

A Centralized Emergency Room Patient Tracking System for Intelligent Cities

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Abstract
Central tracking mechanisms play a vital role in the formation of intelligent cities, by providing fast information sharing, taking precautionary measures and remote intervention. In our study, a centralized system that will provide central tracking of drugs, personnel and patients inside the intelligent city emergency rooms is proposed. The information obtained through the designed pilot system by using RFID (UHF, HF) and iBeacon technologies is evaluated at a central server. The emergency rooms data is shared online with related doctors, nurses and authorized personnel. The details of the hardware and software design, experimentation, results and the performance evaluation have been presented.

Keywords: Emergency, Embedded System, RFID, iBeacon, NFC.

1. Introduction

Severe and hemorrhagic health problems that occur outside the hospital are first intervened in hospital emergency services. Emergency health services also include the transport of the sick and injured to other hospitals when necessary (Yaşar et al. 2000). In our country and in the world, metropolitan emergency services have become special units where many problems coexist due to population density (Yaşar et al. 2000).

Many resources are needed to increase the quality of service and standards in emergency services. Resources that should be consistently available in adequate supply include biomedical equipment, service area, assisting staff, and drug stock. It is unlikely that the emergency services will be completely trouble-free, given the diversity of resources mentioned. This is because the need for urgent intervention with multiple patients at the same time is a difficult situation to overcome with a limited number of resources (Söyük & Kurtuluş 2017). The competence of the intervention staff, the timely and correct implementation of the first intervention, and the availability of the equipment and drugs to be used play a major role in obtaining positive results. In short, all living and non-living resources involved in the intervention need to work at the same time, accurately and precisely. Otherwise, any disruption in emergency services places the life of the patient in danger. Therefore, in order to maintain the quality of service provided, it is necessary to make preliminary preparations by considering the problems that may

occur (Dölek et al. 2005). It can be predicted that only those who live near an emergency service provider can be affected by a large community when they are thought to be living near the emergency services in the city during a natural disaster. However, in case of an epidemic or biological attack around the city, it would be very useful to share an intervention method that is successful in one of the emergency services with other emergency services on the fly. Therefore, it is understood that the importance of coordinating emergency services with a central system is of great importance in terms of creating intelligent cities.
Coordination of emergency services throughout the city is a more difficult process than managing a single emergency service. However, basically the same steps are followed in all emergency services. Instead of a single emergency department, all emergency services staff are based on the method of monitoring medical devices, materials, and medicines (PADC: Personnel, Asset, Drug, Consumable) with electronic labels (tags) and instantly monitoring with wireless readers. It is possible to produce daily, weekly, and monthly proven activity reports after instant follow-ups, and necessary fixes can be made by determining the missing directions.
The capabilities described above are realized in today's industrial automation solutions with Ultra High Frequency (UHF) and High Frequency (HF) radio frequency identification (RFID) and Bluetooth low energy (BLE)-based iBeacon technologies (Florentino et al. 2008). The main purpose of this study is to monitor PADC with modern wireless technologies to coordinate all emergency services in an intelligent city in a completely paperless environment and to reduce loss of emergency services in case of emergency. We are trying to achieve this goal with tablet and smartphone software, which are linked to hospital automation, to enable PADC to be monitored without the need for paper. With PADC monitoring capability, an integrated system can be created that can manage all of the processes of health services.

