Modernizing the Traditional Traffic Light System

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1. Abstract:

With the evolution of Internet connectivity and accessibility, IoT is becoming a powerful tool to solve problems and improve our day-to-day life. The issue of increasing road users is becoming prominent, it leads to major consequences, one of which is the increase of traffic accidents, another is the raise in travel time which in turns can have penalties of its own as well as the effect on the quality of life. This research aims to promote the potential of IoT in enhancing our trafficking systems and enabling features that serve the vehicles that are in emergency situations and benefit road users as well. It will provide the appropriate means for emergent cases. It can deliver situation specific traffic light management that will lessen traffic related problems. The methods in which IoT can be employed is virtually limitless, with the existing of a variety of IoT cloud service providers such as Amazon Web Services(AWS), Microsoft Azure, Google Cloud and others, AWS is among the best as it has a plethora of IoT and other cloud services that can be incorporated together to develop projects ranging from a simple consumer system to a complex industrial grade systems, therefore it will be used in this project. The act of connecting traffic lights to the internet opens up a security risk since it will include critical information such as emergency vehicles and police vehicles information, the reasoning behind including these information is to ease the traffic flow to serve the emergent cases, However, with the security services provided by AWS, the security risks are greatly reduced. In addition to serving emergent cases, a huge variety of information such as weather information, special events, traffic accidents as well as other traffic conditions will contribute in the functionality of the traffic light to mitigate traffic congestion or reduce them. In this project, a miniature traffic light system will be simulated with a microcontroller and it will be connected to AWS IoT Services via the internet, as can be reported, communicating two or more devices and exchanging information using IoT is easily achievable.

2. Introduction:

It is becoming increasingly difficult to ignore the traffic congestion we have been facing lately. Recent rapid traffic growth have heightened the need for a solution as the complaints of delay have been raised as the leading cause of so many accidents. Therefore, Intelligent Light Traffic Systems can be viewed as a fundamental evolution of Intelligent Traffic Management Systems. Municipalities and traffic ministries can put this into consideration as it is seen to help with the trend of traffic growth and congestion through collecting data from sensors, cameras and online resources and using them for better traffic management. The development of Intelligent Light Traffic Systems can play a significant part in directing traffic automatically in order to lead to several positive results such as: reducing congestion and traffic accumulation, increasing the traffic flow and safety of road users which decreases the number of accidents, and giving priority to emergency services vehicles as these sensors are connected to the internet to record data and enable users to monitor the traffic light status. This system model can be integrated with the current traffic light systems and can be scaled to any size and could gradually grow to its intended size and functionality.

3. Literature Review:

Ghazal, B., ElKhatib, K., Chahine, K., & Kherfan, M. (2016, April) brought up the subject of complexity when synchronizing multiple traffic light intersections, therefore makes it harder for conventional systems to handle the variable traffic flow, Ghazal, B., ElKhatib, K., Chahine, K., & Kherfan, M. (2016, April) proposed in Smart Traffic Light Control System[1] a system that uses a PIC microcontroller with a collection of sensors to dynamically change time slots in the traffic light system, they have dynamically changed the timing based on the congestion status, they have suggested to integrate more controllers to expand the connectivity of the traffic lights as a future work.

Traffic is something we deal with on daily bases, the use of new technologies to improve it will make our lives much better, Shukla, S. K. G., Kandeth, A., Santhiya, D. S., & Jayavel, K. (2018) have mentioned in their paper Efficient Traffic Management System[2] that the lack of traffic prioritization is a main cause of traffic congestion and this can be solved using IoT and software. They proposed a system with a Raspberry PI that uses a video feed and image processing techniques and then they send the data to the cloud using ThingSpeak platform. Shukla, S. K. G., Kandeth, A., Santhiya, D. S., & Jayavel, K. have stated that machine learning algorithms can be applied as future work.

Raghu N, Phadke, A., kumar, R., & Joshi, K. (2022, September) have linked the todays congestion issues to a loss in economy and the quality of life in their paper Smart Traffic Light and Dynamic Navigational System for Emergency Vehicles[3], they have emphasized on facilitating the way for emergency vehicles like ambulances to minimize the danger of an ambulance passing a red traffic light signal. In their project they have developed minimum viable product, they have interfaced it with an android application. The backend computation is done on the cloud using google cloud services.

