A Non-invasive Cloud-Based IoT System and Data Analytics Support for Women Struggling with Drug Addictions During Pregnancy

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Abstract. Drug abuse among pregnant women and the subsequent neonatal illness are very crucial clinical and social problems. Drugs misuse during pregnancy places the mother and her baby at increased risk of severe complications including deformities, low birth weight, and mental disabilities. Pregnancy can motivate a woman to enter into an addiction treatment program to protect her unborn baby from the effects of drug misuse. Despite the availability of several treatment centers, many women do not seek needed help during and after pregnancy. Some of the reasons include stigmatization, fear of their babies being taken away by Child and Family Services, and the fear of confinement to a facility. In this paper, we propose a non-invasive Cloud-based Internet-of-Things (IoT) and Data Analytics framework that will provide support for women seeking addiction treatment during pregnancy. The system will use simplified sensors incorporated into a smartwatch to monitor, collect, and process vital data from pregnant women to identify instances of emergencies. During emergencies, the system automatically contacts specific needed service(s) and sends the processed data to the cloud for storage and Data Analytics to provide deeper insight and necessary decision making. The framework ensures that pregnant women are not confined into a facility and are reachable remotely by healthcare practitioners during addiction treatment. These capabilities guarantee that the system is operational during global pandemics like COVID-19. The framework integrates every patient's data into a centralized database accessible to all healthcare practitioners thereby preventing multiple prescriptions of the same medication by different doctors.

Keywords: Drug addiction · Pregnant women · IoT · Cloud · Fog · Healthcare · WBAN

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R. Goleva et al. (Eds.): HealthyIoT 2020, LNICST 360, pp. 20–34, 2021.
https://doi.org/10.1007/978-3-030-69963-5_2

1 Introduction

The unprecedented increase in drug abuse among pregnant women in recent time and the ensuing neonatal illness are very crucial clinical and social concerns. Any pregnant woman that wants to give birth to a healthy baby devoid of medical problems must ensure that she promotes a healthy pregnancy. The possibility of having a healthy baby is drastically reduced if such a woman uses illegal drugs and does not seek addiction treatment during pregnancy. The use of drugs during pregnancy can lead to fetal growth limitations such as diminished body mass and other medical difficulties including preterm birth and infectious diseases. Poole [11] reported that when the fetus is exposed to alcohol, it can lead to varieties of undesirable consequences collectively known as fetal alcohol spectrum disorder, including fetal alcohol syndrome (FAS). The same report stated that FAS occurs at a rate of one to two cases per 1,000 live births in Canada. Some of the manifestations of FAS in births include facial abnormalities, growth deficiencies and damage to the central nervous system. When pregnant women use cocaine, it can lead to narrowing of blood vessels in the uterus and placenta, with the eventual result of malnourished fetal growth [5]. Children given birth to by mothers having issues with addictions suffer from postnatal issues including poor parenting, neglect, abuse, mental illness, and in some cases death. Therefore, there is a need to effectively address these complex prenatal and postnatal problems so as to provide help needed by pregnant women struggling with addictions and their unborn babies.

The importance of addiction treatments for women struggling with drug misuse during pregnancy cannot be overemphasized. Finnegan *et al.* [5], observed that when pregnant women struggling with drug addictions are supported with treatments, they are more likely to give birth to children with lesser birth defects. Over the years, several addiction centers have been set up by both private and public initiatives so as to support individuals struggling with different categories of substance misuse. Pregnancy period has been deemed as a time of increased motivation for women to enter into an addiction treatment program so as to protect their unborn babies from the effects of drug misuse. Despite the availability of these treatment centers, many of these women do not seek needed help during and after pregnancy. Some of the reasons given by such women include stigmatization as a result of their addictive behaviors, fear of their babies being taken away by Child and Family Services (CFS), the fear of being confined to a facility during addiction treatments, lack of access to specific treatment programs for addiction during pregnancy, and lack of support from partners or family members. Finnegan [3] reiterated that the fear of stigmatization makes women reluctant in seeking help with their addictions and when they do, they meet with obstacles that make it difficult for them to obtain needed medical and obstetrical services. Such obstacles include misinformation, denials, and unresponsiveness of the health service providers. In recent time, with the onset of the COVID-19 pandemic, continuous access of pregnant women seeking addiction treatment to healthcare services has been greatly impacted. The concepts

of social distancing and working from home have further contributed to lack of access to such services.

