DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

EMERGENCY SERVICE PATIENT TRACKING SYSTEM

by
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July, 2019
İZMİR

EMERGENCY SERVICE PATIENT TRACKING SYSTEM

A Thesis submitted to the
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by
Hilal BUÇAN

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M.Sc THESIS EXAMINATION RESULT FORM

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EMERGENCY SERVICE PATIENT TRACKING SYSTEM

ABSTRACT

The fact that the purpose of the hospital emergency services is "human life and health" brings these service institutions to a sensitive place. For a very long time, hospital emergency services remained standalone systems. These systems occasionally forwarded the emergency service warnings to the nurses with connecting to the pagers. In the early 1990s, requests for hospital emergency services reporting to be done has increased. Therefore, PCs are being used more for risk management and support quality improvement processes. In the late 1990s, wireless telephones began to replace pocket pagers. These phones are widely used in emergency services because they provided not only simple text messages but also consultation calls. Nowadays, location tracking systems have needed as the next step of improvement. This has resulted in the need of ensuring the integration of the collected location information into the emergency services.

Central tracking mechanisms play a vital role in the formation of smart cities by providing fast information sharing, taking precautionary measures and remoting intervention. In our study, an embedded system based on the system that provides central tracking of drugs, personnel and patients inside the smart city emergency rooms is proposed. In the designed pilot system, information that is obtained by using RFID (UHF, HF) and iBeacon technologies is evaluated at a central server. The emergency room data is shared online with doctors, nurses and authorized personnel. Details of the hardware and software design, experimentations, results and values of the performance evaluation have been presented.

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

ACİL SERVİS HASTA TAKİP SİSTEMİ

ÖZ

Acil servislerdeki metanın “insan hayatı ve sağlığı” söz konusu olması bu hizmet kurumlarını hassas bir yere taşımaktadır. Çok uzun bir süre, hastane acil servis sistemleri tek başına çalışan sistemler olarak kalmıştır. Bu sistemler ara sıra da olsa çağrı cihazlarına bağlanarak acil servis uyarılarını hemşirelere iletmişlerdir. 1990’ların başında acil servis raporlaması yapılması için istekler artmış, PC’ler risk yönetimi ve kalite geliştirme süreçleri desteklemek için daha çok kullanılmaya başlanmıştır. 1990’ların sonlarında kablosuz telefonlar çağrı cihazlarının yerini almaya başlamıştır. Bu telefonlarla sadece basit metin mesajı olarak değil, aynı zamanda konsultasyon görüşmesi de sağlandığından, acil servislerde daha yaygın olarak kullanılmaya başlanmıştır. Günümüzde ise, bir sonraki adım olarak yer belirleme sistemleri ihtiyacı doğmuştur. Bu da, toplanan lokasyon bilgilerinin acil servislere entegrasyonunun sağlanması gerekliliğini ortaya çıkmıştır.

Akıllı kentlerin oluşumunda merkezi takip mekanizmaları hızlı bilgi paylaşımı, hızlı önlem alma ve uzaktan müdahale etme olanakları sağlamaktadır. Bu çalışmamızda, gömülü sistemler desteğinde bir akıllı kentin hastane acil servislerinin merkezi olarak takip edilmesini sağlayacak ilaç, personel ve hasta takip sistemleri sunulmaktadır. Gerçekleştirilen pilot çalışmada, RFID (UHF, HF) ve iBeacon teknolojileri kullanılarak elde edilen veriler bir sunucuya aktarılarak değerlendirilmektedir. Acil durum bilgileri anlık olarak ilgili doktor, hemşire ve yetkilendirilmiş tüm yöneticilere ulaştırılmaktadır. Çalışmanın detaylı donanım ve yazılım tasarımı, yapılan deneyler, deney sonuçları ve deney sonuçlarından elde edilen başarım değerleri paylaşılmaktadır.

Anahtar kelimeler: Acil servis, Gömülü sistem, RFID, iBeacon, NFC

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CHAPTER ONE
INTRODUCTION

1.1 Overview

Severe and hemorrhagic health problems that occur outside the hospital are firstly 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 improve the quality and to raise the standards in emergency services. Resources that should be consistently available in adequate supplies 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 the reason of the need for urgent intervention with multiple patients at the same time which 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 equipments 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, precisely and in a coordinated manner. Otherwise, any disruption in emergency services places the life of the patient in danger. Therefore, it is necessary to make preliminary preparations by considering the problems that may occur in order to maintain the quality of service provided (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 instantly. Therefore, it is

understood that the importance of coordinating emergency services with a central system is of great importance in terms of creating smart cities.

1.2 The Goal of the Thesis

To coordinate the emergency services throughout the city is a more difficult process than to manage a single emergency service. However, the same steps are followed in all emergency services basically. The method is based on real-time tracking by wireless readers in all emergency services. Instead of just a single emergency service for all staff, medical devices, materials and medicines (PADC: Personnel, Asset, Drug, Consumable) which are all attached with electronic labels (tags). 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.

It is believed that identifying, monitoring and controlling the locations of the PADC will improve the quality by providing logistic support by removing the manually populate paper and screen menus in emergency services with a fast working pace and the recommended solution.

The presence and location of PADC that should be present in an emergency room is vital for patients. All emergency service personnel are trying to serve in multiple rooms or compartments in large spaces with number and variety in terms of many devices and materials. In this multivariate environment and a very busy, “race against time” situations, all personnel are engaged in taking care of which resources are used for which patient while he/she is taking medical care. Therefore, it is necessary to create an environment where personnel are fully focused on medical intervention. This is precisely the general scope of our project. It is possible to collect the scope in the following headings:

- Marking of emergency service PADC with electronic labels (tags),
- Marking of patients with tags and matching them with all related PADCs,
- Instant location tracking of patients and PADC,

- Instant status of PADC and monitoring and control of issues affecting them (such as; shift duration, frequency of device maintenance, material stock status, number of drug stocks and expiry date),
- Instantly transfer of patients from emergency service to outpatient clinic services with all health and accounting information,
- Tracking of the health service received by the patient with the evidence,
- Accurate calculation of the cost of PADC used during the service received by the patient.

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 smart city in a completely paperless environment and to reduce loss of emergency services in case of an emergency. We are trying to achieve this goal with tablets 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 and can manage all of the processes of health services.

1.3 Thesis Organization

This thesis includes six chapters and the remaining of this thesis is organized as follows: Chapter 2 summarizes the related works and previous studies. Chapter 3 explains used technologies during the study. Chapter 4 gives the proposed emergency service patient tracking system with used hardware and tracking software system. Five different software applications with a server application and database are explained. Chapter 5 explains test and results about the study. Chapter 6 is the discussion and conclusion part and also offers recommendations for future improvements about this study.

CHAPTER TWO
RELATED WORKS

In recent years, with the development of the concept of the smart city, hospitals have begun to provide benefits from technological improvements in the health care industry (Ömürbek, Demirgubuz, & Tunca, 2013). A study suggests that hospitals should use technology more efficiently and should convert into digital hospitals (Ak, 2013). It is obvious that reducing and balancing the intensity of hospital emergency services in smart cities can only be possible by putting this prediction into practice. However, when modern technologies are not integrated with health services, it can be 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 (Hennema, Blank, Gawlinski, & Henneman, 2006, Anezz, 2005). In 2001, it was determined that approximately 1,200 people had died due to the reasons caused by medication errors 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, errors such as wrong-patient medication or wrong surgery were revealed due to the fact that patient identities were not correctly identified (Blank, Henneman, Maynard, & Benson, 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 another study, it was proposed to improve the structure of the notes and patient forms of the emergency services doctors for the elimination of problems (Redfern, Brown, & Vincent, 2009).

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. It was determined by RFID sensor circuit named İMedPack whether the patient's medication was taken or not. Tracking with RFID has recently become a commonly used method. In one study, the requirements in the

implementation of follow-up in the hospital environment with RFID were discussed. The most important problems for RFID technology are defined as electromagnetic interaction, protection of hospital hygiene, data protection, reliability of application and compatibility for different departments (Lahtela, & Hassinen, 2009). In another study using RFIDs, it was proposed to equip PADC for emergency ambulances with UHF and Near Field Communication (NFC) tags. In this way, both PADC follow-up and patient information are quickly shared (Özcanhan, Dalkılıç, Utku, Alkım, & Akis, 2014).

Considering the recommendations, many examples can be given to marking the objects to be monitored and controlled in health services by electronic labels (tags). East Midlands Ambulance Services in the UK has marked 4000 equipment with tagged electronic labels, has transformed errors and bulky manual access and control operations into error-free and fast automation (RFID Journal, n.d). Automation has also made equipment maintenance more efficient. Since the start of the project, the errors in maintenance dates and the equipment placement in wrong ambulances have been greatly reduced.

Yet another example of paperless automated hospital has been announced in Unite States. This system named as Wireless Information Systems for Healthcare (WISH). WISH is a Wi-Fi and RFID based system designed for health care specifically. The purpose of the WISH is automating the daily routines therefore workload density of the healthcare professionals would be decreased and medication errors during medication administration shall be reduced. WISH is designed to be used as simply as possible. Professionals should login to system just before they start their daily routines. When professionals enter the patients' room, they use a device called as PDA (which has an RFID reader). PDA reads the patient's tag and connects to the electronic patient records therefore professionals could be access necessary information about patient simply and effectively (Yu, Ray, & Motoc, 2006). There are other studies about health care and RFID. Those studies show using RFID technology is effective. Using such a technology is not only eliminates paper usage but also prevents errors, patient waiting time, improves the patient safety and so on (Chowdhury, & Khosla, 2007).

An example of centralization of the data is the study of data stocks in blood banks (Sakarya, Utku, Birant, & Kut, 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 type in urgent situations by referring to the central database instead of separate blood banks.

CHAPTER THREE
TECHNOLOGIES USED IN APPLICATIONS

3.1 C#

C# is the next generation programming language developed by Microsoft. It is derived from the two most commonly used software languages in the software industry, C and C++. The most important feature of C# is that it is a completely object-oriented software language prepared for the .Net Framework platform. C# has a great importance in terms of flexibility and usability. Applications developed in C# can be used on desktop, web, mobile platforms, even on IoT (Internet of Things) systems.

In a short time, C# has become one of the most advanced programming languages in object-oriented languages.

C# was used for developing mobile application, web services, desktop application and web application in the project as primary language.

3.2 IDE: Microsoft Visual Studio

Visual Studio is an integrated software development environment that is designed by Microsoft to develop and publish software. Software can be developed with Visual Studio. You can edit and compile the codes you have written, and easily convert them into applications. It is a program that facilitates the software development process thanks to its many features (code completion, debugging, compilers, graphic designers, database connections, etc.). Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silverlight. Visual Studio includes a code editor supporting IntelliSense. Supported languages include C#, VB.NET, C, C++, TypeScript, HTML, XML and C++ / CLI (Visual Studio, n.d.).

Project's web services methods are developed with Microsoft Visual Studio 2012 shown in Figure 3.1.

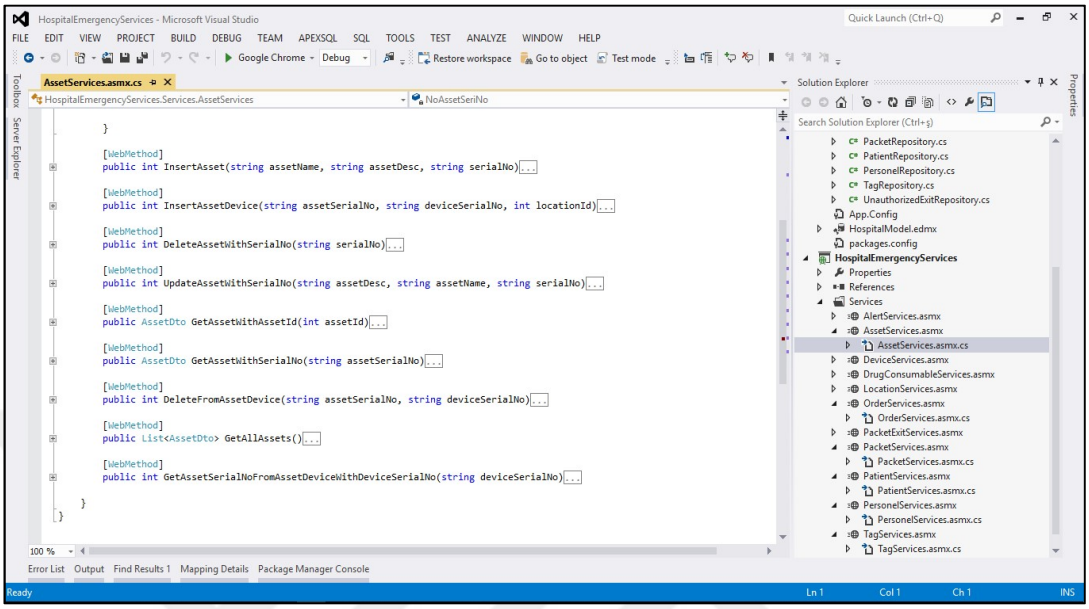

Figure 3.1 Web Service solution on Microsoft Visual Studio Professional 2012

3.3 Web Services

Web Service is part of the program that serves with HTTP protocol over the web. Web services provide data exchange between remote systems or different platforms using a common format such as XML and JSON. A user can use a web service over HTTP. This is called RPC (Remote Procedure Call) (Web Service, n.d.).

