Smart Systems

From Design to Implementation of Embedded Smart Systems

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***Abstract*— This paper aims to explain the design and implementation procedure of embedded Smart Systems. The idea is supported by four different Smart Systems, as Smart Home, Smart Agriculture, Smart Campus, and Seat and Study Module of Smart Library. All designs and implementations contains technological components of embedded systems, mobile application development, cloud based services and client side graphical user interface. Ultimately this paper gives an overview of current state of the art concerning Smart System Design and discusses several issues and possibilities concerning the implementation of four different systems.**

Keywords — smart systems; Internet of things; cloud computing; mobile application development.

I. INTRODUCTION

A Smart system is an embedded system that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and control over the something's functions such as an electronic device, home, or plants. For example, a Smart home system may control temperature, lighting, multi-media, window and door operations, security, as well as many other functions.

There are certain aims about Smart systems that are mainly listed as to integrate technology into daily life, having a safer life and economic gain. It is clear that integration of technology into daily life makes people life easier. In Smart systems, most of the electronic devices will be communicating with software base system and by this way, it will allow user to access information about it wherever the user is and whenever the user wants. People will be checking the smart devices and they can manage the device according to its properties. The data is stored in a Cloud system so the system will be open to development for future. For example, there might be alternative mobile applications such as iOS, Android and Windows Mobile Operating Systems or a web platform can be developed, if it is needed.

This paper aims to give the design and implementation procedure of embedded Smart Systems in details. The idea is supported by four different Smart Systems, as Smart Home, Smart Agriculture, Smart Campus, and Seat and Study Module of Smart Library. In general, these Smart Systems are developed and implemented with four different components that are integrated as a unique system. The first component is hardware. In this component, all the hardware devices are connected to the Arduino board and these devices work according to the command that comes from client or mobile devices. The second component is client side, which has a laptop computer connected to the Arduino board. There is a desktop application with GUI, which receives and sends data from Cloud system to Arduino board or Arduino board to Cloud system. User can access the real time data that comes from Arduino board and it is displayed on a page that works on desktop application. The third component is Cloud System. In the Cloud side, all data and necessary files are stored on Cloud services. All the tables in the database have been developed by using SQL and using Entity Framework technology insertion, deletion and update operations performed. The fourth and the last component is mobile application. The user can install the application and login. After processing some security functions user can easily display the device and values of the sensors that are in Smart system.

The rest of this paper is organized as follows. In Section II, implementation steps of smart systems are given by considering four different smart systems. These smart systems have Hardware components, Software components and Cloud services. All features of these components, use-case diagrams, database designs and implementation steps of each smart system are explained and discussed in details. Finally, the conclusions are presented in Section III.

II. SMART SYSTEM DESIGN METHODOLOGIES

In this section, smart system design methodology is examined by considering four different embedded smart systems as Smart Home, Smart Agriculture, Smart Campus, and Seat & Study Module of Smart Library All systems are fully explained and information about the methods is described in details.

A. Smart Home System

Current trends in today's Smart home systems automated lights, scheduling appliances, automated sensors, mobile, text, email notifications and remote video surveillance. The latest trend about Smart Home systems makes your home into mobile remote controllable homes. User can just control system by touching the device and gets the response. Implementation of Smart Home System includes hardware and software

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components. This section explains these two components and Cloud Services in detail for proposed system. Block diagram of Smart Home System is given in Fig.1.

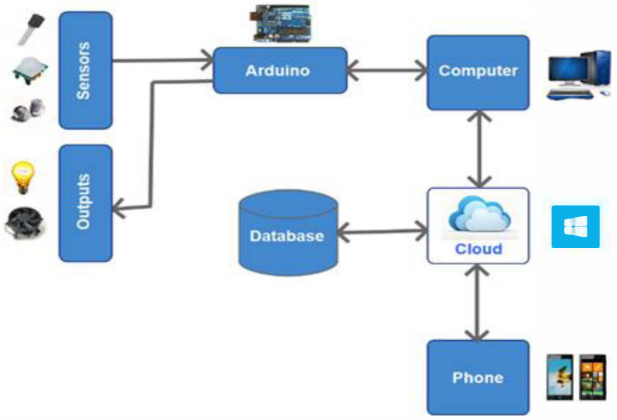

Fig. 1. Block Diagram Representation of Smart Home System.

