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A SMART STREETLIGHTS SYSTEM FOR JEDDAH CITY

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Absract --The Smart City is a city where information technology is the principle infrastructure and the basis for providing necessary services to citizens for smarter and safer. This goal can be achieved by embedding the Internet of Things (IOT) to provide open access to picked information for the development of computerized services. This paper explores opportunities for smart streetlights (SSLs) and the challenges of implementing this technology in the city of Jeddah. It presents the benefits of using SSL and focuses specifically on how to control energy efficiently by designing a proposed system that integrates technologies such as Passive Infrared (PIR) sensor, LEDs, LDR sensor and Arduino microcontroller.

Keywords: Smart Streetlights (SSLs), Internet of Things (IOT), Light dependent resistor (LDR), infrared motion sensor (PIR), Light-Emitting Diode (LED).

I. INTRODUCTION

As the capacity of information and communication technology (ICT) improves worldwide, governments are seeking to implement these technologies for their citizens and their needs. Some cities are moving to introduce and use the Internet of Things (IOT) in different sectors or have already begun to employ these technologies to better serve the citizens. The use of ICT and IOT in day-to-day activities and city infrastructure is crucial to the development of the smart city. Factors such as globalisation, innovation and sustainability in highly competitive markets have accelerated the shift towards smart cities, and one of the most important technologies in these cities is the smart streetlight (SSL), which supports improvements in different areas, such as transportation, energy and weather. This paper aims to explore the opportunities and challenges in the implementation of SSLs in the city of Jeddah in Saudi Arabia. We will present SSLs as a solution for the current, inefficient street lighting, which causes wasteful spending in the energy sector and accounts for a major part of governmental electricity costs. Therefore, the development of a new, more efficient and environmentally friendly smart lighting system is of great importance. This paper focuses specifically on how to improve energy efficiency through a proposed system that integrates technologies such as passive infrared sensors, light-emitting diodes (LEDs), light-dependent resistors (LDRs) and Arduino microcontrollers.

The paper is organized as follows: Section II gives a brief overview of smart cities and their components. Section III presents the problems with the current streetlights in Jeddah; defines SSLs; and discusses the opportunities, challenges, and areas of implementation for SSLs in the city of Jeddah. Section IV gives a brief overview of solutions that might be used to implement SSLs. Section V provides a detailed proposal to solve the challenges of lighting in Jeddah.

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II. Smart City

The smart city became a popular concept. It is explained with a various definition. The concept itself utilized with different names and conditions. Many researches defined the smart city from different perspective and angles.

A. Understanding the Smart City

IBM's divide the smart city into three main characteristics: intelligent, interconnected and instrumented [Harrison et al., (2010)]. In Washburn et al., [2010], a Smart City is defined as "The use of smart computing technologies to make the critical infrastructure components and services of a city- which include city administration, education, healthcare, public safety, real estate, transportation, and utilities- more intelligent, interconnected, and efficient". While [Giffinger et al., (2007)] defined it as "A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens". The Smart city can be defined from improvement perspective, which it is all about the need for continuous improvements trying to reach the sustainability as stated, by [Rios, (2008)]. In addition, some of the definitions describe the components of smart city and how they are connected as stated in [Braverman et al., (2000);Partridge and Helen, (2004)]. In a simple meaning, a smart city is a global concept in which components of ICT are integrated to provide smarter services and solutions to citizens in a straightforward, secure way. The main mechanisms in the smart city are self-response and self-monitoring system [Nam and Pardo, (2011)]. To get a smart city a collection of data, which achieved from Internet of Things (IOT) and advanced technology must be used. IOT term defined as a network of physical things (like buildings, vehicles, devices, etc.), which are implanted with sensors (an electronic device that extracts digital or electrical data from physical things, electronics, network connectivity and software), thereby enabling these objects gathering and exchanging data. The IOT must have the capacity to incorporate flawlessly an extensive number of heterogeneous end systems while receiving open access to select subsets of information to advance computerised administrations. The aim of the integration of core systems in the smart city is to make the smarter system from systems. The systems cannot be isolated from each other. A smart city provides information to infrastructure to improve energy, quickly identify and respond to problems, and collect data to make better decisions.

