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Recent Clinical Survey and Gaps Analysis in Persuasive Ante-natal Healthcare System: A New use-case for Non-Invasive Edge Wearable Robots

[1]A. A Obayi, [2]F. S. Bakpo [3]Okafor Ijeoma Peace, [4]K. C. Okafor
[1]&[2]Department of Computer Science, University of Nigeria Nsukka, Enugu Nigeria
[3]Department of Applied Public Health, Cardiff Metropolitan University, Llandaff Campus, Western Avenue, Cardiff, CF5 2YB.
[4]Department of Engineering, Manchester Metropolitan University, Manchester M1 5GD, UK.
[1]adaora.obayi@unn.edu.ng, [2]francis.bakpo@unn.edu.ng [3]ijpeacx@gamil, [4]k.okafor@mmu.ac.uk

Abstract— Within the African continent, the antenatal health system for both rural and urban dwellers is beclouded by the high rate of maternal deaths because of poor health practices. Existing approaches to pre-natal health systems are defective. The unavailability of grassroots health personnel, the stress associated with visiting health facilities, and the poor ratio of health workers to pregnant women in most tertiary health centres pose new challenges. This article carried out a clinical survey on persuasive computing initiatives for Anti-natal health care service delivery. Three categories of respondents are used including 100 pregnant women, 50 medical personnel from Federal Medical Centre Owerri, Bishop Shanaham hospital Nsukka, and the University of Nigeria Nsukka health center: 50 ICT experts from IEEE Nigeria Section, and ICT Innovation center, (UNN). Survey instruments are validated by computing the Kaiser-Meyer-Olkin adequacy, Cronbach’s alpha, and the Bartlett Test of Sphericity for statistical significance. Parametric statistical tests are employed to evaluate the data collected. *t*-test, Pearson's correlation coefficient, and ANOVA are used for the ANC assessment. For the health practitioners, and IT experts, items on issues relating to the smart device, operational enhancement for health care personnel, cloud communication feedback, data storage, patient data on the provider's shared cloud environment, business continuity, regulatory compliance, backup, recovery, privileged user access and user trust in cloud computing are investigated. For pregnant women, persuasive technology (PT) usability, and accessibility are significant. The findings revealed internal consistency in the usefulness of PT in prenatal care health care services leading to non-invasive wearable robot infrastructure.

Keywords—Persuasive Cloud Computing, Fog Computing, Antenatal Care, Cyber-physical systems, Internet of Things.

I. INTRODUCTION

The term “antenatal care (ANC)” generally refers to a preventive healthcare concept whose aim is to provide routine/regular check-ups that engage health practitioners (medical doctors, nurses, midwives) to monitor, and administer treatment accordingly. The idea is to prevent associated health issues during pregnancy while providing guidance on appropriate health lifestyles deemed beneficial to mother and child [1]. The World Health Organization (WHO), 2015 reported that close to 830 women die daily owing to pregnancy and childbirth, especially in sub-Saharan Africa (compared with other regions of the world [2]. According to WHO, in Nigeria alone, the maternal mortality rate is 814 per 100000 live births [3].

Generally, pregnant women during routine check-ups are provided with detailed information regarding their physiological status, biological variations, and pre-natal nutrition. The provision of regular prenatal care such as antenatal screening/diagnosis remains significant in reducing maternal and child mortality, neonatal infections, and other preventable issues associated with childbirth. Focused antenatal care is the personalized care given to a pregnant woman which emphasizes the women’s overall health status, her preparation for childbirth, and complications.

Maternal mortality is a health indicator that reveals very wide gaps between rich and poor, in urban, and rural areas, within a country. It is known that the major causes of death are hemorrhage, hypertension, infections, and other indirect causes resulting from, pre-existing medical conditions vis-à-vis the pregnancy. The report further highlights that a woman in a developing country dying from maternal-related causes in course of a lifetime is 33 times compared to her counterpart in a developed country. Consequently, WHO suggested four major antenatal visits to identify/treat issues and give immunizations as appropriate to improve maternal health conditions and reduce maternal death rates [4].

Sadly, many women hardly visit hospitals/health centers as appropriate. In the Nigerian context, there are so many challenges. First, at the grassroots level, there is usually unavailability of grassroots health personnel. Even when there is health personnel, the ratio of pregnant patients to the number of health workers is very small. As a result, too much stress is incurred in trying to see health personnel as pregnant women. This eventually leads to an increase in maternal mortality.

Contemporarily, there are various approaches used to modify pre-natal health schemes. These are used to assist women who wish to benefit from prenatal care, viz [4]: policies, education for health workers, and health service re-orientation. Community arbitration has been proposed to alter women’s behavior concerning pre-natal health.
For instance, the use of media campaigns reaches many people, facilitating communities' responsibility for pre-natal

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health consciousness; informative-education-communication interventions, and financial incentives. These interventions when properly harnessed could increase the number of women accessing prenatal care thereby reducing the death of children. Again, for pregnant women that have access to ANC, the initial visit to a health facility allows them to be enlisted as either normal risk or high risk. A detailed highlight of the pregnant woman's background information on their pregnancy is given such as health history, ANC-growth profile, and ultra-scan results. During the prenatal screening, disease conditions are checked as well as the conditions of the fetus/embryo during the early trimester periods by Obstetricians and midwives. In this case, they examine monitoring the pregnant patient's health and fetal growth at the time of pregnancy via regular checks. Essentially, most first-hand evaluations carried out on the pregnant woman include:

- ANC collection of medical history
- ANC blood pressure verification
- ANC default height and weight-balance check (for the pregnant woman)
- ANC current Pelvic evaluation
- ANC evaluation of fetal heart rate
- ANC urine/blood evaluations (blood group and genotype, PCV, VDRL, and virology; RVs, HCV, HBV)

ANC relationship-update leveraging health experts/caregivers.

Besides the approaches highlighted, there are existing models for antenatal care systems starting from the early 1900s to date [5] within the scientific community. Such approaches include parameter standardization [6], iASHA system [7], e-antenatal assistance [8], random forest (RF) [9], Machine Learning [10], PULSS [11], prenatal care kit [12], RMS-MCT [13], Naïve Bayes classifier [14], and Smart care [15].

A. Research Motivation

Despite the highlighted efforts, very little research has been carried out. Existing reports have not presented the most efficient way of giving antenatal care while noting the cost implication in Nigeria for women in rural areas. There is a need for an influential solution that will enhance the ANC system in Nigeria. One approach is to leverage persuasive technology PT [16]. This is a robust cross-disciplinary research domain that emphasizes perspectives on design, build-up, and analysis of disruptive technological devices having the objective of influencing and modifying users' attitudes using persuasion and domain influence without compellation or deceit. Persuasive technology (PT) involving Cloud-Fog orchestration for the ANC system is a solution that will completely change the face of the Nigerian antenatal health system for both rural and urban dwellers. This is derived from the fact/observation that most pregnant women hardly visit healthcare facilities, and, in most cases, there are very few available healthcare practitioners to dispatch compensatory healthcare services. As a result, maternal deaths remain high. Accordingly, WHO- Global Health Observatory (GHO) data [2] highlighted that the maternal mortality trends from 1990- to 2017 are very alarming. One of the sustainable development goals adopted by world leaders in 2015 is to reduce the maternal mortality ratio to less than 70 per 100000 live births by 2030, the need for this arose from the fact that, between 1990 and 2015, the global MMR decreased by 44% from 385 to 216 maternal deaths per 100000 live births. Despite this progress, the world still fell short of the Millennium Development Goal (MDG) projection of reducing the maternal mortality ratio by 75%, *(www.mhtf.org)*.