4. Research Objectives:

This project is set out to address four main goals:

- Explore modern IoT tools and services.
- Connect devices through the use of IoT and cloud services
- Assist with the traffic flow for emergency vehicles.
- Reduce traffic congestion.
- Provide useful traffic information for road users.

5. Methodology:

This project focuses mainly on integrating IoT in the traffic light system to open it to the internet, this will enable traditional traffic light systems to use IoT tools in order to enhance it and mitigate key downsides of the traffic light system. The objective of this project is to explore the ways of which such smart system could work and the advantages of connecting the traditional systems to the internet.

A microcontroller will be used as a “Thing” to simulate a basic traffic light, a perfect fit for my application is the ESP32 microcontroller with a collection of parts, the ESP32 is chosen because of its processing power and Wi-Fi connectivity, as for the IoT platform, I will be using AWS IoT core services for its vast features and expandability.

5.1 IoT Infrastructure:

Accessibility of IoT tools and services has been simplified over the past years, with the presence of major companies in the cloud services, IoT services has become vastly availability for consumer and industrial use. Connecting devices and machines to the internet has become easily done. Three of the major cloud service providers are Amazon Web Services(AWS), Microsoft Azure and Google Cloud. For this research, the focus will be on AWS as it is easily accessible and offers the needed services for the purpose of this paper. AWS has adequate capability to handle/tackle the main components of the proposed Smart Traffic Light System. Firstly, interfacing the "Thing" to AWS using MQTT protocol by utilizing the AWS IoT Core service, in this case, the "Thing" is the traffic light control system and MQTT protocol is the communication protocol that is used to send and receive information between the thing and the internet. Second, using the IoT Rule feature in the AWS IoT Core service to directs the data to the rest of the cloud services within the AWS. Third, a main part of this IoT system is data logging and monitoring, this is done by three main services, CloudWatch, DynamoDB and S3 Bucket, each service offers its unique features for storage, database building and data usage. Lastly, the EC2 service will take care of data processing and computing, it is a service that provides compute instances to process the data. It can also do Artificial Intelligence and Machine Learning computations.

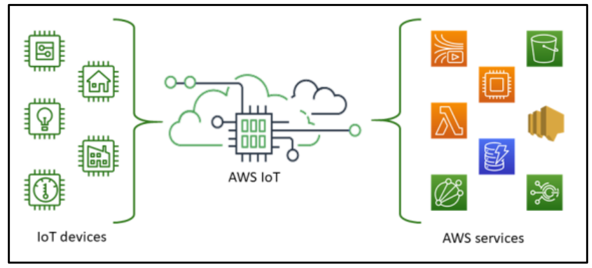


Figure 1 - Source: What is AWS IoT? [4]

These AWS services are fully compatible with each other and easily linked together and a huge benefit of these services are that they are all scalable meaning that they can be used for small and large scale systems, the cost of using these services will scale with usage and service users pay for what they use based on their needs which is a huge selling point for AWS.

5.2. The logic of the Smart traffic light systems

There are two main modes of which the Smart Traffic Light Systems will work, generally, it will be traffic congestion reduction mode, where it will use algorithms and techniques to maximize traffic flow, the traffic lights will be connected to the internet pushing all the existing sensor data to the cloud, these data is used to calculate the traffic figures like traffic flow, number of vehicles, traffic light status and other information, then this data is used in the logic design and algorithms of the traffic light system. At the beginning, the control system logic can include one or two traffic light intersections, it can later be scaled up with time to include more, with using AWS, scalability is fairly easy to be implemented and the logic can be computed in the cloud while the traditional system can be kept for redundancy in case any connectivity issues arise. The other mode will be switched over to when there is an emergency vehicle is in route, the logic and algorithm will prioritize the flow direction of the emergency vehicle to ensure the minimum arrival time, all traffic signals in the route of the emergency vehicle could be armed and ready before the arrival of the vehicle and could take the necessary action in advance to open the way for the emergency vehicles.

