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IoT Enabled Smart Logistics Vehicle using Semantic Communication

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Abstract: The boost in the quantity of users connected to the Internet has been increasing exponentially in the recent past. With this increase, comes the dawn of new technologies and more applications. One such application is the field of Logistics. Having a connected range of vehicles can serve a great purpose in time-critical issues like path-planning, priority-planning, continuous monitoring, and security. The aim of this work is to build a secure navigation system of a connected vehicle using a Wi-Fi module and necessary sensors. This shall enable us to remotely monitor and gather data from the vehicle and make informed decisions regarding the path, and time requirements of the vehicle while maintaining security aspects. Any sensor can be mounted on the vehicle to collect necessary data like temperature, humidity, gas leakages, air quality, soil water content etc. However, connecting several vehicles also increases the bandwidth usage. In order to reduce this bandwidth usage and improve spectral efficiency, semantic communication is introduced. Semantics is the study of inner meaning. Semantic communication is the research interest that deals with the transfer of the meaning of data instead of the data itself. Semantic communication is seen as a valuable method to reduce bandwidth usage and latency significantly. In this paper, we present an Internet of Vehicles (IoV) enabled Smart Logistics Solution using Semantic Communication.

Keywords: *IoT, Logistics, Navigate, Semantic communication.*

1. Introduction

To make the most of existing infrastructure, major goods hubs must improve their logistical operations from start to finish, from quayside unloading to delivering commodities to their final destinations. It's a matter of ensuring that the desired data arrives at the appropriate location at the desired time, as well as making real-time traffic and infrastructure information available to everyone. The person in charge, with the help of a central, smart logistics platform, has a constant overview and can better handle the increasing flows of products, reduce truck downtimes, and avoid traffic congestion.

1.1. Proposed system

For information processing and sharing, logistics organisations now rely on modern ICT solutions. Statistics and information concerning require for logistics forces and provide prospects are attractive more significant aggressive advantages [1, 2]. Unluckily, merely large corporation can give complicated systems. Microscopic and average-sized logistics firms have limited or no IT expertise. As a result, a resolution is mandatory to permit collaboration between smaller logistics companies, lowering operation costs. The SMART move towards, which is built on negotiator expertise and cloud computing, is planned in this study. It will make data assembly and flow easier, as well as present enhanced and less pricey admission to logistics organization systems.

1.2. How does IoT aid in logistics?

Clients, logistics, and transportation businesses can use IoT-based solutions to track where items are at all phases of the transportation process, as well as monitor parameters like temperature, humidity, and vibrations [3, 4]. This information is crucial for transporting delicate products including food, dangerous goods, drugs, and medical equipment. As a result, IoT can be utilised to control transportation conditions and increase delivery efficiency [5]. These technologies give logistic operators, transportation companies, clients, and other stakeholders more control over their freight. Because IoT may be integrated into traditional supply chains to track, trace, and monitor vehicle movement, it may be useful in resolving some transportation issues [6].

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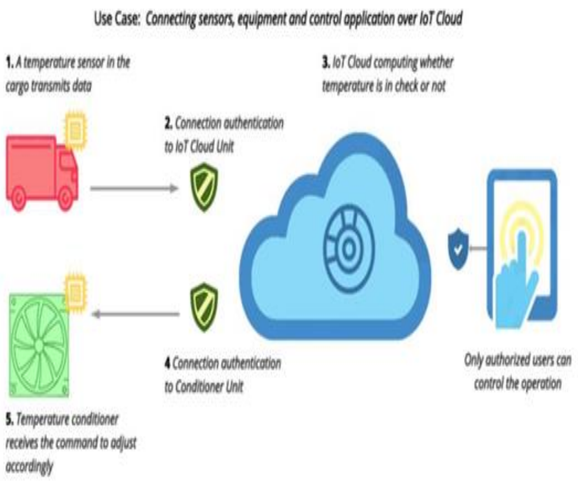

