Development Of Microcontroller And Iot-Based System For Monitoring Key Health Vital Signs

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***Abstract*— In this paper, development of microcontroller and Internet of things (IoT)-based system for monitoring key health vital signs is presented. The system consist of both hardware and web interface through which the measured parameters are transmitted and stored in a web server located at toveramedia.com /HealthMonitor. The paper presented the design of both the hardware and the software components of the system. Model View Controller (MVC) architecture and Visual C# were employed in the design and implementation of the software while the ATMega328 microcontroller, ESP8266 WiFi module, DHT11, DHT22 sensor module and Arduino technology were used in the hardware design. The monitoring system was designed to measure heartbeat, body temperature, ambient temperature and the blood pressure. The measurements captured from the system are time-stamped and in discrete form and they are transmitted via internet connection to the web server located at toveramedia.com /HealthMonitor.**

Keywords: Time-stamped, Visual C#, Internet of Things (IoT), Health Monitor, Model View Controller (MVC), heartbeat, body temperature, blood pressure

1. Introduction

As networking technologies evolve, their applications multiply [1,2]. Over the years we have witnessed diverse categories of network technologies, from the wired networks [3,4,5], to fiber optic networks [6,7,8,9,10,11,12,13] and the popular wireless networks [14, 15, 16, 17,18, 19, 20, 21, 22, 23, 24, 25, 26,27]; among these categories, the wireless network technologies have become the most widely used with applications in satellite communication [28, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37] and the present day Internet of Things [38, 39,40]. The Internet of Things popularly known as IoT is the trending technology employed worldwide today to solve the problems in every sectors of economy [41,42, 43, 44, 45, 46, 47,48]. Internet of Things (IoT) can be described as the interconnection of physical objects and things in a network which is made possible because each of the interconnecting objects and things have things like sensors and embedded software along with network interface hardware that enable them to connect and communicate via the Internet [49,50,51,52,53]. The devices and 'things' ranges from ordinary household objects to sophisticated industrial tools [54,55,56,57]. Importantly, IoT is a major asset that provides multiple benefits to healthcare industry [58,59,60,61, 62,63,64,65,66]. Doctors, nurses and orderlies often need to know the exact point or location of patient and many hospital assets can be tracked through IoT [67,68,69,70,71]. Implementation of IoT systems requires sensors and transceiver technologies for sensing and sending of the sensed data via internet connection to the required destination location or storage facility [72,73]. In IoT networks, there is usually sensor or set of sensors connected via wireless network to the internet [74,75,76,77,78,79,80]. Among several options, Arduino technology is an open source electronics platform that easily accommodate the use of hardware and software to sense and send data via the internet or other communication networks [81,82,83]. The Arduino boards has the capacity to read inputs from a sensor, and send the data over a communication network to a desired location [84,85,86,87]. This paper presented a system that employ time-stamped IoT mechanism to the monitor heartbeat, body temperature and blood pressure of any individuals and stored the measured data on an online storage server. The time stamp means that each data time captured by the sensor has the data capture time associated with it. The body temperature component of the system was calibrated using a clinical thermometer reading. Similar approach was employed in calibrating the heartbeat and blood pressure components of the system.

2. Methodology

2.1 The hardware design

The system design is divided into hardware and software design. The materials used in the hardware design include: Heartbeat sensor, Temperature sensor, Blood pressure sensor, Arduino Microcontroller (ATMega328), Power supply IC (LM317), WiFi Module (ESP8266), Printed Circuit Board (PCB) and Liquid Crystal Display (LCD). The hardware design is segmented into four (4) units namely; the power supply unit, the microcontroller unit, the sensor unit and the WiFi unit [88].

Power Supply Unit: The hardware components can operate on three (3) different voltages, namely: 3.3 volts (for the WiFi module), 5 volts for the microcontroller and its peripherals, and 12 volts as the source voltage. The LM317 adjustable voltage regulator integrated circuit (IC) is employed to regulate and supply the circuit required voltages.

Microcontroller Unit: The microcontroller unit is used to enable user control of the device and the Arduino microcontroller (ATMega328) was used. The selected microcontroller has 13 digital input-output pins and 6 analog pins among other pins and it has onboard 32KB ROM and 2KB RAM which are adequate for the system. The Arduino integrated development environment (IDE) was employed to program the Arduino microcontroller. The Microcontroller unit monitors the input voltages with the current sensor (ACS712), and the voltage sensor (AD205). In line with the device datasheet, the current sensor has the ability of sensing current between 0 ampere to 30 ampere, while the voltage sensor can sense voltage between 0V and 25V.

Liquid Crystal Display (LCD): The Liquid crystal display (LCD) was used to view all parameters and also the user-keyed-in data. The selected LCD consists of 16x2 character display with eight data pins, three control pins and power supply pin. The LCD can be connected in two bits mode (4-bit or 8-bit), but this work adopted the 4-bit mode. The connection of the LCD to the controller is as shown in Figure 1, and the LCD is labeled U11. A resistor rated 560 *Ω* was connected to the anode of the LCD backlight. The essence of this resistor is to prevent the LCD backlight from damage due to excessive current.