Some of the problems encountered include:

i. The negative attitude of pregnant women to prenatal healthcare.
ii. Long waiting time for prenatal appointments.
iii. Nonavailability of maternal healthcare providers especially in the rural areas
iv. Accessibility issues like long distances to healthcare centers and transportation problems.
v. Poor feedback due to uncomfortable relationships between pregnant women and healthcare providers.
vi. Lack of concentration, attention, and fatigue on the part of the caregivers due to many antenatal patients.
vii. The inability of the caregivers due to lack of essential equipment to discover/ identify risk factors that can affect the normal evolution of pregnancy.
viii. Lack of public awareness of the importance of prenatal care.
ix. Lack of competence/ adequate skills on the part of the caregivers.

The cultural norm is that women should be permitted by their husbands to attend antenatal clinics.

Using PT is the only most effective approach to address these problems. With the knowledge that PT, this study will no doubt be useful to pregnant women, health practitioners, and technology experts. This is because this study explores the present ANC situation in the pandemic context and offers a more reliable solution for adoption. The major emphasis is on its enormous benefits.

For pregnant women, the work will improve their maternal healthcare processes with persuasive sensing, monitoring, and analytics from expert health professionals. It also allows for remote access to cloud-based diagnostic domains thereby reducing stress. For health practitioners, it improves their productivity and service delivery to ANC patients while eradicating unnecessary delays in health facilities. For the technology experts, the work will drive ways of ensuring better QoS for patients to health practitioners' interactions. Better approaches to improving downtime will be achieved through the system. It will also ensure that the Fog-cloud integration satisfies the QoS requirements. Persuasive Technology could be largely applied in healthcare systems, sustainable systems, and additional and marketing systems [16].

This article adopted PT which comprises a high-profile marketplace robot system involving IoT-Edge, Fog, and cloud integrations.

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B. Research Objectives

This study is aimed at determining the issues relating to the design, development, and performance model for the application of persuasive prenatal health care technology (PPHCT). Specifically, the study focused on determining:

i. Ways in which smart devices would support women in their health care-center visitation challenges.
ii. Factors that will enable easy usability and accessibility of smart technology by pregnant women.
iii. Ways in which smart devices could enhance the activities of health care personnel in prenatal care services.
iv. Ways in which smart technology would be metered to ensure reliable feedback
v. Ways in which smart device services would be provided to ensure the client's ability to investigate the stored data.
vi. Ways in which smart device services would be managed to ensure a comfortable environment for cloud providers for patient data.

Practices that should be adopted to ensure proper understanding between the clients and the providers

C. Research Questions

The study will find answers to the following questions:

i. In which ways would smart devices support women in their health care center visitation challenges?
ii. What are the factors that will enable easy usability and accessibility of smart technology by pregnant women?
iii. In which ways would smart devices enhance the activities of health care personnel in prenatal care services?
iv. How would the smart technology be metered to ensure reliable feedback computing?
v. How would smart device services be provided to ensure the client's ability to access the stored data?
vi. In which ways would the smart device services be managed to ensure a comfortable environment for cloud providers for patient data?
vii. What practices should be adopted to ensure proper understanding between the clients and the providers?

II. LITERATURE REVIEW

A. Persuasive Adoption and Technology Infusion

This Section is designed to provide a comprehensive reference and suitable background knowledge on persuasive technologies, and pre-natal health care systems in Nigeria. The foundations of cloud computing, Fog/Edge-IoTs leveraging smart devices will be presented. Concept initiatives, evolutions of Persuasive Technologies, their architectural dimension, strategies, and implementations will be discussed. Analysis of existing ANC systems/frameworks and implementations will be reviewed. Furthermore, a summary of related works, comparisons, and limitations of existing works are presented while highlighting the gaps in the literature to place the work into perspective.

ANC PT could persuade, re-orientate, change or reinforce the behavior of antenatal mothers owing to its flexible nature [17]. However, this technology is still growing in number and popularity [18], [19]. Its significance is evoking new ways of adapting persuasive models to different end-users to maximize its relevance [19], [20], [21], [23]. For example, it has been applied to adaptive e-health platforms [24] and other web-related platforms. With PT, prenatal wellbeing can be improved using IoT healthcare networks [25] and social networks. The medical-care and health-related solutions have the most attractive application areas considering the Internet of Things (IoT) as a disruptive technology [26]. Hence, the emergence of IoT has evolved into various medical applications viz: heart-rate monitoring, blood pressure/temperature monitoring, elderly care systems, etc., [25]. Such systems make it possible to enforce adherence to home treatment and medication healthcare providers. In this regard, sensing technologies can be applied in medical, diagnostic, and imaging devices using IoT smart integration. Moreover, IoT-based ANC services can drastically minimize costs, enhance life quality, and always ameliorate user engagement and satisfaction. Similarly, an observed perspective of prenatal healthcare providers indicates that IoT can minimize device downtime via distributed technology interaction. Another component of a persuasive ANC health system is the Fog layer orchestration for an e-Health service [27], Distributed Cloud Computing Initiatives (DCCI) [29], and Persuasive Technologies [30]. With the Fog layer, real-time communication from an end-user to the cloud is reduced by sharing the time between real-time data processing and bulk data processing. It addresses the issue of cloud resource allocation and extends the cloud to the fog layer thereby reducing latency constraints faced by a real-time antenatal user during traffic communication. The Fog layer with its high computes virtual machines having near-zero storage capabilities allows for proximity to the end-users. Continuous mortality in the health sector implies that it could trigger international attention, and loss of support for government policies, among others. With contributions by earlier researchers in IoT, Fog, and Cloud computing, this research will explore its possibilities to address the issues of ANC in the Nigerian health sector.

B. Persuasive Technologies and Strategies

Enormous efforts have been put forward about Persuasive Technology (PT) [16] in the realm of the disruptive domain. Essentially, PT is an innovative concept in today's technologically driven world conceptualized to modify behavioral changes via adaptation of the users using zero coercion with social influence persuasion most importantly [30].

Normally, this type of technological model has been most frequently used in the health sector, management, military training, diplomacy/politics, religion, and marketing/sales. In the ANC domain, human-computer interaction can leverage PT. Essentially; most of the self-identified PT research focuses on interactive and computational technologies such as web-application interfaces, computers, IP platforms, expert systems, and edge mobile devices [31].

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Interestingly, PT builds and relies on results, concepts, and techniques of psychological experimentation as well as a human-device association [32].

The authors [33] carried out detailed research in the field of psychology using persuasive strategies and methods to modify health-related behaviors. The work conclusively argued and identified 8 major forms/types of persuasive strategies. These have been categorized into the following four models viz: Domain Instruction-Style Persuasive Strategy (DISPS), Domain Social Feedback Persuasive Strategy (DSFPS), Motivation-Driven Persuasive Strategy (MDPS), Reinforcement Driven Persuasive Strategy (RDPS).

In context, the ANC model leveraging MDPS and RDPS is the major idea of the proposed Cloud-Fog orchestration infrastructure with ANC's new intelligent design. In this regard, a new concept of ANC-Digital health coaching (provisioning) is the utilization of ANC smart sensors relaying data from patients to cloud systems. This uses MDPS and RDPS as PT to palliate the attention given to ANC patients. This can be applied in diverse medical contexts while improving the general health care practices in Nigeria. Recently, the authors in [34] demonstrated a class of widely adopted persuasive techniques in both web and mobile technologies. With the massive deployment of PT in many domains, particular attention has recently been noticed on behavior change in domains related to health. Various scientific studies [35] confirm that health behavior change arbitrations can influence the behavior of the users. Besides, the most effective arbitration could be modeled on the ANC-Digital health coach where ANC patients are persuaded using digital persuader to encourage tracking their health progress toward their delivery goals.

Furthermore, Captology (i.e, Computers as Persuasive Technology) [30] uses computer systems that are persuasive to influence an individual's behavior or disposition toward a particular activity. This has been widely applied in Virtual coaches [36] involving one-way persuasive communication to the user. This makes PT socially interactive. Some PT examples of socially interactive virtual coaches include ELIZA [37], FitTrack [38], Real Estate Agent (REA) [39], Senior Exercise Agent (SEA) [40], [41], Medication Adherence Agent (MAA) [42], DESIA [43], Wearable Relational Agent [44], Philips Home Fitness Coach [45], EyeToy [46], [47], Mobile personal trainer (MOPET) [48], MindMentor [49]. Furthermore, some Mobile persuasive applications include [50]: Zeer (Mobile ingredients lists), uBoxr (dosage-reminder), iPhone, and disease digital-record tracker.