Figure 1. Use Case

1.3. Semantic Communication

Semantic Communication (SC) are generic networks that are more concerned with the meaning of data [7-9]. A simple example of SC is reducing bandwidth usage by conveying the content of an image rather than sending the whole image. For example, instead of sending the image of an apple, the Quality of Service (QoS) and (QoE) can be maintained simply by sending a string- “apple”. This implies that the sender and the receiver have the same dictionaries for interpreting the meaning of the acquired data. At the receiver end, though the exact data may not be completely reconstructed, the meaning received is enough to proceed with the application. SC also implies that the sender has some computational power that is required to pre-process the sensed data and convert it to a valid smaller information string (or symbols). SC is an emerging research topic that has gained more attention with the advent of 5G and 6G communication standards [10, 11]. In this work, we try to reduce the bandwidth usage of each vehicle by transmitting minimal information bits that convey all the important features of the vehicle and its surrounding.

2. Implementing IoT in the Logistic Chain

Companies will be able to manage inventory products, monitor their status, and construct a smart warehouse system with the use of small, inexpensive sensors. Employees will be able to successfully prevent any losses, assure secure product storage, and properly locate an item needed with the help of IoT technology. The majority of coordinated operations associations have previously decided to carry out IoT innovations. IoT can support the production of a shrewd area the board framework that permits organizations to follow driver movement, vehicle position, and conveyance status easily. A director is informed by a push message after the items have been conveyed to the ideal area.

2.1. Technical Aspects

Following this technique allows us to track the merchandise and send warnings to the receiver's mobile phone via cellular networks. The numerous components described below can be used to track items at a reasonable cost.

- Sensor data- Sensor data from many types of sensors (e.g. temperature, humidity, luminosity, vibration, etc.)
- GPS- Tracking the location to deliver data to the related infrastructure in real time.
- Connectivity- Data transmission to store and compute requires infrastructure like edge or cloud compute devices
- Computing- Internet of Things (IoT) devices, Cloud technologies Real-time monitoring, control, and optimization of transportation processes.
- Control and visualisation- A web interface and mobile application that shows condition information, vehicle whereabouts, and notifications.

2.2. Components

- *Hardware*- Arduino Nano, ESP8266 LolinNodeMCU, RFID/NFC tags, IR sensors, Display, I2C converter, motors, chassis, wheels, connecting cables.
- Software - Arduino Programming language, Google Firebase, MIT AppInventor.

2.3. Model of the proposed logistics vehicles with wifi controlled robot

The model can be divided into two parts. One part deals with the movement of the robot. It consists of the LoLin ESP8266 NodeMCU and the motor driver circuitry. This model works on the differential drive mechanism. This part is shown in Fig. 2.

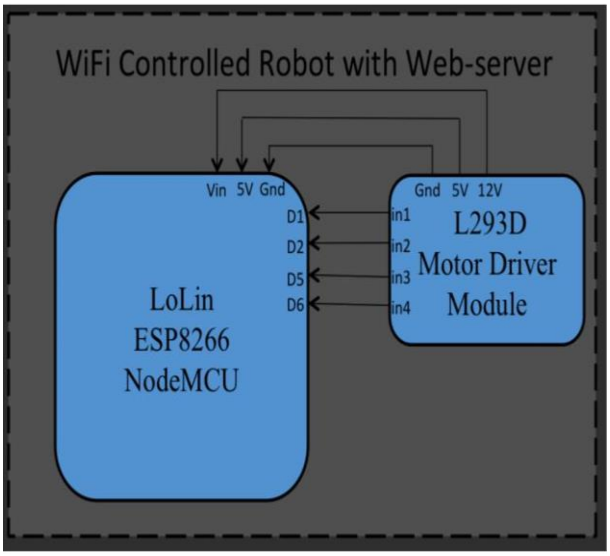

Figure 2. Navigation part

The robot undercarriage is demonstrated for a four wheel drive. The skeleton is then incorporated with high force engines with low turns each moment. The engines are then associated with an engine driver circuit. Examinations were made between L293D engine driver and L298N engine driver. L298N engine driver is favored in view of its capacity to deal with more flow. The likely drop across the engine driver adds up to around 1.5V and this is endurable for our necessities.