There are basically 2 kinds of Web Service. These are Restful and SOAP Web Services. The most important difference between Restful and SOAP Web Service is that you can send and receive any type of output you want, such as XML, JSON, text, HTML with Restful Service; you can only process xml data in the SOAP Web Service concept. The advantage of this structure is to provide access from the desired location regardless of the platform. Thus, programing the language of the program you want to use the Web service is not very important.

3.4 Database

Database is simple software that stores information. A lot of software can store information, but the difference is that the database can manage and manipulate this information efficiently and quickly. The database also has components. Tables, queries and forms are database's components. The data is stored in the tables. It can be a single table or multiple tables. The rows and columns have different functions. Each column contains an information class. In rows, information about the columns is stored. The storage of information by categorizing saves from clutter. The data in the tables are selected as a result of the query and presented in a specific order. A system is also required to interrogate, recall, and find the classified information. SQL is used to query and select the information in the database. SQL stands for Structured Query Language, which is recognized as the standard programming language of database management systems. (Database, n.d).

The most used database programs are Microsoft SQL Server and Oracle.

3.5 Microsoft SQL Server

SQL Server is a relational database management system developed by Microsoft. With this program on personal computers or servers, databases can be created and data can be queried.

In the relational database system, data is kept in tables and these tables can be interrelated in relational terms. With the help of switches, different tables can be associated with each other. Thus, big data is divided into pieces. Using SQL Server, the data can be managed as desired, and multiple results can be returned using stored procedures. In this way, reports of the requested data can be obtained. Relational database systems are generally used in enterprise applications, web applications and desktop applications. (SQL Server, n.d.).

Structured Query Language (SQL) is a programming language used to query information in databases. SQL basically works at a logical level with data. So, in

order to be able to select several records from a table, a condition is chosen to select those records. All records that match the runtime come in one step which can be displayed to the user or sent to another SQL or application. SQL deals with how records come individually, where the database is physically located and how it is stored. (Figure 3.2)

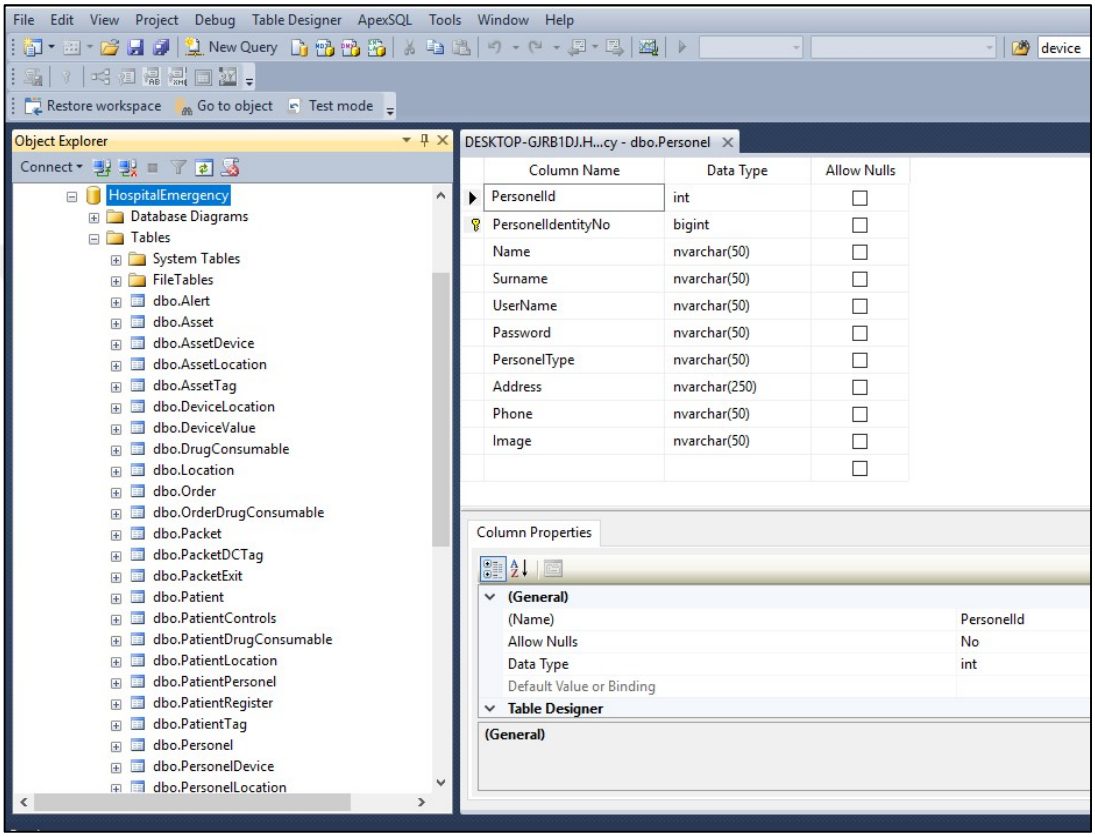

Figure 3.2 Database tables on Microsoft SQL Server 2012

3.6 AngularJS

AngularJS is a JavaScript framework developed by Google. AngularJS provides powerful, dynamic, interactive interfaces using the MVC structure. AngularJS has many different structures such as Data Binding, Routing, and Templates. The aim is to minimize code blocks in the interface and to create a more stable structure. Thus, the development processes become easier. AngularJS that performing many operations on the client, has provided extremely effective benefits in the runtime performance of projects. At the same time this situation, since it doesn't reload in the process of the page, it gives a dynamic appearance and ergonomics. AngularJS allows HTML to be used as template language and allows extending HTML syntax to explicitly express the components of the application.

It does not need libraries like jQuery to work with AngularJS. AngularJS allows developing single page applications. The most important difference from other similar libraries is that it supports two way binding (AngularJS, n.d.).

In this project, management application was developed by using angular framework.

3.7 RFID

Radio Frequency Identification (RFID) technology is used to detect and monitor all kinds of living and non-living objects at a certain distance without touching them. RFID technologies are becoming increasingly widespread in the world and in our country and are used in many sectors. This technology is active and widely used in a wide range of applications in many sectors such as automotive, fuel, logistics, agriculture, healthcare, pharmaceutical, textile, finance, banking, energy, public, production, security, tourism. (RFID, n.d.).

The RFID tag is placed directly on or into objects (product, package, vehicle, asset, people, animal, etc.) to be recognized. The communication required to read the information stored in the chip in the tag is provided by radio frequency (RF) signals

through the antenna included in the tag and reader. The RFID tag is detected by the reader when it enters the reading area and sends the information stored in the chip along with its own code via the antenna to the reader wirelessly and without contact. (Figure 3.3)

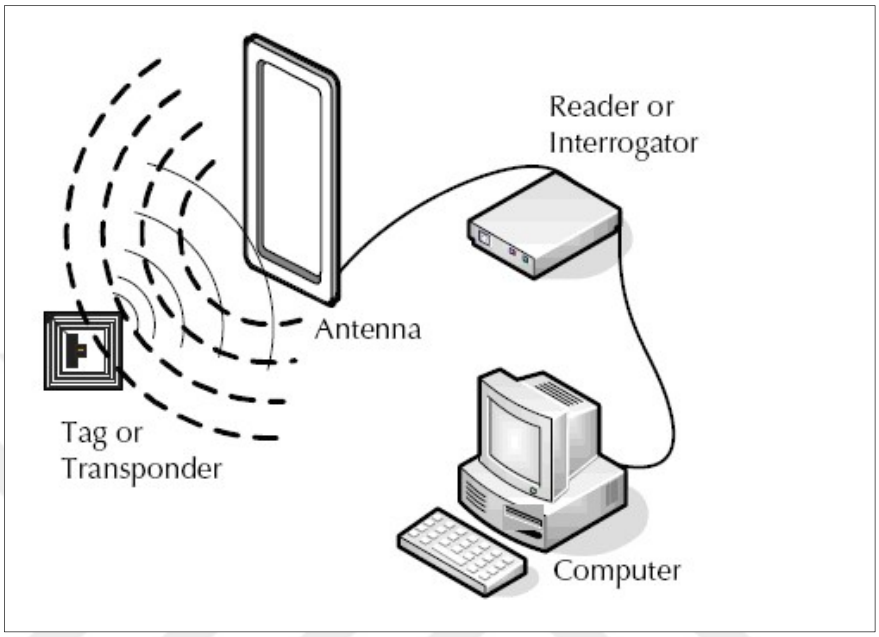

Figure 3.3 Simple RFID architecture

3.8 NFC

Near Field Communication (NFC); is a short-range, wireless, personal communication field technology designed to interact with customer electronics, mobile devices and computers. NFC works by using magnetic field induction and has reader function with tag. Two-way communication can be achieved by touching or bring to close range the devices using this technology. NFC is a wireless communication technology that works poorly than low-bandwidth technologies such as Bluetooth and Wi-Fi and can be used with very short distances (in the range of about 4 cm). NFC establishes the connection faster than Bluetooth 3.0. The connection between the two NFC devices occurs in less than a tenth of a second.

NFC technology was developed by the Sony and Philips brands at the end of 2002 and it was accepted as a wireless communication standard at the end of 2003. (NFC, n.d.).

3.9 iBeacon

iBeacon is a device to determine where mobile users are in the closed spaces. It is a technology that developed by Apple on Bluetooth Low Energy (BLE) technology. iBeacons are the sensors that provide effective communication with the physical environment by triggering some applications in mobile devices with the data packet it sends. One of the most important information to know about IBeacon is that this technology basically provides one way communication. The most important advantage of these devices is their low energy consumption and low costs.

The BLE protocol comes ready without the need for special installation in the devices that has supporting operating systems. They are systems that easily adaptable for all software developers. (iBeacons, n.d.).

CHAPTER FOUR
PROPOSED EMERGENCY SERVICE PATIENT TRACKING SYSTEM

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

1. Modern, automatic PADC scan with truly independent of human interpretation - instantaneous tracking with data acquisition (OTVT)
2. Offering collected PADC location data to mobile devices at anytime, anywhere
3. Automatic registration of cost accounting automatically by associating patient and PADC 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 PADC, use of the current information tools to examine in detail
6. Obtaining statistics on emergency computer service continuity and quality assurance with fast processing computers.

4.1 Emergency Hardware

The hardware units of the designed system and its connections have been composed of the parts listed in Figure 4.1.

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, n.d.),
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.

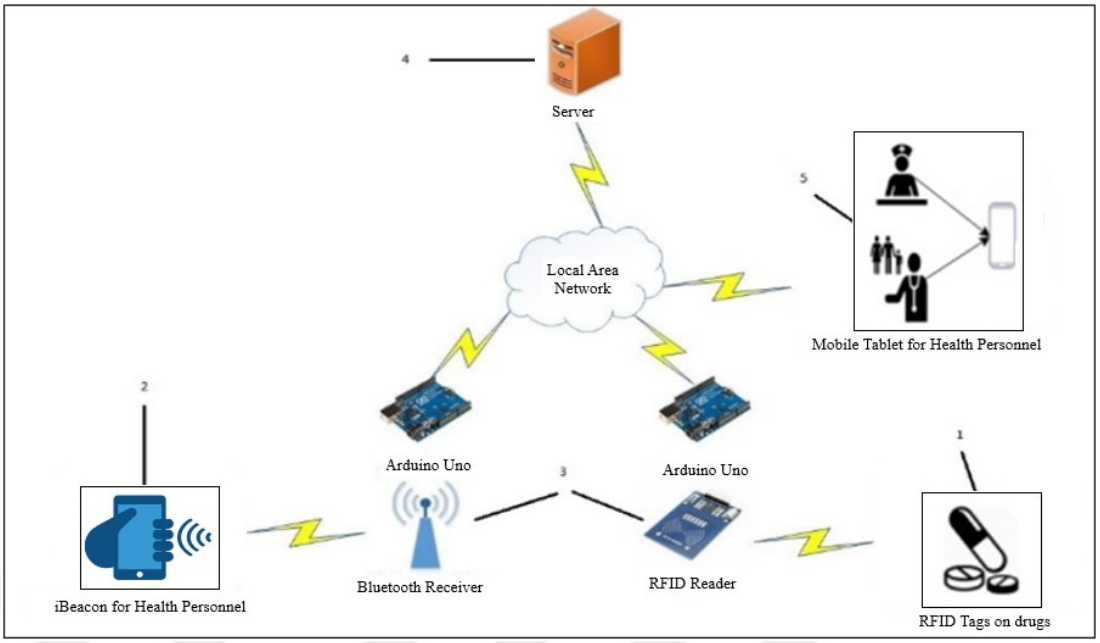

Figure 4.1 Hardware and communication structure for emergency situations

UHF labels are affixed to determine the location of the drug and fixtures (Özcanhan, Dalkılıç, Utku, Alkım, & Akis, 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 the read data is transferred to the server via the local network while the Ethernet module is installed on the same Arduino. 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 gathered information is sent to the server via the Ethernet module.