B. Core Components and Direction of Smart City

According to Nam and Pardo, [2011], the smart city has three core components that consist of technology, people, and institution. The connections between these factors identify the city as smart. Figure 1 explains in detail these components. A variety of the labels can fill into these dimensions.

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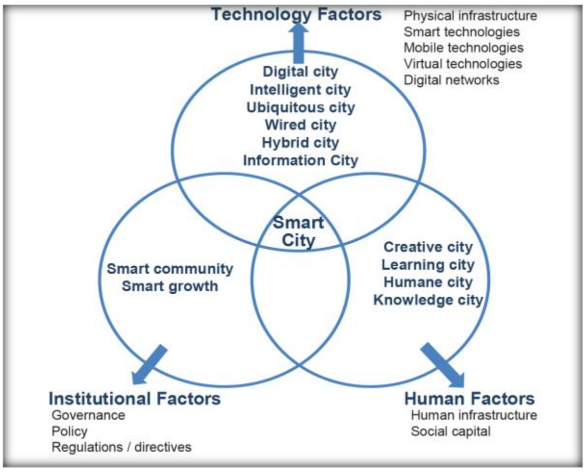

Fig. 1. Core Components of Smart City [Nam and Pardo, (2011)]

The growth potentials for technology include many sectors in the city itself. Figure 2 shows the ways in which cities can be smart.

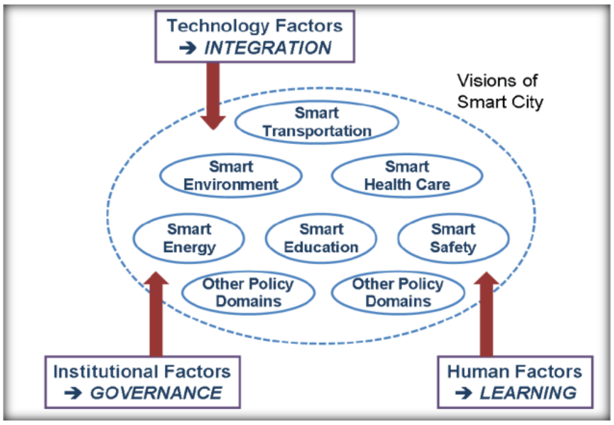

Fig. 2. Direction of Smart City [Nam and Pardo, (2011)]

III. SMART STREETLIGHTS IN SMART CITY

One of the most important focuses in any country is the improvement of transportation, including highways, streets and roads, to optimise the flow of traffic and minimise accidents by ensuring that all roadways are safe and adequately illuminated. Despite the technical tools available, the streetlighting system in Jeddah functions poorly. It depends on sensors, which control the light bulbs, automatically activating them in the dark and switching them off in bright sunlight. The number of streetlights in Jeddah is estimated to be in the hundreds of millions, which means the system consumes a considerable amount of power. The next section will explain in further detail the problems with the current streetlight system in Jeddah [Yoshiura et al., (2013)].

A. Problems of Current Streetlights

Today, streetlights plays a significant role not only in lighting city streets during the night but also providing home security and traffic safety and improving the city's appearance and features. The streetlights in Jeddah are traditional, manually controlled lamps that are turned on or off by simple timer devices depending on the calendar data. These devices are programmed according to the

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location of the installation and do not accommodate variable light situations (e.g. overcast days and dust storms) [Pinto et al., (2014)]. This method provides inadequate monitoring capabilities, which lead to waste of electricity and high expense. Moreover, the current streetlights do not communicate on a network; hence, important data, such as information about defective lamps, luminaire statuses and energy consumption, cannot be accessed, which can cause mistakes in maintenance [Tseng and Hsieh, (2016)]. Additionally, the current streetlights in Jeddah do not always operate properly. For instance, lamps may be broken, some lights are either on or off all the time, electric leakage can occur from exposed wiring, and lampposts can be damaged in traffic accidents. There is no system to report such problems.

The Nottingham PFI Lighting Portal is one strategy that has made it easier to report streetlighting problems in the UK. This website was developed especially to enable citizens to report faulty streetlights using interactive maps for more accurate reporting; this system also permits rapid responses [Nottingham City Council, 2010]. When there are no controls in place to monitor the network remotely, some lighting problems remain unknown until they are reported or until maintenance personnel find the defect.