1) Hardware Components

Technologies and methods have used on hardware is explained in this part. Furthermore, we give a list of activities required to obtain guidance on technologies. Hardware components are Arduino Board UNO R3, LM35 Temperature Sensor, THC-SR501 PIR Move Sensor, MQ135, Air Quality Sensor and LED indicators. Arduino board is an open source physical computing platform based on a simple microcontroller board [1]. Arduino board can be used to develop interactive objects, taking inputs from a multiplicity of sensors or switches, and controlling a multiplicity of lights, fans and other physical outputs [2]. Arduino board has many advantages against other microcontroller platforms. Mainly those advantages are inexpensive, simple, cross platform, clear programming environment, extensible and open source hardware, extensible and open source software [3]. Hardware structure of the Smart home system is called sensor based input layer. In this layer, temperature, move and air quality sensors [4] are connected to Arduino Board UNO R3. These sensors send the data collected by them to a computer to be stored in a cloud service. In addition to this, a problem specific software is developed to manage all sensors on Arduino board and USB ports using Arduino Board 1.0.5 - R2 IDE and Arduino Board Programing Language, which is an open source tool and it is available for extension by experienced programmers.

2) Software Components

Smart home application has a software layer. In this layer, three applications are developed in addition to Arduino sensor control program. One of them is a desktop application as a monitoring system. The desktop application which gets and sends data from cloud system to Arduino board or Arduino board to the cloud system using socket programming. Users can access the in time data that come from Arduino and it is displayed on a page which works on desktop application. Also that program receives data from server side and sends it to the Arduino. For Desktop Application we have made use of C# programming which is under .Net Framework. Graphic user interface of Smart home desktop application is shown in Fig.2.

Fig. 2. Screen Capture of Monitoring Page.

.NET Framework is a technology that provides the infrastructure for developing, running, and managing big data software architectures. As a layered representation, .NET Framework is a layer positioned between the Windows operating systems and applications. While .NET is a platform it is also defined as a technology because it is composed of several parts such as libraries, executable tools, and relationships and integrates with the operating system [5]. Two programs is developed for communicating a socket application in C# [6]. A Server side Socket Program and a Client side Socket Program. Besides implementation details, the most important issue is data security. Data transfer is very important for Smart home application because there is a network and everything can be hacked after trying some ways. There is a data transfer from client to server or server to client and certain algorithms are used for the data transfer security. Data are converted to JSON object, after this process it is encrypted by using Base64 encoding algorithm. It used to alter text and binary data into easy-to-process form to be consumed by various programs as well as transmitted over the network. Before receiving the data using the same algorithm received data is decrypted and send it to the next layer to process. In smart home system, a mobile application is developed to get data from Azure cloud services and the smart home database. This application does not communicate with the sensor layer. A user can track [7] the data and control heating and lightening system of the home using the user friendly mobile application.

3) Cloud Services

Windows Azure is an open and flexible cloud platform that enables easy and fast build, deploy and manage applications across a global network of data centers [8]. People can develop applications using any programming language, any tool or any framework and it enables people to integrate their public cloud applications with the existing information technology environment. Windows Azure includes four main services as: Compute Services, Data Services, App Services and Network Services [9]. In this Smart Home System, SQL Database from Data Services [10] and virtual machine from Compute Services [11] are used. There is a portal which is for SQL Database and it enables user to do whatever they can do while using SQL Server Management Server program and using this portal user can easily run Select, Insert, Update, Delete and Queries. In addition to SQL Database service, a virtual machine is created in Azure Cloud Platform. There is a desktop application which manages the client side and mobile side communication. If client or mobile application wants to send or receive, data have to pass from the virtual machine program. That program is the

middle ware of our system. Azure SQL Database offers flexible manageability and it is a full service-oriented relational database and supports large scale expansion and offers predictable performance. For the query language T-SQL (Transact-SQL) has been used and all the queries which runs on other programs use T-SQL language [12].

