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iBreathe: An Intelligent Access Control Breathalyzer with IOT Integration for Nigerian Public Motor Parks

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ABSTRACT: *This paper proposes an IOT-enabled, microcontroller-based, alcohol detection system for personnel and commercial drivers in Nigerian public motor parks. The aim is to develop a breathalyzer access-control and real-time notification system that prevents commercial drivers from accessing their vehicles if Blood Alcohol Concentration (BAC) values above the Nigerian legal threshold of 0.05g/dl(gram per decilitre) is detected from their breath. The design incorporated a reprogrammable MQ3 alcohol sensor and a servomotor to the turnstile which serves as access limiters to the vehicle. BAC levels above 0.05g/dl automatically locks the turnstile and the driver is denied access to the vehicle. Notifications are then sent to the control rooms via the ThingSpeak platform activated by the NodeMCU for further actions. This work is useful to the Federal Road Safety Corps' (FRSC) and the National Union of Road Transport Workers (NURTW) as regulators of public and private road users, because it will prevent intoxicated commercial drivers in public motor parks from accessing the road and hence reduce alcohol-induced traffic accidents.*

KEYWORDS -*Access Control, Breathalyzer, IoT, ThingSpeak, Transport*

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I. INTRODUCTION

Alcohol consumption accounts for 5% of the global mortality or 1 in 20 deaths arising both from behavioral sequelae like motor vehicle accidents and medical morbidity [1]. The International Center for Alcohol Policies (ICAP) and the FRSC still maintains that Road traffic accidents involving alcohol and drugs remains the leading criminal cause of traffic related deaths in Nigeria [2] and despite the never ending campaigns against drinking and driving by the FRSC and NURTW in commercial motor parks, drivers still find it easy to get behind the wheel after too many drinks.

To truly prevent commercial drivers from driving under the influence in FRSC designated and other public motor parks, access to their vehicles should only be granted if their blood alcohol content is below the legal limit of 0.05g/dlfor Nigeria. This can be achieved using technology-inspired approaches like the microcontroller-based driver breathalyzer access-control turnstile. In this research. We have implemented an operational access-control drivers' turnstile that uses a reprogrammable MQ3 alcohol sensor and a servomotor which serves as an access limiter. BAC levels above the legal threshold automatically locks the turnstile and the driver is denied access to the vehicle. With this modified technique, road accidents due to intoxicated public transport drivers will be greatly minimized and prevented.

The rest of the work is organized as follows; Section II discusses related work on alcohol detection for transportation systems. Section III thoroughly describes the materials and methods used for the design and implementation. Here, all calculations, charts, program pseudocodes, state activity diagrams and circuit diagrams are described. Section IV will show and describe the experimental findings to establish the main points of the work. Thereafter, the closing sections will discuss the findings (results) and conclude with future work.

II. RELATED WORK

Various techniques have been adopted to reduce the prevalence of road accidents occasioned by intoxicated motorists. The alcohol detector in [7] consists of an alcohol sensor, Alternating Current (AC) power supply, LM 358 Operational Amplifier (Op-Amp), and Liquid Crystal Display (LCD) circuitry. This device displays the results of the sensor as it senses the alcohol molecules in air present around it, and displays a warning text when it crosses the fixed threshold set by the LM358 Op Amp. The drawback of this system was that it required whosoever to be tested to be close to the AC power outlet due to the system running on AC power. Also, the LM358 op amp which was acting as a comparator in the circuit and came with a preset value 5 for the threshold upon crossed, had no response such as an alarm to warn that the threshold has been crossed.This system was nowhere close to proving a means of inhibiting a driver if he/she were drunk not to mention real time implementation [7].

James and John [8] proposed an alcohol detection system that alerts the driver through a cell phone. The major components of this system was the GSM module and the LM358 module. This system was a huge advancement from breath analyzers as it was based on GSM technology using the GSM module and dumped the use of alarm circuit but still employed the LM358 Op-Amp. The system alerted via text messages using a GSM module and had a unique ringtone for such text messages set on the cell phone. Its major demerit was the lack of an LCD unit and an alarm circuit which could be useful in cases where the driver is not in possession of his/her phone.

Another drawback is the presence of the LM358 Op-Amp as a comparator instead of using a microcontroller to allow for flexibility in changing the blood alcohol concentration (BAC) threshold due to probability in changes of body chemistry of the driver. The issue of cellphone batteries running down also comes up implying that the system would be inactive in the state that a cellphone battery is dead. Also, with most drivers in the habit of keeping their cellphones in the vibration or silent mode while driving, this inhibited the alerting property of the work [8].

Another alcohol detection system was developed in [9] based on PIC16F877A microcontroller. The presence of the microcontroller allowed for ease of manipulation of the threshold depending on body chemistry. The presence of the microcontroller gave room for addition of other features in the future. The only major drawback was the system's inability for a direct real time implementation due to it being powered by an AC power supply, as the alcohol sensor wouldn't have the opportunity to have at least 3 h full run in time it would get if on DC supply (vehicle battery) to give the sensor the degree of accuracy it requires for its operation [9].