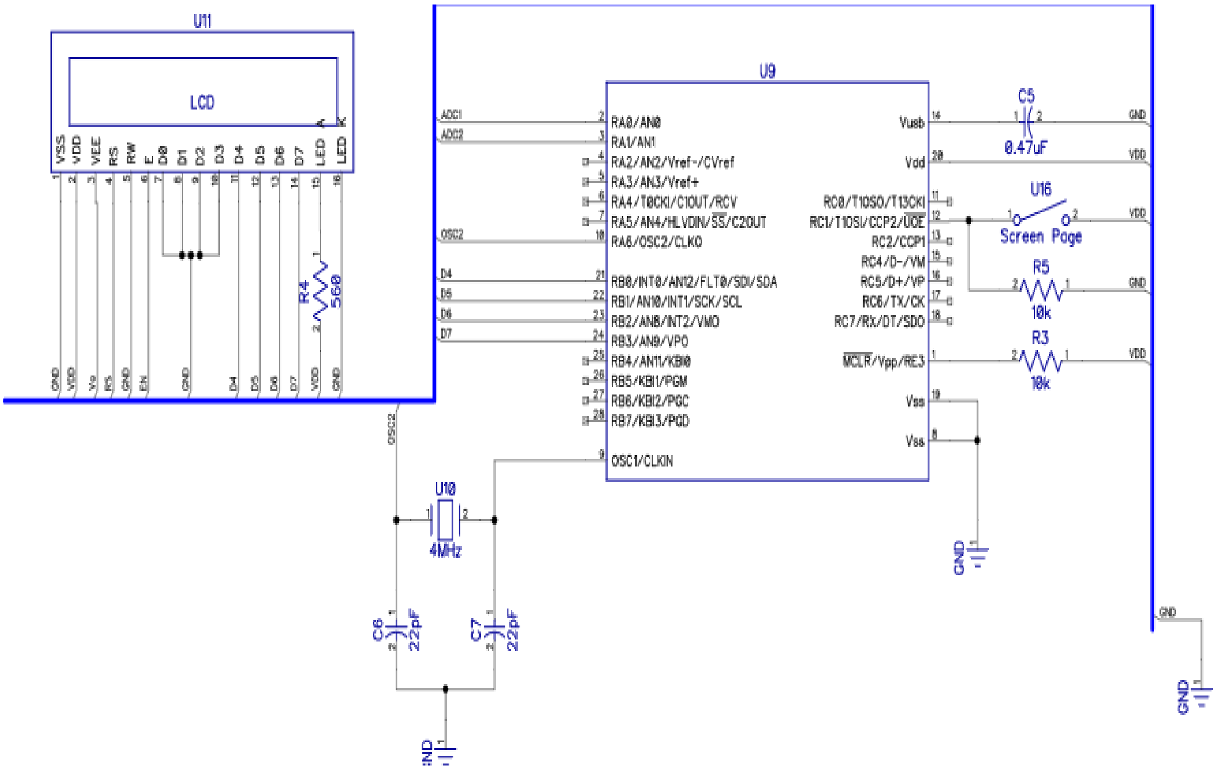

Figure 1 The LCD connected to controller and other component

The WiFi Unit: The WiFi unit was used to transmit the data from the sensors to the cloud and it was powered by 3.3 volts. This module ensured that the system is connected to the Internet and the system has access to the cloud. The WiFi module employed is ESP8266 WiFi Module which has integrated TCP/IP protocol stack for granting the microcontrollers access to the WiFi network. More so, the ESP8266 WiFi Module enough on-board processing and storage capabilities that allows it to be integrated with the sensors. During the operation of the system, the signal captured by the controller from the sensor is communicated to the WiFi which then push it to the cloud upon availability of Network. The Arduino serial monitor is used for testing and debugging of flow.

Sensor Units: This unit consists of set of transducers which detects the physical state of patient and send the response to the controller. These sensor data are also associated with the time of the data capture. Hence, the data captured by the system are time-stamped temperature, temperature sensor, heartbeat sensor and blood pressure sensor.

Temperature sensor: The sensor used for this purpose is DHT 11 & 22 which is also named as AM2302. The AM2302 is a digital-output relative humidity and temperature sensor that uses capacitive humidity sensor and a thermistor to measure the surrounding air, and output a digital signal on the data pin. The sensor is endowed with four (4) pins; Vcc, Gnd, Data-out, and NC. The Vcc pin was connected to the +5v of the power supply; the Gnd was connected to the ground of the circuit while the Data pin was connected to the digital input of the microcontroller.

Heartbeat and blood Pressure Sensors: Heartbeat sensor is an electronic device that is used to measure the heart rate or the speed of the heartbeat. In this work, the heart rate monitor system design was based on Arduino and heartbeat sensor. The blood pressure sensor was used to detect the body pressure. The components required to setup the blood pressure sensor include controller, connecting pins, 220Ω resistor, BMP180 Barometric Pressure Sensor, 16x2 LCD, and bread board.

2.2 The Software design

The software which is a web application was designed done using Model View Controller (MVC) architecture while the program was implemented using Visual C#. In the MVC architecture, the model represents the shape of the data while the class in C# was used to describe the model. Again, the view in MVC was used to design the user interface which was used to display model data to the user and also to modify the data. Also, the controller in the MVC architecture handles the user request.

The system has both firmware and web application. The firmware on the Arduino microcontroller enables the user's temperature, blood pressure, heart beat and ambient temperature to be displayed on the LCD screen on the hardware device of the system. The web app has functionalities and online database that enables the device to capture the data on the user's body temperature, ambient temperature, the user's heart beat data and the user's blood pressure data and then transmit the user's dataset as a record to the online database where the record is stored along with the relevant information about the user.

3. Results and discussion

The implementation of the development of the microcontroller and IoT-based health monitoring system is presented in Figure 2. The blue chip shown in Figure 3 is used to capture the ambient temperature. The internal connectivity of the device before coupling the completely device is shown in Figure 4.The LCD on the device (as shown in Figure 2) is used to displace all the data captured by the device. That display in Figure 2 is enabled by the firmware running on the Arduino microcontroller in the hardware of the system. The red button from the right (in Figure 3), regulates the transmission of the data via the internet connection.

The device is design to capture data on the fingertip for heartbeat and blood pressure using their specific sensors. To measure the user's body temperature, the temperature sensor is placed on the user's armpit and the room temperature is also captured at the same time and then the LCD is used to displace the data captured from the user. When this red button (in Figure 3) is pressed, the user's data captured by the hardware device is uploaded to the online database via the Internet connection between the system and the web server where the web app and online database are hosted. The web app is hosted online with the URL toveramedia.com/healthmonitor platfom.

