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Development of an IoT-Based Device for Monitoring Vital Signs in Ambulatory Patients

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ABSTRACT: *This work aimed to develop ambulatory vital signs monitoring devices using the Internet of Things (AVSMDIoT). This work involves the development of robust signal algorithms with an assemblage of components like Arduino Nano, a suitable length of Velcro, a laptop downloaded with Arduino, jumper wires, soldering lead, soldering tools, temperature sensor, heart rate sensor, ESP module 8266, Spo_2 sensor and respiration sensor. Patients' real-time physiological vital signs, like heart rate, temperature, peripheral oxygen saturation, blood pressure, and respiration sensors, were measured and saved on to cloud using IoT. The effectiveness of AVSMDIoT was determined by comparing the vital signs measured by Welch Allyn's vital signs monitor (WASVM). Then, cost reduction was determined. The results show that sensors gave good algorithms with sufficient data for monitoring vital signs. The developed AVSMDIoT models were successfully stored on the google cloud using wi-fi and ESP modules. The R^2 – values of the relationship between vital signs of AVSMDIoT and WAVSM were more than 0.75, which indicated the reliability of AVSMDIoT. A cost of 84.38% of WAVSM was saved for the production of AVSMDIoT. Thus, developed AVSMDIoT enhanced in monitoring vital signs, cost-effective, saves time and energy with better performance when compared with WAVSM.*

KEYWORDS: ambulatory vital signs; pulse sensor; ESP module; internet of things.

INTRODUCTION

Ambulatory care refers to clinical care that may include diagnosis, observation, treatment, and rehabilitation, not provided within the traditional bed base or outpatient services that can be provided across the primary/secondary care interface [1]. Ambulatory cares are daily service with extension that involves clinic visits, medical offices, and outpatient treatment and requires urgent, routine, or emergent situations scheduled based on indications to visit, such as sports physical examinations, immunizations, blood tests, scans, endoscopies, and biopsies [2]. Several settings like a hospital, fee-for-service medical practices, community health centers, school and university health centers, ambulatory surgical centers, family planning clinics, mental health centers, and urgent care centers use its applications [2]. An ambulatory electrocardiography (AECG) monitor is a device used for continuous monitoring of the electrical activity of a patient's heart muscle for 24 hours or longer. The AECG can be used on patients with symptoms related to cardiac arrhythmias (e.g., pulse, syncope) and also for assessing anti-arrhythmic drug response and pacemaker and implanted cardioverter/defibrillator function.

Furthermore, the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure recommended that an ambulatory blood pressure monitor be used in patients with suspected white coat hypertension, those with apparent drug resistance, and those exhibiting hypotensive symptoms while taking antihypertensive medications, those with episodic hypertension, and those with autonomic dysfunction. Also, ambulatory heart rate monitoring may be used as part of a program to improve cardiovascular fitness, identify a physiological marker to stress reactivity, and monitor heart rate changes related to any cardiovascular disease or condition. Additionally, skin temperature monitoring can be used for training people to promote vasodilation or peripheral blood flow and can also be used to assess vascular responses to stress. Ultimately, the ambulatory activity monitor has applications in many fields of science and medicine for the assessment of pathological states with movement-related components, including sleep quality and patterns, geriatric inactivity, hyperactivity (e.g., attention deficit hyperactivity disorder), neurological conditions, and cancer-related fatigue or chronic fatigue syndrome, also valuable for monitoring and assessing effects of drugs on the central nervous system, it also finds use in biological and behavioral studies related to activity and chronobiology [3].

In 2005, the United States designed outpatient services that have cared for an estimated 1.2 billion visits to physician offices, clinics, and emergency rooms given a rate of four visits per person annually [4], with the uses of external ambulatory monitors like a Holter monitor, event monitor, and real-time monitor [5]. The increase in ambulatory care was attributed to screening for admission to the hospital, follow-up care and care after discharge, Early diagnosis, preventive, curative, and rehabilitative care on an ambulatory basis, effective treatment, and it's less capital-intensive for both practitioners and patients [2]. The most common intervention for patients in the hospital may be attributed to the measurement of fundamental indicators of a patient's health conditions called vital signs like blood pressure, temperature, pulse rate, oxygen saturation, and respiratory rate [6] with the cheapest monitoring means. Still, their clinical performance and accuracy are limited in the literature [7]. Nurses and doctors need to learn and appreciate vital sign changes and implications for patient care [6, 7].

Challenges faced by ambulatory care are patient identification issues, failure to diagnose correctly, inadequate screening and follow-up, over-sedation problems, and communication problems due to far and in-between visits [1], thereby caused by human factors and prevented by monitoring [8]. Today, vital signs determine patient risk and deterioration [8 - 10]. The importance of monitoring vital signs in clinical practice is indisputable. However, due to the dynamics of biomarkers, their best monitoring technique, data interpretation, and frequent measurement still need to be clarified [11, 12]. Thus, the risk associated with an intermittent change in the measurement of vital signs with continuous monitoring using novel wearable technology is limited in the literature. Internet of Things (IoT) is an aspect that use to settle the issue of the interconnection of, for example, things to things, human to things, and human to human, things in the physical world for stepped up, with regards to trading data, employing the internet, to achieve interconnection to each other. IoT can be actualized using Barcodes, Zigbee, WI-Fi, radio frequency identification technology (RFID), sensors, and smartphones [13]. IoT utilizes innovative interfaces seamlessly arranged with essential components in data, social and business undertakings, design of self-controlling material things and making decisions without direct human intervention, aviation for activity checking, transport coordination, security, and healthcare, as presented in Figure 1 [14-16]. In biomedical engineering, IoT helps transmit physiological signals to the google cloud for storage, retrieving, and monitoring [16-23], with the use of sensors, actuators, blockchain networks, and cloud computing [24-26], following sequential mechanisms of identification, sensing, communication, computation, serving, and semantics [27]. This data-driven diligence helps with diagnostic ability, disease prediction, and implementing preventive measures. The collective and comprehensive evaluation of data from different vital signs patients, such as implants and smart devices, can provide healthcare solutions like patient monitoring and interventions associated with chronic disease in extreme environments like remote areas [28]. Still, IoT and applications in healthcare have not been employed fully due to technicality and economic feasibility. In this work, ambulatory vital signs monitoring device with IoT was developed and tested.