2. Related Works

In recent years, with the development of the concept of the smart city, hospitals have begun to benefit from the benefits provided by technology in the health field (Ömürbek et al. 2013). A study suggests that hospitals should use technology more efficiently and convert into digital hospitals (Ak 2013). It is obvious that reducing and balancing the intensity of hospital emergency services in intelligent cities can only be possible by putting this prediction into practice. However, when modern technologies are not integrated with health services, it is seen that serious losses are experienced. For example, medical errors constitute a significant fraction of the causes of death in the United States (Henneman et al. 2005). Ten of every 100 hospitalized patients and 18 of every 100 patients in the emergency department suffer from medical malpractice (Henneman et al. 2006, Anezz 2006). In 2001, it was determined that approximately 1,200 people had died due to reasons caused by drug application mistakes in the UK (Preston 2014). In another study, it was found that 78 of every 100,000 patients admitted to emergency departments reported drug application failure (Pham et al. 2014). In a different study, due to the fact that patient identities were not correctly identified, errors such as wrong patient medication or wrong surgery were revealed (Blank et al. 2006). Errors and deficiencies seen in emergency services are clearly indicated in the study, which can be removed by integrating emergency services (Eryılmaz 2007).
In response to the reporting of so many mistakes, academics have directed their attention to paperless health care work. In one study, an intelligent health service system platform was proposed using the Internet of Things (IoT) (Yang et al. 2014). On the recommended platform, smart medicine called the iMEDBox was designed and checked for the use of drugs. Whether the patient's medication was taken or not was determined by an RFID sensor circuit named İMedPack. In another study using RFIDs, it was proposed to equip PCMI for emergency ambulances with UHF and Near Field Communication (NFC) tags. In this way, both PCMI follow-up and patient information are quickly shared (Özcanhan et al. 2014). An example of the centralization of data is the study of data stocks in blood banks (Sakarya et al. 2006). With the developed database model, it is anticipated that all blood bank data will be collected in a central database with XML format even if they come from different platforms. This makes it easier to find suitable blood in urgent situations by referring to the central database instead of separate blood banks.

3. Technological Capabilities of Today’s System

Prior to the detailed description of the proposed solution, the technological capabilities of today, internalized in the proposal, are listed below:

1. Modern automatic scanning independent of human interpretation of PCMIs - instantaneous tracking with data acquisition (OTVT)
2. Offering collected PCMU location data to mobile devices at any time, anywhere
3. Automatic registration of cost accounting automatically by associating patient and PCMI marked with electronic tags with modern database servers

4. The fact that the details of the medical intervention seen by the patient are proven at the time of the details in all the modern computer environments
5. In order to increase the efficiency of PCMİ, use of the current information tools to examine in detail
6. Obtaining statistics on emergency computer service continuity and quality assurance with fast computers.

3.1. Emergency Hardware

The hardware unit of the designed system and its connections have been composed of the parts listed in Figure 1.

1. UHF tags for drug and asset tracking,
2. NFC cards and iBeacon for patient and personal tracking,
3. UHF, NFC, and BLE reader runs on the Arduino board (Arduino Uno Rev3) ,
4. Server for decision support application and converting collected data to valuable information,
5. Mobile devices for drug orders, sharing patient information, and sending notification when required.