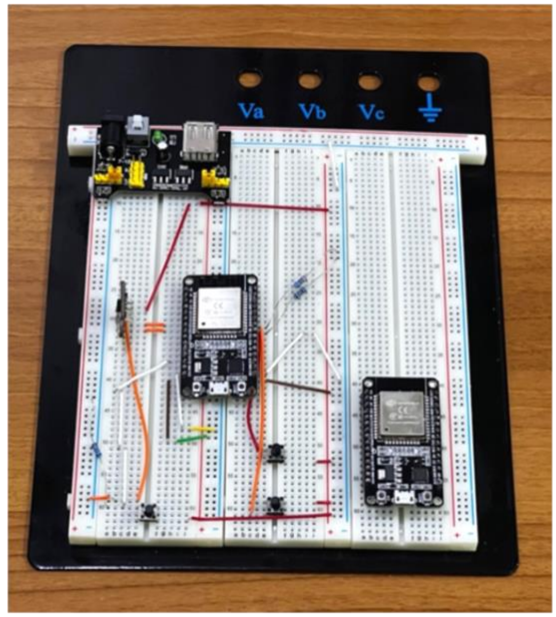
5.3. Hardware Specifications

For this project, the ESP32 will be the main processor and IoT device because of its processing power, IOs and communication capabilities. Two total ESP32 will be used in this project.

Specifications	
CPU	Xtensa 32-bit Dual Core microprocessor (160 – 240 Mhz)
Memory	320 KiB RAM
IOs	36 GPIO ports
ADC	14 ports
DAC	2 ports
WiFi	802.11 b/g/n
Bluetooth	V4.2

In addition to the ESP32, the VL53L0X Time of Flight sensor will be used to measure the distance, it is a laser based time of flight sensor that sends a pulse signal at a certain rate and measures the time for the pulse to reflect on surfaces.
Furthermore, this small project will use three push buttons and an LED, for this project, the LED integrated in the ESP32 will be used.

The project is built on a prototyping board (breadboard) as in the picture

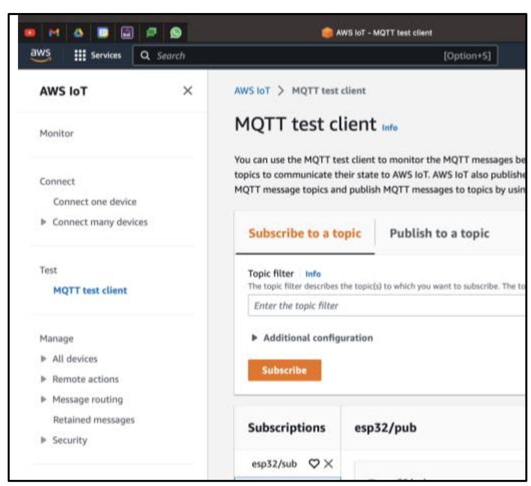


5.4. Software and IoT Service Configurations

This section will be split into two major steps, interfacing the ESP32 with AWS IoT Core and programming the main code.

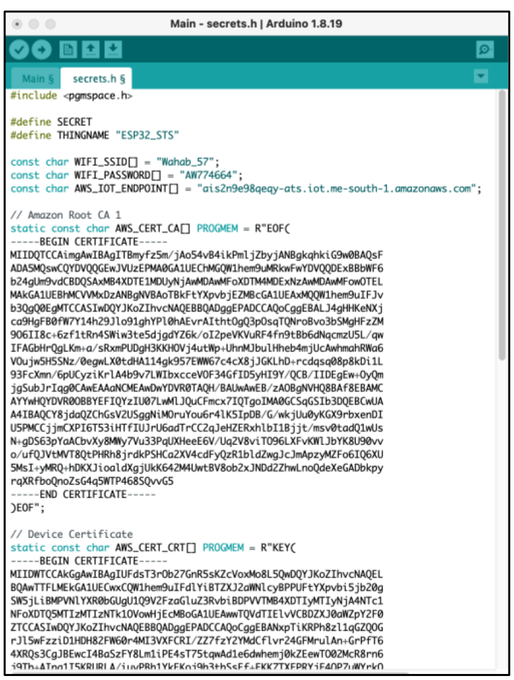
5.4.1. Interfacing the "Thing" with AWS IoT Core

First, a free account in AWS has been created and setup to use IoT core service, then a new "Thing" is created with the appropriate configurations and settings. In this project, the configurations are set for MQTT protocol.