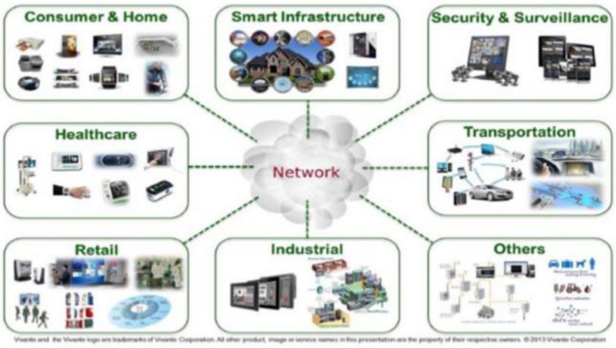


Fig. 1: Internet of Things Areas [14].

MATERIALS AND METHODS

Materials

Arduino Mega/mini 2560, ATemega microcontroller, a suitable length of Velcro, a laptop downloaded with Arduino, temperature sensor, heart rate sensor, ESP module 8266, SpO_2 sensor, respiration sensor, ESP module, 22µF ceramic capacitors, vero board, stretch sensor were sourced locally and obtained from Mikro C electronics USA. In addition, a Digital multi-meter, screwdrivers, epoxy gum, perspex cutter, and hand drilling machine were workshop tools.

Design Consideration

The system is classified into two parts: Hardware & Software, where the hardware unit consists of a transmitter section and a receiver section. The software unit consists of languages like python, MATLAB (MathWorks Product) version 2013a, and their interface. Some locally available hardware components were used in the designed circuit, where the software programming part was after successful fabrication. The exact software used was Arduino mega/mini.

Components Connectivity, Algorithm, and mode of Information Transfer

The ADC module in the microcontroller has seven analog inputs; it also has high and low voltage references, which are always in our code set to 5 V and 0 V, respectively. The sensor's analog voltage output is applied to channel A_3, A_4, A_1, and A_2 pins. Algorithms for measuring vital parameters are as follows:

1) Initialize the microcontroller:
    Clock frequency = 8 MHZ.
    Initialize I/O ports
    Initialize TFT Display.
2) Set the ADC channel for the said pins above.
3) Acquire the data by reading the ADC every 50ms and storing it. Find the maximum frequency that corresponds to the total value.
4) Check if it is outside the limit;

The microcontroller unit (MCU) performs warning procedures when the vital parameters are out of limit. The methods for the warning are:

1) Starts send message procedures.
2) Set the counter to zero.
3) Next, set the buzzer pins to 5 (turn on the buzzer).
4) Delay for 1s.
5) Reset the buzzer and pins to 5 (turn off the buzzer).
6) Delay for 1s.

7) If counter ≠ 5, go to step 3.

This involves using a multi-meter to test the circuit after mounting it on a breadboard before transferring it to the Vero board. The software is responsible for better working the system and interfacing activities. Both sections operate in a parallel process. Hardware comprises transmitter and receiver sections. The transmitter section was directly attached to the patient or human body. The proportional-Integral controller was used and connected to all IoT, temperature, pulse oximeter, RR, and blood pressure sensors, hardware units in the module, as well a DC power supply of 5v, was connected to ESP 8266. The IoT server was attached to the system and allowed connectivity for data exchange with other devices. IoT enables connected objects to identify and control remote access across networks. The outputs of heartbeat, temperature, blood pressure, SpO_2, and respiratory data were displayed on LCD at the user end. All the information was first acquired, processed, and stored in the memory of ESP 8266. Then, the stored information was transferred to the receiver employing an IoT server. Thus, the algorithm for the entire process was done by Arduino-Nano as follows, as presented in Fig. 2:

1) Initialize the microcontroller:
2) Recognize the limit of heart rate, blood pressure, respiration rate, peripheral oxygen saturation, and body temperature.
3) Start measuring the said parameter in the two above.
4) Display the values.
5) If any of the parameters are> MAX or < MIN
    a. Display the values on LCD.
    b. Send data to the internet.
    c. Set counter=0
    d. Turn on the buzzer continuously.
    e. If the value comes to normal;
    f. Turn off the buzzer.
    g. If counter < 5, go to step d. If the values are within the limit, display the reading on the TFT display) go to step 3.

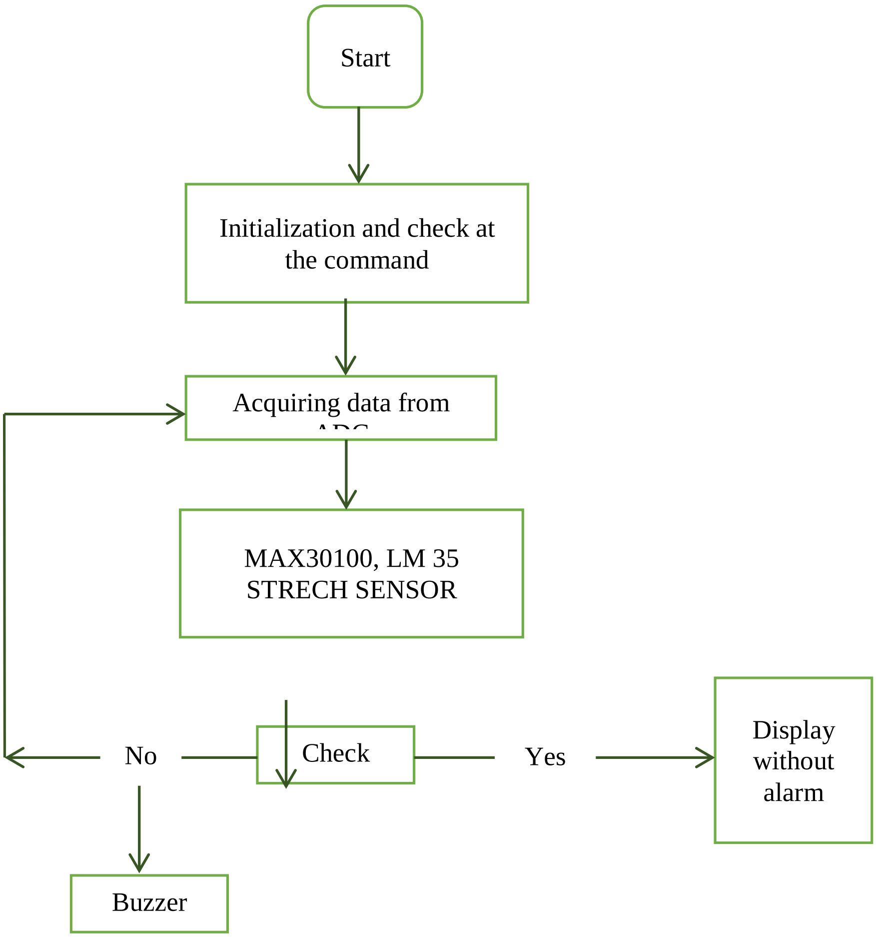


Fig. 2: Flowchart of the algorithm

The block diagram of the developed ambulatory vital signs monitoring device with IoT (AVSMDIoT) is presented in Fig. 3. The sensors are connected to the programmable logic circuit (PLC) on board. The value from the PLC was displayed and sent to the Web Server using ESP8266 wi-fi connectivity. The parameters can be viewed by the Android application installed on doctors' and patients' phones. In this design system, the Arduino board was used as the development board, and the Arduino IDE of the 1.8.8 model used was C^{++} High-Level Language Compiler.

