Multiple Zones Surveillance System Using RFID

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Abstract: - Monitoring and tracking the activities of individuals (or objects) in multiple zones or areas simultaneously is quite a challenging task. It is a very common practice to use observation cameras or to have security personnel to guard the specified areas. However, area surveillances using these common methods may become tedious when the activities to watch out for increases. More cameras as well as manpower are needed to cater for the increment of activities for each zone. On top of that, should anyone (or objects) vacates or trespasses the designated areas, it would take some time to identify them, hence resulting complexity in tracing their whereabouts. To overcome these challenges, we propose a surveillance system for multiple zones using RFID technology. Individuals or objects to be monitored are tagged using RFID tags that hold unique identification. Each zone is allocated with one RFID reader, which will transmit the information of activities of the respective zones to the host computer in the control room. The security personnel in the control room would be able to identify which individual or objects that are out of their designated zones or trespassing to another zone based on the tags that has been detected by the reader. Should the tags are removed without authorization, alarm will be generated. Every activity transactions are recorded in a database for future references or actions. A case study of inmate tracking system is conducted and demonstrated to prove the capability of the proposed method.

Key-Words: - Radio Frequency Identification (RFID), multiple zones surveillance, RFID reader, RFID tags

1 Introduction

There are various techniques in monitoring activities in designated areas. One typical example is the use of baby monitor that allows parents or caretakers to hear when an infant is awake while out of the hearing range of the infant. The sounds made by the infant will be picked up by the microphone and sent via the transmitter to the receiver that is held by the person taking care of the baby [1].

Another common method of area surveillance is by using observation cameras. These cameras will transmit visual signals to the receiver that could be watched by personnel working in the control room. However monitoring using this method becomes troublesome when the number of activities in the monitored area increases. Sharp observation by the personnel on every activity would be highly required. On top of that, as highlighted by [2], occlusions of monitored people by crossings and shading of other people would definitely occur in a crowded area. This means some views would be obstructed and hence surveillance becomes less efficient. To overcome this problem, it was proposed by [2] to have matching algorithm of spatio-temporal image from multiple cameras that could track objects against occlusions.

Another powerful technique for area surveillance is by using night vision whereby it increases the in-the-dark visibility without using visible light source [3]. Using thermography technique, activities are detected through human or living temperature. However the disadvantages of this particular technique are that the temperature could only be detected on the surface and the cameras are very costly [4].

Most of these techniques, however, only cater for single zone surveillance or for single application. Although not as many as the single zone surveillance, there are several techniques designed for tracking and monitoring activities in more than one zone simultaneously. This feature is very useful for surveillance of large areas that are segregated to partitions. The partitions could be walls, gates or barriers (indoors) or it could be higher/lower ground level, water surface or huge rocks (outdoors).

Observation cameras can be used for surveillance in multiple zones. The cameras are mounted in each zone and the activities detected by these cameras could be monitored in the control room. Some surveillance systems have the capability to prioritize their task in monitoring multiple areas. If an object is detected in a higher prioritized zone, the camera that initially track another object in another area can immediately move to the prioritized area [5]. This feature is especially useful when the numbers of observation cameras are lesser than the number of zones to be monitored.

Works by [6] proposed a distributed visual surveillance system, in which multiple areas are monitored by multiple cameras via a Local Area Network. The system is capable to combine information from the multiple camera units to obtain a consensus decision in terms of types of object that are detected in the area.

These current practices, although considered reliable for monitoring activities in multiple zones, have some setbacks. First of all, there are possible cases whereby the objects could not be detected by the cameras due to obstructed views. It could also be a tedious task for observation when the activities in the multiple zones to be monitored increases. Another drawback with this current practice is that in case of anyone (or objects) vacates or enters another zone without authorization, there is no system to identify them and hence becoming difficult to trace their whereabouts.

Realizing many limitations on the surveillance methods, we are proposing a surveillance system using the Radio Frequency Identification (RFID) technique. RFID technology is a wireless sensor technology, which is based on the detection of electromagnetic signals. It is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags which carry data on transponders, antenna which collects the transmitted data, RFID reader that receives and reads the collected details and host computer that keeps the software base data collection and manages the system [7]. Like broadcast television and radio, RFID system uses four major frequency bands: low frequency (LF), high frequency (HF), ultrahigh frequency (UHF) and microwave frequency. The systems that are coming up in the market today operate in UHF band whereas old RFID systems typically use LF and HF bands [8].