As shown in Figure 4.1, the data from the readers is collected in a database on a server. Collected and processed data is presented to health care providers, patients, relatives and authorized administrators via mobile devices as a warning, report or information by wireless communication technology according to sharing and authorization rules.

4.2 Emergency Service Tracking Software

In the structure shown in Figure 4.1, it appears that all the data are stored in a single server. In Figure 4.3, 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. 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.

4.2.1 Database

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. Separate database tables are created for each unit. Relationships are represented with relation tables. Each row have their own unique value for parse and the intended row lines can be easily reached (Figure 4.2).

Personnel, Asset, DrugConsumable and Patient are basic database tables which the data includes for tracking. Location table contains information about the rooms and locations in the emergency and the table where RFID device information is kept for each location is ReaderDevice table. After read operation, incoming data can be written to DeviceValue table. Relationships between tables are established with Primary Key value in tables. For example, when the reader at a particular location reads a tag, tag owner can be determined with tag id value and the tag owner's location at that time can be reached.

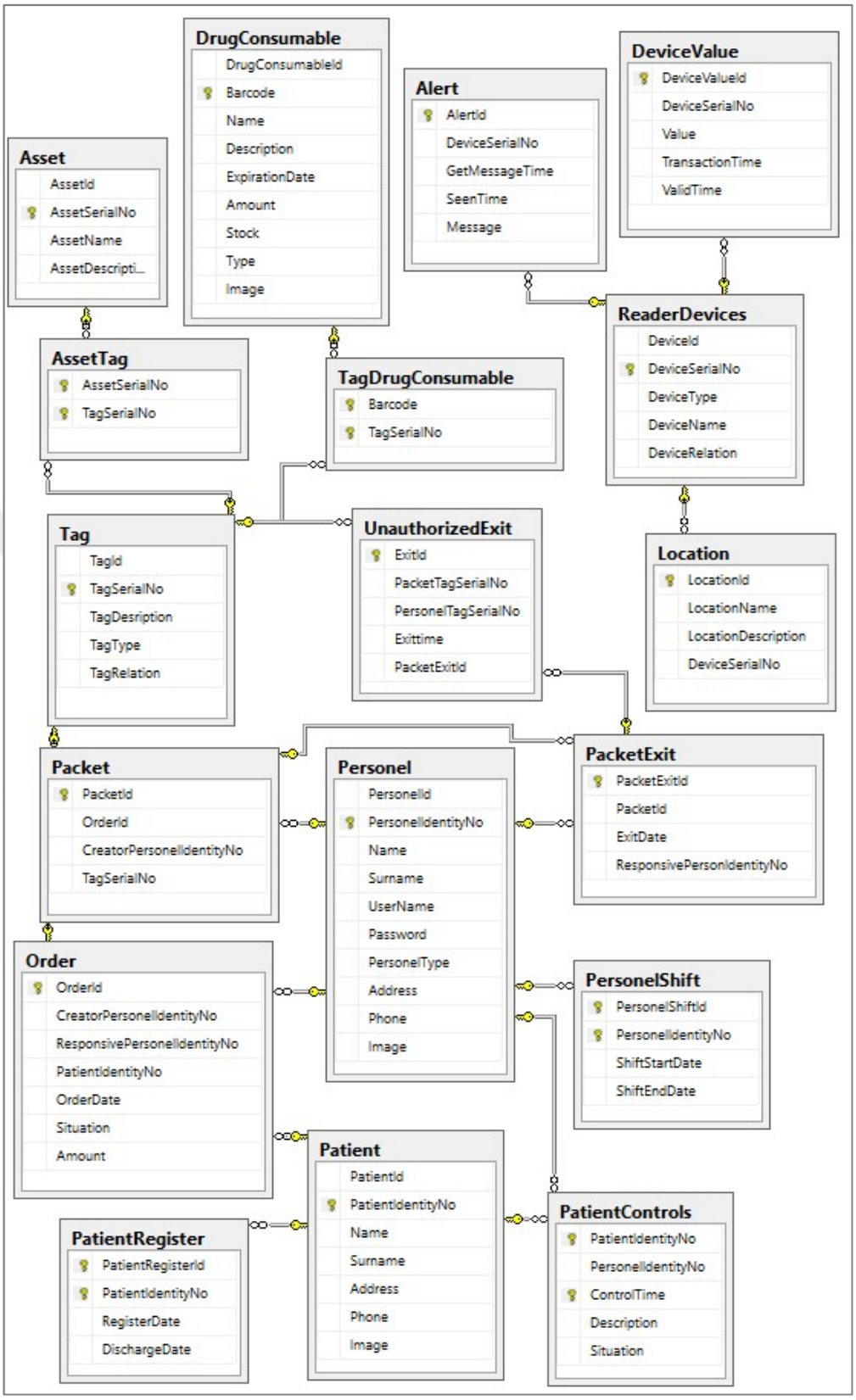

Figure 4.2 Part of database diagram

4.2.2 Server

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.

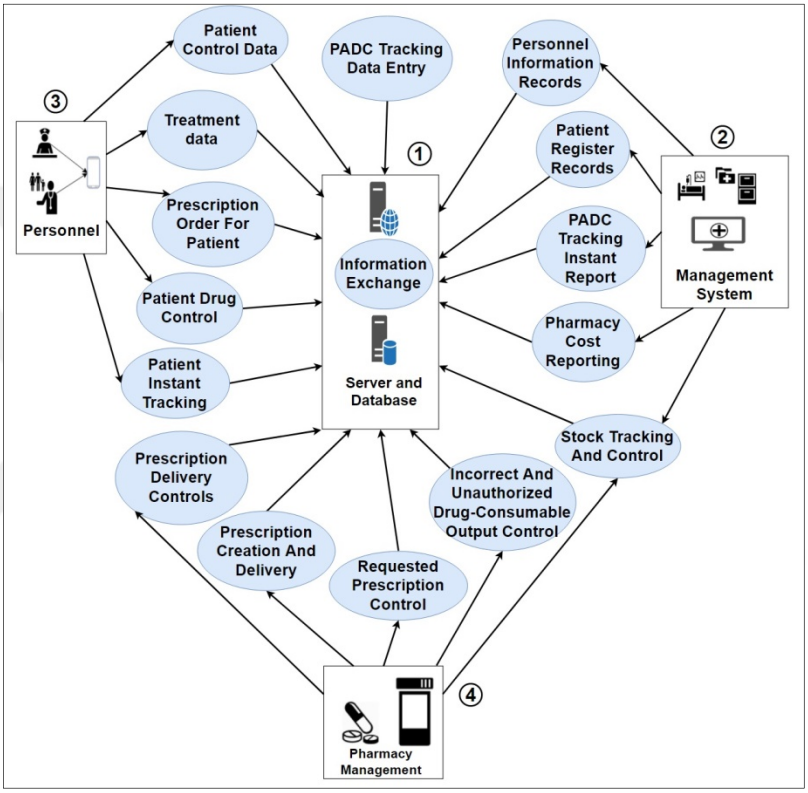

Figure 4.3 Emergency service tracking software scheme

Service operations are divided into parts to be used more easily. For example, PatientService service methods include patient operations and Locationservice service methods include location operations. Patient and Location service methods are shown in Figure 4.4 and Figure 4.5.

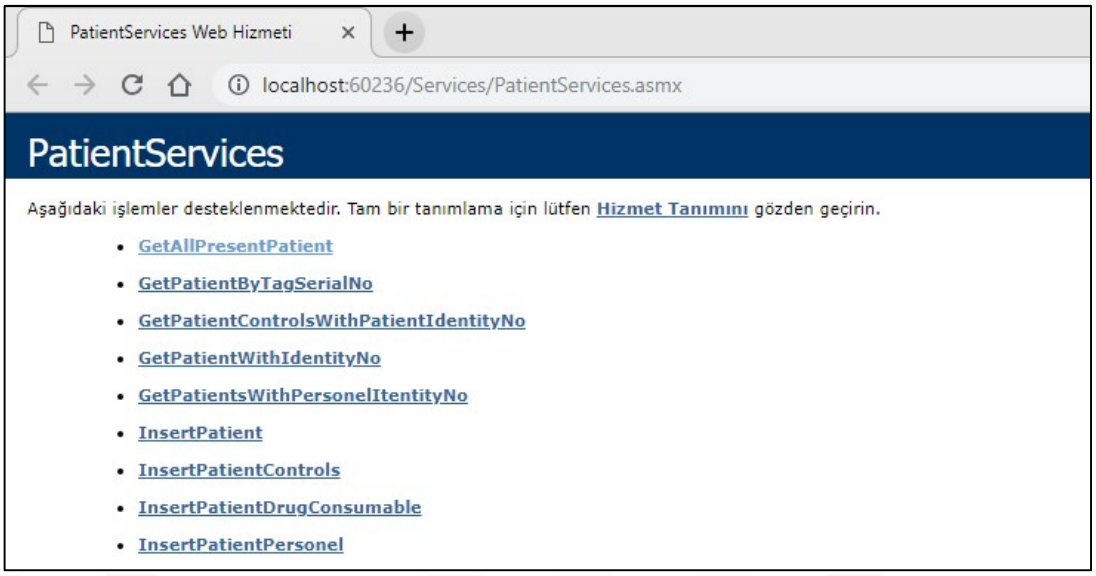

Figure 4.4 PatientServices.asmx service methods

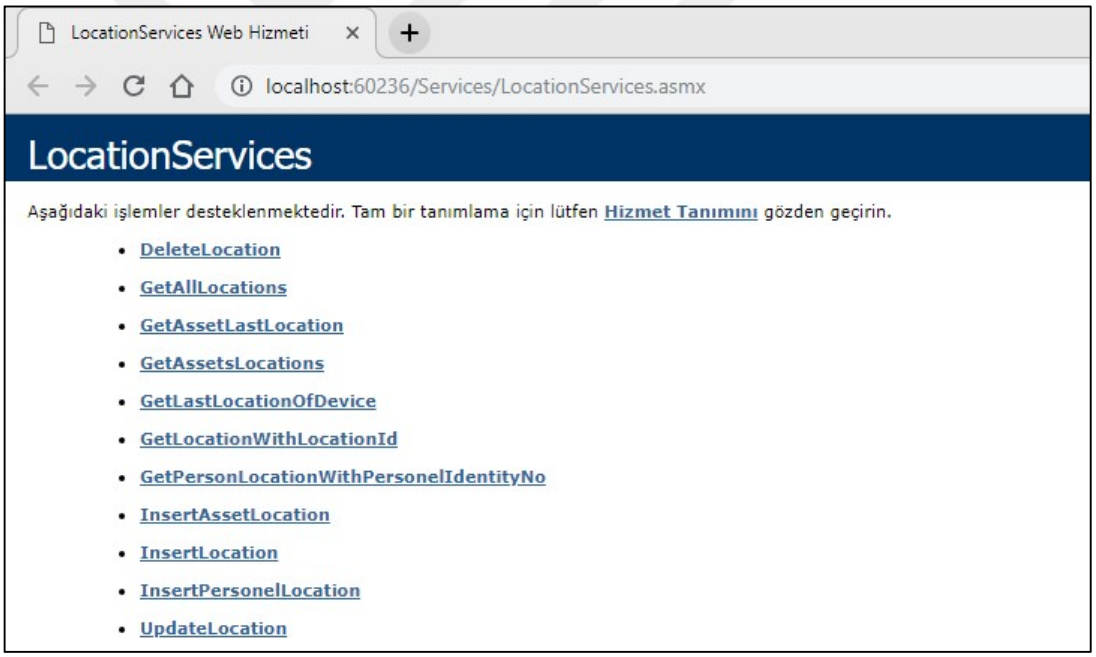

Figure 4.5 LocationServices.asmx service methods

4.2.3 Management Platform

The second item is the Management Platform. This platform involves hospital system registry as well as the reporting operations. 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 also carried out through this system. With the instant reporting system, all the data needed at the moment can be accessible. PADC's instant location and hospital border violations are controlled through this platform.

There are different operations that users can do

a. User Login
    I. Doctor
    II. Nurse
    III. Information Desk
    IV. Registration Desk
    V. Pharmacist
b. Hospital Asset Information Entrance
c. Hospital Drug and Consumable Information Entrance
d. Hospital Room Location Information Entrance
e. Patient Registration
f. Pharmacy Stock and Record Controls
g. Staff Information Entrance
h. Patient Report Controls
i. PADC Tracking

The right menu in the application shows properties the user can choose. In Figure 4.6, Personnel page shows the personnel information within the hospital as new personnel registration entries and working hours can be made from this screen. In Figure 4.7 shown, user can filter list by identity number or personnel name.