A Mobile Health (m-Health) solution as a PT was studied [51]. Similarly, Mindless Computing as a PT was studied in [52]. The work produces the design of technologies for behavior change hinging on theories and concepts from psychology and behavioral economics. Other studies on Captology vis-a-vis PT have been studied [53], [54], [55], [56], and [57].

A summary and comprehensive comparisons of the above PT have been discussed and studied [36] focusing on conversational capabilities, target user, manifestation format, visual manifestation, conversational capabilities, social capabilities, and evaluation basis. Recent dimensions such as Cloud Computing, Fog, Edge, and IoT are yet to be fully explored in the case of ANC PT. The next Section reviews Cloud; Fog, and Edge device/systems computing as well as IoT as evolving dimensions of PT

C. Cloud Computing Efforts

In [58], Cloud computing is described as storing, processing, and transmitting information at a place/location that is not managed or owned by the information's owner. The information can be retrieved at anytime, anywhere based on demand via the internet. In this regard, overseeing the infrastructure, software and administrative tasks is done by a hosted service provider that owns and provides the services to the clients. In this case, the health provider does not have the responsibility to maintain hardware and software depending on the offering (private, public, and hybrid) and Service model [59].

As opined in [58], cloud-based technologies and smartphones, biosensors and wearables can generate patients' data. Also, data gotten from doctors' tablets, test machines, nurses' records, and MRIs can be used by healthcare personnel to improve healthcare, especially in remote patient monitoring [58]. In this regard, patient-based monitors generate and communicate a continuous data feed from the patients to the doctors and healthcare personnel. With CC, third-party institutions such as service providers will collate data from their devices and operating systems. Collation of all these data in such a way that a doctor to see all the needed information about a particular patient is no easy task but can be achieved to benefit ANC systems. Cloud computing offers a high-capacity network supporting autonomic virtualization and service-oriented computing for end devices. Multi-tenancy, performance, resource-pooling, scalability, and dynamic-on-demand provisioning of resources, security, etc makes CC very acceptable for integrating ANC health systems. Wearables with health monitoring capabilities are the most visible kits for patients [58]. For instance, sales of more than 23 million Fitbits and iWatches were recorded [60]. Many more devices could be developed with a focus on metrics like exercise, calorie loss, heart rate, sleep patterns, etc. so that the patients receiving this medical information can act on them because of their ease to understand. The authors in [61], developed a digital medical record system (CBEMRS) that is cloud-based in its functionality. The system was evaluated using sample test datasets to analyze the impact system. The work failed to account for cloud-related QoS metrics needed for data access in decision-making. The work [62] proposed Mobile JXTA with Cloud Computing. The work laid its focus on identifying process dynamics considering emergency medical contexts using integrated cloud services with P2P JXTA. Their work is concerned with helping to promote a healthy rural community leveraging the idea of cloud-community cloud for preventative-medical service delivery. The study further investigated mobile cloud-telecare involving ambulance alert alarms (AAA), patient health monitoring, and emergency care approaches. The work did not identify QoS issues for cloud-based integration. Also, data offloading with the Fog layer was not visible in the work. Similarly, the authors [63], [64], presented Mobile JXTA (Juxtapose) which deals with the transmission of messages (audio and video) through P2P service to doctors and patients. Their idea is that better interaction between the hospital, doctors, and nurses can be achieved using a disruptive mobile healthcare system. Though the system can support audio and video messages, cloud-based M-health integration processes and knowledge mining were not highlighted for QoS provisioning.

In [65], an intelligent information system (IIS-BAN-CC) leveraging Body Area Networks (BANs) and CC technologies was proposed for ANC including child healthcare. In the work, physical signs are detected using wearable sensors, data mining, and CC. They were used for medical model design and data processing. QoS provisioning considering vital network metrics was not discussed in their work. In [66], Posyandu cloud design (PCD) was proposed as a cloud-based health application. However, emphasis was on its database table design structure which can support the speed of data collaborative processes which includes collection, processing, and distribution of data and multi-tenant architectures. In [67], a cloud-based framework for customized and dynamic fetal growth curves that seeks to facilitate the isolation of pathological states/anomalies at the pregnancy timeline is presented. The work tackles the challenges of fetal biometric data for the management of clinical data obtained on a globalized network scale. QoS provisioning considering vital network metrics was not discussed. The work in [68] proposed an M-Health solution for pregnant women by providing a way of replacing the traditional and tedious ways of face-to-face interviews by collating environmental factors that endanger maternal health. Their proposed m-Mamee platform is used to monitor and assesses ANC patient-external exposure using a generic computing architecture while addressing ANC patients' daily habits with sensor-based data integration.

In [69], [70], Cloud-based Mhealth systems explicitly record vital signs based on monitoring daily activities and management of chronic health. The review work [71] highlighted the absence of robust health services for maternal/fetal health care conditions [72]. The work focused on mobile software-embedded architectures for maternal and fetal wellbeing. In [73], 74], 75], a cloud-based data-based intelligent support System with a dedicated Body Sensor Network (BSN) was employed to monitor signaled parameters for the fetus and the mother respectively. These works explored intelligent support systems for located-based monitoring of ANC patients to prevent pregnancy complications and related childhood diseases in rural/remote areas where there is absolute availability of reliable healthcare services. Authors [73] surveyed the use of healthcare services, medical history, etc., engaging in oral interviews with ANC patients. The collected data were subjected to analysis and broken into significant variables for decision support system integration. The work in [74] proposed that mHealth architecture should be used to monitor the blood pressure balance of ANC patients who are suffering from G-Diabetes. Their architecture is a generic 3-tier model comprising a patient's mobile application, a patient management system for medical experts, and a distributed agent environment. In the system, the patients input their data, and the G-Diabetes symptoms harvested are examined by healthcare experts who remotely understudy the ANC patient's samples. Similar to the research in context, the Fog-based ANC system follows this approach, but this will need the active participation of the stakeholders, especially pregnant women. Wearable sensing technologies have been employed [76], [77], [78], [79], [80], and [81] to effectively monitor the health status of pregnant women and to monitor fetal movements. Furthermore, the work [18], used multiple regression analysis to ascertain the acceptance index of cloud computing in hospitals especially for tracking and analyzing patient data needed for treatment in the most effective way.

D. Fog Computing Dimension and Theoretical Taxonomy

In this section, various efforts were considered to enhance the computational capability of cloud computing. This is a computing model which offers data, computational storage, and services in a manner that emphasizes proximity to near-edge devices (e.g, network gateways) while handling layer-3 data (network level), on users' smart devices rather than moving/transmitting data to a remote location for processing [83]. This is recently finding its application in healthcare services with the advent of IoT [85]. Some efforts include Fog [83], Edge [84], and IoT [85] computing. Let's briefly look at these concepts with the view of integrating them into the ANC proposal in this research. Owing to the numerous challenges of IoTs, this work now focused on expanding the capability of IoT at the edge layer using Fog computing as a data-off-loader/orchestrator in this work.

