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Smart Care: Body Area Sensor Network Conceptual Architecture for Elderly and Non-Critical Patient Care

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ABSTRACT

People with disabilities, the elderly, those who are sick, and children all need assistance. Staying with them 24 hours a day, seven days a week is impractical, and it also has an effect on the care receiver's psyche, making them feel overly reliant. Various architectures have been proposed, but none of them discuss generalization, feasibility questions, which are important for any care seeker, and also lacks focus on elderly people and non-critical patients care. As a result, an accessible, efficient architecture that allows our loved ones, especially the elderly and non-critical patients, to live healthier lives is required. It is important for health practitioners to be able to monitor the body status of those receiving care in real-time and to provide them with timely input on their health. As a result, the proposed generalizable architecture recognizes all stakeholders, as well as vital signs in thehuman body. Consolidates all of them into an IoT-based smart care infrastructure comprising a non-invasive hybrid body area sensor networks supported by cloud computing platforms, machine learning, and data analytics models, with the aim of assisting in the provision of high-quality, low-cost care to the elderly and non-critical patients. Finally, the design was validated through a survey and professional consultation with 45 experts, who agreed with the proposed architecture 82.2 percent of the time.

Keywords -**Smart Care Architecture, Elderly andNon-Critical Patients Care, IoT Smart care, HybridBody-Area Sensor Network**

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I. INTRODUCTION

A. Background

Care is the need; it should not make the care receiver weak, dependent, and limiting him/her from exploring his/her potential. Elderly, Children, Patients[1], and the disabled require care and treatment hence they can be referred to as care receivers. Shortage of workforce, increase in patients, elderly population and children, similarly the evolution of new communicable infectious diseases -sometimes harmful to care giver health, improvement in survival rate from traumaresulting increase in numbers of people with severe disabilities[2], high population growth, and all of the above 7billion and increasing population increased demand for technology-based quality care. Providing quality care at an affordable cost, for the ever-increasing population, it is a great challenge. Mostly manual care is practiced till date in hospitals, homes care centers, which requires the involvement of health professionals to a large extent[3], the involvement of humans leads to human negligence, bias, anger, error, and misconducts reducing the quality of care[4-6]. The population of more than 7 billion and growing, need smart solutions for providing care to the needy. Advancement in technology specifically IoT and smart technologies relieves the pressure of caring for the needy[7-12]. Medical care and health care aremajor application areas of IoT. Recently advanced technologies intelligent monitoring system[1,3,13], Body Sensors Networks[7,14,15], Wireless Sensor Network[15],Wearable technologies have improved people's health and made caring easier -in overall healthcare got better. With time every field is being more intelligent and technology-driven so the caring has been. Caring for the needy has evolved as smart care. Smart Care focuses on digitizing patient medical records, and caring for patients, elderly, children, disabled using technology. Electronic health records ensure their secure interoperability of medical records largely benefitting the care process[16]. Research shows that adaptation of smart care technologies provides a superior cure, reduce cost, man power[14,16,17]. Smart care usefulness varies from providing a safe pregnancy period[18], monitoring and caring for critical patients[8],ubiquitous health monitoring[33] and allowing older people to live independently.

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B. Problem Domain

- Shortage of manpower to provide care to patients and elderly but on the other side the continued growth in the number of patients, elderly population, and communicable diseases.
- Presence of human negligence, bias, anger, error in care.
- Lack of emphasis in human body vital signs and the use of relevant technology reducing health professional's involvement in care.

C. Objectives

- To create a conceptual IoT based smart care architecture for non-critical patient and elderly care.
- To explore the ways for reducing direct human involvement in patient and elderly care via technological solutions.
- To identify vital parameters that define health status and suitable technologies to measure those parameters.

D. Research Questions

RQ1. What could be the smart care architecture that could be applicable to non-critical patients and elderly care?

RQ2. How IoT body areas sensor network technologies can be useful to provide smart care thus reducing human involvement in care?