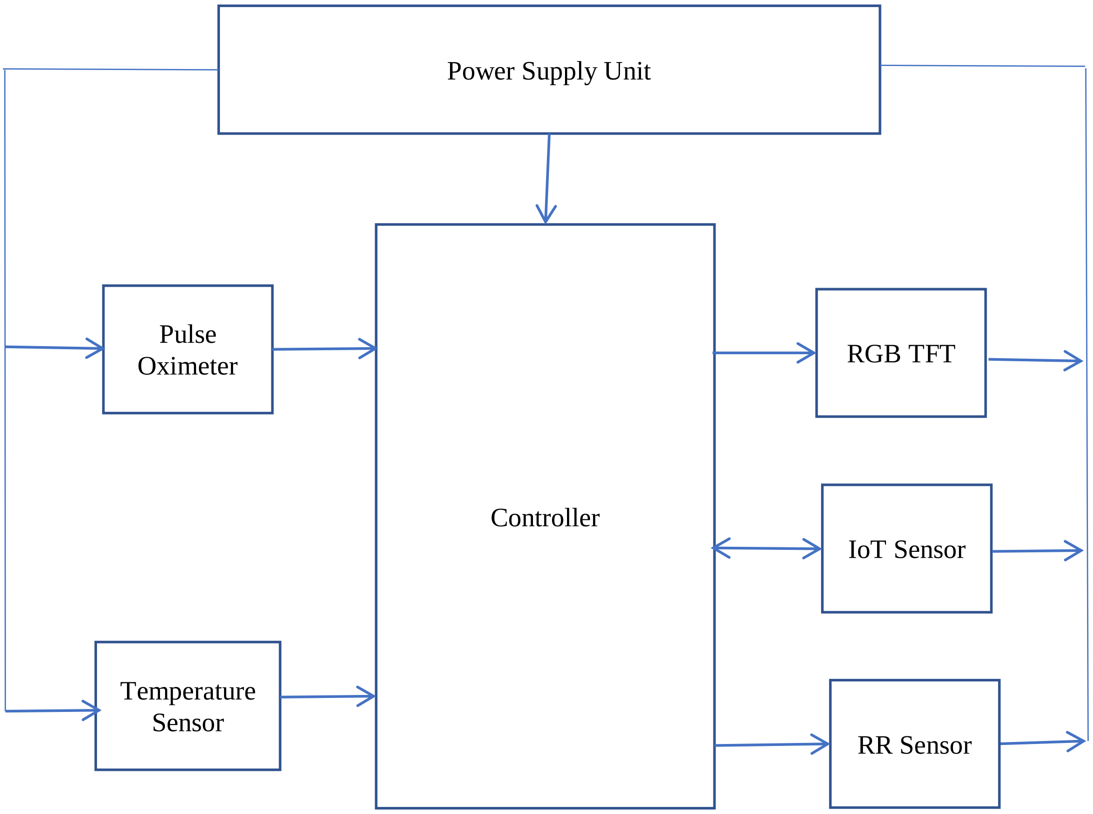


Fig. 3: Block Diagram of AVSMDIoT

Inputted Microcontroller Code

The input microcontroller code for the Arduino Uno and nano software was C^{++} for programming to measure the patient ambulance care conditions (heart rate, temperature, blood pressure, SpO_2, and respiratory measurement) are presented in Plate 1 (Appendix A)

Voltage Regulation for Power Supply and LM 1117

The percentage voltage regulation used for power supply and LM 1117 can be evaluated using equation (1).

$$V_R = \frac{V_{NL} - V_{FL}}{V_{NL}} \text{x } 100. \quad (1)$$

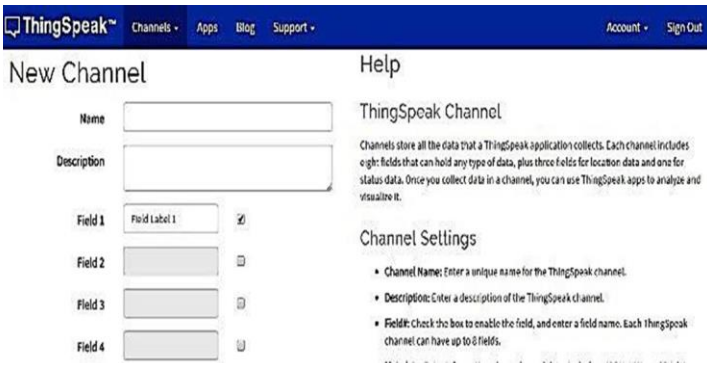
V_{NL} and V_{FL} represent low load voltage and full load voltage, respectively.

Overall System Performance Test

The random test was conducted on twenty patients in the Renal Dialysis unit of Abubakar Tafawa Balewa University Teaching Hospital Bauchi using an IoT platform called New ThingSpeak Channels and log in as illustrated in Plates 2 and 3, respectively. The results of system performance tests using developed (constructed) AVSMDIoT for heart rate, blood pressure, respiration, temperature, and peripheral oxygen saturation monitor and that of the Welch Allyn vital signs monitor. MicroSoft Excel was used as model to obtain correlation coefficients between the developed AVSMDIoT and Welch Allyn's vital signs monitor.

Plate 1: New ThingSpeak Channel 1

After creating an account, go to channels and create a new channel. Now write the name of the channel and the name of the Fields. Also, tick the check box for the 'Make Public' option below in the form, and finally, Save the Channel. Now a new channel has been created.