The screenshot of the dashboard for the admin on the web app is shown in Figure 5. The web app admin dashboard shows that there is module for the doctor, for the patience, for the hospital the device is used and for the incidences or measurement data records capture with the device. The screenshot of the webpage showing the form for capturing the patient's details is shown in Figure 6 while the screenshot of the webpage showing the list of patients registered on the systems web application is shown in Figure 7. Again, the screenshot of the webpage showing the time-stamped data record of patients is shown in Figure 8.

Figure 2 The picture showing the complete developed health monitoring system

Figure 3 The picture showing another view of the complete developed health monitoring system

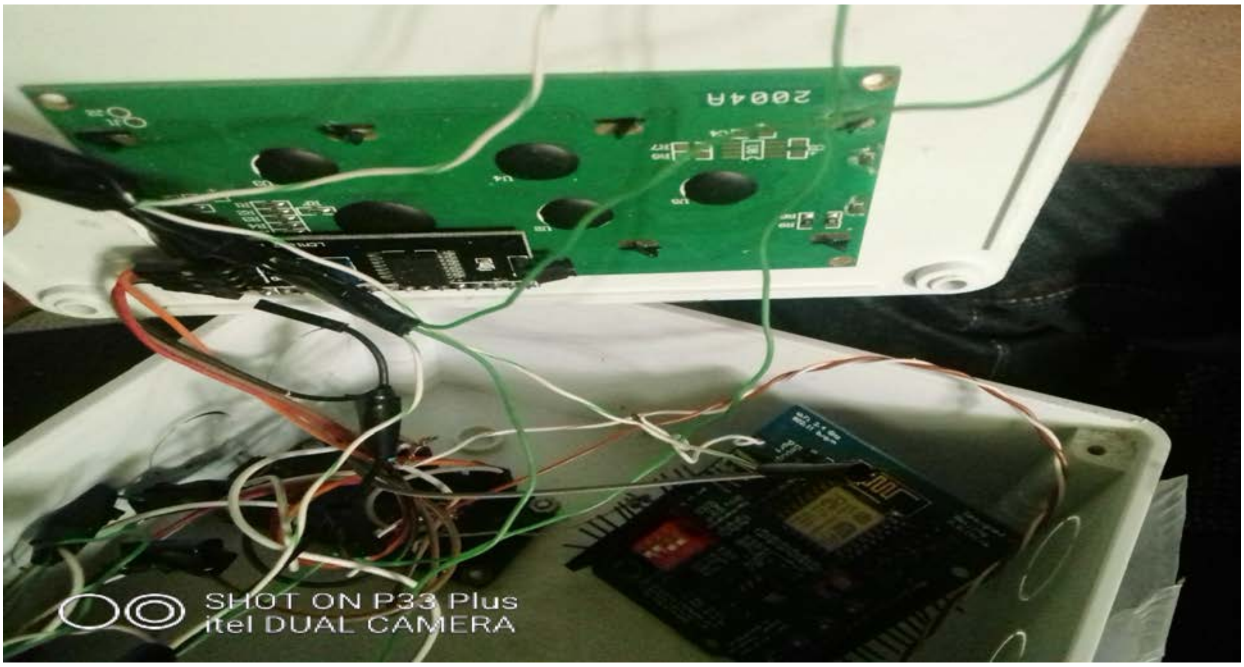

Figure 4 The picture showing internal connectivity of the device before coupling the completely device