The author in [86] offered a more generalized definition stating that it is a distributed computing model having a widely connected array of devices (both heterogeneous and homogenous) with resources at the network edge, interacting together to harness elastic computational storage in an abstracted domain-environment even to huge proximity associated client nodes/devices [86]. In the health care domain, Fog computing offers real-time processing with event responses needed in the critical ANC sector [87]. As highlighted [88], FC is useful in cases of device-to-device communication between a huge number of devices/components for located-based data storage, data execution processes, and health record cloud-data extraction. This demand for a reliable network connection works with FC as it also takes care of issues concerning network connectivity and traffic. To widen the researcher's horizon on Fog interventions, recent works on Fog computing were studied in [90], [91], [92], [93], [94], [95], [96], [97], [98], [99],[100],[101],[102], [103], [104], [105], [106], [107] and [108]. These efforts reinforced the imperatives of persuasive technology, especially with Fog computing. This offers energy savings and enhances link utilization while eventually increasing the service quality metrics delivered to the end-users/ANC patients. Within the context of IoT/Edge services, Fog computing provides improvements to IoT/Edge services [109] as detailed in Table 1, Table 2. These efforts gave a summary of related works on Fog/ IoT Integration while

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Table 3 highlights various works, their limitations, and the proposed new contribution to the ANC system.

Table 1: Fog computing Remediation to IoT/Edge challenges [109].

S/N	IoT/Edge Challenges	Fog Orchestration Contribution
1	Latency profile Constrains	The Fog layer performs all computing operations e.g. handling data analysis, as well as latency-based (proximity-driven) user activities (This required remedy to satisfy low-latency limitations of IoT/Edge services.
2	QoS link-bandwidth Issues	FC supports layered data traffic from IoT/edge devices to the cloud. With FC, link bandwidth optimization enables data processing to be achieved based on service requirements, and computational resources on the network. Hence, minimizes the volume of data to be pushed into the cloud- thereby saving network bandwidth at large.
3	Resource-constrained Devices/ Optimization	FC is used to carrying out tasks needing enormous resources considering the resource-drained devices especially the activity could not be sent to the cloud space. The implication is that device energy consumption, processing cycles, utilization, complexity, etc are all reduced.
3	Non-Maskable Services/ Uninterrupted services	FC operates independently to maintain continuous services regardless of network connectivity irregularities to the cloud.
4	IoT Security Issues	FC provides a proxy instantiation for the devices to synchronize/update the device's software and security credentials. This is good for resource-constrained devices which have few security functions. With FC, the security status of nearby devices can be monitored.
5	Quality of Service (QoS) provisioning	FC ensures high-speed caching capability, thereby maintaining availability, stability, etc.

Table 2: Summary of Related works on Fog/ Internet Medical Things Integration [110].

Author's References	Publication Year	Type of PT contribution & limitations
Oliveira *et al.* [111]	2023	FC infrastructure/IoT/Edge device and Machine Intelligence. The proposed PArtitioning Networks for Constrained DEvices (PANCODE) was not adapted to ANC infrastructure and uses multilevel partitioning.
Wazid *et al.* [112]	2023	AI-enabled secure connectivity scheme in fog computing-based healthcare system (AISCM-FH). FC, IoT, Blockchain, and AI fusion appears complex.
X. Jia *et al.* [113]	2023	Blockchain-powered Internet of Medical Things (IoMT) infrastructure. The issue is the complexity of security algorithms.
J. I. Khan *et al* [114]	2022	Investigated IoT, AI, cloud computing, edge computing, deep learning techniques, blockchain technologies, social networks, robots, machines, privacy, and security techniques within the COVID-19 healthcare domain.
Mudawi [115]	2022	Medical IoT application
Chakraborty & Kishor [116]	2022	Internet of Medical Things (IoMT)
Ghosh *et al* [117]	2022	IoMT Based Emergency Mobile Healthcare application
Ke [118]	2022	SDN-Fog computing application
Khan *et al.* [119]	2022	Digital Twin health application
V. Gazis et al. [120]	2022	Deep Learning-Based Fog/IoT adaption in health systems
Javaid *et al.* [121]	2022	Medical wireless body sensor application in healthcare
Hayyolalam et al. [122]	2022	Edge- IoT- health application
C Mayer et al [109]	2022	Fog IoT application
Ren *et al*. [123]	2022	Blockchain SDN- Fog- IoT assisted healthcare application
Saha et al. [124]	2022	IoT Monitoring Application for COVID-19
Roy et al. [125]	2022	Software-Defined Fog-IoT application
Manocha & Bhatia. [126]	2022	IoT Monitoring Application.
Okafor et al. [83]	2017	Experimented and highlighted QoS metrics between Fog and Cloud Spine-leaf models of Edge services
Enzo *et al.* [127]	2017	Presented the Fog-of-Everything (FoE) concept, which linked FC and the Internet of Everything, while showing simulation significance.
Asghar *et al* [27]	2021	Modeled IaaS, PaaS, and SaaS for Fog environments while using CloudSim and iFogSim to enhance Cloud architecture.

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Table 3: Related works on Prenatal Health care Technologies

Authors/ References	Work Done	Limitations	Evaluation Tool used	New Contributions
			-Research questions for Patients -KS- normality test -Non-parametric statistical methods	
Lakshmi et al. [6]	Parameter standardization on prediction accuracy using Decision tree classification (DTCA) algorithms for the medical diagnosis problems	There is no system validation based on other Decision tree algorithms	DTCA	- Edge Analytics for parameter sensing at the Edge
Aparna et al [130]	Developed an automated risk assessment tool using machine learning (i.e. classification and regression trees (CART) for pregnancy care.	The Automated Pregnancy Risk Assessment Tool is localized and lacks remote Fog/Edge integration	CART/Neural Network Training based on confusion matrix (Low, medium, and high)	- Employed crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation. - designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer
Antoni [131]	Developed a Handheld-based patient identification system using RFID/IEEE 802.11b WLAN for patient's identification.	- Focused on design implementation, and evaluation without discussing its performance efficiency. - No cloud-Fog leverage for the expert system	-RFID reader hardware module, Microsoft's Windows Mobile 2003 OS, Software APIs, software wedge. -Employed Serial RS-232 digital port on the iPAQ scalable port interface.	- Employed Crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation. - designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer Tools: Riverbed, C++, IoT Boxes
			Microsoft Excel tool Achieved performance rate of 79%.	

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				-Employed SMS feedback -Employed Fog orchestration load balancer Tools: Riverbed, C++, IoT Boxes
			Questionnaire & Direct Observation Ultrasound machine with an integrated electronic medical record (EMR) and clinical DSS -Toolkit Ancillary Equipments	
Marco *et al.* [134]	Analysis of sensors for positioning, of fetal movement detection	- Limited to 6 pregnant women - Measured only fetal kicks using Porti7 Device. -- Absence of cloud integration. - Non-exploitation of Fog-based algorithms	-Used Cross-validation -BinaryMapping problem -Used F-score metric (i.e. sensitivity) from reference accelerometer	- Employed crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation. - designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer with QoS analysis Tools: Riverbed, C++, IoT Boxes
Andreas *et al* [135].	-Proposed ANN schemes for providing effective early screening for a fetal crown. This is only for 1st Trimester Noninvasive Prenatal Diagnosis	- Absence of cloud integration - Non-exploitation of Fog-based algorithms	Used ANN and computational intelligence approach for noninvasive prenatal diagnosis of chromosomal abnormalities	- Employed crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation. - designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer with QoS analysis Tools: Riverbed, C++, IoT Boxes
Mohammod *et al* [136]	-Presented a health-based Cyber-Physical-Systems for ANC tele-observation to reduce the fatal risks.	- Absence of cloud integration	Survey using Online academic databases for articles published on maternal telemonitoring	- Employed Crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation.