The ESP8266 NodeMCU is then incorporated alongside the engine driver circuit and Wi-Fi orders are tried over the neighbourhood server. An Android application is created utilizing MIT App Inventor involving the TCP guidelines for the controller of the robot.

The second part is the sensing part. It consists of all the sensors and displays. The sensors can be easily modified as per the requirement of the application. The sensors are controlled by the secondary microcontroller- the Arduino Nano board

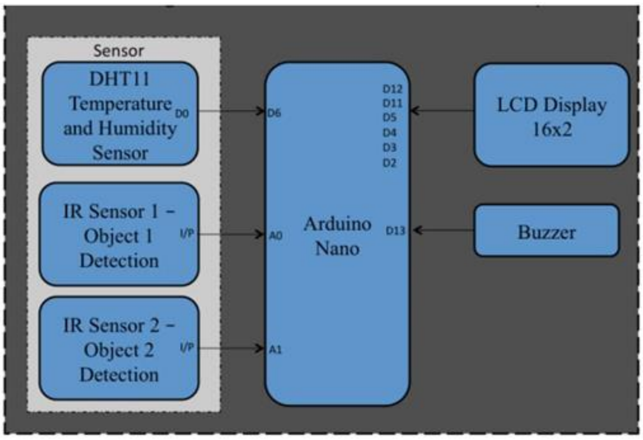

Figure 3. Sensing part

3. System Model

The ESP8266 Module is in charge of connecting to the Wi-Fi network as well as operating as a server in this arrangement. A basic HTML page is prepared for the client, and the browser that accesses it acts as the client.

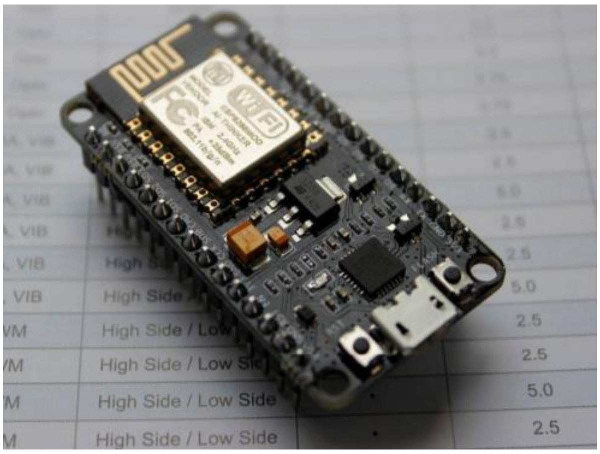

Figure 4. ESP8266 NodeMCU

3.1. ESP8266 NODEMCU

The ESP8266 NodeMCU board fills in as the framework's focal handling unit. The Arduino IDE C++ compiler will be utilized to program this module. The ESP8266 WIFI Module is an independent SOC with an inbuilt TCP/IP convention stack which gives admittance to Wi-Fi organization to any microcontroller. The ESP8266 might run a program or offload all Wi-Fi organizing exercises to another CPU. An AT order set firmware is pre-modified into each ESP8266 module. The ESP8266 module is a minimal expense board with a huge, and quickly expanding, local area. Fig. 2 shows how the module works with 802.11n and 802.11b organizations. This infers it might work as an Access Point AP, a Wi-Fi station, or both a station and an AP.

3.2. Chassis Setup

A four-wheeled solid arrangement is utilized with the end goal of outside route. Four DC engines, 50 rpm and 10kgcm force, are utilized for supporting the framework. The engines are fuelled by a 12V Lead Acid battery. The arrangement likewise contains a H-span circuit, which adjusts the control of the microcontroller with the turning and route of the wheels. The H-span circuit is principally a L298N chip associated with an intensity sink. It is connected to the microcontroller, which gives the contribution to be taken care of to the engines and in this way controls the movement of the robot.