RQ3. What could be the major human body vitals and corresponding technologies to monitor them in order to provide smart care?

The paper is organized as follows. In Section II Related work. Section III the proposed architecture along with involved hardware and software components, Discussion and Evaluation of implementation are in Section IV. Finally, Section V Concludes with limitations and future work.

II. RELATED WORK

This section reviews the related literature that focuses on providing some real-life conceptual architecture for caring for the elderly and patients making use of IoT and sensors.

TABLE I
ACTORS AND TECHNOLOGIES USED IN SMART CARE SYSTEM

Paper	Actors	Technologies
[7]	Patients, Physicians, Hospital, Family members	Body Sensor Network, Server, Wireless communication mediums (3G/CDMA/GPRS)
[8]	Patient, Medical Staffs, Local and remote users, Network Operators, Sensors, Hospital	6LBR,6LR,6LRR,6L HT, IoT Smart Gateway, REST Web-based paradigm, RFID
[18]	Core Users, Clinical Experts, Researchers, and Other Organizations, Manager, Hospital	Smartphone, GPS, Internet, Android Mobile App
[19]	Elderly people, Carer or service provider, Sensor, Server	Passive infrared movement sensors, Server, Public Telephone network, Software, Alarm
[20]	Patients, Physicians, Hospital, Research Institutes, Medical manufacturer and Distributors, Health insurer, Employers, Government	RFID and 2D barcodes , Web 2.0 and 3.0 technology, EHR, Big data-enabled business intelligence , Sensors, Smart phones
[21]	General Physicians , Socio Care provider/Informal Carer, Care Homes, Hospitals, Older People.	Mobile/Web Application, Smartphone, Server
[22]	User (Elderly) ,VirtualCareGiver, Caregiver, System Support Engineer	Cloud Services, Physical Sensors, Household Electronics, Virtual Robot
[33]	Medical Personnel, Healthcare Professionals, Caregivers, Patients	Zigbee, Bluetooth, Personal Digital Assistant (PDA), GPRS, ECG sensor, EMG sensor, blood pressure sensor, two-axis accelerometer, TinyOS

In Table I actors means the humans or individuals associated in the architecture. Mainly following document were highly considered to propose the overall architecture, their corresponding summary is underneath:

A. BSN-Care: A Secure IoT-Based Modern Healthcare System Using Body Sensor Network [7]

Secure IoT healthcare system using the Body Sensor Network [14,15], called BSN-Care [7]. Continuously monitors and reports the patient's body status using a collection of tiny-powered and lightweight wireless sensor nodes with the aim to treat the patient. Additionally, it notifies the concerned authority (family, medical staff) in case of emergency.

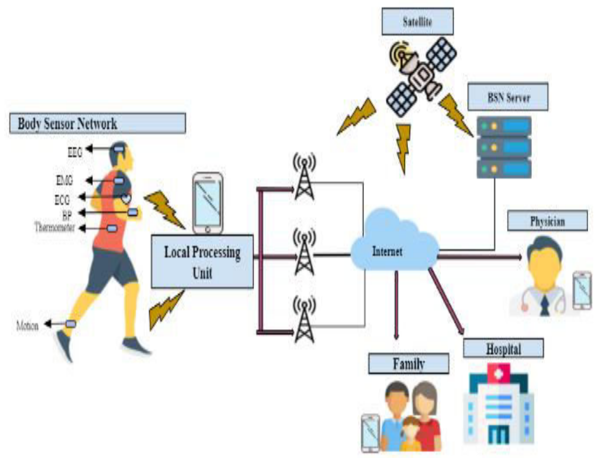

Figure 1: BSN-Care: A Secure IoT-Based Modern Healthcare System Using Body Sensor Network.[7]

B. An IoT-Aware Architecture for Smart Healthcare System[8]

IoT-based,Smart Hospital System (SHS) architecture for automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes. Inputs are sensed, stored, and processed to alert, monitor, thus obtained visualized outputs are made accessible to local and remote users.

