An Implementation of Efficient Smart Street Lights with Crime and Accident Monitoring: A Review

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Abstract:- Smart street lights with crime and accident monitoring are the technology that adds sensors and cameras to regular street lights to make public roads safer and more secure. These smart streetlights have motion sensors, cameras, and other detection tools that can pick up on possible crimes or accidents and let the police know. They can also collect data on traffic patterns, weather conditions, and other factors that can affect public safety. The data collected from these smart streetlights can be analyzed using artificial intelligence (AI) and machine learning algorithms to identify patterns and trends that can help authorities make informed decisions about how to improve public safety. For example, if the data shows that a particular intersection is prone to accidents, management can improve road infrastructure or increase police presence there. Smart streetlights with crime and accident monitoring can help improve public safety and reduce crime rates by providing real-time monitoring and analysis of public spaces. They can also work with other smart city technologies to make cities more efficient and environmentally friendly. The primary objective of this research article is to find the solution to the problem above in the form of smart streetlights (SSL), a type of smart device capable of communicating with each other wirelessly, relaying important sensor data or video data to improve the usability of the city. Further, this article consists of numerous literature reviews, methodology, and analysis of findings, such as how the authors abstracted the findings and results from the literature review. The authors have also included an implementation of the Tinkercad workflow to showcase the complete circuit board.

Keywords: Smart Street Lights (SSL), Traffic Monitoring, Crime Monitoring, Cloud Computing, Edge Computing, Containers, Tinkercad, Sensors.

1. Introduction

Smart streetlights are advanced lighting systems that incorporate technology to benefit urban areas. They are designed to be energy-efficient, environmentally friendly, and cost-effective, and they offer a range of features that traditional street lighting systems do not.

Energy Efficiency: Smart streetlights use LED technology, which is more energy-efficient than traditional lighting sources. This means that they consume less energy and can significantly reduce energy costs. Motion Detection: Smart street lights are equipped with sensors that detect motion, allowing them to turn on and off automatically based on the presence or absence of people or vehicles. **Remote Monitoring and Control**: Smart street lights can be remotely monitored [1-3] and controlled, which makes it easier for municipalities to manage their lighting systems and respond quickly to maintenance needs. **Data Collection**: Smart street lights can be equipped with sensors that collect data on air quality, temperature, humidity, and other environmental factors. This data can be used to inform city planning and resource allocation decisions. **Safety and Security:** Smart street lights can improve safety and security in urban areas by providing brighter and more consistent lighting, deterring crime, and increasing visibility [4-7]. Smart streetlights are a promising technology that can help cities become more sustainable, efficient, and livable. Fig 1 presents the lighting intellistreets.

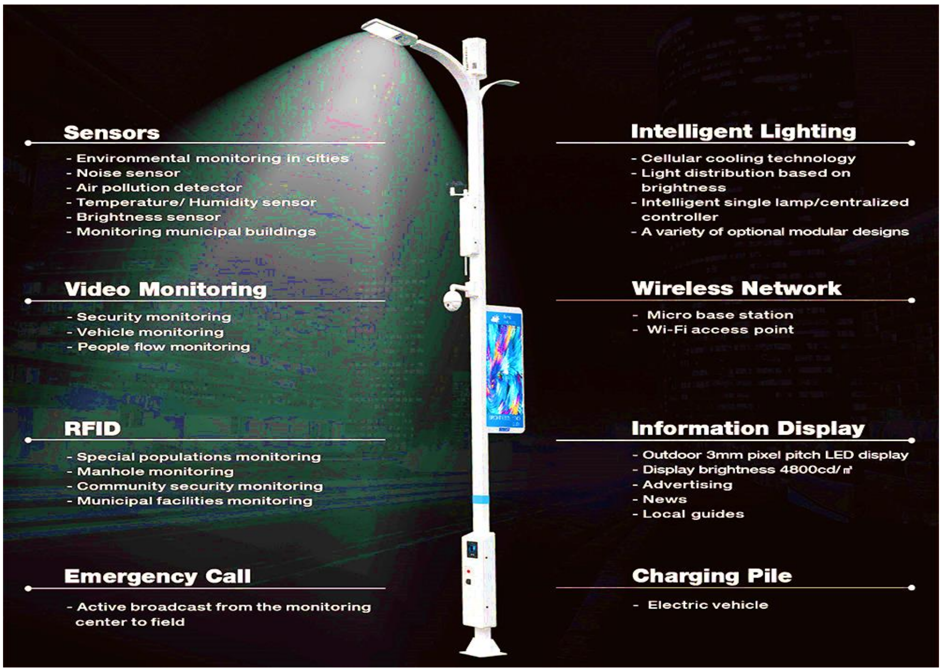

***Figure 1** presents the LightingIntelliStreets [8]*

During the first phase of the proposal, we analysed the problem statement to lay out our problems regarding the street lights. We then proposed an application to come up with a possible solution for the street lights. We have also mentioned the requirement of the proposed smart street light and the design principle [8-11] of the smart street light system. We drew out an architecture for reference and constraints, explaining all the functional entities.

In the project's second phase, we are using the reflection from the previous section and the group project to find out the parts that could be further refined and enhanced. In this project, we have added machine learning and artificial intelligence to work more efficiently with the proposed cloud and edge computing. Although the suggestion and implementation of machine learning and AI will be challenging.