2 Problem Statement - Pregnant Women and Drug Addiction

Close to 3% of the 4.1 million women in the United States that are within the childbearing age but abuse drugs are believed to keep on using drugs even when pregnant [8]. The United States' 2010 National Survey on Drug Use and Health (NSDUH) stated that 4.4% of pregnant women between the age of 15–44 years reported illicit drug use [12]. According to the 2006–2007 Maternity Experience Survey done in Canada, 10.5% of women smoked cigarettes daily or occasionally during the last three months of pregnancy, 10.5% drank alcohol during their pregnancy, and 1% used street drugs while pregnant [11]. In [10], Reproductive Health Working Group in Alberta reported that 2.3% of women who gave birth to live infants in 2006 used illicit drugs during pregnancy. On the national level, [16] stated that the 2008 Canadian Perinatal Health Report shows that 11% of pregnant women consumed alcohol while 5% of women used illegal drugs during pregnancy. Another report by [7] revealed that in the previous year, among Canadian women of childbearing age, 76.7% consumed alcohol, about 11% used cannabis, and 2.1% used illicit drugs including cocaine, ecstasy, speed, hallucinogens and heroin during pregnancy.

The effect of drug misuse during pregnancy both on the mother and the unborn baby cannot be overemphasized. Center for Behavioral Health Statistics and Quality [26] reported that about 7 million people in 2015 suffer from illegal drug use disorder while about one to four deaths were attributed to drug misuse, tobacco and alcohol. But it was estimated by the same report that only about 14% of adults with illegal drug use disorder actually received treatments within the year. The author in [3] stated that when pregnant women engage in drug misuse, it places the mother at increased risk of several childbirth complications including early pregnancy loss, premature detachment of the placenta from the wall of the uterus, placental insufficiency, sudden rise in blood pressure, convulsions or coma, premature labor, premature rupture of membranes, and postpartum hemorrhage. Apart from the effect of drug addiction on the mother and child, Florence *et al.* [27] stated that misuse of prescription opioid costs the U.S. economy more than 78.5 billion every year.

2.1 Notable Signs of Drug Misuse in Pregnant Women

Pregnant women and other people struggling with illicit drug addictions irrespective of the type of the drug can be distinguished using some pathological set of behaviors that associate with the misuse of any illegal drug. American Addiction Centers [24], grouped these behaviors into four main categories including impaired control, social impairment, risky use and pharmacological indicators (tolerance and withdrawal). **Impaired control** of substance includes evidence

of someone using a larger amount of a substance than intended, using it for an extended period than intended, and uncontrolled cravings for the substance such that the user is unable to function or think of anything else. **Social impairment** is characterized by sets of harmful behaviors exhibited as a result of repeated use of a substance. Evidence of this includes people continuously using substances even when the usage has caused them their jobs, families, friendships and other social responsibilities. Such a one might also give up or reduce important recreational activities like playing sports with friends. **Risky use** of substances is manifested when substance users continued with the usage of drugs despite the harm they experienced. Such a one continued to use the substance despite they are in physically hazardous scenarios like driving a car, continuous smoking of cigarettes even though the abuser is experiencing respiratory problems and continuous drinking of alcohol even when a pregnant woman knows that it is dangerous for the fetus. The last notable sign of drug misuse in people including pregnant women is categorized as **pharmacological indicators**. This has to do with the level of adjustment that the body makes so as to tolerate frequent misuse of drugs. When someone has developed tolerance for a drug, the body will respond to a drastic stoppage of the drug by exhibiting withdrawal symptoms. These symptoms could be very fatal and as such, pregnant women attempting to stop the misuse of illicit drugs need medical support and other related support systems so as not to endanger the health of the fetus.

