

# Embedded Systems for User Identification in Access to Objects and Services Using Mobile Phone

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**Abstract** — Possibilities of design and implementation of embedded systems for user identification and access to different objects and services using mobile phone are considered, proposed and described in the paper. Such systems are applying different communication technologies and embedded devices and are valuable for different identification applications. One practically proposed, designed and implemented embedded system solution, using smart mobile phones and embedded devices with virtualized server platforms, for user identification in access to vehicle public parking garages purposes is presented. Data exchange technologies between smart mobile phones, centralized system, as well as hardware and software platforms, used to realize parking booking and access in such identification system are considered. Obtained results along with developed Web and mobile applications, as well as embedded application for interfacing smart mobile phones with embedded device and virtualized server platform are described.

**Keywords -** *embedded systems; user identification; access to objects and services; smart mobile phone; vehicle parking places; virtualized server platforms*

## I. INTRODUCTION

Access control to different objects and services was always discussed and there are many such existing developed applications. The most known applications use different access cards or key entry. Rapid development of embedded systems, small powerful devices, mobile and cloud applications can increase usage of such systems in combination with smart mobile phones and devices. Such systems enable access control in a manner called digital access control [1]. It can be realized using different wireless communication technologies (NFC, Bluetooth, ZigBee, IP, etc.) [2-5]. Such communication technologies enable interconnection of different types devices and are provided to many small and powerful devices (embedded boards, smart watches, smart phones and smart wearable). Combining the communication technologies and small embedded devices many applications can be developed

to access object or service with limited access. The objects or services itself can be public parking spaces or garages, business buildings or smart homes and smart buildings and other types of buildings, as well as health services, education services, electronic payment services, where access control management is required. The security management in such objects, buildings and services is important issue of concern, also, to prevent different types of intrusions and misuses [6].

Smart phones are standard communication devices used by many persons. Smart (SIM) card in the mobile phone can memorize needed data about the mobile phone user, as well as different identification data (ID), as user name, access passwords and other data. Also, smart mobile phones are provided with different wireless communication technologies: GSM, GPRS, Bluetooth, NFC, WiFi. It gives possibility for mobile phone to be also used as universal user identification device. The smart mobile phone could replace other user identification elements, as are identity card, driving license, health card, passport, student index, remote device for access to some area or to a car, for entering sports events, concerts, public transport vehicles, for electronic payments and similar. Many of the user identification resources that a person carries can be integrated into a smart mobile phone.

One practical design and implementation of the system for user identification and access control to the parking objects and/or garages using smart mobile phones and embedded devices, such as microprocessor boards, communication modules and centralized system is proposed and described in the paper. Embedded solution that was developed, presented and described enables in advance parking lot booking and user identification and access, in public parking spaces or garages.

## II. DESIGN OF SYSTEM FOR USER IDENTIFICATION AND ACCESS TO PARKING OBJECTS USING MOBILE PHONE

A microprocessor based identification system to realize a parking booking, identification and access control is proposed.

Such system is intended to be used for management of parking places in public garages and/or parking places. Such management is realized by user identification and authentication tasks using mobile phones. The proposed architecture of the system is presented in Fig. 1. The implemented system has three main parts: centralized subsystem, subsystem for user identification and data acquisition and processing subsystem.

The centralized system uses developed Internet Web application along with a database to realize parking booking, storing bookings, booking management and the ability to check free parking places on public parking places or garages. The management of the booking includes booking confirmation,

checking of realized booking and cancellation of booking. All those activities can be accomplished by a developed mobile application that communicates with the centralized system part. The user identification subsystem is used to identify the user during access to the parking place who has already booked a vehicle parking place. Following successful user identification, this subsystem communicates over communication sub module and over data acquisition and processing subsystem with centralized subsystem to verify the validity of the parking place booking. Using the mobile smart phone the user can establish parking place booking in every time and from every location. To use the mobile application that communicates with the centralized subsystem part, an Internet connection is required.

