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Remote Health Monitoring System for Elderly Living in Old-Age Home

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***Abstract*—**Need of automated monitoring system for elderly living at old-age home is a demand in today's world. Internet of Things (IoT) and Cyber-Physical System (CPS) based health monitoring system can help in achieving the solution of that demand. We present design of remote health monitoring system for elderly living in the old-age home. It improves the quality of life and enables early detection and timely recovery of the disease in an elderly at the old-age home. It consists of wearable and low power medical sensor devices able to transfer data to the base station via wireless technology like Bluetooth, ZigBee or Infrared. It enables to connect medical sensors at any time and from anywhere. A base station collects data from sensors and send it to the respective caregivers. To make user interaction simple, we can use either MATLAB or KST which is a data viewing and plotting tool and it has an inbuilt data analysis functionalities.

Keywords*—CPS, Sensors, Base Station, Wireless Communication Technologies*

I. INTRODUCTION

The Internet of Things (IoT) is an emerging area of interest for current developing networks. It has varied field of applications like industry, healthcare, transportation, smart home, etc. The IoT Connect both inanimate (nonliving) and living things by using sensors for data collection. Three Cs in it is: Communication, Control and Automation, and Cost Saving [1]. And it can be defined as "Network of physical devices, vehicles, buildings and other items-embedded with actuators, sensors, electronics, software, and network connectivity that enables these objects to collect and exchange data [2]". Another new concept is the Cyber-Physical System (CPS) which is a mechanism controlled or monitored by computer-based algorithms [3]. It has the ability to add more intelligence to social life. Examples of CPS include smart grid, autonomous automobile systems, distributed robotics, medical monitoring, process control systems, and automatic pilot avionics. CPS in the healthcare plays an important role, consists of medical devices and medical infrastructure. CPS relies on sensing, processing and networking. It provides an application in-hospitals and in-home patient care regardless of the patient's location. The main aim of the Medical Cyber-Physical System (MCPS) is to provide the highest quality continuous care to the patients. In remote health monitoring system, sensors like BP sensor, an ECG sensor, thermometer, and SpO2 sensor are used to sense the patient's vital information like Blood Pressure, ECG, body temperature, Blood oxygen saturation respectively. These sensors are then connected to the base station through IEEE 802.14.5/ZigBee or Bluetooth. Raspberry-Pi is used as a base station. Because of the advantages of the Raspberry-Pi, it can also be used as a controller and not just as a base station. Sensed signal from the sensors are received at the base station which controls the signals and converts the received analog signal into digital signal which is suitable form for data transmission. Also Raspberry-Pi sent the received data to the mobile devices through the E-mail or through SMS. Such monitoring enables early detection and timely treatment of the disease. Hence, while designing CPS architecture for healthcare application, special attention needs to pay to ensure the data security. There are also a number of important issues to consider like requirement to store and manage the huge amount of data collected from the sensors. In addition, healthcare applications require computing resources for intelligent decision making based on massive patient's data.

This paper presents a review of remote health monitoring a system for elderly living in the old-age home. Section II shows the literature survey. In section III, we present the generalized architecture of CPS for health monitoring in old-age home. Section IV provides overview of the sensors used at old-age home. Various wireless communication technologies for data transmission between the sensors and base station is described in section V. Section VI briefly mentions the device used in the base station. Section VII presents the GUI used at the user level for the systematic view of the received data, followed by a conclusion.

II. LITERATURE SURVEY

Reference [4], explain the overview of MCPS consists of medical devices that collect the patient's vital information and sent it to the caregivers via communication network. They also give the case study of the generic PCA Infusion pump for the pain control of the post-operative patient. MCPS have some challenges like the High assurance software, interoperability, autonomy, security and privacy, certifiability, etc. The set of device type and algorithm which defines how

those devices should interact in a given clinical scenario is a Virtual Medical Device (VMD). Smart alarm is used to give clinicians an information about the patient's state and can be configured to alert the clinicians in a deteriorated state. In the smart alarm system, physiological data is integrated and processed to provide clinical decision support. These data can be used directly to control therapeutic delivery devices, forming a physiological closed-loop system.

CyPhyS+ is a Reliable and Managed Cyber-Physical System for Old-age Home [5]. They consider two usage models: Individual-centric healthcare and Community-centric healthcare services, which independently or in a combination provide efficient remote health monitoring services to the elderly. They propose an architecture whose objectives is: 1) The network deployment cost should be minimal, 2) Post-deployment overheads at the old-age site should be minimal, 3) An inmate of the home should be able to comfortably wear the monitoring device and perform his/her normal routine without device causing any interruption, 4) The medical data transfer should be reliable and secure, 5) System should enable a remote doctor take medical vital readings of an old-age person from anywhere/anytime. The functional components of the network subsystem of CyPhyS+ comprises of network monitoring using 6PANview and message reliability by achieving loss free packet transmission, packet forwarding scheme for 6LoWPAN LinkPeek and application level loss recovery over UDP. ECG analysis algorithms were evaluated on with data from Physionet Database and Real ECG data obtained from the ECG sensor used in CyPhyS+ system. They also conducted extensive field trials across various parts of Bangalore city, India to evaluate the system under different deployment scenario.