Typical utilization of RFID technology nowadays is the tracking of products throughout the supply chain. This application is a replacement to the bar code scanners used for similar purpose. As outlined by [9], RFID does not require line-of-sight access to read tag, has a long read range, can read multiple tags simultaneously and can store more data. All these attributes makes the RFID technique more reliable and attractive as compared to the normal bar code readers. Works by [10] also highlights the capability of RFID technology in pharmaceutical supply chain.

The RFID technology also is used as a replacement to identification cards with magnetic stripes. These magnetic stripes, apart from having lower memory capacity as compared to the latter, tend to wear out and lost important information after some time [11].

Other applications can be seen from works by [12] who proposes a smart parking application while works by [13] proposes a smart document tracking system using the RFID technology, known as ‘Docutrax’. This system is equipped with a complete database to track tagged documents using low frequency tags, within different academic buildings in a university. Notification on the document status could be updated to the person in charge via short messaging services (SMS).

In the proposed method of multiple zones surveillance, individuals or objects are labeled with RFID tags that have unique identification. RFID readers will be placed at designated areas allowing activities within the areas to be monitored by security personnel in the control room. The personnel will be able to identify which individual or objects that exit permitted zone or enter prohibited zones, based on the tags that has been detected by the reader. If the tags are removed without authorization, alarm will be generated. All the activity transactions are kept in a database for future references or actions.

A case study of inmate tracking system is conducted and demonstrated to prove the workability of the proposed method. This proposed system has been presented in [14], and will be further elaborated in this paper.

2 Approach and Methods

Several factors were taken into consideration in ensuring the workability of the proposed system. The critical factors include choosing suitable operating frequencies, selecting appropriate transmission and receiving signals between readers and tags, antenna design, battery lifetime as well as selection of tools.

2.1 Operating Frequencies

Radio Frequency (RF) signals are usually in the form of sinusoidal or almost sinusoidal signals. The frequency, which is the number of signal repetition per second, varies widely for different RFID systems. The common operating frequency bands for RFID system is as shown in Table 1 [15].

Table 1: Common operating frequency bands for RFID systems

Frequency bands	Characteristics	Typical Applications
Low 100-500 KHz	-Short to medium read range -Inexpensive -Low reading speed	-Access Control -Animal Identification -Inventory Control
Intermediate 10 – 15 MHz	-Short to medium read range -Potentially inexpensive - Medium Reading speed	-Access Control -Smart Cards
High 850 – 950 MHz Ultra-High 2.4 – 5.8 GHz	-Long Read Range -High Reading Speed -Line of sight is required -Expensive	-Railroad, car monitoring -Toll collection system

The low to high frequency bands employ inductive coupling while the ultra high frequency band employ radiative or backscatter coupling. These characteristics are defined based on the size of antenna used with relative to frequency wavelengths. When antennas are comparatively smaller than the frequency wavelengths, the effects of current flowing in the antenna is cancelled when viewed from great distance. Presence of object could only be detected if it is located near to the antenna. This system is called inductive coupling, in which the wavelength (less than 2000 m) is much longer than the antenna [16]. Fig. 1 shows the basic circuitry of inductive coupling.

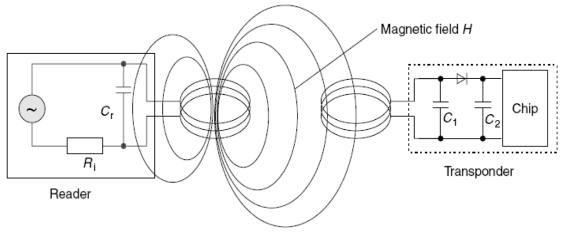

Fig. 1: Inductive Coupling in RFID systems

On the other hand, the antenna size for backscatter coupling is significantly larger as compared to the frequency wavelength (less than 20m). Larger antenna size results in higher frequency band, which has higher capability as compared to the ones that employs inductive coupling. Fig. 2 shows basic circuitry of backscatter coupling. The figure shows signal transmitted by the reader, P1 is reflected by the transponder in backwards direction [17].