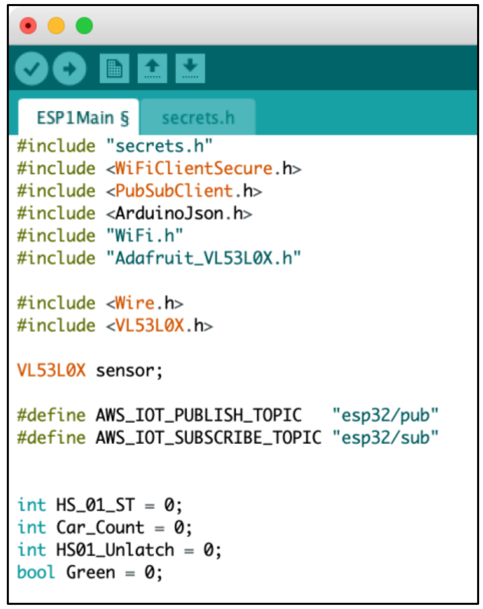
a subscribe topic and a publish topic is created to be used in the ESP32 code, in addition to that, certificates and keys files are generated and downloaded from AWS to be used for the ESP32 code.
In the ESP32 code, the subscribe topic and a publish topic is matched with AWS

Additionally, the keys and certificates as well as the WiFi configurations are coded.



5.4.2. Main Traffic Light Logic

The code for the traffic light is as follows:



The needed libraries are first called in the program and the variables are defined, AWS related functions and commands are added to initialize the connection to the IoT Core Service.

This piece of code does the following:

- Use the first push button to switch between the normal mode and the emergency mode
- The emergency mode will trigger the traffic light to green when an ambulance approaches
- The time of flight sensor is used to simulate an emergency vehicle approaching the traffic light
- When there is a traffic congestion, the program will trigger the green light at an early stage in order for the traffic to clear before the emergency arrives.
- A second push button is used to count up the number of cars at the intersection, this is used to simulate a traffic light congestion.
- A third button is used to reset the number of cars to zero.

All of these information is passed to AWS and are accusable. The second ESP32 is used to simulate another intersection traffic light, this second one will use similar configurations to connect to ASW IoT core but it will receive the data from the first traffic light.

Using that data, it will control the status of its traffic signal, this is the main code:

```
}

void messageHandler(char* topic, byte* payload, unsigned int length)
{
  Serial.print("incoming: ");
  Serial.println(topic);

  StaticJsonDocument<200> doc;
  deserializeJson(doc, payload);
  if (doc["Signal Status: "] == "Green") {
    Green = 1;
    Serial.println("Turn traffic light to green");
  }else if (doc["Signal Status: "] == "Red"){
    Green = 0;
    Serial.println("Turn traffic light to red");
  }
```

The code takes the information sent from the first ESP32 through the cloud and acts accordingly, it prepares the signal to turn green ahead of time to clear the way for the emergency vehicle

The full code is available in the appendix.

6. Conclusion and Future Work

By enabling IOT on the current traffic system, the system will have access to the information from ground sensors, cameras, radars and online recourses to identify congestion areas, car data, cars destinations, special events and incidents, and based on these parameters, it can determine how it will behave, for this project, connecting the microcontroller to the internet and sending and receiving information is achieved. An improved prototype might use a camera and computer vision to detect emergency vehicles.

7. References

[1]Ghazal, B., ElKhatib, K., Chahine, K., & Kherfan, M. (2016, April). Smart Traffic Light Control System.

[2] Shukla, S. K. G., Kandeth, A., Santhiya, D. S., & Jayavel, K. (2018). Efficient Traffic Management System.

[3] Raghu N, Phadke, A., kumar, R., & Joshi, K. (2022, September). Smart Traffic Light and Dynamic Navigational System for Emergency Vehicles.

[4]AWS. (n.d.). *What is AWS IoT?* Amazon Web Services.