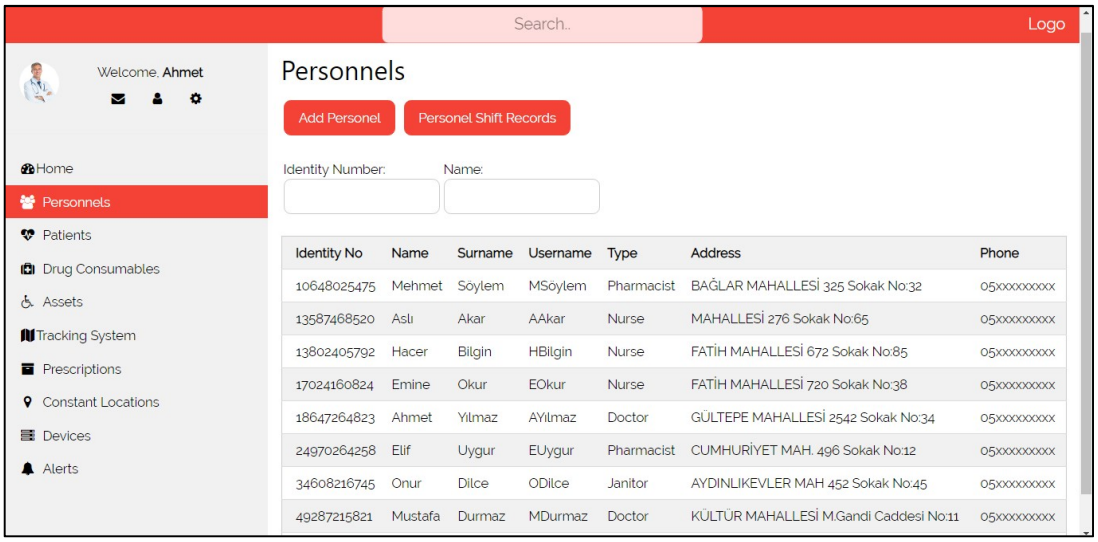

Figure 4.6 Management platform personnel page

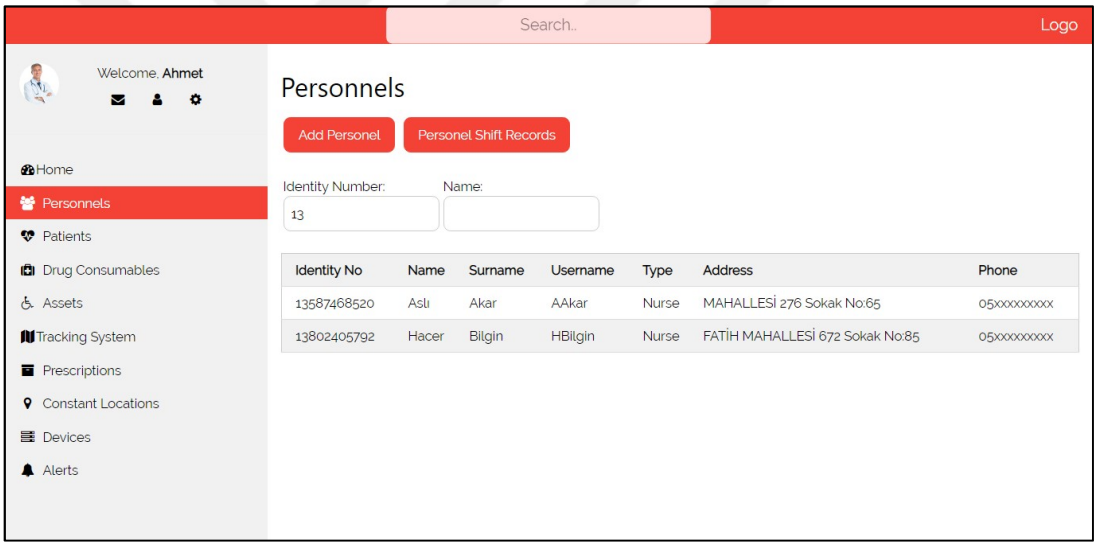

Figure 4.7 Management platform personnel page filtering by identity number

Patient page can list the patients at that moment in the hospital. (Figure 4.8) When a patient record is selected, Patient Detail page will open. Figure 4.9 shows Patient Detail page with patient information and drugs used by patient.

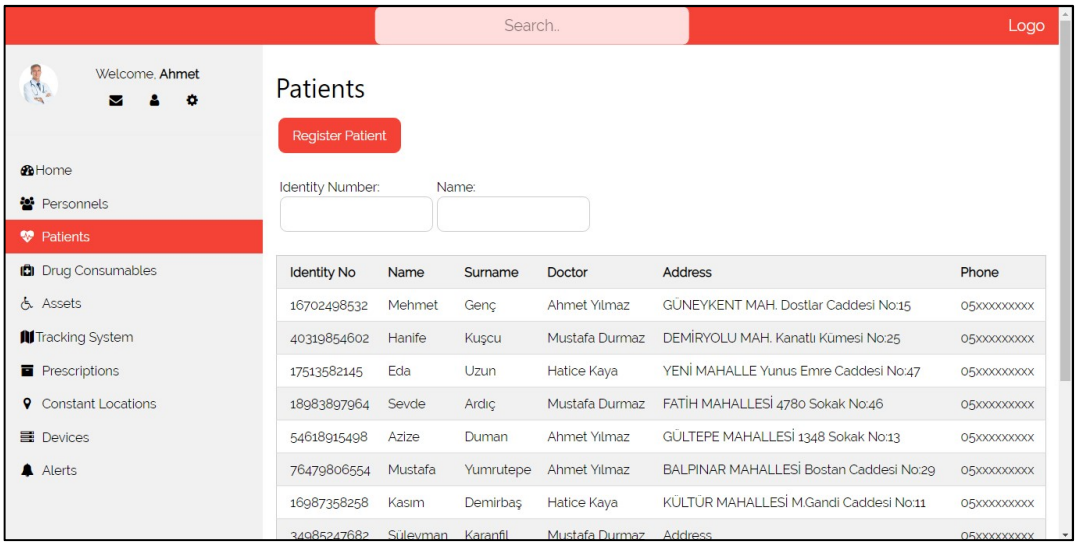

Figure 4.8 Management platform patients page

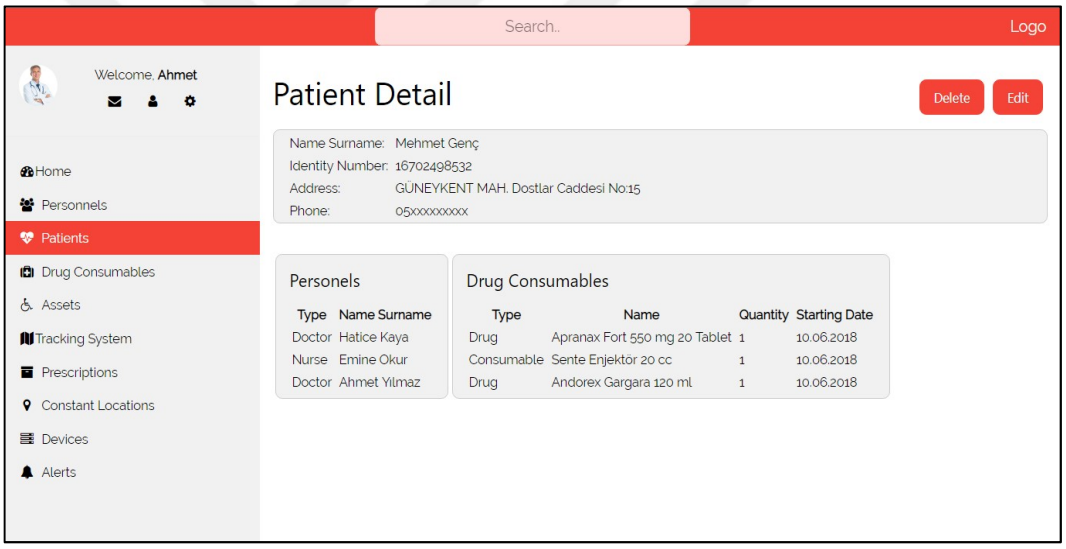

Figure 4.9 Management platform patient details page

Information on where the staff and patients are located can be tracked from the Tracking System page. Figure 4.10 shows Tracking System page that user can filter list by an identity number or name.

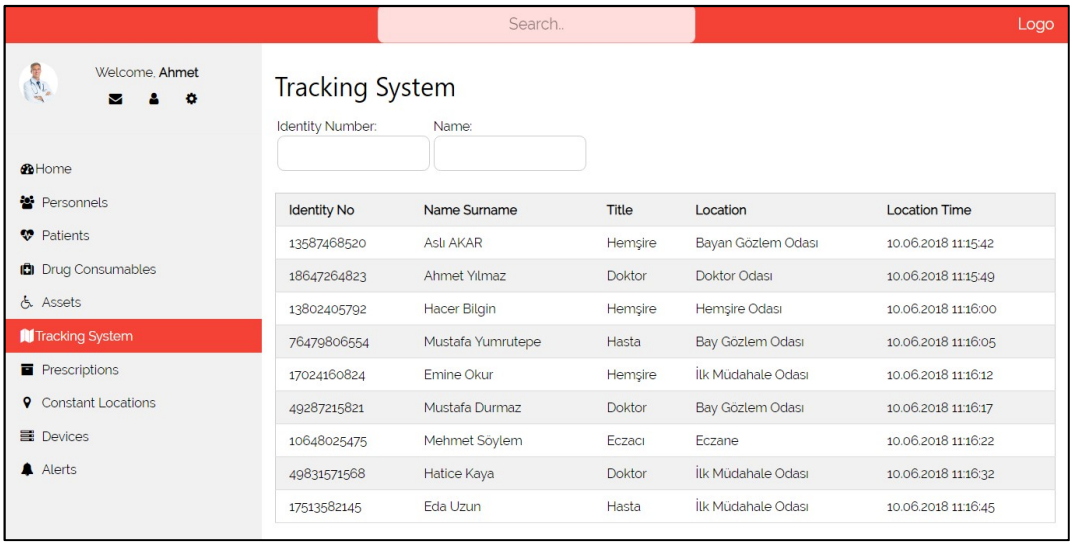

Figure 4.10 Management platform tracking system page

Figure 4.11 shows Asset page that includes registered asset information in the hospital. In Figure 4.12, Devices page is shown that RFID devices can be tracked. Figure 4.13 shows Constant Location page that includes rooms in the hospital to define location.