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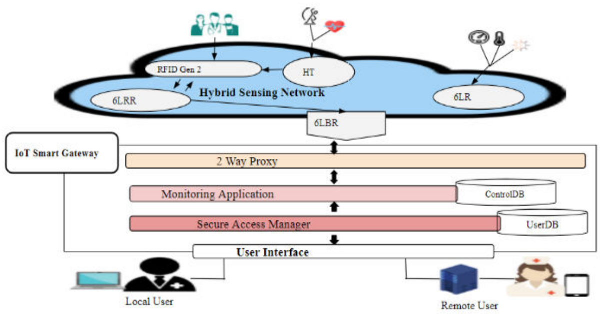

Figure 2: An IoT-Aware Architecture for Smart Healthcare System [8]

C. Smart Care: An Intelligent Assistant for Pregnant Mothers [18]

Cloud-based mobile app healthcare architecture for expectingmothers to have a healthy maternity period. Interconnecthealth professionals, provide feedback and monitor them-monitoring is a manual based on the input provided.

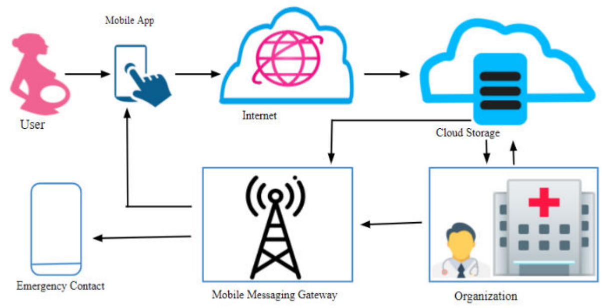

Figure 3: Smart Care: An Intelligent Assistant for Pregnant Mothers.[18]

D. Smart care technologies: meeting whose needs?[19]

Paper supports smart care as a need-based approach (meaning caring those who need it only) and illustrates a technological solution for caring elderly people through a case study of pre-existing intelligent home monitoring systems [3,24] for independent living elderly people.

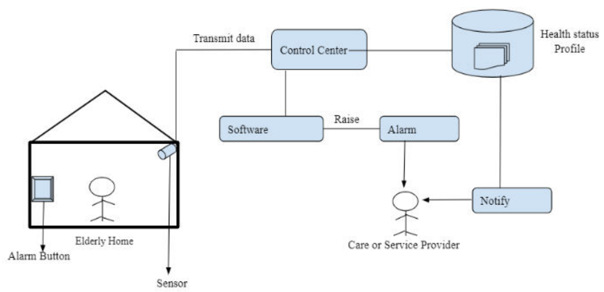

Figure 4: Smart care technologies: meeting whose needs?[19]

E. A Smart Healthcare Systems Framework[20]

Proposes a comprehensive smart healthcare system framework conceptualizing data-driven and cloud-enabled smart healthcare systems for quality cost-effective health care services. Cloud-enabled sustainable smart healthcare system, integrated with electronic health records (big data) and emerging mobile solutions (such as novel biosensors, wearable devices, and intelligent software agents). It also emphasized the need for quality assurance, coordinated care, cost reduction, and coordinated information systems.

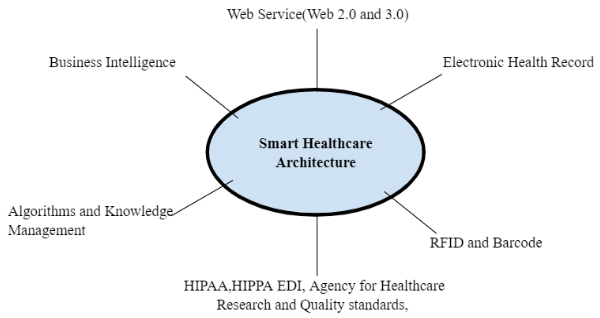

Figure 5: A Smart Healthcare Systems Framework.[20]

F. The SmartCare pathways An initial step towards implementing integrated eCare[21]

Applied ICT specifically mobile app (for telecare, tele health, and data exchanges) to deliver quality care service to European Union's older population based on an integrated socio and health care pathway(architecture) through setting a common standard for all the specifications to be used in the architecture.