		- Non-exploitation of Fog-based algorithms.	systems using sensors integrated with Physical systems and information decision systems	- designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer with QoS analysis Tools: Riverbed, C++, IoT Boxes
Tadele *et al* [137]	-Selected efficient data mining algorithm for an accurate predictive model to manage fetal health movement during pregnancy. -Classify correctly fetal health state with an Up-to-date pregnancy dataset. -Proposed a model for fetal movement which improves the diagnosis quality for pregnant women suffering from decreasing fetal movement (DFM) using ensemble Methods	Limited to Survey datasets for prediction analysis. -No physical implementation of the system for nonintrusive/invasive deployment	.-Used University Dataset for fetal predictive model	- Employed crobanch Alpha tests for internet consistency. - Employed Classified survey for design formation. - designed a Non-invasive Edge device for ANC parameter aggregation - Designed Fog based network for QoS provision. - Employed support vector machine. -Employed SMS feedback -Employed Fog orchestration load balancer with QoS analysis Tools: Riverbed, C++, IoT Boxes

E. Summary of Related Works

The summary of various studies carried out on ANC systems is highlighted. The work [138] used bivariate and multivariate logistic regressions to study the use of ANC, health-institutions offerings, and post-ANC services in Nigeria. The work showed that a sizable number of pregnant scarcely participate in ANC visits. Other related works on Prenatal Health care systems haven be studied in the Decision support ANC system (iASHA) [7], Decision tree classification algorithm ANC [6] [8], ANC data mining (DM) technique-Random forest (RF) [9], Obstetric ultrasonography ANC [11], Remote monitoring ANC system [13], Naïve Bayes classifier ANC [14], Mobile phone-based ANC [139], telematics based ANC system [140], distributed database management ANC model [141], ANC Machine learning and statistical analysis [142]. The study highlights ANC designs offering practical techniques for both localized, remote-monitoring, spatial monitoring as well as decision-making measurements. While these form a significant part of the ongoing solutions, there are still limitations identified/visible in the existing models to capture and determine the correlations in routine habits, lifestyle manners, and default sources of persuasion in using the available health facilities and available experts. The need to examine/ascertain the reasons for maternal and fetal health could be found via computational intelligence. In this regard, the system seeks to address these concerns, by providing motivational and reinforced persuasion via technology. In this case, all the stakeholders including the pregnant patients can access mobile technologies for effective and efficient maternal health. Section 2.5 highlights the overall research gaps found in the literature.

F. Research Gaps in Existing Prenatal Health Proposals

Globally, the antenatal health system for both rural and urban dwellers has challenges with a high rate of maternal deaths because of poor health practices. The existing approaches to prenatal health systems are not designed to suit the peculiarity of the Nigerian environment. The identified gaps from the literature survey include:

i. The use of persuasive technology involving Cloud-Fog orchestration for the ANC system has not been exploited to address the problems facing the Nigerian ANC system.
ii. ANC model leveraging MDPS and RDPS in Cloud-Fog orchestration infrastructure to ANC's new intelligent design is novel and has not been exploited in literature.
iii. A baseline survey involving selected health workers, pregnant women, and IT professionals from respective institutions as respondents has not been explored to understand the peculiarities of the Nigerian environment.
iv. The use of computational intelligence involving parametric tests viz: t-test, ANOVA, Pearson's correlation coefficient, and Cronbach alpha tests have not been explored.

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v. The design of Cloud-Fog orchestration infrastructure for ANC systems involving embedded programming framework (EPF) with PIC-controllers, decision variable sensors, and text SMS with C++ programming scripts has not been explored. Analysis of QoS provisioning for an efficient ANC system involving PT such as web, mobile phone, etc has not been explored in the literature.

III. RESEARCH METHODOLOGY

A. Clinical Survey Approach

This research selected tertiary and primary health centers in Enugu State (Nsukka) and Imo State (Owerri) independently, both in the southeastern part of Nigeria. Questionnaires were distributed to 100 pregnant women, 50 health workers, and 50 IT professionals that served as respondents from Federal Medical Center Owerri, Bishop Shanaham hospital Nsukka, UNN health center, IEEE experts (IEEE Nigeria Section), and ICT Innovation center University of Nigeria Nsukka, Nigeria. Survey questions were used to measure respondents' perspectives based on a Likert-type scale viz: Strongly disagree, Disagree, strongly disagree, undecided Agree, strongly agree. In this case, parametric Statistic tests were employed (t-test, ANOVA, Pearson's correlation coefficient, and Cronbach alpha tests) to arrive at findings. In this regard, the ANC assessment for each of the 100 pregnant women participating in the observational survey was analyzed. This was done to optimize antenatal health (OAH) services in Nigeria. The enrolled patients were properly identified as pregnant women in various stages of their pregnancies (1st, 2nd, or 3rd trimester). This was used to represent an 'elevated risk' group. The data collated was analyzed using confirmatory statistical analysis (CSA). The survey instruments were validated by computing the Kaiser-Meyer-Olkin adequacy, Crobanche Alpha Test, and the Bartlett Test of Sphericity for statistical significance. Computational (statistical metrics) including t-test, Repeated-Measure ANOVA, and Pearson's correlation coefficient are used in the survey persuasive strategies. Various constraints like age, gender, and level of education will be used to identify any significant differences within the participant groups. A performance hardware model for ANC transactions with the cloud data center will be developed for smart remote interventions (for ANC patients). Fog cloud orchestration network algorithms will be developed and validated through a simulation study. This system seeks to improve pre-natal healthcare delivery in Nigeria.

B. Research Hypothesis

HO$_1$. There is no statistical difference between the mean responses of women who registered in the first trimester and those who registered in the second trimester on how smart devices can support women in their health care center visitation challenges (***t*-test**).

HO$_2$. There is no correlation between the responses of pregnant women on the item that says that "Antenatal health care processes in the primary/tertiary health center are too rigorous and stressful" and the one that says that "A smart or handy device for pregnant women can have the impact of improved antenatal services.
(**Pearson's correlation coefficient**).

HO$_3$. There is no statistical difference between the mean responses of men and women medical practitioners on how smart devices would enhance the activities of health care personnel in prenatal care services. (**t-test**)

HO$_4$. There is no significant difference between the mean responses of medical practitioners in three different health centers on how the smart technology would be metered to ensure reliable feedback computing (**ANOVA**).

HO$_5$. There is no statistical difference in the mean responses of medical practitioners in primary health centers and those in secondary health centers on how smart device services would be provided to ensure the client's ability to investigate the stored data (***t*-test**).

HO$_6$. There is no statistical difference in the mean responses of medical practitioners and IT experts on how the smart device services would be managed to ensure a comfortable environment for cloud providers for patient data (***t*-test**).

C. Research Question Interpretation

In this section, we present the findings associated with various research questions in the survey. In a previous work [143], Kaiser-Meyer-Olkin adequacy, Cronbach's alpha, and the Bartlett Test of Sphericity for statistical significance. Parametric statistical tests are employed to evaluate the data collected.

Research Question 1: In which ways would smart devices support women in their health care center visitation challenges? Table 4 shows the mean and standard deviation of respondents regarding this question.

Table 4: Mean and standard deviation of respondents on how Smart devices would support women in their health care center visitation.

	ITEMS	Mean	Std. Deviation	Decision
1.	I visit the health facility for an antenatal checkup on my appointment date.	4.66	0.711	AGREE
2.	I visit the health facility for an antenatal checkup only when I have issues	2.03	1.244	DISAGREE
3.	I don't visit the health facility for antenatal checkups till I am due to deliver.	1.52	0.973	DISAGREE

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4.	I used antenatal facilities in my previous pregnancies.	3.57	1.333	AGREE
5.	The efficiency of the antenatal care facility in your health care center could be rated very high.	3.79	1.076	AGREE
6.	Pregnant women spend much time waiting to receive care from health personnel.	3.75	1.285	AGREE
7.	Antenatal health care processes in the primary/tertiary health center are too rigorous and stressful.	3.46	1.417	AGREE
8.	Health care personnel (nurses & doctors) are cordial in the relationship and give proper attention to pregnant women.	4.12	0.866	AGREE
9.	Most pregnant women wish to have lesser visits to healthcare centers.	3.48	1.240	AGREE
10.	The cost of medical bills for antenatal care is high.	3.13	1.399	DISAGREE
11.	Location of residence makes some pregnant women not to be regular in visiting either tertiary or primary health centers.	3.44	1.307	DISAGREE
12.	The inability to afford medical bills makes some women not visit their health centers as regularly as supposed.	4.01	1.099	AGREE
13.	There is a need for a smart device that should be able to influence -s or make inquiries from home.	4.09	1.004	AGREE

In the context of ways in which smart devices would support women on their health care center visitation challenges, it can be observed from the table that with exception of items 2, 3, 10, and 11, pregnant women generally agreed that smart devices will help in handling the other challenges raised in this context **Research Question 2:** What are the factors that will enable easy usability and accessibility of the smart technology by pregnant women? Table 5 shows the mean and standard deviation of respondents in context.

