IoT Based Continuous Monitoring and Measurement of Pulsatile Blood Flow: A Review

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Abstract— **Recent technology has more advantages in the field of medical industry with the help of Internet of Things (IoT). The objective is to design a system with wireless capability which monitors the pulsatile blood flow rate. In normal monitoring of the patient, doctors or nurses have to be present near the patient to monitor the amount of blood flow. The main concept is to provide an effective controlling and monitoring system that can be easily implemented in any hospital and can be easily controlled by nurses. This paper discusses the various performance of the systems that are capable to automatically monitor the flow velocity and volume of blood with the help of less manpower and in a more secured way.**

Keywords—Internet of Things, Blood Flow, Flow Sensor, Flow Meter

I. INTRODUCTION

One of the most important physiological parameters, and also one of the most difficult to reliably calculate, is blood flow. This is because instruments inside the body to calculate the flow through blood vessels must follow certain strict specifications; for example, standards for sensitivity and stability depend on the flow magnitude, position and diameter of the individual vessels. Normal blood flow velocities in vessels with diameters ranging from 2 cm to a few millimeters differ over a wide range.

The flow of blood reveals huge information about the patient and has a range of useful applications like in medical electronics, beauty industry and sports. The analysis of blood flow helps people to stop activities that creates hinderance in blood flow. In biomedical signal analysis for patient monitoring, the blood flow measurement is relevant for clinical and research applications. The fluctuations in amount of blood in the patient organ can cause the consequences of organ damage. In the past the flow of blood is measured with the help of an air tight U-tube which was attached to the vessel of blood. Various improvements in the direct measuring flowmeters are done. For measuring the total amount of blood in the other organs these methods were used. Due to the disadvantages in the earlier methods new methods were proposed to measure the flow of blood.

There are several commonly used methods for calculating the velocity of blood, Invasive (surgical) and non-invasive (through the skin). A technique was developed to measure and monitor the flow of blood in humans. This technique consisted of an optical fiber sensor with a Fiber Bragg Grating element and a LED [1]. A new system was invented to measure the blood flow using a wearable laser blood flowmeter. The principle behind this system was that, a laser diode will pass the light and that light travels throughs the optical fiber. By applying optical telecommunications device technology, this innovation was achieved [2]. A system was designed to monitor the blood flow using an ultracompact flow sensor and an application in smartphone. The system design was consisted of a blood flow sensor which was linked with an application in a laptop/smartphone, and this design makes it possible to monitor the blood flow from anywhere and at any time [3]. An IoT based intravenous system was designed. In this design, a wireless sensor network system was designed which was based on liquid level and measuring the flow rate. The design was consisted of the components like: Ultrasonic sensor, Microcontroller, a GSM module and temperature sensor [4].

In the fields of Communication and Information Technology, Nano sensors and the Internet of Things (IoT) advances in the fields of health care and bio-medical engineering have been incredible. Using Wi-Fi technology, parameters such as heart rate, sugar levels, blood pressure, etc. can be viewed and transmitted. Nothing is more precious than the life of the patient, given the health sector. It is not the number of patients or money that counts in such a scenario, but it is the quality of care that is significant. This system's main concept is to provide a cost-

effective, secure, simple and automated controlling and flow monitoring that can be easily implemented in any hospital and can be easily controlled by nurses and can control the flow rate from a distance.

II. RELATED WORK

Albert Ruiz-Vargas et al. [1] presented the design for measurement and monitoring the flow of blood in humans. In this paper, measurement of the fluctuations in blood was calculated with the help of sensor consisting of a Fiber Bragg Grating element and Light-Emitting-Diode. The blood was heated by the light emitting diode (LED), and the disturbance in flow were detected with the help of sensor. Experiments were performed with different flow rates. Ultrasound flow sensor was used to compare the data obtained. Results which were obtained concludes that the signals from optical and ultrasound sensor correlate with the Pearson coefficients, dependent on the pulsatile frequency. The system was capable to measure the flow of blood under pulsatile flow conditions.

