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IoT Based Smart Fuel Monitoring System

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Abstract: ***In today's fast paced world, monitoring systems are necessary to track the changes in the environment for better understanding of current scenarios and predictions thereof. The same is true for fuel tanks in vehicles as well. By keeping strict track of fuel intake and consumption, vehicles can be made more fuel and cost efficient. This can be done using remote monitoring and data collection systems deployed at the site of the fuel storage tank. This proposed monitoring device is built on Atmega16 computer that takes fuel tank level information from its sensors and analyses this data at the sensor edge to find patterns using edge analytics technology. These patterns and data are streamed to the internet, either an android app or a website. This paper presents the implementation of such a monitoring system based on Internet of Things (IoT) technology to protect the fuel customers from theft at the gas stations and formulate better conservation strategies.***

Index Terms: Fuel Monitoring; Internet of Things (IoT); Edge Analytics; Atmega 16; Cloud; Flow Sensor; Load Sensor; Wi-Fi.

I. INTRODUCTION

In current times, petroleum is a very limited resource. As a result fuel prices climb higher every day. It has become more than difficult for the average human being to keep up with the skyrocketing prices of fuel every day. Adding to that are fuel thefts by fuel sellers/providers which result in more financial loss for the common people. Tampering of fuel apparatus at gas stations is not uncommon these days, resulting in customers paying more than the amount of fuel they actually purchase[1]. This calls for a system on the customer's side to be put in place to track their fuel intake to avoid financial losses. Many technologies provide the solution for the above mentioned problem. Especially, Internet of Things(IoT) can help control and monitor the fuel consumption and level of fuel in the tank. Internet of Things (IoT)[2] is a concept that allows a variety of things to have a presence in an environment and to be interconnected by the virtue of wired or wireless connections and unique addressing schemes. These devices (things) are capable of interacting with each other and cooperate over this network resulting in new applications/services and reach varied goals. This concept converges the real, the digital and the virtual devices to create smart environments that make areas like energy, transport, cities, etc. more intelligent. The primary goal of Internet of Things (IoT) is to enable devices to be connected anytime, anywhere using any path/network and service. Edge analytics is a fairly new branch of data analytics that involves analyzing the gathered data at the edge (or the site of the device, sensor, etc.) rather than transporting all the data to the main site. This not only helps save time but also saves space occupied by unnecessary data.

Contribution of the Authors: Identified the problems in current fuel measurement systems and took upon the research of the traditional fuel measuring systems alongside the technology of Internet of Things and Edge analytics. Proposes a novel fuel monitoring system by using Internet of Things and edge analytics method. Implemented the fuel measurement system using Atmega16. The following paper is organized as follows: This section gives the introduction about IoT and Edge analytics method. Section 2 briefs about the survey on different fuel measurement methods in vehicles, fuel consumption monitoring systems and the use of edge analytics. Section 3 describes the fuel measuring systems currently in use in vehicles and elaborates their shortcomings. Section 4 proposes a better system to keep track of the intake and usage of fuel. Section 5 shows the implementation result. The results obtained from the experimental implementation give rise to the conclusion on how the proposed system is better than the one currently in use.

II. RELATED WORKS

Shaik Qadeer describes in his paper on low cost fuel consumption that an Infra-red sensor is incorporated to the existing odometer which gives electrical signal in the form of pulses as the wheel rotates. As the tank empties, the float drops and varies the resistance. This voltage signal obtained due to change in resistance is fed to a DC motor. This motor is placed on the instrument panel which has a pointer to show various levels of fuel. The voltage obtained from the level sensor is calibrated to give fuel volume in liters.

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To avoid fluctuation in the voltage signal a stabilization circuit is designed and employed. The IN4007 diode is used for unidirectional flow of signal; to carry out the working a PIC 16F877A microcontroller is used. It's a 40 pin IC with 5 ports and supports in circuit serial programming.

