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# A COMPARATIVE STUDY OF THE IMPLEMENTATIONS DESIGN FOR SMART HOMES/SMART PHONES SYSTEMS

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**Abstract**

Actually many people are adopting smart home technology to improve their home comfort and their quality of life. But despite the diverse of technology components, choosing the right one can be confusing. This paper presents a comparative study of the main components of a Smart Home/ smartphone systems such as communicative protocols (Blethoot, Wi-fi, Zigbee and UWB), microcontrollers (Arduion and Raspberry Pi) and devices. Also it describes their main characteristics and performances like power consumption, transmission time, and complexity.

***Keywords:***

Smart home;
Automation systems;
Wireless protocols.



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## 1. Introduction

Internet of Thing is a network of internet-connected objects able to collect and exchange data using embedded sensors. It can support numerous applications and services in various domains, such as smart cities and smart homes [1]. IoT ensure to people to be connected anyplace and anytime, using any network and any service [2].

Automation is an application of IoT technologies. It is a system of operating a process by electronic devices with the minimization of human intervention. It is the monitoring and the controlling of the devices in homes, by using different types of sensors and actuators that control lights, temperature, and humidity [3]. The main example of automation system is the house automation or Smart home. It is a home which presents an easy and convivial life style. The main objectives of smart home are comfort, healthcare, and security services [4]. Usually a smart home is a home which is equipped with ambient intelligence technologies that meets the needs of its owners through guaranteed comfort and safety by implementing connections with the outside world to act in the house [5]. Smart homes offer a better quality of life by introducing automated appliance control and assistive services [6].

Inside the smart home, mobile networks will exist with various wireless technologies. It will connect a set of devices [7]. Since smart phones are very usable, a smart phone application

controlling our automation system is often easier to interact with than human machine interface using a PC. Smartphone will provide an interface for monitoring and controlling smart home devices from anywhere with mobile coverage. Fig.1 shows a model of smart home system controlled by a Smartphone

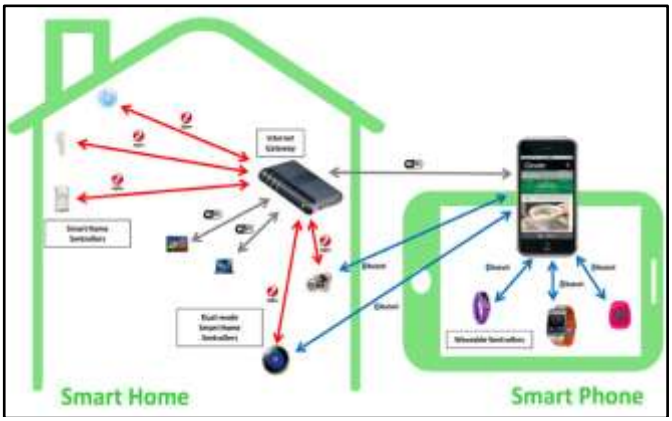
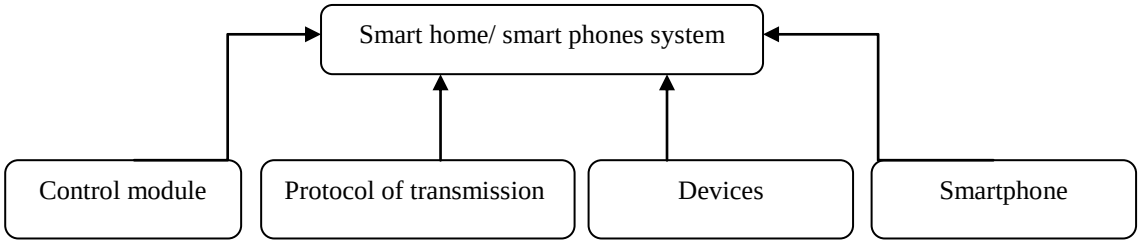



Figure 1: Model of smart home system monitored by a Smartphone

Alexandre Chaverot, president of the French company Avidsen (which manufactures and manages the Thomson box) said: "What has the Smartphone changed? All First, with the Smartphone, the consumer has an interface very playful man-machine, very easy to use. (...) With the Smartphone we are constantly connected to the Internet and all that can be behind the Internet in a very playful way (...) The Smartphone has simplified everything to excess and has enabled permanent connectivity [8].