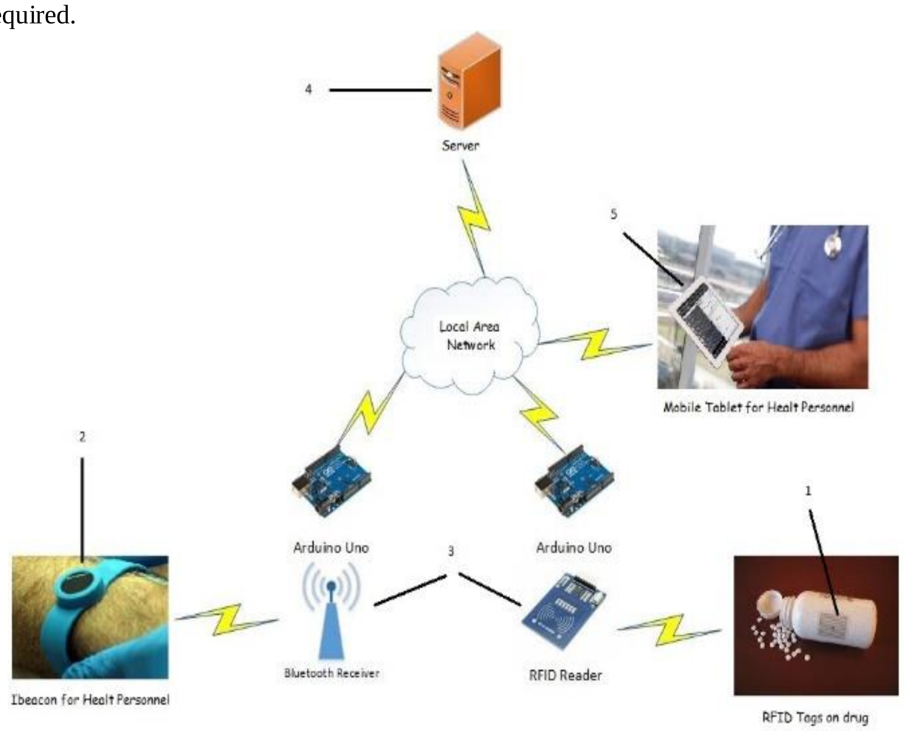

Figure 1. Hardware and communication structure for emergency situations

UHF labels are affixed on them to detect removal from the place where the medicines and fixtures are located and where they are located (Özcanhan et al. 2014). With the UHF-RFID reader installed on the Arduino card, the location of the object that is attached on the label is determined, and through the Ethernet module installed on the same Arduino, the read data is transferred to the server via the local network. Therefore, the exchange of medicines and medical devices can be followed by readers placed in the rooms and the gates. The locations of health personnel (doctors, nurses, and assistant staff) are determined by iBeacons. The BLE module mounted on the Arduino card detects the signals emitted from the iBeacons attached to the officers, and the sensed information is sent to the server via the Ethernet module.

As shown in Figure 1, the data from the readers is collected in a database on a server. Collected and processed data is presented to healthcare providers, patients, relatives, and authorized administrators via mobile devices as a warning, report, or information by wireless communication technology according to authority and sharing rules.

3.2. Emergency Service PADC Tracking Software

A In the structure shown in Figure 1, it appears that all the data are stored in a single server. In Figure 2, the general scheme of the emergency service application’s software is given. In the proposed software design, there are three different software items and a server item in which these software items are linked to the data. The items are:

1. Server for data connection management,
2. The management platform where the authorizations are made, and the reporting and registration processes are held,
3. The mobile platform where doctor data entries are made,
4. The desktop platform on which the pharmacy management system is built.

The data is stored and managed by the Microsoft SQL Server database management system that forms the basis of the first item. All the data needed in a single database is collected. The data is delivered to mobile and desktop computer platforms via a single server. ASP.Net web service technology is used for the server. Different platforms have access to data by providing access to a single central server, making it easier to maintain the system.