A buzzer is installed to alarm the user if the bike is consuming fuel excessively. This alerts the owner of the vehicle that there is a problem with the performance of the bike and it needs to be serviced [3]. Osueke [4] uses the metal tank to store the fuel. The framework has a fuel sensor encoder comprising of a sensor utilized in encoding or unraveling the dimension of fuel gas in the tank. Also, the low vitality ultrasonic gadget is fitted with sensor estimating the fluid dimension at one point. It comprises of a couple checked sensors. It has an in circuit sequential programming port connector which sends and gets the encoded sign from the fuel sensor appended to the tank. It has a PC show framework which is a PC framework utilized in interfacing the ICSP port connector for showing the status of or the dimension of the fuel in the tank. Loadcell, clarifies Raveena in her paper[5], is a transducer with strain check that estimates the heaviness of fuel tank dependent on the power connected and it has an extension circuit to change over the adjustment in protection from electrical sign. It is changed over by four strain checks inside the heap cell which shapes the wheat stone scaffold circuit. The yield electrical sign are sent to the Arduino Uno fixed underneath the fuel tank. The yield signals from the heap cell are given to the Arduino Uno that changes over the weight an incentive into liters. The GSM modem transmits the deliberate fuel levels while filling of fuel tank to the particular proprietors. [5]According to Mahadev Satyanarayanan [6], computer vision analytics running on the cloudlet in near real time, use a version of edge analytics. Only the results (recognized objects, recognized faces, and so on), along with metadata (such as the owner, capture location, and timestamp) are sent to the cloud. The tags and metadata in the cloud can then help in further customized analysis/searches of the content of the video. Pre-processing videos on cloudlets also offers the opportunity of employing content-based storage optimization algorithms to hold on to only one of the many similar videos. Thus edge analytics is used to make analytical decisions closer to the sensor/device to save time and resources otherwise spent on communicating entire chunks of gathered data to the cloud. Similar data can be discarded and only the data with some prospective effects on current conditions is moved forward to the cloud.

Weisong Shi[7] says in his research that processing data at the edge proves to save time and increases reliability. Owing to this, there is a shift to edge analytics in most systems these days. There is also a possibility of saving bandwidth if a larger portion of data could be handled at the edge rather than uploaded to the cloud. It is also more efficient to analyze data at the edge since edge connects both end user and cloud physically and logically helping long distance networks together for data sharing along with traditional cloud computing paradigm. Actual records of fuel filled and consumed by vehicles is hard to come by these days. This results in financial losses on the consumer's part, elucidates Mrs. S.A. Chiwhane[8]. Proper monitoring and tracking of fuel consumption and intake is required to solve this issue. Therefore, a system based on the IoT technology is devised to track the fuel consumption in vehicles. The information fuel transaction can be stored in the database of the system. It proves to be better than the existing systems as it calculates the current filled fuel as well. The IoT technology provides security of user identity for authentication of users trying to access the data.Monitoring systems keep track of the changes in their environment. This proves true for fuel tanks as well where a monitoring system keeps track of fuel consumption and patterns of consumption. A complete fuel monitoring system can be implemented with the use of sensors, Raspberry Pi and an Internet of Things platform, to monitor the data and send it to a mobile device for further analytics. This analysis of data is used to determine better ways for fuel consumption, fuel consumption patterns and trends, helping save financial losses along with discovering more eco-friendly ways to consume the limited resource, describes Areeg Abubakr Ibrahim Ahmed[9]. Chi-Lun Lo[10] and partners proposed a fuel utilization estimation framework incorporates OBUs, client gadgets, an information investigation server, and a database server. The OBU incorporates a position module, a middleware module, and a correspondence module as pursues: The position module can bolster a worldwide situating framework (GPS) to get and break down satellite sign for evaluating the area (i.e., longitude and scope) and speed of the vehicle. The correspondence module can bolster the methods of long haul development (LTE), and the OBU can interface with the information investigation server through the correspondence module and cell systems. The middleware module can bolster hypertext exchange convention (HTTP) and illustrative state exchange (REST), and the OBU can intermittently call application program interfaces (APIs) and send the development data (e.g., OBU ID, vehicle type, driver ID, timestamp, longitude, scope, and vehicle speed) to the information investigation server. This examination proposes a fuel utilization estimation strategy which incorporates a development data gathering technique, a fuel data accumulation strategy, and an improved structure technique. The procedure of the development data accumulation technique incorporates: accepting the development data from the OBUs; breaking down and putting away the development data; and figuring the measure of every vehicle speed interim (i.e., driver conduct in this examination) for each OBU and every driver amid a period interim. The procedure of the fuel data gathering technique incorporates: accepting the fuel amount data from the client gadgets; breaking down and putting away the fuel amount data; and ascertaining the measure of fuel amounts for each OBU and every driver amid a period interim. The procedure of the improved creation technique incorporates: accepting the examples of driver practices from the development data gathering strategy; getting the examples of fuel utilization from the fuel data accumulation strategy, and to investigate the arrangement of fuel utilization as per the example of driver conduct.