The most definitive related work done on this subject matter is the system proposed by Uzauirue et al in [11]. Two Blood Alcohol Content (BAC) thresholds are set and monitored with the use of a microcontroller. When the first threshold is reached, the developed system transmits the BAC level of the driver and the position coordinates of the vehicle to the central monitoring unit. At the reach of the second BAC threshold, the IoT-enabled alcohol detection system shuts down the vehicle's engine triggers an alarm and puts on the warning light indicator. A prototype of this scenario is designed and implemented such that a Direct Current (DC) motor acted as the vehicle's engine while a push button served as its ignition system. The efficiency of this system is tested to ensure proper functionality.

Fig. 1 shows the graphical representation of the fatalities and fatality rate for the past decades. The decreasing order of the chart can be deduced and as such in few decades to come and with the recommendation and implementation of our proposed system there might be no accident caused by drunk driving.

The proposed system in this work is a very innovative system which will help to keep the roads free from drunk driving related accidents by not only preventing the drivers from getting behind the wheels in the first place, but also reports real-time notifications and sends such report the regulators.

Fig. 1. Fatalities and fatality rate per 100 million VMT in alcohol-impaired-driving crashes,2005–2014 [11]

III. IBREATHE: THE TECHNICAL DESCRIPTION

3.1 Materials

The major components of the system positioned in the driver-access turnstile consists of the MQ3 sensor (Alcohol sensor) which senses the alcohol molecules in the air around the driver to determine if the driver is drunk or sober. The system makes use of a push button, Arduino ATmega 328PU microcontroller, LCD screen, buzzer, DC motor, and GSM Module (SIM 900L) for sending data. The hardware is powered by a 12-V battery. The LCD screen used to display the BAC levels and the WIFI module sends out notification to the FRSC and NURTW remote offices.A webpage via the Thinkspeak utility is setup in the control rooms to show the BAC levels of the driver and real-time visualization for IOT.

Power Supply: A 12-V was employed in this project. This 12-V is then stepped down to 5-V by the voltage regulator circuit so as to power the microcontroller and the sensors as 5-V is required by the circuit for its operation.

Alcohol Sensor: The simple gas sensor - MQ3 is appropriate for recognizing liquor, this sensor can be utilized as a part of a breathalyzer with its high sensitivity to alcohol and small sensitivity to Benzene, which can be balanced by the potentiometer. Tin oxide (SnO2) is a main material of MQ-3 gas sensor is, due to its lower conductivity in clean air. Table 1identifies the characteristics of this material, whileFig 2 describes the structure and configuration.

Arduino Uno: Arduino is a microcontroller board and can be used with the ATmega328P. It has 14 digital in-put/yield pins (of which 6 can be utilized as PWM yields), 6 simplesources of info, a 16 MHz quartz precious stone, a USB association, a power jack, an ICSP header and a reset catch. It contains everything expected of a microcontroller. Fig 3 shows the mapping method used to get the ATMEGA328P interfaced with an Arduino Uno board.

Sim900D: Fig 4is an ultra-compact and reliable wireless module-SIM900D. It is a complete Quad-band GSM/GPRS module in a SMT type and designed with a very powerful single-chip processor integrating AMR926EJ-S core. Furthermore, SIM900D can be compatible with SIM340DZ. It is repackaged to allow it to function as a gizDuino (Arduino Compatible) Shield as well.

Table 1 MQ-3 Specification Sheet

A. Standard work condition

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
V_H	Heating voltage	5V±0.1	ACOR DC
R_L	Load resistance	200KΩ	
R_H	Heater resistance	33Ω ±5%	Room Tem
P_H	Heating consumption	less than 750mw	

B. Environment condition

Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10℃-50℃	
Tas	Storage Tem	-20℃-70℃	
R_H	Related humidity	less than 95%Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	minimum value is over 2%

C. Sensitivity characteristic

Symbol	Parameter name	Technical parameter	Remarks
Rs	Sensing Resistance	1MΩ - 8 MΩ (0.4mg/L alcohol)	Detecting concentration scope: 0.05mg/L—10mg/L Alcohol
α (0.4/1 mg/L)	Concentration slope rate	≤0.6	
Standard detecting condition	Temp: 20℃ ±2℃ Humidity: 65%±5%	Vc:5V±0.1 Vh: 5V±0.1	