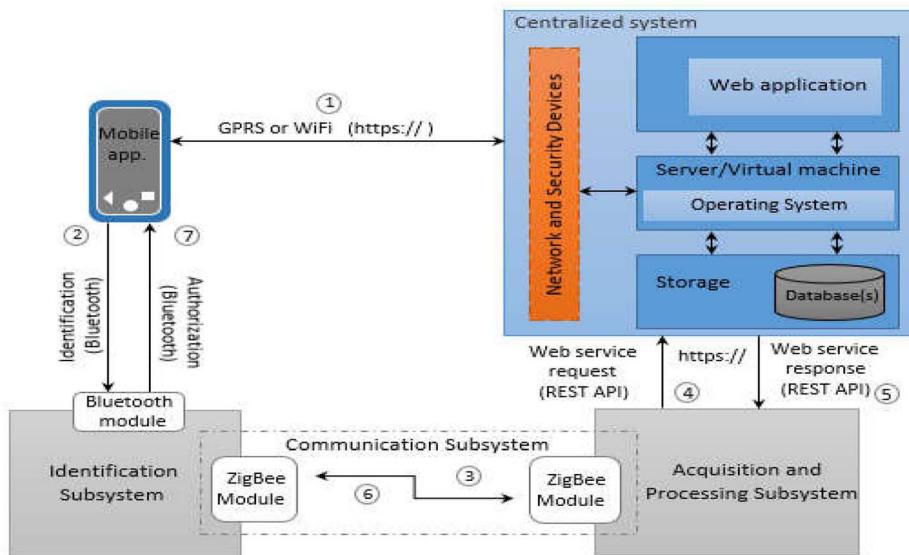


Figure 1. Proposed overall system architecture of design and implementation

Initially the user realizes a parking place booking. In this step, a request for parking place booking is sent to the centralized system that in backward sends the confirmation or not in case of successful booking or not. The given solution proposes and enables using GPRS (General Packer Radio Service) or wireless WiFi connection of mobile phone to communicate with centralized system. The workstation in centralized system can use and uses the wired or wireless Internet connection. The communication is realized over the secure and encrypted channel through port 443.

The second step is user interaction with the embedded system at the entrance of public parking garage or parking space. In case the user has realized the parking booking, the user identification and booked parking lot authorization follows. Identification process implies checking the user identification data to verify the booking of a parking lot. This is done by initializing Bluetooth communication between the user mobile phone and the embedded system on the entrance of public parking garage or parking space. The embedded system is powerful board interfaced with ZigBee based communication module to communicate with another ZigBee based communication module for data exchange. After

receiving data from the user smart phone, the embedded board transmits the data over ZigBee based wireless module to other embedded device for processing. This board is the interface and processing subsystem between the embedded board at entrance and the centralized system with its Web application and database. After the data processing, this subsystem transmits the user identification data to the centralized system by calling Web service to check the identification. Following this, on the centralized system the query is processed and the Web service responds with successful or unsuccessful message.

The acquisition and processing subsystem, after receiving the response, transmits the answer over ZigBee wireless communication back to identification subsystem that informs user over Bluetooth on mobile phone about the identification. If the identification was successful it sends also data, such as booked parking place and other relevant information to user.

The centralized system itself is a server with a developed Web application and database for data storage and processing. Solution with a virtual machine in private cloud is proposed and used. Depending on the requirements such as heterogeneous processing, security, budget, environmental

space, etc., centralized system can be divided into two or more servers acting in a cluster or as a heterogeneous system to provide stability and system consistency. The centralized system can be part of a public cloud on what the Web application and database need to be installed and configured. It can also be part of a private cloud in a company.