We also have completed the analysis of resources and the potential risks by indicating the nine sections where possible improvement could occur [12-14] . We are also trying to add more sensors to implement more functions to the smart street light. We are moving to an era where electric vehicles will dominate in the future, and intelligent street lights will also work together with the vehicles synchronizing information exchange. There is an increase in electric charging stations in first-world countries as well as Malaysia [15,16]. To focus on solving the current issues of smart street lights, we have acquired literature reviews from a few research papers and applied a method of gathering the data. Then forming results and findings with the collected data and showcase the updated Tinkercad with a few new features added to the SSL system.

The following points focused on this research article:

- This research article discusses Smart Street Lights (SSL).
- This research article discusses Traffic Monitoring and Crime Monitoring.
- This research article discussed Cloud Computing.
- This research article is Containers, Tinkercad, and Sensors.

2. Literature Review

The monitoring process can include the use of various technologies such as surveillance cameras, sensors, and other monitoring devices. Data collected from these devices can then be analyzed to identify patterns of criminal activity or accidents and to develop strategies for preventing or responding to these incidents. Crime and accident monitoring can be used to help law enforcement agencies identify high-risk areas and allocate resources more effectively. It can also be used to help communities identify areas where additional safety measures may be needed, such as increased lighting or improved pedestrian infrastructure. Crime and accident monitoring is important for maintaining public safety and reducing crime and accidents in communities. With a smart streetlight system in place, communities may feel more secure. Strategically placed lamps can reduce both the crime rate and energy consumption. Traditional street lighting systems waste a lot of energy by leaving their lights on all night, from 6 p.m. to 6 a.m., regardless of traffic or people in the area. Constant strain is placed on [17-19] lighting budgets due to rising energy prices, high maintenance expenses, and rising public expectations. Technology that can help cities better monitor and regulate their energy resources is becoming more viable thanks to semiconductor and wireless technology developments. Fig 2 presents the traffic monitoring system.

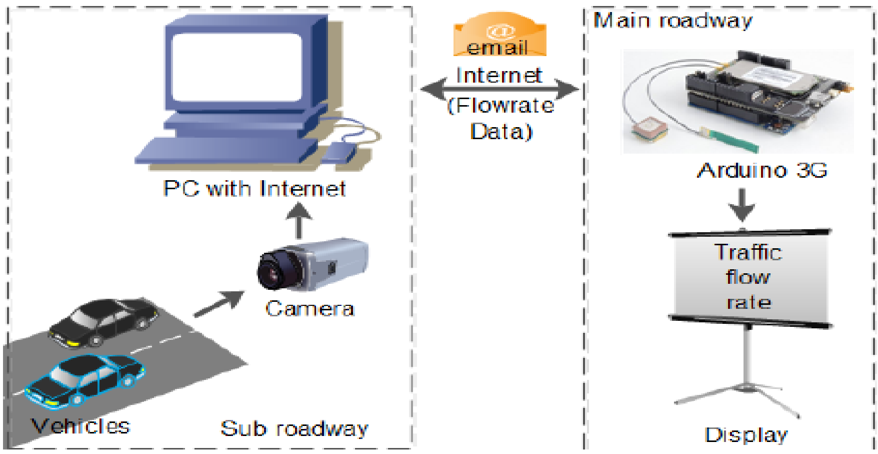

Figure 2 *presents the traffic monitoring and crime monitoring [20]*

Here, we suggest a low-cost method for keeping an eye on the money spent on streetlights and providing helpful life-cycle management for the entire streetlight infrastructure. The primary function of modern smart street lighting systems is to respond to foot traffic by turning on or off and adjusting brightness. This way, when no one is on the street at night, the lights may be turned off to save energy. Moreover, we can automatically identify any broken lighting without human involvement. The benefits of this system include reduced energy use and savings due to the lights being dimmed during periods of low activity, such as late at night. Also, the broken bulb is identified instantly by the system using web-based software [20-22]. When lamps are dimmed rather than turned off entirely, CO2 emissions can be lowered while safety is increased. Many streetlight system case studies and models are crucial to developing smart cities. LDR, IR, LED, UART, and a CPU comprise the usual components of a smart streetlight system's architecture. An LDR is a photoelectric sensor used to turn on and off LED streetlights in response to changes in ambient temperature. Movement is tracked by infrared sensors that provide data to a central processing unit. The streetlight is turned on and off with the help of a relay and an LED that responds to its surroundings. With the computer's UART interface, the lighting system may be managed. There is a pressing need to lessen the burden of streetlights' high energy consumption and upkeep costs in urban areas. The research indicates that 18%–of the streetlight system uses 38% of city electricity resources [23,24]. It is feasible to reduce power consumption without jeopardising human safety by employing optimal systems and processes. Recent studies on intelligent lighting systems have focused on finding ways to reduce the need for human involvement, energy usage, and overall system costs. Until now, the most common method for automating light switching and intensity has been to employ a controller in conjunction with several sensors. Evaluating the effectiveness of various street light configurations in terms of energy savings and illumination is crucial. Energy-efficient methods and the design of smart street lighting in terms of technology, types of lights, operating patterns, and communication have all received attention from many nations to lower greenhouse gas emissions. Simple temporal control circuitry for switching on and off the lights is typical of most traditional street lighting control systems that need human intervention [25, 26]. Yet they haven't accounted for the natural light or the swaying of nearby items. To reduce the street lighting system's energy consumption, the lights should turn on and off based on the presence of a moving item and the surrounding illumination. Reduced power usage in street lighting can be achieved through the use of motion and detection-based control systems. Less energy is used when streetlights are activated in response to the presence or absence of passing people or cars. When compared to a control system with a specified and fixed behaviour, an adaptive control system for smart street lighting in a city's infrastructure can reduce energy consumption by up to 35%. Compared to traditional systems, street lighting automation and control systems based on the EN15323 standard may reduce energy usage by 45 percent [27]. Using a three-phase lighting system and developing a control unit to regulate the brightness of each luminaire results in greater efficiency than a conventional single-phase street lighting setup. Factors that influence active loss reduction include pole-to-pole distance, luminaire density, outdoor lighting dimming ratio, weather, wire conductivity, and street sand classification. LED lights, brightness sensors, motion sensors, and a low-range communication network are the main components of a smart street lighting system. To save energy, the LED lights will activate and deactivate in response to passing pedestrians and cars. Using traffic intensity data and a dynamic dimming profile for LED luminaires, optimal energy savings and increased safety may be attained. To have a low-cost solution that reduces power consumption, a microcontroller-based [28] energy-efficient LED street lighting system manages five distinct brightness levels based on weather and daylight conditions, utilising various sensors including light, rain, lasers, etc. Wireless communication technologies are increasingly being integrated into street lighting systems because they can improve efficiency, facilitate installation, and allow for greater customization. No substantial changes are required to the existing infrastructure for Wi-Fi-enabled remote on/off control of street lighting. Implementing a centralised control system for remote monitoring and control of LED lights is now feasible through their integration with a low-power communication protocol like Zig Bee. To save the most electricity possible, a smart lighting system built on a low-power ZigBee network employs electrical control of LED lights that can adjust their brightness in response to the amount of light in the area and the traffic volume. Experimental results reveal that this system may reduce energy consumption by 68% to 82% compared to traditional metal halide lighting. The system was placed on a university campus. LED-based smart street lighting systems require intelligent controls for power optimization [29]. This can be accomplished by maintaining a greater level of intensity for high-speed items, such as vehicles, bicycles, and pedestrians, and lowering the intensity for slower-moving things. LED, battery, infrared sensor, and LDR are all components that may be used to create such a system, and together they can save as much as 40% on monthly energy costs. In addition to automating the light settings, solar-powered autonomous street lighting systems can include GPS-based safety measures for people in dangerous circumstances. Fire, ambulances, and police stations are all part of the emergency infrastructure.