The smart home/smart phone system is based on main components which are:




- **Control module** (Central controller): It is a hardware device that receives the users' orders and collects the data then transmits them to the home appliances
- **Protocol of transmission**: It is the language smart home devices use to communicate with one another.
- **Devices and appliances**: Such as sensors which detect and respond to some type of input from the environment.
- **Smartphone**: A smartphone app is dowlned on the smartphone. It allows user to control the home remotely and stay connected through alerts and notifications

In spite of the growth of smart home systems, its success hinges upon solving three challenges of interoperability, usability and cybersecurity [9].

- **Interoperability**: the main issue for the smart home technologies and devices is that they can share information between them. So a smart home is a system which achieves full interoperability and ensures full devices communication.

- **Usability**: A basic challenge is the usability. It is important for smart homes because it is concerned with the effectiveness, efficiency, and user satisfaction of systems [10].
- **Cybersecurity**: Smart homes come with some security concerns. It is integrated wirelessly, so hackers who find a way to access the network may have the ability to leave the home vulnerable to an intrusion like turn off alarm systems or turn devices on and off rapidly, which could ruin some electronics.

This paper presents an overview of home automation systems. It's describes the implementation of some implemented home automation techniques and it compares their cost, performance and other proprieties. This paper also discusses the comparison of some popular home automation techniques and presents their advantages and disadvantages.

## 2. Related Work

Most smart home implementations generally make use of a wireless sensor network for communication between home appliances and main unit technologies [11]. Then, researchers focus not only on hardware and software technologies designed but also communication [12].

Various smart systems have been proposed and consist of different technologies and appliances. In the research [13] the authors present the design and implementation of a low cost home automation system. The system is implemented with Arduino BT card (as a 8-bit microcontroller board based on the ATmega168) and the appliances are connected to the input / output ports of this card via relays. The communication between the cellular phone and the Arduino BT card is wireless. For the cell phone script is written in Python, it is portable and can run on any platform of the Symbian operating system. This Python script communicates with the Arduino BT board and sets up an ad-hoc communication protocol between the two devices, which allows controlling the behavior of the Arduino BT board.

In another research work the authors M. Rana and R. Singh [14] present a smart home based on the ATmega128 microcontroller and Bluetooth technology. The project consists of the mobile application developed on the Android platform; it is required to use this system which can be downloaded for free on Google Play and the electronic circuit board which is used for control and consists of a microcontroller, a Bluetooth module, a relay control circuit and relays which serve to switch electrical charges on the circuit and switch the power supply. The microcontroller used in this system is high performance and low power RISC architecture based on 8 bit MCU. The process of the system is as follows: The Android application sends a message that is received via the Bluetooth module and transmitted using the USART serial interface to the microcontroller which performs the necessary actions.

J.Bangali and A.Shaligram [15] present a smart home based on GSM (Global System for Mobile communications) technology. The communication between users and home environment is done only via the SMS (Short Message Service). The system is implemented with the microcontroller IC. The central controller is Atmega644p which is 8-bit Microcontroller with 16/32/64K Bytes and in-System Programmable Flash. In addition to a SIM548C based GSM module. It provides GPRS multi-slot class10 / class8 capabilities and supports GPRS. The system detects and collects information from the sensors, makes a decision and sends SMS to a corresponding number using a GSM modem. If it detects an interruption of its sensors, the microcontroller will send an SMS to the owner of the house. The main advantage of this system is that it gives good response to the sensor and sends SMS when it detects intrusion. The defect of it is that it is limited only to mobile network area.

In the research [16], B.Davidovic and A.Labus implement a smart home using Wi-Fi, Raspberry PI, Android device and Bluetooth. Raspberry PI device is used to control the flow between mobile device and sensors that works on 700 MHz ARM processor and 512 MB RAM. Raspbian OS is used on Raspberry PI and the server running on Raspberry PI device is written in Python - since Raspberry PI has Python already installed on it. Communication between the Raspberry PI and devices (smart home appliances) is done through Wi-Fi network whereas the communication between the Raspbery PI and the smartphone is done via Bluetooth.