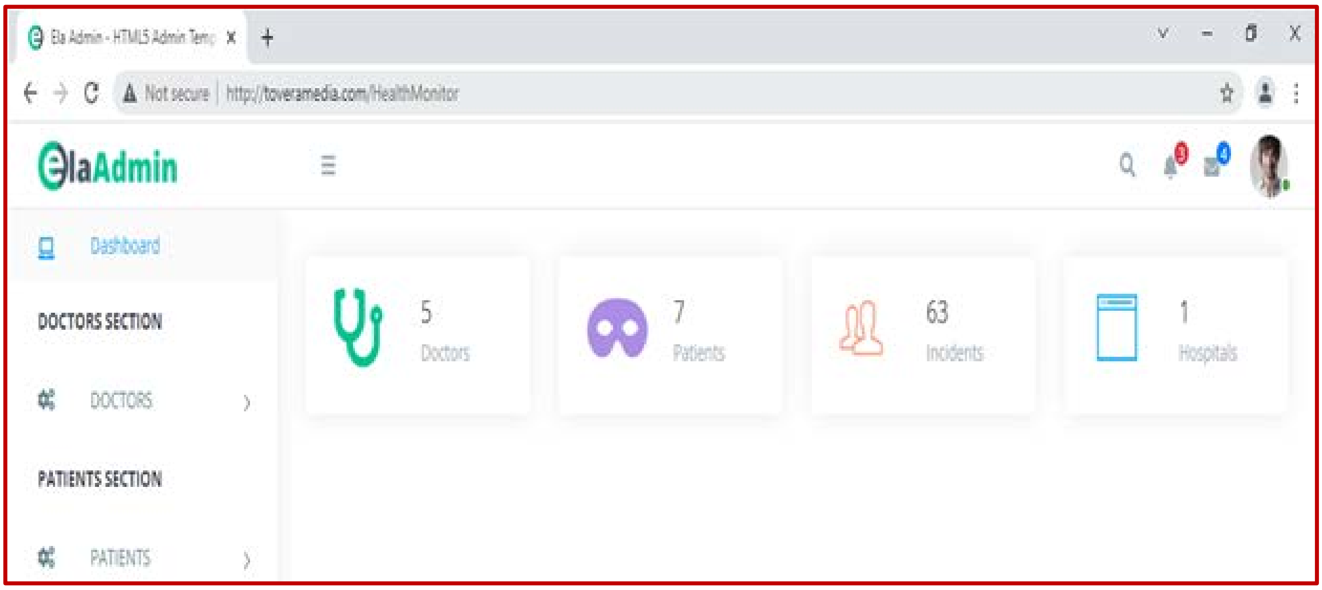

Figure 5. The screenshot of the dashboard for theadmin on the web app

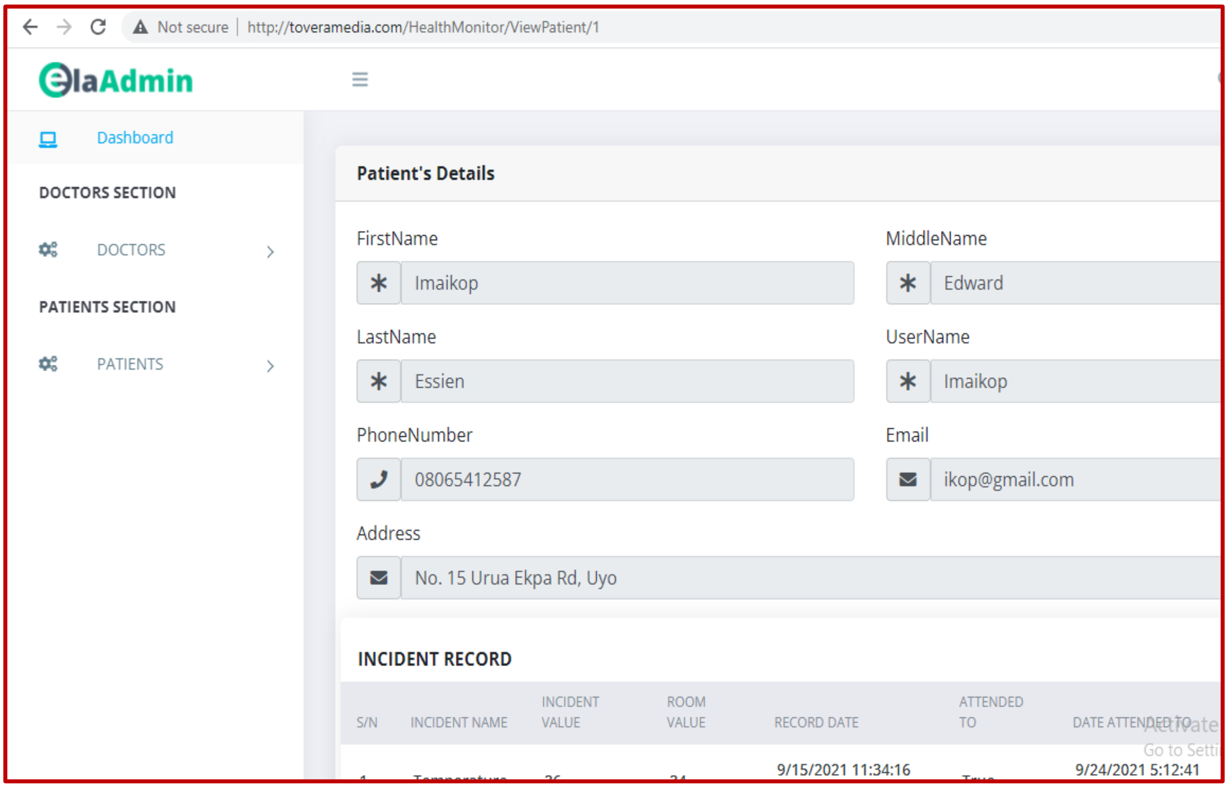

Figure 6. The screenshot of the webpage showing the form for capturing the patient’s details

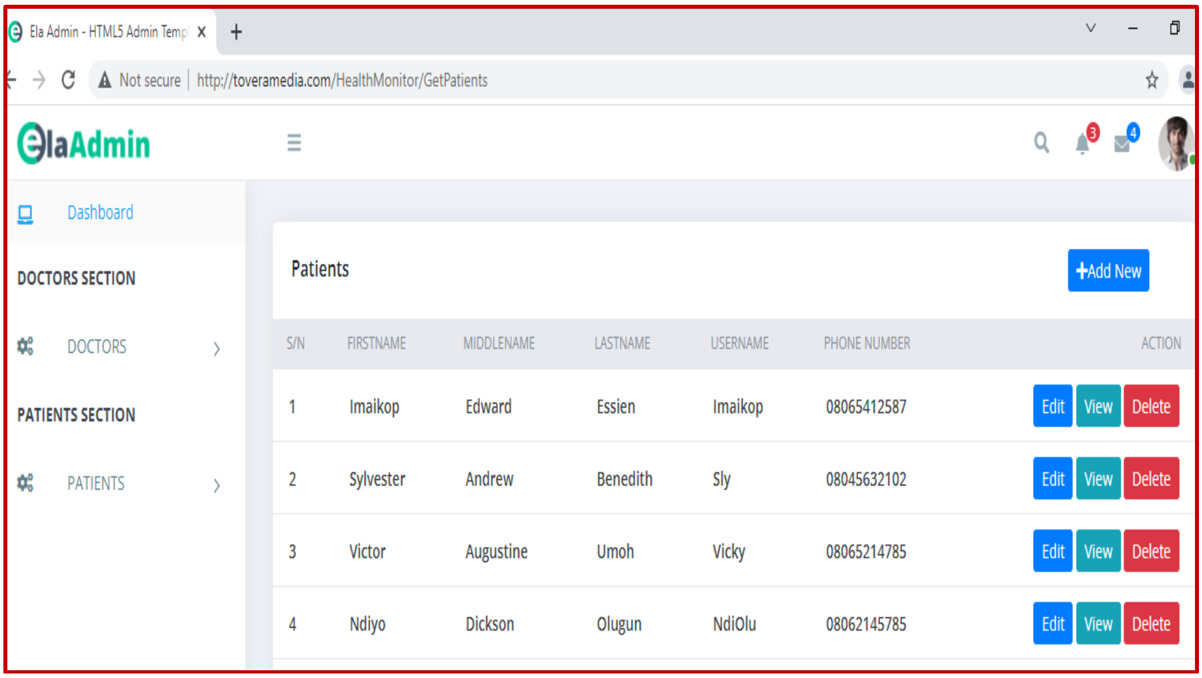

Figure 7. The screenshot of the webpage showing the list of patients registered on the systems web appplication

