Spring 5-2015

VCare: A Personal Emergency Response System to Promote Safe and Independent Living Among Elders Staying by Themselves in Community or Residential Settings

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VCARE: A PERSONAL EMERGENCY RESPONSE SYSTEM TO PROMOTE SAFE AND INDEPENDENT LIVING AMONG ELDERS STAYING BY THEMSELVES IN COMMUNITY OR RESIDENTIAL SETTINGS.

By

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Telecommunications Engineering

Under the Supervision of Professor Tadeusz Wysocki

Lincoln, Nebraska

May, 2015

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University of Nebraska, 2015

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‘Population aging’ is a growing concern for most of us living in the twenty first century, primarily because many of us in the next few years will have a senior person to care for - spending money towards their healthcare expenditures AND/OR having to balance a full-time job with the responsibility of care-giving, travelling from another city to be with this elderly citizen who might be our parent, grand-parent or even community elders. As informal care-givers, if somehow we were able to monitor the day-to-day activities of our elderly dependents, and be alerted when wrong happens to them that would be of great help and lower the care-giving burden considerably. Information and Communication Technology (ICT) can certainly help in such a scenario, with tools and techniques that ensure safe living for the individual we are caring for, and save us from a lot of worry by providing us with anytime access into their lives or activities, and as a result check their

functional state. However, we should be mindful of the tactics that could be adopted by harm causers to steal data stored in these products and try to curb the associated service costs. In short, we are in need of robust, cost-effective, useful, and secure solutions to help elders in our society to ‘age gracefully’. This work is a little step taken towards that direction.

"Let the light of knowledge shine unto the darkest corners of ignorance".

-Anonymous

Dedicated to my parents for their unending love and support and especially to my mother who's strived so hard to put me where I am today.

To my grandfather who's not around today, but has been my source of inspiration always.

To Rini who does so much for me to make each day of my life brighter than the previous day.

To my wonderful sister

…

And to those countless people who have seen me grow, inspired me, have been near me when I needed them the most, and continue to spread joy in my life.

Thank you all.

Acknowledgements

Firstly, I would like to thank my advisor Dr. Wysocki for being there to guide me through this ordeal, for being as patient and kind so as to bear my ignorance at times, for constantly supporting and encouraging me, for pouring over me his expert advice whenever needed, and for believing in my ideas and trusting my abilities. I have greatly benefitted from having the chance to work under his guidance, and look forward to collaborating with him in the future, as well as continue to share this great student – teacher bond that binds us.

I would also like to extend my gratitude and thank Dr. Sharif for the support and motivation he's provided me with since day one, and Dr. Tiller for his ever-enthusiastic and spirited pep talks, Sushanta Rakshit for being such a nice senior, to the professors in the department of Electrical and Computer Engineering who have taught me so much during these two and a half years, and last but certainly not the least to God Almighty for being with me each moment and filling me with the strength and courage needed to face challenges in life.

“Knowing is not enough; we must apply.

Willing is not enough; we must do.”

—Goethe.

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List of Acronyms

API Application Programming Interface

CDSU Central Data Storage Unit

CI Communication Interface

COTS Commercial off The Shelf Telephone

CSS Cascading Style Sheets

CU Communication Unit

ECG Electro Cardiogram

EEG Electro Encephalogram

EOG Electrooculography

ERU Emergency Response Unit

FTC Federal Trade Commission

GPS Global Positioning System

HTML Hyper Text Markup Language

HTTP Hypertext Transfer Protocol

HTTPS Hypertext Transfer Protocol over SSL

IADL Instrumented Activities of Daily Living

ICE Interactive Connectivity Establishment

IMU Intelligent Monitoring Unit

MCU Multiple Control Unit

NAT Network Access Translation

PC Personal Computer

PERS Personal Emergency Response Systems

PIR Passive Infrared

PMI Passive Monitoring Interface

PMU Passive Monitoring Unit

PSTN Public Switched Telephone Network

RFID Radio Frequency Identification

SCHSA Senior Citizen Home Safety Association

SIP Session Initiation Protocol

STUN Session Traversal Utilities for NAT

SVG Scalable Vector Graphics

TCP Transmission Control Protocol

TURN Traversal Using Relays over NAT

UDP User Datagram Protocol

UI User Interface

VGA Video Graphics Array

VSI Video Surveillance Interface

VSU Video Surveillance Unit

WebRTC Web Real Time Communication

Wi-Fi Wireless Fidelity

WSN Wireless Sensor Networks

W3C World Wide Web Consortium

XHTML Extensible Hypertext Markup Language

XML Extensible Markup Language

XUL XML User Interface Language

Chapter 1. Introduction

1.1. Motivation

Medical sciences have advanced rapidly during the past century, leading to eradication of epidemics, upping of health standards, and improvement in ‘quality of life’. As a result, the average age of the population has risen steadily, hence there are more seniors living in our societies than ever before. Most such individuals live independently away from their family members, vulnerable to either high risk accidents (chronic seizures, falls etc.) or threats (burglary, fires etc.). A wide array of technologies like Video Surveillance, Home Monitoring Applications or Personal Emergency Systems (PERS) have managed to considerably reduce the possibility of such threats or accidents by making it possible to keep vigil over elderly citizens and alert family members, or emergency workers whenever such disasters occur. However, a number of drawbacks have been observed in previous generations of such technologies. For example in **Personal Emergency Systems** False alarms were common due to presence of physical buttons. Also the requirement for manual operators, and landline phone connections added to the overall costs. **Home Monitoring Solutions** suffered from issues arising out of non-user friendly or complicated design while Privacy Intrusion or Costly Infrastructure were commonplace in the realm of **Video Surveillance Systems**. Therefore there was a definite need for improvements in these Systems to overcome the aforementioned shortcomings, as well as the imminent need to build new products, platforms or solutions to cater for the needs of the elderly people and their carers.

Research efforts in the past years by scientists, engineers and technologists in this and related fields of healthcare and wellness have borne fruit resulting in noble interventions.

Today we see technology such as medication management kits that allow older adults to take control of their personal health and well-being [1] , [2] , [3] , [4]or those that allow them to connect, communicate and exchange ideas with their peers, as well as with family and friends [5]. The use of everyday technological objects like mouse in monitoring people's health [6] can reduce costs, increase mobility, and contribute towards changing the traditional model of care-giving which was previously confined to primary healthcare settings such as hospitals or nursing homes. Despite such efforts and concomitant ideas, most of such existing products require the individual to buy highly specialized devices, the makers of which charge the user a recurring fee to use proprietary technology. For instance, to use Philips Go safe a person is required to buy a pendant and tele-hub as shown in Figure 1.1. Also user is required to pay $55/ month if wishing to be monitored by a third party emergency service provider.

Figure 1.1 Philips Go Safe

However, modern Telecom infrastructure, fast and easily affordable broadband connections, and falling prices of electronics technology have contributed immensely towards the advancement of healthcare. As a result, it has become easier to try and improve the state of well-being of the 'care-hungry' baby boomer generation. No longer are we limited by possibilities, or bounded by non-availability of resources created due to a closed eco-system of proprietary technologies, and are free to choose any tool we wish to in order to create better technology.

This work has been greatly inspired by the need to have holistic platforms which ensure cost-efficient, robust, and simplified aging in place. Our sincerest objective is to overcome many of the shortcomings discussed above. In addition, we also feel the need to take care of several important factors, such as the elderly individual's limited cognitive and physical limitations, spending capacity, ergonomical requirements; all of which we trust are determinants of successful products specifically targeted towards use by elders [7].

1.2. Contribution of this Thesis

The most valuable contribution of this work is the creation of a platform which reacts to an emergency situation by sending a distress alert like normal Personal Emergency Response Systems. Additionally, it can be used as a platform for **social engagement**; as a means to secure the elderly individual's periphery against fire or burglary threats through the **video surveillance** feature; or a means to check functional status using its **passive monitoring capability**, thereby making it to monitor elders, enhance their security and promote safe and healthy aging among them. Such a tool will help psychologically in instilling feelings of security, create a sense of emotional attachment, and reduce the disconnectedness many of them face as a consequence of living alone. [8].

The major features of our platform - VCare are listed below:

'Soft' Panic Button – Having a 'soft' panic button reduces the chances of false alarms often observed in PERS having hard panic buttons.

'Soft' phone - cheaper alternative to *landline* or *ip* phones ([9] (Figure 1.2)) generally used in emergency systems.

Simple UI – Many systems overload the user with more information at a time. We try to present only critical information that is required to perform a task or make a decision; Buttons are kept large and fonts are made Big for easy-readability.