4) Conclusions of Smart Home System

In this Smart Home System, a new, unique and complete smart home system architecture and its infrastructure is designed and implemented. The proposed smart home system includes client, cloud and mobile sides. There is an Arduino board in the client-side for hardware devices. There is also a desktop application developed to communicate with the Arduino board. In the cloud-side, Windows Azure platform is the main platform for the database, and the web services. All codes has been developed by using MS Visual Studio and programming C#, briefly .Net Platform, except the programming parts of the Arduino board. SQL Server Management Studio is for developing the database and it works on Azure Cloud services. Entity framework architecture is the main communication tools and it provides communication between the client side and the server side. On the mobile side, a program that works on Windows Phone is developed and it communicates with cloud side to share or work for any process. The implementation of such a smart home system has a unique and simple design, but it is effective and has a complete system architecture and infrastructure. The users can access all the devices and manage them according to the various options. The proposed and developed smart home system provide users to have easier, safer and more comfortable life.

B. Smart Agriculture System

In this section, design and implementation steps of Smart Agriculture System is explained in details. This system is for people who are interested in agriculture that can give more productive and faster results about the humidity of soil, air pressure, temperature, and location of sensors. In Smart Agriculture System, the communication between Arduino Board and Raspberry Pi has provided by using Machine-to-Machine technology. While communicating the devices, wireless sensor communication are preferred. By using Internet platform, data is transferred by sensors to an Android based mobile device. Implementation of Smart Agriculture System also includes hardware and software components. This section explains these two components and Cloud Services in detail. By detecting the following features are transferred to the Arduino in the Smart Agriculture System: level of humidity of soil, temperature and air pressure, light intensity, and the GPS location of devices. After that the data gathered by using wireless technology is sent through mobile data network to the server which is located in the Internet media. Hardware components in the Smart Agriculture System are Arduino, Raspberry Pi, Humidity Sensor of Soil – YL38, Air Pressure and Temperature Sensor – BMP180, Light Intensity sensor – LDR, GPS module – Ublox NEO6M-V2, Wireless Sensor – Xbee Serie2, XBee Dongle, USB Adaptor – ZTE 3G, XBee Shield, Arduino Uno R3, Solar Panel and Battery 2400 mAh, Software components in the Smart Agriculture System are Raspbian, Java, Python, and MySQL.

1) Hardware Components

As explained in previous section, Arduino is a physical programming platform which uses processing infrastructure and is an I/O card. The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. So that people who are interested in programing languages like Python and Scratch can discover and learn more about it by using them. It has an ability of doing everything such a desktop computer can do. XBee is a new technology that is started to use in 2005-2006. Regarding to IEEE 802.15.4 standards, the significant features of this new technology are lower power consumption, long-range data transmission, and network support. In smart home system, XBee and sensors are communicated with the Wireless technology. Technical Specs are Indoor/Urban: up to 30 meters, Outdoor line-of-sight: up to 90 meters, transmit power is 1 mW. UBlox GPS sensors are used for finding sensor kits location. Sensitivity is key feature while choosing GPS sensors. These are the specs of GPS sensor: -165dBm sensitivity, fast time-to-first-fix and external antenna detection. Measuring the air pressure is necessary for weather forecast. BMP180 digital air pressure sensor is selected for this measurement. Specs of BMP180: Pressure range: from +9000m to -500m relating to sea level. LDR Photo resistors are inversely proportional with the light intensity on them. Resistance value is decreasing as non-linearly by the light falling on photo resistors are increasing. Minimum resistance of LDR occurs at the daytime while maximum occurs in the dark. The humidity of the soil is measured by YL38, it is the resistance of water inside soil. Block diagram of Smart Agriculture System is shown in Fig.4.