As reported by [24], for example, withdrawal from cocaine misuse is normally demonstrated in three major phases including initial crash, acute withdrawal and extinction period. The initial crash period is characterized by extended sleeping, increase in appetite and the feeling of depression or agitation of the individual with the cocaine addiction. The acute withdrawal period is characterized by periods of sleeplessness, anxiety, fatigue and irritability. While the extinction period climaxed with the thought of suicide and intense cravings for cocaine which might continue for several months even after the stoppage of cocaine. As further explained in the same report, withdrawal from alcohol has varieties of side effects including seizures, fever, severe confusion, hallucinations, agitation, fatigue, muscle aches, loss of appetite, dizziness and sleeplessness to mention a few. Finnegan *et al.* [4] reported that medical issues perceived in babies delivered by heroin-addicted mothers are functions of the quantity of prenatal care received by the mother as well as the level of exposure of the fetus to drugs from the mother during pregnancy. The authors stated that when a pregnant woman is exposed to multiple drugs, it can lead to overdose and complicated withdrawal symptoms that can endanger the health of the woman as well as the fetus. Therefore, it is important that pregnant women exhibiting these symptoms are provided with immediate medical attention and other necessary support to prevent further fatalities.

2.2 Classifying Addictions in Pregnant Women and Identifying Level of Prenatal and Postnatal Support Needed

Addictions in pregnant women or in any other people can be classified into three different levels based on the ability to carry on with day-to-day activities. These include functional, semi-functional and non-functional addictions. We use this simplified taxonomy with the intent of describing the functional level of the addicted pregnant women with respect to their ability to go about their daily activities. This will help us to determine the level of support needed as they undergo addiction treatment during and after pregnancy. These classifications closely agree with the taxonomy presented in [15] where substance use disorder was described using three sub-classifications including mild addiction, moderate addiction and severe addiction.

The pregnant women that fall within the category of **functional** (mild) addiction are those that though they use illicit drugs and may sometimes experience overdose, but they are able to carry on with their day-to-day activities including maintaining a job or profession, maintaining a shelter, attending medical related appointments and are able to control their behaviors during drug misuse. At the other end of the addiction spectrum is the **non-functional** (severe) addicted pregnant woman. These women lose total control of themselves when using illicit drugs and as such they are not able to maintain a job, accommodation or provide the basic necessity of life to keep themselves and their unborn babies healthy during and after pregnancy. These categories of women are the most vulnerable as they have the tendency to exhibit all the negative effects of drug addiction both in the pregnant mother and their babies. They are mostly homeless, malnourished and needing intensive medical attention during and after pregnancy. At the center of the addiction spectrum is yet another level of addiction which we refer to as **semi-functional** (moderate) addiction. The women in this class of addiction are able to carry out some basic activities of life but with close supervision or support from other people. These women might be in and out of jobs frequently as a result of their addictive tendencies, they could also be homeless most times or needing help to live with friends and family members. They cannot be relied on to keep medical appointments or to maintain a daily schedule that will be advantageous to their health and that of their unborn babies.

2.3 Supporting Addicted Pregnant Women - Issues and Challenges

Misuse of illegal drugs in pregnant women can be very challenging to treat by the current healthcare system. The fact that there are different levels of drug addictions in pregnant women suggests that they will require different levels of support system. Therefore, there is a need to develop a holistic treatment approach and integrated support services that consider the level of support needed by the addicted mother during treatment without adverse effect on both mother and child. Finnegan [3] confirmed that the pregnancy is a period of increased motivation for women to enter into an addiction treatment program. Despite this, many pregnant women do not enter into addiction recovery programs during pregnancy.

Some of the reasons emanate from the discrimination and stigmatization experienced by pregnant women as a result of their addictive behaviors. This can create a huge barrier to engaging in prenatal care and drug misuse treatment programs. Some other reasons why pregnant women do not seek addiction treatment during pregnancy include illiteracy, fear of their babies being taken away by Child and Family Services (CFS), the fear of being confined to a facility during addiction treatments, lack of information about and access to specific treatment programs for addiction during pregnancy, and lack of support from their partners or family members.