Figure 1.2 Panasonic KX-TG7623B – A Landline Phone Used in many PERS

Use of Passive Sensors – many aged people get offended by the idea of being monitored by *Video* or *Camera sensors*, thinking that it would intrude into their privacy. *Bio-wearable sensors* like hand cuffs or pressure monitors are not preferred because they cause irritation or discomfort to the user. We use *passive sensors* which monitor the users from a distance without interfering with their privacy and without having to be worn.

Data privacy, security & reliability– Collected data is discarded after regular intervals, reducing the chances of snooping or data hacking attempts. Data security is increased by keeping network hops low - Or Connecting the sensor directly to cloud through Wi-Fi Modules. As a result there are Minimum network hops, Minimum points of attacks or intrusions. Data reliability is bettered again by using less. network hops again, and not requiring the use of gateways.

Minimal Storage Requirements – Only useful data is retained, with user related data discarded after fixed intervals, unless explicitly specified in system settings not to.

Minimal running or maintenance costs –Use of freely available and open source technologies as far as possible, Use of everyday gadgets – such as Tablets, PCs or Laptops – eliminating the need to buy extra hardware or use proprietary technology. No requirement for Tele-Health Hubs or gateway devices causing Minimum dependence on infrastructure, therefore leading towards overall reduced costs.

Social Connections improved – Apart from using our product to interact with doctors, or carers, users can socially engage with friends and family, and peers thereby negating the ill effects caused by ‘social disconnectedness’ and loneliness.

The second contribution of this work is an equation designed specifically to measure wellness among elderly people. This equation is applied to data collected by passive sensors to determine the probability of an abnormal situation.

The rest of the document is organized as follows: Chapter 2 gives a back ground of our work, discusses the currently available technologies or work already done in this field, the limitations and advantages observed. Furthermore, we talk about work which shaped our thoughts, provided us ideas, before introducing the problem statement. Chapter 3 is the proposed solution which provides a detailed description about the underlying technology: hardware and software involved in making our product work. Chapter 4 discusses Results, and Chapter 5 is used to conclude and summarize our findings. Chapter 6 is the final chapter in this document, talks about future possibilities in this research area.

Chapter 2. Background

2.1. Overview

‘Population aging’ is a new phenomenon in the wake of sudden aging of the world population resulting from declining death rates and birth rates [10], and is synonymous to rising healthcare expenditures and ever increasing care-giving burden on the society [11]. More and more elders are looking ahead towards options of aging at home or residential surroundings within the company of familiar people given both the psychological and monetary benefits of doing so. But often times, seniors wishing to do so have no option but to live alone or face social isolation exposing them to psychological stress, and accidents or threats. To counter these vulnerabilities of aging alone, there exist several categories of technologies which promote safe aging among seniors. Below is a synopsis of significant work in this area.

2.2. Related Work

<u>Home and Personal Monitoring Systems:</u>

A large number of such systems provide sustainable independent living solutions to the elderly, and are able to monitor their daily activities, provide regular and continued assessment of their physical and cognitive health, and generate automated alerts during emergency times. Some of these systems can diagnose health conditions by monitoring just a single activity such as the work done by Nambu et al. [12] which monitors TV watching among users. The smart cane developed by Wu et al. [13] can inform elderly users of fall risks by studying their cane usage and walking patters. The project IMMED

[14] monitors instrumented activities of daily living (IADL) in dementia patients using a wearable camera.

Eklund et al. [15] as part of SensorNet (Fig 2.1) deploy a heterogeneous wireless network (WSN) which integrates sensors to provide quality health and security to the elder citizen living at home. It provides privacy by providing remote monitoring privileges only to authorized and authenticated care givers, supports heterogeneous devices and provides alerts to care givers in the event of an accident or acute illness, and most significantly it secures data by performing local computation.

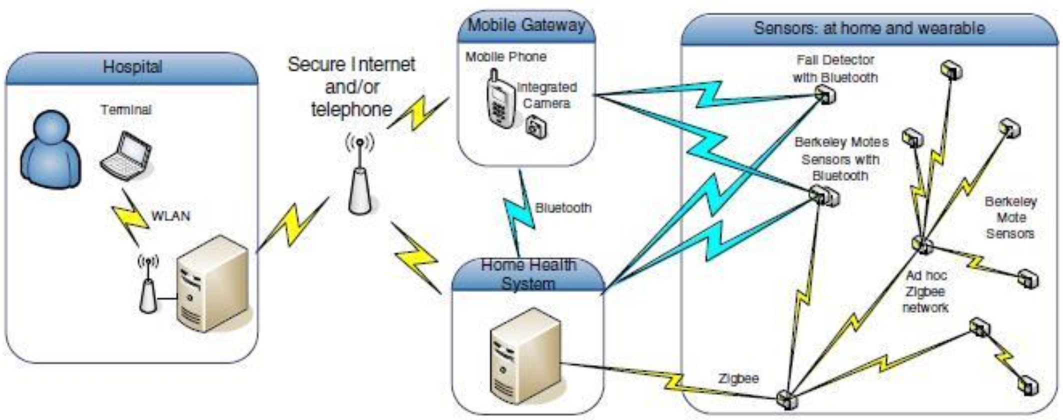

Figure 2.1 SensorNet - part of the ITALH Smart Home Project

The system features two types of sensors: 1) Telos Rev B Mote 2) Wearable Accelerometer based fall sensing device. Data or alert signals are forwarded to the outside world through either the mobile gateway or the Home Health Gateway.

The Emergency Response actions based on the alert signals include: *querying the user status*, *storing or forwarding the data*, or *placing a telephone call to inform the neighbor or healthcare service*. Both Bluetooth and ZigBee (802.11.4) protocols are supported within the system. The Berkley motes communicate within themselves or with the Home Health Gateway using ZigBee protocol, while all communication to the Mobile Gateway whether coming from ZigBee Motes or Fall-Detector Sensor happens through Bluetooth. Internet connects both the gateways to the Hospital or Emergency Monitoring Service.

Positives:

- **Bandwidth saved**. Only useful data transmitted once in a while.
- **Data Privacy**. User related data not transmitted. Only that related to system events or alerts, Encrypted Data.

Negatives:

- **Increased Costs**. Gateway devices required.
- **Increased Complexity.** Multiple Communication Protocols involved. Greater No. of hops from source to destination.

AMON [16] is a wearable wrist worn monitoring device developed for high-risk cardiac/respiratory patients which performs unobtrusive, continuous, long-term monitoring without interfering with patients daily activities or restricting their mobility. Some features include continuous collection and evaluation of multiple vital physiological signatures, multi-parameter medical emergency detection, and connection to the nearest medical center through cellular networks. (Figure 2.2)

Positives:

- **Mobile & Portable**. These are extremely easy to use and carry around.

Negatives:

- **User Discomfort**. Longer usage may cause skin irritation, rashes.

Figure 2.2 AMON- Wearable Prototype

LifeShirt [17] is a data acquisition and processing platform consisting of a garment, a data recorder, and PC-based analysis software. It consists of sensors integrated with the LifeShirt garment for continuously and consistently monitoring respiration, Electrocardiogram, activity and posture apart from other functions like pulse oximetry, Electroencephalogram/ Electrooculography measurements, blood pressure, temperature, and acoustic monitoring. (Figure 2.3)

Positives:

- Innovative solution.

Negatives:

- **Social Stigmatization**. May not be acceptable to the fashion conscious**.**

Grantham K.H. Pang [18], Department of Electrical and Electronic Engineering at the University of Hong Kong develop a Health Monitoring System to aid elderly people living alone (Fig. 2.4). Bluetooth technology used is to send a signal from the fall sensor to the Tablet which can share data with the outside world or upload data to a web server through Wi-Fi or 3G. The sequence of events which happen when an accident occurs is as follows:

- Signal Activation received by tablet.
- Upload to Internet and portal via Wi-Fi/3G.
- Automated phone call or message to tablet for confirmation.
- Notice to personnel and confirmation.
- Emergency call for assistance and dispatch of vehicle, or other assistance.

<u>Positives:</u>

- No. of hops minimized.
- User Friendly Web User Interface.
- Data from multiple devices such as Glucometers, thermometer, blood pressure monitors can be uploaded and tracked.
- Use of 3G/ Wi-Fi enabled Tablet as Gateway Device. No need for costly proprietary translator/ gateway.

Jeon et al. [19] developed a portable and low-cost fall detector using a 3 axis accelerometer as the sensor. When a fall is detected, the PERS inbuilt immediately generates a system alert to which the user must respond with some action. If within the stipulated time, there is no activity from the user, a message is immediately sent to the monitoring center asking for help.

Aghajan et al. [13] have developed a fall detection system to assist vulnerable people to reduce the occurrence, and associated consequences of accidents at home. A wireless sensor network (WSN) is used for smart home monitoring while a distributed vision-based analysis is used to detect occupant's posture. Feeds from multiple cameras are provided to a collaborative reasoning function to determine significant events. This way, the system can assess situations, anticipate problems, produce alerts, and provide explanations and advise to carers.