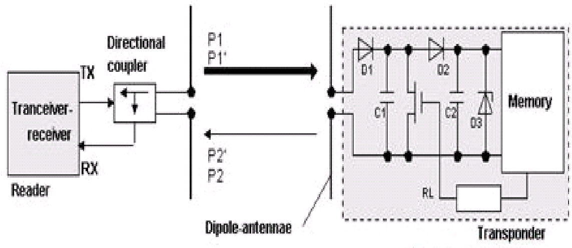

Fig. 2: Backscatter Coupling Circuit

Signal propagation by the frequency bands should adhere to the safety standards set by regulatory authorities. The safety standards are in terms of maximum permissible exposure (MPE) limits as well as Specific Absorption Rate (SAR). The MPE as well as the SAR would vary according to the duration of exposure as well as type of frequency band involved. According to results produced by work of [18], radio frequency is categorized as non-iodization radiation that can operate in high frequency and at low power without causing adverse effect to human tissues. The SAR rating produced by the frequency range of 900 MHz, for example, is less than 0.2W/kg, which is within a safe region. A summarized guideline on the permissible radio frequency and microwave exposures by major international organizations were referred from [19].

The proposed surveillance system requires the RFID tags to be worn at all time. Hence the selected frequency band should be within allowable range (950 MHz or below) to avoid adverse effects to the individuals under the surveillance.

2.2 Antenna Design

Antenna is significant for transmission of signals within RFID systems. Equations used for antenna design are as follows:

$$L = N^2 R \mu_0 \ln\left(\frac{R}{r}\right) \quad (1)$$

where L is coil inductance (H), N is number of coil turns, R is antenna radius (m), r is wire radius (m) and μ_0 is set constant at $4\pi x10^{-7}$.

To create a suitable resonating circuit, the capacitor values could be obtained from the following formula:

$$C = \frac{1}{(2\pi^2) f_0{}^2 L} \quad (2)$$

where C is the capacitor (F), f_0 is resonant frequency (Hz) and L is the inductance value (H) obtained from equation (1).

2.3 Transmission and Receiving Signals between Readers and Tags

Two common communication protocols for RFID systems are Readers Talks First (RTF) and Tag Talks First (TTF). RTF systems mean that the reader will be first to send command to the tags for communicating data and signal. For TTF system, the tags continuously send information once it is powered up, without waiting for command from the RFID reader [16]. Usually, the TTF condition uses a special RFID tag which contains various specialized sensors, such as temperature, humidity, shock/vibration, light, and pressure.

Selection on the communication protocols for the surveillance system varies according to applications. If the activities to be monitored are at a high security area, it is best to opt for TTF protocol to ensure continuous information received from the tags.

2.4 Battery Lifetime

Battery lifetime is taken into consideration for design criteria as it substantially affect the overall performance of the RFID system. If the battery is almost depleted, it may potentially provide false read from the RFID tags. The common types of RFID batteries are Lithium-ion. The lifetime of these batteries are dependent on how frequent it is being used. Therefore, to avoid unnecessary waste on the battery consumption, the tag transmission should be switched to hibernating mode when it is not in use.

2.5 Tools

2.5.1 RFID Tags

RFID tags are classified into three different types, which are passive, active and semi passive. Each type of tags has its own operating characteristics and the means by which it receives the power for transmission [20]. Active tags require batteries to be mounted on them. They have the capability to initiate communication within the RFID systems, such as powering up processors, memory as well as sensors. The lifetime of the tags is solely dependent on the battery lifetime. The active RFID tags could be detected at a distance up to 30 m from RFID reader [21].

Passive tags, on the other hand do not have any internal power source, therefore rely completely on the signals generated by the readers. Passive tags do not expire over life time as they have no batteries [22].

Active RFID tags are chosen for this proposed surveillance system as they could be detected at a farther distance as compared to the passive tags.