New Channel

Name
Description
Field 1 Field Label 1 ☑
Field 2 ☐
Field 3 ☐
Field 4 ☐

Help

ThingSpeak Channel

Channels store all the data that a ThingSpeak application collects. Each channel includes eight fields that can hold any type of data, plus three fields for location data and one for status data. Once you collect data in a channel, you can use ThingSpeak apps to analyze and visualize it.

Channel Settings

- **Channel Name:** Enter a unique name for the ThingSpeak channel.
- **Description:** Enter a description of the ThingSpeak channel.
- **Field#:** Check the box to enable the field, and enter a field name. Each ThingSpeak channel can have up to 8 fields.

Plate 2: New ThingSpeak Channel 2

After this, go to API keys and copy the Write API key, which is needed during coding. Check the Full code at the end. The ESP8266 communicated to the Arduino and sent the data to ThingSpeak. The ESP 8266 is connected to the router network provided in the code and transmits the sensor's data online. The data on ThingSpeak is displayed in Plate 3 and accessed from anywhere over the internet.

Ambulatory Vital sign monitor using IOT

Channel ID: 1945656
Author: bmasisal85
Access: Private

To patient vital sign monitor

Channel Stats

Created: 6 days ago
Last entry: about 3 hours ago
Entries: 74

Plate 3: New ThingSpeak page for login

Mechanical Structure

The casing for AVSMDIoT was constructed using plastic rubber of 1mm thickness with the dimensions as presented in Fig. 4.

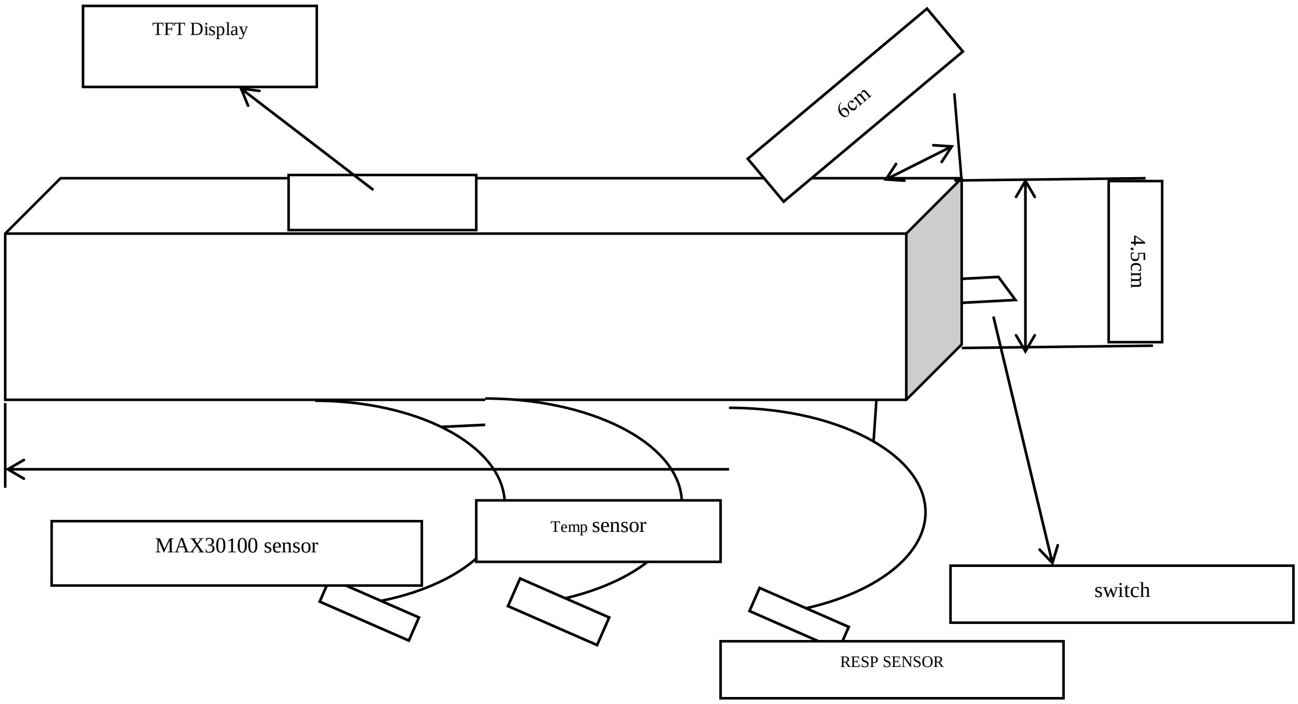


Fig.4: System casing.

RESULTS AND DISCUSSION

The circuit diagram and Voltage Regulation of

The power supply unit of 9V/5V was tested for the voltage output under no-load and full-load conditions. At no load, the voltage was measured to be 9.02V/5.01V, while at full load, the voltage was 8.95V/4.98V. The percentage voltage regulation was calculated using equation (1), and the circuitry of the developed AVSMDIoT is presented in Figure 5.
At low load:

$$V_{RL} = \frac{9.02-8.95}{9.02} x\ 100$$

$$= 0.78\%,$$

At full load:

$$V_{RF} = \frac{5.01-4.98}{5.01} x\ 100$$

$$= 0.60\%.$$

The performance of the power supply was found to be satisfactory since the percentage voltage regulation is low and regular.

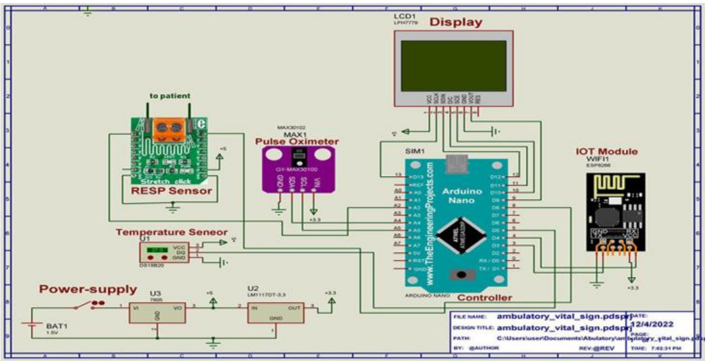


Fig. 5: Circuit diagram of AVSMDIoT

LM 1117

At no load, the voltage was measured to be 3.3V, while at full load, the voltage was 3.27V. The percentage voltage regulation was obtained to be 0.91%:

$$V_R = \frac{3.3-3.27}{3.3} \times 100$$
$$= 0.91\%$$

Developed AVSMDIOT

The functional unit, module, subsystem, and system testing methods were employed using a digital multi-meter, voltage indicator, and breadboard to test and troubleshoot the process on the power supply unit, the LM series, and ESP8266: the Vero board and the prototype of constructed AVSMDIoT as presented in Plates 4 and 5, respectively.