Negatives:

- **Privacy intrusion Concerns.**

Figure 2.3 LifeShirt – A Smart Garment

- Elderly individuals not amiable to the idea of being monitored through Smart/ IP Cameras or Video Sensors.

Figure 2.4 A Personal Emergency Response System by Pang

Video Monitoring and Surveillance systems have huge potential as independent living solutions, letting family care-givers check elderly relatives or their home surroundings while away. These days, such systems allow only authenticated users to log on to home camera systems through smartphone applications thus allowing more convenience. Fleck et al. [20], have designed a video monitoring platform based on distributed system architecture using network of smart cameras which are tasked with performing geo-referenced tracking and activity recognition. Fall detection is taken as an example to demonstrate the functioning of their system.

<u>Positives:</u>

- Home or Periphery Monitored using **gadgets of everyday use** such as Smartphones.
- Only **authenticated users** allowed access to Home Camera Systems.

An example of a commercial success in the category of video monitoring is Netgear's VueZone [21].

The Ubiquitous Home project [22] uses passive infrared (PIR) sensors, cameras, microphones, pressure sensors, and RFID technology for monitoring older adults. Most of these smart home platforms, employ ubiquitous computing techniques and provide environments augmented with computational resources that provide information and services whenever required, as and when data becomes available. The needs of people form the foremost priority in such digital environments with heterogeneous devices, inter-connected within a network coordinating together to serve these needs and provide for a holistic user experience.

Negatives:

- **Use of Passive Sensors.** Privacy not encroached upon. Monitoring from a distance, no need to be body worn.

Personal Emergency Response Systems:

Personal Emergency Response Systems are special class in Aging Technologies which either function independently or form integral part of products and mechanisms like Smart Homes, Video Surveillance Systems or Fall Detectors discussed above.

The Federal Trade Commission (FTC) in its document 'FTC Facts for Consumers' [23] defines a Personal Emergency Response System (PERS) as follows –

"An electronic device designed to help a disabled or an older person living alone".

Figure 2.5 illustrates the system diagram from the work of Douglas Pierce & Jeffrey S. Prough [24], credited as being inventors of the very first Personal Emergency Response Systems.

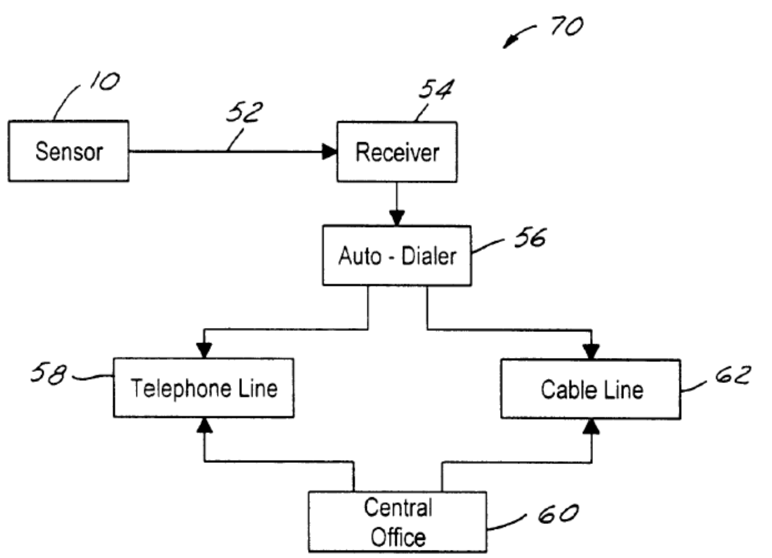

Figure 2.5 First Generation PERS System Diagram

The first and most primitive Personal Emergency Response Systems consisted of three components: an elder-worn panic button, a speaker-phone/ console and a central monitoring service. When the elderly person pushed the panic button, a radio signal was sent to the speaker-phone/console, causing the console to call a pre-programmed telephone number over a conventional telephone line.

An example of a first generation PERS system is 'Safety Bell' [25] - an initiative of Senior Citizen Home Safety Association (SCHSA) and provides emergency support services for elderly citizens. In order to speak to the operator, the user is required to press the main unit or the portable remote trigger device during an emergency situation.

<u>Negatives:</u>

- The elderly had to be within close range of the speaker phone; otherwise it was assumed that he was unconscious and emergency services were summoned unnecessarily.
- Sometimes while taking a nap, button would get accidentally pushed, raising false alarms.
- Paying for the central monitoring service, was an expensive proposition.
- The need for a landline phone/ console itself was an impediment.

Waraporn et al. [26] proposed a prototype called Community Warning System Services, using Session Initiation Protocol technology to enable civilians to share such information to Control Center. Control Center can accumulate evidences of emergency cases and make the right call to emergency response teams. This is an improvement over usage of legacy phone systems used in previous generation PERS.

<u>Positives:</u>

- Session Initiation Protocol (SIP) used instead of conventional PSTN telephony services.

<u>Negatives:</u>

- **Manual reporting of incidents/ events.** Not reliable enough. Should have been augmented by sensors.

Michael K. Dempsey [27] in his work designs a PERS which does not require a central monitoring service. This eliminates the need to levy monthly charges. His system also contains all the necessary information and intelligence required to summon aid and communicate with a standard, unmodified, commercial-off-the-shelf (COTS) telephone or communication device; further reducing cost or complexity.

Positives:

- Role of Central Monitoring Services terminated, resulting in **Cost Savings**.
- Chances of being helped during emergency situations **increased**.

Samraj et al. [28] use a glove to communicate to the Emergency Response System through hand gestures, thereby nullifying the role of physical buttons.

Positives:

- Communication to Console through Gestures.
- Role of Physical Buttons Eliminated.
- Chances of False Alarms minimized.

Chances of the senior being helped on time by emergency teams considerably increased.

Table 2-1 gives a side by side comparison of two Commercially Available Personal Emergency Response Systems: AT&T EverThere [29] and Philips Go LifeLine [30]. Associated monthly fee, and the need to buy specialized devices reduce the utility of such products.

Table 2-1 Comparison between AT&T EverThere and Philips Go Life

AT&T EverThere	***Philips Lifeline Go***
• Portable device with call button • Hands-free voice communication with the care center • Internal accelerometer to automatically determine a fall • GPS for instant Location determination.	• Water-proof pendant with help button. • Pendant is on cellular mode in outdoor settings. • Calls made through in-home communicator in indoor settings. Cellular mode switches off.

Social Engagement Tools:

Social engagement tools provide users with an opportunity to ask about health concerns, interact and learn from peer groups about health conditions or issues that they might be faced with. The end goal is to leverage internet and social media technologies to gain knowledge about health and to create an atmosphere of social connectedness and positive psychological and physical health of the elderly. Reports have showed increased usage of social networks and internet among seniors [31]. Also demand for smart tools that promote the feeling of social belongingness among seniors is expected to rise considerably in the coming years and will significantly reduce the ill effects of 'aging in loneliness'. An application this technology is demonstrated in the work by Rowan et al. [32] in which a familiar household object, the picture frame, is populated with iconic imagery from memorable moments that occurred during the last 28 days of a person's life. Another product, SenseCam, by Srinivasan et al. at Microsoft, captures a digital record of the wearer's day in terms of a series of images and a log of sensor data [33].

<u>Anomaly Detection Algorithms</u>:

Anomaly detection refers to the technique of finding patterns in related data that obeys expected behavior [34]. Many anomaly detection techniques such as clustering-based methods, statistical methods, and information theoretic methods, exist which are extensively used to formulate emergency detection algorithms integrated into video surveillance, home monitoring, or fall detection systems integrated to smart homes. Anomaly detection has previously been used for detecting wandering patterns or hazardous situations using several types of heuristic methods based on spatiotemporal information [35], classification [36], and goal analysis [37].

We devise our anomaly detection function based on the work of Mukhopadhyay et al. [38] in which they define two wellness functions β1and β2 used to estimate the well-being of seniors from data gathered from daily usage of house hold appliances. While the first function (β1) is deduced from the non-usage or inactive duration of the appliances, the second function (β2) is deduced from over-usage of a few specific appliances. Both the equations from their work are denoted below:

Wellness Function 1, $\beta 1 = 1 - t/T$

Where, β1 = Wellness function of the elderly based on the measurement of inactive duration of appliances t = Time of Inactive duration of all appliances (i.e.) time during which no appliances are used.

T = Maximum inactive duration during which no appliances are used, leading to an unusual situation

If β1 = 1.0 that indicates the elderly is in healthy wellbeing situation.

If 0.5 < β1 < 1.0 the situation indicates some unusual situation.

If β1 < 0.5 then care is required.

Wellness Function 2, $\beta 2 = 1 + (1 - \frac{Ta}{Tn})$

Where β2 = Wellness function of the elderly based on excess usage measurement of appliance.