2.5.2 RFID Readers

RFID reader is a transceiver that has combination of transmitter and receiver. Its role is to query the tag and receive data from it. In executing this project, the long-range RFID system is applied. The long-range implies that the distance between the reader and tag is greater than 1m.

2.5.3 Host Computers

The host computer is very important in any RFID system. The host computer could be personal computer, laptop, server or a workstation as long as they run database and control software. All information collected from the tags and detected by the readers are processed by the host for monitoring or diagnosis purpose. [23]

Communications between the RFID readers, tags and host computer is as illustrated in Fig. 3 [7]. RFID tags transmit information through the RFID readers wirelessly while connection between the readers to host computer could be either through cables or wireless network.

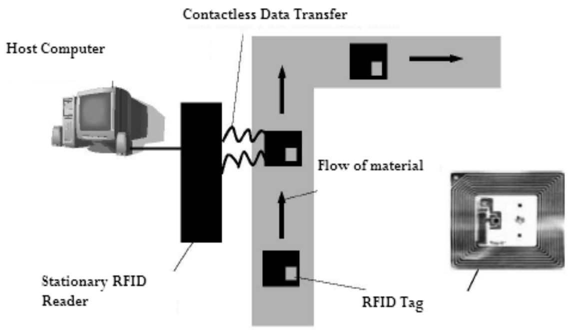

Fig. 3: Communications between RFID readers, tags and host computer

2.7 Procedure Identification

The flowchart of the RFID area surveillance system is as shown in the Fig. 4.

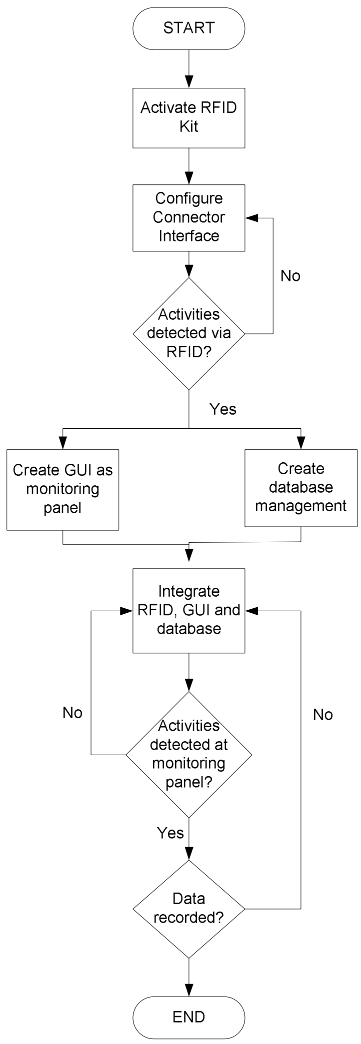

Fig. 4: RFID Multiple Zones Surveillance System

The first step in the area surveillance system is actually placing the RFID kits which consist of the tags and readers at specified locations. The tags were attached to the subjects to be monitored while the readers were positioned at designated areas. When the readers are switched on, a power up message will be automatically sent to the Host software. Depending on the type of communications which are either RS-232 or Ethernet or WLAN, all activated readers could be easily identified by a simple network search.

The activated readers will send a wake up command to the RFID tags which are normally in hibernating mode. If the command is intended for the particular tag, the tag will be activated and transmit its ID and other information such as location and its movements to the assigned reader. The reader will send the signals back to the host computer.

For ease of monitoring, the Graphical User Interface (GUI) was designed. To cater for our case study which is the inmate tracking system, the GUI will display information of the inmates (name, room, bed and tag numbers, current) as well as officers in charge. For storage of information on the current and past activities, a database management was developed. The multiple zone surveillance system is complete when all the RFID, GUI and database systems were integrated. The integration of these systems results in activities in the designated areas being detected at the monitoring panel as well as data history being efficiently recorded.

3 System Development

This work is divided into two parts which are hardware configurations and software programming. The hardware development involves integrating RFID tags, RFID reader and the host computer. Software programming involves development of database using SQL 2005 and user interface using Microsoft Visual Basic 2005 Express. Set up and design was done using phpMyAdmin interface.