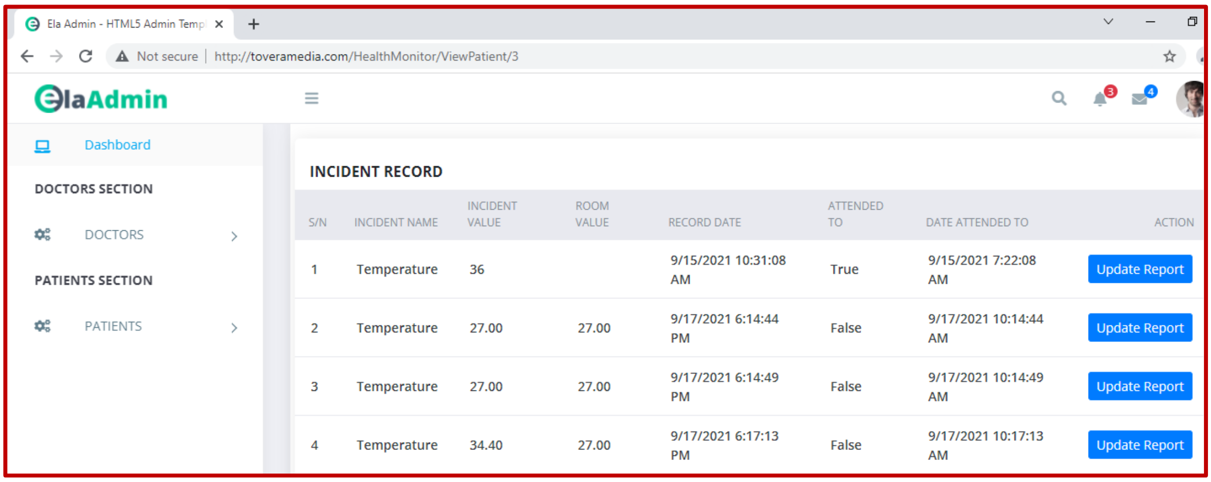

Figure 8. The screenshot of the webpage showing the time-stamped data record of patientes

4. Conclusion

The development of microcontroller and loT-based health monitoring system is presented. The device measure four key parameters namely, heartbeat, body temperature, ambient temperature and blood pressure. The device has the capacity to operate both online and offline. The device also makes use of fingertip to capture data such as heartbeat and blood pressure while the body temperature sensor is placed in the armpit to capture the body temperature data. Some of the major components in the device construction are as follows ATMega328 microcontroller, ESP8266 WiFi module, DHT11, DHT22 sensors module and LCD. The device is been calibrated with the existing device in ST.LUKE'S HOSPITAL ANUA,P.M.B 1003,UYO AKWA IBOM STATE, NIGERIA with the following instruments or devices: pulse oximeter CE012 IPx2, manufactured by Human Accurate Biomedical Technology Co.Ltd, Body Infrared Thermometer DJ-8861 and BP Accoson and Son (Surgical) Ltd 5PQ.

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References

1. Buratti, C., Conti, A., Dardari, D., & Verdone, R. (2009). An overview on wireless sensor networks technology and evolution. *Sensors*, *9*(9), 6869-6896.
2. Boutaba, R., Salahuddin, M. A., Limam, N., Ayoubi, S., Shahriar, N., Estrada-Solano, F., & Caicedo, O. M. (2018). A comprehensive survey on machine learning for networking: evolution, applications and research opportunities. *Journal of Internet Services and Applications*, *9*(1), 1-99.