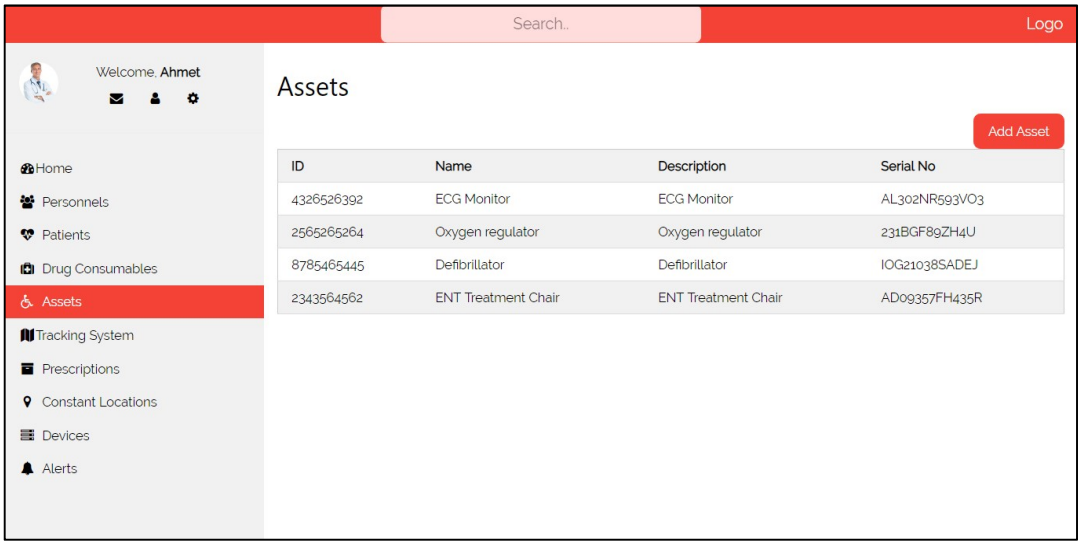

Figure 4.11 Management platform assets page

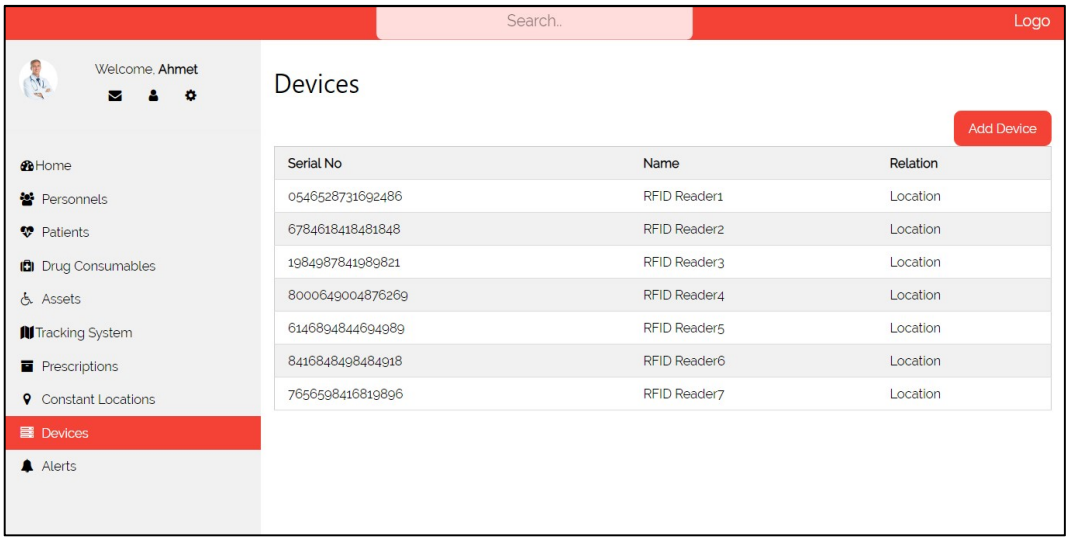

Figure 4.12 Management platform devices page

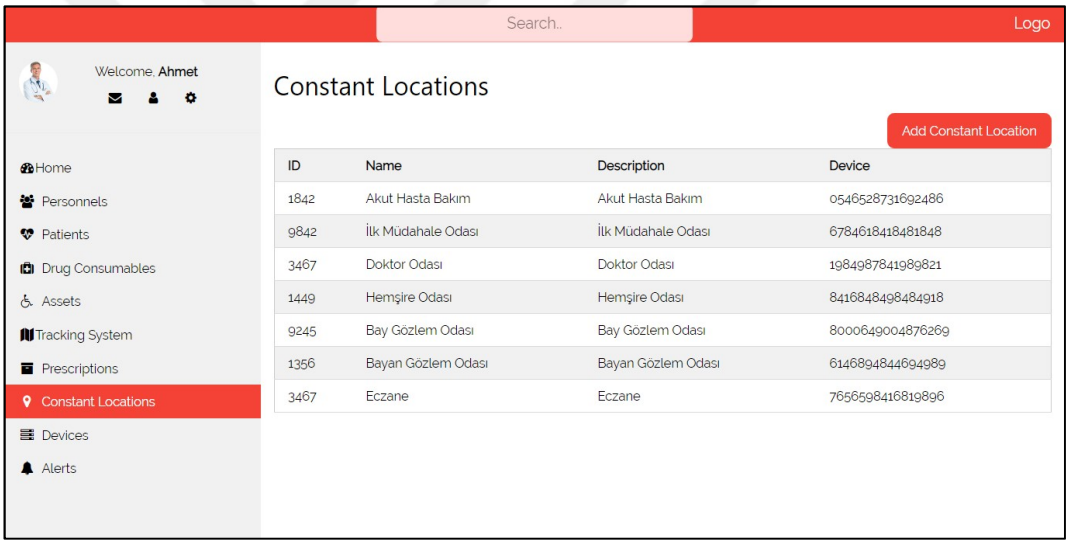

Figure 4.13 Management platform constant locations page

In Figure 4.14, Drug and Consumable page is shown that the drugs and consumables registered in the hospital pharmacy can be tracked. Prescriptions page where doctors prescribe prescriptions for patients is shown in Figure 4.15. In this screen, if the user chooses a prescription, the contents of the prescription given to the patient can be monitored. (Figure 4.16) When the user clicks the Packet Exit button on the Prescription page, Packet exit page will open and list packets that taken from pharmacy. In Figure 4.17, Packet Exit page is shown with listed packets and selected packet's information. Figure 4.18 shows Unauthorized Exit page that can be opened

Unautorized Exit button in the Prescription page. User can monitorize packets that are incorrect outgoing from pharmacy. In Figure 4.19, Alerts page is shown that list warnings for incorrect packet can be seen.