Furthermore, Jeddah's current streetlights do not have any additional features to support transportation and environmental communications, such as traffic reports, route recommendations for users, accident alerts, air pollution monitors or warning systems for natural disasters. Recently, new technologies have been developed that may present a solution to this problem by providing administration, control and measurement by an intelligent service to decrease costs and improve the reliability and efficiency of streetlighting. One component of Saudi Vision 2030 is to improve the quality of citizens' lives by ensuring high-quality services in different fields, including transportation, roads and electricity. Thus, we will focus on developing an SSL system to support this vision. The next section provides information about SSLs and their applications [Parekar and Dongre, (2015)].

B. Smart Streetlights (SSLs)

SSLs are intelligent lights that gather dynamic data through sensors and generate information for device or user requests [Ouerhani et al., (2016)]. SSLs require a collection of components, such as computers, sensors, energy measurements, lighting fixtures and 5 SSL transceivers connected with the networks. These components provide monitoring, reporting and control and include a dashboard and a configuration page. This lighting system offers more advanced techniques than the traditional lights [Hui et al., (2015)]. SSLs applications can be used to manage and control integrated communication systems to ensure safety and optimise energy saving, cost saving and efficiency [Pinto et al., (2014)]. SSLs also offer features such as variable light strength in accordance with the time of day and communication capabilities to enable on-time data transference. Additionally, this system gathers information about energy consumption and error limits and sends remote dimming instructions [Tseng and Hsieh, (2016)]. The utilisation of the system can save a lot of electrical power, which can increase the lifespan of the lights and decrease the associated costs. SSLs offer the following advantages:

(1) Reduce the electronic power consumption
(2) Reduce the need for human resources
(3) Long lifespan of lamps
(4) Automatic start up and shutdown of streetlights
(5) Detection of pedestrian or vehicle motion

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C. The Opportunities and Areas of Implementing SSLs in Jeddah

Applications of SSLs extend to areas of transportation and energy consumption. Besides transportation area and energy consumption, SSLs is relevant to weather monitoring and accident alert as well.

Energy Management Area. SSLs with IOT components have been integrated into energy-consuming parts of lighting systems (e.g. switches, power outlets, bulbs, networks and sensors). These components connect with the utility supply company to adjust power production and energy usage efficiently. Moreover, communication between these components can enable users to access these devices remotely or control them via cloud-based interfaces. SSLs save energy by sensing their surroundings and communicating with sensors in other devices (e.g. smart cars and smartphones). Once the light receives a signal from another nearby smart device, the streetlight switches on; however, if no signal is received, the light switches off [Parekar and Dongre, (2015)].

Transportation and Traffic Area. SSLs and the IOT can be embedded in or can communicate with many transportation-related technologies, such as smartphones, users, traffic lights, vehicles, streetlights, sensors and other infrastructural mechanisms. The communication between these transportation components can provide smart traffic control, smart parking, vehicle control, safety and road assistance. SSLs can handle traffic data and suggest routes for users relying on a navigation system. At the same time, SSLs can examine road conditions, send notifications to the city to change the speed limit on the road when conditions are dangerous and re-route users to avoid bad roads [Ouerhani et al., (2016)]. In addition, smart lighting systems can connect to traffic lights to allow them to change automatically according to the traffic density on the roads. Traffic data gathered by sensors in SSLs are stored in the cloud, and identifiers detect the arrival of emergency services, such as ambulances or law enforcement vehicles. Traffic lights are controlled according to these data. Unlike traditional traffic light systems on fixed timers, smart traffic controls can change light durations depending on traffic levels [Nancy and Sivarajani (2016)].

Weather Monitoring Area. SSLs with IOT connectivity also can support environmental protection by collecting data on temperature fluctuations, humidity levels, air pollution, noise pollution and atmospheric. Smart lighting systems, furthermore, can be used in emergency situations to provide more effective aid and offer early warning systems for earthquakes, tsunamis and other natural disasters. SSLs sensors can be programmed to collect weather data obtained by environmental monitoring devices and stored in the cloud, which is updated dynamically by the weather monitoring committee. These sensors can be used to alert citizens about abnormal levels of contaminants in the air and to provide timely warnings that can protect lives and avoid human-made environmental disasters, such as explosions and gas leaks. In addition, SSLs have the potential to monitor the movements of wildlife and their habitats [Ouerhani et al, (2016)].