G. VirtualCareGiver: Personalized Smart Elderly Care [22]

Purpose an efficient and reasonable virtual agent[23,24] care robot for individual elderly people with personalization features using cloud services and smart agents. It has three main components; VirtualCareGiver (VCG)-robot agent, which gives actual care to the user, VirtualCarePersonalizer (VCP) -sets personalization based on individual information, and CareTemplate -defines command or task to be executed by the virtual agent.

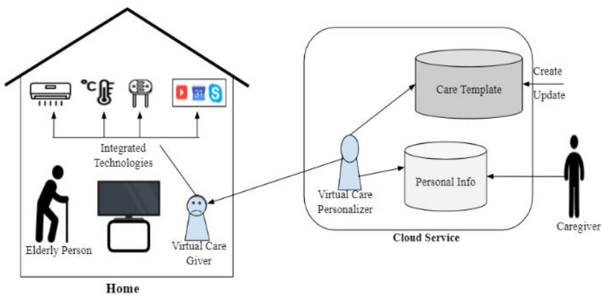

Figure 6: VirtualCareGiver: Personalized Smart Elderly Care[22]

H. System Architecture of a wireless body area sensor network for ubiquitous health monitoring[33]

Majority authors has presented a hardware architecture consisting of motion sensor, ECG sensor for heart rate on which information flow is coordinated by the network coordinator and personal server. Along with the corresponding software architecture that manages the sensor nodes, their data capturing, communication and

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information flow, time synchronization and power management with a user-friendly graphical user interface.

I. Mobile Wireless Sensor Network: Architecture and Enabling Technologies for Ubiquitous Computing[34]

The ubiquitous computing model includes a hierarchical multi-tiered architecture for mobile wireless sensor networks, as well as corresponding technologies such as RFID, MobileIPv6, GRID Technology, and Mobile Peer to Peer were mentioned. In this the application of mobile wireless sensor network for providing quality care to patients has been stated as one of the application scenarios.

J. Body sensor network -A wireless sensor platform for pervasive healthcare monitoring[35]

Body sensor network architecture consisting of temperature sensor, accelerometer, ECG, microphone, non-invasive blood pressure interfaced with each other in the human body is presented for health status monitoring. Where the collected information is linked to a local processing unit attached to the body itself. Having a micro controller as the coordinator and flash memory as a cache storage.

Majority of the above architectures have illustrated the use of IoT to provide care to patients, elderly, children's, disabled. They provided continued monitoring, emergency notification, predicting health complications implemented through the use of Wearable and Body Sensor Network, Wireless Sensor Network. To better know the sensors in WSN, BSN, and Wearable's readers are referred to [7,8,14,15,25,26]. Emphasized architecture [19] to be need-based innovation rather than imposing preexisting Expressed architectures via a case study of literature but lacks technical detail and excludes health professionals. [20] Provides a broad architecture comprising roles of all actors in the healthcare system, lessemphasis on how to provide care.[21] Elaborates smart care being implemented in Europe, input sensing is manual and lacks real-time monitoring. From web application for caring [18,21] to care robots [1] to IoT based smart care system [7-10,27] has been proposed and research is continued. But the major problems to be addressed in smart care to smart healthcare remains security, wearable, power consumption, generalizable usefulness, real-time monitoring, incorporating role of major vital signs. Above, studied literature focus on specific domains that lack generalization to accommodate all types of care, lack to mention major vital signs to monitor health status and respective sensing devices to measure those parameters and coordinate information flow among all major actors of the smart care framework. So, this new architecture tries to address those to provide a smart care framework for non-critical patients and the elderly based on IoT devices and cloud computing services.