3.1 Hardware Configuration

In developing the prototype, we have chosen Active Wave RFID products due to their compatibility to the design criteria of our proposed system. The criteria that we seek are active RFID system that utilizes communication protocol of Tag Talk First (TTF) with the frequency range within 950MHz or below.

The selected active RFID readers and tags work at an ultra high frequency of 927MHz. Communications to the host computer is done either by RS-232 cable, Ethernet (802.3) or wireless network (802.11).

The active RFID reader is designed for fast and easy system integration without losing performance, functionality or security. This active RFID reader consists of a real time processor, operating system, virtual portable memory, and transmitter/receiver unit in one small self-contained module that could be installed in the ceiling or in any other convenient location. The Active Wave RFID reader has two modes of operating ranges which are 30 meter (100 feet) from the tag at 433MHz and 85 meter (280 feet) from the tag at 916MHz, 927MHz, or 868MHz [22]. The working frequencies of the Active Wave system are based on the international platform of RFID systems. The long read range Active Wave RFID system employs a midrange frequency, and a unique complex software algorithm to provide noise immunity and error-free operation in high-interference environments.

One of the outstanding features of the selected RFID system is its true anti-collision capability. Anti-Collision algorithms allow simultaneous reading of large numbers of tagged objects, while ensuring that each tag is read only once. This feature is very essential in ensuring data integrity, when several RFID tags at multiple zones are read at one single time.

The RFID reader field strength can be configured ranging from 0 to 20, so that the RF field can be estimated by setting the strength ratio as shown in Table 2. For the proposed surveillance system, the reader field strength is adjusted according to the size of the zone. If the size of the zone is large, the reader field strength should be high.

Table 2: Reader field strength ratio to estimate distance

Field Strength Ratio	Estimated Distance (m)	Field Strength Ratio	Estimated Distance (m)
1	4.25	11	46.75
2	8.50	12	51.00
3	12.75	13	55.25
4	17.00	14	59.50
5	21.25	15	63.75
6	25.50	16	68.00
7	29.75	17	72.25
8	34.00	18	76.50
9	38.25	19	80.75
10	42.50	20	85.00

The active wristband tag is the size of a wristwatch, however much lighter. This tag is designed to be worn around the wrist. The tag is equipped with temperature sensor as well as tamper switch. If the wristband is unfastened or cut, the sensor at the tag can detect temperature difference and will immediately send an alert to the system.

Typically the tags are in the hibernating mode until being activated by the reader or field generator. If the command is specifically sent to the particular tag, the tag will awaken and send its ID and other required information to the assigned reader. To conserve battery life, the tags could be configured to automatically wake up at predefined intervals, report necessary information to the system, and then return back to the hibernating mode. If the tag misses the scheduled reporting time, alert system will be generated by the host computer.

The active RFID reader and active wristband tag used in the prototype is as shown in Fig. 5.

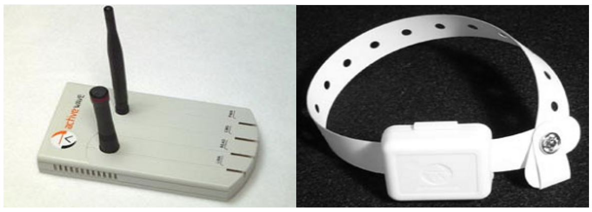

Fig. 5: Active Wave RFID Reader and Wristband Tag

3.2 Software Programming

The software is designed to specifically cater for our case study which is the tracking of inmates. Database setup and design was done through the phpMyAdmin interface. Four tables were created to store data which are an alarm or alert history table, inmate table, officer table and readers table. Fig. 6 show all the tables that have been created.

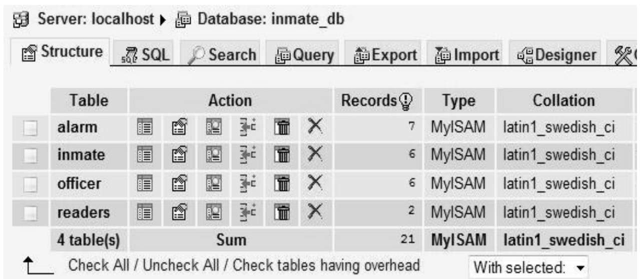

Fig. 6: Inmate Tracking Database

All the alarm current status and history will be stored in alarm table. It has five fields which are acknowledged, id, name, zone, and progress time. The field of acknowledged indicates the current status of the particular inmate. Status 'OK' indicates the inmate is in the permitted zone while 'Alert' status shows that conflict has occurred. The conflict could be either the inmate has violated the permitted zones or has removed the wrist tag. Fig. 7 shows example of updated alert status in the system database.

