❒ 3123

Automatic control system of highway lights

Yasir Hashim[1], Mohammed Nazmus Shakib[2]
[1]Department of Computer Engineering, Faculty of Engineering, Tishk International University, Iraq
[2]Faculty of Electrical and Electronic Engineering Technology, Universiti Malaysia Pahang, Malaysia

Article Info	ABSTRACT
	This research provides new effective and cheap designed system for save electrical energy dissipation in all urban area roads and highways. The aim of this system is to minimizing the waste electrical power on highways and urban area roads. The designed system depends on two Arduino circuit types, master and slave. The master Arduino has an ability to detect the day light by light dependent resistor (LDR) sensor and cars movements by pyroelectric infrared (PIR) sensor, according to these conditions, the master will send a signal by XBee module works as transmitter to the following five slaves Arduinos which are waiting for a signal and receive it by XBee module works as receiver to turn ON the lights for 5 minutes then OFF it if there is no car movement on the street. The system can mount directly to the highway lights. The system has been tested and applied on the street lights, the system works perfectly and slaves respond fastly and effectively to the master Arduino signal. *This is an open access article under the CC BY-SA license.*
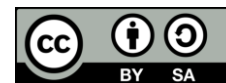
Corresponding Author:

Yasir Hashim,
Department of Computer Engineering,
Tishk International University,
Kurdistan, Erbil, Iraq.
Email: yasir.hashim@tiu.edu.iq, yasir.hashim@ieee.org

1. INTRODUCTION

Automation is one of the most important things in life and plays a big role in the world. Automatic systems have been widely increasing around the world and the reason is that of the busyness of the population, and to make the daily lives of thousands easier and more under control. In this research, the design of a highways and urban street lighting system will have proposed for saving huge amount of power in the highway streets [1-4]. Basically, lighting the streets and highways is an important part of traffic and it is increasing day by day with the increment of traffic density and also increasing of huge power consumed in it. The more any city grows, the more highways among cities needed, thus the more lights will be necessary to illuminate the highways during nighttime. Undoubtedly, the highways need a lot of power to supply those lights, and that becomes quite expensive. Despite its expense it's also a waste, the reason is on some days you might have highway which rarely no any cars drive on. So why should we waste all this energy to keep those lights on while no car is on those streets when we can turn them on whenever a car decides to take that road. And that is the aim of this research, to minimize the cost to keep those lights on, and to save energy for future use, providing an automated, simple, and effective smart street lighting system [5, 6].

Energy usage and the board plots at home, business and industry have been effectively executed with regards to the shrewd matrix. Be that as it may, general society road light framework has not been taken under genuine thought. The immense measure of the electrical intensity of numerous nations is devoured in lighting the avenues. Be that as it may, vehicles go with a low rate in explicit timeframes and parts of the roads are not possessed by vehicles after some time. Two wide-extending patterns in the public arena today are urbanization

and awareness of economic improvement. The urban regions develop bigger which requires new specialized answers for the urban foundations to be vitality proficient. One such imperative framework is road lighting. More road lighting is expected to fulfill the all-encompassing systems of streets, and numerous road lights are obsolete and should be supplanted. As per different past investigations, road lighting is one of the biggest electrical vitality purchasers and records for relatively 40% of the aggregate electrical vitality utilization in urban communities. This piece of the city framework is along these lines a section which is feasible for the regions to enhance and in this way spare both vitality and cost [7].

Road lighting establishments are additionally, aside from vitality devouring, urgent as far as solace and security since they give lighting to streets, boulevards, open territories, asphalts etcetera [8]. Lighting has a huge significance as an urban situation maker and one of its most huge capacities is to give individuals direction, help to orientate and give wellbeing. Out in the city, is the place individuals meet and an intriguing lighting move individual to remain outside, which thus makes the city safe [9]. The ordinary road light framework is the potential buyer of power, and extensive measure of power squandered.