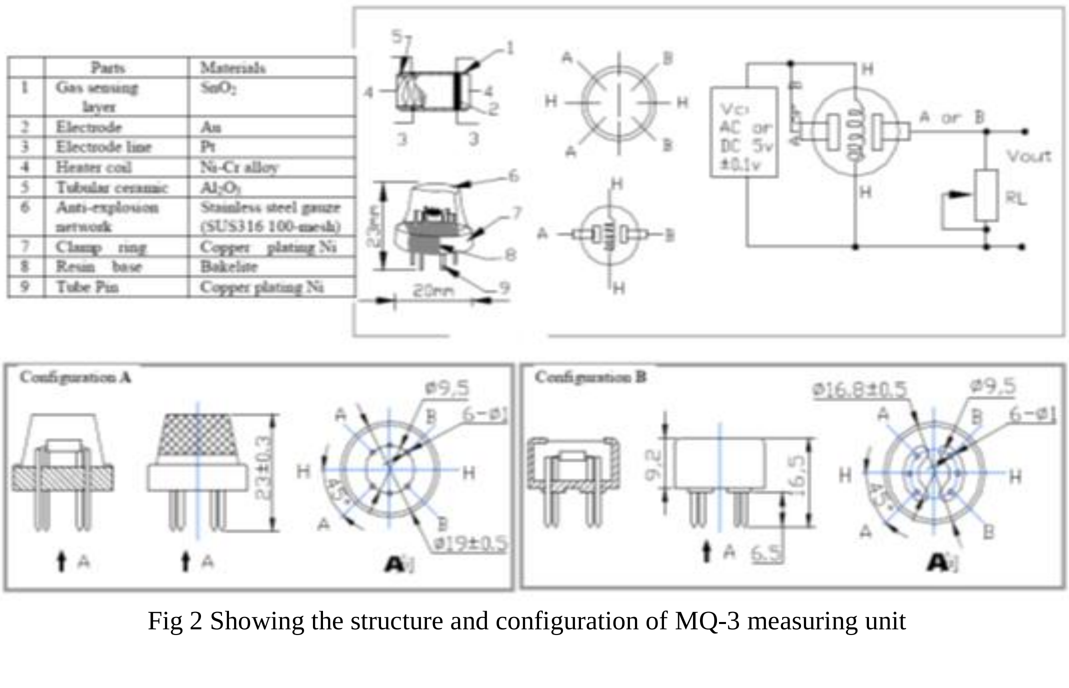

Fig 2 Showing the structure and configuration of MQ-3 measuring unit

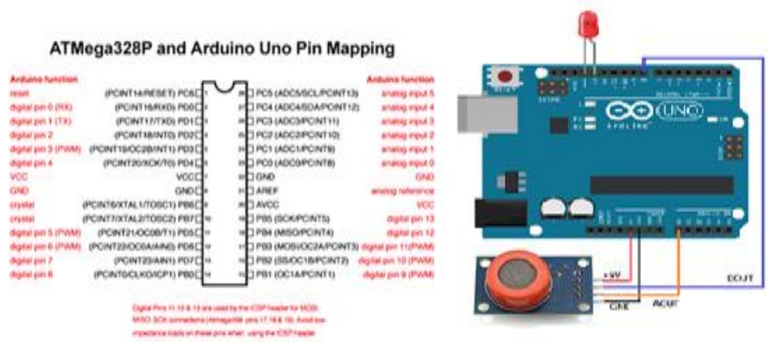

Fig. 3Interfacing the ATMega328P with Arduino Uno

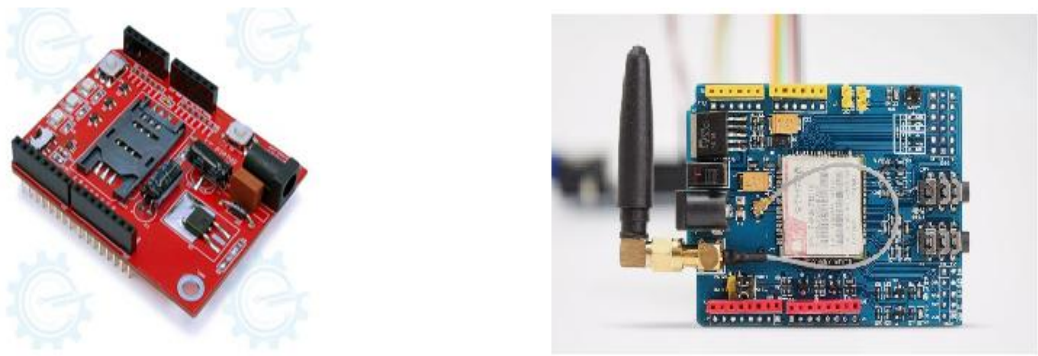

Fig 4. The SIM900D shield with Arduino

3.2 Description and Design of iBreathe

Consider the general state activity chart in Fig 5. We designed and implemented a microcontroller-based reprogrammable MQ3 alcohol sensor, modified to an access control utility which detects the alcohol levels of drivers before they embark on a journey through driver-turnstile access gate. Reprogrammable microcontroller units using servo motors locks the turnstile and denies the driver access to the car if a BAC level greater that 0.05 g/dL is recorded twice. The process is repeated until a driver with BAC levels lower than 0.05 g/dL is recorded and the turnstile is open for a journey to begin.

Furthermore, real-time notifications to the FRSC office is activated by using the NodeMCU integrated IoT-based ThingSpeak platform and GSM to be accessed by FRSC and National Union of Road Transport Workers(NURTW) control rooms.