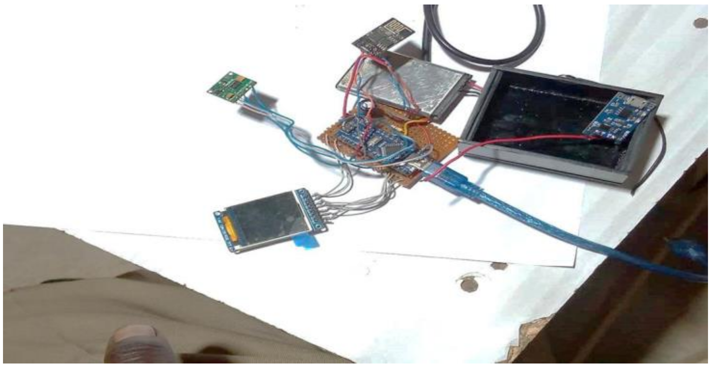


Plate 4: Vero board of developed AVSMDIoT

Plate 5: Prototype with measured data of constructed AVSMDIoT

Data of Vital Signs and Exportation on thing speak Page

The obtained data from AVSMDIoT for vital signs were saved and exported for storage on the cloud using a wi-fi module as displaced on ThingSpeak channel pages are presented in Fig. 6 and Fig. 7, respectively. The effectiveness of developed AVSMDIoT may be attributed to the sensitivity of sensors used for vital signs.

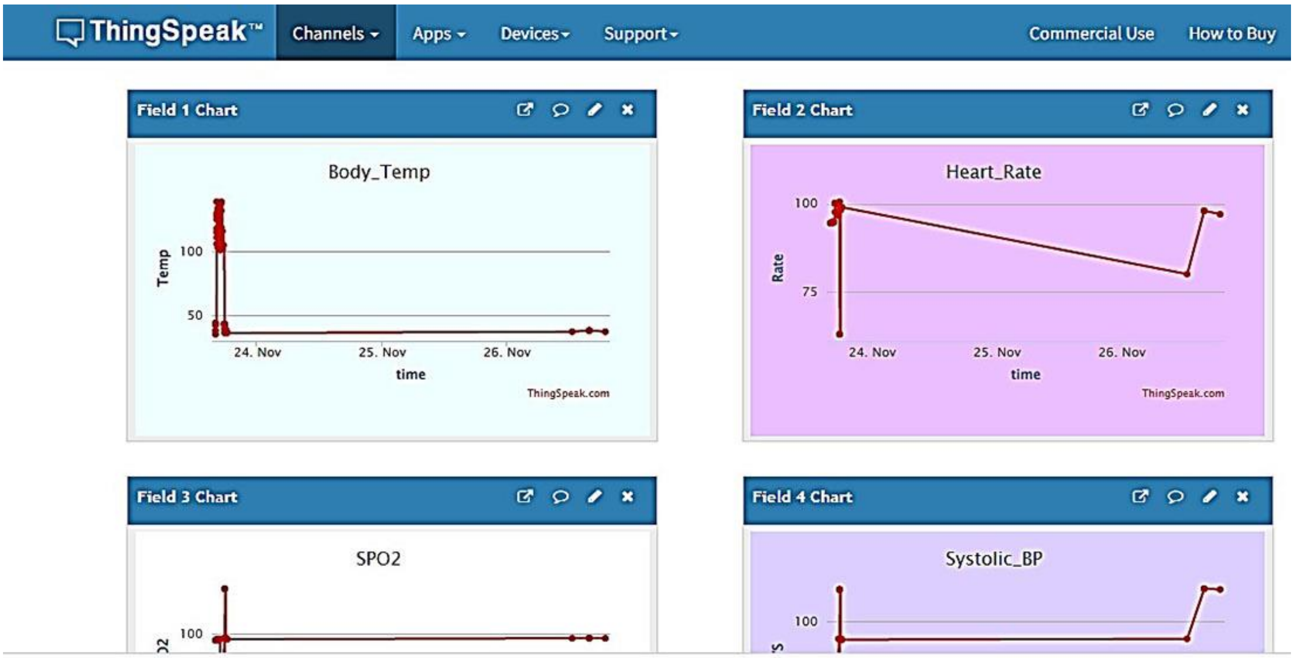
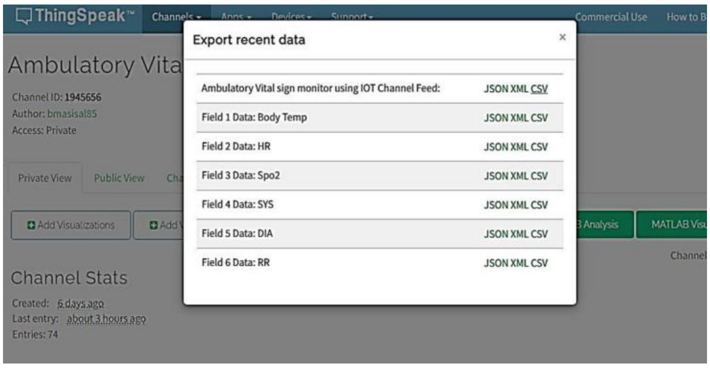


Fig. 6: Data of vital signs from the thing speak page



Ambulatory Vita

Channel ID: 1945656
Author: bmasisal85
Access: Private

Channel Stats

Created: 6 days ago
Last entry: about 3 hours ago
Entries: 74

Export recent data

Ambulatory Vital sign monitor using IOT Channel Feed:	JSON XML CSV
Field 1 Data: Body Temp	JSON XML CSV
Field 2 Data: HR	JSON XML CSV
Field 3 Data: Spo2	JSON XML CSV
Field 4 Data: SYS	JSON XML CSV
Field 5 Data: DIA	JSON XML CSV
Field 6 Data: RR	JSON XML CSV

Fig. 7: Data exportation page from thing speaks page

Overall System Performance

The results of the random test on twenty patients in the Renal Dialysis unit of Abubakar Tafawa Balewa University Teaching Hospital Bauchi of system performance on the developed AVSMDIoT heart rate, blood pressure, respiration, temperature, and peripheral oxygen saturation monitor and that of the Welch Allyn vital signs monitor (WAVSM) are presented in Fig. 8-13, respectively, with models and correlation coefficients for better comparison of values.