3. Accident Monitoring

Accident monitoring is the process of tracking, observing, and analyzing accidents or incidents that occur within a particular environment, such as a workplace or a community. The goal of accident monitoring is to identify potential hazards and risks and to develop strategies to prevent future accidents from occurring. Accident monitoring can involve various methods, including data collection and analysis, observation, and reporting. It may also involve the use of technology, such as sensors or cameras, to detect and monitor accidents or incidents. Accident monitoring is essential for several reasons. First, it helps to identify patterns and trends in accidents, which can be used to develop more effective prevention strategies [30]. Second, it helps to identify areas of risk and potential hazards, which can be addressed before accidents occur. Finally, accident monitoring can help to improve safety culture and increase awareness of the importance of safety in the workplace or community.

The research paper by (Iwasaki, Misumi, and Nakamiya, 2015) is regarding the automatic surveillance of traffic flow to identify traffic accidents without delay, and uses infrared cameras to capture stills of the road. The paper uses a combination of spatiotemporal image processing techniques, alongside a Viola-Jones detector for vehicle detection, multistage.

Cascade of classifiers for windshield identification and correction procedures for the misrecognition of vehicles. After vehicle recognition, the car's speed is obtained by tracking the vehicle's movement using the cascade classifier and is classified into three different speed categories. Afterwards, conditions for traffic accidents are set by the user for the automatic surveillance of the traffic flow, and if these conditions are met, then a traffic accident is estimated. The research paper by (Wang, Cai, Chen and Chen, 2016) uses an automotive infrared sensor to detect vehicles using a 2-step framework consisting of vehicle candidate generation (VCG) [31] and vehicle candidate verification (VCV). The methods for VCG include applying a low threshold to the pixel values of the infrared stills, so that pixels with higher points – indicating higher temperature, are retained. A region-searching algorithm is applied to eliminate the hotspots which are not vehicles, and contouring segmentation is done. The methods for VCV include using a deep belief network (DBN) based classifier for the classification of cars, which resulted in a detection rate of 93.9% for vehicles, alongside a backpropagation algorithm to fine-tune the parameters of the DBN-based classifier.

4. Crime Monitoring

Crime monitoring is the process of gathering and analyzing information on criminal activities in a particular area or jurisdiction. It involves using various tools and techniques to collect data on crime trends, patterns, and occurrences and identify potential hotspots. The research paper by (Hussain, Sheng and Zhang, 2019) reviews research work between 2010-2018 regarding human activity recognition. The research works presented the different approaches used for activity recognition. The authors separated them into four main categories: radio frequency-based, sensor-based, wearable device-based, and [32] vision-based. Besides, the authors explained the process of human recognition. It can be generally separated into four main phases: selecting and deploying sensors, collecting data from the sensors, pre-processing and feature selection from the data, and using machine learning to recognize or infer activities. The reviewed research also discussed different techniques for device-free human activity recognition. The authors grouped the method into 3 main categories: action-based, interaction-based, and motion-based. Besides, the 3 main categories were further divided into 10 sub-categories. Action-based activities include research for gesture recognition, posture recognition, behaviour recognition, activities of daily living, fall detection and ambient assisted possession. The research of motion-based approaches had been separated into tracking, motion detection and people counting. For interaction based, the authors reviewed works related to human-object interaction. The research paper by (Tripathi, Jalal and Agrawal, 2018) discussed suspicious human activity recognition. The authors focus on the following abnormal activities: abandoned object detection, health monitoring of elder or patient at home, theft detection, accident, or breaking traffic rules activities (illegal U-turn, reckless driving, illegal parking etc.), violence detection (shooting, punching, hitting, slapping) at public places and fire detection. Also, the authors had listed a few issues and challenges on developing an intelligent video surveillance system including shadow of objects, [33] illumination changes, noise in the images, partial or full objects occlusions, more crowds, blurred objects, real-time processing, poor resolution, and static object detection. Then, the authors reviewed some studies on abnormal human activity recognition from video surveillance. Generally, the recognition of suspicious human activity has 4 main steps: foreground object detection, tracking or non-tracking-based object detection, feature extraction, classification, behaviour analysis and recognition. Besides, data sets that help to evaluate the performance of a system are listed by the authors for each field.