III. ARCHITECTURE

A. Body Parameter

The overall status of individual health is predicted based on listed vital parameters sensed via sensors. A complete list and details about the vital signs and sensor can be found in[7,25,26,28,30]. Thus, identified vital sign parameters to measure and report individual overall health status are:

TABLE II
VITAL BODY PARAMETER AND RESPECTIVE SENSORS

Parameter	Sensor/Devices	Use
ECG	Wearable ECG Sensor (Shimmer3)	Electrical signal of heart
Oxygen level	Pulse oximeter	Oxygen saturation in Blood
Temperature	Wearable Skin Temperature sensor	Body temperature
Blood pressure non-invasive	Sphygmomanometer/ Finger Cuff Sensors	Blood Pressure
Pulses	Pulse Sensor	Heartbeat or pulse rate
Electroencephalo graphy	Wearable EEG	Electrical activity of the brain
Electromyograph y	Wearable EMG Sensors (Shimmer3 EMG sensor), Myoware muscle sensor	Electrical activity of muscle tissue
Motion	Motion Sensors	Body movements

B. Proposed Architecture

Here a reliable architecture for providing quality care to care obtainers using IoT based sensors is proposed. It consists of four layers.

(i)Hybrid body sensor network -collects health vital details and real-time video footage.

(ii)Base station and the internet -the communication medium for the exchange of information.

(iii)Server -processing and visualizing obtained data, health status predictions, and role-based access control for security.

(iv)User interface -health status and the video feed are presented to concerned actors.

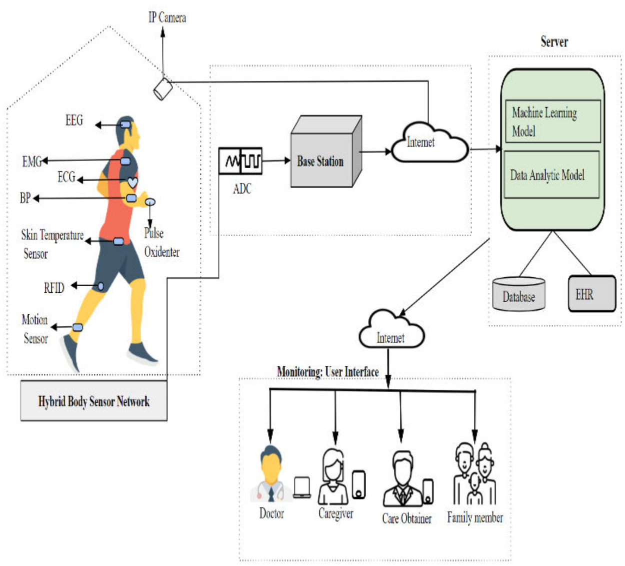

Figure 7: Proposed Architecture for Smart Care

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Body health status monitored using a wearable body sensor network [7,14] consisting of EEG, EMG, ECG, BP sensor, temperature sensor, accelerometer sensor, pulse oxidant, pulse sensor interfaced through Arduino ethernet rev3 board and having input power supply of 36-57V. Then further transmitted to the remote server via a base station in real-time. RFID tag is used to uniquely identify the care obtainers [29]. Base station is the computer that receives data from the Arduino transferred via RS 232. Data sensed from the body sensor network is updated in the electronic health record (EHR). In the server, the preexisting data from electronic health records [16,17] and sensed data are fed to train a machine learning model using a supervised machine learning approach. Simultaneously EHR data and real-time sensed data from care receivers are visualized using data visualization models. Thus, obtained results and analytics are accessed by doctors, caregivers, family members and care obtainers via the internet using a web/mobile portal. The health professionals can monitor body status and provide continuous feedback or report in case of an emergency. Also, telecare facility whenever required using the skype or hangout.