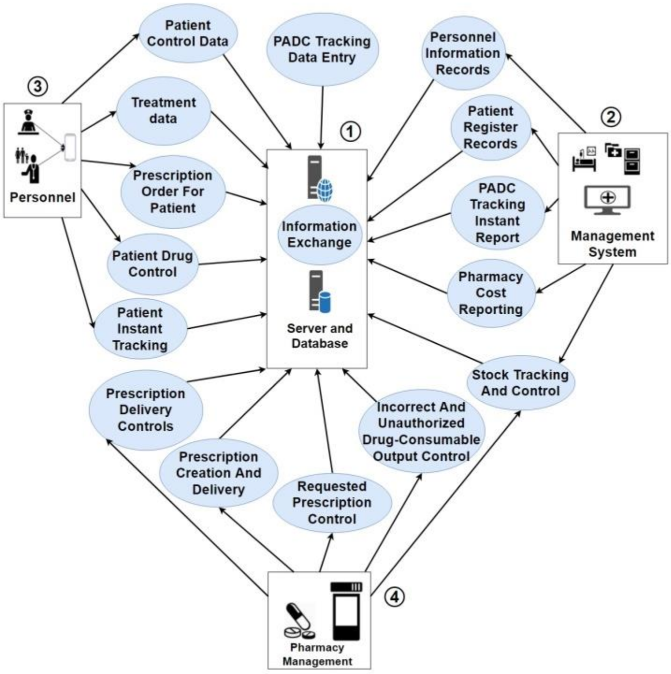

Figure 2. Emergency service tracking software scheme

The second item is the Management Platform; this involves hospital system registry procedures as well as the reporting platform. Information and working hours of staff in the hospital are recorded through this platform. Entry and exit records of medicines in the emergency department pharmacy, stock and date controls, and cost status reports are carried out through this system. With the instant reporting system, all the data needed at the moment is accessed. PADC's instant location and hospital border violations are controlled through this platform.

An application-loaded mobile phone or tablet platform with special functions for doctors is the third item. The doctor can access all the interventions he/she has performed for the patient from the mobile device and can access all the information about the patient when he/she needs it. In addition, doctors provide drug registrations from the emergency department pharmacy by entering the request records of the drugs to be given to the patient without mobile application. Thus, the instantaneous information of the health personnel on the patient's intervention is realized without paper. Through the patient's instant follow-up and emergency warnings, all interventional procedures related to the patient can be observed. In this way, it is possible to maintain more accurate and reliable records in the system and to make detailed controls quickly and easily by the managers. With this automation achieved, the workload and human factor of all employees are reduced.

Drug management in the emergency department pharmacy is the element that relates to patient safety and cost accounting. Automatic control of the correct amount of prescription drugs packed in the proper way at the right time is achieved as follows:

According to the doctor's requests, the pharmacy creates a prescription for the drug package of the patient. During the packaging phase, both the package and all the objects in the package are attached with the UHF label, and the RFID reader is used to register the package and its contents in the database. Incorrect or incomplete delivery is avoided by comparing requested medicines and package contents with software. The packages are identified by the identity of the delivery receiver, by reading the NFC card belonging to the person. All pharmacies and packs departing from the pharmacy are checked by the reader located at the exit of the pharmacy. In case of unauthorized drug delivery or uncontrolled delivery at the exit, a warning system is activated to inform the operator of the error. Outputs are reported instantaneously with queries to be made to the database. Along with this, there is a warning and reminder about the drugs and materials that are decreasing, ending, or reaching expiration date in the pharmacy. Medical devices are followed in the same way. The requests generated in Figure 3 are transmitted by the health personnel (Tier 1) to the central database server (Tier 3) via the pharmacy management platform (Tier 2), and the health services provided to the patient after the abovementioned steps are shown.

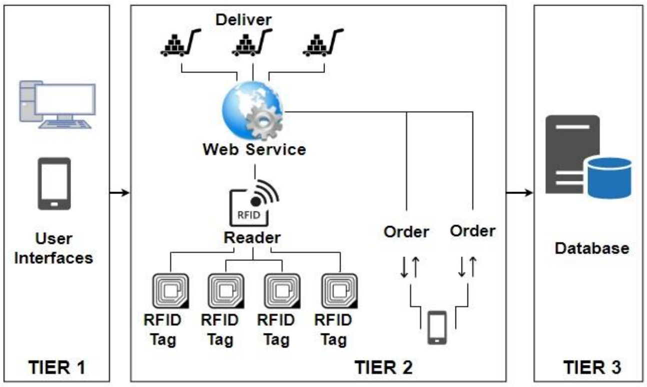

Figure 3. Pharmacy management application architecture

4. Tests And Results

4.1. Test Setup

For the proposed Emergency Service Tracking Application, without being tested as integrated, each item has been tested separately in the hardware, and each function has been tested in the laboratory separately in the software. Then the whole system has been tested by combining all components. In the experimental setup, server, notebook, two tablets, three Arduino Uno cards, UHF RFID reader, RFID reader, NFC reader, three BLE modules, three iBeacons, three Ethernet modules, 10 RFID tags, and 5 NFC cards have been used. Figure 4 shows the laboratory environment in which the emergency service scenario is simulated. As shown in the figure, the server is located in one of the rooms, and a room entrance is equipped with a BLE reader that detects personnel and patient entrance. In the room representing the pharmacy, a UHF RFID reader connected to the notebook positioned on the table and RFID, NFC, and BLE readers connected to the Arduino Uno have been installed. There is also a BLE reader in the corridor that is responsible for patient and staff identification. Using an Ethernet module on all three Arduino Uno units, data is transferred to the server via wired network.