III. TRADITIONAL FUEL MONITORING SYSTEM

The traditional fuel gauge system are designed to show a shortage of fuel even when there is sufficient fuel in the tank, these systems are notoriously inaccurate in measuring the actual amount of fuel in the tank. Some embedded systems were incorporated into this fuel gauge system to make the measurements more accurate.

The traditional system makes use of the resistive float type sensor to measure the amount/level of fuel in the tank. This system involves two parts, 1) the "Sender unit" responsible for measuring the level of fuel in the tank, 2) the "gauge unit" responsible for displaying the measure fuel levels, explains Vinay Divakar[11]. The sender unit is located in the fuel tank of the car and it consists of a float made of foam, which connects to a thin, metal rod. The end of the metal rod is fixed on a potentiometer. The potentiometer changes its resistance depending on the level of fuel in the tank based on the position of the float. The gauge consists of a bimetallic strip. When resistance decreases, current increases and thus the strip is heated resulting in non-uniform expansion of the strip, and thus it curves, and this bending action is what moves the needle on the fuel gauge. There are certain problems faced by the use of the above described system though. These problems result in inaccurate fuel readings. When the tank is full, the float is at its highest point and completely submerged in fuel, which results in the needle showing 'full tank'; but the needle cannot move down, unless the fuel is at the lowest point of the float. This means even if fuel is being used, the needle would show 'full tank' for quite some time before starting to move down. Similarly, the lowest range of the float does not coincide with the bottom of the tank, so the needle shows 'empty tank' long before the fuel actually gets over resulting in inaccurate overall readings.

IV. PROPOSED IOT BASED FUEL MONITORING SYSTEM USING EDGE ANALYTICS

The above stated problems are rectified in the new proposed system for fuel monitoring. This system measures the amount of fuel filled in the tank more accurately and relays this information to the user's mobile phone app or to a web page. The system would also track the fuel consumption patterns using edge analytics technology to help the consumer figure out better ways of fuel conservation and cost efficiency. This is done by using flow and load sensors in the fuel tank to tack the intake and consumption of fuel. This acquired information is then analyzed on site to determine consumption patterns. The fuel intake data and the analyzed data is then sent to the user's mobile phone app incorporating the edge analytics and Internet of Things (IoT) technology.

The following components make up this proposed system-

Fuel Tank : The tank employed in this system would be essentially the same as the tanks currently in use in vehicles, with a couple of flow sensors fitted at the inlet and outlet, and a load sensor at the floor of the tank.

Flow Sensor: Flow sensor, practically works on Hall Effect method. It is basically a simple frequency counter that produces a series of pulses which are proportional to instantaneous flow rate.[12] The equation of flow rate of fuel can be shown as follows:

$$Q=V*A$$

- Q is flow rate/total flow of fuel through the pipe.
- V is average velocity of the flow.
- A is the cross-sectional area of the pipe.

1) Pulse frequency (Hz) = 7.5Q, Q is flow rate in Liters/minute.

2) Flow Rate (Liters/hour) = (Pulse frequency x 60 min) / 7.5Q. In this proposed system, the flow sensors are used both at the inlet and the outlet of the fuel tank for the measurement of the flow of the fuel being poured in as well as being consumed. The model used here is YFS201. Here, the fuel enters the tank through the inlet and passes through the flow sensor as shown in fig. 1. Similarly while being consumed; the fuel passes through the flow sensor at the outlet. The Paddlewheel sensor is a practical and most normally utilized water stream meter. It might likewise be utilized to gauge stream rates of water-like liquids. Numerous paddlewheel sensors are sold with the addition or stream fittings. Like turbine meters, they require a 10 pipe distance across of straight pipe on the channel and 5 pipe widths on the outlet. The rotor of the paddlewheel sensor is fitted opposite to the stream rate. It will reach a restricted cross-area of the stream.