5. Adaptive Lightning & Weather Sensors

The research paper by (Yang, Lee, Chen, Yang, Huang and Hou, 2020) suggested a smart streetlight system that can efficiently configure, deploy, and manage the streetlight. The researchers implemented Docker, a container-based virtualization technology to achieve high scalability and fast deployment. NoSQL and in-memory databases are integrated for database design to provide flexible data management. An asymmetric key and an SSH encryption tunnel is designed in this research paper for data transmission. Also, legitimacy validation via token is conducted when all services are connected [34] . As a result, this system could satisfy the requirement of low latency, data throughput, and configuration, and hence realize a smart city. Besides that, it offers a flexible storage and management service that could handle the massive data processed by the city. The research paper by (Sikder, Acar, Aksu, Ulugac, Akkaya and Conti, n.d.) provides an overview of an intelligent lighting system (SLS). A SLS usually consists of 3 components, namely lamp unit (LU), local control unit (LCU) and control center (CC). LU is the lamp which is equipped with various sensors, LCU is the component that collects data from an area of LU,and CC is the central server where the sensor data is sent from the LU and processed the data. The researchers' SLS architecture will require long-range and short-range communication protocols. The researchers have given examples of communication protocols such as Zigbee, 6LoWPAN, Wifi etc. The researchers also explained some of the usage scenarios for IoT-enabled indoor and outdoor SLS and provided a power consumption analysis. From the result, the SLS can reduce up to 33.33% power consumption in both indoor and outdoor settings.

The research paper by (Keh, Lau and Mohamad, 2020) aims to develop and design a smart street lighting system based on Wireless Sensing Network (WSN) technology while using an adaptive control mechanism to realize energy-saving street lights. The paper uses energy-efficient LEDs in the street lights, alongside the implementation of Pulse Width Modulation (PWM) technology for the adaptive control mechanism. The illumination of the street lights is based on environmental sensors such as motion sensors, rain sensors, lightdependent resistors (LDR), and so on [35]. The default control is the adaptive mechanism, but when heavy traffic or severe environmental conditions – heavy rain, flash floods, etc.- the lighting will be reverted back to a normal, non-adaptive level. The research paper by (Satrya et al., 2017) proposes a weather-aware remote monitoring system for street lights through color-changing LEDs and weather sensors. Different weather, like fog, rain, snow, and so on will affect the visibility of the street lights. Therefore the paper has implemented LEDs that vary in color depending on the current weather situation then, so as to be able to increase visibility [36]. The paper uses WSN technology and connects wireless ZigBee sensors to existing streetlights for the provision of sensor data. Public weather reports back up the sensor data. The research paper by (Kucicky, Kolarik, Soustek, Kuncicky, and Martinek, 2020) proposed a modern smart lighting control system that integrated Message Queuing Telemetry Transport (MQTT) protocol and Ethernet network. The advantage of the proposed system by the researchers is that system fits the requirements of smart cities [37]. The proposed connection and controlling of public streetlights allow fast expansion of Smart technologies and related services. The researchers also discussed the requirements and influence of technologies to network bandwidth.

6. Methodology

We collected the information by first searching for relevant journals and articles that are in relation to our smart street light system and we read it through thoroughly. Once the reading material was eligible for our criteria, we adopted a few characteristics and tried to propose and implement it into our system. We took cost into consideration and finalized an idea where it would be the most cost-effective as well as functional, effective product to the market. First, we would need to find the features in-depth and get to know more. Once we know more features, we would compare them to similar ideas, but they mostly do not have street lights integrated into them and the features are set up separately [38]. The research paper by (Iwasaki, Misumi, and Nakamiya, 2015), having features of crime monitoring and the smart street light system would be better if crime monitoring could be implemented as it would bring better security to the people in the area. We bring forth the good features where it could only bring benefits to the people. We could also implement integrated crime monitoring, but it would cost us more than what we could afford, and it would only serve the same purpose of monitoring crime. We have also put in other features like speed monitoring to merge the speed camera to the traffic light, and this would be more efficient and cost-effective to do.