Shingi Mino et al. [2] designed a wearable laser blood flowmeter. A blood flowmeter with a laser included was described in this paper. This Flowmeter was a smaller version of a conventional desktop-based flowmeter. The principle behind this system was that, a laser diode will pass the light and that light travels throughs the optical fiber. The light from the laser diode was scattered and reflected due to the blood cells and tissue in the capillaries. The light which was scattered by the tissue passes through the second optical fiber to a photodiode and gets converted in an electrical signal. By applying optical telecommunications device technology, this innovation was achieved.

The system proposed by Kei Kuwabara et al. [3] consisted a flow of blood which was monitored using an application in a smartphone and by using an ultracompact flow sensor. A huge amount of information was revealed by measuring the flow of blood which was flowing through the entire body and supports the changes in life with physical and emotional state. The study reveals that, if the blood flow could be easily measured and monitored in daily life, then it was able to use this measurement system in the useful applications such as sports and health. In the paper they have proposed a system design that was consisted of a blood flow sensor which was linked with an application in a laptop/smartphone. As per the paper, the design makes it possible to monitor the blood flow from anywhere and at any time.

Kanchi Rao. et al. [4] published a paper on development and design of IoT based IV system. Wireless sensor networks with IoT Cloud were adopted by Health care organizations which was beneficial, especially when large numbers of patients and their subsequent data were present was considered. If a patient was given an Intravenous (IV) fluid in intensive care unit. Now it was important to monitor the velocity of flow and the volume of fluid in bags by the nurse allocated to that patient. If that patient was not taken care properly then it may result in the death of the patient. In this paper, a wireless sensor network system was designed which was based on liquid level and measuring the flow rate. The design was consisted of the components like: Ultrasonic sensor, Microcontroller, a GSM module and temperature sensor. The advantage was that, it was useful to track the information wirelessly. Therefore, the problem faced by the patients such as back flow of blood and the blood which was loosed due to the fault of nurses was avoided by measuring the flow rate and the level of fluid.

Koert A. de Waal et al. [5] studied the technique which was focused on the method called central blood flow measurement with the help of doppler effect in newborn infants. The measurements of central blood flow measurements were in and around the heart. This method included the cardiac output and also the cardiac input and extracardiac and intracardiac shunts. Right or left ventricular output (RVO or LVO) in central circulations were measured as central blood flow (CBF) and at superior vena cava were measured as cardiac input. The methodology of CBF measurements in newborn infants was described in this paper. The paper had given the complete overview of blood blow measurements using doppler ultrasound system.

A.K. Jayanthy et al. [6] studied the measurement of blood flow techniques and applications. As blood carried all the nutrients and oxygen that our body need to stay healthy so it was important to measure the amount of blood flow in the body. Improper supply of blood flow to organs were caused due to the several diseases. An important information for the treatment of a disease had been obtained from the measurement of the blood flow. In the initial stage of disease, there was a change in blood flow and that change was very fast, so the physicians were provided with the new method for the treatment of the disease in the initial stage.

The monitoring system of R. Priyadarshini et al. [7] of autonomous patient blood flow was controlled using IOT method. The color sensors to describe the implementation of control system and the detection were used in this method. The sensor included a red laser which was at simple low-cost and a photodiode and to focus the beam on the light sensor an optics was included. This system together with a drip chamber was very useful. The method provided an accurate flow rate measurement and an accurate volume of the infused substances. The objective

of the design was to constantly monitor the volume of the solution with good reliability and accuracy.

Shyama Yadav and Preet Jain [8] proposed a method to monitor and control the saline wirelessly. The system was consisted of a device to monitor, a central monitor and a system to control. IR sensor was used as a device to monitor, which senses or detects the infusion drip rate. The solution bag was set to a particular level. As per the study, if the level of the solution crosses beyond its limit, then this information was passed to the nurses wirelessly. The objective of this proposed system was to reduce the continuous observation of the patient.

