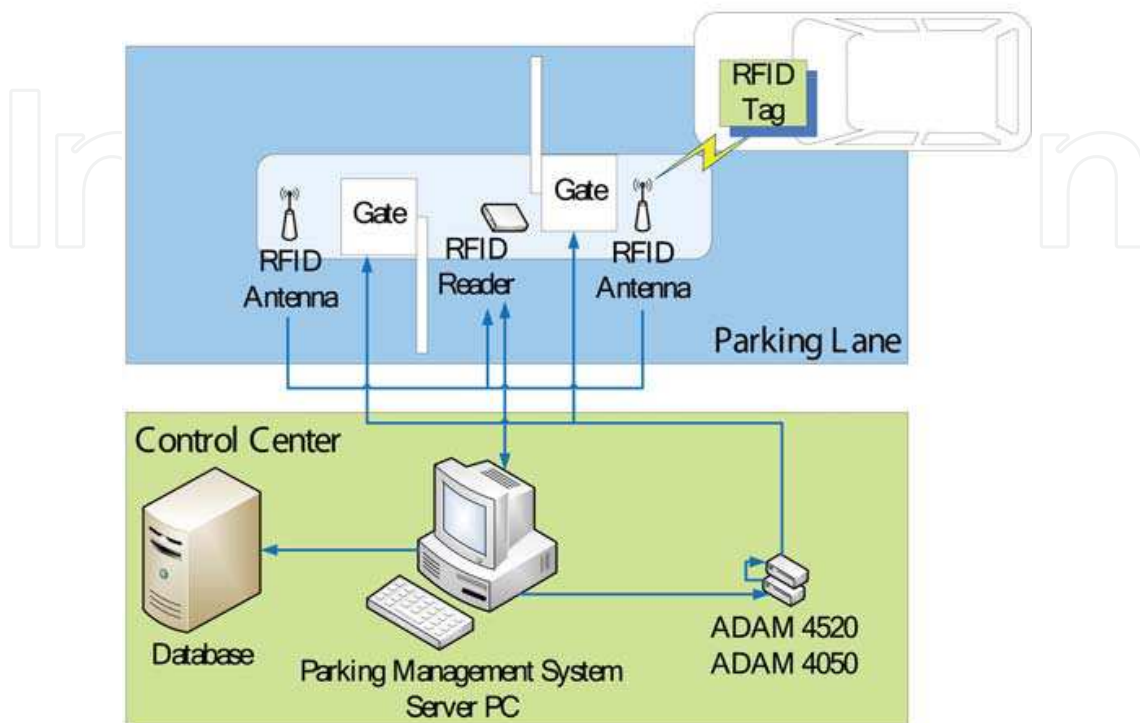


Fig. 3. The real implementation of RFID parking system.

To guarantee the stability and accuracy of RFID tag detection and identification within the finite time, the power of antenna is set as 30 dBm and the power state of antenna and reader are always on. The protocol for RFID antenna to communicate with RFID tag is EPC Global Generation 2. Considering the performance of RFID tag, two types of the RFID tag with size 4.40"X4.125" that for polyester and that adhesive to glass are used.

The verification shows that the distance from antenna to the RFID tag depends on the type of tag. The material and weather take affection. RFID tag assembled by polyester has the better ability of weather resisting. When test in the rainy day, there is a layer of water and mist. It apparently reduces the transmit distance about 16~33% especially more than 50% when there is a layer of water on the glass with the RFID tags that adhered on glass. In addition, the verification also shows that the distance from antenna to the RFID tag is normally about 4 m of polyester type tag and about 2 m of that adhered on glass. In other words, there are at least 6 m from the fence of the gate to the car since the antenna is located 2 m before the fence of the gate. It means that there will be more than 0.7 seconds (if the mobility of the car is limited and lower than 30 km/hr) for the system to open the fence of lane gate. Therefore, in most cases, the fence of the lane gate can open in time and the car can enter the gate into parking lot smoothly. The RFID tag assembled by polyester can achieve 99.75% identification accuracy. On addition, the RFID that adhered on glass is affected by the material and thickness of sunshade. Under the situation of car window closed, the identification accuracy is only 45% when dark or thick sunshade used. In opposite, the accuracy reaches 85% if only limp or normal sunshade used.

4.2 Bio-information management system

In opposition to the normal RFID tag, the tag for bio-information gathering which is embedded into the animal or human should be designed safely. The RFID tag can be used as the growth-record or supply chain stage history. In this case, the RFID system focuses on the information gathering and updating. Hence, to control the hardware directly is not the main function of the RFID system.

However, most RFID Tags with the limited memory cannot provide and record many information. To enhance the limited memory of RFID tag, all the information should be simplified according to the code conversion. Each code may indicate that "What event located at Where (area, location) at When (time, date, etc.)".

