An Investigation on IoT-based Approaches for Street Lighting in Smart Cities

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Abstract
Nowadays, smart cities are one of the most important application areas of Internet of Things (IoT) technologies. In smart cities, there are technological systems in many different areas such as pollution, traffic density, weather, lighting systems, gas and water leakage monitoring to provide comfort for city residents. The improvement on IoT technologies decreased installation and maintenance costs of these systems considerably. IoT also enables highly automated monitoring in smart cities. In this study, an investigation and evaluation of the approaches covering the use of IoT technologies for street lighting in smart cities is performed. Recent IoT applications have been taken into consideration particularly, and hence 18 different approaches are examined in depth. Different components of these solutions, such as IoT technologies, hardware platforms, operating systems, cloud information technologies and sensors are evaluated. With this paper, the studies considering street lighting in the smart cities have been thoroughly examined and the orientation of the technology has been determined. We believe that the comparisons and the investigations in the paper will guide to the researchers aiming at working in this field.

Keywords: Smart Cities, Internet of Things, Smart Street Lights, Light Depending Resistors.

1. INTRODUCTION

The Internet of Things (IoT) is one of the most promising areas today. IoT is used in many domains such as Smart Cities, Smart Public Transportation, Industry, Production, Agriculture, and Health. IoT is a structure that objects are connected to each other and to rest of the Internet. The "thing" is any object that can connect to the Internet and exchange information. In IoT, things are interconnected, and they can also exchange data. The main improvements which facilitate the development of IoT can be listed as downsizing of circuits, less energy consumption and increasing CPU performance [1].

There are some fundamental elements in the concept of IoT. Devices in IoT can be a simple sensor to measure light intensity, temperature and humidity. This structure can be used in a wide range of areas such as smart cities, smart public transportation, tea machines, dishwashers, cars, buildings and industrial devices.

At the lower level, IoT devices exchange data using a network layer. The most known protocols in the IoT domain are Wi-Fi, Bluetooth, Zigbee, Cellular Network, NB-IoT, LoRAWAN (Long Range Wide Area Network). Some common application protocols are HTTP, MQTT, CoAP, AMQP and XMPP [1].

Smart cities offer many opportunities to the public through IoT and many other technologies. Intelligent parking, health services, traffic monitoring, garbage control, fire control, air pollution monitoring and smart lighting are examples of these opportunities. With smart lighting, energy efficiency and automatic control are provided in smart cities. In this paper, the recent studies in the literature related to these systems have been examined in detail and the technical orientation has been determined.

The rest of the paper is organized as follows. In Section II of the paper, investigated recent studies are given. In Section III, smart lighting IoT technologies are discussed. In the last section, conclusions are drawn.

2. INVESTIGATED RECENT STUDIES

Recent studies, published between 2016 and 2019, including IoT smart city and lighting studies are examined. In this section, these 18 studies will be briefly introduced. In the next section, these studies will be discussed in detail.

Intelligent lighting systems in IoT-based smart cities constitute a popular research area [2 - 8]. It is possible to work together with many different technologies. Within this context, the work in [2] introduces a solar lighting system for intelligent city control cards. In [3], the Raspberry Pi development environment is used to control IoT system hardware to provide intelligent lighting. The design of a supply system for smart cities is described in the study given in [4]. Energy efficiency is very important in IoT applications [5, 6]. Some studies also include IoT-based intelligent management systems [7, 8]. Energy efficiency is also very important in smart home services [9 - 13]. In the study presented in [9], the IoT system can be controlled by an Android smartphone application. The work in [10] provides environmental monitoring and control inside a home automation environment. In [11], a home IoT system with sensor nodes is developed. Smart home systems using Arduino are also encountered [12]. Moreover, smart home system is studied within the scope of using MQTT protocol [13]. There are also IoT studies using LDRs in many areas such as agriculture [14], environmental monitoring [15], solar energy [16], office [17], renewable energy [18], and weather station [19]. In these studies, operating systems mostly include Linux and its variants. Almost all of these studies use LDR and some benefit from cloud computing. In some of these studies, ready-made hardware tools such as Raspberry Pi are used.

3. SMART LIGHTING IoT TECHNoLOGIES

When the IoT studies for the smart cities are examined, the main components in which the systems differ are sensors, hardware platform, operating system, physical communication environment and cloud computing platform. We present a summary of the examined studies in Table 1 with taking into consideration these components. The technologies encountered in all studies are also evaluated in the following subsections.

Table 1. Comparison Table

Study	Sensors	Hardware platforms	Operating Systems	Physical Com. Interface	Data/Cloud Platforms
[2]	LDR	Arduino Uno	-	Wifi	-
[3]	LDR	Raspberry Pi	Raspbian	Wifi	Apache Tomcat Ser.
[4]	LDR	Raspberry Pi 3	Raspbian	Wired Net.	-
[5]	LDR	Raspberry Pi	Raspbian	GSM	-
[6]	LDR	Arduino	-	Wifi	-
[7]	LDR	Arduino Nano	-	Wifi	Database
[8]	LDR	Arduino Uno	-	Wired Net.	Database
[9]	LDR	Arduino Mega	-	Wifi	-
[10]	LDR	Raspberry Pi 3	Raspbian	Wired Net.	Cloud
[11]	LDR	Arduino Uno	-	Wired Net.	XAMPP Ser.
[12]	LDR	Arduino	-	GSM	-