### III. HARDWARE IMPLEMENTATION OF PROPOSED SYSTEM

The overall system placed at parking object or place is composed of two subsystems. The other part is the centralized system that is interfaced over the Internet connection to the internal subsystem. The subsystems are composed of Raspberry PI model 2B boards, ZigBee communication wireless XBee modules, Bluetooth module with USB connection and a workstation. The presentation of the subsystems is shown in Fig. 2. On the entrance of a parking space or garage proposed hardware solution consists of Raspberry PI board. Bluetooth module and XBee module are used on this board to realize wireless communication between the user mobile phone and Raspberry PI board, as well as between the Raspberry board and the workstation. On the workstation side, XBee module is used for wireless receiving data. The XBee modules are configured and programmed to act as end device and coordinator to realize the communication, but can be further expanded in case of needs to use additional router node. This can be accomplished using different ZigBee based topologies, depending on the requirements [4,6]. The proposed hardware architecture helps handling data stream in both directions to perform the user identification and authorization.

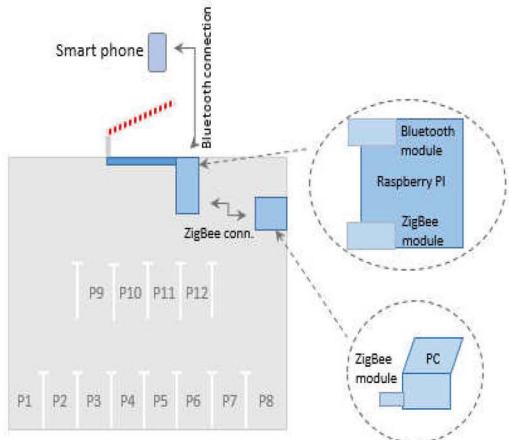


Figure 2. Proposed embedded system developed solution for access, identification and authorization

When the user approaches the entrance and initiates mobile phone Bluetooth communication with the Raspberry PI embedded board, the booked parking ID is transmitted over the Bluetooth connection. Then the ID is sent to the workstation over ZigBee wireless communication using XBee module. On the receiver side, the workstation acquires the booked ID data and processes for further transmission. The transmission is realized by calling Web service hosted at centralized system. Used Raspberry PI board can run different operating systems and the boards in the proposed system are running Linux OS.

### IV. EMBEDDED SOFTWARE IMPLEMENTATION

Several software modules were developed to provide needed system functionalities. The software modules were developed using Java programming language and the popular Eclipse development framework. There exist two embedded software modules in the system: one on the embedded Raspberry PI board running on lightweight Linux OS and the other on workstation for communication with XBee module and centralized Web application.

The software module for Bluetooth communication, deployed on the Raspberry PI board, is used for communication of user mobile phone and Raspberry PI board at the entrance of the parking object or parking space. Initially, Bluetooth service is registered to define the data type for stream. Then Bluetooth connection is opened and listens to incoming connections. When user initiates connection using mobile application, data of user identification are transmitted over Bluetooth connection. After receiving, the data are parsed and transmitted over XBee module to the workstation.

The software module on the workstation is developed to receive data from entrance of parking garage or parking object over ZigBee communication protocol. The data is received using XBee module connected to workstation. After receiving, the data is being processed to transmit to the centralized system Web application, by calling the Web application Web service to verify the user booking. This data is sent to prove identification and booking of parking place. If the Web service responds with successful status, data is sent back in opposite direction to user to inform user on mobile phone. In such situation user gains possibility to enter and park to the previously booked parking place. The workstation requires active Internet connection to establish the connection to the centralized Web application. In case the user did not realize any booking, no communication is required between such devices and user can entry the parking space or the garage using mobile phone and search for free parking place.

### V. IMPLEMENTATION OF WEB AND MOBILE APPLICATION

Web application is developed using different frameworks and it is hosted on server on what the application server is installed and configured. The application server uses encrypted connection and server certificate needs to be installed. Web application manages reservations and identification of authorized users with access to parking facilities, garages and/or public parking areas. It is understood that such users have necessary (registered) identification and access data such as user name, password, and other information, with the aim of booking parking spaces and user identification for access to parking place. Reservations and access to the central application is realized with mobile application using encrypted connection. Web application was developed using the ASP.NET framework along with the MVC pattern. The programming language used was C #.