Ta = Actual usage duration of any appliance.

Tn = Maximum usage duration use of appliances under normal situation.

Under normal condition, Ta < Tn; No Abnormality

Only if Ta > Tn then β2 is calculated using the eq. (2).

The value of β2 close to 1 to 0.8 or so may be considered as normal situation. If β2 goes less than 0.8, then it indicates the excess usage of the appliance corresponding to an unusual situation.

2.3. Problem Statement

As discussed in previous chapters, most of the work done in developing gerontological tools have resulted in a wide variety of products in different categories such as video surveillance, home monitoring, and fall detection which help the older adults with different aspects of their daily lives, but suffer from the a variety of problems:

False Alarms – This is mostly due to the presence of hard ‘Panic Buttons’ in conventional or some of the new age PERS. Accidental Pushes by elderly persons can trigger alarms, thereby unnecessarily involving the attention of emergency services.

Requirement for manual operators – Manual operators in emergency response centers need to be paid for. This creates the need to charge monthly fee to the user.

Land Phones, gateways, tele-health hubs or other extra hardware – also adds to overall costs.

Complicated user interface or design - Cognitive or physical ability to perform tasks deteriorates with age. Cluttered design adds to complexity, impacting the user's willingness to use such products.

More network hops - more points of failure. More network hops make these systems more vulnerable to data attacks since there are more points of intrusion.

Multiple Network Protocols - Adds to complexity. Need for translator/ gateway devices adds to costs.

Not pressing the button when unconscious– Can delay emergency responders from reaching the elderly individual.

Data Privacy User’s Personal and Health related Data is maintained in public databases.

Chapter 3. The Proposed Solution: VCare

3.1. Overview

The system achieves multi-modal functionality through the use of software and hardware components. The current implementation supports three important features: 1) video surveillance to secure the periphery against threats like burglary, fire etc. 2) audio/ video interaction to let the seniors engage in social/ well-being related conversations with family members and care-givers 3) passive monitoring to check functional status of the inhabitant. We try to incorporate most of the positive points, and resolve some or many of the negative points as seen from other people's work as reviewed in Chapter 2.

Video Monitoring and Audio/ Video Interaction is achieved with WebRTC so as to achieve seamless communication between different devices having multiple OS. Use of such a freely available technology will minimize the total running costs involved. Also, being cross-platform WebRTC saves the user from the need to buy specific devices. He/ she can utilize the smart gadget he/ she has as our application can work on any gadget of everyday use such as phone, tablet, or PC. The only requirement is that of a standard camera which we believe is commonly available in most of these devices.

For passively monitoring elders, we employ pressure, bend, and occupancy sensors. We foresee that using passive sensors as opposed to bio or video/ camera sensors will make our product more acceptable to elders. This is due to the fact that such sensors do not require to be worn by the user causing discomfort, or do not create privacy concerns.

The sensors in the system are also connected directly to the cloud through Wi-Fi modules. This is done with the aim to reduce the number of network hops which is synonymous to reducing the number of vulnerable points for attackers to attack on. Also, this reduces the number of '*points of failure*' and results in improved efficiency. We deviate from the previously observed norm of using multiple protocols such as ZigBee and Bluetooth in VCare. The objective of doing so is to avoid the need to buy costly gateway devices to translate between different protocols and also to reduce the complexity.

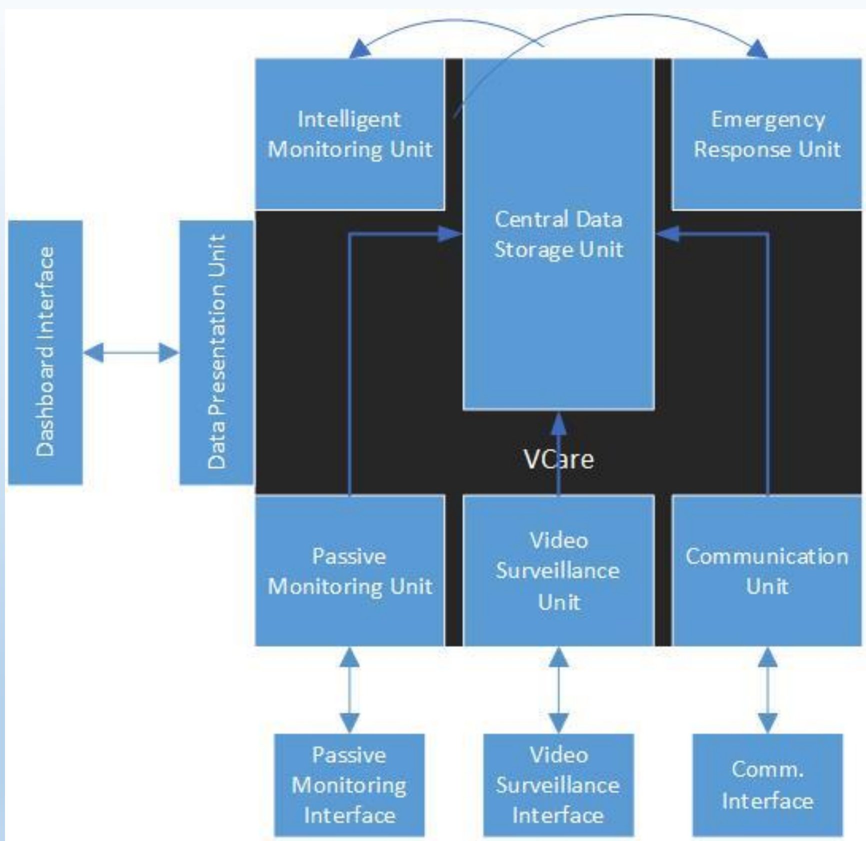

Figure 3.1 System Block Diagram

Another issue, which we try to solve is the effect of having a physical ‘panic’ button. This is done by providing a ‘soft’ panic button in the User Interface itself. Having a button implemented in software minimizes the chances of accidental push by the user, and therefore of false alarms. Also our system, being more intelligent, can take decisions to inform whoever needs to be informed through email or phone calls, even if the user is not able to press the button. The use of ‘*soft phone*’ or email to link the seniors to the outside world, zeroes the use of a land phone as exhibited by many other systems, causing further cost savings.

The problem of complex User Interface is solved by having Big Fonts, Big Buttons with clearly marked texts, White Back Ground throughout. Also steps to achieve Goals for e.g. to **make a call to the physician** are kept extremely low. Only information critical to the task is presented keeping in mind that the Cognitive or perceptual to perform tasks which require major understanding deteriorates with age. No special effort is required either on the part of the care-giver or the care-recipient to learn to use the UI.

Having a dashboard which presents all data in meaningful format, allows for more effective decision-making and effective care-support. This can empower the informal care-givers, neighbors, and others. And reduce the role of emergency services.

Data is saved on the cloud, and discarded after use. This ensures privacy and prevents unnecessary wastage of storage space.

3.2. System Components

The system block diagram is shown in Figure 3.1.

Communication Unit (*CU*): This Unit lets the user communicate/ be communicated with using the soft phone in the system. This unit also sends emails in case of distress.

Video Surveillance Unit (*VSU*): This Unit secures the user by using the camera/ vision sensors in tab, smartphone, or PC.

Passive Monitoring Unit (*PMU*): This unit is used to monitor the user for changing functional status utilizing the pressure, bend, and motion sensors in the system. This also consists of Wi-Fi modules which connect the sensors to the internet.

Emergency Response Unit (*ERU*): This unit alerts care-givers, fire responders or other people configured as emergency contacts in the system.

Intelligent Monitoring Unit (*IMU*): This unit tests the functional status by using the wellness equation on incoming data.

Central Data Storage Unit (*CDU*): This resides on the cloud and is the store house for every kind of data flowing inwards into the system.

Communication Interface (*CI*): Lets the user control the Communication Unit.

Video Surveillance Interface (*VSI*): Lets the user control the Video Surveillance Unit.

Passive Monitoring Interface (*PMI*): Lets the user control the Passive Monitoring Unit.

Dashboard Interface (DI): Lets the user view the system results, and configure system settings.

3.3. System Working

The elderly person is secured by a net created around him/her by the passive monitoring unit (pmu), video surveillance unit (vsu) and the communication unit (cu). The *pmu* consists of pressure, bend, and occupancy sensors needed to monitor a person during sleep. The sensors are connected to the internet through Wi-Fi modules attached to them. The *vsu* consists of camera enabled smart phones, tablets or web-cam enabled PC or laptops with Wi-Fi/ 3G capability. The *cu* also consists of the same smart gadgets or laptops and PCs with the same features as those used in *vsu*.