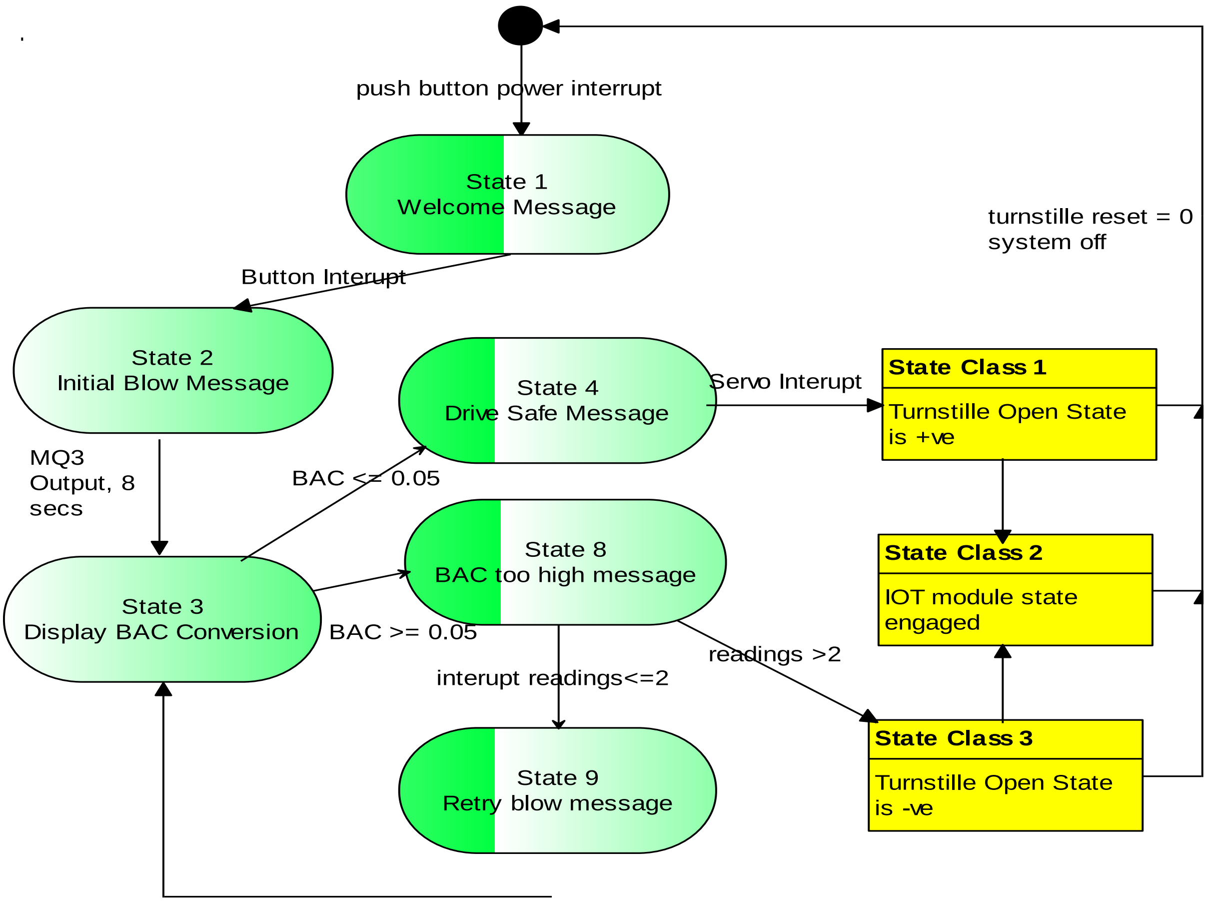

Fig 5 State diagram for modelling the system

3.3 Methods

This research improved the work in [11], where the authors had interfaced sensor modules via a GPIU to the kick starter of the car for activation only when required threshold values are met, however our model proposed a preventive approach and implementation by embedding the MQ3 alcohol sensor in a turnstile driver access door to prevent even an initial entry to the vehilcle if threshold values fail.This work also integrated a GSM module and an IoT-based ThingSpeak platform to the regulators' webpage for an online alert and reporting system, which aids safety management from any location.

The push button regulates the interactions between the environment via sensors and the measured element. This is activated by the Human Computer Interaction component. If the breathe received after the push button is activated shows readings >=0.05d/dl, it will cause the buzzer to beep once for 1 minute and a red LED light indicating that the worker is "Drunk" and cannot drive. This drunken worker will be denied access because the turnstile gate will remain closed as the servo motor will maintain its initial locked position. Immediately this activity takes place, short message alert is sent to the respective authorities indicating the status of the worker as "Drunk".

The reverse takes place if operational conditions are less than the country standard threshold conditions as the gate automatically opens via the servo motors action. To achieve this, the servo motor changes position to the clockwise direction enabling the door or gate to open and a green LED indicates a success. The Alcohol status of the worker or driver will be sent as short message alert to the respective authorities. The LCD displays on its screen the activities going on in the breathalyzer.

The easiest way to measure alcohol content is to obtain a breath alcohol reading and convert it into a blood alcohol level. The ratio of breath alcohol to blood alcohol is 1:2100, meaning that for every 1mg of alcohol in a person's breath, there are 2,100mg of alcohol per liter of blood. A BAC of 0.05% is equivalent to 500mg/L of blood alcohol, and 500/2,100 = 0.231mg/L of breath alcohol. Therefore, the procedure for converting breath alcohol to BAC is indicated in equation (1) below:

$(Alc_{BREATHE} mg/L) * 0.21 = Alc_{BLOOD}{}^{\%}$(1)

The MQ-3 is a semiconductor sensor that is particularly sensitive to alcohol. This module is composed of a tin dioxide (SnO_2) layer for gas sensing, which is less conductive than pure air. When alcohol gas exists in the surrounding environment, the conductivity of the MQ-3 increases. The sensor uses its A0 pin to output a resistive analog signal that is dependent on the alcohol concentration present. The MQ-3 measures the amount of alcohol by measuring the resistance inside the sensor. Both of these properties are inversely proportional to one another. A higher concentration of alcohol in the air will result in a lower resistance within the sensor and a higher voltage output.