For example, the aquiculture or livestock industry (husbandry, breeding) creates the records or history of each livestock (such as pig, cow, etc.) or plant. In the following case, the breeding of pig is the example presented.

In the past, the live stock in the farm is marked by each farmer. The livestock in the farm wears the specifically designed RFID tag. For example, an ear tag is the RFID tag which is stabbed into the pig ear. When the information such as protective inoculation, weight, etc., should be updated, the manager can induct the RFID tag via the handheld RFID system or device.

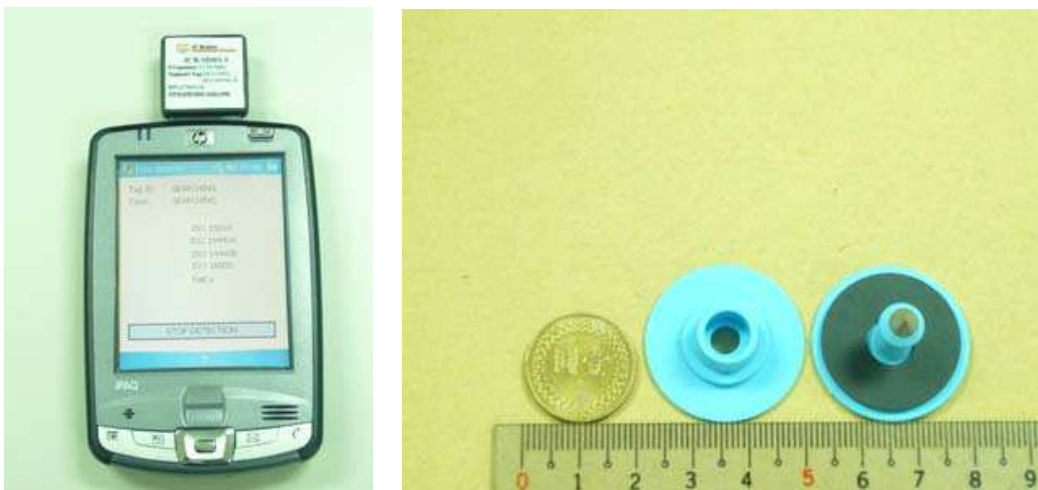


Fig. 4. (a) The RFID system embedded in the handheld device. (b) The ear tag (blue object) for pig.

Similar to the modular RFID embedded parking guard system, when the RFID system gains the information from the RFID tag, the RFID reader passes the information to the Main System. The Main System acts as the bridge for the different third party applications. For example, when the gaining the weight of a pig, the RFID system inducts the RFID tag for the identification of this pig. Then, the weight value and the unique ID of the RFID ear tag is written into the third party application such as database. Each unique ID of RFID ear tag relates with the corresponding data recorded in the database. In addition, RFID system also writes the information into the ear tag. Therefore, the supply chain of the livestock can gain the information immediately and trace the possible information such as the infection disease, current situation of the transmission, etc.

4.3 Human interface and services system

Since the RFID system provides the possibility of identification, individual services for each served individual are available. There were many existed systems or applications about

context-aware or location-aware deployed. These applications use the GPS to locate the user's location (Ashbrook, D. & Starner, T., 2002). Then, according to the record of GPS, the service application server provides the location related information to the user. Although the GPS hardware can be plugged-in many handheld devices, to enable that every mobile device or user equips the GPS is not practicable. In addition, it also consumes the power of the mobile devices when GPS is used. Furthermore, the users of context-aware or location-aware services exactly need the direction or information they required but not the exactly value of longitude and latitude in the world. Hence, to provide users with the fitting local information and the related direction of the required personal service without too much useless or unnecessary information gained is more important.

In addition to GPS, according to the orientation made by the station of wireless cellular system (Bahl, P. & Padmanabhan, V.N., 2000), the related information according to the user's location can be given to the user via cellular system. Not only supply the public services but also give the personal services, the context aware researches (Han et al., 2008) were also proposed.

Research in (Ciavarella, C. & Paternò, F., 2007) was proposed that considering the user's related location. The services and information of user-location-related public places such as the museum (Tesoriero, R. et al., 2008) are provided. According to the requirement of users, different services are given through wireless network or cellular system to different users even they are in the same places.

However, in (Jian, M.-S. (b) et al., 2008), what kind of the context, the corresponding context services, and the context-aware RFID system are important to be provided for user is still an issue of the existing system. In addition, there is no standard of operation modes of the RFID systems implemented for the context-aware services.

Hence, only the concept of context and location-aware service based on RFID system is introduced in this section. The Middleware Platform is the main system to manage the internal and external system connections. This platform also makes the information connection to other business management system or database via software API and Internet network. In addition, the related information to the RFID tag inducted is presented by user interface.