Additionally, we have also come up with the features like weather monitoring and adaptive lighting to the street lights to make it more collective to data like everyday weather data, as another bonus add-on information to the weather station and contributing by sending out effectively collected data. It is seemingly much simpler to transfer such data via smart streetlights. The features like crime monitoring, accident monitoring, weather monitoring, speed cam, and adaptive lighting, we have thoroughly seen through several articles of different ways in terms of implementation. The selected ones in this report are the most efficient and more environmentally friendly option by saving more cost and saving more natural resources to implement such ideas [39]. If this system was implemented, we would have a detection rate of 93.9 percent of vehicles on the road for the accident monitoring system as well as the detection of criminal activities. We also have adaptive lighting that can save 33.3% of indoor and outdoor lighting through the implementation of adaptive lighting, which really saves electricity.We also have a weather sensor that could send the data to the public weather reports using 6lowpan technology. Through the research paper by (Sikder, Acar, Aksu, Ulugac, Akkaya and Conti, n.d.), we have altered the protocols we used in smart street lights. We have compared them with other literature reviews and found out that this suits us the best. In order to satisfy the requirement of low latency, we chose to implement Docker, a container-based virtualization technology for the deployment to achieve high scalability and fast deployment. This means NoSQL and in-memory databases are integrated for database design to provide flexible data management [40]. We also have chosen to implement encryption to secure the data by using an asymmetric key and an SSH encryption tunnel is designed in this research paper for data transmission. We picked these technologies, to help with the enhancement of the data transmission and the no need of setting up plenty of databases. Though we have other encryption that's available, the team has chosen the one as it was the optimal one for our street light system.

7. Results and Findings

The protocols that we are implementing in our proposed SSL system is a short-range communication protocol that links the local control unit with all the SSL controllers and long-range communication protocol that connects the local control unit to the SSL platform. After discussion with the team, we have decided to use 6LoWPAN protocol for short-range communication. 6LoWPAN is a low-power wireless mesh network with its own IPv6 address in each node. The node may connect through open standards straight to the internet. 6LoWPAN originated from the concept of the Internet Protocol being able. It should be applied to even the tiniest devices and allow devices that are low-power with limiting capabilities of processing to be able to participate in the IoT. 6LoWPAN is able to provide a higher data rate to ensure fast and smooth communication between the components. It also allows different applications to have access to the system by providing a common application platform for the purpose of sensor networks or IoT device integration. Besides, 6LoWPAN is a very good choice because it consumes less power. This helps us to achieve our goal of lowering the energy consumption of a street light system. It can support up to 1000 nodes and has a wider range compared to other available protocols. Whereas, LoRaWan is being used as the long-range communication protocol because it offers a large coverage area of up to 5km in urban areas and 15km in suburban areas. Also, the main reason why we choose this protocol is because of its low power consumption and its ability to handle up to 1000 nodes for a single LoRa gateway. Moreover, the security is guaranteed because LoRaWan uses two layers of security that are network security and application security, both using 128-bit session keys. We have decided to use cloud computing and Edge computing as a platform to power the SSL system. We will first explain why we choose Cloud computing. When any critical data is lost, cloud computing provides excellent protection. Because the data is kept in the system, it may be readily retrieved even if your computer is destroyed. You may even delete data from lost computers remotely to prevent it from falling into the wrong hands. Cloud computing also offers high availability. Downtime may be catastrophic for companies that rely on apps to operate their essential activities. Companies may come to a halt as a consequence of server failure, and getting back online can be a difficult and time-consuming procedure. Losses may be substantial. However, cloud hosting eliminates server failure that may cause downtime.

A cloud environment is developed with a guaranteed 99.9 percent uptime to provide predictable and coherent performance. This is because customers on virtual machines may move from the clustered server in case of a problem. Cloud computing is also cost-saving. The necessity for in-house storage and application needs, as well as overhead expenses such as software upgrades, administration, and data storage, may be eliminated by the usage of remote servers. Whereas Edge computing increases data security. Since data is decentralised and dispersed across the devices in which it is generated, the whole network is impossible to dismantle or compromise all the data in one attack. Furthermore, Edge computing architecture provides an innovative solution to the reduction of latency. It brings the critical processing tasks closer to end users for a faster and more responsive service. The advancement in the technology of processing and storage makes it easier for internet-based devices to increase processing capacity and enable them to analyse most of the data collected locally instead of transmitting it to a Cloud Computing server. The protocols we used for secure communication between Edge and Cloud are RTMP AND WebSocket implemented in the edge node. The RTMP protocol maintains a continuous connection between the player client and server, enabling it to function as a conduit and provide

video data to the viewer quickly. When transferring data, RTMP requires a three-way handshake since it is built on top of the Transmission Control Protocol (TCP). The initiator (client) requests that the accepter (server) establish a connection; the accepter replies; and the initiator accepts the response and establishes a connection between the two ends. As a result, RTMP is very reliable. RTMP has different variations. The one we are focusing on here is RTMPS which is a secure version of RTMP. With the RTMPS streaming protocol, the stream between encoder and CDN may be securely streamed, but not only by encrypting it. RTMPS also safeguards against the impersonation of the domain. Among the sender (you) and the recipient (a CDN), a handshake is utilized to verify that your material is really being sent to the correct destination. But both the video encoder that streams the material and the CDN site that you broadcast must support it in order to utilise secure live RTMPS streaming. On the other hand, WebSocket Secure (WSS) protocol utilises conventional SSL and TLS encryption. The client and server may exchange encrypted WebSocket communications via a mutually agreed permission and authentication mechanism. This is important when dealing with messages that involve the government, military as well as corporate. Another two protocols are used for communication between the Web browser and the cloud: "HTTP/2" and "WebSocket." The HTTPS protocol is used to encrypt data sent between the browser and the cloud. To further improve the performance and features of our SSL system. We have decided to apply Machine Learning to the system. Machine learning can improve the overall IoT scalability by analysing and summarizing the data before it is transferred from one device to another. That being said, it shrinks large amounts of data to easily manageable size and allows large quantities of IoT devices to be linked. Also, Machine learning is able to analyse and address inefficiencies to notify a business where they spend unnecessary time and suggest a new workflow for better time management.