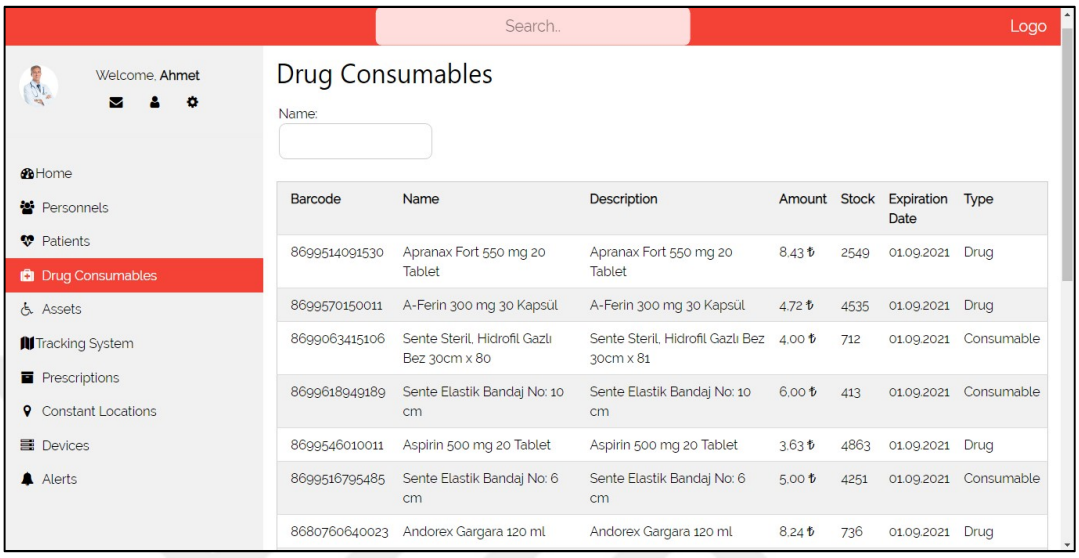

Figure 4.14 Management platform drug and consumables page

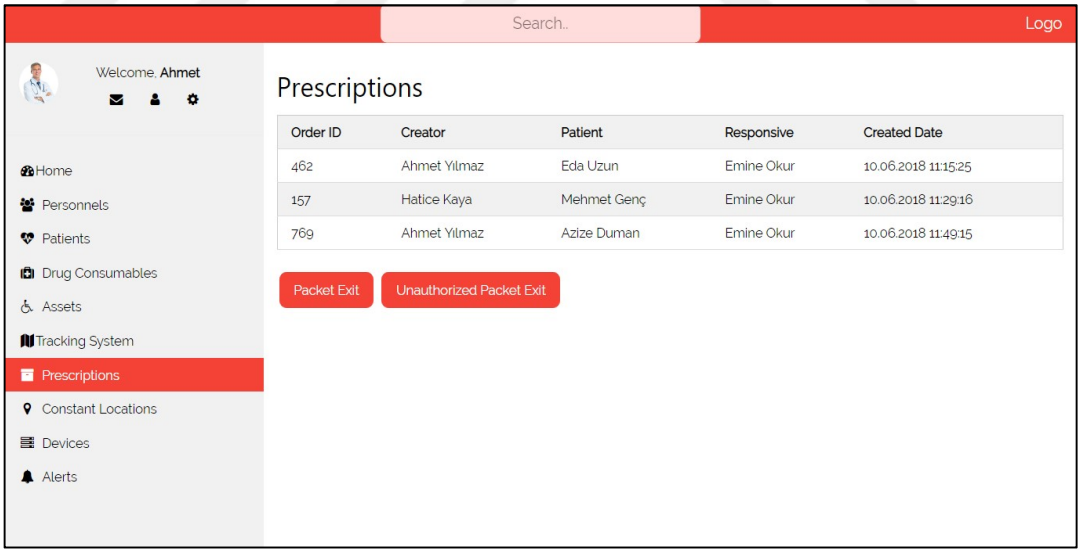

Figure 4.15 Management platform prescription page

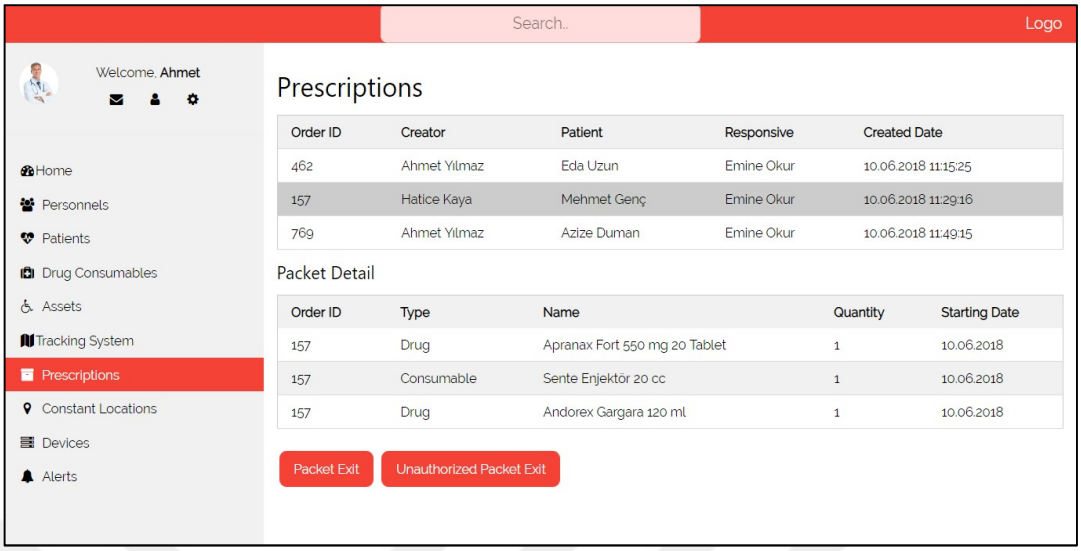

Figure 4.16 Management platform prescription page prescription details

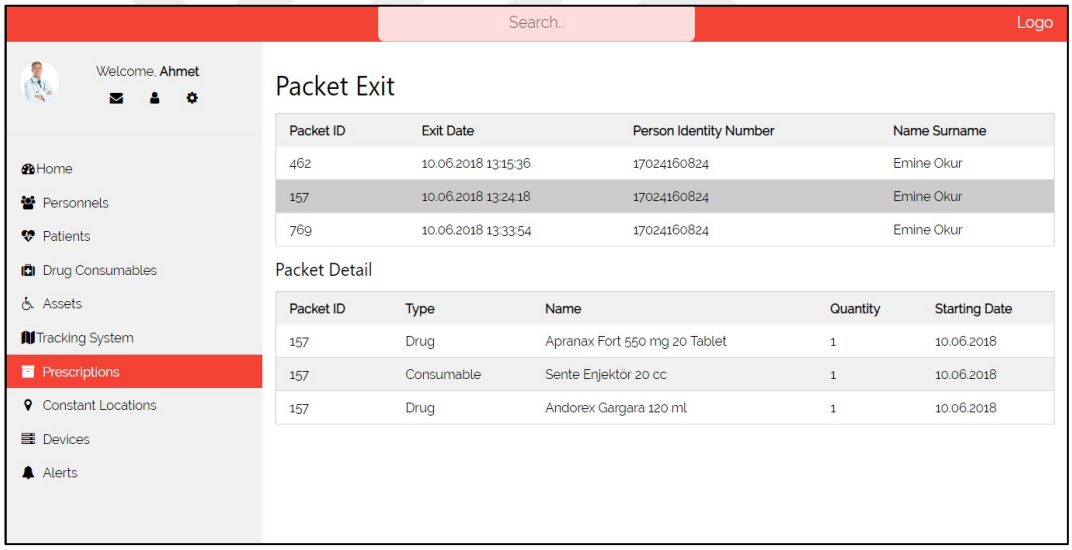

Figure 4.17 Management platform packet exit page packet details

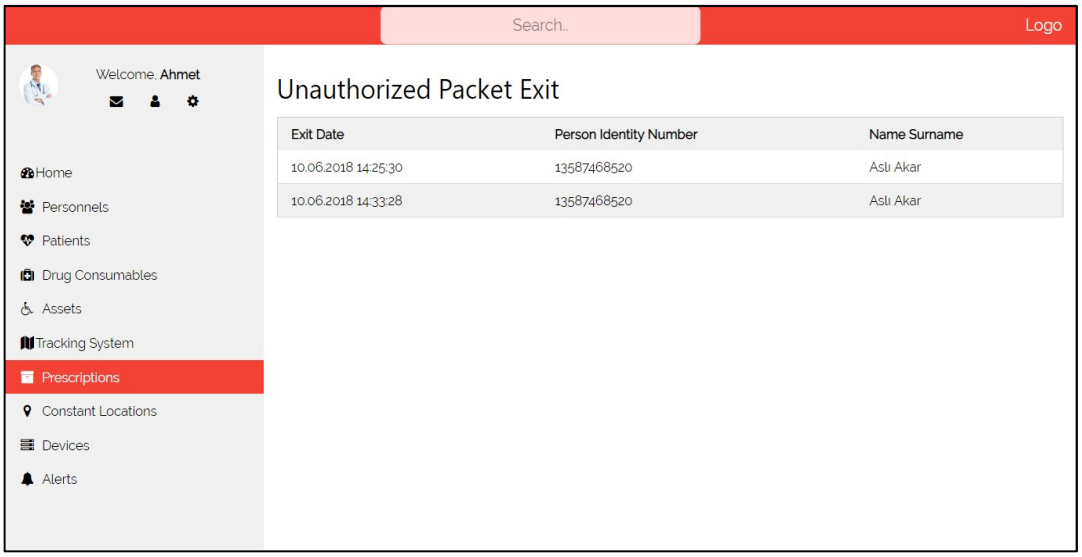

Figure 4.18 Management platform unauthorized packet exit page

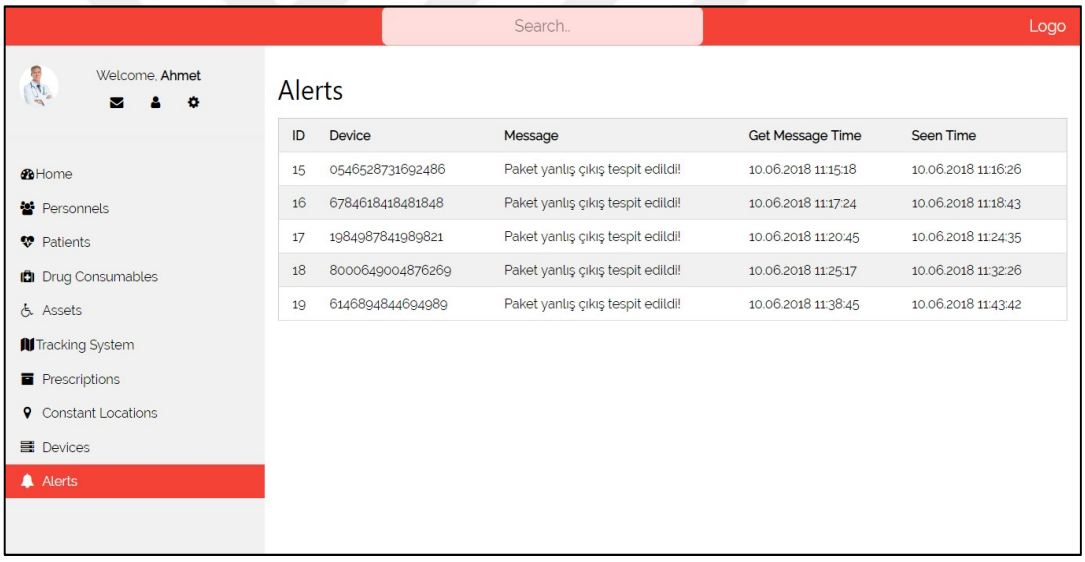

Figure 4.19 Management platform alerts page

4.2.4 Mobile Application for Personnel

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 it is needed. In addition, doctors provide drug registrations from the emergency department pharmacy by entering 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. The workload and human factor of all personnel are significantly reduced with this automation system.

In Figure 4.20, Patient List page is shown. This page shows the list of patients treated by the doctor with this application. Figure 4.21 shows that doctor can select patient to see patient detail. When doctor clicks “Add Prescription” button, Prescription page is opened. In this page, doctor creates a prescription for selected patient. In Figure 4.22, Prescription page with drug and consumables list that can be selected is shown. Each selected drug and consumables listed in Cart page are shown in Figure 4.23. When Save button is clicked, items in cart are saved for patient prescription he/she is treated by.

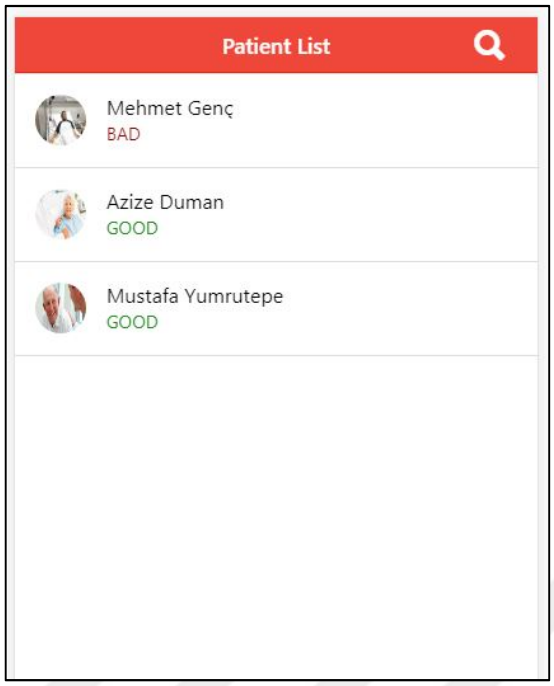

Figure 4.20 Mobile application patients list page

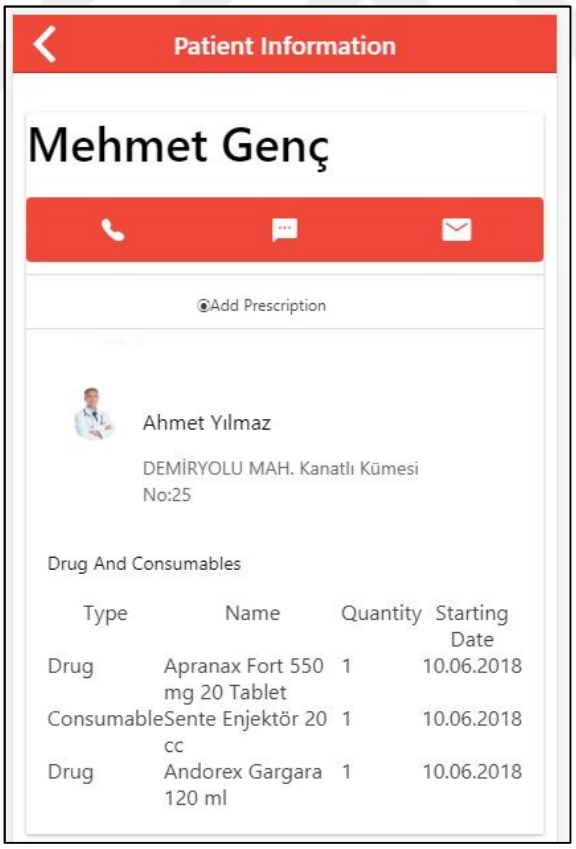

Figure 4.21 Mobile application patient detail page

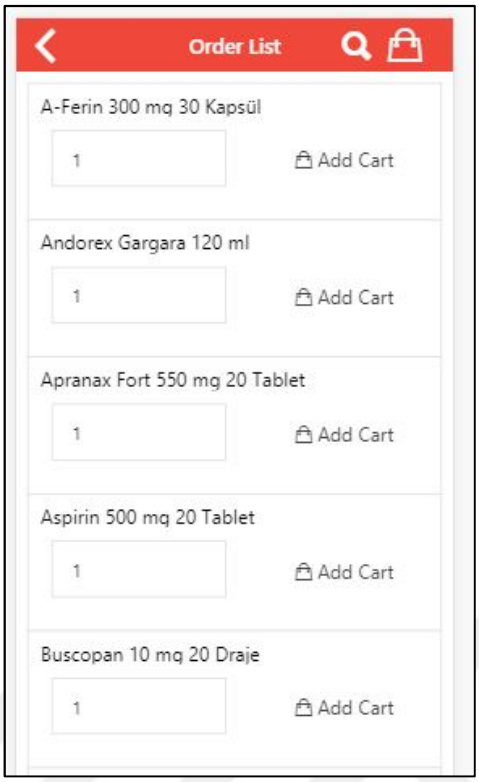

Figure 4.22 Mobile application prescription page

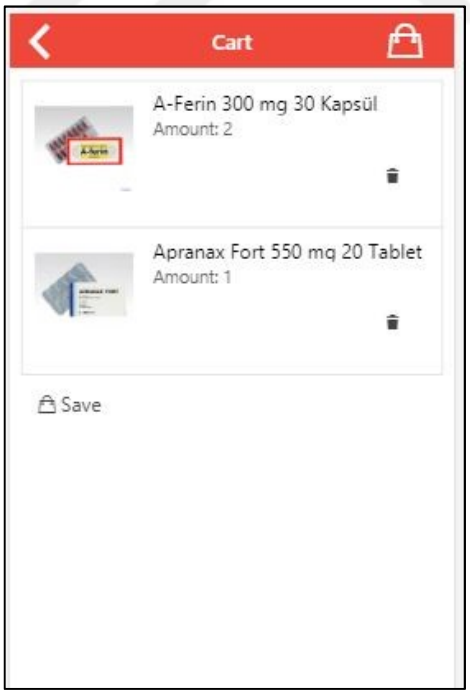

Figure 4.23 Mobile application chart list page

4.2.5 Pharmacy Application

Drug management in the emergency department pharmacy is an important 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 package and all the objects in the package are attached with the UHF label and then the RFID reader is ready to be 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 identity of the receiver who takes over the package is determined by reading the personal NFC card. All pharmacies and packs departing from the pharmacy are checked by the reader located at the exit of the pharmacy. In case of unauthorized or uncontrolled drug delivery at the exit, a warning system is activated to inform the operator. Outputs are instantaneously reported with queries to be made to the database. Along with this, there is a warning and a reminder about the drugs and materials that are decreasing, depleting, or reaching expiration date in the pharmacy. Medical devices are followed in the same way. The requests generated in Figure 4.24 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.

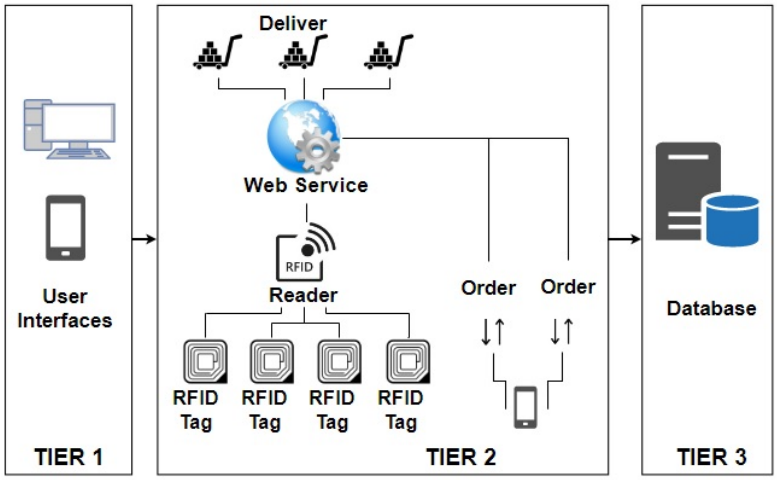

Figure 4.24 Pharmacy management application architecture

In Figure 4.25, Home screen contains four main operations. If prescription button is clicked, system shows new and old orders come from the doctor.

Delivers button directs to delivers page. In this page, pharmacist can see delivered orders. If materials button is clicked, pharmacist can observe all materials with their properties. System creates an alarm if there is a material which expire date is close or is in critical stock level. Also, if there is a wrong outgoing order from the pharmacy, system creates an alarm too. Pharmacist can see them in Alerts. Pharmacist should log in the system to access all these operations.

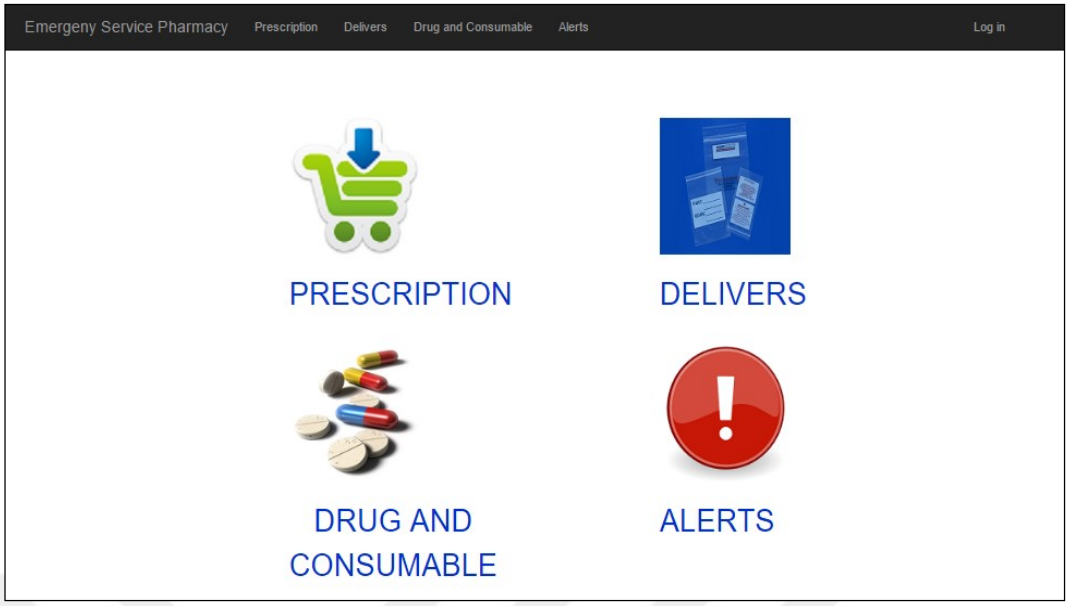

Figure 4.25 Pharmacy management home screen

In Figure 4.26, pharmacist can see orders and information that are coming from the personnel. New incoming orders are shown at the top of list.