T.N.Kumar and T.C.kala [17] propose as smart home system based on raspberry pi board which is connected to all the electronic home appliances and also it is connected to the Wi-Fi by using Wi-Fi module. The proposed system can be operated and controlled through the smart phone or computer or tablet. Raspberry PI 2 is interfaced with either PC or Mobile Phone by Using Web Protocol. Raspberry PI is connected to Electronic Switching System. The authors [17] choose MQTT (Message Queue Telemetry Transport) protocol. It is a type of IOT (internet of things) protocols. And for implementing MQTT protocol the author use mosquito broker or Node.js.

TABLE 1 shows the summary of central controller and the protocol of transmission used for the implementation.

TABLE 1: Summary of various smart home systems

| paper | Central controller | Protocol of transmission | Smartphone controller |
|---|---|---|---|
| [13] | Arduino BT | Bluetooth | Python script |
| [14] | ATmega128 | Bluetooth | Android platform |
| [15] | Atmega644p | GSM | SMS |
| [16] | Raspberry PI and Android | Bluetooth | Android |
| [17] | Raspberry PI | Wi-Fi | Mobile phone |

Several home automation systems have been implemented with different methods and tools, which requires a comparative study of all these elements.

**3. Comparative Study**

Many researchers present Smart Home by using different components and equipment. The efficiency of the proposed systems depends on the choice of these devices. Generally, smart homes offer comfort, security, safety and remote control. Then a home is flexible and easy to use is a home which is based on the correct choice of wireless technologies for communication and of the microcontroller. The next sections discuss smart home elements that are essential for the functionality and efficiency of smart homes like the protocol of communication, the control module and sensors.

3.1. Technologies and protocols

There are a variety of technology platforms, or protocols, on which a smart home can be built like Bluetooth, ZigBee, WI-Fi, Z-Wave. Choosing a smart home protocol depends on many factors such as power consumption, bandwidth and cost.

a) Bluetooth

Is an easy communication protocol which makes digital devices forms a network in which the appliances and devices can communicate with each other [13]. Bluetooth is at the core of hundreds of products. It has higher data bandwidth which make it operates in the 2400-2483.5 MHz range within the ISM 2.4 GHz frequency band. Also it has a high communication rate, great security and low cost, so it can be implemented as a real time system [18] [19]. Bluetooth has a physical range of 10m to 100m [20], so for devices that require a constant connection. However, it has been reported that the newest version of Bluetooth (Bluetooth Low Energy, or BLE) will be capable of forming mesh networks, greatly extending its range [21].

b) Wi-Fi

Wi-Fi is another protocol for wireless home network. It is an advanced automation system that uses radio frequency to transmit data through the air. With an initial speed of 1 mbps to 2 mbps, it transmits data with a frequency band of 2.4 GHz thus establishing the concept of frequency division multiplexing technology and ranges from 40-300 feet [22]. Wi-Fi is an open global standard built on the IEEE 802.15.4 MAC/PHY. Wi-Fi defines a network layer above the 802.15.4 layers to support advanced mesh routing capabilities [2].

c) ZigBee

ZigBee is a protocol for communication among devices used for home automation. It is an IEEE 802.15 standard and resembles Bluetooth and Wi-Fi standards [19]. ZigBee is the most popular wireless network communication technology because of its low power consumption and open specifications [23]. ZigBee networks support devices with longer range and it network is a robust network and that is easily scalable [24]. It is a wireless mesh network standard targeted at battery-powered devices in wireless control and monitoring applications.

d) UWB

Ultra Wideband is a wireless technology for transmitting large amounts of digital data over a wide spectrum of frequency bands with very low power for a short distance. One of the most exciting characteristics of UWB is that its bandwidth is over 110 Mbps, which can satisfy most of the multimedia applications such as audio and video delivery in home networking and it can also act as a wireless cable replacement of high speed serial bus [25]

More details about proprieties of these technologies are presented in TABLE 2.

TABLE 2: Comparison of the Bluetooth, Wi-Fi and Zigbee protocols

| | **Bluetooth** | **Wi-Fi** | **ZigBee** | **UWB** |
|---|---|---|---|---|
| **Standard** | IEEE 802.15.1 | IEEE 802.11 | IEEE 802.15.4 | 802.15.3a |
| **Battery life** | hours | days | years | |
| **node** | 7 | 256 | 65000 | 8 |
| **Data rate** | 732 Kbits/s | 11-105 Mbits/s | 250 Kbits/s | 110 Mbits/s |
| **Range** | 1-10m | 30-100m | 10-30m | 10m |
| **Power consumption** | medium | high | Very low | Lowe |
| **RF frequency** | 2.4 GHz | 2.4 - 5 GHz | 868MHz -2.4 GHz | 3.1-10.6 GHz |
| **Application focus** | Cable replacement | Web, video and email | Monitoring and control | Cell phones, audio players |

We compared these standards on several criteria. Discussion on this topic seems to center on performance factors like data rate, transmission range and Power consumption.