The system was calibrated using a bottle of hand sanitizer with an ethanol content of 72%. Translating this gas concentration of 0.72mg/L in air to blood, the expected BAC level was: (0.72) × (0.21) = 0.15%. After the sensor's analog output was filtered, an ADC average for the buffer's current elements was obtained, the average value normalized and converted it into a BAC percentage. The derived conversion result is described in equation (2):

$$BAC_{\%} = [[Alc_{MAX} - Alc_{MIN} / ADC_{MAX} - ADC_{MIN}] * [ADC_{AVG} - ADC_{MIN}] * [R_S/R_0] * [0.21] \quad (2)$$

Through the LinkServer debugger built into the MCUXpresso IDE, the ADC equations (3) to (4) were indentified from the result bits in the ADC0->DAT[2] register. Equations (5) to (7) which are specific to alcohol thresholds were also derived from the MQ-3 datasheet and are as indicated below:

$$ADC_{MAX} = 4{,}095 \quad (3)$$
$$ADC_{MIN} = 2{,}050 \quad (4)$$
$$Alc_{MAX} = 10 \text{ mg/L} \quad (5)$$
$$Alc_{MIN} = 0.05 \text{ mg/L} \quad (6)$$
$$R_S/R_0 = 0.4 \quad (7)$$

Where Rs=sensor resistance that changes based on the gas concentration and Ro = sensor resistance at known concentration in fresh air or without other gases.A sample calculation is given below as an example of how the general equation (2) behaved during the testing phase of the project when the system was simulated using the 72% ethanol sanitizer. The ADCAVG value observed through the debugger during this stage of testing was 2,424, so the experimental result was calculated to be:

$$BAC_{\%} = [[10 - 0.05/4{,}095 - 2{,}050] * [2{,}424 - 2{,}050] * [0.4] * [0.21] = 0.15\% \quad (8)$$

As expressed in Equation (8), the theoretical BAC level for these conditions was expected to be 0.15%. After testing the BAC conversion formula with multiple ADC averages, we observed experimental values that consistently matched expectation. When testing the device with human alcohol consumption, the BAC percentage based on body type, alcohol type and time elapsed with a 1.5oz. shot of 76% liquor gave an estimate of 0.07%, which was the same BAC result reported in the project prototype under same conditions.

Fig. 6and 7below shows the schematic and circuit diagram of the system. The circuit schematic and functionality was simulated and tested using Proteus 8 before deploying to production. Furthermore, the sections of the codes developed have been shown here in Fig 8(a)-8(c) for clarity and reproducibility.