Accident Alarm. SSLs can provide accident alerts. For example, when any accident occurs on the road, the sensor in the vehicle involved sends out an alarm. The SSLs receive this message and alert both the police and nearby emergency medical services. At the same time, the system also notifies other vehicles near the accident [Ouerhani et al., (2016)].

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D. The SSLs Implementation Challenge

Over the past five years, districts around the world have implemented advances in lighting, such as LED technology, that can halve the energy costs of traditional technologies, saving money through lower operations and longer system lifespans [U.S. Department of Energy, (2016)]. Nevertheless, there are some roadblocks in the transition to SSLs that range from specialized technical challenges to approach issues. In this section, we will discuss these challenges.

Implementing SSL technology requires a large experiment area to test the efficacy and results of the smart lighting system, yet the costs must be kept at a level feasible for many different countries. This is especially true in light of the extent of infrastructure changes that must occur to create a smart system, the number of SSL posts needed and the costs of contracting with vendors to complete the project, which could lead to financial difficulties for some municipalities [Shahzad et al., (2016)]. In fact, the establishment of SSLs in city space takes years, and during this time, many issues may arise. This project must achieve security, interoperability between heterogeneous systems and usability for drivers. In addition, the framework must be versatile to accommodate new applications and to avoid a lack of standardisation. Sensors must function in challenging conditions, such as rainy weather, and there is a possibility that sensor components could be damaged in abnormal conditions [Beeraladinni et al., (2016)]. Dynamic information is hard to assemble and handle and requires appropriate upkeep. At the same time, privacy and security must be considered because in the future, SSLs may have information on all users that should be protected in the right way. Thus, cities must raise citizen awareness of the system and its applications. Other significant challenges in implementing SSLs involve ensuring that new vehicles have the technology to support the SSL system and connecting the sensor devices to these vehicles. Applications also must be provided for mobile devices to allows users to interact with SSL sensors [Murthy et al., (2015)].

IV. SUGGESTED SOLUTIONS

In this section, we will give a brief overview of solutions mentioned in the related literature, namely the following:

- Wireless Sensors Networks, which have the advantages of simplicity and flexibility in term of implementation and installation [Beeraladinni et al, (2016)].
- ZigBee , a superior choice for energy-efficient outdoor lighting [Hui et al, (2015)].
- Power Line Communication (PLC), which is considered the natural choice to support smart light control.
- GSM technology, which uses power efficiently by remotely accessing and monitoring a system and can improve fault detection and maintenance [Parekar and Dongre, (2015)].

V. PROPOSED SOLUTION

The problems with the current lightening system in Jeddah are clear. These problems occur in different sectors, and we propose our project as a solution to Jeddah’s lighting issues. In this section, we will present our SSL system and describe in detail the main components of this system and the steps for implementation. There are certain factors that must be taken into account to design a good streetlighting system – namely, power consumption, cost, traffic and accuracy in terms of time or condition. It is essential to find a smart solution for each facet of the lighting problem, including power wastage and the installation of remote controls to monitor the network, fix problems, handle traffic, suggest routes for users, provide accident alerts and evaluate air pollution.

The first stage in implementing SSLs is to introduce IOT technologies. Sensors used in streetlights can act as nodes in the network and communicate with each other to exchange data. The system is based on wireless network control for real-time monitoring of road lighting. To make the

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devices communicate with each other, the system requires protocols, wireless networks and the integration of different technologies. The data collected by the SSLs can be stored and monitored at Jeddah's data centre in the Jeddah municipality. All the solutions will be combined in a centralised dashboard, which is a powerful and flexible control broker that can send and receive data amongst data centres, sensors, SSLs, and third-party sectors, such as the General Authority of Meteorology and Environmental Protection, Saudi Electricity Company and Jeddah Traffic Police.