[13]	LDR	NodeMCU	-	Wifi	Adafruit IO Cloud
[14]	LDR	Arduino	-	Wifi	Database
[15]	LDR	Raspberry Pi	Raspbian	Wired Net.	-
[16]	LDR	Arduino	-	Wifi	-
[17]	LDR	Raspberry Pi	Raspbian	Wired Net.	Database
[18]	LDR	PIC Based Mic.	-	Wifi	Database
[19]	LDR	NodeMCU	-	Wifi	IBM Bluemix Cloud

3.1 Sensors

In smart lighting systems, light sensors are the most important part of the physical layer. Within this context, our investigation showed that Light Depending Resistors (LDR) are used in all studies. There are different technologies for detecting light intensity like Ambilight sensors. But LDRs are inexpensive and most preferred. LDRs are basically passive components whose resistance varies with the intensity of the light falling on the component. LDRs are used with a different resistor whose value does not change in the circuit. As light falls on the LDRs, they form a voltage divider circuit, and hence the voltage at the voltage divider changes. Thus, an analog signal is obtained which varies according to the intensity of the light. Figure 1 shows a LDR sensor.

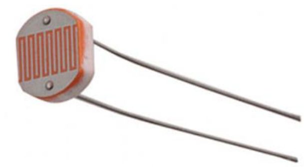

Figure 1. A LDR sensor [20]

3.2 Hardware Platforms

We see that the studies examined herein mostly include systems that have no operating system such as Arduino [2, 6 - 9, 11, 12, 14, 16], NodeMCU [13, 19] and PIC [18]. In addition, hardware platforms such as Raspberry Pi that run with the operating system are also frequently used [3 - 5, 10, 15, 17]. These present designs made by companies with special processors and ready-to-buy hardware platforms. While companies can develop hardware according to their needs, they can also use ready-to-buy development environments by considering the factors such as development cost and speed. Ready-to-buy development platforms e.g. Raspberry Pi and Arduino also enable both easy code development and the implementation of a wide range of IoT technologies. In some platforms, blocks to facilitate Internet access are already available. Internet modules can be added easily into the other platforms in which the Internet connection is unavailable.

The LDR sensor output signal should be connected to an analog signal input port of the hardware development environments. Conventional analog circuit designs are available for this purpose. However, these traditional methods work alone and do not allow any remote monitoring. These methods do not apply to IoT systems. Different methods, tracking the light intensity analog signal, have been encountered. These are analog-to-digital converters (ADC) and general-purpose input outputs (GPIO). ADC and GPIOs are available on hardware platforms with a processor and intelligent tracking mechanism.

3.3 Operating Systems

There are operating systems running on some of the development platforms discussed in the previous section. Operating systems can be implemented with different software languages and architectures. During our investigation, only Raspbian operating system that is a Linux distribution was encountered in the studies e.g. [3 - 5, 10, 15, 17]. Raspbian is developed for Raspberry Pi development platform. Apart from Raspbian, there are different operating systems for IoT domain such as Android Things and Windows 10 IoT which can be used in street lighting applications. Moreover, there exists stand-alone software running on some dedicated platforms which cannot be considered as full-fledged operating systems such as Arduino and NodeMCU [2, 6 - 9, 11 - 14, 16, 18, 19].

3.4 Physical Communication Interface

One of the most important features of IoT systems is the access to a database or cloud computing over Internet Protocol (IP). All of the studies examined in this study consist of IP-based systems. While some of these studies use classical wired IP structure [4, 8, 10, 11, 15, 17], remaining solutions use wireless physical environments such as GSM [5, 12] and Wifi [2, 3, 6, 7, 9, 13, 14, 16, 18, 19]. Here, the use of an IoT-specific system such as LoRaWAN, NB-IoT or Sigfox has not been encountered yet. In the future, with the widespread use of IoT systems, the use of these technologies is expected to increase, especially in smart cities.

3.5 Data/Cloud Platforms

The sensor information can be collected on different cloud platforms such as Google Firebase, Samsung Artik and Microsoft Azure. These platforms often provide users with convenient interfaces and analysis capabilities. However, these common cloud environments are not used in the IoT applications we examined. Instead, some sort of specific cloud platforms [10, 13, 19] and/or databases [3, 7, 8, 14, 17, 18] are used. It is predicted that the use of cloud will become widespread shortly in these IoT applications.

4. CONCLUSION

In this study, 18 different recent smart lighting applications used for IoT smart city are examined. The trends in IoT technologies are determined during the investigations. The technologies considering sensors, hardware platform, operating system, physical communication interface and data/cloud platform are examined.

Light sensors are the most important part of the physical layer of the systems. Within this context, our investigation showed LDRs are used the most. Different hardware platforms were also examined in this study. These present designs made by companies with special processors and ready to buy hardware platforms such as Raspberry Pi or Arduino. While companies can develop hardware according to their needs, we see that they can also use ready-to-buy development environments by considering factors such as development cost and speed. There are operating systems running on these development platforms.

During our investigation, different real-time operating systems are also encountered in addition to Linux and derivative operating systems. Rasbpian is currently used in many applications. Moreover, there exists stand-alone software running on some dedicated platforms which cannot be considered as full-fledged operating systems. However, it is anticipated that the use of IoT-specific operating systems will increase in the future. One of the most important features of IoT systems is the access to cloud computing over IP. All of the applications examined in this study consist of IP-based systems. Wired network, Wifi and GSM are still used frequently for IP based communication. It is predicted that technologies such as LoRaWAN, NB-IoT or Sigfox will become widespread in the future. Taking into account the choice on the repositories, it is still common to use of databases to save and evaluate data comparing to cloud-based solutions. However, the cloud usage has recently emerged and it is quite likely that most of the applications will be based on the cloud platforms in the near future. We believe that the comparisons and the investigations given in here may guide to the researchers aiming at design and implementation of street lighting systems in the smart cities.

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