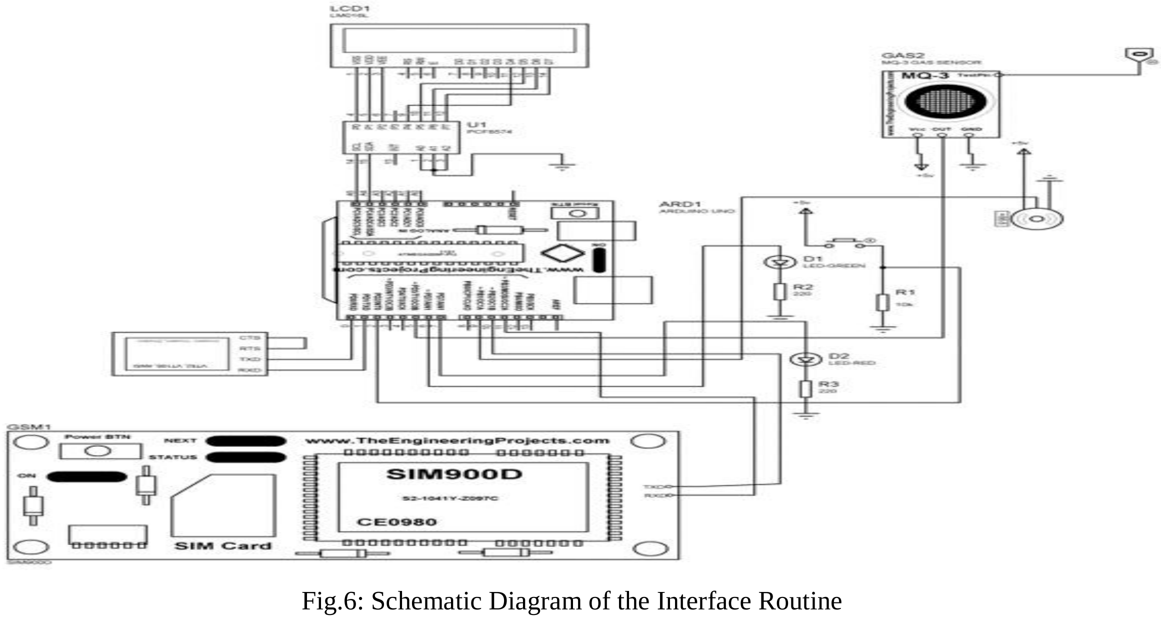

Fig.6: Schematic Diagram of the Interface Routine

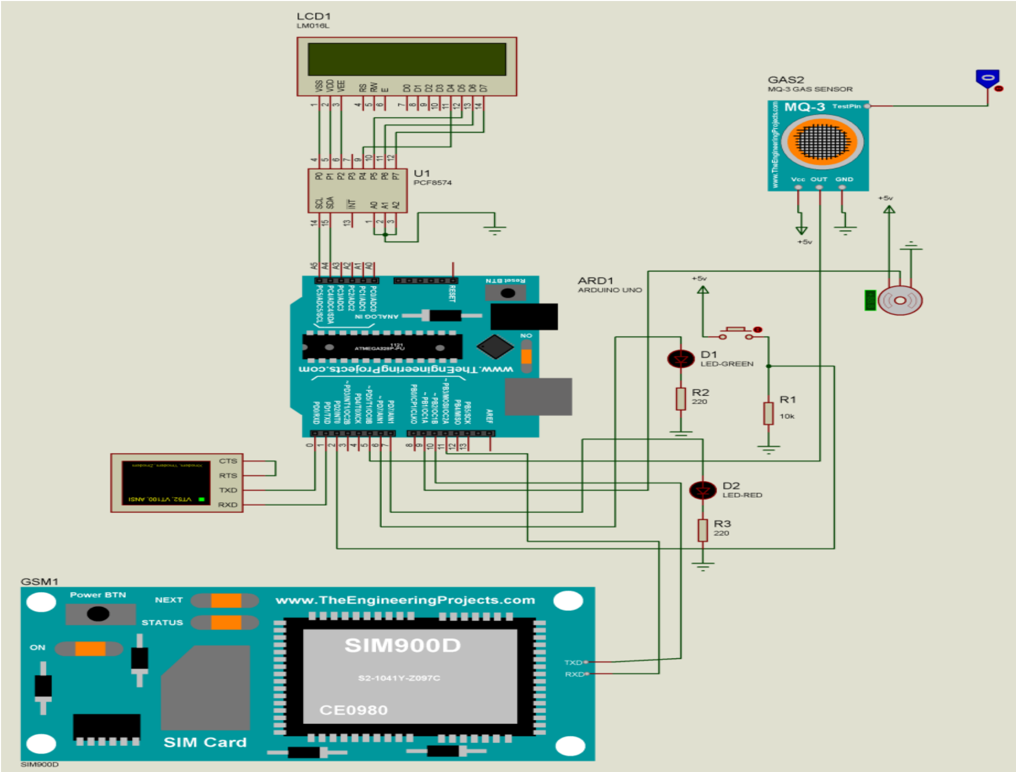

Fig.7: Circuit Simulation of the Interface Routine

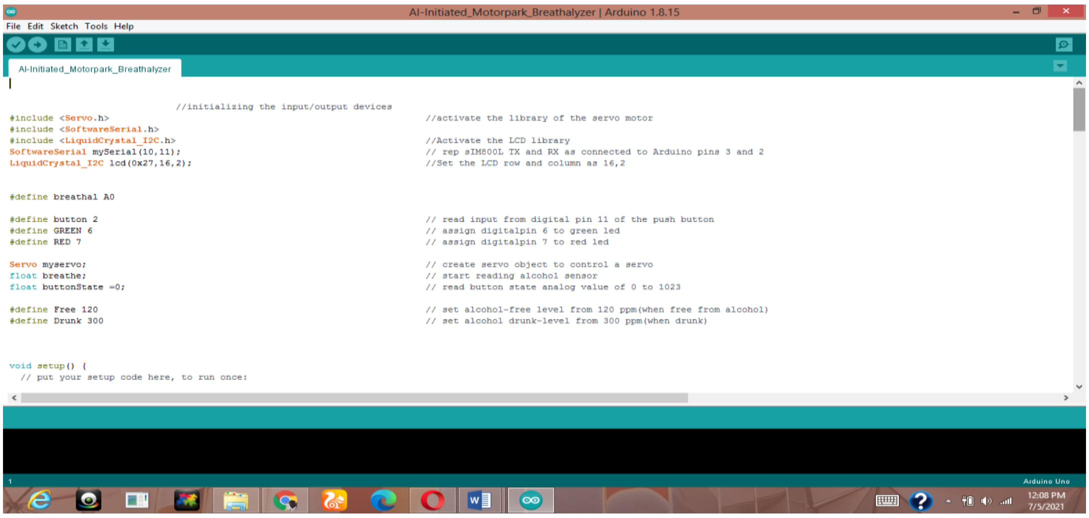

Fig 8(a) Sections of the Arduino Code for Header File and function Defination

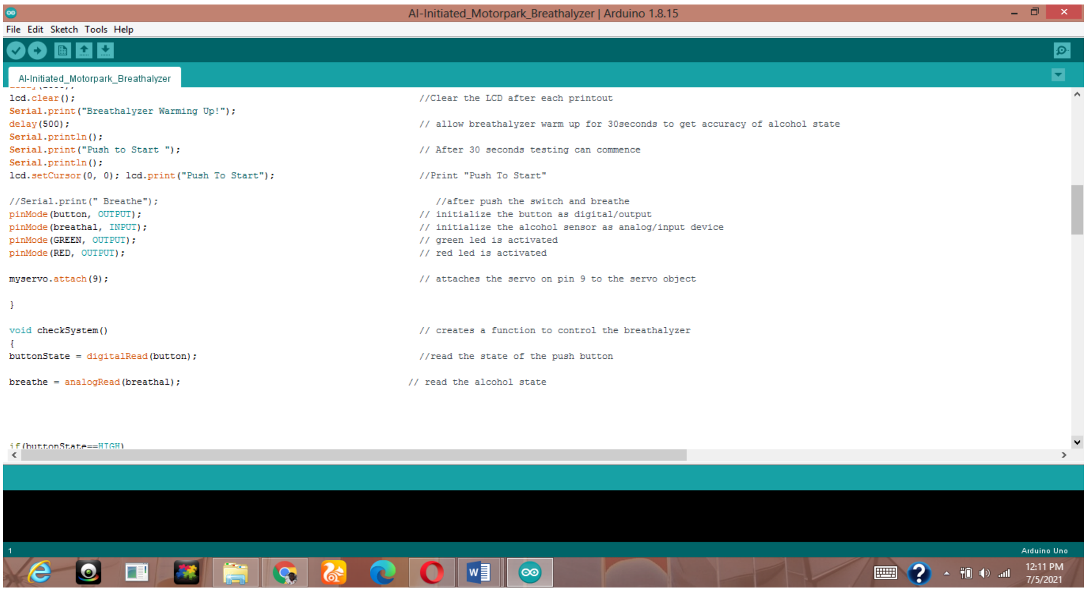

Fig 8(b) Sections of the Arduino Code for Initialization

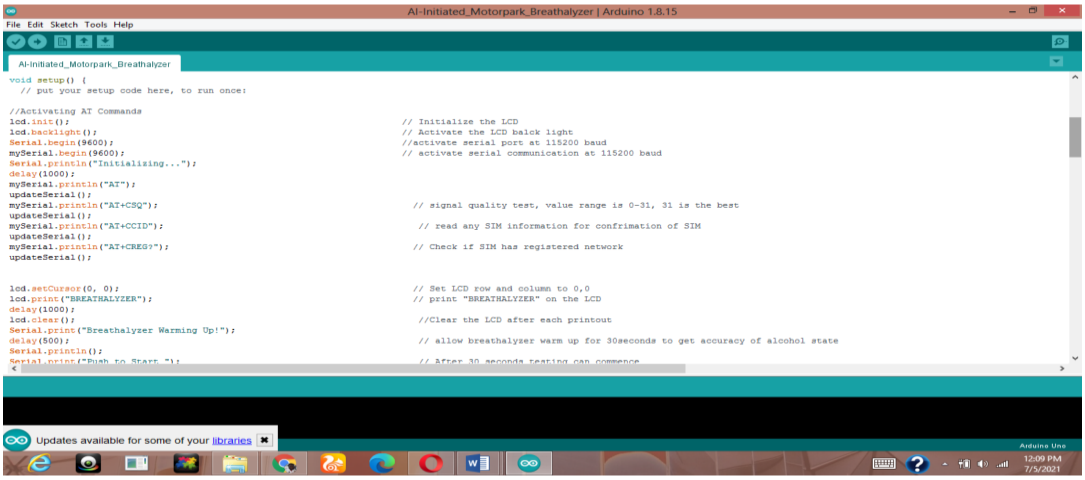

Fig 8(c) Sections of the Arduino Code for LCD and SIM serial Comms

Activity No.	Procedure Description
1.	Initialize: SoftwareSerialmySerial();intsensor;int speaker; intsms_count; *** Initialize MQ3, IoT-interface module, GSM, LCD, push button, buzzer ***
2.	Input Country legal threshold values: Alcohol_alert_Val;
3.	Check status of parameters: Parameter_Status; Alcohol_stat
4.	Turnstille Push button()= 1, ***activate alcohol detection***
5.	IF Alcohol level detected < 0.05,
6.	Display Status and Message turnstile LCD and Open door
7.	ELSE Lock Turnstille Door, Activate Buzzer and Display message on LCD
8.	Generate and Send parameter status through the IOT interface and dedicated GSM lines

9	RESET all Turnstille parameters for next user
10.	Redo (3) to (9)
11.	IF no next user, Terminate process and set system state to 0

Table 3.1 iBreathe Operational Pseudocode

IV. RESULTS AND DISCUSSION

The research set out to vary the approach used in [11], which integrated a breathylyzer to the kick starter of the vehicle. However, in this research, we have set up an automated access control turnstile to the car which prevents an entry if the breathylyzer tests fail. When this happens status reports are sent to an authorized control rooms for necessary actions. Fig 10(a) – 10(b) shows the testing of the AT Command alongside a GSM phone number. The AT Command codes "AT +CMGS" registered the GSM phone number starting with "+234" to activate sending messages when the MQ-3 Gas sensor is ready to communicate its activities. The AT Command was initiated from codes in the Arduino program of the MQ-3 Alcohol sensor. Fig 11 shows the test-run of the programmable MQ-3 sensors interfaced with the ATmega MCU with the output readings displayed on the LCD and indication lights. Fig. 12 shows the ThingSpeak interface for the IOT control interface. The interface shown monitored statuses of the results of the turnstile and can be accessed through the Internet.The assembled utility is displayed in Fig 13.