Communication between the individual segments of the system is achieved through Web services. WCF is framework used for development of service-oriented applications. Using WCF, data can be sent as asynchronous messages that can be

simple, such as one character or word sent as XML, or complex such as a series of binary data. Microsoft SQL Server on the centralized side was used to develop the database for data storing, retrieval and management for the implemented embedded system. Because of its simplicity and reach set of features the entity framework was used.

Visual Studio 2015 was used as development tool for the Web application and for development of Web services. Applications are located at the central Web application server, IIS installed on the server machine. Web services are hosted on separate Web service server. User interacts with the central system through the Web services. After user logs on to the application, the service verifies if user exists in the database and if he/she has the rights for access to a particular object, garage or the parking lot. Part of software for Web service method that checks whether user exists in the database and that have granted access to particular object is shown in Fig. 3.

```
public bool FindUser(string id)
{
    using (SiMobtelEntities ent = new SiMobtelEntities())
    {
        var nid = Convert.ToInt32(id);
        UserHasAccessToObject user;
        user = ent.UserHasAccessToObject.Where(p => p.UserId == nid).
            Select(p => new UserHasAccessToObject
            {
                UserHasAccessToObjectId = p.UserHasAccessToObjectId,
                UserId = p.UserId,
                ObjectId = p.ObjectId,
                DateFrom = p.DateFrom,
                DateTo = p.DateTo
            })
            .First();
        if (user != null) return true;
        else return false;
    }
}
```

Figure 3. Part of software for Web service method on Web application

Client (user) part of the system is the mobile phone application. Mobile smart phone is used as parking place booking device and as user identification device. The developed mobile application supports Android OS. The Android studio development framework was used for development of the mobile application with user interface for login to the system and communicate with the Web application. Once the mobile application is installed and launched, the application requires users to enter a user name and password. After logging in to the system, the main application user interface opens to the user. User can realize vehicle parking booking and some major settings in the application.

User interface for opening and closing of the door when entering a public parking space or garage is shown in Fig. 4. Pressing the button "activate Bluetooth connection" Bluetooth on the user phone is activated and phone is connected via Bluetooth to the Raspberry PI board of entrance of parking space or garage. Once when the connection is successfully established, "open/close the door" option is active. Selecting this option starts verification process for the user access rights. The user gets message if has been identified for the object that he/she is requesting the access. In case that it is confirmed that

user has access, the system will automatically open the parking gate or garage door and record the entry in a central database.

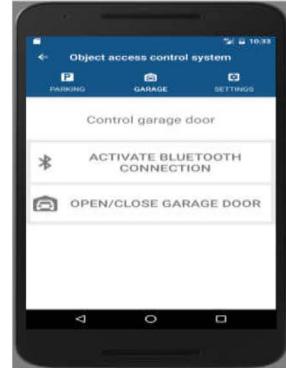


Figure 4. Mobile application user interface to access parking object

## VI. CONCLUSION

The rapid development of powerful mobile phones and embedded systems is affecting the entire business and private requirements and activities. The mobile applications are transforming humans and employees the daily living and working style, offering simplicity, time saving and efficiency. Such mobile phone usage will continue to grow in business and private purposes. The mobile phones already have enough hardware resources to be used as valuable devices for many tasks in business buildings, public spaces, public and private objects, industry or different kind of services. The proposed embedded system for user identification and access to objects or services with limited access using mobile phone shows the possibility of implementation of a system for access control and parking place management. The system has advantages to users and employees in case of business buildings access also. The advantages are time saving and organization in a manner of decreased parking place search time, better organization and retention avoidance. Used boards and mobile phone have enough hardware resources to run OS along with developed Java application and mobile application, respectively. The system is low-cost and very flexible. With small modifications it can be used in many similar applications that need user identification.

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