- **Data rate**

One performance factor was the data rate. Wi-Fi and UWB provide a higher data rate, while Bluetooth and ZigBee give a lower one. The raw data rate will be high enough (maximum of 250 Kbit/s), but is also scalable down to the needs of sensor and automation needs (20 Kbits/s) using wireless communications. Bluetooth has a data rate approximately 732 Kbits/s.

- **Transmission range**

Another performance factor is the range of communication. Wi-Fi serves up for PAN and WLAN area networks with an average range between 30 to 100 meters. Whilst Zigbee is restricted to Wireless Personal Area Networks (WPAN) with a range 10-30meter. The range of a Bluetooth and UBW connection is between 1 and 10 meters. Due to this short range, a Bluetooth connection is said to create a personal area network (PAN). The figure 2 compares technological characteristics (data rate and range) of the four wireless technologies

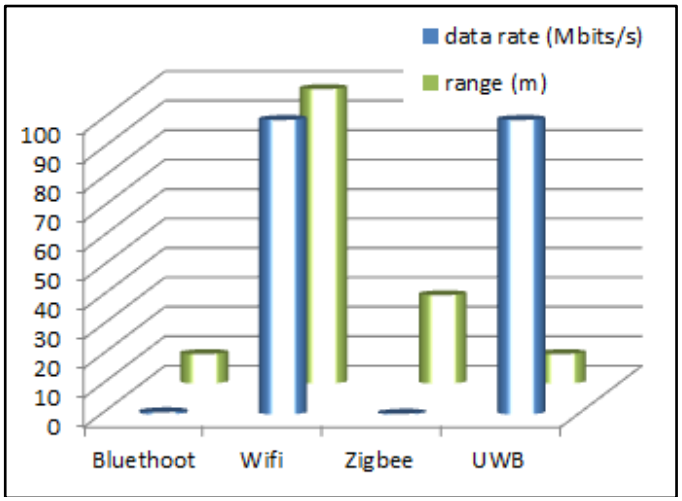



Figure 2: Comparison of data rate and range for the Bluethoot, Wifi, Zigbee and UWB

- **Power consumption**

Wi-Fin and UWB are not a good selection in terms of energy usage. Wi-fi is designed for a longer connection and supports many devices. UWB is used for short range and high data rate applications. Unlike to Bluetooth and ZigBee, they offer very low power consumption because they are intended for short ranges and low data rate. Recently Bluetooth developed a new feature called Bluetooth Low Energy (BLE) that can make the applications run on a small battery for four to five years.For ZigBee, it is can be characterized as low-power variant of Wi-Fi, as it covers the same area as Wi-Fi and transmits through furniture, walls and floors. The difference compared to Wi-Fi is that ZigBee hardly uses energy and enables coin cell operation that can last for 10 years or more.

From this comparison, Wi-Fi is speed and flexible; it has the longest range 100 m while ZigBee, Bluetooth, and UWB are intended for short range 10 m. ZigBee and Bluetooth have a low cost and consume less power. UWB and Wi-Fi provide higher data transfer rates.

3.2. The control module

The control module consists of as microcontroller which is basically a board that implements the control and data busses to communicate with the other devices. TABLE 3 compares the two currently used microcontrollers: Arduino and Raspberry Pi.

a) Arduino

Is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software [26]. The Arduino IBOARD is a microcontroller Board Based on the IBOARD with 54 digital input / output pins [27][28]. It is a 8 bit Atmel AVR Microcontroller which comprises of 32K and 512K of onboard flash memory, 2K of RAM, runs at 8- 84MHz clock speeds with voltages of 2.7V 12V. Programming is done using C. The code is written in the computer and then sent through USB cable for execution. Its power consumption is less than 0.5 watt [29].

b) Raspberry Pi

Raspberry Pi is a fully functioned computer, a system-on-chip (SoC) device. It is a credit-card-sized single-board minicomputer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools [30]. The Raspberry Pi has a Broadcom BCM2835 system on a chip, which includes an ARM1176JZF-S 700 MHz, Video Core IV GPU, and was originally shipped with 256 megabytes of RAM, later upgraded to 512 MB. It does not include a built-in hard disk or solid-state drive, but uses an SD card for booting and long term storage [31] [32].