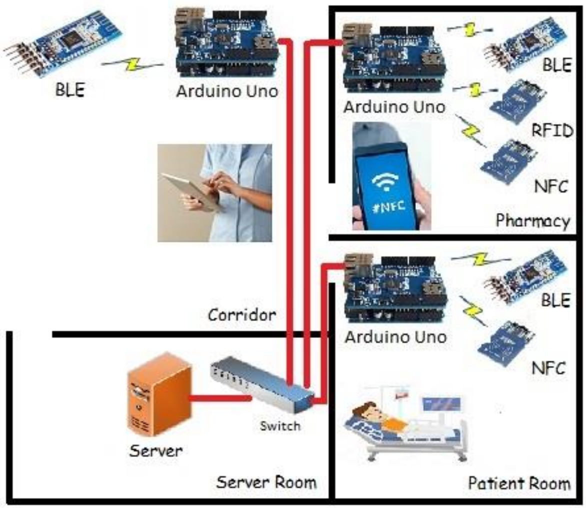

Figure 4. Test environment view

In this scenario, the stock information of the drugs in the emergency department pharmacy has been entered through the software developed in the database on the server. The doctor, who is electronically labeled and interfaced with an accepted patient, orders medicine for the relevant patient from the mobile device approved by the hospital after the ID-password check. When the pharmacist receives the medication for the patient, the healthcare medicines are taken out of the range of the RFID and BLE reader at the exit, and the medicines that are taken out of the room are transferred to the server via the Ethernet cable. Thus, the drug stock control and the drugs applied to the patient are detected. The used medical devices and other inventory are followed in the same way. The designed system records the information of the room, not the position of the observer being followed. In order to determine the presence of the iBeacon inserted object in the room, the BLE readers are positioned at the most appropriate locations. With the medical information entered by the doctor for the patient, it is integrated with PCMI and patient follow-up.

4.2. Test Results

Test setup items have been tested individually. Then the items have been combined to test the operation of the pilot system. In the experiments, volunteer students have assumed the roles of health personnel and patients. The results of the experiments are shown in Table 1. Positioning with the iBeacon was repeated 300 times. In 100 of the experiments, the presence of personnel in the pharmacy room was tested. In another 100 of the experiments, the presence of personnel in the corridor was tested. In the third 100 of the experiments, the presence of personnel in the patient room was tested. In these experiments, a total of 9 erroneous readings were made. There is no delay in data transmission due to the use of wired network in transferring the information to the server. Reading the RFID labels, preparation of the drug package 100 times with the test, and the check of the package at the exit of the pharmacy have been tested 100 times. A total of 7 reading errors were detected in the experiments. With the NFC card reading process, the health personnel's drug delivery from the pharmacy and the identification of the drug applicant were tested 100 times, with 200 tests in total. In the NFC card reading tests, a total of 8 faulty readings were encountered. Testing of the pilot system has been performed with a scenario of serving a patient in the emergency department. A patient outcome report has been obtained for the experiments in which all items worked together, such as prescriptions, medication order, drug package preparation, drug delivery, package control, application to the patient, and software following the whole system. At the end of the experiments, a total of 5 faults were detected.

In the iBeacon, UHF, and NFC tests, the results were recorded according to the following definitions.

True Positive (TP): The actual readings are the number of correct detections of the sensors.

False Positive (FP): The number of times the sensor does not detect reading, even though it is a reading.

True Negative (TN): The number of non-read detections when the sensor is not reading.

False Negative (FN): The number of read detections, even though the sensor has no reading status.