Table 5: Mean and standard deviation of respondents on the factors that would enable easy usability and accessibility of smart technology by pregnant women.

	ITEMS	Mean	Std. Deviation	Decision
1.	A smart or handy device for pregnant women can have an impact on improved antenatal services	4.36	0.828	AGREE
2.	A smart device for pregnant women is good to be made available both at home and in hospitals.	4.28	0.798	AGREE
3.	A smart device for pregnant women should be affordable	4.41	0.723	AGREE
4.	A smart device for pregnant women should allow patients remotely have prescriptions from pregnancy health experts	3.99	1.034	AGREE
5.	A smart device for pregnant women should be portable for mobility weights	4.27	0.878	AGREE

The table above shows that all the items soliciting information in this context were agreed to be the factors that would enable easy usability and accessibility of the smart technology for pregnant women.

Research Question 3: In which ways would smart devices enhance the activities of health care personnel in prenatal care services? Table 6 shows the mean and standard deviation of respondents in context.

Table 6: Mean and standard deviation of respondents on how smart devices would enhance the activities of health care personnel in prenatal care services.

	ITEMS	Mean	Std. Deviation	Decision
1.	There should be incentives for health caregivers for using a smart devices for pregnant women.	4.47	0.706	AGREE
2.	Health caregivers are usually fewer than pregnant patients and the use of smart devices will reduce the antenatal care pressure.	4.15	1.019	AGREE
3.	The parameters of the smart device for pregnant women should be easy to interpret	4.47	0.563	AGREE

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4.	A smart device for pregnant women with a cloud computing application can solve the problem of management efficiency.	3.65	1.070	AGREE
5.	A smart device for pregnant women is a widely accepted device.	3.68	0.945	AGREE
6.	Large cloud storage/ expert system should be well-secured	4.29	0.676	AGREE
7.	A smart device for pregnant women should be accurate and widely accepted.	4.15	0.610	AGREE
8.	There is no cloud transmission interface and supports in the existing antenatal systems.	3.65	1.276	AGREE
9.	A smart device for pregnant women could have a positive impact on preventive maternal deaths	3.94	1.099	AGREE
10.	Smart devices for pregnant women and cloud computing apps are new in Nigeria	4.47	0.563	AGREE
11.	Adopting cloud-based technology will solve the challenges for patients to a reasonable level.	4.18	0.834	AGREE
12.	Existing antenatal solutions are so burdensome and less dynamic and could be enhanced by the smart device.	3.65	1.152	AGREE

From the table above, it can be observed that all the items seeking opinion on research question 3 were agreed upon by the respondents to be how smart devices would enhance the activities of health care personnel in prenatal care services.

Research question 4: How would smart technology be metered to ensure reliable feedback computing? Table 7 shows the mean and standard deviation of respondents in context. It can be observed from Table 7 that all the items soliciting opinion in this research question generally agreed to be how smart technology would be metered to ensure reliable feedback computing.

Table 7: Mean and standard deviation of respondents on how smart technology would be metered to ensure reliable feedback computing.

	Descriptive Statistics			
	ITEMS	Mean	Std. Deviation	Decision
1.	Patients need to seamlessly communicate with the cloud expert systems for query advice.	4.12	0.981	AGREE
2.	The internet cloud should always provide access to feedback.	4.36	0.784	AGREE
3.	Feedback from the smart device into the internet cloud (cloud SaaS web page) should be fast.	4.36	0.800	AGREE
4.	The previous history sent to the expert cloud should be kept safe.	4.48	0.590	AGREE

Research Question 5: How would smart device services be provided to ensure the client's ability to investigate the stored data? Table 8 shows the mean and standard deviation of respondents in context. Observation from Table 8 shows that all the items eliciting information on research question 5 all agreed to be how smart device service would be provided to ensure the client's ability to investigate the stored data.

Table 8: Mean and standard deviation of respondents on how smart device service would be provided to ensure the client's ability to investigate the stored data.

	ITEM	***Mean***	***Std. Deviation***	***Decision***
1.	End-users need to know where the cloud providers store their data.	3.79	1.254	AGREE
2.	There is a need for providers to obey local privacy (Service Level Agreements) requirements on behalf of their clients.	4.15	0.932	AGREE
3.	There is a need for providers to store their client data in design specifications that are consistent with the client's data privacy and security requirements.	4.36	0.614	AGREE

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4.	Clients need to be able to investigate their trimester data stored in the cloud.	4.05	0.925	AGREE
5.	In case a client can't investigate his stored data, the provider should do so but without any malicious operation on the data.	4.13	0.997	AGREE

Research Question 6: In which ways would smart device services be managed to ensure a comfortable environment for cloud providers for patient data? With regards to research question 6, Table 9 shows that all the items raised were agreed to be ways in which Smart device service would be managed to ensure the comfortable environment of cloud providers for patient data.

Table 9: Mean and standard deviation of respondents on how smart device service would be managed to ensure the comfortable environment of cloud providers for patient data.

	Items	Mean	Std. Deviation	Decision
1.	Patients will not be comfortable having their data stored in a shared environment on the cloud.	3.88	1.017	AGREE
2.	Patients' data can be protected by the providers in the shared environment using encryption.	4.12	0.793	AGREE
3.	Encryption would solve data-shared environmental problems.	4.16	0.911	AGREE
4.	The providers must be available at an acceptable rate.	4.40	0.621	AGREE
5.	The providers should be able to devise a mechanism to ensure the availability of a server in case one server goes down.	4.52	0.610	AGREE

Research Question 7: What practices should be adopted to ensure proper understanding between the clients and the providers? Table 10 shows the mean and standard deviation of respondents in context. It can be observed that the mean responses of the respondents on all the items soliciting information in research question 7 are all above 4.0. This indicates that the respondents generally agreed that all the items are the practices to be adopted to ensure proper understanding between the clients and the providers.

Table 10: Mean and standard deviation of respondents on the practices to be adapted to ensure proper understanding between the clients and the providers.

	Items	Mean	Std. Deviation	Decision
1.	The cloud providers must be able to have long-term viability for external data values.	4.39	0.656	AGREE
2.	In case the cloud provider is acquired by another company, the patient's data should still be available.	4.34	0.700	AGREE
3.	Data should be stored such that the patient should still have access to his data even if he changes his cloud provider.	4.31	0.724	AGREE
4.	There should be external audits and security certifications to confirm the cloud provider's reliability	4.22	0.864	AGREE
4.	External auditing of cloud provider's reliability and good service level agreement is essential for quality of service	4.20	0.856	AGREE
6.	If the cloud provider violates any agreements with the patient data, there are enough authorities to investigate it	4.19	0.919	AGREE

D. Hypothesis Interpretation

***H_{O1}*:** There is no statistical difference between the mean responses of women who registered in the first trimester and those who registered in the second trimester on how smart devices can support women in their health care center visitation challenges. Table 11 shows the *t*-Test Analysis of the mean and standard deviation in context. In the analysis above, "sig (2-tailed)" are the figures showing the probability/significance level in which the calculated t-value will be significant. By the decision rule, the hypothesis is rejected when the (2-tailed) value is ≤ 0.05, else accept the hypothesis. From the table, the significance level of item 9 is less than the stated 0.05 level of significance therefore the null hypothesis is rejected. However, the significance level of all other items is greater than 0.05 therefore the null hypothesis is accepted. Let $N_1 = 49$, $df = 99$, * = Significant at 0.05 (reject hypothesis); $N_2 = 52$.