N Kumar [9] published a paper on IoT architecture and system design for health care system. Advantage of this system was that, the healthcare approach enables the medical devices with the Internet of Things (IoT) and the high precision sensors. The healthcare devices with Internet of Things (IoT) which had the healthcare cost reduced leads to the huge adoption and affordability. The system with healthcare consisting IEEE and constrained Application Protocol was described. The information related to the methods which are designed in the recent times in the field of healthcare with the help of Internet of Things (IoT) based architecture were provided in this paper. The measurement of heart rate, body temperature, and electrical activity (ECG) were done with a multi sensor-based system in which the blood glucose was sensed. A survey of recent technology in healthcare system with Internet of Things (IoT) were described in this paper.

III. METHODOLOGIES FOR BLOOD FLOW MEASUREMENT SYSTEM

Blood flow measurement system mainly comprises of three parts – Inertial Measurement Unit, Data communication and Processing with a display. The whole system can be categorized as illustrated in Fig. 1.

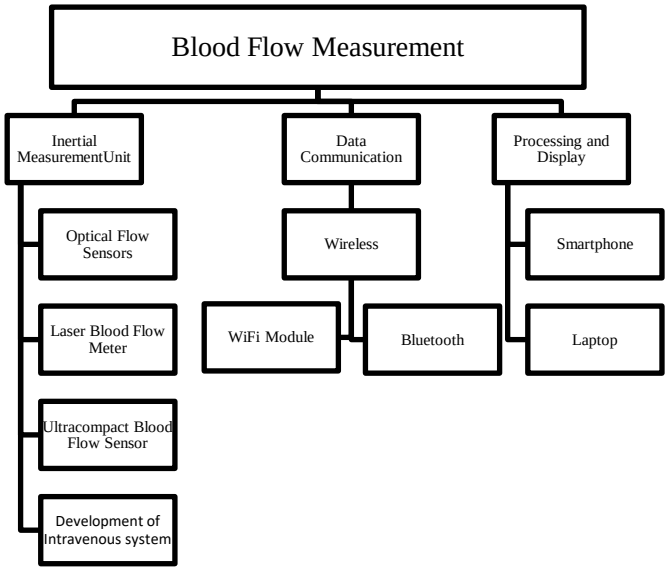

Fig. 1: Taxonomy of Blood Flow Measurement

A. Blood Flow Measurement System using Optical Flow Sensors

Optical flow sensors are used to perform the measurements of blood flow. The measurement system consists of a single mode optical fiber with a Fiber Bragg Grating (FBG) element to calculate the change in the temperature and a multimode fiber to guide the Light Emitting Diode (LED). The single mode and multimode fibers are connected with connectors and SMA respectively. MATLAB software was used to analyzed the data obtained from the optical and ultrasound sensors. Data which is obtained from the optical sensor are then compared with each flow rate to balance the highest frequency from the ultrasonic sensor. At each flow rate, frequency from the pulsatile flow were determined. Signals from both the sensors were synchronized and using the Pearson's correlation coefficient (PCC) the output from each sensor were correlated. To measure the average signal using the region under the curve process, three cycles were used at each flow rate. At each flow rate, average signals which are obtained from both the sensors were fitted using the method of 4-parameter-logistic regression. Optical power was converted into the flow with the help of the equation which was derived. The data obtained from both sensors

were tested using transient occlusion of the arterial or venous tubing.

B. *Mesaurement of Blood Flood Using Laser Blood Flow Meter*

The blood flow measurement is based on the principle, when the laser diode passes the light that travels through the tissue and an optical fiber. The light from the laser is scattered and the light is reflected by the blood cells in the capillaries and by the tissues. The velocity distribution of the blood that flows in all direction is 1 mm/s or less. The light which is scattered from the tissue is transported to the second optical fiber and to a photodiode and it is converted into electrical signal. The frequency of the scattered light changes due to the doppler effect. The scattered light is proportional to the velocity of blood cells. The flow of blood which is measured is based on the signal which is detected. The frequency from the laser light is too high to be detected. The difference ranges from a few hundred hertz to several tens of kilohertz between the frequency of reflected light from the tissue at rest and the frequency of the reflected light from moving blood cells. A beat signal is generated when the two lights interfere. With the sum of the products of all blood cells that travels at each specific velocity multiplied by the original velocity, we can calculate the flow of blood. Therefore, we can measure the flow of blood by combining the frequency and the products of beat signal.