←T→			ack	id	Name	alertType	Zone	ProgressTime
			OK	EE8369	Canto Ala Bonte		20	2009-06-01 12:49:33
			Alert	ME8786	Mantelo Satan	OUT OF ZONE	20	2009-06-01 12:43:46
			OK	IS5924	John Steve Mayer		10	2009-06-01 12:49:22
			OK	CI34030	Thomas Jeans		10	2009-06-01 12:49:30
			ALERT	EE8244	Sir Alex Yon	TAMPERED	20	2009-06-01 12:45:59
			OK	CHE8691	Phantom Assasin		20	2009-06-01 12:48:16

Fig. 7: Alert Status Database

The inmates profile and information are stored in inmate table. It has seven fields which are id, name, room, house, bed, tag_id, and enroll date. The room field stores the information of which zone the particular inmate belongs to. Enroll field stores date of inmate enrollment at the prison.

Officer table is used to store all officers or operators information in the inmate tracking system. The table consists of three fields which are id, name and password. The last table is readers table that have two fields which are reader id and reader number. The purpose of this table is to assign one zone for one reader.

For this prototype, we have created two zones, which we classified as 10 for first zone and 20 for second zone.

4 System Integration

The Inmate Tracking System was developed by using all the hardware and software development as discussed in the previous sections. Tests have been conducted to ensure that all hardware is functioning as required and software is producing the desired outputs. To demonstrate the system, a total of six wrist tags were divided into two different areas around respective reader.

Fig. 8 shows the block diagram of movement of inmates with tag IDs 200 and 203 being tracked at respective locations. Two readers are being placed at the two specified zones.

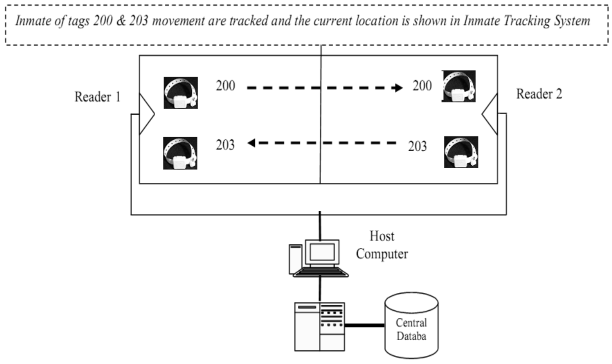

Fig. 8: Inmate Tracking System

To login to the system the officer needs to enter his assigned ID and password as in Fig. 9.

Fig. 9: Inmate Tracking System login

Once allowed to access the system, the officer will be shown with the main window interface as in Fig. 10. This window shows the current locations of all the inmates and total number of inmates in each zone.

Fig. 10: Main window of Inmate Tracking System

To start tracking or updating database while monitoring the inmates, officers will need to turn on the RFID reader. This is done by clicking the ‘Connect’ icon at the main window. Once the RFID reader is turned on, the ‘ON’ sign will be displayed at the main window. This indicates that the system is ready in the tracking mode, as shown in Fig. 11.

Figure 11: System in tracking mode

If there is a need to increase or decrease the coverage area or to be connected with more or less RFID readers, the officer just need to click on the ‘Configure’ button. This is to add new or remove IP addresses of the particular reader(s). This is shown in Fig. 12.