There are some automation systems that well known to use in electrical power controlling such as programmable logic controller (PLC), supervisory control and data acquisition (SCADA) and Arduino based controlling system. The PLC is a device that used mainly in industrial control applications, this controlling device is used oftentimes in the industry because it can be integrated with other industrial devices, strong, and its programing comparatively easier [10-12]. The SCADA control system could be monitor a real-time electrical power generation including hybrid power system contains wind turbine, solar modules with rechargeable battery with ability to measuring data [13-15]. Comparing these controlling systems with Arduino based system, Arduino has creative inspiration in electronics engineering with controlling purposes. The impact of its revolutionary applications with modern ideas has been take attention of researchers around the world [16-18]. For the time being, Arduino is popular used because it helps researchers to design more accessible controlling systems due to the simplified version of C++ with ATmega328 microcontroller [19].

This research is intended with designing an automated system based on Arduino, this system must be added directly to the lighting system in highways to control the lights ON/OFF depending on the conditions under the lights in the highway, and so, this system is an economical energy saving system for highways lights. The idea is turning all the street lights off during the daytime and when it becomes night when the roads and streets are not occupied by any cars the lights would be turned off. Whenever a car decides to take the road it would be detected by a sensor called an IR Sensor and will automatically illuminate the road and turn the lights on for that specific car.

2.   METHODOLOGY AND RESULS OF DESIGNED SYSTEM

Firstly, it must split the lights in the highway into groups of lights each group has 5 lights, if we assume the spacing between light is about 20m then each group will cover 100m long of street. In each group has one Arduino master circuit to detect the car movements and send signal to the 5 slave Arduinos to ON or OFF the lights of group, as shown in Figure 1. So, the system mainly contains two types of circuits, master and slave. The master Arduino also has an ability to detect the day or night time. If it's daytime, then it will do nothing until it becomes night then it detects motion during the night and when detects a motion it will send a signal to the following five slave Arduinos which are waiting for a signal to turn ON the lights or not. After a fixed time, duration which is set at five minutes if the master Arduino pole did not detect any further motion coming from the sensor, it will send no signals which will make the slave light poles OFF after the five-minute periods. Alternatively, if it detects new motion despite the fact that its light poles are ON and the five-minute timer is processing it will send another signal which will reset that five-minute period. So, according to this principle, when the car detected by the master Arduino, the lights will be ON ahead the car with distance of 100 meter, that means, the 5 lights poles as illustrated in Figure 2.

In order to get a general idea and be clarified about the system design, a general block diagram is presented in Figure 3. The system has 2 main parts, master and slave, for master side, first block is presenting the photocell light sensor that detects whether it's nighttime or daytime, if it is a daytime the switching light process does not take place rather the photocell light sensor will wait until the moment it detects darkness so the light switching process starts. If it is a nighttime, then the master Arduino will detect the car movement on highway by pyroelectric infrared (PIR) sensor. if the PIR sensor detected a car movement it will send a signal to the master Arduino and the microcontroller will send a signal to the next 5 Slave Arduino nodes immediately by the XBEE transmitter, the next 5 slave nodes will get the signal through a XBEE receiver and will pass it to the microcontroller then the slave Arduino will use the relay module to turn the light ON. Then, if there are no cars movements in the street for 5 minutes (no signal coming from master node) the lights will turn OFF automatically by the slave Arduinos.
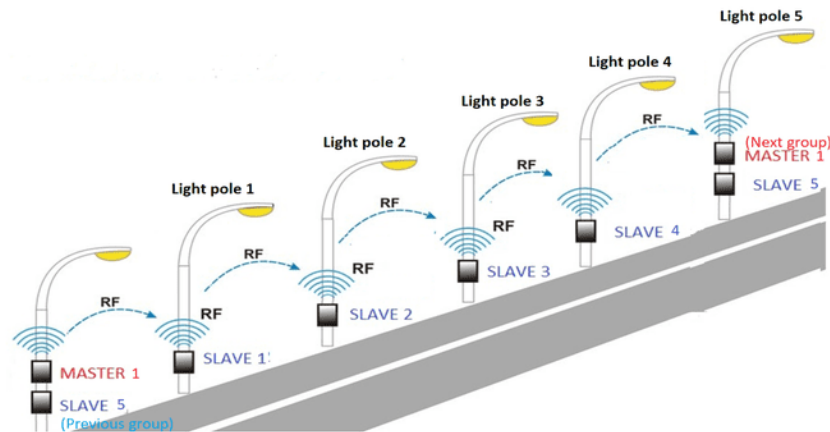
Figure 1. The system design, one master and 5 slaves Arduino mounted on 5 highway light poles
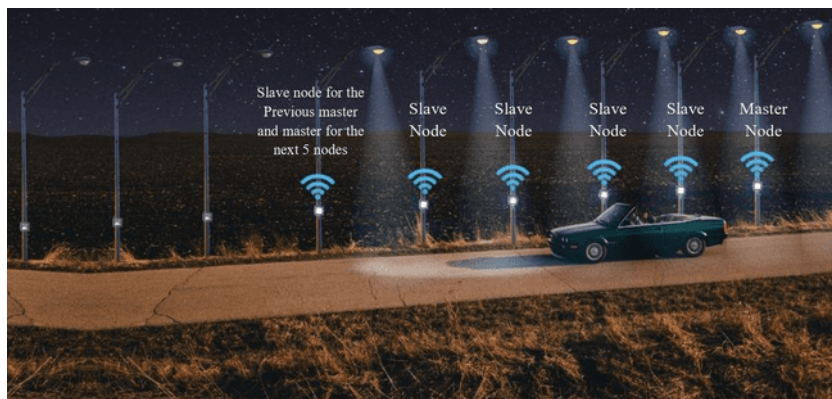