3 Method of Solution - IoT Support for Drug Addicted Pregnant Women

The goal of this research is to use a lightweight IoT (Internet of Things)-based wearable device (smartwatch) to support pregnant women struggling with drug addiction with the intent of providing them with access to real-time medical support especially during emergencies and global pandemics like COVID-19. The wearable device, with the aid of the inbuilt sensors will be used to monitor and collect vital data such as blood pressure, heartbeat rate, movement pattern, and body temperature from the pregnant women. The data collected could be immediately processed using the mobile phone of the pregnant woman or could be processed using an edge/fog computing device. The basic data analytics can be performed at this level to determine if the user is in need of urgent medical assistance. When there is an emergency, the mobile phone or edge device will alert the necessary emergency service(s) automatically so as to immediately attend to the need of the pregnant woman. The major advantage of this approach is that the technology will allow pregnant women struggling with addiction to go through a rehabilitation process without being confined to a controlled facility. In addition, location data collected through the sensors embedded into the smartwatch of a pregnant woman can be used to enhance an automated contact tracing system for anyone that has been in close contact with any pregnant women showing symptoms of COVID-19. In the rest of this paper, we will present the details of the different technologies and techniques of our proposed approach, the challenges of using this approach to support pregnant women struggling with addictions and how to overcome these challenges.

3.1 IoT in Health-Care

Fan *et al.* [20] described the Internet of Things (IoT) as a network consisting of several devices interacting together in a machine to machine communications with the aim of collection and exchange of data. IoT and the development of other wireless technologies like Wireless Body Area Network (WBAN), have been earmarked as potential solutions for enabling patient's health monitoring applications that can be streamlined in real-time to health practitioners, especially during emergency [19]. WBAN is the intercommunication of several wearable or

implanted mobile sensors with the aim of collecting vital data from the body to a home base station where it can be processed and sent to a health center for needed care [16]. Certain human body parameters including movement pattern, heart rate, blood pressure, body temperature and respiration rate can be measured by sensors and portable devices without human intervention [14].

With the increasing support and integration of IoT in healthcare services and applications, handling the massive healthcare data that need to be stored, secured, managed and exchanged between devices, and accessed ubiquitously can be very challenging. A potential solution to overcoming these challenges is the use of Cloud computing. Cloud computing in recent times has become a de facto standard for providing on-demand computing resources because of its mobility, scalability and security. Cloud computing can be used as a backbone network to provide storage and network services to support IoT healthcare systems [22]. Recently, there is an increasing change in computing paradigm from centralized (Cloud) computing to decentralized (Fog/Edge) computing [23]. The concept of Fog or Edge computing was first introduced by CISCO as they attempt to provide a network solution that extends the computing power and storage capability of the Cloud closer to the edge of the WBAN [21]. Fog computing brings the Cloud closer to the network users, thereby enabling the collection, storage and local processing of data. The advantages of Fog computing include real-time processing, reduced network latency, improved data privacy and reduced cost of implementation [14].

3.2 Related Work

In this section, we present a review of some research that has been done that has close connection with our proposed system. The intent of this review is to analyze what has been done with respect to IoT for healthcare delivery, so as to identify why the current systems are not suitable to provide technological-based support for pregnant women struggling with drug addiction. Baker *et al.* [1], described generally the basic elements of an IoT in the healthcare system. The authors introduce a framework that can be used in various IoT for healthcare applications without particular reference to how to apply it in supporting pregnant women with drug addiction. Farahani *et al.* [2], introduced a systematic IoT e-health ecosystem made up of hardware and software devices without a specific implementation of such IoT models. Kumari *et al.* [9] presented a three-layer healthcare architecture for real-time applications that includes a fog computing layer. The authors further addressed the opportunities and challenges of implementing such IoT-enabled architecture for health service delivery. In [13], the authors presented an IoT system that can collect data about patient health status through multiple sensors and the data collected can be conveyed to a remote server for real-time analysis. [6] proposed a fog computing-based framework which was applied on a prototype so as to accelerate the response to mobile patients.

Dang *et al.* [14] described a system where a network of connected sensors record a patient's vitals and the data is continuously sent to a broker. The broker in turn analyzes and stores processed data on the cloud. The system allows a subscriber to directly monitor patients from any location and to respond immediately to emergencies. The system was not investigated for supporting sensitive applications like the monitoring of pregnant women with addiction problems in which the patients cannot be attached with sensors that can easily be detached from the body during a medical crisis. There is a need to investigate a framework that uses sensors that are embedded within mobile devices that are normally worn by users (e.g. smartwatch) and not an extra attachment or carry on for the user. Pasluosta *et al.* [17] investigated an IoT technology for monitoring patients suffering from Parkinson's Disease. The author concluded that wearable sensors for observing gait patterns, tremors, and general activity levels could be used in combination with vision-based technologies (i.e. cameras) around the home to monitor progression of Parkinson's Disease. This work only investigated IoT for Parkinson's Disease and there is no significant correlation with application that involved monitoring addiction in pregnant women. In [25], an ECG sensor was used to measure heart activity of patients using a microcontroller. Though the authors suggested that such a system could be used to predict incidents of heart attack, the bulkiness of the system makes it unsuitable for use in monitoring addicted pregnant women.