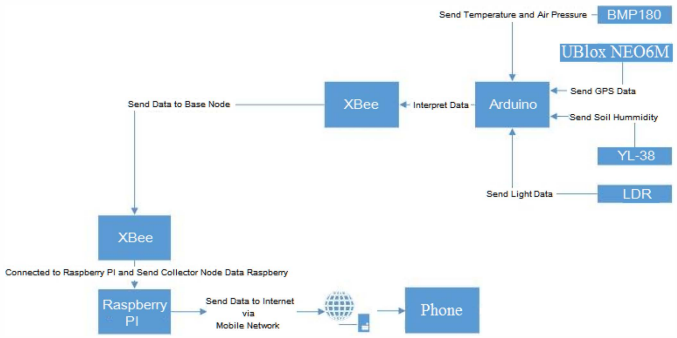

Fig. 4. Block Diagram of Smart Agriculture System Hardware Components.

2) Software Components

MySQL is preferred as the database system in Smart Agriculture System. MySQL is a simple, fast and reliable database system. MySQL provides access to several programming languages such as Java, Python, PHP, etc. This the main reason to choose MySQL as database. On the other hand, Flask is chosen to establish a micro-framework to code a small Web API. In Smart Agriculture System, a mobile application is also designed to collect data from the sensors whenever the user wants. In this Android-based Mobile Application, user is able to read the data received from devices. When the user desires to see data collected by the sensors, the user selects the sensor first, and then the user reaches the data from that date to a day before, according to the sensor. The user may reschedule his data daily, weekly, and monthly from the sign located at upper panel. Daily, weekly and monthly collected data is available for user's demand as shown in Fig.5.

Fig. 5. Sense Daily, Weekly and Montly Design of Mobile Applicaiton.

3) Cloud Services

Digital Ocean Cloud Service is decided to use in Smart Agriculture System. The most significant reason for choosing Digital Ocean Cloud Service is that the company which provides Virtual Private Servers complete the setup and put the system into service directly in a very short period time. The images of most operating systems are ready for use while setting VPS up. Ubuntu 14.04 is selected as operating system of Smart Agriculture System. Ubuntu is the most widespread Linux-based desktop operating system that has more than 20 million users. Ubuntu consists of free software that allows people to publish, copy, and change/develop/use the codes.

4) Conclusions for Smart Agriculture System

Smart Agriculture System is designed to make efficient and to create higher productive agricultural activities in today's world. Users are encouraged to make a more conscious farming due to missing time before this application. It is provided to optimize the cost. The users that are downloaded Mobile Application and they can keep follow the data of their lands even if they have distance from the land where they are planted, as long as the area which user is at has the Internet connection. In Smart Agriculture System, Machine to Machine communication devices have been used and provided wireless communication with each other. Data received from the user through sensors in the field of agriculture are first transferred to Raspberry Pi and then it is provided to transfer to the Internet media. After that, the user can view the collected data when he wants to see at all the time on his Android-based mobile devices just using the Internet.

C. Smart Campus System

In Smart Campus System, an Android application has been designed and implemented to guide the visitors of the Kadir Has University throughout the campus using beacons that are located in strategically designed points. The software has been developed with Android Studio and Special Android Indoor SDK. Android SDK uses path loss model and trilateration for localization. The system allows users to navigate in the campus with a 3D map while providing them directions to the daily events that take place. Also an augmented reality has been created using camera view of the mobile device's to further help with the navigation. Application is automated so that data containing daily information about events are extracted from the university's website and kept in database. The system has been implemented on approximately 9000m2 indoor area with 150 beacons. The most important part of this system is localization with Bluetooth beacons. Localization using beacons can be achieved using a range of techniques, such as trilateration multi–lateration and cell–based methods. Due to the read range of about 15m, beacons are not precise enough to consider just the reachability of the sensor nodes as in the RFID–based approach. Thus, it is suggested to employ Received Signal Strength Indications (RSSI) for positioning.

Trilateration method is used to compute the distance of the traveler from each of three beacons. The traveler's position is determined as the point of intersection of three circles, each centered at one of the beacons. The radius of each of these circles is the estimated distance of the traveler from that beacon. Multi-lateration based localization is based on measuring the time intervals between the transmission of a pulse from the traveler and its reception at multiple receivers. Such measurements require features that are not supported in the low-cost beacon devices. Cell-based methods determine the location of the traveler based on only the visibility of beacons, without using any distance measurements such as RSSI. Localization is determined by the limited range of each of the beacons. Traveler's position is deduced by the region of intersection of the ranges of all visible beacons.