$\overline{X}_1$= mean score for women who registered in the first trimester, $\overline{X}_2$=mean score for women who registered in the second trimester, $S.D_1$= standard deviation for women who registered in the first trimester, $S.D_2$= standard deviation for women who registered in the second trimester.

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Table 11: *t*-Test Analysis of mean and standard deviation of responses of women who registered in the first trimester and those who registered in the second trimester.

	First Trimester		Second Trimester		t-cal	Sig (2-tailed)
	X_1	**$S.D_1$**	**X_2**	**$S.D_2$**		
1.	4.67	0.72	4.63	0.77	0.26	0.79
2.	1.88	0.99	2.15	1.41	-1.14	0.259
3.	1.39	0.77	1.62	1.11	-1.19	0.24
4	3.31	1.34	3.75	1.37	-1.64	0.10
5.	3.71	1.14	3.79	1.07	-0.34	0.74
6.	3.90	1.25	3.48	1.34	1.62	0.11
7.	3.37	1.35	3.50	1.46	-0.47	0.64
8.	4.10	0.87	4.23	0.68	-0.83	0.41
9.	3.84	1.16	3.04	1.24	3.34	0.00*
10	2.80	1.38	3.33	1.40	-1.92	0.06
11.	3.63	1.33	3.21	1.32	1.60	0.11
12.	3.98	1.15	3.96	1.14	0.08	0.94
13.	4.22	1.01	3.90	1.07	1.55	0.13

$H0_2$: There is no correlation between the responses of pregnant women on the item that highlights "Antenatal health care processes in the primary/tertiary health center are too rigorous and stressful" and the one that highlights "A smart or handy device for pregnant women can have the impact of improved antenatal services. Table 12 shows the Correlation computation in context. Now, If the *p-Value* is less than the 0.05 significant level, the null hypothesis is rejected otherwise, it is accepted. From the table, the p-value is approximately 0.03 which is less than 0.05, therefore the null hypothesis is rejected. This implies that the fact that antenatal health care processes in the primary/tertiary health center are too rigorous and stressful. This affected their responses which admitted that there is a need for a smart handy device for pregnant women for improved antenatal services. From Correlation Table 12, it can be seen that the correlation coefficient (r) equals 0.06, indicating a relationship. $p < 0.001$ [NEVER write p = 0.000] and indicates that the coefficient is significantly different from 0.

Table 12: Correlation Computation

	ITEM 7B	*ITEM 1C*
Pearson Correlation	1	0.21
Sig. (2-tailed)		0.03
N	116	116
Pearson Correlation	0.21	1
Sig. (2-tailed)	0.03	
N	116	116

Pearson's correlation coefficient, r

P-Value

Number of pregnant Women

H_{O3}: There is no statistical difference between the mean responses of male and female medical practitioners on how smart devices would enhance the activities of health care personnel in prenatal care services. Table 13 shows the *t*-Test Analysis of the mean and standard deviation in context. Let $N_1 = 7$, $df = 32$,* = Significant at 0.05 (reject hypothesis), $N_2 = 27$.
$\overline{X}_1$= mean score for Male medical practitioners, X_2=mean score for female Medical practitioners, S. D_1= standard deviation for male medical practitioners, S.D_2= standard deviation for Female medical practitioners.
From Table 13, the analysis shows that the significance level of items 6 and 9 is less than 0.05. This means that the hypothesis for the two items was rejected while that of the remaining ten items was accepted.

Table 13: *t*-Test Analysis of mean and standard deviation of responses of male and female medical practitioners.

S/N	MEN Medical Practitioners		Female Medical Practitioners		t-cal	Sig (2-tailed)
	X_1	***S.D_1***	***X_2***	***S.D_2***		
1.	4.71	0.49	4.41	0.75	1.03	0.33
2.	4.71	0.49	4.00	1.07	1.70	0.10
3.	4.43	0.54	4.48	0.58	-0.22	0.83
4	3.86	1.07	3.59	1.08	0.58	0.57
5.	3.86	1.07	3.63	0.93	0.56	0.58
6.	4.29	0.76	4.30	0.67	-0.04	-0.01*
7.	4.29	0.49	4.11	0.64	0.67	0.18
8.	3.71	1.25	3.63	1.31	0.15	0.09
9.	3.86	1.46	3.96	1.02	-0.22	-0.11*
10	4.57		4.44	0.58	0.53	0.13
11.	4.43	0.54	4.11	0.90	0.90	0.32
12.	4.29	0.54	3.48	1.19	1.69	0.80

H_{O4}: There is no significant difference between the mean responses of medical practitioners in three different health centers on how the smart technology would be metered to ensure reliable feedback computing. Table 14 shows the ANOVA Analysis of Responses of Medical Practitioners in context. From the Table, F-ratio is significant at the 0.05 level and 2 and 31 degrees of freedom (*df*) for numerators and denominators respectively. The hypothesis is however rejected if the value of F-cal is greater than the critical value of *F*, otherwise, accept the hypothesis. Hence, Table 13 table, therefore, shows that the null hypothesis stated for all the items were accepted

Table 14: ANOVA Analysis of Responses of Medical Practitioners in three different health centers.

Items		Sum Of Squares	DF	Mean Square	F-Cal	Critical Value Of F	Sig.	Decision
	Between Groups	4.338	2	2.169	1.56	1.56	0.226	Accept
	Within Groups	43.103	31	1.390				
	Total	47.441	33					
	Between Groups	1.693	2	.847	1.10	1.10	0.345	Accept
	Within Groups	23.836	31	.769				
	Total	25.529	33					
	Between Groups	2.131	2	1.065	1.54	1.54	0.230	Accept
	Within Groups	21.398	31	.690				
	Total	23.529	33					

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4.	Between Groups	.381	2	.190	0.61	0.61	0.549	Accept
	Within Groups	9.648	31	.311				
	Total	10.029	33					

***H**$_{O5}$:* There is no statistical difference in the mean responses of medical practitioners in primary health centers and those in secondary health centers on how smart device services would be provided to ensure the client's ability to investigate the stored data. Table 15 shows the *t*-Test Analysis of Mean and Standard deviation in context. Let *N_1 = 11, df = 32,* = Significant at 0.05 (reject hypothesis), N_2 = 23.*

$\overline{X_1}$= mean score for Medical practitioners in Primary Health Center, $\overline{X_2}$=mean score for Medical Practitioner in Secondary Health Center, $S.D_1$= standard deviation for Medical practitioners in Primary Health Center, $S.D_2$= standard deviation for Medical practitioners in Secondary Health Center.

From Table 15, the analysis shows that the significance levels of all the items are greater than 0.05 and this means that the hypothesis for all the items was accepted.

Table 15: *t*-Test Analysis of mean and standard deviation of responses of medical practitioners in primary health centers and those in the secondary health center.

S/N	Medical Practitioners in Primary Health Center		Medical Practitioners in Secondary Health Center		t-cal	Sig (2-tailed)
	X_1	***$S.D_1$***	***X_2***	***$S.D_2$***		
1.	4.09	0.83	3.74	0.82	0.79	0.44
2.	4.18	0.41	4.13	1.00	0.28	0.78
3.	4.09	0.30	4.39	0.50	-1.84	0.08
4	4.18	0.41	3.91	1.08	0.86	0.40
5.	3.91	0.54	4.09	1.36	-0.82	0.42

***H**$_{O6}$.* There is no statistical difference in the mean responses of medical practitioners and IT experts on how the smart device services would be managed to ensure a comfortable environment for cloud providers for patient data.
Table 16 shows the *t*-Test Analysis of Mean and Standard deviation in context. *N_1* = 34, *df* = 83,
*= Significant at 0.05 (reject hypothesis), *N_2* = 51.

$\overline{X_1}$= Mean Score for Medical Practitioners, $\overline{X_2}$=Mean Score for IT Experts, $S.D_1$= Standard Deviation for Medical Practitioners, $S.D_2$= Standard Deviation for IT Experts.
In the above table also, it can be observed that the significant level (2-tailed) for all the items is greater than 0.05 the null hypothesis is therefore accepted.