8. Tinkercad Workflow

Tinkercad, a web-based 3D design platform, uses Secure Sockets Layer (SSL) to secure its website and ensure that user data and information are protected during transmission. SSL is a protocol used for securing internet communications by providing encryption of data in transit between the user's browser and the Tinkercad website. When a user connects to the Tinkercad website, their browser initiates a secure SSL connection to the Tinkercad server. The SSL connection encrypts the data transmitted between the user's browser and the server, preventing unauthorized access to the data [41]. This helps to protect sensitive information such as login credentials, personal information, and design data. Tinkercad uses a trusted SSL certificate issued by a reputable Certificate Authority (CA) to ensure the authenticity and integrity of the SSL connection. This means that users can be confident that they are communicating with the genuine Tinkercad website and that their data is protected from interception and tampering by third parties. Tinkercad's SSL system helps to ensure that user data is kept secure and private during transmission over the internet, which is essential for maintaining trust and confidence in the platform.

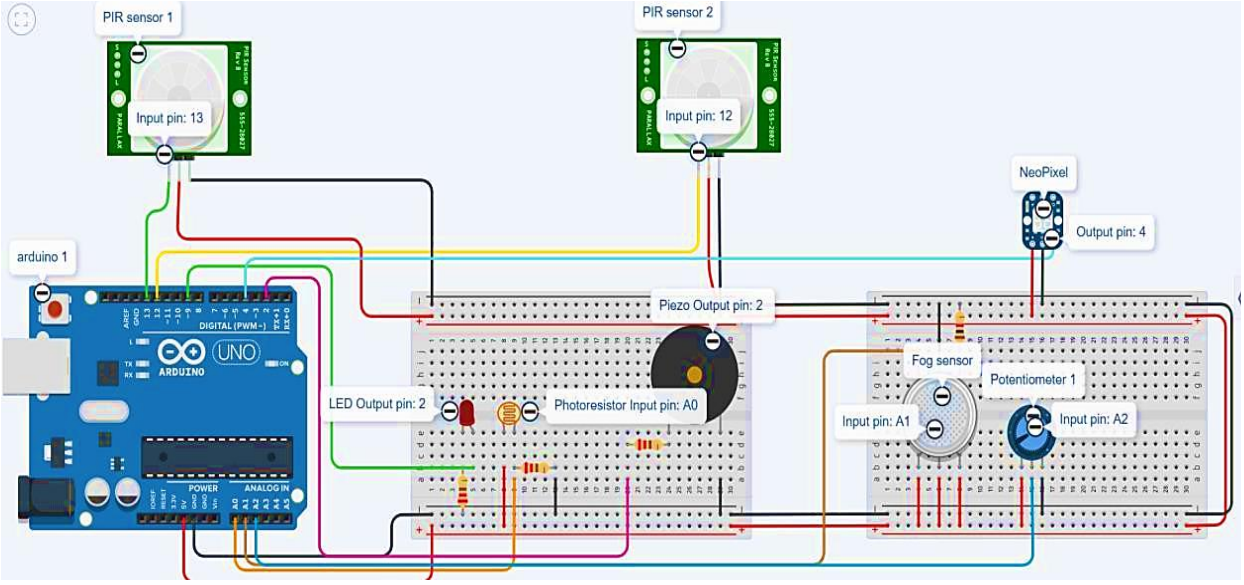

Figure 3 presents the Tinkercad SSL system

As shown above, Fig 3, presents the tinkercad SSL system, this is the first part of the SSL system that demonstrates how dynamic lighting control, crime/accident monitoring, and humidity monitoring work. The brightness around the area of streetlight, motion, and fog detected helps in lighting control. The photoresistor is used to detect the amount of light around the street light. If the surrounding light is bright, for example, during day time, the LED representing the streetlight will not light up. The LED will not light up when the smoke detector detects minimal fog. The photoresistor works along with the smoke detector that detects fog around the streetlight. In the situation where there is no motion detected by the PIR sensor (indicating no car or objects nearby), but the brightness of the light is under a certain level, and the amount of fog reaches a certain point, the LED will light up but not with the full brightness. However, when there is motion detected, the LED will brighten up for a few seconds, manifesting the streetlight to be brighter for better vision. To achieve the minimum power consumption, The LED will not light up even though the PIR sensor detects motion, but the brightness around the streetlight is sufficient, and the fog level is low. This explains the situation where there is a car or people detected by the sensor in the daytime but definitely, the vision is clear enough, so there is no need for a streetlight to be lit up. The whole process will loop again after one second to decide the value set to the LED.Potentiometer as an input will act as the sensor for monitoring humidity. Neo Pixel from "Adafruit" will be used as the output here, which consists of Red, Blue and Green LEDs. The value gathered by the sensor will determine the amount of light presented on the LEDs. The Red LED will be the brightest when the surrounding is dry. The Blue LED will appear brightest when the surrounding is wet. And the Green LED is the middle output when the humidity is at a moderate level [42]. A crime/accident monitoring feature is also included here. Because the infrared camera is not available in Tinkercad, we decided to replace it with a

PIR sensor. When there is motion detected (indicating there is illegal human activity or accident), the buzzer piezo will be activated. Fig 4, presents the temperature feature part 1.