Load Sensor: Load sensor is a transducer that measures force, and converts this force in an equivalent electrical signal. Load cells generally use a strain gauge to detect measurements, but hydraulic and pneumatic load cells are also in use. The load sensor here, will be used to get a more accurate measure of the fuel present in the tank at all times. The sensor used is Honeywell model 53. It is designed to be placed at the bottom of the fuel tank as represented in fig. 1.

AVR *Microcontroller*: AVR is a group of microcontrollers created by Atmel starting in 1996. These are altered Harvard design 8-bit RISC single-chip microcontrollers. AVR was one of the first microcontroller families to use on-chip streak memory for program stockpiling, rather than one-time programmable ROM, EPROM, or EEPROM utilized by different microcontrollers at the time. The AVR engineering was brought about by two understudies at the Norwegian Institute of Technology (NTH), Alf-Egil Bogen and Vegard Wollan. Among the first of the AVR line was the AT90S8515, which in a 40-stick DIP bundle has a similar stick out as an 8051 microcontroller, including the outer multiplexed address and information transport. The data gained by the microcontroller is sent to the cell phone just as the cloud through the Wi-Fi module as shown in fig 1.

Wi-Fi Chip: The ESP8266 is a minimal effort Wi-Fi chip with full TCP/IP stack and MCU (microcontroller unit) ability created by Shanghai-based Chinese maker, Espresso. The chip initially went to the consideration of western producers in August 2014 with the ESP-01 module, made by an outsider maker, AI-Thinker. This little module enables microcontrollers to interface with a Wi-Fi system and makes straightforward TCP/IP associations utilizing Hayes-style directions. Be that as it may, at the time there was no English-language documentation on the chip and the directions it acknowledged. The exceptionally low cost and the way that there were not very many outside segments on the module which proposed that it could, in the end, be cheap in volume, pulled in numerous programmers to investigate the module, chip, and the product on it, just as to interpret the Chinese documentation. The ESP8285 is an ESP8266 with 1 MB of the implicit blaze, taking into consideration single-chip gadgets equipped for associating with Wi-Fi. The information from the microcontroller is conveyed to the cell phone through the Wi-Fi chip with the assistance of an android based IoT application named "MQTT Dashboard".

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By arranging this application with the Wi-Fi chip, all information of inflow and surge of the fuel in the tank can be followed through the client's cell phone. The Wi-Fi module conveys the broke down data from the framework site to the cell phone and the cloud as portrayed in fig 1.

Software Requirements: The Proteus Design Suite is a restrictive programming apparatus suite utilized basically for electronic structure robotization. The product is utilized for the most part by electronic plan engineers and electronic professionals to make electronic schematics and electronic prints for assembling printed circuit sheets. It was created in Yorkshire, England by Lab focus Electronics Ltd and is accessible in English, French, Spanish and Chinese dialects. The smaller scale controller recreation in Proteus works by applying either a hex record or an investigate document to the microcontroller part on the schematic. It is then co-reenacted alongside any simple and advanced hardware associated with it. This empowers its utilization in a wide range of venture prototyping in regions, for example, engine control, temperature control and UI plan.