4 Cloud-Based IoT Support for Drug Addicted Pregnant Women

Healthcare support and monitoring system that confines the user to a restricted facility is not desirable for supporting the different categories of addicted pregnant women requiring different levels of support. The functional addicted women are able to go about their daily activities despite their momentary addiction tendencies and as such should not be confined to a facility for addiction treatment. In addition, IoT systems that use sensors implemented on a circuit board that needs to be attached to the body or sensors that need to be attached to different parts of the body are also not desirable for supporting addicted pregnant women. This is because, the sensors will constitute as extra weight or object that the pregnant women might find inconvenient to carry around. When a pregnant woman is also going through a crisis due to addiction, the attached sensors could be easily stripped off by the pregnant women, leading to monitoring failure.

In order to solve the problems associated with monitoring addicted pregnant women, we propose an IoT-enabled healthcare support system that uses a smartwatch that is normally worn by the user. The smartwatch is embedded with essential sensors that are needed to monitor the behavior of the pregnant woman during drug overdose or when exhibiting withdrawal symptoms. This approach will provide the pregnant women with a non-intrusive and portable monitoring system that allows the users to go about their day-to-day activities while receiving addiction treatment. Another advantage is that the pregnant women will

find addiction treatment services more accessible and attractive since they are not confined to a place or required to carry around a heavy monitoring device. Likewise, the approach disallows the embedding of monitoring sensors under the skin of pregnant women. To the best of our knowledge, this will be the first time that a non-invasive Cloud-based IoT healthcare service delivery is being considered for supporting pregnant women struggling with drug misuse.

The architecture of our proposed IoT-enabled healthcare system is presented in Fig. 1. The body sensors embedded within the smartwatch constantly monitor and collect pregnant women health parameters including movement pattern, body temperature, blood pressure and heart rate. The data collected are sent to the user's mobile phone where it is temporarily stored and analyzed before it is sent to the cloud for permanent storage and further processing. If a health concern or emergency incident is detected when the data is processed within the mobile phone, the mobile phone will automatically alert the respective health service provider needed to support the pregnant woman at that instance. Alternatively, instead of using the mobile phone for processing, the collected data can be sent by the mobile phone to an edge or fog computing device where it can be analyzed to provide real-time support for the user. As a result of this design, the health caregivers are able to monitor pregnant women remotely and are able to respond in a timely manner to crisis and emergencies due to drug misuse.

5 The Architecture of IoT Support for Drug Addicted Pregnant Women

The architecture presented in Fig. 1 is a four-layer architecture consisting of the sensor/WBAN layer, the personal server/fog computing layer, the cloud computing layer and the medical service layer.

5.1 Sensor or WBAN Layer

The Sensor or WBAN layer is where health-related data are collected from the body of the users with the aid of sensors embedded within the smartwatch worn by the users. [1,18] identify some portable sensors that can be used for collecting data from users in a WBAN. Some of the sensors that we consider relevant to collecting data related to drug addiction behavior in pregnant women include the Accelerometer for measuring body movement so as to track users steps and sleeping patterns, Heart Rate monitor, EMG (electromyography) sensor for monitoring muscle activity, Oximetry sensor for measuring blood oxygen which is the key to reporting accurate pulse rates, skin conductance sensor for measuring the galvanic skin response or how much a user sweats, Blood Pressure sensor, skin temperature sensor for monitoring user's body temperature and GPS to identify user's current location.