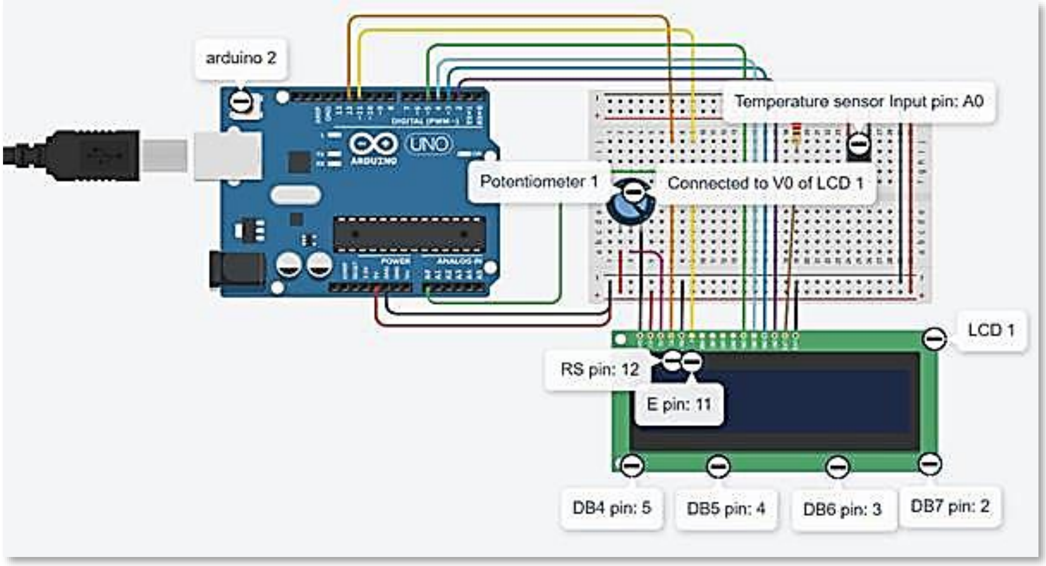

Figure 4 *Temperature Feature Part 1*

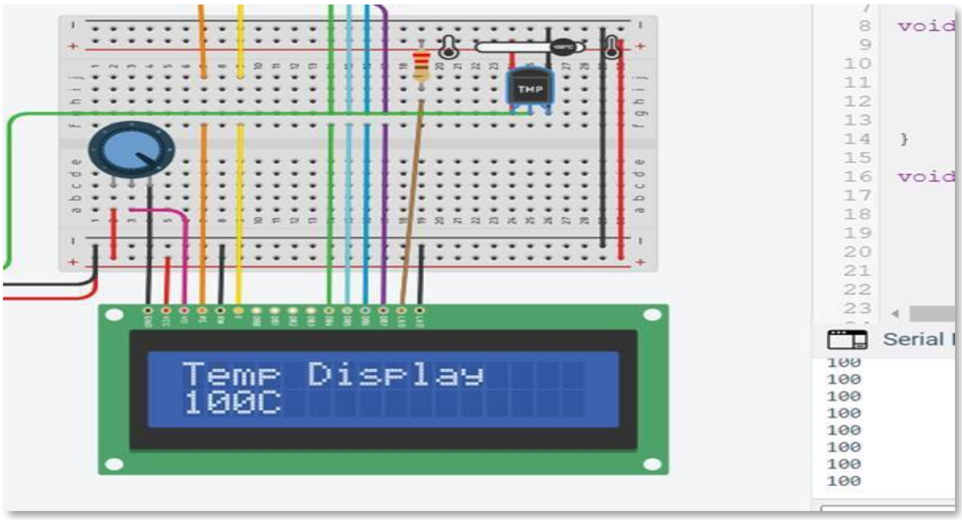

Figure 5 *Temperature Feature Part 2*

Pictured above in Figure 4 and 5 shows the second part linked to Arduino 2. The feature that is focusing here is temperature detection. A potentiometer and a temperature sensor and a LCD are being used. The LCD will display the actual temperature detected by the temperature sensor. And the potentiometer will allow turning on and off of the LCD by the users.