Heart Rate

Fig. 8 revealed the relationship between the heart rate measurement of constructed AVSMDIoT against that of WAVSM for twenty candidates. The high magnitude of 0.8421 for the R^2 –value was obtained; this indicated a high correlation of 84.91% and low variability of 15.79% in heart rate measurement using AVSMDIoT and WAVSM. The low variability may correlate to noise due to the unacceptable conditions of the candidates that were not considered during the design and production stage. This model equation (2) correlates better heart rate performance based on the heart rate's accuracy, which is justified by the R^2- value within an acceptable range of greater than 0.75. The high positive intercept value of the model indicated high susceptibility of produced AVSMDIoT as against WAVSM. Thus, the developed AVSMDIoT is a suitable ambulatory device for measuring heart rate.

$$Y= 0.8769x + 10.372. \qquad (2)$$

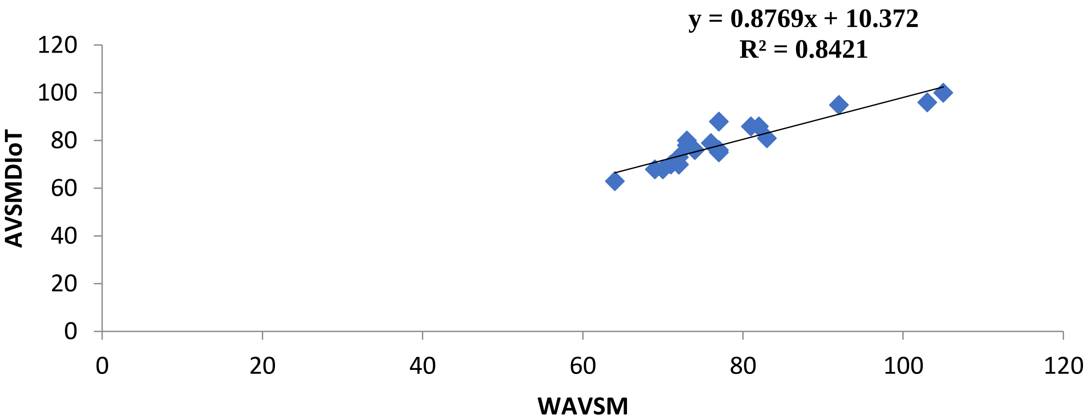


Figure 8: Heart rate measurement for developed AVSMDIoT against WAVSM

Temperature of Patients

The temperature measurement of the twenty candidates using AVSMDIoT and WAVSM are presented in Fig. 9. A linear model of equation (3) was obtained with a high correlation value of R^2 (0.9559), this means temperature values among the patients are considered accurate for a designed device, which is 95.59%, while 4.41% may be due to signal noise associated with environmental factors that were not considered during design. This equation (3) also shows an exemplary monitoring device since the R^2- value is more significant than 0.75. Therefore, it can be deduced that the slope of greater than one (1) shows a better temperature measurement performance of AVSMDIoT compared with WAVSM. At the same time, a negative intercept indicated non-susceptibility. Thus, AVSMDIoT is a better ambulatory device for measuring patients' temperature.

$$Y = 1.2275x - 8.0392. \quad (3)$$

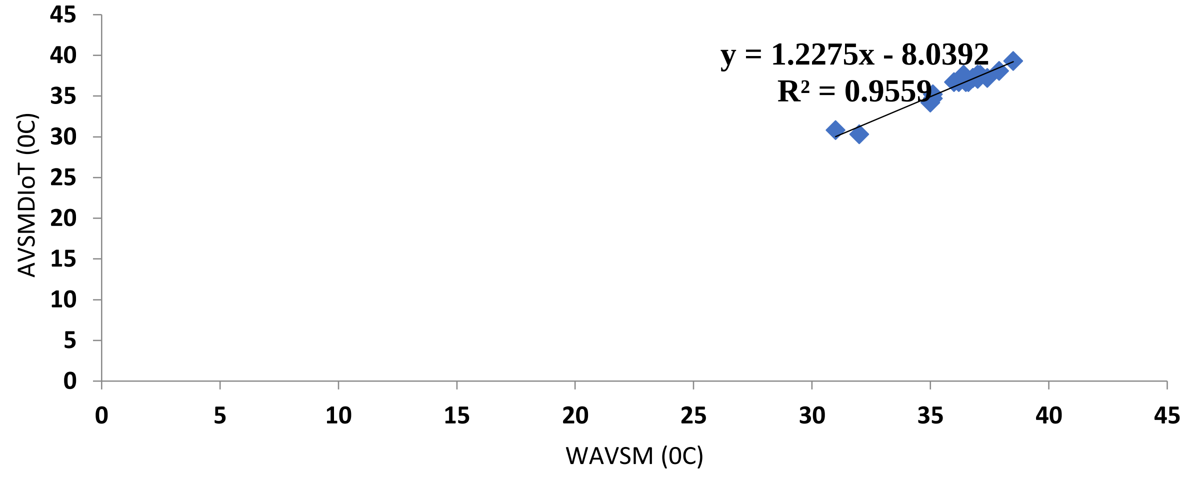


Figure 9: Temperature measurements for designed AVSMDIoT against WAVSM

Diastolic Blood Pressure

Fig. 10 illustrates the diastolic blood pressure among the patients using AVSMDIoT and WAVSM. A linear model (equation 4) was generated from patients' heart rates in comparisons using AVSMDIoT and WAVSM. Equation 4 exhibits a good correlation of 91.88 %; this indicates high correlation accuracy of designed AVSMDIoT based on materials with low noise of 8.12 % compared to when WAVSM was used to measure diastolic blood pressure. The 8.12 % of error may be due to the unstable conditions of patients, environmental factors, and the complex nature of patients. Hence AVSMDIoT is more accurate in measuring the diastolic blood pressure of patients than WASVM due to a positive slope of more than one (1) in the model with negated intercept, i.e., non-susceptibility.