5.2 Personal Server/Fog Computing Layer

The Personal Server or Fog Computing layer is the link between the Sensor layer, the Medical Service layer and the Cloud Computing layer. The health-related data collected by the sensors are sent using the short-range Zigbee or Bluetooth wireless technologies to the pregnant women smartphone which will serve as the gateway. An example of such a gateway is the Android gateway [34] which enables local storage and pre-processing of data collected from the WBAN sensors. This layer can be implemented using a cell phone or using an edge/fog network device. The services performed at this layer includes initialization, configuration, and synchronization of the sensors. Sensors readings are also collected at this layer for immediate processing and integration of data so as to provide real-time insight and decision making about the state of the user. The pregnant women could also be provided with audio and graphical interface to disseminating alert messages or needed guidance during medical crises. When the user is experiencing medical emergencies as indicated by the analyzed data, the Personal Server layer will establish a secured long-range Internet communication with the Medical Service layer and alert the respective remote healthcare service provider.

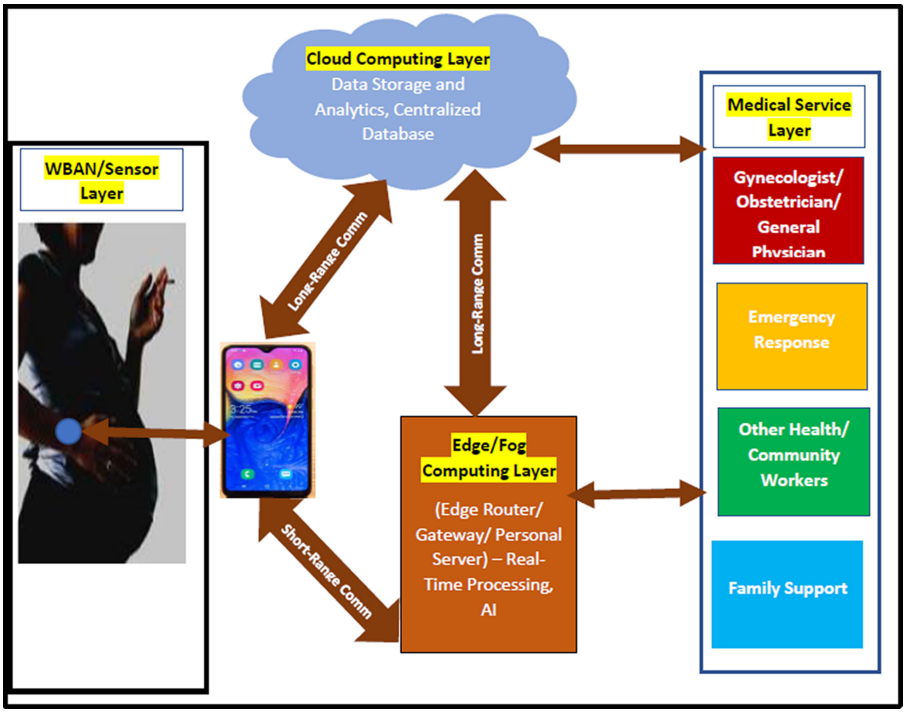

Fig. 1. Cloud-based IoT support for drug addicted pregnant women

5.3 Medical Service Layer

The Medical Service layer is made up of all the medical, family and community support services that are needed by pregnant women struggling with addiction. The layer allows real-time monitoring of the patient by service providers including Gynecologist, Obstetrician, General Physician, Emergency Response team, Health/Community Workers, families and friends. These groups of stakeholders are automatically contacted or alerted when there are cases of emergencies relating to the pregnant women (patient). Depending on the type of emergencies, the Personal Server layer will provide a detailed account of the situation of the patient, the current location of the patient and the level of support needed by the patient. In addition, the healthcare service providers will have access to a cloud-enabled centralized Medical Database that provides historical data and results of analysis of both current and previous data collected by the IoT system. The IoT system grants access to the centralized database depending on the level of services that are provided by a service provider. The advantages of the centralized Medical Database include providing real-time access to vital medical information about patients, providing deeper insights and decision making functionality based on the results of the Big Data analytics done in the cloud system, and preventing double-doctoring which can lead to multiple prescriptions of the same medication. Double-doctoring is a situation that can arise when there is no centralized medical database in which a doctor can prescribe a medication without reference to a previous prescription made by another doctor of the same medication. Also, the personal data collected through the sensors at the fog layer would be useful for medical personnels in providing swift medical support for COVID-19 infected pregnant women with underlying medical conditions.