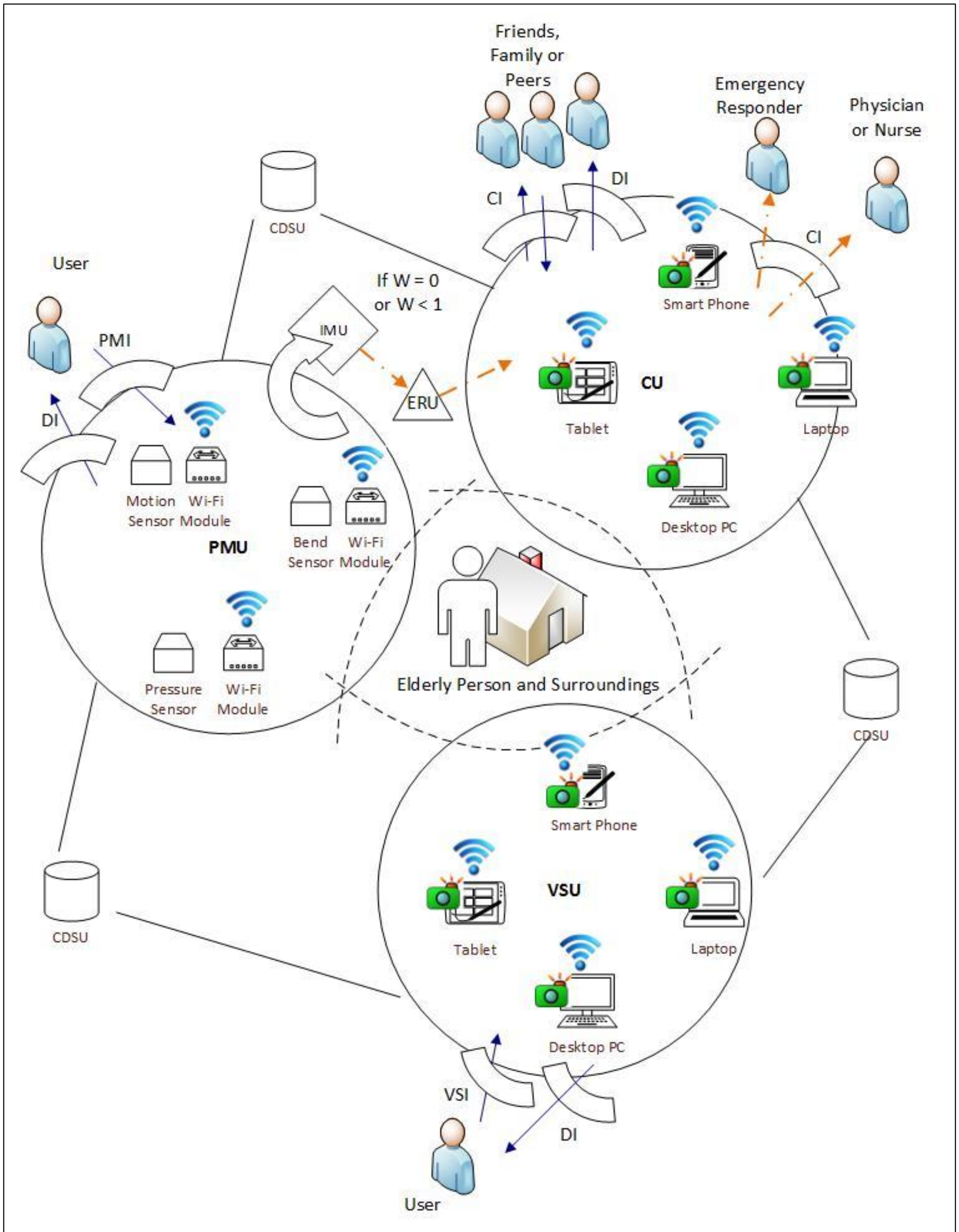

Figure 3.2 System Architecture Diagram

All the four interfaces namely passive monitoring interface (pmi), video surveillance interface (vsi), communication interface (ci), and dashboard interface are web-based interfaces. While *pmi*, *vsi*, and *ci* are used to control the respective units, the *di* is used to view system results, get insights into the well-being of the individual person or to configure system settings.

The pmu sensors collect data and send it to over to *cdsu* to be stored in string format for limited duration. Also, the same data is sent to imu for analysis using the wellness equation. In case, of an emergency the *imu* immediately activates the *eru*, which in turn sends an alert to subscribed contacts through the communication interface.

Data collected by *vsu* is stored in the form of binary large objects or **blobs** in *cdsu*. Only authorized users can view the video feeds, which are deleted after regular intervals **t**.

The pmu also sends data to intelligent monitoring unit (imu) for it to be analyzed. *Imu* uses the anomaly detection algorithm based upon the wellness equation given in Section 3.5 of this Chapter. When the situation is determined to be abnormal, the imu alerts carers or family members through ci as shown in the Figure 3.2. If however the situation is found to be normal, no action is taken by *imu*.

3.4. Background Technology

3.4.1. Video Surveillance & Audio/ Video Interaction

WebRTC or Web Real-Time Communication is a communication framework drafted by the World Wide Web Consortium (W3C) [39] that supports browser-to-browser applications for voice calling, video chat, and P2P file sharing. WebRTC provides better ease of use and higher security than most currently available commercial telephony systems. It also allows multiple devices with multiple OS having multiple browsers to communicate with each other using a common set of communication protocols. Figure 3.1 shows the complete architecture of the WebRTC, with the underlying protocols.

To acquire data and transmit it over the network, WebRTC used the following Application Programming Interfaces (APIs):

MediaStream: get access to data streams, such as those from the user's camera and microphone.

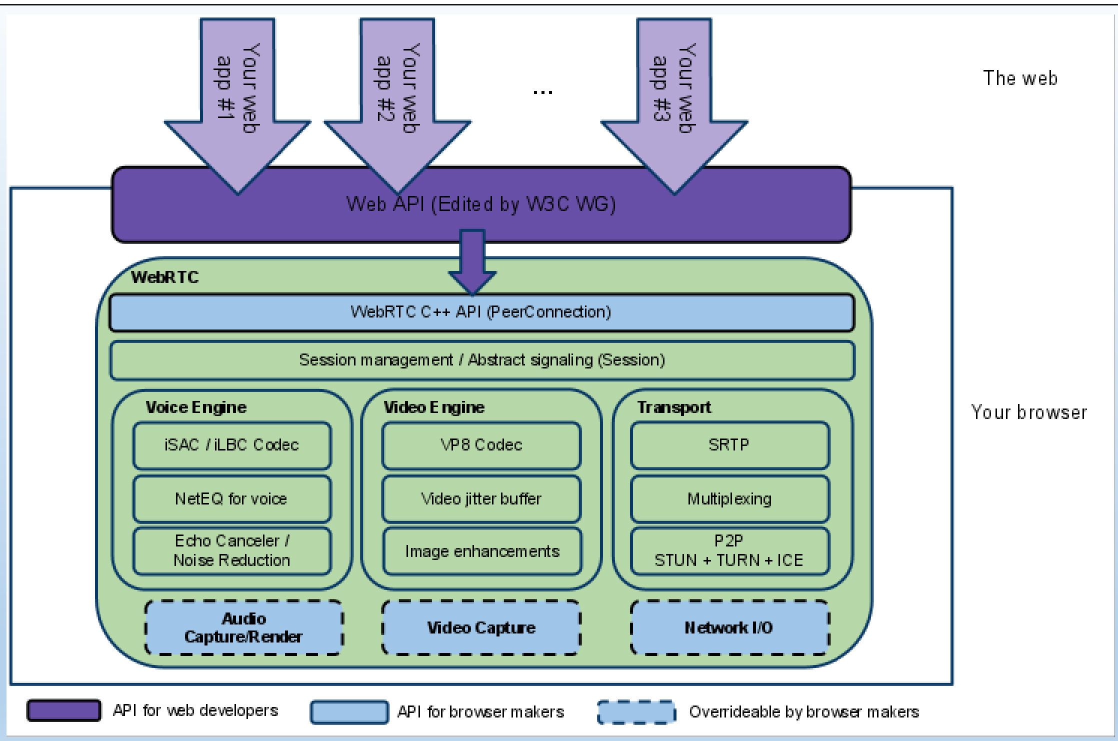

Figure 3.3 WebRTC Architecture [42]

RTCPeerConnection: audio or video calling, with facilities for encryption and bandwidth management.

RTCDataChannel: peer-to-peer communication of generic data.

Apart from the above, WebRTC also requires a mechanism to coordinate communication and to send control messages, a process known as **signaling**. The protocols of signaling are not specified by the WebRTC specification, which is why we need to rely on third party Servers for our signaling requirements. We use a Signaling Service Called onSIP for our purpose.

Signaling

Signaling is used to exchange three types of information.