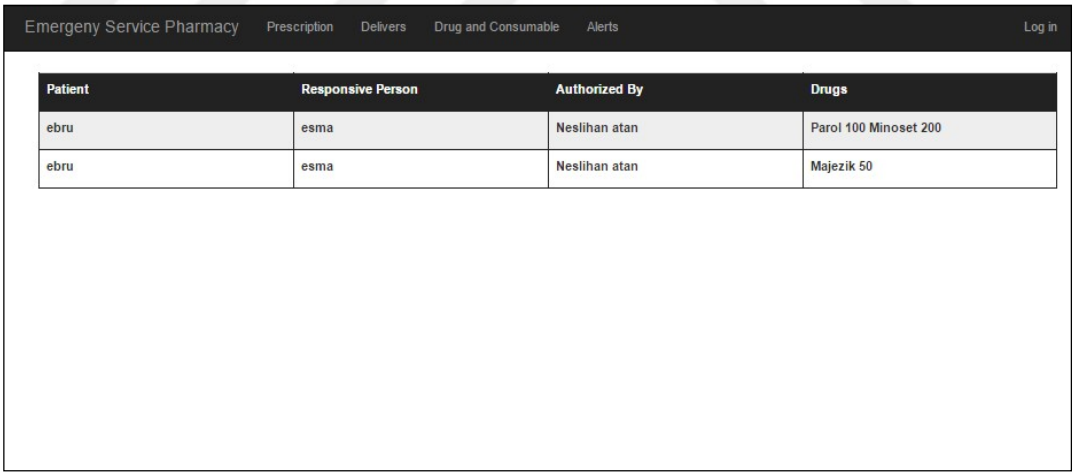

Figure 4.26 Pharmacy management prescription page

In Figure 4.27, pharmacist can see delivers information like patient, responsive person who is supposed to take the prescription, an authorized person who gave the prescription. Also, it shows drugs that are in prescription list.

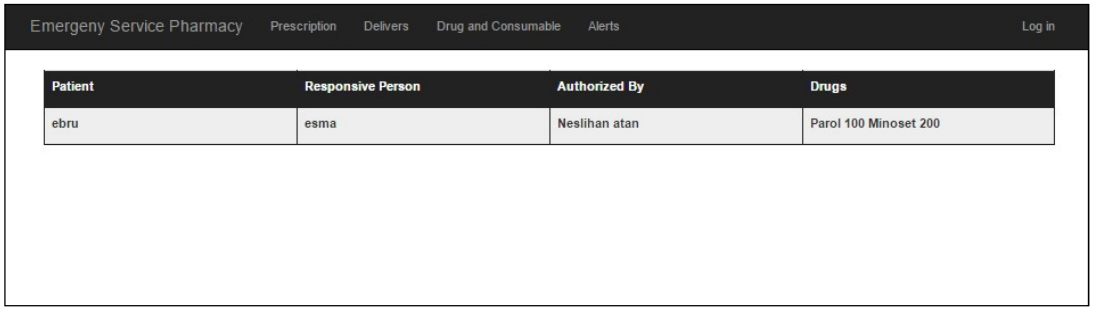

Figure 4.27 Pharmacy management delivers page

Drug and consumable page is shown in Figure 4.28. In drug and consumable page, pharmacist can see all materials include drug and consumables. There are two opening and closing fields. So, pharmacist can see drugs and consumables as a list in this page. Pharmacist can also track stocks.

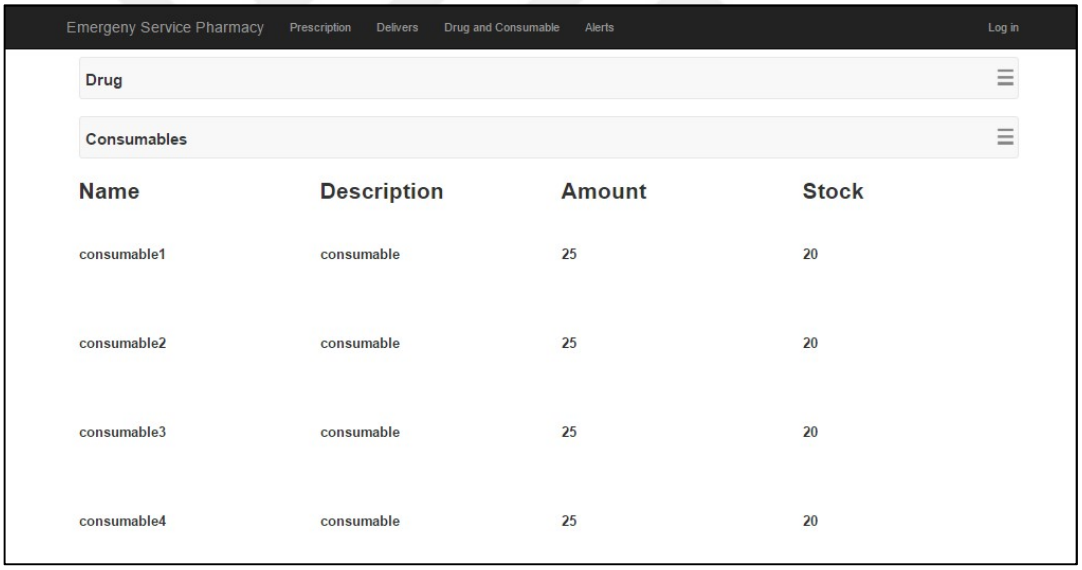

Figure 4.28 Pharmacy management drug and consumable page

There is a form application to create order and packet functions. Figure 4.29 shows a create order tab and Figure 4.30 shows create packet functions. In Figure 4.31, the outgoing packet can be checked. In Figure 4.32, pharmacist can monitor unauthorized exits and drugs that are close to expiry date or critical stock level of drugs. There is a list of all pending prescriptions in Figure 4.33. Pharmacist can monitor completed prescriptions and details of them in Figure 4.34.