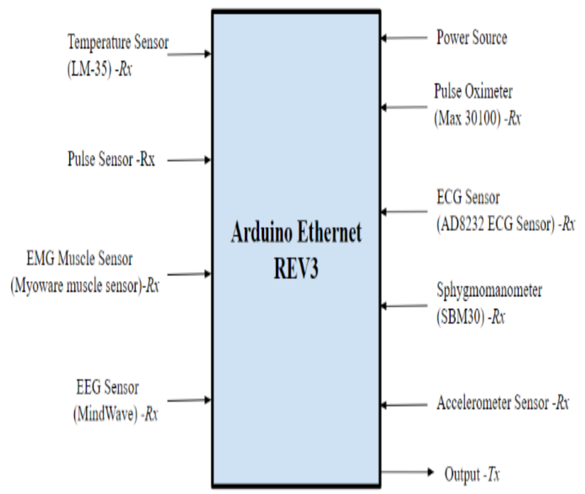

Figure 8: Block Diagram of Sensor Interfacing

IV. EVALUATION AND DISCUSSION

Generalized architecture that can be implemented to all four types of care obtainer is needed and this four-layered wearable architecture can be great to elderly and non-critical patients and to some extent to disabled, but in case of children it might not be great as they might not be able to wear the hybrid body sensor thus requiring the involvement of external human assistance. Monitoring and being in touch seem to be the care and curing procedure. But we don't emphasize continuing monitoring for all, rather monitoring health status based on the need would be appropriate i.e., continues monitoring for unstable category patients, 3 times a day health vital sign information collection for potentially unstable and 2 times a day health vital sign collection for stable category patients. But these conditions may vary per professional suggestions.

TABLE III
VITAL SIGN AND NORMAL RANGE

Vital Signs	Normal Range	Remarks
Body Temperature	97.8^0 F – 99^0 F/ 36.5^0 C - 37.2^0C	-
Pulse rate	60 - 100 pulses/minute in an adult 70 - 100 pulses/minute in a child	Fluctuate with exercise/emotion. Athletes may have a different rate
Blood Pressure	90/60 - 120/80 mm/hg	-
Oxygen Saturation	75 to 100 millimeters of mercury (mm Hg)	Normal arterial blood oxygen saturation levels are 95–100 percent- below 90 percent are low
Heart ECG	PR interval – Normal range 120 – 200 ms (3 – 5 small squares on ECG paper). QT Interval – Normal range up to 440 ms	Pulse rate between 60 - 100 pulses/minute is normal ECG rate
Brain EEG	10 µV to 100 µV in amplitude when measured from the scalp and about 10–20 mV whenmeasured by electrodes.	Normal brain waves occur at a rate of up to 30 per second
Footsteps/ Motion	Approximately 4,000 and 18,000 steps/day	Below 4000 might affect body

Table 3 represents the healthy body vital signs normal range compiled from[27,28,30,31,32], it guides health status determination and any vital sign deviating beyond the normal range is considered potentially unstable. Table 3 has been initially crafted based on the data from [27,28,30,31,32] and further refined and validated based on the feedback of 23 practicing doctors that reviewed the architecture. Through literature, we found a common smart care architecture for patients and elderly requiring the active involvement of care obtainer, health professionals and caretakers using IoT technologies through

(i) Maintaining an Electronic Health Records (EHR) of care obtainer -for smooth flow of information, coordinated exchange of information among health professionals.
(ii) Regular monitoring of Care obtainer health status (continuous monitoring if critical) -IoT technologies and sensors' best options.
(iii) Keep Care Obtainers in close contact with health professionals (Doctors), allowing them to monitor care obtainer health status analytics and provide a telecare facility.