C. *Blood Flow Measurement using Ultracompact Wearable Blood Flow sensors*

The proposed new method for calculating blood flow is shown in Fig. 2. The ultracompact wearable flow sensor consists of two parts: a device sensor and smartphone with an application. A sensor head and main unit are the components of the sensor device. A sensor head consists of a photo diode (PD) and a light diode (LD). A sensor head also consists of a light sensitive element which is installed in it. The light is detected by the photo diode when that light is scattered back as the light from the laser shines on the skin. A frequency shift is generated when the light that strikes on the skin and is scattered by the RBC moving in the vessels and that frequency shift is proportional to the velocity of RBC that are moving in blood vessel. By analyzing the spectrum frequency of the signal which is detected we can find out the data related to the flow of blood. The data which is related to the flow of blood can be displayed on the smartphone that gives the visual images such as graph or animation of the blood flow and its volume.

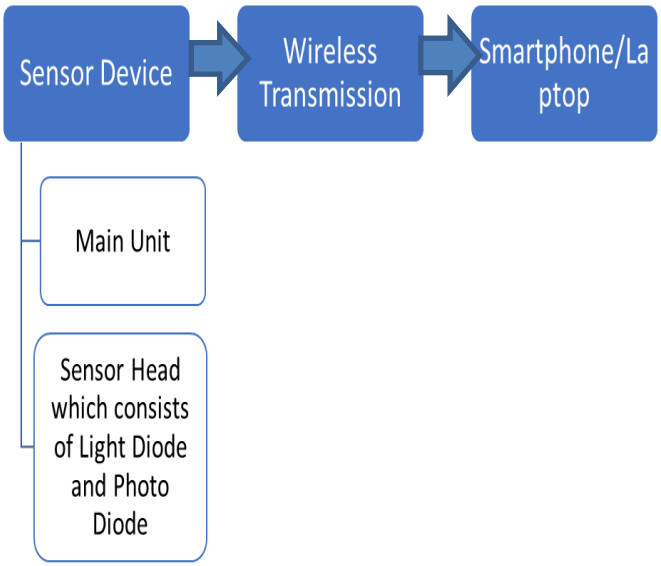

Fig. 2: Blood Flow Sensor Configuration system

D. *Mesaurement of Intravenous Invasion using IoT*

Patient's health is more important in the medical field. Regarding the patient's health, the E-fluid monitoring system is needed to develop in present situation. The setup of the entire system is shown in Fig. 3, in which the system measures the amount of fluid, measures the total drop count and this information is conveyed to doctors or nurses when the level of fluid reaches a specific level. Therefore, for this purpose a new method was proposed which includes a measuring system and WSN (Wireless Sensor Network) based liquid level. The system design consists of temperature sensor, microcontroller, GSM module and Ultrasonic sensor. In the developed design, an ultrasonic sensor is used for sensing the level of fluid and to monitor the total amount of fluid level. The sensed fluid level is the electrical signal converted, and the signal is sent to the microcontroller afterwards. The temperature was measured using a temperature sensor for operation with a low voltage of 5V. To emit the light an IR sensor is used, which is located in the drip chamber. The light is transmitted from the IR sensor's LED whenever the drops are blocked in the drip chamber. During this IR detected automatically gains the radiation from the object. Therefore, IR sensor counts the each drop in the drip chamber. As we monitored the drop count and level of the fluid, if the collected values cross the set point or the reaches the specific value an alert message is send through

GSM module to the particular nurse who is taking care of that patient.