Fig10a: AT Commands + Alcohol Status

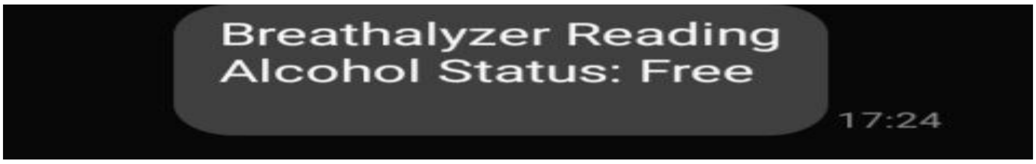

Fig 10b: SMS sent showing BAC levels<0.05g/dl (Free)

Fig. 11. Output of the MQ-3 sensor module showing on the LCD with a failed breathalyzer test

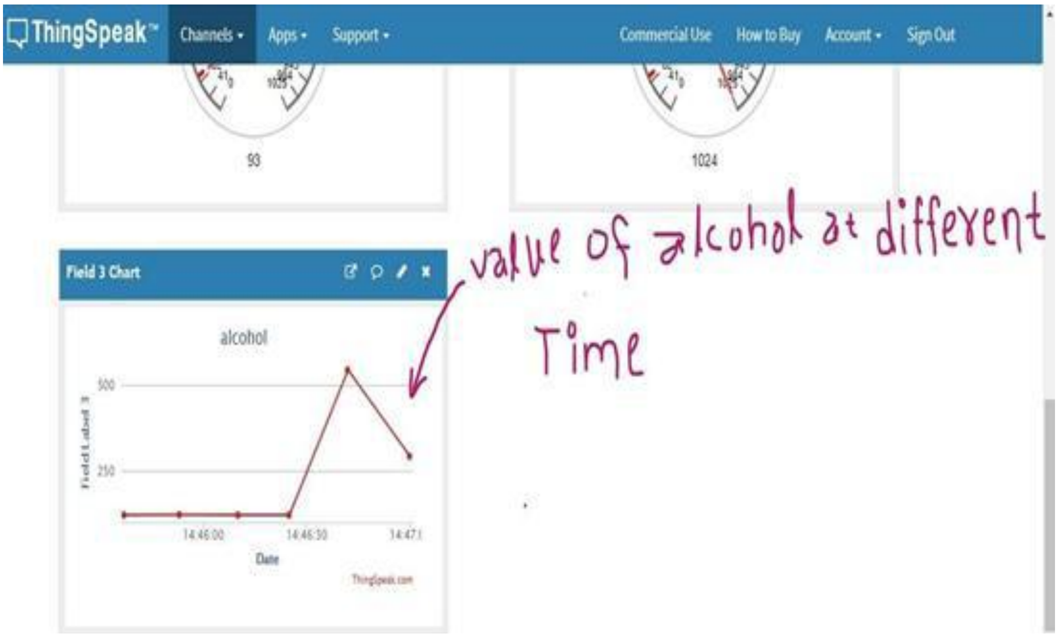

Fig. 12. The IOT ThingSpeak interface for the system

Fig 13 showing the integrated system with the turnstile to the car park

V. CONCLUSION

This research focused on the design and implementation of an IOT-Enabled Breathlyzerfor Access Control in Nigerian Public Transportation Systems. We developed an automated breathalyzer access-control and real time notification system that prevents drivers from accessing their vehicles if Blood Alcohol Concentration

(BAC) values above the Nigerian legal threshold of 0.05g/dl is detected in their breath.

An MQ3 alcohol sensor and a servomotor to the turnstile which serves as access limiters to the vehicle were integrated in the design. BAC levels above the Nigerian legal threshold level of 0.05g/dl automatically locks the turnstile and the driver is denied access to the vehicle. Notifications are then sent to the control rooms via the ThingSpeak platform activated by the NodeMCU for further actions. Through SMS alerts, the alcohol status of the driver at the turnstile can be communicated to the regulatory bodies at the motor park and/or anywhere in other parks across the country.

This Turnstile will be positioned in the motor parks and will be manned by the union representatives to ensure that drivers aiming to embark on a journey must pass through the breathalyzer door before a vehicle is assigned to them. The ThingSpeakIoT analytics platform will enable the analysis of situations, make data-driven decisions, identify trends and make summary reports to the NURTW and FRSC agencies that serve as regulators and union representatives of Transport Workers all with an aim to reduce alcohol-induced traffic accidents.

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