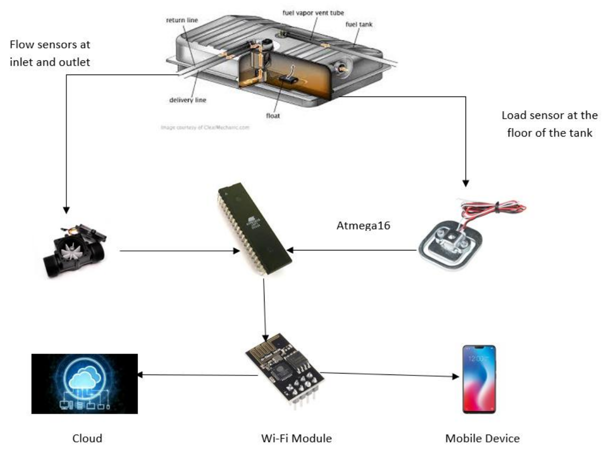

Fig.1 Proposed Smart Fuel Monitoring System

The fuel is poured into the tank through the inlet where it passes the flow sensor as shown in fig. 2. The flow sensor measures the amount of fuel being poured into the tank and replays this information to the Atmega16 microcontroller. This information is then displayed on the LCD screen on the board. The load sensor present at the bottom of the fuel tank (shown in fig. 2) reads the amount of fuel present in the tank at any given point. This information is also sent to the microcontroller. When the fuel is being consumed, it leaves the tank through the outlet where another flow sensor measure the amount of fuel going out (as in fig. 2). The microcontroller collects this information as well and then analyses the fuel being consumed and determines patters based on these consumptions using edge analytics concept. The raw as well as analyzed data is sent to the cloud and user’s mobile device though the Wi-Fi module present on site (See fig. 2). Thus the user gets accurate measurements of fuel intake and usage at the tip of their fingers and can further use this information to make their vehicles fuel and cost efficient for better savings.

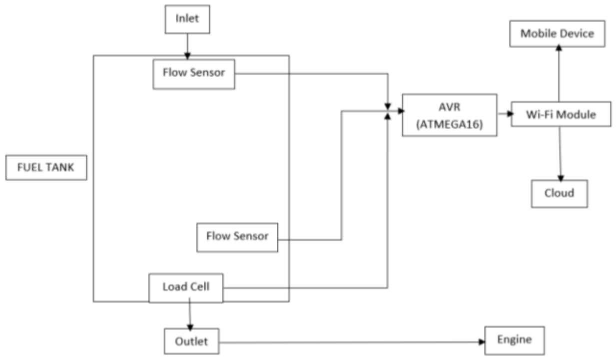

Fig. 2. Flow Graph of proposed Smart Fuel Monitoring System

V. RESULTS AND DISCUSSION

The proposed system is made of using the 2 paddle wheel flow sensors (YFS201) at the inlet and outlet of the fuel tank, a load sensor at the bottom of the tank. These sensors are connected to the Atmega16 microcontroller which is in-turn connected to an LCD display that displays the values of fuel intake and consumption. The microcontroller is also attached with a Wi-Fi module to replay the collected information to the cloud as well as user mobile device. The system is implemented in the following way,

A. *Fuel Tank and Load Sensor*

Fuel tank is fit with a load sensor at the bottom as shown in fig. 3. The information collected by the load sensor is fed to the microcontroller.

Fig.3 Load Sensor to be placed under the Fuel Tank

B. *Fuel Tank and Flow Sensors*

The inlet pipe and outlet pipe of the fuel tank are fit with one floe sensor each that measure the amount of fuel going on and out o the tank and relay this information to the microcontroller (see fig. 4).

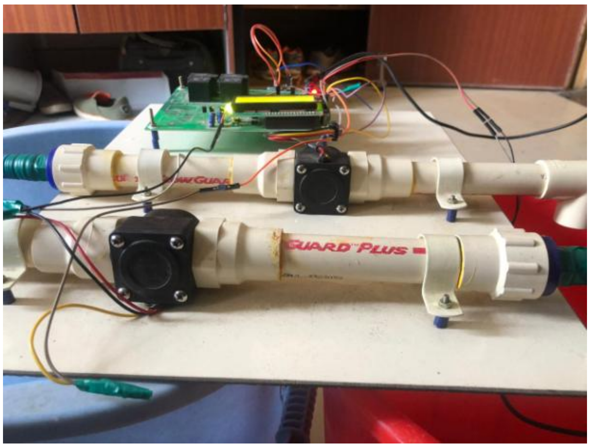

Fig. 4 Flow Sensors fitted in the Fuel Tank

C. *Microcontroller and Wi-Fi Module*

The microcontroller, Atmega16 collects information from the three sensors above and analyses this data for consumption patterns (fig. 5). The Wi-Fi module (ESP8266) attached with the microcontroller helps in sending information over to he cloud as well as the user's mobile device.