The following is a list of the proposed system aims to solve the problems that the current lighting system presents in Jeddah:

A. The Proposed Solution to Reduce Electricity Consumption

The proposed SSL system design is intended to replace Jeddah's traditional lights, which are turned on or off by simple timers depending on the date on the calendar. In the new model, we can connect wireless technology and LDRs to identify the strength of daylight so that streetlights are turned off automatically in the daytime and turned on when daylight fades, which decreases the need to manually switch road lights. Furthermore, Jeddah's streetlights currently remain on from 6:00 p.m. to 6:00 a.m. regardless of whether pedestrians or vehicles are present. The peak time of movement is generally from 6:00 p.m. to 10:00 p.m., but continuous, full-strength lighting after this period leads to the loss of an enormous amount of energy. To overcome this problem, we can use passive infrared (PIR) motion sensors, which will communicate with the microcontroller so that the streetlight shines at 100% of its capacity only when there is movement in the street and otherwise glows with 10% of its maximum intensity when there is no movement [Meher, (2015)]. The principle of this operation is to control the intensity of the streetlights in response to the needs of road users [Castro, (2013)].

The following list presents in detail the components needed to develop an automated SSL system to reduce electricity consumption.

(1) Sensors: One of the sensors will use to recognize light, whereas the other will detect pedestrian and vehicle motion on the road.
(2) Wireless Communication: The network will enable the lights to transmit and receive data Thus, when motion is detected near one light, the adjacent lights will turn on as well, providing enough light for pedestrians or cars.
(3) Microcontroller: The microcontroller will act as the processing unit and will have the following functions: (i) processing data received from the sensor, (ii) controlling the intensity of the light output according to the results of data processing and (iii) communicating with the wireless interface by receiving and sending control signals.
(4) Dimming: This involves adjusting the LED lighting levels so that the lighting level decreases when there are no pedestrian or cars on the streets.
(5) Control: Intelligent algorithms will be used for smart control of the lights to quickly respond to the needs of road users.
(6) Even Power Consumption: Adjusting the brightness levels of lights can cause uneven power consumption, which adversely affects power companies' usage forecasts. These forecasts are crucial to ensure that the right amount of power is produced to avoid overproduction or shortages. Our solution aims to account for this issue by implementing an algorithm that dynamically controls the network to maintain even power usage.

By using this concept, we can develop an automatic streetlight.

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B. Transportation (Reporting Car Accidents with SSLs)

This proposed SSL system also has the potential to improve road safety not only through lighting control but also by monitoring traffic. In the current system, when a car accident happens, someone typically notices the crash and reports the station or calls an emergency number. In this scenario, the response is delayed, and in this time, many deaths may occur and road obstructions may worsen. As stated in section 3.3, the SSLs will overcome some common transportation issues, including accident reporting and traffic jams. One of the important steps in implementing an SSL system is ensuring that cars are equipped with the right technology. The SSLs will have attached routers that use RFID technology to receive help messages from cars involved in accidents. In this system, when a car crash occurs airbag sensors would immediately activate to communicate with other sensors in the car that would transmit details such as identification, car speed before the accident, the number of passengers and the location of the accident. All this information will be collected through the following embedded components, which are also illustrated in Figure 3:

(1) Erasable programmable read-only memory (EPROM) that will save important information about the car, such as identification
(2) A microcontroller that extracts the data from different sensors and sends them as a packet to the router
(3) A speed sensor that will capture the car's speed until it comes to a standstill
(4) Four Weight Sensors (one for each car) that will determine the possible number of passengers (Figure 3 illustrates where the sensors will be located)
(5) Four impact sensors, one on each side of the car (i.e. front, back, right and left), that will activate the airbag sensor
(6) FID module tags [Sherif et al, (2014)]

In the SSL system, the coordinator is responsible for collecting the data from all the routers. Then, in the case of an accident, the help message is sent to the coordinator, which routes the message to the integrated communication centre from Najm centre, which is responsible for reporting the accidents to employees. Alternatively, the coordinator could be programmed to route help messages to police cars near the accident.