1) Hardware Components

In this system, a beacon infrastructure has been used. Bluetooth networking transmits data via low-power radio waves. It communicates on a frequency of 2.45 Gigahertz. Bluetooth Beacon is a wireless technology that broadcasts small pieces of data. The data can be anything, such as an ambient data (temperature, air pressure, or humidity) or micro-location data (asset tracking, retail) or orientation data (acceleration, rotation). The transmitted data is generally static but it can also be dynamic and change over time. Due to the use of Bluetooth Low Energy (BLE), beacons can be designed to run for years on a single coin cell battery. Data packets transmitted over the beacons consists of four main pieces of information. **UUID** is a 16 byte string used to distinguish a large group of related beacons. **Major** and **Minor** is 2 byte strings. **Major** is used to differentiate smaller subset of beacons within larger group, **Minor** identifies individual beacons. **Tx Power** is used to determine distance from beacon. Devices can use this as a baseline to give a distance estimation.

2) Software Components

Android Studio is the official Integrated Development Environment – IDE for Android app development. It is used to create native android application. Special Android Indoor SDK is a platform that enables users to get their location inside a building. The product is specialized in indoor areas where the GPS is not suitable. It calculates indoor location of the user by gathering the signals from BLE Beacons. It is well suited to provide indoor location services such as positioning, navigation, advertisement, analytics, 3D maps. It is used for positioning and routing. MySQL is an open-source relational database management system. PHPMyAdmin is a free and open source tool written in PHP intended to handle the administration of MySQL or with the help of a web browser. It is used to access database via web browser. Brackets is an open source code editor for web designers and front-end developers. Filezilla is a free FTP solution for both client and server. It is used for transferring PHP files to a server, local files to server.

3) Implementaion

In Smart Campus System, PHP used to fetch data out of Kadir Has University website event page. This stored data fetched from database via PHP to mobile application. JSON

Parser used to show this event list in mobile application. With list view option mobile application manage to show all the events to the user. As shown in Fig.9, there is a splash screen page in this application. When timers is up splash screen switch to the event list page. Information regarding to events are fetched from the website and kept in the database. With (x,y) map of Kadir Has Campus application manage to pin point locations to create a pathway from current user location to created point of interest. System has been implemented on approximately 9000m2 indoor area with 150 beacons. Fig.8. shows the block diagrams used to make certain functionalities in the application. In this system different types of components such as Web server,API server and application have been used.

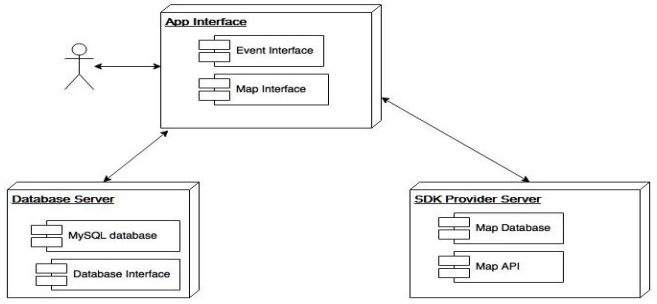

Fig.8. Block Diagram of the Application.

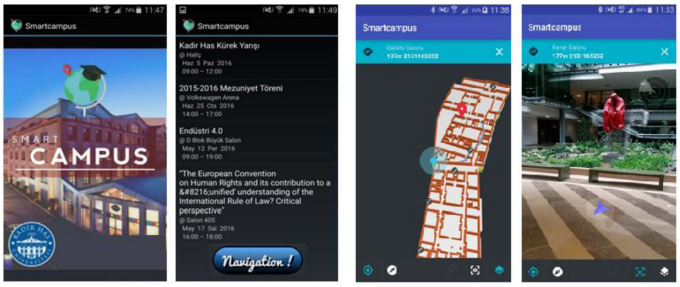

Fig.9. Splash, ListView, Routing Screens and Camera Mode of the Smart Campus Mobile Application.