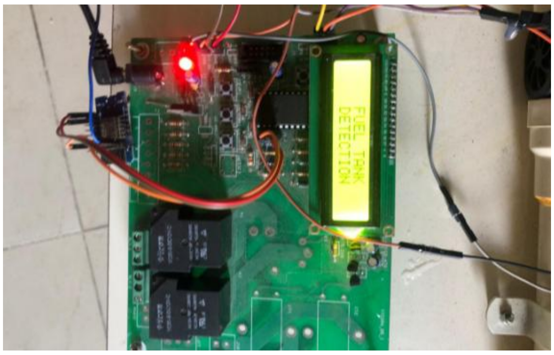

Fig. 5 Atmega16 and Wi-Fi Module (Fig. 5)

D. *LCD Display*

The collected information is also displayed on an LCD display on site for instant access (as shown in fig. 6). This data can be directly taken for analysis or can be accessed through cloud.

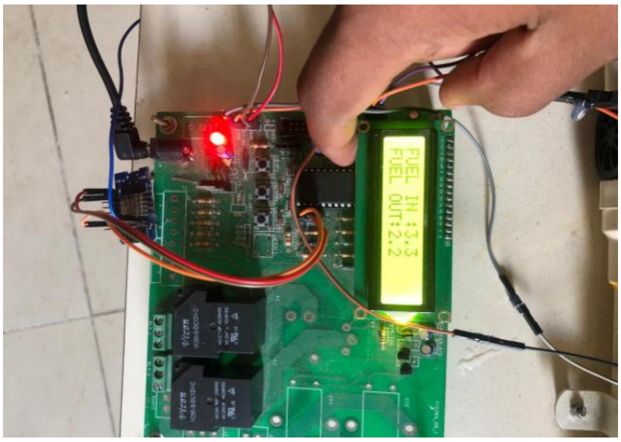

Fig. 6 LCD displaying Sensor Readings

E. Mobile Device and Cloud

The data collected and analyzed on site is sent to the cloud for storage and to the user's mobile device for quick access. The user also gets a graphical representation of the fuel intake and usage by the vehicle on their mobile device as shown in Fig (a), (b) & (c)