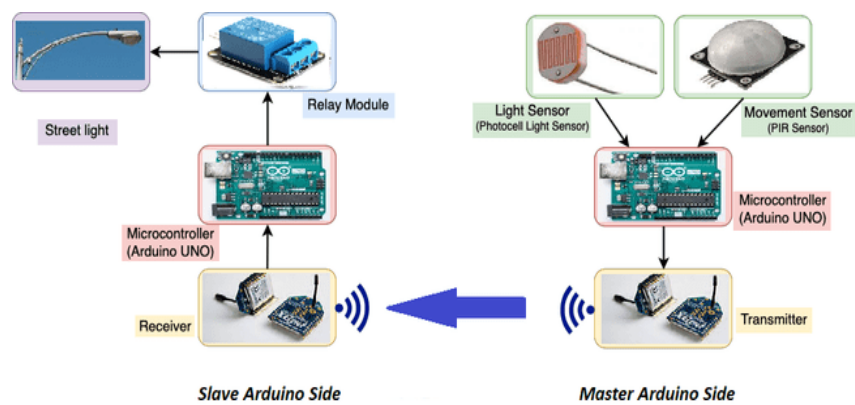Figure 2. Respond of system with car movements

Figure 3. The block diagram of proposed system

The Algorithm of system will be as following:
STEP1: START
STEP2: Master Arduino check the sun lights by light sensors
STEP3: If there is a Sun light then Step-2
STEP4: Master Arduino check the movement of cars by PIR sensor
STEP5: If there is no cars movement move to Step-2
STEP6: Master Arduino send signal to next 5 Salves Arduino
STEP7: The next 5 Slaves Arduino turn ON their highway lights

STEP8: Slave Arduinos check signal from master Arduino for 5 minutes
STEP9: If YES there is signal from master Arduino, Then Step-7
STEP10: If NO, Then the Slaves Arduino turn OFF their highway lights
STEP11: move to step-2
STEP12: END