Fig.9. also shows the routing screen after the user chooses the preferred location to travel. 3D map is provided and main parts such as walls and stairs are shown. Fig.9. also shows the camera mode of the routing screen. User can choose this mode to get further assistance. Arrow located in the bottom of the screen shows the path.

4) Conclusions for Smart Campus System

Smart Campus System aims to help visitors of Kadir Has University navigate easily around the campus using beacon infrastructure. Smart Campus application can provide directions and positioning. Performance analysis shows that average margin of error for the entire campus is 14.4 meters. This is not applicable in indoor positioning however it can be acceptable when providing directions and routing. Android SDK localization is based on trilateration model. Research shows that mapping RSSI values to distance is both difficult and unreliable due to the construction materials, furniture, and complex features. Cell based method can be used to overcome this problem since it does not rely on RSSI or other indicators.

D. Seat and Study Module of Smart Library System

Smart Library System is designed and implemented to control the usage of Kadir Has University Information Center. Students have some problems to find a seat in the library especially at exam weeks. In order to solve this problem, Seat and Study Module of Smart Library System aims to provide more effective usage for seats. Smart Library System is implemented by using Arduino as hardware component. The software is developed by using programming languages, C#, HTML, CSS, JavaScript on Microsoft Visual Studio. For the storage, Windows Azure cloud service platform is used to store database. The system shows available and occupied seats depending on the data from RFID card readers. Sound and temperature sensors are used to provide a better study area. Students can display the status of seats and some information about library from outside of the library via mobile application. Librarians can manage the condition in the library easier with this system, and they can analyze library usage. Block diagram representation of Seat and Study Module of Smart Library System is given in Figure 10.

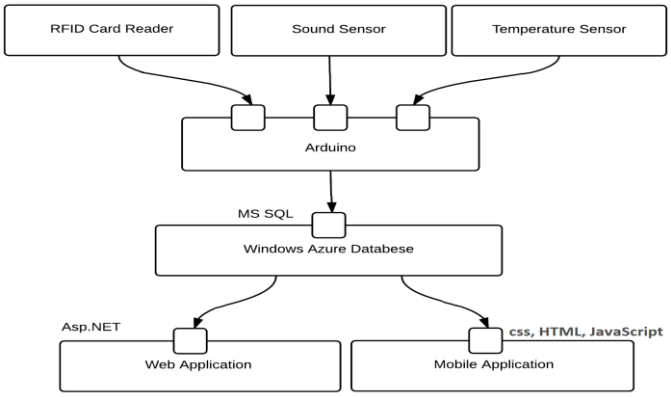

Fig. 10. Block Diagram Representation of Smart Library System.

1) Hardware Components

The hardware of the system is based on Arduino. Some useful sensors are combined to system to get some measurements. Therefore, the connection is built between the sensors and Arduino board. Hardware components of the system are; Arduino Mega 2560 R3 microcontroller board is used ATmega2560 microcontroller. MFRC522 RFID Card Reader has writing and reading functionality some of Mi–fare cards. This RFID card reader works only with 13.56 Mhz frequency. Humidity and Temperature Sensor Card–DHT11 measures humidity and temperature of environment. Sensor accuracies are respectively humidity and temperature ±5%RH, ±2°C. Grove Sound Sensor –ESP8266 measures level of sound of environment. Wi-Fi Shield–ESP13 is compatible with Arduino Uno and Mega microcontroller boards. The shield use 802.11 b/g/n wireless standard for communication.

2) Software Components

In order to get data from sensors in the correct format, codes are written for Arduino board. Arduino IDE 1.6.8 is a software tool to write code for all types of Arduino boards. Arduino programming language is a type of simplified C++ programming language. This language has basically three blocks as definitions, setup() and loop(). Form application is developed to connect Arduino board to computer via USB cable. Visual Studio 2015 Community is an IDE developed by Microsoft. It is used for developing Windows forms, console, web and mobile applications with using C# programming language, but it has also support other programming languages like C/C++ and VB.NET. C# 6.0 is used in Visual Studio IDE.