Figure 5. Chassis model

To imitate the driving of the vehicle, an android application is utilized to control the vehicle. In a certifiable situation, the vehicle will be driven by the driver.

3.3. Semantic Communication

A wide range of sensors can be attached to the vehicle. For example, a Dallas Humidity and Temperature (DHT) sensor is a low cost sensor that can be used to detect the atmospheric temperature and humidity. Several other low cost sensors can be added to sense the environment as per the requirements. This also includes the usage of cameras. In case cameras are used, a low cost microprocessor like a Raspberry-Pi can be of very good use. In this work, we do not use a camera. We only use auxiliary sensors to build the proof of concept. The values of the different sensors are combined and denoted as a single symbol that can be transmitted as a single ASCII character. This reduces the amount of data that needs to be transmitted. Obviously, the dictionary used to encode the data from the sensors has to be present at the receiver also, so that the information can be accurately decoded.

The security aspect of SC is a nice research topic in itself. Since the dictionaries used for encoding and decoding the information is kept private, the middle-men, if any, will not be able to decipher the information. This makes SC inherently more secure. However, this poses the important question of standardisation of the dictionaries. The encoding and decoding schemes may cause significant differences in the networking aspect of the application. Another important aspect of concern in SC is the resource allocation. Standards have not been set for the metrics that define the quality of SC. Resource utilization when implementing SC is a complicated term to define because, the transmission does not carry the exact data. In this work, we are only concerned with the proof of concept. In the future, we can extend this work to include accurate metrics for the evaluation of the quality of the network. Network measurements when implementing SC will be of particular interest in our future works.

4. Implementation

In this work, the vehicle communicates with a mobile app. This represents a central server unit that can connect to different vehicles. This very application can be modified into a web-app or a private secure node that exploits edge computation to store all the information of and from the vehicles.

The sensors used in this work are DHT sensor for temperature and humidity, SR04 ultrasonic sensors to detect obstacles on the path of the vehicle, RFID tags to improve security, GPS sensors to share the location, pressure sensor to detect any abnormal pressure activity, vibration sensor to detect any abnormal vibrations, sound sensor to monitor any emergencies, and Force Sensitive Resistive (FSR) sensors to detect any impacts of concern on the vehicle. These are all analog values that can be converted to digital values that make more sense.

On the whole, there are 9 different sensors active. The goal is encode convert these values into minimal number of symbols. Each sensor value can be compressed to one of the three readings- Normal (N), Abnormal (A), and Emergency (E). So, each of the 9 sensors can give one of the three states.

The 9 sensors can give 3 states each. So there are a total of 3^9 combinations. This amounts to 19683 combinations. When we consider a standard 8-bit ASCII character, we have 256 different symbols. So, 2 ASCII characters are more than sufficient to represent the 19683 combinations.

Enconding the values of 9 different sensors in 2 8-bit characters (2 bytes in total) is a massive reduction in the amount of data that needs to be transmitted. Since this is a very small value, we use our spectral bandwidth very efficiently. This also allows us to transmit more frequently to keep our entire network more up to date with the environmental changes concerning the vehicles.

If we proceed with autonomous networks, being able to communicate more frequently becomes important because the network relies on fast updates about the changes in the environment [12- 15].

5. Result

A Real Time model robot that could unpleasant landscape with a live video transfer was built and tried. An Android application as User Interface to control the robot's route in light of the video transfer, was delivered as found in Fig. 6. A smaller gadget inside a packaging was made as found in Fig. 8. A format of the PCB configuration was planned involving Eagle programming as found in Fig.s 9 and 10.