- Session control messages: to initialize or close communication and report errors.
- Network configuration: computer's IP address and port.
- Media capabilities: codecs and resolution specifics of the ‘caller’ and ‘callee’ browser.

Exchange of network and media information

- Alice creates an RTCPeerConnection object with an ICE candidate handler.
- The handler is run if and when n/w candidates become available.
- Alice sends serialized candidate data to Bob, via the signaling channel e.g. WebSocket.
- When Bob gets a candidate message from Alice, he adds the candidate to the remote peer description.

WebRTC clients (known as peers – e.g. Alice and Bob here) also need to discern and exchange local and remote audio and video media information, such as resolution and codec capabilities. Signaling to exchange media configuration information proceeds by exchanging an 'offer' and an 'answer' using the Session Description Protocol (SDP).

- Alice creates an offer, adding her local session description.
- This session description is sent to Bob via their signaling channel.
- Bob sets the description Alice sent him as the remote description.
- In this step Bob sets up an answer, saving the remote description he got from Alice, so that a local session can be generated that is compatible with hers. Also he adds his own local description to the answer so as to send it to Alice.
- When Alice gets Bob's session description, she sets that as the remote description on her end.
- Data begins to flow.

Major Challenge in Signaling:

Signaling in WebRTC involves a major challenge. This is due to the fact that most often, public computers or ip Devices are behind Firewalls requiring NAT. In such scenarios, it is difficult for the device to get its network or ip configurations. To cope with NAT traversal and other network vagaries STUN protocol and its extension TURN are used by WebRTC.

Interactive Connectivity Establishment (ICE) is the framework used by WebRTC for connecting to peers, such as two video chat clients. Initially, ICE tries to connect peers directly, with the lowest possible latency, via UDP. In this process, STUN servers have a single task: to enable a peer behind a NAT to find out its public address and port.

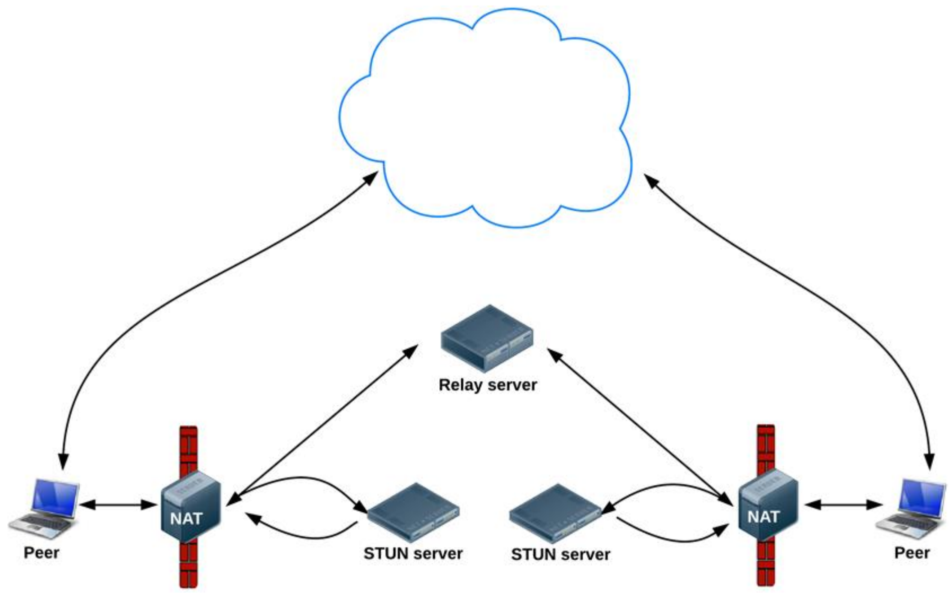

Figure 3.4 Network Configuration and Initiation

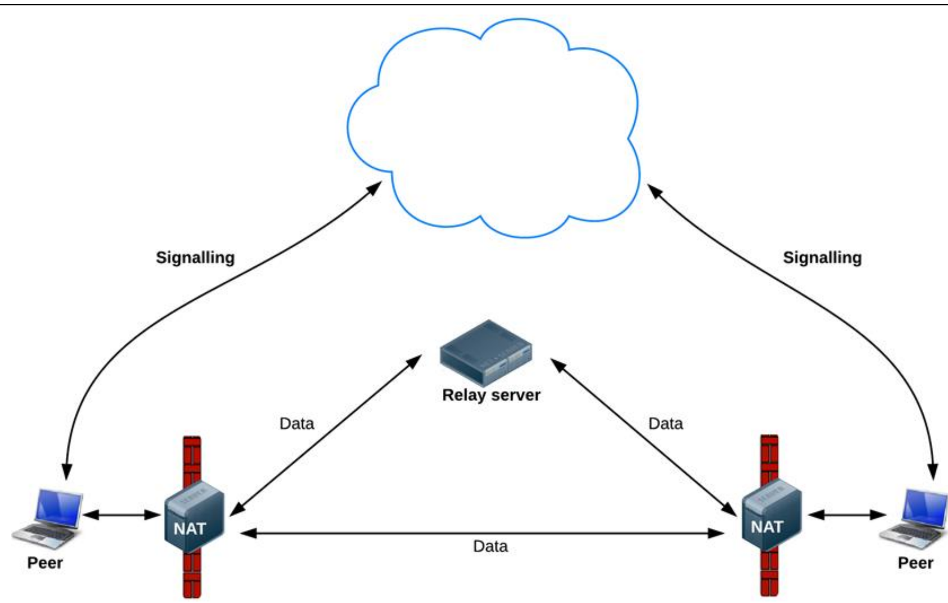

Figure 3.5 Data Flow

If UDP fails, ICE tries TCP: first HTTP, then HTTPS. If direct connection fails, particularly because of enterprise NAT traversal and firewalls, ICE uses an intermediary relay TURN server. In other words, ICE will first use STUN with UDP to directly connect to peers and, if that fails, will fall back to a TURN relay server.

Network peer finding stage is illustrated in Figure 3.2 while the data exchange as it happens after successful peer discovery is shown in Figure 3.3.

Network Topology

WebRTC as currently supports one-to-one communication, but when used in more complex network scenarios: for example, with multiple peers each communicating each other directly, peer-to-peer, or via a Multipoint Control Unit (MCU).

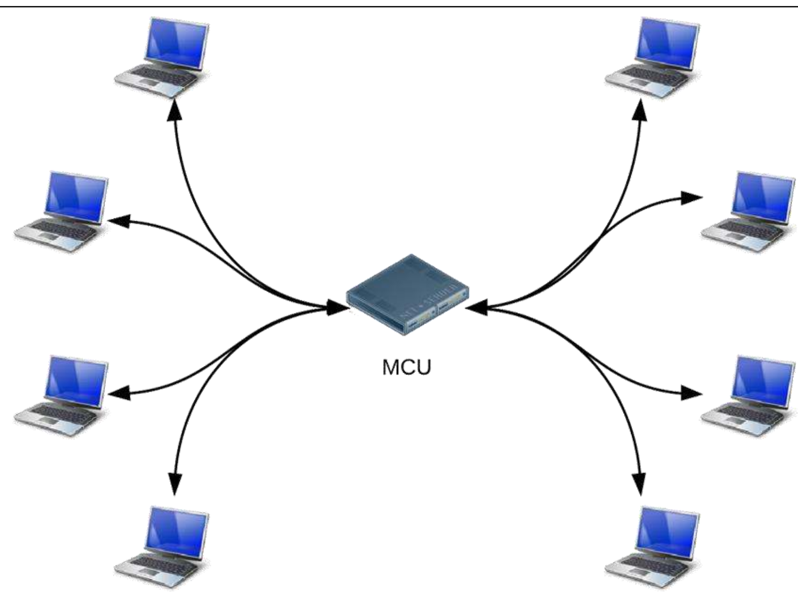

Figure 3.6 Network Architecture

MCU is a server that can handle large numbers of participants and can do selective stream forwarding, and mixing or recording of audio and video. Figure 3.4 shows the network topology.

3.3.2. Storage and Web Hosting Requirements

For our hosting and data storage needs, we depend on Microsoft Cloud Azure which is a cloud computing platform and infrastructure, for building, deploying and managing applications and services through a global network of Microsoft-managed datacenters.

3.4.2. Hardware used in Passive Monitoring Unit

Pressure Sensor

A pressure sensor typically measures pressure, of gases or liquids. Pressure is the force required to stop a fluid from expanding, and is usually stated in terms of Force/Area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed, and generates a signal which is electrical in nature. These sensors are used for controlling and monitoring thousands of applications in today's world.

Figure 3.7 A Digital Pressure Sensor

Some like piezoelectric sensors can sense high speed changes in pressure, while others are found in traffic enforcement cameras, which function in a binary (off/on) manner, i.e., when pressure is applied functioning as some sort of pressure switch.