5.4 Cloud Computing Layer

The physiological data collected overtime at the Personal Server layer can become so massive that it requires a larger, permanent and secured storage system. In addition, such Big Data requires a storage system where extensive processing and data analytics can be carried out so as to derive deeper insights into the patient's condition with the aim of proving decision making support for the medical practitioners. Therefore, the Cloud Computing layer serves as the center where the massive physiological data are aggregated, stored, processed and analyzed to provide support to healthcare service providers. The cloud system also hosts a centralized Medical Database where both historical and current medical data are stored for centralized access by medical practitioners and other healthcare stakeholders. As more and more data are being added from the Personal Server layer, machine learning algorithms could be engaged to allow the system to learn from the past and current data to make predictions and provide vital information about the patient's symptoms and possible diagnosis. Machine learning allows the identification of trends in medical physiological data that were formerly unidentified so as to provide specific diagnosis, treatment plans and decision support for healthcare service providers. The patients could also

be alerted as a result of the outcome of the data analytics and machine learning algorithms implemented in the cloud. For instance, if the data collected suggests that a patient is becoming restless and agitated, the system could send an alert to the patient and instruct the patient on what can be done to calm down.

6 Big Data Problem in IoT Health Applications - A Case of Drug Addicted Women

The advent of IoT in health applications such as neonatal care and ambient assisted living [28], wellness recommendation [29], ECG health monitoring systems [30], and prognosis [31] accentuates the generation and collection of high volumes, high velocity, wide varieties, and valuable data with various degrees of veracity-popularly referred to as 5Vs of big data. Our proposed IoT and Data Analytics system for drug addicted women is made up of several sensors collecting vital data in different forms and format from users at real-time. The heterogeneous physiological data collected overtime from the users will gradually snowballed to a massive data. Some of the anticipated challenges of this Big Data collection from the IoT support system for the drug addicted women includes dealing with errors in the captured data, handling increase in time required for data processing and analytics, ensuring data privacy, and providing a scalable data storage system.

6.1 Data Analytics for IoT Health Support for Drug Addicted Pregnant Women

The Big Data collected from the addicted pregnant women would be a good platform for fine-grained data analytics that will provide deep insights on the pregnant women's health status. This platform can also provide intelligent recommendations for the physicians, emergency support unit, and other healthcare service providers. Therefore, the Data Analytics component of our proposed system will employ several data munging techniques such as feature extraction and dimensionality reduction to optimize the data and ensure that noise and redundancy are eliminated from the data. In addition, we will employ machine learning algorithms such as neural networks and decision trees to allow the system to learn from the past and current data for enhanced predictive analysis. This will help to provide vital information about the patient's symptoms and possible diagnosis. Besides, data mining techniques such as association rules would be employed to identify trends in medical physiological data that were formerly unidentified so as to provide specific diagnosis, treatment plans and decision support for healthcare service providers. We will ensure that a lightweight predictive algorithm is deployed at the Fog layer of our proposed IoT system so as to provide immediate and on-demand healthcare services to the users. Furthermore, our proposed system will profit from the implementation of Big Data processing frameworks including Apache Spark [32] and Kafka [33] so as to speed up the data analytics process and provide a platform for enhanced scalability as the size of the healthcare related data increases.

7 Conclusion and Future Research Direction

In this paper, we presented a non-invasive cloud-based IoT healthcare infrastructure for supporting pregnant women seeking treatments from drug misuse during pregnancy and public emergencies like COVID-19. We discovered that the current IoT systems that use bulky devices or devices inserted under the skin to monitor patients' vitals are not desirable in this application. The novelty of our proposed system stems from its ability to allow pregnant women seeking addiction treatment to continue with their normal daily activities while receiving intensive healthcare support without being confined to a facility. The system also profits from real-time local data analysis at the fog layer as well as the extensive data analysis at the cloud layer. The local data analysis provides immediate services to the pregnant women while the extensive cloud-based data analysis provides long term support for the pregnant women as well as the supporting health service providers. A detailed description of our Data Analytics approach will be presented in a future paper. In our future work, we plan to implement the IoT-based healthcare system with the aim of evaluating its efficiency and effectiveness in supporting the intended users. We will also consider relevant security and safety issues that have to do with the usage of the proposed system especially during global pandemics like COVID-19

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