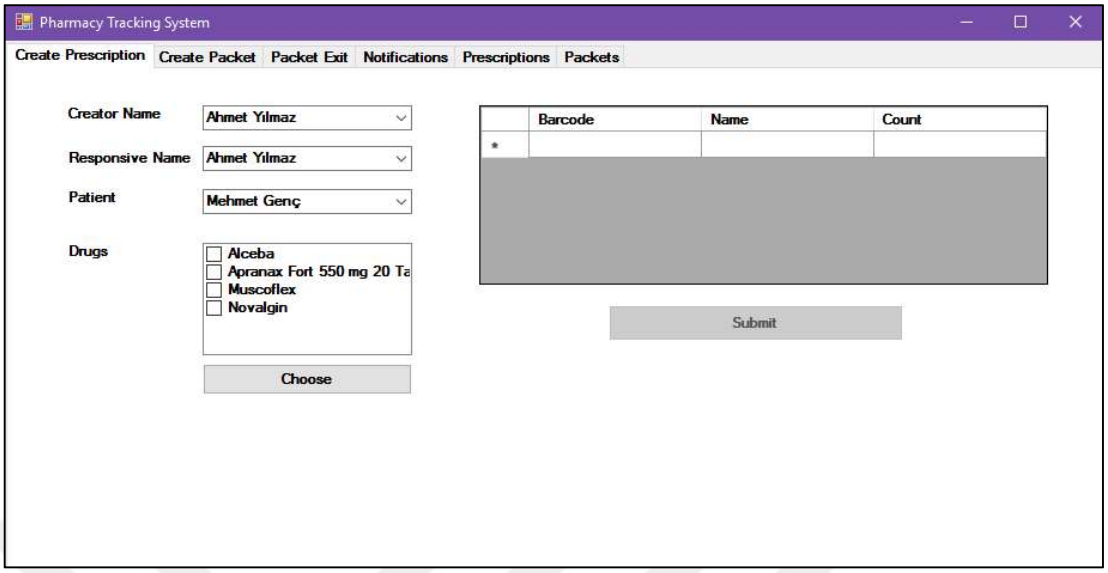

Figure 4.29 Create order tab

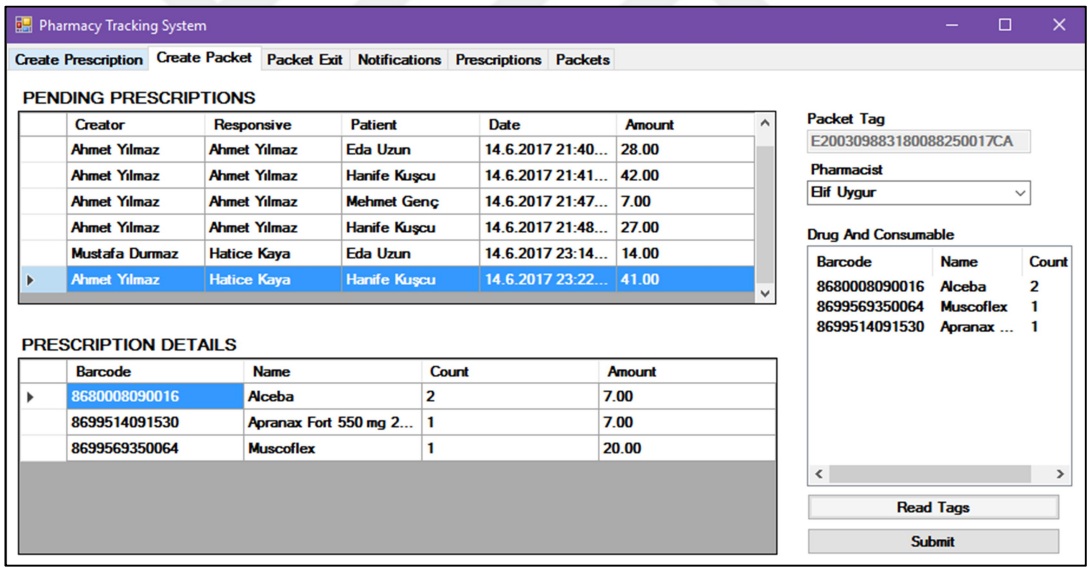

Figure 4.30 Create packet tab

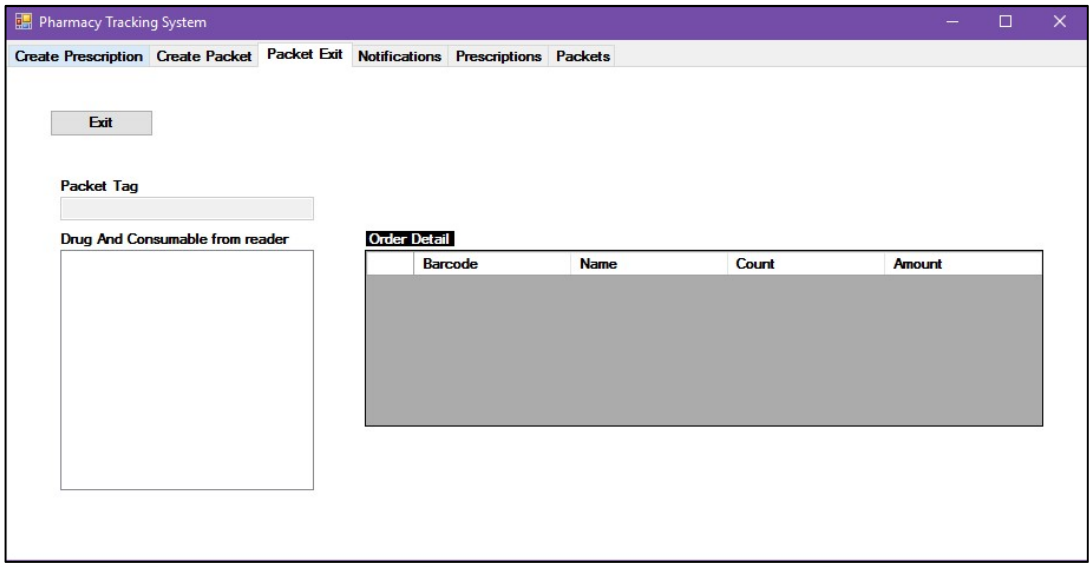

Figure 4.31 Packet exit tab

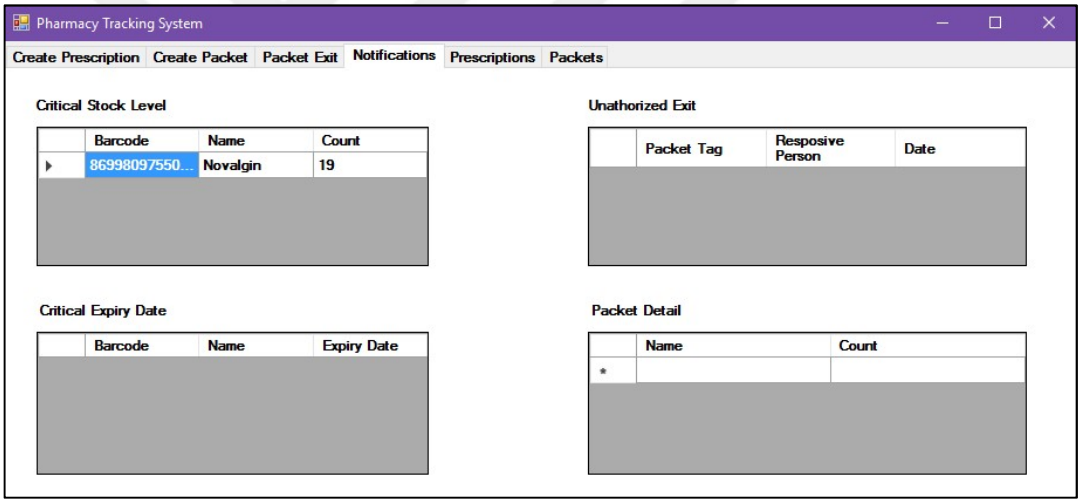

Figure 4.32 Notifications tab

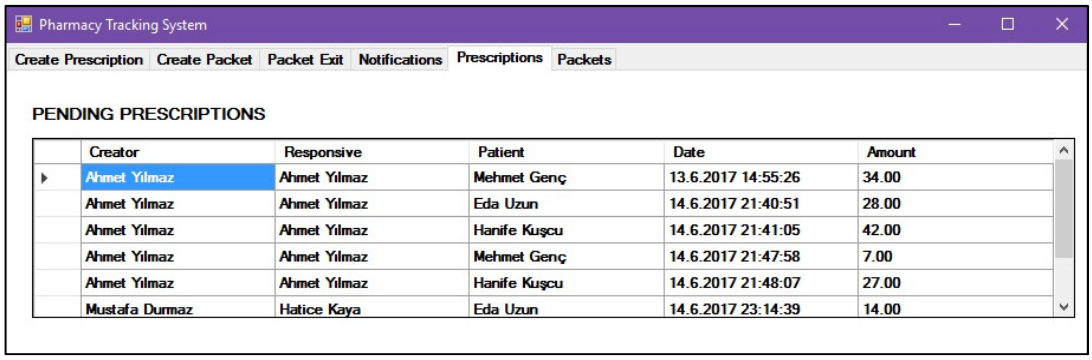

Figure 4.33 Prescriptions tab

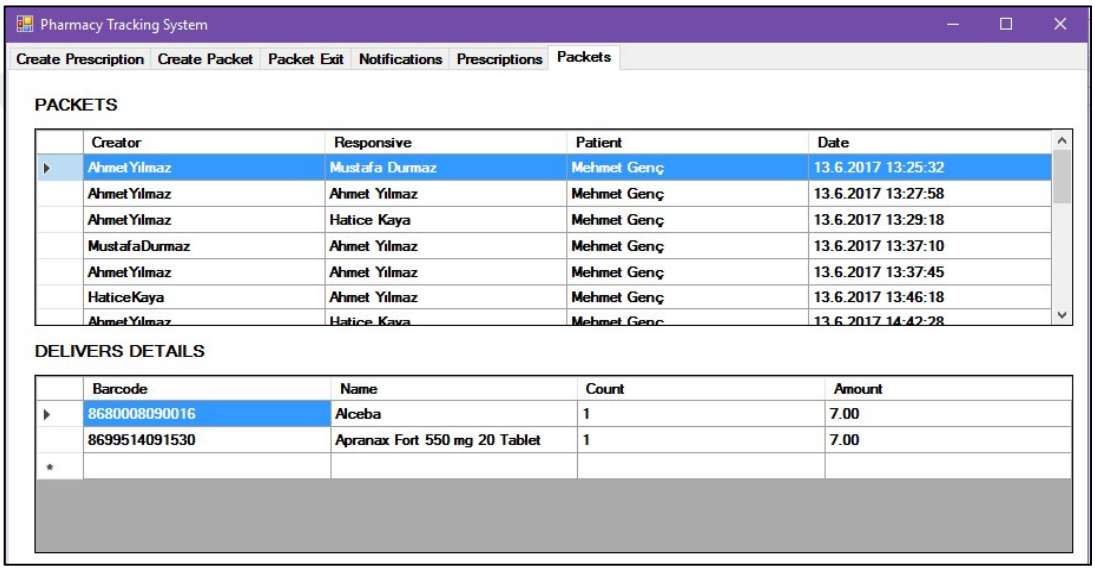

Figure 4.34 Packets tab

About Packet exit tab, the RFID reader should read a packet tag, a personnel tag and drug tags. System takes packet information from database with packet tag. System compares two packet lists: One of them is from the RFID reader and the other one is packet detail. System also compares personnel tag and responsive personnel tag that is given in prescription. When they don't match, system gives an alert and saves the unauthorized exit to the database as shown in Figure 4.35. Then, the right drug tags are tried. Drug lists are matched. System saves packet exit to the database.

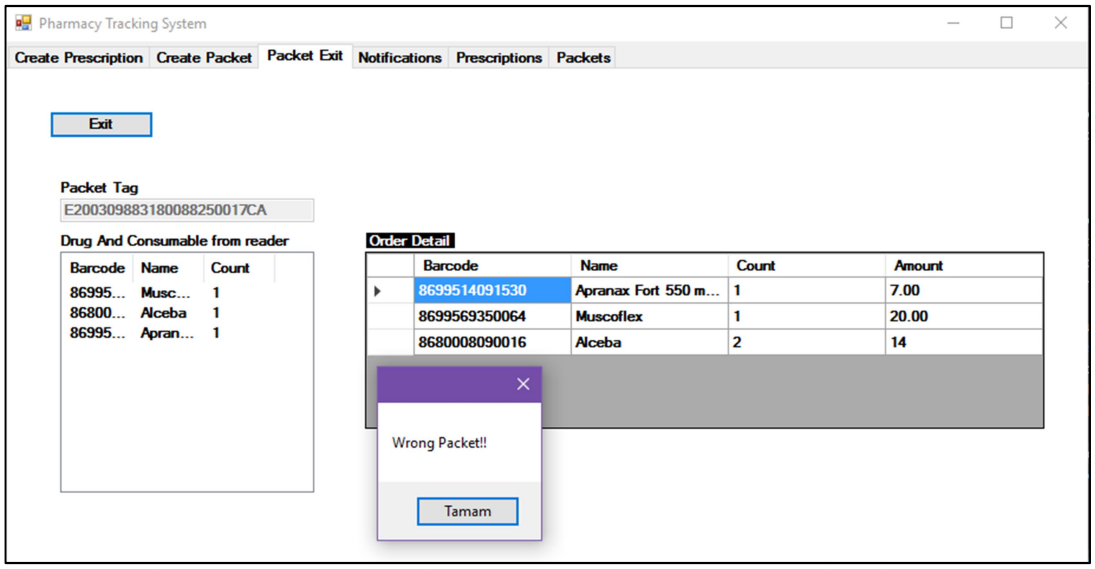

Figure 4.35 Unauthorized packet exit tab

CHAPTER FIVE
TESTS AND RESULTS

5.1 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 separately in the laboratory in the software. Then, the whole system has been practiced with the combination of all components. In the experimental setup, a server, a notebook, 2 tablets, 3 Arduino Uno cards, a UHF RFID reader, a RFID reader, a NFC reader, 3 BLE modules, 3 iBeacons, 3 Ethernet modules, 10 RFID tags and 5 NFC cards have been used. Figure 5.1 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. By using an Ethernet module on all 3 Arduino Uno units, data is transferred to the server via wired network.

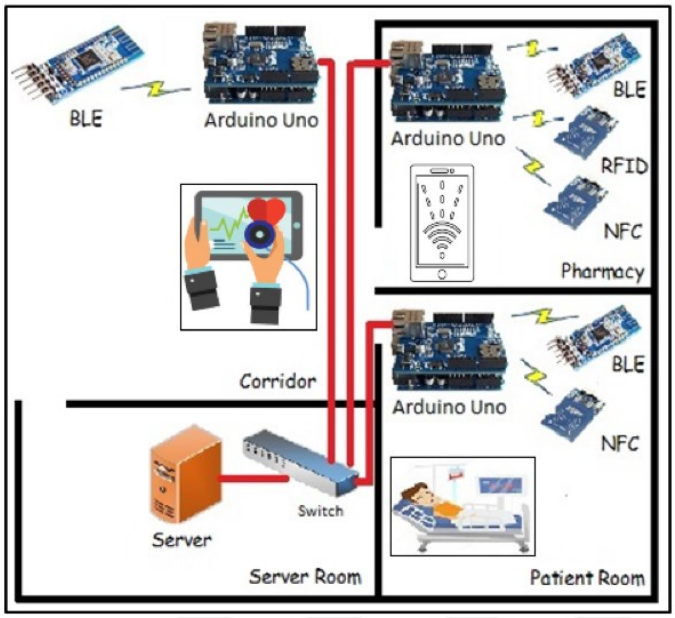

Figure 5.1 Test environment view

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 labelled 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 health care medicines are taken out of the range of the RFID and the 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 medical devices and other inventory which is in use 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, BLE readers are positioned at the most appropriate locations. With the medical information entered by the doctor for the patient, it is integrated with PADC and patient follow-up.

5.2 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, volunteered

students have played the roles of health personnel and patients. The results of the experiments are shown in Table 5.1. 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 final 100 of the experiments, the presence of personnel in the patient room was tested. In these experiments, a total of 9 erroneous readings were studied. There was no delay in data transmission with wired network by transferring the information to the server. As reading the RFID labels, preparation of the drug package 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. NFC card reading process is also tested. Receiving drugs from pharmacy by healthcare personnel is tested 100 times and the identification of the person who give drugs to patient were also tested 100 times. It total 200 tests were run. In the NFC card reading tests, a total of 8 erroneous readings were analyzed. Pilot system test has been performed as a scenario which includes 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, preparation of drug package, drug delivery, package control, application of 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 recorded 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 are counted correctly in the final report.

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

True Negative (TN): Number of prescriptions, medication order, preparation of medication package, delivery of medicines, package control and no application of the patient are not 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 5.1 Notations

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

CHAPTER SIX
DISCUSSION AND CONCLUSION

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

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \times 100 \quad (6.1)$$

$$Sensitivity = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} \times 100 \quad (6.2)$$

$$Specificity = \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FP}} \times 100 \quad (6.3)$$

$$Error\ Rate = \frac{(measured\ value - actual\ value)}{\frac{measured\ value + \ actual\ value}{2}} \times 100 \quad (6.4)$$

Table 6.1 Performance table of studies

Performance (%)	**iBeacon Reading**	**UHF Tag Reading**	**NFC Tag Reading**	**Patient Result Report**
Accuracy	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 6.1 shows the results obtained by placing the results of TP, FP, TN, and FN given in the equations (1, 2, 3, 4) in Table 5.1. According to Table 6.1, the accuracy of detecting PADC 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 smart cities are used in emergency services, particularly 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 PADC tracking contributes to the Ministry of Health's Paperless Hospital project,
2. All services of emergency services in the city can be monitored and guided with the PADC tracking and monitoring system,
3. Clinical outcomes that are vital for patients,
4. Significant administrative outputs in terms of hospital management,
5. Important outcomes in terms of job satisfaction and increased productivity of doctors and nurses,
6. Warnings and reminder services can be provided on decreased inventory or approaching expiration dates of drugs, materials and devices of oncoming maintenance dates,
7. Compatible work services on different computer platforms is possible with the use of XML data type,
8. Ability to work in harmony with the interfaces of different portable computer manufacturers,
9. This can serve as an example for other health services,
10. This platform can increase confidence in national income, community health and health services.

A proposal which uses modern technologies to ensure that all emergency services in a smart city are monitored and directed, has been performed. The hardware and software design of the recommendation is explained in detail. The pilot system, the

test method and the results of the individual items of the proposed platform integrated with a scenario are presented. The results show that the pilot system works successfully in the laboratory environment with the proposed prototypes.

With the software developed according to the scope of the project, the work processes of the emergency services were made more systematic. This study will be a novelty in the overall health care system as there are no studies practiced for emergency service workflow processes. It is known that different studies are carried out for paperless hospitals both in Turkey and abroad. Our project will be the first step that can make a great contribution to the process of realization and testing of paperless hospital automation. PADC structures can be tracked locationally and separately with installed and implemented hardware systems. All actors in emergency services can be followed by using active and passive electronic labels which are RFID technology products. Every asset attached with those labels, would be integrated with an object-based database design. At this point, the lack of such work in emergency services will create awareness in terms of the functioning of the system.

The proposed pilot system is preparing for a more comprehensive scenario that simulates multiple emergency services. In this new scenario which is not required much more hardware and software than the content described in current work, requires detailed planning and preparation because of the increasing greatly number of experiment points to be taken on and the number of health care professionals. The last stage of the experiment, to be conducted in a real emergency service environment, is also planned as one of the future works.

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