The Flowchart of system will explain the complete mechanism of smart highway light system. Figure 4 shows the master Arduino flowchart, in this flowchart, the process starts the photocell light sensor will actively check if it's nighttime or daytime. If it was daytime, then it will stay idle but if it was nighttime then the PIR Sensor will work for car motion detection. This will be met with two conditions, has motion been detected? If yes, then it will send a signal to the 5 slaves Arduino to turn the lights ON. Figure 5 presents the flowchart of slave Arduinos, in this flowchart, the slave Arduinos' side has to check if there are any signal comes from the master Arduino. If yes then it will turn the lights ON for five minutes, also if a new motion is detected before the five-minute is finished then the master Arduino will send another signal that will restart count the another five-minutes time. If there is no signal, then it will actively wait for a signal which is shown in Figure 5. The whole process is continuous and looped. The process will not stop unless met with a technical issue.
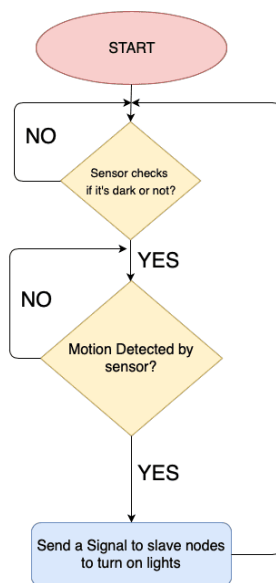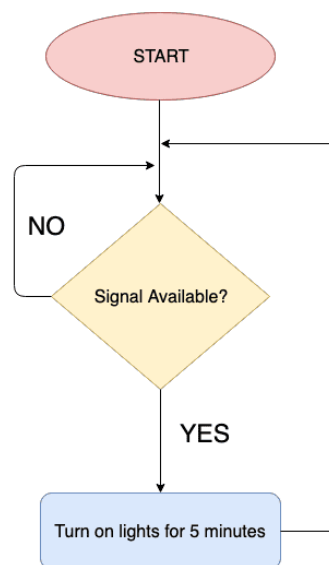
Figure 4. Flowchart for master Arduino   Figure 5. Flowchart for slave Arduino

Covering every required building block of a circuit is very important and essential for a complete description of a research and its ideas. The parts that were used in this project, that work in collaboration with each other to create an interlocked system that enables us to reflect ideas into reality in a flawless functioning form are as follows. Arduino uno has been used as a microcontroller for both sides master and slave circuits, Arduino is an open-source hardware and software company, user community that designs and manufactures single-board microcontrollers and microcontroller kits for designing digital devices and interactive objects that manage to sense and control objects in the physical and digital world. The board is supplied with many digital and analog input/output (I/O) pins that may be interfaced to diverse expansion boards known as shields and other circuits. The board has 14 digital pins, 6 Analog pins, and programmable with the Arduino IDE (integrated development environment) via a type B USB cable. It can be powered by a USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. Arduino uno will serve as a foundation for the exchange of information in this research.

For detection car movement in the street, the PIR sensor has been used, PIR is an abbreviation for passive infrared sensor, which is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. They are most often used in PIR-based motion detectors. The term passive in this instance refers to the fact that PIR devices do not generate or radiate energy for detection purposes. They work entirely by detecting infrared radiation (radiant heat) emitted by or reflected from objects. A PIR-based motion detector is used to sense the motion of people, animals, or other objects. They are commonly utilized in burglar alarms and automatically-activated lighting systems. They are commonly called simply "PIR", or sometimes "PID",

for "passive infrared detector". That is why PIR Sensors are a perfect match for the research. It is effectively compatible with Arduino uno and a great way to detect motion and heat emitting from cars [20-22].

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

In electronics and telecommunications, a transmitter or radio transmitter is an electronic device which produces radio waves with an antenna. The transmitter itself generates a radio frequency alternating current. Similarly, to the transmitter in radio communications, a radio receiver, also known as a receiver, wireless or simply radio is an electronic device that receives radio waves and converts the information carried by them to a usable form. In order to have a network of communication between Arduino master and Arduino slave it needs some form of medium and the one that has been used in this project are radio waves that are transmitted by a device called XBee. Digi XBee is the brand name of a family of form factor reconcilable radio modules that come from Digi International. The initial XBee radios came to introduction through the Max-Stream brand in 2005 and were based on the IEEE 802.15.4-2003 standard by default manufactured for point-to-point and star communications at over-the-air bandwidth rates of 250 kbit/s. There were two models were initially introduced a lower power 1 mW XBee and the higher power 100 mW XBee-PRO. Since the first addition, numerous new XBee radios have been introduced and environs of wireless modules, gateways, adapters and software have been evolved and upgraded [23-25].

The XBee radios are all able to be used with the least number of connections power (3.3 V), ground, in and out data also known as (UART) Universal asynchronous receiver-transmitter, along with other endorsed lines being reset and sleep. In addition, many XBee families have other forms of flow control, input/output (I/O), analog-to-digital converter (A/D) and signal lines built in. An adaptation called the programmable XBee has an extra on-board mainframe for user's code. The programmable XBee and a surface-mount adaptation of the XBee radios were both introduced in 2010 so they are fairly recent.