3. Auzanneau, F. (2016). Transferometry: A new tool for complex wired networks diagnosis. *Progress In Electromagnetics Research B*, *70*, 87-100.
4. Auzanneau, F., Ravot, N., & Incarbone, L. (2016). Chaos time domain reflectometry for online defect detection in noisy wired networks. *IEEE Sensors Journal*, *16*(22), 8027-8034.
5. Venghaus, H., & Grote, N. (Eds.). (2017). *Fibre optic communication: key devices* (Vol. 161). Springer.
6. Ozuomba Simeon and Chukwudebe G. A.(2003) *An improved algorithm for channel capacity allocation in timer controlled token passing protocols, The Journal of Computer Science and its Applications (An international Journal of the Nigerian Computer Society (NCS)) Vol. 9, No. 1 , June 2003 , PP 116 124*
7. Ozuomba Simeon and Chukwudebe G. A. (2004) *A new priority scheme for the asynchronous traffic in timer-controlled token passing protocols, The Journal of Computer Science and its Applications (An international Journal of the Nigerian Computer Society (NCS)) Vol. 10, No. 2 , December 2004 , PP 17 -25*
8. Ozuomba Simeon and Chukwudebe G. A.(2011) ; *"Performance Analysis Of Timely-Token Protocol With Variable Load Of Synchronous Traffic" NSE Technical Transactions , A Technical Journal of The Nigerian Society Of Engineers,* Vol. 46, No. 1 Jan – March 2011, PP 34 – 46.
9. . Kalu, S. Ozuomba, G. N. Onoh (2011) ANALYSIS OF TIMELY-TOKEN PROTOCOL WITH NON-UNIFORM HEAVY LOAD OF ASYNCHRONOUS TRAFFIC. Electroscope Journal Vol. 5 No. 5 (2011)
10. Ozuomba Simeon , Chukwudebe G. A. and Akaninyene B. Obot (2011); *"Static-Threshold-Limited On-Demand Guaranteed Service For Asynchronous Traffic In Timely-Token Protocol " Nigerian Journal of Technology (NIJOTECH)* Vol. 30, No. 2 , June 2011 , PP 124 – 142
11. Kalu C. , Ozuomba Simeon, Onoh G.N. (2013) Dynamic Threshold limited timed token (DTLTT) Protocol *Nigerian Journal of Technology (NIJOTECH)* Vol. 32. No. 1. March 2013, pp. 266-272.
12. Ozuomba, Simeon, Amaefule, C. O., & Afolayan, J. J. (2013). Optimal Guaranteed Services Timed Token (OGSTT) Media Access Control (Mac) Protocol For Networks That Support Hard Real-Time And Non Real-Time Traffic. *Nigerian Journal of Technology (NIJOTECH) 32*(3), 470-477
13. Kalu, C., Ozuomba, Simeon., & Anthony, U. M. (2015). STATIC-THRESHOLD-LIMITED BuST PROTOCOL. *European Journal of Mathematics and Computer Science Vol, 2(2).*
14. Rackley, S. (2011). Wireless networking technology: From principles to successful implementation.
15. Wong, K. D. (2011). *Fundamentals of wireless communication engineering technologies*. John Wiley & Sons.
16. Akpan, Itoro J., Ozuomba Simeon, and Kalu Constance (2020). "Development Of A Guard Channel-Based Prioritized Handoff Scheme With Channel Borrowing Mechanism For Cellular Networks." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 2, February - 2020*
17. Ogbonna Chima Otumdi , Ozuomba Simeon, Philip M. Asuquo (2020) Device Hardware Capacity And RSSI-Based Self Organizing Map Clustering Of 928 Mhz Lorawan Nodes Located In Flat Terrain With Light Tree Densities *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 9, September - 2020*
18. Idio, Uduak, Constance Kalu, Akaninyene Obot, and Simeon Ozuomba. (2013) "An improved scheme for minimizing handoff failure due to poor signal quality." In *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*, pp. 38-43. IEEE, 2013.
19. Asuquo, A. E. , Enyenihi H. J., Simeon, O.(2022) Design and simulation of load adaptive energy saving schemes in IP over Wavelength-division multiplexing (WDM) networks *Journal of Multidisciplinary Engineering Science and Research (JMESR)* Vol. 1 Issue 3, September – 2022 : http://www.jmesr.co.uk/wp-content/uploads/2022/11/JMESRN42350038..pdf
20. Atakpo, F. K., Simeon, O., & Utibe-Abasi, S. B. A COMPARATIVE ANALYSIS OF SELFORGANIZING MAP AND K-MEANS MODELS FOR SELECTION OF CLUSTER HEADS IN OUT-OF-BAND DEVICE-TO-DEVICE COMMUNICATION. *Journal of Multidisciplinary Engineering Science Studies (JMESS).*
21. Anietie Bassey, Simeon Ozumba & Kufre Udofia (2015). An Effective Adaptive Media Play-out Algorithm For Real-time Video Streaming Over Packet Networks. European. *Journal of Basic and Applied Sciences Vol, 2(4).*
22. Emenyi, M., Udofia, K., & Amaefule, O. C. (2017). Computation of optimal path Length for terrestrial line of sight microwave link using Newton–Raphson algorithm. *Software Engineering*, *5*(3), 44-50.
23. Bassey, A., Udofia, K. M., & Uko, M. C. (2016). MITIGATING THE EFFECT OF PACKET LOSSES ON REAL-TIME VIDEO STREAMING USING PSNR AS VIDEO QUALITY ASSESSMENT METRIC. *European Journal of Engineering and Technology Vol*, *4*(3).
24. Nsidibe-Emmanuel Nonye, C., Udofia, K. M., & Obot, A. B. (2019). DUAL BAND RECTANGULAR MICROSTRIP ANTENNA ARRAY FOR WIRELESS COMMUNICATION. *European Journal of Basic and Applied Sciences Vol*, *6*(1).
25. Abiodun A. Aduke , Akaninyene B. Obot, Kufre M. Udofia (2018) Compact Dual-Band Triangular Microstrip Antenna with Broadband Characteristics for WLAN Applications International Journal of Science and Engineering Investigations 7 (79), 132-136