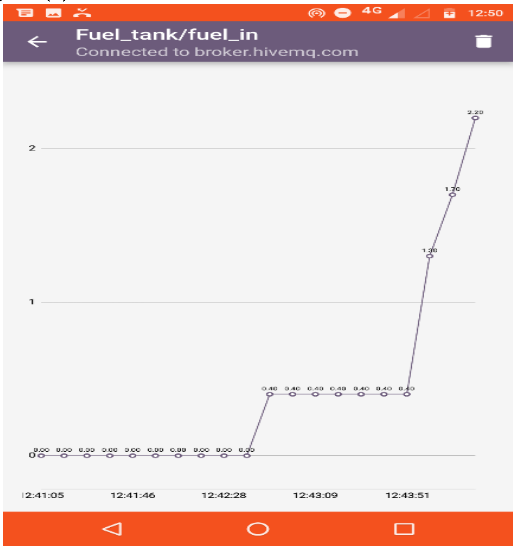

Fig. 7 (a) Fuel Intake

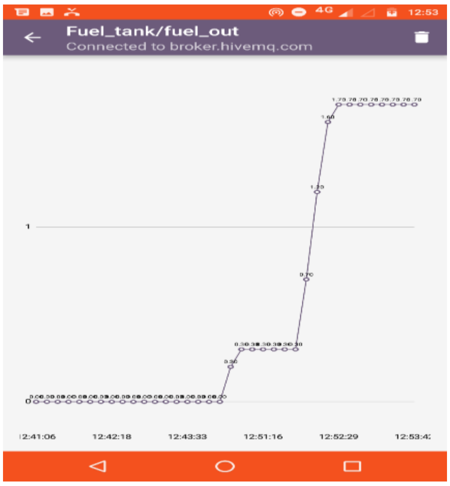

Fig. 7 (b) Fuel Usage

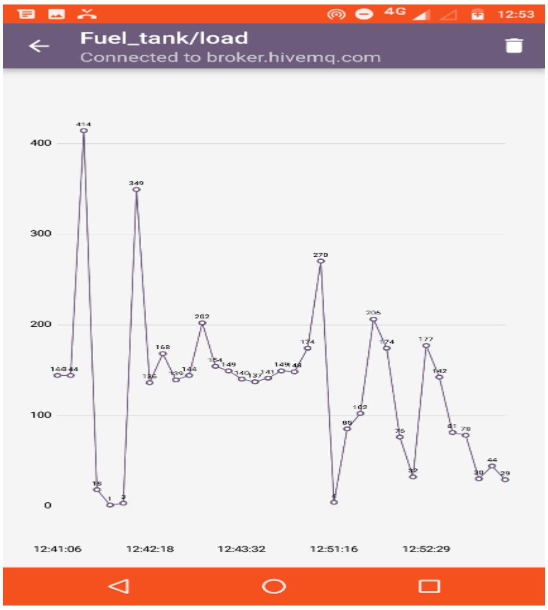

Fig. 7 (c) Load Cell values on Mobile Device

The collected data is stored on cloud and can be further used to give users personalized suggestions to make their vehicles more fuel efficient based on their fuel consumption and driving patterns. This would help them make their vehicles efficient and cost effective. The data collected is stored in the cloud in a tabular form for better and easy understanding of the patterns as shown in fig. 8.

Fuel IN	Fuel OUT	Load
3.0	1.7	32
3.0	1.7	76
3.0	1.7	174
3.0	1.6	206
3.0	1.2	102
3.0	0.7	85
3.0	0.3	4
3.0	0.3	270
3.0	0.3	174
3.0	0.3	148
3.0	0.3	149
3.0	0.3	149
2.8	0.2	149
2.4	0.0	148
2.4	0.0	146
2.4	0.0	145
2.2	0.0	150
1.7	0.0	144
1.3	0.0	146
0.8	0.0	144

Fig. 8. Readings Stored on Cloud Accessed through Remote Computer

There is an option provided to the user to get the information on their mobile device in either graphical form as shown above or in numerical form as shown in figure 9. This describes the fuel taken in, the fuel consumed and the fuel left in the tank in three different values on the mobile device in Litres. While the graphical representation easily shows the variation in intake and consumption over time, the numerical values are easier to read for day to day monitoring of fuel consumption and also for cross checking with the petrol pumps when buying fuel. Therefore the two options have been made available to the user to use as and when required depending on the user's needs.

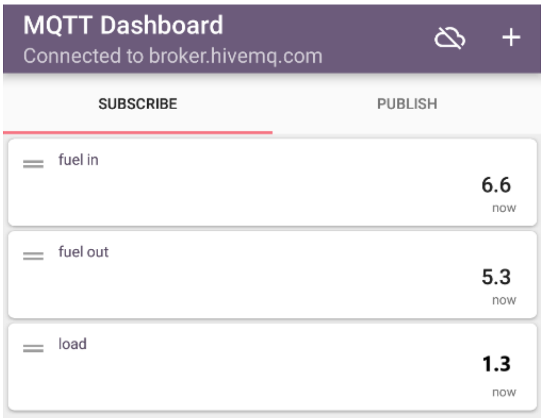

Fig. 9. Numerical Values on User's Mobile

VI. CONCLUSION

A new system for measuring fuel intake and consumption is developed to tackle the issues present in the current systems deployed in vehicles as well as to provide the consumer with a way to cross check the readings shown at gas stations. This would help avoid thefts as well as give helpful insights into making vehicles fuel efficient and cost effective according to the individual user. Future work into this system could include personalized predictions given to the consumers on how to save fuel as well as specific tips to bring down fuel costs. In the light of the fact that gasoline is a perishable resource, tis system can help users utilize the fuel more efficiently so as to make it last longer while newer fuels are being discovered.

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Dr. P. Vijayakumar is currently working as Associate Professor in School of Electronics Engineering at VIT university Chennai campus, India and completed his Ph.D in Wireless Security at Pondicherry University during 2015. He has totally 12 years of teaching and research experience and published more than 40 research papers in SCOPUS /SCI Indexed National / International Journals and Conferences. His area of specialization is Elliptic and Hyperelliptic Curve Cryptography, Blockchain technology, Cryptography and Network Security, Cryptographic Algorithms, DNA Steganography, Embedded System and IoT.

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