.Net Framework 3.5 is an application development platform based on open Internet protocols and standards by developed Microsoft. Database is designed and created to store the data coming from Arduino. Database is placed at cloud server. Microsoft SQL Server is a database management system that is provided to create and manage of databases. Fritzing is an electronic circuit design program, and it is used for connecting electronic circuit components. In general, this program is used for designing IoT projects along with Arduino and sensors.

3) Cloud Services

Microsoft Azure Cloud Service Platform is a cloud platform that allow to build, deploy and manage applications and services. Also, this platform includes IaaS (Infrastructure as a Service) and PaaS (Platform as a Service) supports. Hybrid mobile application is developed to use the same application for Anroid, iOS, and Windows Phone platforms. Apache Cordova framework is used for mobile application development. The framework allows HTML5, CSS3 and Javascript languages for cross platform mobile development. Ionic Framework is a front-end software development kit to develop hybrid mobile applications. This framework is also open source and can set up on Visual Studio. Graphical User Interface Design is achieved by the following software programs such as Adobe Kuler is a color design program that help to front-end web and mobile application developers for their color design of projects. Adobe Illustrator CS6 is a vector graphic design program that is used for web site and mobile application interfaces and logos, posters and banners designs. Design of Mobile Application for the Seat and Study system is shown in Fig.11.

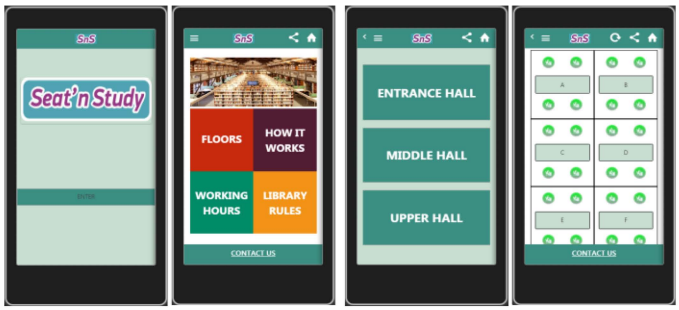

Fig. 11. Screen Design of Mobile Application.

4) Conclusions for Seat & Study Module of Smart Library

As a result of Smart Library system design, it is useful for users. This system prevents students to waste of their time. This system shows physical status of seats and effective use of seats in the library. Hardware part is effective and cheap for a smart system. Arduino reduces the cost, and meets the needs. It is done by using existing student ID cards, and it provides to see who uses library and how many hours spend in the library. It prevents users who put their books on the desk to occupy the seat when they are out of the library. These users can be determined from the system if they continue to behave in this way. Measuring the sound level and temperature is helpful to make the conditions suitable for users. This system does not allow to users have more than one seat at the same time. Seats in the library are used effectively. Seat & Study, mobile application, is useful for students because they can display the status of the seats before they reach to the library. For any situation, information about the system is stored in the database that is located in the cloud. Cloud services provides more secure, large, and easy to manage area for storage. Due to these reasons, data for Smart Library system is saved by using new technologies. Finally, Smart Library system includes several technologies such as Arduino, database, cloud services, mobile services, and mobile application.

III. CONCLUSIONS

In this paper, design and implementation procedure of embedded Smart Systems is explained in details by considering four different Smart Systems as Smart Home, Smart Agriculture, Smart Campus, and Seat and Study Module of Smart Library. All designs and implementations contains hardware, software and cloud components, and also technological components of embedded systems, mobile applications, and client side graphical user interface. Ultimately this paper gives an overview of current state of the art concerning Smart System Design and discusses several issues and possibilities concerning the implementation of four different systems. All systems are implemented by providing a new, unique and complete smart system architecture and its infrastructure. The proposed smart systems includes client, cloud and mobile sides.

The implementation of such Smart Systems have a unique and simple design, but it is effective and has a complete system architecture and infrastructure. The users can access all the devices and manage them according to the various options. The proposed and developed smart systems provide users to have easier, safer and more comfortable life.

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