26. Udofia Kufre. M., Ogungbemi Emmanuel Oluropo (2017) Determination and Comparative Analysis of Refractivity Profile and Fade Depth for Microwave Links in Lagos International Journal of Information and Communication Sciences 1 (3), 59-62
27. Kalu, C., Ozuomba, Simeon. & Udofia, K. (2015). Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. *European Journal of Engineering and Technology, 3 (8)*, 30-43.
28. Kodheli, O., Lagunas, E., Maturo, N., Sharma, S. K., Shankar, B., Montoya, J. F. M., ... & Goussetis, G. (2020). Satellite communications in the new space era: A survey and future challenges. *IEEE Communications Surveys & Tutorials*, *23*(1), 70-109.
29. Maral, G., Bousquet, M., & Sun, Z. (2020). *Satellite communications systems: systems, techniques and technology*. John Wiley & Sons.
30. Simeon, Ozuomba (2014) "Fixed Point Iteration Computation Of Nominal Mean Motion And Semi Major Axis Of Artificial Satellite Orbiting An Oblate Earth." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 1 Issue 4, November – 2014*
31. Simeon, Ozuomba (2014) "Fixed Point Iteration Computation Of Nominal Mean Motion And Semi Major Axis Of Artificial Satellite Orbiting An Oblate Earth." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 1 Issue 4, November – 2014*
32. Simeon, Ozuomba. (2017). "Determination Of The Clear Sky Composite Carrier To Noise Ratio For Ku-Band Digital Video Satellite Link" *Science and Technology Publishing (SCI & TECH) Vol. 1 Issue 7, July – 2017*
33. Afahakan, K.M Udofia, M.A. Umoren (2016) Analysis of rain rate and rain attenuation for earth-space communication links over Uyo-Akwa Ibom StateNigerian Journal of Technology 35 (1), 137-143
34. K.M Udofia, I.E. Otung (2008) Evaluating time diversity performance on an on-board processing satellite to earth station downlink The Second International Conference on Next Generation Mobile …
35. K. M. Udofia (2011) Time Diversity Modelling and Implementation for Broadcast Satellite Systems at V-Band
36. O. Achor Jane, M. Udofia Kufre, B. Obot Akaninyene (2017) Seasonal Variations of Site Diversity Along Earth-Space Paths in Nigeria International Journal of Information and Communication Sciences 1 (3), 54-58
37. Maral, G., Bousquet, M., & Sun, Z. (2020). *Satellite communications systems: systems, techniques and technology*. John Wiley & Sons.
38. Rose, K., Eldridge, S., & Chapin, L. (2015). The internet of things: An overview. *The internet society (ISOC)*, *80*, 1-50.
39. Li, S., Xu, L. D., & Zhao, S. (2015). The internet of things: a survey. *Information systems frontiers*, *17*, 243-259.
40. Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on industrial informatics*, *10*(4), 2233-2243Chopra, K., Gupta, K., & Lambora, A. (2019, February). Future internet: The internet of things-a literature review. In 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon) (pp. 135-139). IEEE.
41. Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. Business horizons, 58(4), 431-440.
42. Kshetri, N. (2017). The economics of the Internet of Things in the Global South. Third World Quarterly, 38(2), 311-339.
43. Ozuomba, Simeon, and Etinamabasiyaka Edet Ekott. (2020). "Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators." *Science and Technology Publishing* (SCI & TECH) Vol. 4 Issue 8, August – 2020
44. Ozuomba, Simeon, Ekaette Ifiok Archibong, and Etinamabasiyaka Edet Ekott (2020). Development Of Microcontroller-Based Tricycle Tracking Using Gps And Gsm Modules. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 1, January - 2020*
45. Maduka, N. C., Simeon Ozuomba, and E. E. Ekott. . (2020) "Internet of Things-Based Revenue Collection System for Tricycle Vehicle Operators." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.
46. Thompson, E., Simeon, O., & Olusakin, A. (2020). A survey of electronic heartbeat electronics body temperature and blood pressure monitoring system. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 8, August – 2020
47. Zion, Idongesit, Simeon Ozuomba, and Philip Asuquo. (2020) "An Overview of Neural Network Architectures for Healthcare." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020
48. Misra, G., Kumar, V., Agarwal, A., & Agarwal, K. (2016). Internet of things (iot)–a technological analysis and survey on vision, concepts, challenges, innovation directions, technologies, and applications (an upcoming or future generation computer communication system technology). American Journal of Electrical and Electronic Engineering, 4(1), 23-32.
49. Ghosh, A., Chakraborty, D., & Law, A. (2018). Artificial intelligence in Internet of things. CAAI Transactions on Intelligence Technology, 3(4), 208-218.
50. Patel, K. K., Patel, S. M., & Scholar, P. (2016). Internet of things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges. International journal of engineering science and computing, 6(5).