We compared these standards on several criteria related to performance factors:

- **Power consumption**

Arduino uses less than 100mA of current, often much less and there are sleep mode software libraries like narcoleptic that give even lower consumption. The Raspberry Pi has impressive specifications and requires more power than the Arduino. Then Raspberry Pi consumes substantially more current and there are no sleep modes available to substantially reduce this.

- **Power Input and clock speed**

Both a Raspberry Pi and an Arduino can run on a 5V DC input. But if the power drops on the home, if it is a Raspberry Pi based system, you must shut it down within the operating system like any other computer, or else risk corruption and software problems. Unlike on Arduino, it will just start running code when it's plugged back in and you won't end up with a corrupt operating system or other software errors. For the clock speed, the Raspberry Pi is 40 times faster than an Arduino.

Other factors for performance include integrated Development Environment, storage and open source are assigned with values as given in TABLE 3. This makes the Arduino a better option for small, portable projects and the Raspberry Pi is better suited for complex projects with software components.

TABLE 3: Typical parameters of Adruino and Raspbery Pi

| | **Arduino** | **Raspberry Pi** |
|---|---|---|
| **Price** | 20-30 | 35-39 |
| **RAM** | 2KB | 256MB |
| **Processor** | 16MHz AVR ATmega328P | 900 MHz Broadcom ARM Cortex-A7 |
| **Storage** | 32 KB | n/a |
| **Language** | Arduino | Python, C, C++, Java, Ruby |
| **Input voltage** | 7-12V | 5V |

3.3. Devices and appliances

To make the home smarter, it is necessary to have some devices or appliances connected to the internet which make the home controlled remotely using a smartphone. Many devices are on the market. Among the variety of devices category, sensors and multimedia device are the most used to implement a home automation system.

Light sensors are used to measure the luminance level of the home and accordingly lights will be turn ON or OFF [15]. Temperature sensors are used to measure some time both temperature and humidity like SHT75 sensor [33]. These sensors can be used as a comfort system that will alert when the room temperature is higher or lower. For example, if it's not the safest temperature for baby's room an alarm should sends user a notification. Many researchers use PIR (Passive Infra-Red) sensor to detect whether a person has moved in or out of the sensor's range. It is used for security systems to detect suspicious movements [34] [35]. It is small, low power, easy to use and it has a wide lens range [36].

Among the objectives of smart home system is provide the security to user. This security system can be implemented through using multimedia device as microphones, proximity sensors, and alarms [37]. Cameras are the most important device to ensure home security. It takes a picture of the situation in the home and sends it with the appropriate alarm. The camera can be also used to learn the habit of the users and collect information about the environment that may be used to predict the likelihood of intrusion events [38].

There are many smart home device categories, so smart homeowner can control everything from lights and temperature to conform and security in the home. There should be additional methods and programs to improve the quality of detection of sensors and their performances. Then more researchers are required to obtain a whole smart home

## 4. Conclusion

With the right technology choice, smart home solutions can help make the home safer, smarter and more efficient. Therefore this work presents a comparative stady of the implementations designe for smart home/ smart phone systems. It is a general overwiew which discusses some components and compars the technologies used for home automation.

This paper has presented an overview of the four most popular wireless standards. Bluetooth is more convenient, but it is implemented only in the short range. Wi-Fi is a very popular technology used. It allows communications over the Internet without needing a protocol translator. ZigBee is an efficient and cost effective wireless because it offers low data rate for personal area networks. For UWB, it is a used for short range and its main advantage is the high data rate applications.

For the smart home micro-computer, Arduino based home automation system is a low cost and easy to use for small project. RasberryPi is more used for the complex project because of its speed and storage.

The comparison presented in this paper would benefit in choosing an appropriate technologies to implement a low cost-effective and flexible smart home system which must be easy to use, effective and more convivial.

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