In order to configure the two Xbees to connect to each other it's required a frequency channel between the two devices by setting up Personal Area Network (PAN) ID, and in order to make the configuration happen it needs X-CTU software. The XBees need to connect to computer through an XBee USB adapter board. For the testing and evaluation purpose of the designed smart highway lighting system, the master and slave Arduino circuits, as shown in Figures 6 to 8, has been built and mounted on the street lights poles with distance 20 m. According to the test result, the system works effectively and efficiently with very fast response of slave Arduino after the car movement detected by the master Arduino. The saving consumed power will depend strongly on the car movements on the highway, if the car movement reduced by 20%, so the consumed power also will have reduced by 20% and it will be huge amount of power and reduced the emission of CO_2 especially for the long highways at urban area.
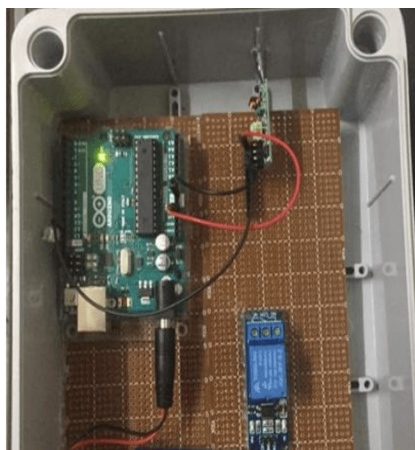