Bend Sensor

Bend sensors or Flexion sensors, measure the amount of deflection caused by bending the sensor. There are numerous ways of sensing deflection, out of which the three most common types are:

- conductive ink-based
- fiber-optic
- conductive fabric/thread/polymer-based

Bending the sensor beyond a certain point or angle may permanently damage the sensor. Instead, they are to be bent around a radius of curvature. The smaller the radius of curvature and the more the whole length of the sensor is involved in the deflection, the

Figure 3.8 A Bend Sensor

greater the resistance will be as compared to the resistance if the sensor is fixed at one end and bent sharply to a high degree.

<u>Occupancy/ motion Sensor</u>

A **motion detector** detects moving objects, particularly people and it is often integrated with a system that automatically performs a task or alerts a user of motion in an area. Motion detectors form an indispensable component of security, automated lighting control, home control, energy efficiency, and other useful systems.

Most standard motion detectors can detect motion up to distances of at least 15 feet (5 meters). Tomographic motion detection systems have much higher range because the radio waves are at frequencies which penetrate most walls and obstructions.

Motion detectors have found large scale use in domestic and commercial applications, and sometimes used in lieu of a true occupancy sensor in automating street lights or indoor lights in walkways. Very often, they form part of a burglar alarm which alerts the home owner or security service when motion of a possible intruder is detected. Such a detector may also trigger a security camera in order to record the possible intrusion.

Figure 3.9 A Motion Sensor

Android Tablets

Samsung Galaxy Tab

The Galaxy Tab 2 used in our work has a front-facing VGA camera, and a standard rear camera. It features TI OMAP4430 1.0 GHz dual-core chip set, and support for 3G/ Wi-Fi.

Laptop PC

The laptop used as our base station has the following specs:

Windows 8

AMD A6-1450 Quad-core 1 GHz

29.5 cm (11.6") HD (1366 x 768) 16:9

AMD Radeon HD 8250 with Shared Memory

4 GB, DDR3L SDRAM

500 GB HDD

3.4.3. Coding Tools Used

IDE – Microsoft Visual Studio

Microsoft Visual Studio is an integrated development environment (IDE) used to develop computer programs for Microsoft Windows, as well as web sites, web applications and web services. It can produce both native code and managed code, and supports multiple programming languages and frameworks. Most of our Front End and Back End code has been written using VS because it has many helpful features for the coder. Also the built-in designer was extensively used to design the GUI for our web applications. Some features like auto code completion, easy code refactoring, easy options to deploy code to database and the cloud were found extremely useful during our endeavor.

Back End Code– ASP.NET

ASP.NET is an open source server-side Web application framework designed for Web development to produce dynamic Web pages. We followed the ASP.NET MVC, framework to write most portion of the back end Code. For database queries, we utilized Microsoft's Entity Framework.

Front End Code – JavaScript, HTML5, CSS

JavaScript is a dynamic computer programming language. It is most commonly used as part of Web browsers, whose implementations allow client-side scripts to interact with the user, control the browser, communicate asynchronously, and alter the document content that is displayed. The syntax of JavaScript is actually derived from C, while the semantics and design are influenced by the self and Scheme programming languages. It was used to write the logic behind user controls.

HTML5 is a core technology markup language of the Internet used for structuring and presenting content for the World Wide Web. It was used to give shape or form to the user controls.

Cascading Style Sheets (CSS) is a style sheet language used for describing the look and formatting of a document written in a markup language. While most often used to change the style of web pages and user interfaces written in HTML and XHTML, the language can be applied to any kind of XML document, including plain XML, SVG and XUL. Along with HTML and JavaScript, CSS is a cornerstone technology used by most websites to create visually engaging webpages, user interfaces for web applications, and user interfaces for many mobile applications. It was used to style the user controls.

Sensors API

The API documentation given in [40], was referred to program the passive sensors to interact with the cloud.

Authorization: Every request must contain an Authorization http header bearing an auth token.

Example:

```
curl -i -XGET -H "Authorization: Bearer foobar" ...
```

Accept: Every request should specify an Accept header that pins the api version.

Available versions are:

master [default]

v2

v1

Example for v2:

```
curl -i -XGET -H "Accept: application/vnd.littlebits.v2+json"
```

GET Device id:

```
curl -i -XGET -H "Authorization: Bearer TOKEN" -H "Accept:
application/vnd.littlebits.v2+json" https://api-
http.littlebitscloud.cc/devices/DEVICE_ID
```

Returns an Array of device objects:


```
[
  {
    "id": "000001",
    "label": "000001",
    "subscribers": [],
    "subscriptions": [],
    "user_id": "1",
    "wifi": {}
  },
  {
    "id": "000002",
    "label": "000002",
    "subscribers": [],
    "subscriptions": [],
    "user_id": "1",
    "wifi": {}
  }
]
```


Output: Device output is always a POST request

```
Example command : curl -i -XPOST -H "Authorization: Bearer TOKEN" -H "Accept:
application/vnd.littlebits.v2+json" https://api-http.littlebitscloud.cc/devices/DEVI
```

POST

```
? percent
  | <Int:Range:0-100>      —— a percent of the maximum current output
  – default: 100

? duration_ms:
  | <Int>                  —— output will be sustained for given milliseconds
                           – if the duration_ms is `-1` it will last forever or until another
output is received by device
  - maximum value: 32000
  - default: 3000 (3 seconds)
```

3.4.4. Storage and Hosting

For our hosting and data storage needs, we depend on Microsoft Cloud Azure Suite of Technologies which is a cloud computing platform and infrastructure, for building, deploying and managing applications and services through a global network of Microsoft-managed datacenters.

3.5 Anomaly Detection Algorithm

The passive monitoring unit uses an anomaly detection algorithm based on the Wellness Equation which previously had been mentioned as being one of the contributions of our work.

Rather than using time duration, we use number of occurrences of an activity carried out to determine well-being of an individual. Let us assume that a person when healthy performs an activity a fixed number of times per unit duration. This can be marked as N. While monitoring let us say that the number of times that the same individual performs the same activity during the same unit duration is n. **We hypothesize** an increase of greater than 70% or a reduction in less than 70% to be indicative of an individual's well-being.

Therefore, we define the wellness factor, $\boldsymbol{W}$ as follows:

Wellness factor, $(\boldsymbol{W}) = 1 - (\mathbf{n} / \mathbf{N})$

Where,

n = no. of occurrences of an activity during monitoring,

N = no. of occurrences of an activity during when a person is healthy.

We set 70% as the threshhold for the algorithm to generate the alarm signal. Meaning, when n is 70% more or 70% less than N that triggers *imu* to send an alert input to *eru* in order for it to know that something is wrong, and the care-givers or family members need to be informed.

Therefore the lower threshhold is given as:

If $n = N + 0.7\,N$ or $n = 1.7N$

Then, $W = 1 – 1.7N/ N$

Or ***W = -0.7***

Likewise the upper threshhold is given as:

If $n = N – 0.7\,N$ or $n = 0.3\,N$

Then, $W = 1 – 0.3N/ N$

Or ***W = 0.7***

Which allows us to conclude that during abnormal times $W>0.7$ or $W<-0.7$, and during normal times $-0.7< W< 0.7$.

Chapter 4. Results

4.1 Discussion – Passive Monitoring Unit & Anomaly Detection Algorithm

The passive monitoring unit (pmu) was used to conduct tests and to determine the wellness factor (*W*). Sleep was chosen as an activity which is the reason motes were placed around the bedside of the volunteer as shown in the image (Figure 4.1). Data was collected for a total duration of 7 hours of which the first hour was used to train the system in order to set **N** to a fixed value. This was done for all three motes namely motion (1), pressure (2), and bend (3). Table 4-1 shows the location of the motes, the duration the test. Table 4-2 shows the data that was used to train the system for normal situations. The motion sensor reported most of the readings (average of 53 events), while the pressure and the bend sensors reported lesser events in comparison. Most of the calculated values of W lie between the desired range of -0.7 to +0.7 but on three occasions, W was found to be lying in the abnormal zone (Table 4-3). This is because the two motes on those instances did not record any reading. However, since the motion sensor's readings in those occasions suggest that the volunteer had been moving during that time. Since the algorithm polls ***W***s from all sensors before triggering an alarm through *eru* that is the reason why a distress signal was not generated.

Figure 4.1 Mote 1 (Motion), Mote 2 (Pressure) & Mote 3 (Bend) in Passive Monitoring Unit.