In opposition to the RFID service based on server PC, some handheld devices also support the embedded RFID system. The RFID tag can be used as the commercial advertisement. Every user can use their handheld devices to induct the RFID tag of the advertisement to gain the information. In addition, if the user requests the further information, the handheld device can obtain the services or information via Internet network connection. The handheld device can also communicate with the PC based server. Therefore, the further services such as database query can be obtained via the server.

For example, people who locate in the different area may require the individual services. The services can be actively provided to the users via local area server. Or, the user can use the mobile handheld devices to actively access the services from local area server or main server.

In this example, the RFID systems are deployed 1) at the specific area or location such as the entrance of the rapid transit system or the information service machine, or 2) within the handheld devices such as PDA or mobile phone. When a user is given an only readable RFID tag, the related information or the user's on demand service conditions about the user is given by himself and on demand recorded in the database.



Fig. 5. The framework of service application with RFID system.

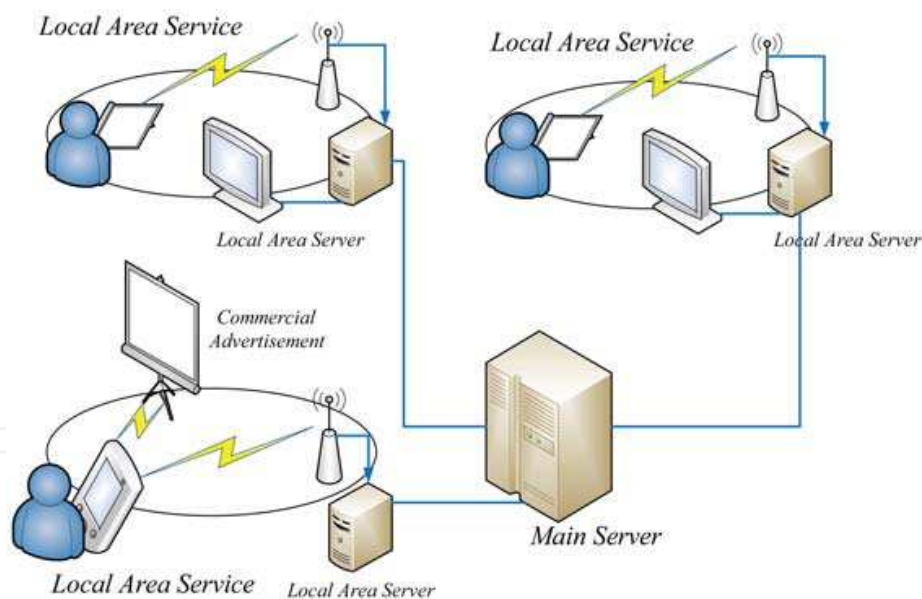


Fig. 6. The concept of service system.

When the user requires the local area public or personal services, the user should be at the tiny induction area such as a local area information center or a service station. Then, the RFID system placed in the specific area induces the RFID tag and gain the information such as unique ID number from the RFID tag. The reader of RFID system then sends the information to the local area server via Internet.

After receiving the information, the local area server responses the on demand required services corresponding to the specific local area that the on demand required services were

recorded in the database before. At last, the user can gain the location-aware information or services via user interface. In addition, the database can record the history of the user's requirements. The statistic user requirements can be used to classify that what kind of the service the user requests most. Next time the service server can provide the personal services according to the classified results. In other words, the users can be served with the services they most pay attention to. Fig 7 indicates the flowchart of the RFID tag utilization.