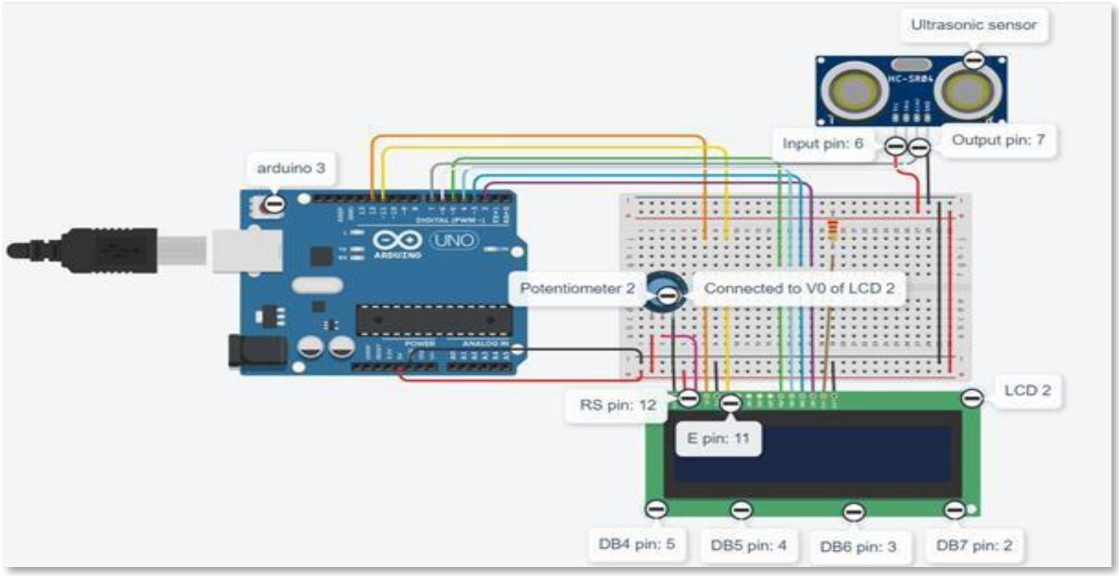

Figure 6 *Speed Detection Feature Part 1*

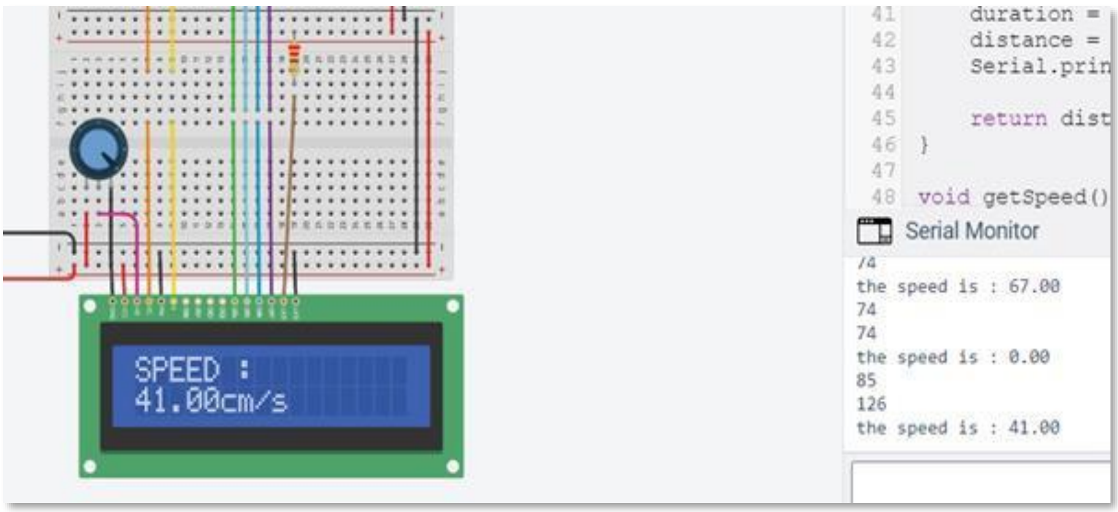

Figure 7 *Speed Detection Feature Part 2*

Figure 6 and 7 above displays the part that connects to Arduino 3 which focuses on the speed detection feature. There are potentiometers, ultrasonic sensors and an LCD. The ultrasonic sensor detects the distance of an object. And the speed of the object will be obtained through calculation and the delayed time plays an important role in speed calculation. The speed of the object is then displayed on the LCD.

9. Discussion

There are many benefits that can be brought by the SSL, however, there are still limitations for the system where one of them is the higher complexity of SSL than the traditional streetlight system due to the connections between more sensors in the SSL to achieve the required functions. Another challenge would be the lack of proven business cases since the idea of implementing IoT on streetlight systems was only introduced in recent years. And regarding the lifespan of lighting infrastructure, the embedded system needs to be highly adaptable over a long period of time which is normally around 20 years [43]. Privacy would also be one of the issues for the SSLwith the large amount of private or confidential information collected from the sensors.

The future improvement needed to overcome the challenges mentioned above includes a scalable platform to integrate the components in the system to reduce the complexity of the system. The SSL should offer ease of maintenance; hence the maintenance cost can be reduced and hence increasing cost efficiency [44]. The software system used to support our SSL has to be upgradable in order to adapt for a long period of time. Cyber security and data encryption are crucial to protect the private and confidential information collected from the sensors.

10. Conclusion and Future Work

In conclusion, our proposed SSL system can achieve the two main objectives of this paper. The objective of our proposed application is to introduce adaptive lighting whilst lowering energy consumption rates and also to allow real-time monitoring of the surroundings of the street lights, be it for traffic monitoring or crime monitoring. The new SSL system has implemented various sensors ranging from a photoresistor sensor that detects the brightness of light around the streetlight to further decide if it is required to switch on a streetlight, a smoke detector that detect the fog level around the streetlight, PIR sensor that detects motion and potentiometer that detects the humidity around the streetlight. All data collected from these different sensors are essential to decide if any situation requires a streetlight to be switched on or off. This stands out from the traditional streetlight in Malaysia currently which is set to switch on for a fixed period without analysing the actual situation. To achieve a better traffic and crime monitoring system, we have implemented infrared sensor cameras that can identify objects in dim areas and an ultrasonic sensor for speed detection to lower the chance of a vehiclefrom speeding up. Also, Piezo sensor is used, which will buzz a tone to notify the nearby police if there are suspicious illegal activities or accidents happening within the coverage areas. The second objective of the paper is to lower the maintenance cost for the streetlight. The problem that arises with the traditional streetlight is the need for a routine check-up by a technician or through citizen complaints in order to identify a faulty streetlight. The SSL system that we proposed implemented fault detection and alarm FE. Electric parameter values are used to monitor the functioning condition of SSLs. The FE may detect errors or disconnects in SSLs, and, if any faults or disconnections occur, it will produce a fault report. It then activates an alert and automatically provides notice. For example, if a light or circuit is not functioning correctly, the SSL platform will create an alert message and transmit it promptly to the maintenance personnel.

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