Table 4-1 Placement of Sensors and Run Time

Mote ID	Connected to	Type of Sensor	Time of Usage	Annotated Activity	Runtime
1	Facing Bed	Motion	Night	Sleep (SL)	7
2	Under Bed	Pressure	Night	Sleep (SL)	7
3	Between Bed & Wall	Bend	Night	Sleep (SL)	7

Table 4-2 Training Data

Mote ID	Time Slot	No of Events (N)
1	4/18/2015 @11:00 p.m. – 11:59 a.m.	46
2	4/18/2015 @11:00 p.m. – 11:59 a.m.	15
3	4/18/2015 @11:00 p.m. – 11:59 a.m.	2

Table 4-3 Readings for n, and calculated Wellbeing Factor (W) for each sensor.

Time Slots	Mote ID (m1)	No of Events (n1)	W1	Mote ID (m2)	No of Events (n2)	W2	Mote ID (m3)	No of Events (n3)	W3
4/19/2015 @12:00 a.m. – 1:00 a.m.	1	46	0.061	2	11	0.266	3	3	-0.5
4/19/2015 @1:00 a.m. – 2:00 a.m.	1	66	-0.35	2	11	0.266	3	0	1
4/19/2015 @2:00 a.m. – 3:00 a.m.	1	49	0	2	12	0.2	3	2	0
4/19/2015 @3:00 a.m. – 4:00 a.m.	1	49	0	2	0	1	3	2	0
4/19/2015 @4:00	1	60	-0.22	2	12	0.2	3	0	1

a.m. – 5:00 p.m.									
4/19/2015 @5:00 a.m. – 6:00 a.m.	1	49	0	2	15	0	3	3	-0.5

4.2 System Comparison

In this section we have picked three innovative solutions that have been developed in the area of monitoring and emergency response systems and compare them side by side with our own system VCare.

The work of Grantham Pang [18] minimizes data traversal in the network to preserve user privacy and save bandwidth, and data transmission is avoided unless absolutely necessary. Furthermore, only authenticated users have access to the system. Communication in the system requires 3G/ Wi-Fi/ Bluetooth support in the devices. A significant feature in this work is the provision of a user friendly web interface for people to upload data from various channels and view insightful renderings in the form of charts and graphs. Channels here refer to devices like digital thermometers, gluco-meters, pulse oximeters etc.

The work of Narongrit et al. [26] uses ip Cams, GPS and humans for information collection. The gateway is indirectly reached through an ip network. Communication channels include PSTN, Emails, Cell Phones, Soft Phones, ip Phones.

The work of Eklund et al. [15] ensures data privacy by transmitting encrypted data and using secure protocols. The sensor motes use ZigBee to inter-communicate with each other and with the fixed gateway. Bluetooth is used by both motes and the Wearable Accelerometer to communicate with the mobile gateway device which in this case is a Nokia 6670.

VCare in comparison uses just Wi-Fi or 3G to connect to the internet in order to post important information collected from *pmu* or *vsu*. Also data privacy is provided by transmitting limited data like in Pang's case. Need for gateway or translator devices is eliminated by having the devices transmit data directly to the internet. This saves costs and also provides protection against data intrusion attempts. Compared to the works discussed, our web-interface is not device or OS specific. A direct comparison between our work and that of others is drawn in Table 4.1 below.

Table 4-4 Comparison Table between VCare and other similar systems.

Feature	***Grantham Pang***	***Community Warning System Services Using SIP***	***SensorNet***	***VCare***
Privacy	User related data not transmitted. Data transmitted only if explicitly asked for by authenticated users.	*NA*	Encrypted Data. Only useful transmissions.	Only useful data transmissions.
Communication Protocols	Bluetooth, Wi-Fi	NA	ZigBee 802.11.4	Wi-Fi 3G

	3G		Bluetooth	
Sensors	Fall Sensor	Ip Cams GPS Humans	Telos Rev B Mote Wearable Accelerometer based fall sensing device	Pressure, Bend Occupancy
Gateway	Android Tablet	No direct gateway. Control Center System → Ip Network → Gateway	Mobile Gateway: Nokia 6670/ 6680 telephone. Specs: Symbian OS, 3G/ Bluetooth. Role: Wearable Sensor sends data to this Gateway through Bluetooth.	NA (Directly connected to the cloud through Wi-Fi modules.)

			<u>Fixed Gateway</u>: Windows XP based PC Specs: Bluetooth/ ZigBee Role: Berkley Motes send data to this gateway.	
User interface	User can upload data from various channels to the user-friendly web portal. The channels could be : thermometer, blood pressure monitor, blood gluco-meter,	*NA*	*NA*	Three Interfaces namely video surveillance interface, passive monitoring interface, and communication interface to control the respective

	scale, oximeter with heart rate monitor etc.			units. The fourth interface helps to display system information and configure settings.
Communication Channels	Calls (*PSTN/ Cell Phones/ Soft Phones/IP Phones*) Emails.	*NA*	*NA*	Calls (*Soft Phones*) Emails

Chapter 5. Conclusion & Summary

Due to advancements in medical sciences during the past century, upping of health standards, and improvements in ‘quality of life’, the average life expectancy of the population has risen steadily while the death rates have dipped. This has caused a shift in the population balance, and countries around the world have or will have more seniors in their society than ever before. This rapid shift will give rise to a new phenomenon called ‘Population Aging’ and will negatively affect our ability to deliver quality care and good standards of living. As many of the seniors are having to live alone, higher are the chances of social disconnectedness and associated negative psychological impact. In addition, there are high chances of accidents from falls or cardiac seizure, or threats from fire or burglaries. Smart home monitoring and surveillance systems, mobile or personal emergency response systems, or fall detectors and smart garments are being extensively used to monitor the functional state and wellness of such seniors, and are able to alert the emergency worker or family members before an accident turns fatal. But many of these products, devices or solutions suffer from shortcomings like Complex UI, higher costs of hardware, associated monthly charges, and problems like False alarms due to presence of physical buttons in Emergency response gadgets. To overcome these shortcomings as well as to serve the needs for all those involved in the care-continuum including the elderly citizen himself, we need complete all-in-one solutions which not only serve the task they are assigned but also perform multi-modal functionalities. Such interventions will instill feelings of security and help to make the lives of elders much better than what they are without using them. It is foreseen that in the coming days the usage of such technology will increase considerably due to falling prices of broadband, internet and telecom technology plus cheap and easy availability of electronics technology. As such there is a huge market potential for 'aging in place' technologies, which will also play a major role in the coming days to counter the effect of 'population aging'.

Driven by the combined needs arising from the challenges posed due to population aging on current infrastructure and resources, plus the lack of solutions which are made keeping in mind cost/ privacy worry and cognitive & perceptual requirements of elderly people, we form a wellness equation which measures the wellness in people to determine their functional status, and alerts the care-givers or emergency aid workers, through our system before an emergency condition occurs. Our system can also be used as a tool to secure surroundings of the individual living alone from external threats, and connects the individual to his/her family members to reduce boredom or connects the individual to his/her doctors or care-givers so that he or she or she can be provided with online consultations/ tips for improving his/her health and wellness. The system provides features like:

'Soft' Panic Button – to minimize the chances of false alarms caused due to hard panic buttons.

'Soft' phone – to reduce system costs incurred.

Simple User Interface – to present information in a lot less complex way to care-givers and care-recipients.

Use of Passive Sensors – to make the user more willing to be monitored, since no requirement to wear or be deprived of privacy.

Data privacy, security & reliability–minimum n/w hops lessen the point of intrusions, reduce latency, points of failure etc.

Minimal Storage Requirements – Saving just the needed data and trashing unused data saves space.

Minimal running or maintenance costs – Use of freeware, less infrastructure, and sticking to use of everyday gadgets in place of burdening the user with having to buy specialized, task-specific and proprietary devices saves costs and minimizes or terminates the need for the user to pay monthly charges.

Social Connections improved – The user is not isolated from the society and benefits from interactions with family members, friends, relatives or peers. Also, one can ask for medical advice/ tips from physicians by using the anytime audio/ video call feature.

Lastly the wellness equation works by comparing the number of occurrences of incidents like side changes in between sleep during normal times, against those occurrences of the same happening during abnormal times. The comparison yields a 'wellness factor' or W if the value is between -0.7 to +0.7, it is a normal situation, if the value is < -0.7 or value > +0.7, the system is trained to detect it as an abnormal situation and inform whoever needs to be informed or whosever's contact details are pre-configured in the system settings as emergency contacts.

Chapter 6. Future Work

The future of elderly care-giving and well-being monitoring will be determined by our ability to create digital environments which are more sensitive, more responsive and more adaptive to human needs, cater to the needs for family care-givers as well as dependent individuals, and promote healthy and safe independent living at home or community settings. This will have multiple impacts 1) Reduce the need for human intervention, therefore no need to hire full time professional care-givers. 2) Empower family members to take the role of informal care-givers to further reduce the costs. 3) Reduce the need to place seniors in long term or acute care such as hospital or nursing homes hence move away from traditional form of care-giving approach, also further contributing to lowering of costs.

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