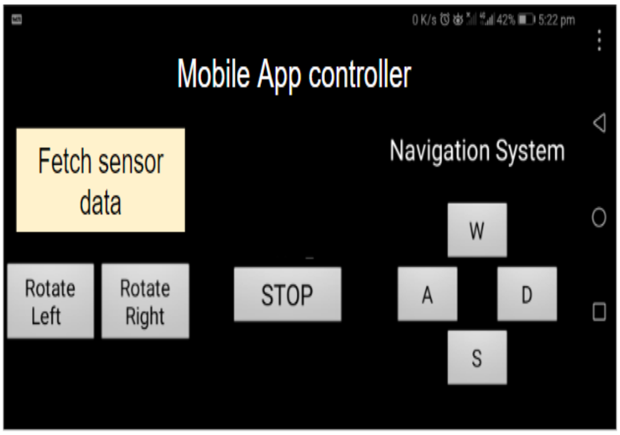

Figure 6. App Design

By implementing SC, the total information to be transmitted as reduced drastically. This is shown in the Fig. 7. There are three cases that are being compared in Fig. 7. In the first case, we assume each sensor has an analog value ranging from 0 to 1023. This accounts for 10 bytes. ($2^{10} = 1024$). So for all 9 sensors, the total number of bytes that need to be transmitted is 90 bytes.

In the second case, the reduced states Normal, Abnormal, Emergency are transmitted. In this case, only one byte is required to denote the value from each sensor. So, 9 sensors require 9 bytes.

In the third case, with complete SC implementation, the ASCII characters are used to represent the different combinations of the sensor states possible. So, only 2 bytes are required.

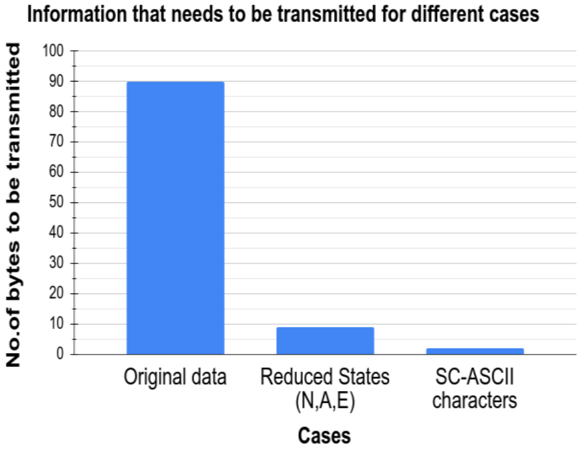

Figure 7. Comparison of number of bytes that need to be transmitted when SC is implemented

Clearly, there is a massive reduction in the number of bytes that need to be transmitted. There is a 98% reduction seen in this case. Note that this percentage will be even higher when the number of sensors increases to 10. This is because, 2 ASCII characters can be used to represent 256^2 (= 65536) combinations of the states. Currently, we only have 19683 combinations.

6. Conclusion and Future Scope

This model is a remote controlled, shrewd operations answer for manageable vehicle. The focal point of this venture was to plan and execute a strong frame with Wi-Fi empowered controller framework with a microcontroller and suitable sensors mounted on it. The L298N engine safeguard gives the suitable H-span circuit for moving the wheels, which play out the real development. It is controlled utilizing an Android application on a PDA. This model is pointed toward further developing operations and security. It very well may be utilized in various regions by changing the sensors that gather the data.

The proof of concept for Semantic Communication has been implemented successfully and the improvement in spectral efficiency is very obvious. So, we believe this research direction can lead to a highly optimized networking paradigm.

This project can be improved by implementing GPS based automated navigation. Computer Vision for obstacle avoidance and cliff detection can be implemented to improve the functioning of the robot. Path planning algorithms can be implemented for outdoor autonomous navigation. Next steps can be to include performance metric studies to evaluate the quality of Semantic communication. Network measurements can be made to study the impact of Semantic Communication in real world scenarios.

Conflicts of interest

The authors declare no conflicts of interest.

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