$$Y = 1.1055x - 8.939. \quad (4)$$

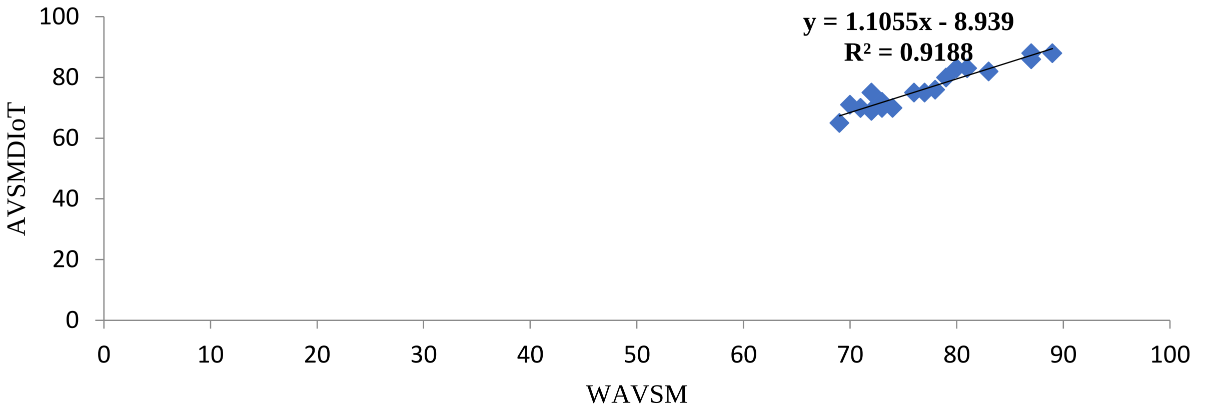


Figure 10: Diastolic Blood pressure measurements for designed AVSMDIoT against WAVSM

Systolic Blood Pressure

Fig. 11 depicts the systolic blood pressure measurement for patients using AVSMDIoT and WAVSM. An empirical linear model was obtained as equation (5). The model was correlated with an R^2 –value of 0.826 which is more than 0.75, indicating that it is 82.6% accuracy with low variability of 17.4% noise, which may be associated with unsteady state and environmental factors as an unnoticeable error that could exist when measured. Thus, systolic blood pressure is considered a good measure as an output of ambulatory care devices. Furthermore, AVSMDIoT may be considered a good design compared to WAVSM due to the high positive intercept value. Hence AVSMDIoT is more accurate in measuring the diastolic blood pressure of patients than WASVM due to the positive slope of the model, which is more than 0.75 with a positive intercept value.

$$Y = 0.7573x + 26.237. \qquad (5)$$

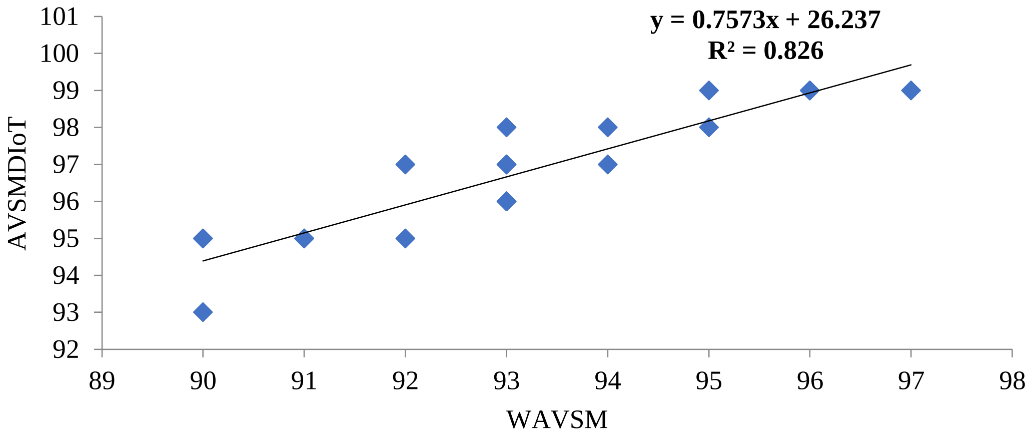


Figure 11: Systolic Blood pressure measurements for designed AVSMDIoT against WAVSM

Peripheral Oxygen Saturation (SPO_2)

Peripheral oxygen saturation measurements of candidates using AVSMDIoT and WAVSM are presented in Fig. 12. The correlation model obtained for SpO_2 measurement by AVSMDIoT and WAVSM is represented as equation (6). The model revealed a good correlation of 83.45 % with low variability of 16.55%. The high correlation coefficient indicated good design with low variability, which may result from environmental factors. A high positive intercept value revealed an increased susceptibility of AVSMDIoT to measure SpO_2 than WAVSM.

$$y = 0.2933x + 70.36. \quad (6)$$

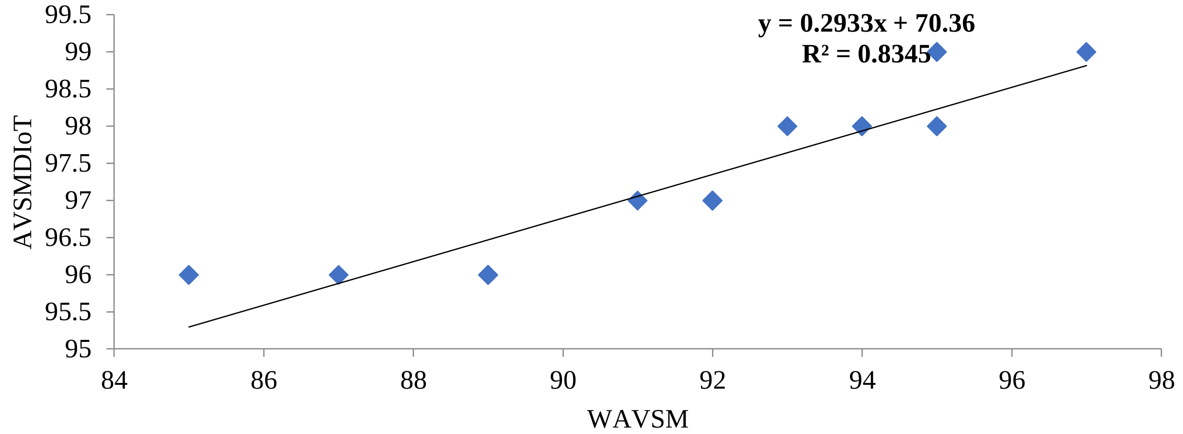


Figure 12: Peripheral oxygen saturation (SPO_2) measurement for designed AVSMDIoT against WAVSM