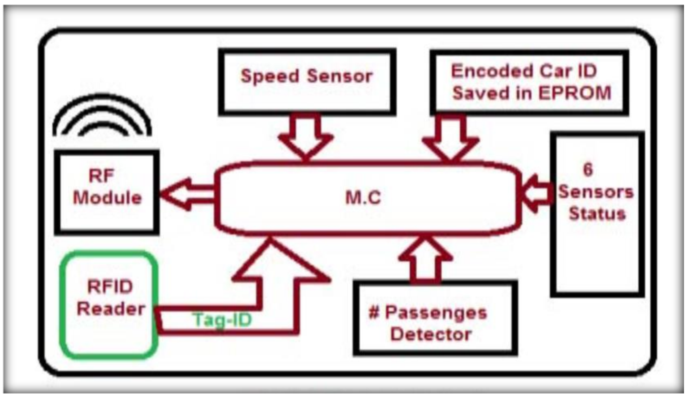

Fig. 3. Components embedded in the car [Sherif et al, (2014)]

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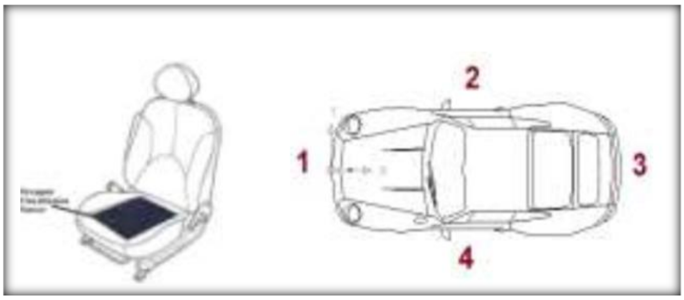

Fig. 4. Placing Sensors in the cars [Meher, (2015)]

C. Environment SSL Solution

Particularly because it is a coastal city, Jeddah experiences constant weather fluctuations and is exposed to wind gusts, high temperatures and dust. The smart lighting system should work efficiently in variable environments; thus, we propose the inclusion of weather detection technology in the SSLs as follows:

- We propose the attachment of environmental sensors in smart streetlighting systems to detect changes in air conditions, which would be displayed on an LED monitor. Such sensors come in many different forms and can monitor noise, temperature, humidity, wind speed and wind direction [Castro et al., (2013)]
- In cases of dust storms, natural light levels are reduced even when the sun is up, so the intensity of the SSLs should increase in this scenario.

PVDF sensors can be attached to the SSLs smart street lighting. When these sensors detect dust, they can send information to the control system to receive an order for increased lighting. The PVDF sensor changes the mechanical influence of dust to electrical motion so that electrical signals can be translated as the influence of dust [Beard, (2005)].

D. Street Light Maintenance and Monitoring

The maintenance and monitoring of SSLs is an essential and time-consuming process. The smart lamps have specific lifespans and can be disabled at any time. As a result, the lights must be replaced immediately to ensure the required levels of visibility and safety. The proposed system can monitor itself using the controller for each light node (LN), which can sense the state of the electronic ballast and hence the state of the lamp. When a failure is detected, the controller is equipped with a wireless transceiver to transmit this information along with the location of the LN to the nearby roadside unit (RSU). The RSU, in turn, sends the information to the central server. If the controller itself fails, a simple technique can be used to detect the failure. Specifically, each RSU would be responsible for maintaining a list of the LNs in its area of coverage according to MAC addresses. Each LN would send an 'I am alive' signal to the RSU every 10 minutes. If the RSU does not receive a signal from one of the LNs, it can send a message of failed detection to the monitoring server. The traffic authority can use specific software that has the ability to automatically obtain health status reports for all the lights on the street. If any node failure is detected, the agency can send technicians to the location of the error to change the light [Pinto et al., (2014)].

VI. IMPLEMENTATION OF PROPOSED SOLUTION

In this part, we will focus on the presenting energy solutions using a simulation. This section illustrates the proposed system and present an overview of a profitable solution to the problem of

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energy consumption from streetlighting. In this model, energy use is minimised through LEDs that turn on only when needed and otherwise remain switched off.

A. Components of Proposed Solution

(1) LEDs: This lighting technology is most suitable for enabling complete control over streetlights and supporting lower energy consumption.
(2) Arduino programming: This allows the microcontroller to operate and execute system processes.
(3) Passive Infrared (PIR) sensors: These sensors react to infrared energy emitted by objects. PIR sensors contain two detectors configured as inputs and depend on the motion of an object. As the object enters the field of one detector, there is a positive differential change. As the object moves to the next field, there is a negative change.
(4) LDR sensors: These sensors contain photoresistors with a relatively high resistance value. When light falls on these materials, they emit electrons. When the light frequency exceeds a set value, the emitted electrons acquire the energy to jump into the conduction band.