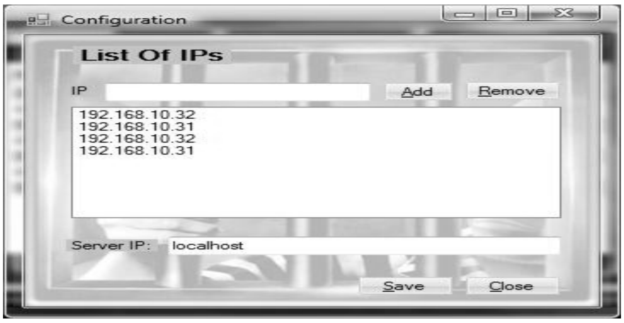

Fig. 12: Readers IP Configuration

The officers also are able to add inmate and officer profiles by clicking the ‘Add Officer’ and ‘Add Inmate’ buttons respectively and the forms as in Figs. 13 and 14 will appear. After all the required information has been filled in and submitted to the system, the data will be stored in the MySQL database.

Figure 13: Add Inmate Profile

Figure 14: Add Officer Profile

The system will give an error message if duplicating data is being entered as shown in Fig. 15.

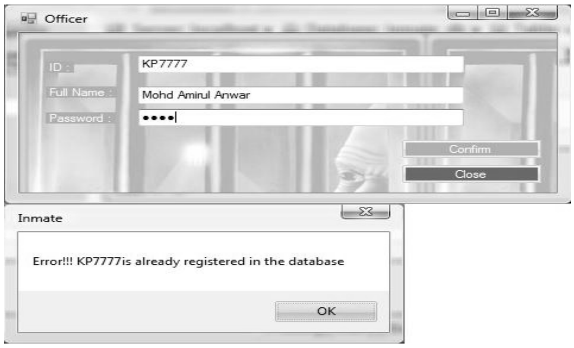

Fig. 15: Error Message for Duplicating Data

The data stored in the database could be retrieved by clicking the ‘Inmate List’ or ‘Officer List’ respectively. Fig. 16 shows list of inmates at the assigned locations and each inmate is assigned with unique ID. The system also show when they entered the prison. Fig. 17 shows all the registered officers who are allowed to access the system.

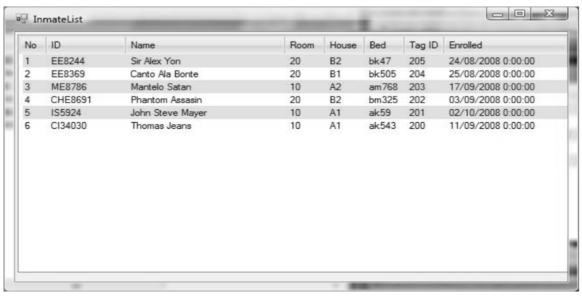

Fig. 16: List of all Registered Inmate

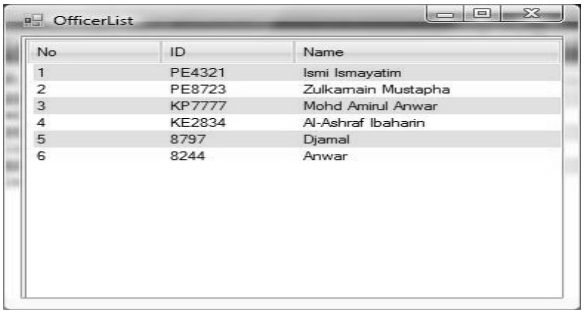

Fig. 17: List of all Registered Officer

If there is a conflict such as inmate crossing beyond his permitted zone, an alert signal will pop up on the host computer. The alert message contains the name of the inmate as well as his past and present location as shown in Fig. 18.

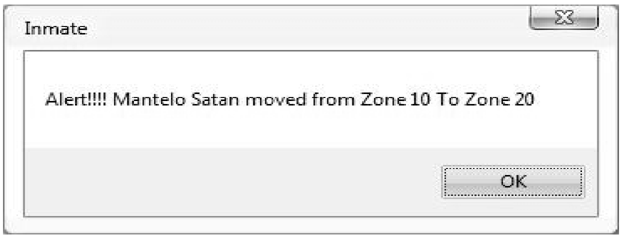

Fig. 18: Alert Pop up for Moving out of Zone

If the tag has been tampered, the alert signal will pop up as well, as shown in Fig. 19. The inmate name will be displayed. These features will caution the officers in charge to take immediate actions.