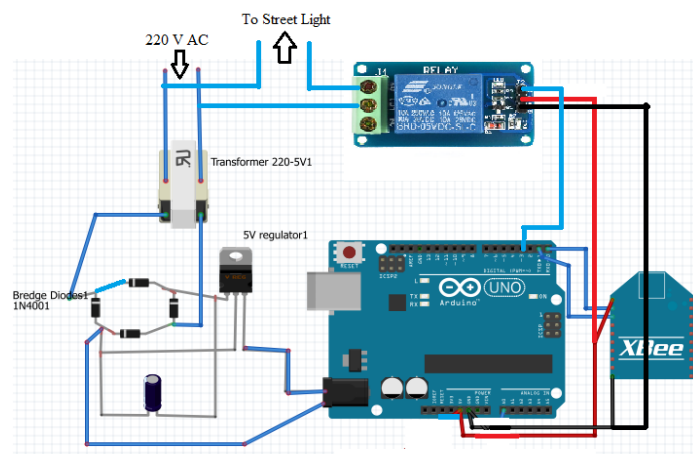
Figure 6. Slave Arduino

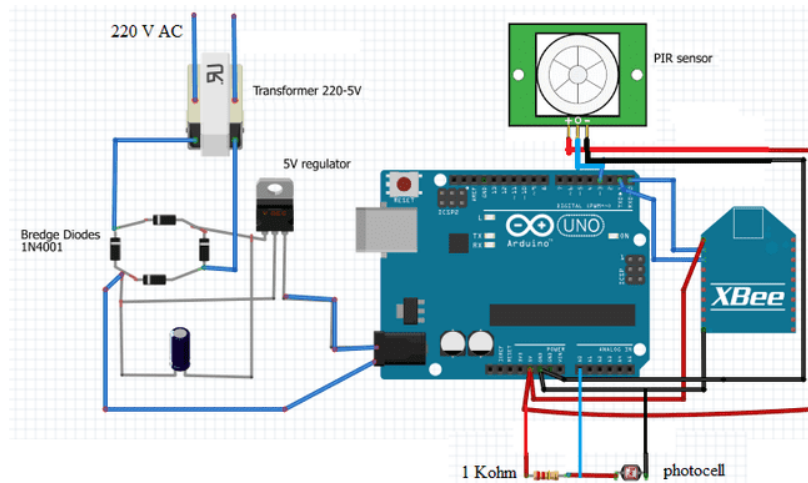Figure 7. Slave Arduino circuit diagram

Figure 8. Master Arduino circuit diagram

3.   CONCLUSION

This research provides better use of electrical energy dissipation in all urban area roads by implementing Arduino circuit (master or slave) with each highway light. The master Arduino circuit includes light dependent resistor (LDR) to detect daylight, PIR sensor to detect cars movements, and XBee module for communication and send signals to the next five slaves Arduinos. The slave Arduino circuit includes relay module to ON or OFF the highway light, and XBee module for communication and receive signals from master Arduino. The testing of prototype system has been done and proofs a reliable and fast respond of master and slave Arduinos. This research will make an immense difference in the country's management of energy and energy expenditure. It will operate in the best way if integrated with attention and preservation. It is unquestionably obvious that the expense of implementing the smart street light system is financially worth applying. The money required for the equipment and setting up the hardware in street light poles and the employees maintaining the system is far less than allowing all this electrical energy go to waste.

REFERENCES

[1]   Lau S. P., Merrett G. V., Weddell A. S., White N. M., "A traffic-aware street lighting scheme for Smart Cities using autonomous networked sensors," *Computers & Electrical Engineering*, vol. 45, pp. 192-207, 2015.
[2]   Christian P. Janssen, Stella F. Donker, Duncan P. Brumby, Andrew L. Kun, "History and future of human-automation interaction," *International Journal of Human-Computer Studies*, vol. 131, pp. 99-107, 2019.
[3]   Berberian B., Sarrazin J. C., Le Blaye P., Haggard P., "Automation Technology and Sense of Control: A Window on Human Agency," PLoS ONE, vol. 7, no. 3, pp. 1-6, 2012.
[4]   Somayya Madakam, Rajesh M. Holmukhe, Durgesh Kumar Jaiswal, "The Future Digital Work Force: Robotic Process Automation (RPA)," *Journal of Information Systems and Technology Management*, vol. 16, pp. 1-17, 2019.
[5]   Khatoun R., Zeadally S., "Smart cities: concepts, architectures, research opportunities," *Communications of the ACM*, vol. 59, no. 8, pp. 46-57, 2016.
[6]   Moghadam M. H., Mozayani N., "A street lighting control system based on holonic structures and traffic system," *3rd International Conference on Computer Research and Development (ICCRD)*, pp. 92-96, 2011.
[7]   Kaleem Z., Ahmad I., Lee C., "Smart and energy efficient led street light control system using ZigBee network," *12th International Conference on Frontiers of Information Technology (FIT)*, pp. 361-365. 2014.
[8]   Castro M., Jara A. J., Skarmeta A. F., "Smart lighting solutions for smartcities," *27th international conference on Advanced information networking and applications workshops (WAINA)*, pp. 1374-1379, 2013.
[9]   Lavric A., Popa V., Sfichi S., "Street lighting control system based on large-scale WSN: A step towards a smart city," *International Conference and Exposition on Electrical and Power Engineering (EPE)*, pp. 673-676, 2014.
[10] Erwani Merry Sartika T., Rudi Sarjono, Diki Dwi Saputra, "Prediction of PID control model on PLC," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 1, pp. 529-536, 2019.

[11]   L. Yong-Qiu, "Research on the PLC Technology Solutions in Four-Story Elevator Control and Renovation," *8th International Conference on Intelligent Computation Technology and Automation (ICICTA),* pp. 780-783, 2015.

[12]   Haolan Wu, Yangyang Geng, Ke Liu, Wenwen Liu, "Research on Programmable Logic Controller Security," *IOP Conf. Series: Materials Science and Engineering*, vol. 569, no. 042031, pp 1-12, 2019.

[13]   Aryuanto Soetedjo, Yusuf Ismail Nakhoda, Abraham Lomi, Farhan, "Web-SCADA for Monitoring and Controlling Hybrid Wind-PV Power System," *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 12, no. 2, pp. 305-314, 2014.

[14]   Soetedjo A., Lomi A., Nakhoda Y. I., Tosadu Y. P., "Combining Web SCADA Software and Matlab-Simulink for Studying Wind-PV-Battery Power Systems," *International Journal of Computer Science*, vol. 10, no. 2, pp. 51-57, 2013

[15]   A. Setiawan, Sugeng, K. I. Koesoema, S. Bakhri, and J Aditya, "The SCADA system using PLC and HMI to improve the effectiveness and efficiency of production processes," *IOP Conf. Series: Materials Science and Engineering*, vol. 550, no. 012008, pp. 1-9, 2019.