B. Hardware Requirement

The elements of the suggested system identified here depend on the mechanisms of the input, output and controller. The inputs include two sensors (LDR and PIR) and the power supply, which is managed by switching the power on and off. The LDR sensors detect and measure light levels. The PIR sensors detect the motion of vehicles to specify the traffic level. When the vehicle crosses the PIR laser beam, the sensor starts counting. The system also makes decisions depending on how many vehicles are detected by the sensor. The two outputs (LED and light intensity) are connected to the microcontroller. The streetlight uses the LED to control brightness based on the intensity module. The intensity module performs three brightest to test the different conditions; sensor inputs include streetlight period and level as wells as the surrounding and number of vehicles. In this proposed system, the Arduino UNO is the system controller; this was chosen because it offers better cost reduction, compatibility, size compression and connectivity compared with other controllers.

C. Software Development

To operate, the system first determines the level of surrounding light. There are three available levels. The first level occurs during daylight, when streetlights generally are switched off. During the night, the lighting level is based on two conditions: vehicle motion and appropriate light production. If the LDR sensor detects that it is dark and the PIR sensor detects motion, the LED lights will glow at 100% (second level). If the LDR sensor detects that it is dark and the PIR sensor detects no motion in the street, the lights will glow at 10% of capacity (third level). The whole process of energy efficiency is illustrated in the following figure:

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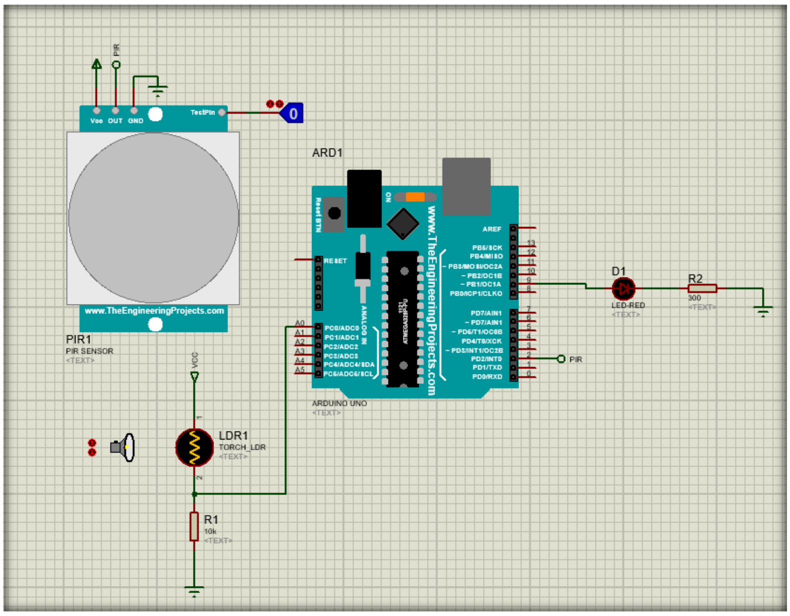

Fig. 5. Simulation diagram for the Proposed System

VII. Discussion

This paper explores the existing problems with streetlights in the Saudi Arabian city of Jeddah. It discussed the various problems and usefulness of the current streetlights in terms of light control, energy consumption and maintenance. The paper then explored how the city could take advantage of its lighting system through the development of a smart city. We then proposed SSLs as a solution to Jeddah's lighting problems. The recommended smart lighting system overcomes the problems inherent in the city's current lighting by controlling the lights through a central system, reducing energy consumption and adding new features, such as car accident reports and weather monitoring.

VIII. Conclusion

The concept of the smart city has great potential to improve citizens' quality of life through IOT technologies. Streetlights in Jeddah must be improved, and the implementation of SSLs is one strategy to improve the city's energy use, transportation system and environmental awareness. In this paper, we have discussed smart city and current problems of streetlights in Jeddah. After that, we have explained the capabilities of implementation smart streetlights and the challenges that may face in implementation. Finally, we suggested the solution to our case study in Jeddah. Then we provided a suggested solution for the area of energy by using simulation.

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