Table 16: *t*-Test Analysis of Mean and Standard deviation of Responses of Medical Practitioners and IT Experts

S/N	Medical Practitioners		IT Experts		t-cal	Sig (2-tailed)
	X_1	***$S.D_1$***	***X_2***	***$S.D_2$***		
1.	3.74	1.082	3.98	0.97	-1.09	0.28
2.	4.03	.758	4.18	0.82	-0.84	0.41
3.	4.21	.729	4.14	1.02	0.34	0.74
4	4.35	.544	4.43	0.67	-0.57	0.57
5.	4.50	.564	4.53	0.64	-0.22	0.83

The determination of the issues relating to the design and development of a performance model for Persuasive Prenatal Health Care technology has been contextualized. From the survey, a suggestion of how smart devices would support women in their healthcare-center visitation challenges has been addressed. The factors that enable easy usability and accessibility of smart technology by pregnant women are clear. How smart devices could enhance the activities of health care personnel in prenatal care services is determined. All other issues highlighted in the objectives are determined.

From the findings, it was observed that the internal consistency tests motivated an ongoing smart ANC design for health service delivery in Nigeria. In context, pregnant women will be given a handheld toggle that is placed non-invasively on the body regardless of fetal movement. This senses critical parameters. The normal, abnormal, and high risks conditions are then pushed to the cloud expert systems that then respond with solution feedback.

At the end of the study, a novel infrastructure for system integration is proposed. This comprises edge sensors, a 5G gateway Fog layer, Cloud analytics, and a PIC microcontroller chip with LCDs. A heartbeat sensor AD8232 ECG/Heart rate monitor module will be used to keep track of the heart rate when its probe is attached to the patient's body. The blood pressure could then be computed from the heart rate. A PH level sensor (A27 PH value detector/acquisition module) will be employed to ascertain the PH level of the pregnant patient. This will check for slightly acidic or slightly basic depending on the individual, gender of the baby in the womb, etc. Again, by complex emulation theory, Urine will be collected and poured into the PH sensor. Buttons are pressed on the device and the PH value is displayed on the LCD.

A heart rate probe is placed on the patient, buttons are pressed and the measured edge parameter/s (e.g., heart rate) are available on the LCD. This ANC heart/pulse-rate information is equally used to calculate and display blood pressure on the LCD. At the press of a button, all this acquired information is sent to the cloud via SMS leveraging the Fog layer orchestrator. The wireless sensors can be positioned on the abdomen having the navel as a localized marker. The K^{th} sensor could be placed on the back and hence not physically visible. The precise placement of the wireless sensors follows an On-body sensor placement (Non-invasive or Non-intrusive sensor placement of smart devices) [134]. A deployment context will be presented in Section III. In all, a very strong government policy is required for full adoption.

III. USE-CASE FOR NON-INVASIVE WEARABLE ROBOTS

Figure 1 depicts a new use-case for Non-Invasive Edge wearable Robots. The Cloud-Fog orchestration infrastructure is a smart 4-tier architecture comprising [143]: the edge IoT presentation tier, Fog middle tier, service-oriented processing tier, and Cloud analytics tier. The edge IoT presentation tier is the user access layer interface, and it is designed using IoT sensor nodes with C++ scripts. The Fog middle tier connects the presentation edge IoT presentation tier with the embedded application programming interfaces and Cloud analytics tier together. The Fog middle tier is also called QoS latency business logic for the upstream or downstream traffic. It was designed using C++ scripts and it runs on the Fog gateways.

This work introduced Optimum Probability Density Function Transmission Protocol (OPDF-TCP) for datastream movements from the edge to the Cloud and vice-versa [143]. The Cloud analytics tier together is the part of the system that is responsible for the analyzing storing the data i.e., the Patients data-streams and houses the database management system.

For the ANC network architecture in Figure 3.1, the embedded sensors are located at the network edge with the ANC patients. Edge sensors are integrated with real time monitoring communication with sensed application data. Hence, it functions primarily as a transducer for extracting parameters $i_1.....i_n$. The extremely sensitive edge device modulated via the logical transceivers/controllers and then connects to the Fog ports/controller.

The primary function of the Fog layer is to dynamically isolate compute resources while setting up an efficient transactional workflow using the OPDF algorithm [143].

Incidences of real-time data collection, lightweight processing, data-caching, agent-aggregation, and homogenous load-balancing are fixed at the Fog layer via OPDF. This orchestrator's role consequently enhances computational QoS, security, reliability, and distributed fault tolerance. The Edge-Fog layers provide connectivity and traffic transport between mobile edge ANC patients and the backend cloud data enters.

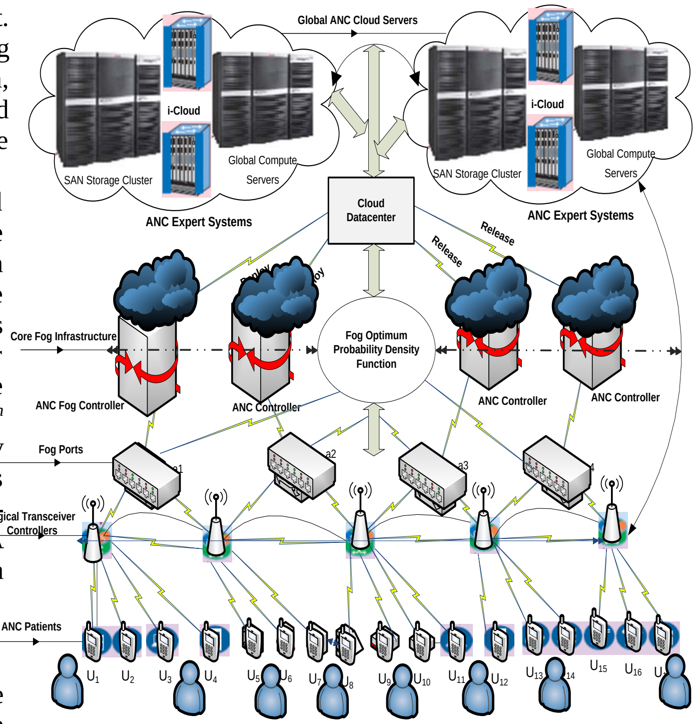

Fig 1. Use-case Edge Wearable System Architecture.

Finally, the Cloud layer situates the ANC expert systems for intelligent analytics especially in prescribing instantaneous diagnosis for any of the patients regardless of the trimester status. The Cloud offers massive storage, and data processing and supports deep learning analytics in a unified management framework. It enables efficient and responsive monitoring, management, and planning through its OPDF intelligent algorithm.

IV. Conclusion

This paper discussed a clinical survey and gaps analysis for persuasive prenatal healthcare technology. A comprehensive literature on PT and behavioral transition from legacy health systems to IoT-Fog cloud infrastructure is presented. Three distinct groups were used to investigate how smart devices would support vulnerable women and the challenged. Easy usability, accessibility, etc were considered. Data obtained from the primary and secondary health centers were used to test the baseline hypothesis. The findings qualify the role of the PT smart ANC system. PT is shown to facilitate complex decision-making in resilient health systems. Also, findings show that Clinical decision-making through complex can have substantial impacts on ANC patients. With PT, data collection and storage from ubiquitous sources can enhance medical informatics. A proposed ANC expert cloud system will offer predictive diagnoses as well as analyze the collected data from the ANC-Fog Node, and dynamically initiates priority or best-effort decisions and directives. Hence, a user-friendly persuasive technology (C++ Antenatal sensing and monitoring product) is currently being embedded in hardware that will greatly improve the quality-of-service delivery of antenatal processes. This will reduce the maternal mortality rate. Further research will focus on neural-network-based performance models using Market Place Service Robots as a Cyber-physical integration for predictive analytics.

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