[16]   Mechelle Grace Zaragoza, Haeng-Kon Kim, "Comparative Study of PLC and Arduino in Automated Irrigation System," *International Journal of Control and Automation,* vol. 10, no. 6, pp. 207-218, 2017.

[17]   Yasir Hashim, Abdul Hafiz Mohd Idzha, Waheb A Jabbar, "The Design and Implementation of a Wireless Flood Monitoring System," *Journal of Telecommunication, Electronic and Computer Engineering*, vol. 10, no. 3-2, pp. 7-11, 2018.

[18]   C. Nayyar, B. Valarmathi and K. Santhi, "Home security and energy efficient home automation system using arduino," *2017 International Conference on Communication and Signal Processing*, pp. 1217-1221, 2017,

[19]   W. K. Saad, Y. Hashim and W. A. Jabbar, "Design and Implementation of Portable Smart Wireless Pedestrian Crossing Control System," *IEEE Access*, vol. 8, pp. 106109-106120, 2020.

[20]   K. Guravaiah and R. Leela Velusamy, "Prototype of Home Monitoring Device Using Internet of Things and River Formation Dynamics-Based Multi-Hop Routing Protocol (RFDHM)," *IEEE Transactions on Consumer Electronics*, vol. 65, no. 3, pp. 329-338, 2019.

[21]   R. Ma, J. Gong, G. Liu, and Q. Hao, "Enabling Cognitive Pyroelectric Infrared Sensing: From Reconfigurable Signal Conditioning to Sensor Mask Design," IEEE Transactions on Industrial Informatics, vol. 16, no. 7, pp. 4436-4446, 2020.

[22]   D. Yang, K. Rao, B. Xu, W. Sheng, "PIR Sensors Deployment with the Accessible Priority in Smart Home Using Genetic Algorithm," *International Journal of Distributed Sensor Networks*, vol. 2015, pp. 1S-10, 2015.

[23]   Leccese F., "Remote-control system of high efficiency and intelligent street lighting using a ZigBee network of devices and sensors," *IEEE transactions on power delivery*, vol. 28, no. 1, pp. 21-28, 2013.

[24]   Siddiqui A. A., Ahmad A. W., Yang H. K., Lee C., "ZigBee based energy efficient outdoor lighting control system," *Advanced Communication Technology (ICACT), 2012 14th International Conference on IEEE,* pp. 916-919, 2013.

[25]   Monali Y. Khachane, "Intelligent Street Lighting System," *Int. J. Eng. Res. Comput. Sci. Eng.,* no. vol 5, no. 2, 2018.

BIOGRAPHIES OF AUTHORS

Yasir Hashim, the author was born at Iraq, 1969, he received the B.Sc. and Master of Engineering in Electronics and Communications Engineering from the University of Mosul, Mosul, Iraq, in 1991 and 1995 respectively. He completed the Ph.D. in Electronics Engineering-Micro and Nano-electronics from Universiti Science Malaysia (USM), Penang, Malaysia, in 2013. He is currently a Senior Lecturer in the Faculty of Engineering, Tishk International University, Erbil-Kurdistan, Iraq. His research interests include Microelectronics and Nanoelectronic: Nanowire transistors, FinFET transistor, Multistage Logic Nano-inverters. The author has teaching experience in undergraduate fields of Electrical and Electronics Engineering for 17 years and supervised postgraduate student in Master and PhD levels.

Mohammed Nazmus Shakib received his B.Sc. degree in Electronics Engineering from Multimedia University, Malaysia, the M.Sc. degree from National University of Malaysia, Malaysia and the Ph.D. from the University of Malaya, Malaysia. He is currently attached to the Faculty of Electrical & Electronics Engineering Technology, University Malaysia Pahang, Malaysia. He has published many international conferences and journals. He is also a Reviewer of a few journals such as IET, PIER, JEMWA, IEEE Access, and Elsevier. His research interests mainly include electronics, sensors, RF, measurement antennas, patch antennas, wearable devices, implantable devices, wireless communication and UWB technology.