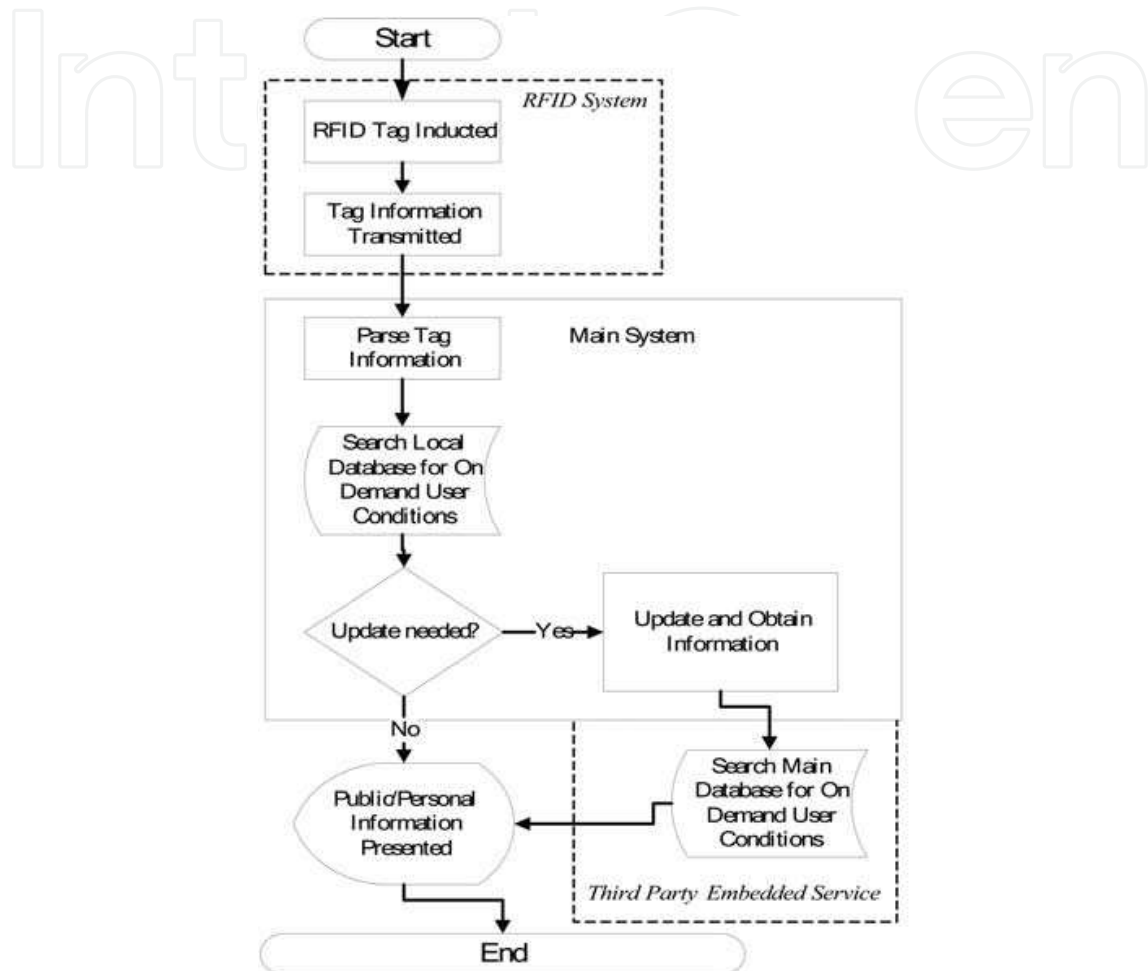


Fig. 7. The flowchart of end user RFID tag utilization in the service application.

Considering the popularity of handheld devices such as PDA and mobile phone, the devices which powered by battery with portable ability can be used as the service devices. There are many handheld devices that capable of plugging in the SD or CF type of appliances. These handheld devices can also access the Internet and communicate with other service applications. In addition, there are RFID systems that sized as a SD card. Hence, a handheld device can be the RFID system.

As the only readable RFID tag is used on the commercial advertisement, an individual and unique ID, and business related information are recorded in each commercial advertisement RFID tag. When the advertisements with the commercial RFID tags are placed in public, an end user device with RFID System user can actively read the commercial RFID tag information of the advertisement interesting in. Then, through the Internet, the requested service or detail of the advertisement according to the read commercial RFID tag information can be obtained.

After obtaining the RFID information of the commercial advertisement, the handheld device can 1) present the requested services according to the information scanned from the RFID tag via on demand defined data format such as XML, or 2) present the requested services according to the database that built in the handheld device, or 3) access the Internet for the further services searching and presentation.

If the requested services can not provided directly by the handheld device (such as that the RFID tag without XML format or no related service recorded in the database of handheld device), the communication between the handheld device and local area server via wireless network is established. Then, the local area server provides the requested location-aware services or business of the related sent RFID tag on the commercial advertisement are presented in the user's mobile device.

7. Conclusion

In this section, several applications and services based on RFID system integration are proposed to integrate the existed service systems, devices, and third party business database. The proposed integration system may need to provide the interface or module that can easily embed different types of RFID systems in. In addition, this section presents the three possible conditions of integration which correspond to the applications. The verification shows that the integration systems are realistic and can provide the different services or applications. The total cost of infrastructure establishment for these services can be also reduced.

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The number of different applications for RFID systems is increasing each year and various research directions have been developed to improve the performance of these systems. With this book InTech continues a series of publications dedicated to the latest research results in the RFID field, supporting the further development of RFID. One of the best ways of documenting within the domain of RFID technology is to analyze and learn from those who have trodden the RFID path. This book is a very rich collection of articles written by researchers, teachers, engineers, and professionals with a strong background in the RFID area.

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