Respiratory Measurement

The respiratory measurement among the patients using AVSMDIoT and WAVSM is shown in Fig. 13. Linear model (equation 7) generated from a respiratory measurement of patients using devices, AVSMDIoT and WAVSM offers a good correlation of 90.47 %, this indicates high accuracy of the variability of designed AVSMDIoT with a low noisy effect of 9.53 % when compared with when WAVSM was used to measure respiratory parameters. The 9.53 % of error may be due to environmental factors, the irregular position of the patients, and irregular fluctuation of patient breathing when measured. Hence AVSMDIoT is more accurate in measuring the diastolic blood pressure of a patient than WASVM due to a positive slope of more than 1 in the model with negated intercept.

$$y = 1.3713x - 6.0556 \quad (7)$$

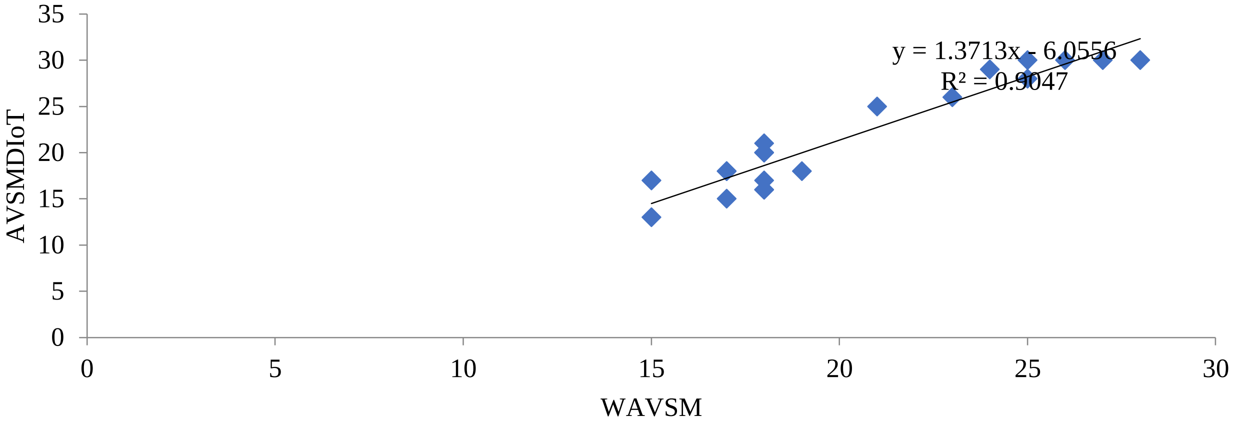


Figure 13: Respiratory measurement for designed AVSMDIoT against WAVSM

Cost evaluation of AVSMDIOT

The cost evaluation of materials used for designing ambulatory vital signs monitoring devices using IoT is presented in Table 1. The cost of WAVSM in the market is One million eight hundred thousand nairas (#1,800,000:00). The cost variation when comparing the cost of developed AVSMDIoT. That of WASVM in the market was found to be #1,518,792:50, an 84.38% reduction; this indicated that AVSMDIoT locally produced is cost beneficiary to Nigeria's economy, provides a job for people as well as reduces the cost of ambulatory care if embarked upon by Biomedical Engineer Engineering.

Table 1: Bill of Engineering Measurement and Evaluation

S/N	MATERIALS	QUANTITIES	AMOUNT(N)
1	Microcontroller (Arduino Nano)	1	9,000:00
2	Rechargeable lithium-ion battery	1	1,200:00
3	100uF Electrolytic Capacitor	2	600:00
4	Max30100	1	12,000:00
5	10-kilo ohm resistor	2	200:00
6	Esp module	1	15,000:00
7	1k ohm resistor	2	200:00
8	16 MHz Crystal	1	3000:00
9	22pf ceramic capacitors	2	400:00
10	7805 regulator IC	1	300:00
11	Lm 1117 regulator IC	1	500:00
12	Switch	1	200:00
13	Plastic casing	1	1,500:00
14	TFT display	1	15,000:00

15	Temperature sensor	1	3000:00
17	Vero board	1	1000:00
18	Soldering wire	1	1000:00
19	Connecting wires and connectors	One roll	1000:00
20	Cost of the patent (administrative)		30,000:00
21	Registration of company and Products		35,000:00
22	Cost of energy consumption		20,000:00
23	Logistics		23,100:00
24	Utilities		10,000:00
25	Tax		18,007.50
20	Miscellaneous		80,000:00
	TOTALS		**281,207:50**

The cost reduction in percentage was evaluated using equation (7):

$$C_R(\%) = \frac{C_{\text{WAVSM}} - C_{AVSMDIoT}}{C_{\text{WAVSM}}} x100\% \tag{7}$$

C_R, C_{WAVSM}, and C_{AVSMDIoT} represent the cost reduction, WAVSM, and constructed AVSMDIoT, respectively.

$$C_R(\%) = \frac{\#1{,}800{,}000{:}\,00 - \#281{,}207{:}\,50}{\#1{,}800{,}000{:}\,00} x100$$

$$C_R(\%) = 84.38\%$$

CONCLUSION

The advancement in healthcare delivery, especially in developing monitoring devices for vital signs with IoT, becomes valuable if technically and economically feasible. Based on this work, the following conclusion was drawn:

- An algorithm of AVSMDIoT was designed based on a percentage of voltage regulation of 0.78 and 0.60% for low and total power supply, respectively, and 0.91 % power supply for LM 1117 IC regulator with use of Arduino nano microcontroller and Esp module.
- A developed AVSMDIoT was built and confirmed to function upon the passed unit, modules, subsystems, and system testing.
- Real-time and linear models of vital signs were obtained for AVSMDIoT.
- The reliability of AVSMDIoT was obtained with a high magnitude of the correlation coefficient, R^2-values greater than 0.75 for all vital signs measurement (heart rate, blood pressure (systolic), blood pressure (Diastolic), respiration, temperature, and peripheral oxygen saturation) when compared to WASVM.
- The developed AVSMDIoT prototype saves 84.38 % of the cost of WAVSM in the market.

Author Contributions: The developed AVSMDIoT models were successfully stored on the cloud using wi-fi and ESP modules. The R^2 – values of the relationship between vital signs of AVSMDIoT and WAVSM were more significant than 0.75, which indicated the reliability of AVSMDIoT. A cost of 91.93 % of WAVSM was saved for the production of AVSMDIoT. Thus, developed AVSMDIoT enhanced in monitoring vital signs, cost-effective, saves time and energy with better performance when compared with WAVSM. All authors have read and agreed to the published version of the manuscript.

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