In patient outcome report experiments, the correct and incorrect recordings of the results were made according to the following definitions:

True Positive (TP): Number of prescriptions, medication order, preparation of medication package, delivery of medicines, package control, and application of the patient, counted correctly in the final report.

False Positive (FP): Number of prescribing, medication order, preparation of medication package, delivery of medicines, package control, and application to the patient, not counted correctly in the final report.

True Negative (TN): Number of prescribing, medication order, preparation of medication package, medication delivery, package control, and not being applied to the patient, not being included in the final report correctly.

False Negative (FN): Number of mistakes in prescription writing, medication order, preparation of medication package, delivery of medicines, package control, and failure to apply to the patient.

Table 1. Result Table of Performed Experiments

Experiment	Repetition	TP	FP	TN	FN
iBeacon Reading	300	142	8	149	1
UHF Reading	200	96	4	97	3
NFC Reading	200	97	3	95	5
Patient Result Report	300	147	3	148	2

5. Discussion

The performance of the proposed designs is measured by the results of the tests. Universal performance measures are calculated using the following equations:

$$Accuracy = \frac{TP+TN}{TP+FP+FN+TN} \times 100 \quad (1)$$

$$Sensitivity = \frac{TP}{TP+FN} \times 100 \quad (2)$$

$$Specificity = \frac{TN}{TN+FP} \times 100 \quad (3)$$

$$Error\ Rate = \frac{(measured\ value - actual\ value)}{\frac{measured\ value + actual\ value}{2}} \times 100 \quad (4)$$

Table 2. Performance Table of Studies

Performance (%)	iBeacon Reading	UHF Tag Reading	NFC Tag Reading	Patient Result Report
Accurary	97	96,5	96	98,3
Sensitivity	99,3	96,9	95	98,6
Specificity	94,9	96	96,9	98
Error Rate	3,0	3,5	4,1	1,7

The accuracy value shows how accurate the sensor readings of the proposed design are. Sensitivity refers to the rate at which sensor readings can be detected. Specificity is the rate at which sensor readings are not detected. The error rate indicates the incorrect detection rate of the proposed design.

Table 2 shows the results obtained by placing the results of TP, FP, TN, and FN given in Table 1 in the equations (1, 2, 3, 4). According to Table 2, the accuracy of detecting PCMI is over 96%. The error rate in the patient outcome report is 1.7%. Considering drug mistakes in paper-based emergency services, it is thought that the proposed design will minimize many vital problems, especially the accuracy of medicines given to patients, if intelligent cities are used in emergency services, especially the correctness of medicines (Bişkin & Cebeci 2017).

With the proposed suggestion, the following contributions are given to emergency services provided in smart cities:

1. Immediate and paperless Emergency Service PCMI tracking contributes to the Ministry of Health's Paperless Hospital project,
2. With the PCMI tracking and monitoring system, all services of all emergency services in the city can be monitored and guided,
3. Warnings and reminder services can be provided about decreased inventory or approaching expiration dates of drugs, materials, and devices of oncoming maintenance dates,
4. Compatible work services on different computer platforms is possible, with the use of XML data type,
5. This can serve as an example for other health services,
6. This platform can increase confidence in national income, community health, and health services.

6. Conclusion

A proposal has been made that uses modern technologies to ensure that all emergency services in a smart city are monitored and directed. The hardware and software design of the recommendation is explained in detail. The test method and results of the individual items of the proposed platformand the pilot system integrated with a scenario are presented. According to Table 2, the accuracy of detecting PCMI is over %96, the error rate in the patient outcome report is %1.7. The results show that the pilot system works successfully in the laboratory environment with the proposed prototypes.

The proposed pilot system is preparing for a more comprehensive scenario that simulates multiple emergency services. In this new scenario, where the hardware and software it contains is not much more than the content described in our work, the number of points to be taken during the role, the health care workers to consider, and the experiments require more detailed planning and preparation. The last stage of the experiment, to be conducted in a real emergency service environment, is also planned as future work.

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