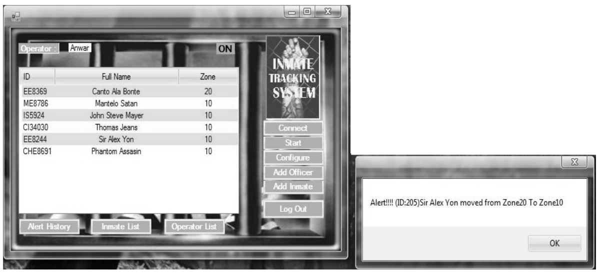

Fig. 19: Alert alarm pop-up for tag tampered

All the conflicts that have happened can be viewed by clicking the ‘Alert History’ icon and the history will be displayed as in Fig. 20.

Fig. 20: Records of Alert History

5 Discussion

The case study shows the capability of the proposed RFID system for multiple zones surveillance. This surveillance system can be considered to be more reliable as compared to the current ones in the market. As the detection system is based on the unique identification from the tags instead of visual identification, situations like obstructed view could be avoided. Furthermore this system gives the freedom to individual or objects to move around from one zone to another, while guarding them against entering prohibited zones.

At the moment, only two zones or designated areas were created to track the mobility of the subject. The number of zones could be increased by adding more RFID readers, depending on required usage. The readers could be placed within enclosed rooms for indoor surveillance or placed outdoors. The capability of detection will depend on the operating frequency of the RFID systems. For tracking of objects within short distance, lower frequency bands are sufficient. The proposed system employs an ultra high frequency band that has a capability of detection up to 10 meters. This feature makes it very suitable for monitoring of individual or objects in a large area.

The proposed system has a high data transfer rate, which is about 100 kbit/s. This is an advantage as more information from the monitored activities in the surveillance zones could be retrieved in such a short time. Taking an example of the inmate tracking case study, in the occurrence of zone violation by any inmates, their profile information including their names, tag ID, bed number and date of enrolment, to name a few, could be quickly obtained by the officers in charge.

This system could cater for various other applications. One example is monitoring of newborn babies in hospitals where RFID readers could be placed at the nursery as well as at the mothers’ rooms. Should the babies are taken out of these areas without authorization, alert system could be generated to avoid them from being missing. This feature is also useful as the attached tags could store necessary information of both mother and baby to prevent any mix-up. Other suggested application for the proposed system is to track personnel working in hazardous areas.

Several challenges were encountered while testing this system. The major challenge is that system with ultra high frequency band, which is employed for this work, could not penetrate water. Lower frequency bands however have the advantage to be immersed in water and provide accurate reading due to their low absorption characteristics [16].

Another challenge that we came across is that detection of the tags could be hindered by unwanted interference such as cell phone tower, which may interfere with RFID reader. Hence for this particular case, it might be recommended to use other methods of area surveillance. Further investigation and research should be conducted to address this limitation.

Further works shall be done to ensure better reliability of this system. As this surveillance system utilizes active tags, the functionality of this system is dependent on battery lifetime. Weak batteries could cause unwanted false readings from the tags. Hence, apart from setting time schedule for tag signal transmission to conserve battery lifetime, it might be helpful to have battery indicator for the tags. This feature would allow users to be aware of battery conditions and can replace them before becoming completely depleted.

Another recommendation to boost up the capability of the system is by integrating it with Global System with Mobile Communications (GSM) module to develop short message services (SMS) capabilities. The SMS could deliver notifications of current and conflicting status to authorized officers or person in charge without having to be in the control room all the time. The applications of this SMS functions could be further developed for other desired applications.

6 Conclusion

As conclusion, the objectives of this project have been achieved. The active RFID systems have been integrated with Graphical User Interface (GUI) for detection, monitoring and tracking of activities within the designated areas. The prototype of inmate tracking system had confirmed the capability of the system to conduct multiple zone surveillance effectively. Activities as well as identification of people (or object) were captured effortlessly. In the event of the person or object crosses over the area border or if the RFID tags were removed without authorization, the alarm system were triggered and alerted at the monitoring panel. Database management is also incorporated with the system for the purpose of data storing and could be retrieved for later use. All the features of the proposed system help in eliminating time consumption unnecessarily. The designed system could be applied to various other applications due to its ease of usage and effectiveness.

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