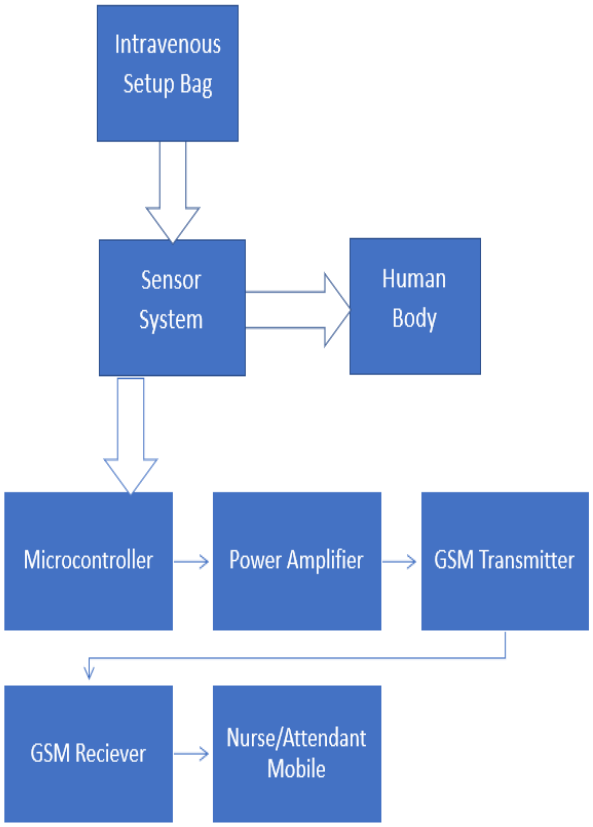

Fig. 3: Intravenous Setup

IV. CONCLUSION

In this paper, techniques to develop a system to measure and monitor the blood flow have been studied. Many systems were analyzed to measure the flow velocity of blood and the volume of blood. The technique for blood flow measurement developed with the help of optical fiber sensors required more research to determine the sensors behavior under physiological conditions. The other method to measure the blood flow was used a laser blood flowmeter. This method was complex as it required the integration of the products of the signal power from the laser and their frequency. Another technique was used to design an intravenous system. It was found that the performance of the system was much superior as compared to other systems. It used WSN (Wireless Sensor Network) based liquid level and sent alert message through GSM module. The review study reveals that the blood flow measurement with the incorporation of Internet of Things (IoT) is required in the field of biomedical electronics. will have more advantages. This method will bring a drastic change and much required change in medical services.

REFERENCES

[1] Albert Ruiz-Vargas, Scott A. Morris, Richard H. Hartley and John W. Arkwright, "Optical Flow Sensor for Continuous Invasive Measurement of Blood Flow Velocity,"Journal in Biophotonics-May 2019.

[2] Shingi Mino et al., "Wearable Laser Blood Flow Meter,".

[3] Kei Kuwabara et al.,"Blood Flood Observed With Smartphone-Ultacompact Wearable Blood Flow Sensor,".

[4] Kanchi Rao, and Koluthuri Supriya, "Design and Development of Iot Based IV Infusion System,".Emerging Trends in Electrical, Communications, and Information Technologies pp 487-499.

[5] K. A. de Waal, 'The Methodology of Doppler-Derived Central Blood Flow Measurements in Newborn Infants', Int. J. Pediatr., vol. 2012, no. 3, pp. 1–13, 2012.

[6] A.K. Jayanthy, N. Sujatha and M. Ramasubba Reddy, "Measuring Blood Flow: Techniques and Application," in 2011 Volumes/Vol6Issue2/IJRRAS_6_2_12.pdf..

[7] R.Priyadharshini and S.Sandhiya, "Autonomous Patient Monitoring and Blood Flow Control Using IoT," Volume – 02, Issue – 03, March – 2017, PP – 54-63.

[8] Shyama Yadav and Preet Jain, "Real time cost effective e-saline monitoring and control system" 2016 International Conference on Control Computing, Communication and Materials.

[9] N. Kumar,"IoT Architecture and System Design for Healthcare Management," in 2017 International Conference on Smart Technologies for Smart Nation.