Incorporating BSN, cloud services, data analytics, and machine learning can address the need for sensing the human body's vital status by connecting all actors and predicting, visualizing body status. Telecare using pre-existing technologies like google hangout and skype to get digital feedback from the health professionals rather than frequently visiting hospitals [22]. Secure socket shell (SSL) will ensure the secure communication of data and information between client, server and base stations. User authentication allows in maintaining privacy. SSL and user authentication will ensure confidentiality, authenticity, and integrity of data. EHR has been used widely around the developed nation for integrated, interoperable digital records of patients, and has a global consensus that EHR leads to more efficient, safer, and higher-quality care [16,17]. Some of the most expensive software in history has been the EHR software. They being affordable in case of large hospitals but small ones often cite EHR difficult to afford due to high capital and maintenance costs. But a survey finding in [17] found hospitals with electronic-records systems were less likely to cite capital requirements and high maintenance costs as the primary barriers than hospitals without such systems. EHR incorporated in the architecture will store and provide access when required in a secure way to all concerned ones. This reduces the crowd in hospitals, reduces stress of visiting hospitals i.e., psychological benefit. Using virtual care robots [22], artificially intelligent robots can be a viable technology, but using robots for care receiver assistance and providing health care service requires high accuracy, ethical acceptance, and other socio-psychological aspects. For the validation of smart care architecture expert consultation was done and a survey was carried by paying them a personal visit, with participants from different relevant field of study the doctors with a MBBS degree, IoT expert and information technology experts with doctorate of philosophy (P.H.D), professionals in the field of electronics and communication, professionals in the field of computer science and engineering. In total 45 people responded, out of which majority of participants agreed with the architecture and use of vital signs for elderly and patient care. Out of the 23 MBBS doctors 21 agreed with the smart care architecture and all of the 23 agreed with the use of body vital for providing smart care. Among the 4 PHDs 1 agreed with the architecture and 3 provided feedback which were included and later on they also agreed with the architecture. From the total 18 information technology and IoT professionals working in the industry, 15 agreed initially and 3 gave feedback which were accommodated later after which they also agreed with the architecture. Regarding the use of vital signs for providing smart care to elderly and patients. This was asked only to the doctors and all of the doctors agreed the listed body vital signs to be useful to provide care. Overall summary of the survey is below.

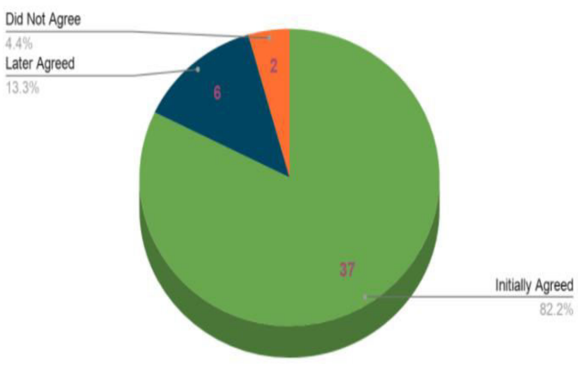

Figure 9: Response Summary for Architecture Validation

V. CONCLUSION

Care obtainers, caregivers, family members, and health professionals are the major actors that need to be interconnected for smart care. The internet and specifically the cloud computing services is the best technology to interconnect all actors. IoT based sensors can sense the inputs and machine learning techniques can extract the interpretation from those data. Through the interconnection of all the major actors, tools and technologies like data analytic, machine learning models, cloud services, telecare, closed-circuit television (CCTV) feed, and IoT based sensors can be used to achieve major requirements of smart care which are monitoring and providing real-time feedback, reporting an emergency, interconnecting all actors. Health status can be predicted based on the vital signs, for the digitization of medical records an electronic health record achieves that goal. Thus, this offered architecture can give quality affordable care to the elderly and patients at place of their comfort without need of much human intervention. Finally, the majority of the health and IT professionals aggreging with the architecture makes it more robust.

A. Limitations

Some limitations of this work are stated below:

- Architecture is highly based on literature, expert guidance hence requires additional experimental works.
- Vital signs by wearable EEG sensor and non -invasive blood pressure sensor might be less accurate.
- Dressing a body area sensor network and continuously monitoring may be irritating for care obtainers.

B. Future Work

- Conducting experimentation on offered architectures and evaluating real observed findings.
- Explore for the non-wearable sensor network that can be attached at homes to observe patient vital signs.
-Injecting the concept of IoT based smart nurse for providing care.

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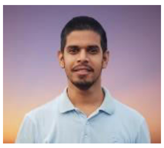

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