51. Talwana, J. C., & Hua, H. J. (2016, December). Smart world of Internet of Things (IoT) and its security concerns. In 2016 IEEE international conference on internet of things (iThings) and IEEE green computing and communications (GreenCom) and IEEE cyber, physical and social computing (CPSCom) and IEEE smart data (SmartData) (pp. 240-245). IEEE.
52. Noura, M., Atiquzzaman, M., & Gaedke, M. (2019). Interoperability in internet of things: Taxonomies and open challenges. Mobile networks and applications, 24(3), 796-809.
53. Aheleroff, S., Xu, X., Lu, Y., Aristizabal, M., Velásquez, J. P., Joa, B., & Valencia, Y. (2020). IoT-enabled smart appliances under industry 4.0: A case study. Advanced engineering informatics, 43, 101043.
54. Madakam, S., Lake, V., Lake, V., & Lake, V. (2015). Internet of Things (IoT): A literature review. Journal of Computer and Communications, 3(05), 164.
55. Patel, K. K., Patel, S. M., & Scholar, P. (2016). Internet of things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges. International journal of engineering science and computing, 6(5).
56. Malik, A., & Om, H. (2018). Cloud computing and internet of things integration: Architecture, applications, issues, and challenges. In Sustainable cloud and energy services (pp. 1-24). Springer, Cham.
57. Chacko, A., & Hayajneh, T. (2018). Security and privacy issues with IoT in healthcare. EAI Endorsed Transactions on Pervasive Health and Technology, 4(14), e2-e2.
58. Premkumar, A., & Srimathi, C. (2020, March). Application of blockchain and iot towards pharmaceutical industry. In 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 729-733). IEEE.
59. Lee, C. K. M., Cheng, M. N., & Ng, C. K. (2015). IoT-based asset management system for healthcare-related industries. International Journal of Engineering Business Management, 7(Godište 2015), 7-19.
60. Georgios, L., Kerstin, S., & Theofylaktos, A. (2019). Internet of things in the context of industry 4.0: An overview.
61. Almulhim, M., & Zaman, N. (2018, February). Proposing secure and lightweight authentication scheme for IoT based E-health applications. In 2018 20th International Conference on advanced communication technology (ICACT) (pp. 481-487). IEEE.
62. Ezz El-Din, H., & Manjaiah, D. H. (2017). Internet of nano things and industrial internet of things. In Internet of Things: Novel Advances and Envisioned Applications (pp. 109-123). Springer, Cham.
63. Bakar, N. A. A., Ramli, W. M. W., & Hassan, N. H. (2019). The internet of things in healthcare: an overview, challenges and model plan for security risks management process. Indonesian Journal of Electrical Engineering and Computer Science (IJEECS), 15(1), 414-420.
64. McAllister, T. D., El-Tawab, S., & Heydari, M. H. (2017, April). Localization of health center assets through an iot environment (locate). In 2017 Systems and Information Engineering Design Symposium (SIEDS) (pp. 132-137). IEEE.
65. Dash, S., Shakyawar, S. K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: management, analysis and future prospects. Journal of Big Data, 6(1), 1-25.
66. Stawicki, S. P., Jeanmonod, R., Miller, A. C., Paladino, L., Gaieski, D. F., Yaffee, A. Q., ... & Garg, M. (2020). The 2019–2020 novel coronavirus (severe acute respiratory syndrome coronavirus 2) pandemic: A joint american college of academic international medicine-world academic council of emergency medicine multidisciplinary COVID-19 working group consensus paper. Journal of global infectious diseases, 12(2),
67. Holten Møller, N. L., Bjørn, P., Villumsen, J. C., Hancock, T. C. H., Aritake, T., & Tani, S. (2017, February). Data tracking in search of workflows. In Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing (pp. 2153-2165).
68. Helmreich, R. L., & Schaefer, H. G. (2018). Team performance in the operating room. In Human error in medicine (pp. 225-254). CRC Press.
69. Bruni, T., Lalvani, A., & Richeldi, L. (2020). Telemedicine-enabled accelerated discharge of patients hospitalized with COVID-19 to isolation in repurposed hotel rooms. American journal of respiratory and critical care medicine, 202(4), 508-510.
70. Dziemidok, P., Gorczyca-Siudak, D., & Danielak, M. (2021). Is It Possible to Prevent Sars-Cov-2 Infection in a Non-Infectious Diseases Ward during the Pandemic on the Example of a Diabetes Clinic Institute of Rural Health, Lublin, Poland?. International Journal of Environmental Research and Public Health, 18(14), 7593.
71. Abbasian Dehkordi, S., Farajzadeh, K., Rezazadeh, J., Farahbakhsh, R., Sandrasegaran, K., & Abbasian Dehkordi, M. (2020). A survey on data aggregation techniques in IoT sensor networks. Wireless Networks, 26(2), 1243-1263.
72. Yelamarthi, K., Aman, M. S., & Abdelgawad, A. (2017). An application-driven modular IoT architecture. Wireless Communications and Mobile Computing, 2017.
73. Samuel, Wali, Simeon Ozuomba, and Philip M. Asuquo (2019). EVALUATION OF WIRELESS SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 11, November - 2019*

74. Samuel, W., Ozuomba, Simeon, & Constance, K. (2019). SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 6 Issue 12, December - 2019*
75. Johnson, Enyenihi Henry, Simeon Ozuomba, and Ifiok Okon Asuquo. (2019). Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm. *Universal Journal of Communications and Network, 7(1), 9-20.*
76. Njoku, Felix A., Ozuomba Simeon, and Fina Otosi Faithpraise (2019). Development Of Fuzzy Inference System (FIS) For Detection Of Outliers In Data Streams Of Wireless Sensor Networks. *International Multilingual Journal of Science and Technology (IMJST) Vol. 4 Issue 10, October - 2019*
77. Simeon, Ozuomba. (2020). "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June - 2020*
78. Simeon, Ozuomba. (2020). "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 12, December - 2020*
79. Ogbonna Chima Otumdi , Ozuomba Simeon, Kalu Constance (2020). Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 2, February – 2020*
80. Portalo, J. M., González, I., & Calderón, A. J. (2021). Monitoring system for tracking a PV generator in an experimental smart microgrid: An open-source solution. Sustainability, 13(15), 8182.
81. Kondaveeti, H. K., Kumaravelu, N. K., Vanambathina, S. D., Mathe, S. E., & Vappangi, S. (2021). A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations. Computer Science Review, 40, 100364.
82. Sayed, S., Hussain, T., Gastli, A., & Benammar, M. (2019). Design and realization of an open-source and modular smart meter. Energy Science & Engineering, 7(4), 1405-1422.
83. Sastra, N. P., & Wiharta, D. M. (2016, October). Environmental monitoring as an IoT application in building smart campus of Universitas Udayana. In 2016 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS) (pp. 85-88). IEEE.
84. Kumbhar, H. (2016, August). Wireless sensor network using Xbee on Arduino Platform: An experimental study. In 2016 International Conference on Computing Communication Control and automation (ICCUBEA) (pp. 1-5). IEEE.
85. Manatarinat, W., Poomrittigul, S., & Tantatsanawong, P. (2019, July). Narrowband-internet of things (NB-IoT) system for elderly healthcare services. In 2019 5th international conference on engineering, Applied Sciences and Technology (ICEAST) (pp. 1-4). IEEE.
86. Al Qundus, J., Dabbour, K., Gupta, S., Meissonier, R., & Paschke, A. (2020). Wireless sensor network for AI-based flood disaster detection. Annals of Operations Research, 1-23.
87. Chikezie, Aneke, Ezenkwu Chinedu Pascal, and Ozuomba Simeon. (2014). "Design and Implementation Of A Microcontroller-Based Keycard." *International Journal of Computational Engineering Research (IJCER) Vol, 04 Issue, 5 May – 2014*
88. Otumdi, Ogbonna Chima, Kalu Constance, and Ozuomba Simeon (2018). "Design of the Microcontroller Based Fish Dryer." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 11, November - 201*