The eHealth Sensor Shield V2.0 allows Arduino and Raspberry Pi users to perform biometric and medical applications where patient monitoring is done by using 10 different sensors: pulse, SpO2, GSR sweating, breathing, body temperature, ECG, glucometer, sphygmomanometer, accelerometer and EMG [6].

This information can be used to monitor in real time the condition of a patient or to get useful data in order to be subsequently analyzed for medical diagnosis. These information gathered can be wirelessly sent using any of the six connectivity options available: Wi-Fi, 802.15.4, 3G, GPRS, Bluetooth and ZigBee depending on the application.

Reference [7] attempted to design a standard for an integrated clinical environment manager. Their standard, called the ICEMAN standard, gives a meta-model for describing medical devices and a communication protocol to enable plug-and-play connectivity for compliant devices. To demonstrate the capabilities of that standard, they implemented a service-oriented system that can pair requirements of the application with the device capabilities, based on the ICEMAN device meta-model. This system enables devices to interoperate with the manager in a driverless fashion.

Over the past few decades the capability of using new devices for health monitoring system has increased significantly. But the increase in usage of low cost sensor and various communication media for data transmission lead to inefficiency in processing massive amounts of data in real time.

Medical devices are used everywhere in the CPS healthcare, but each device works on its own and in isolation. Interoperable medical devices lead to clear benefits for the care provider and for the patient that help in more accurate assessment of the patient's health. Requirement for integration of medical devices are remote access (to remotely access the device from the supervisor), workflow model (set of steps to specific action in patient care), certification [8].

Taxonomy of CPS in healthcare consists of following elements: 1) application, 2) security, 3) sensing, 4) data management, 5) computation, 6) communication, 7) architecture, and 8) control/actuation [9]. General challenges in CPS are lack of CPS standard, lack of verification and validation tools, time management in architectural design, CPS architecture. Also challenges in CPS healthcare are software reliability, medical device interoperability, data extraction, security and privacy, system feedback, complex query processing and lack of prototype architecture in CPS in healthcare.

A number of sensors that monitor vital signs, location sensor, and environmental sensors (light, temperature and humidity) can all be integrated into a Wearable Wireless Body/Personal Area Network (WWBAN). WWBAN architecture is a 3-tier architecture compasses of tier-1: wireless medical base stations, tier-2: Personal Server (PS) and tier-3: Medical Server (MS) [10]. Different scenarios in our wireless body area network system for multi-patient monitoring in medical centers is when the device is used for multi patient monitoring or individually in a medical center, representing one floor and one room respectively [11]. A multi-hopping WBAN prototyping system for multi-patient monitoring uses two medical standards: WMTS for long distance and MICS for short distance wireless transmission respectively.

CPS in the health network also includes use of cloud computing to send the patient's vital signs from the sensor via the communication system for further use, to record and store the continuously changing parameters measured from the sensor, to monitor and assist the patient from anywhere and at any time, to alert authority in case of increase or decrease in any vital sign, to store personal medical record virtually [12]. They also mention that there are a number of big data methods are available like data preparation (segmenting and filtering), data transformation, data integration (gathering data from distributed sensors), data reduction, etc., prepare it for the further use at the research center or at hospitals. Health data may be either event based or real time (present time data).

Reference [13], proposes a CPS named e-SURAKSHAK, which is capable of sensing person's vital sign and sending it to a centralized database wirelessly. They use 6LoWPAN wireless communication protocol. The system architecture of e-

SURAKSHAK consist of three tiers: 1) Environmental tier, 2) Control tier and 3) Service tier. Environmental tier consists of edge routers and sensors that sense patient's vital health parameters, communicate through 6LoWPAN protocol, and upload sensed data to an electronic database. Gathered information from the environmental tier is stored and processed in the Control tier that consist of an electronic database. The hardware design of e-SURAKSHAK is divided into two modules: Mobile Mote (low power consumption for longer battery life) and Interface Module (supplying power to the sensors and mobile mote).

III. GENERALIZED ARCHITECTURE OF CPS FOR HEALTH MONITORING IN OLD-AGE HOME

The generalized architecture for the health monitoring in an old-age home is shown in Fig. 1 which consist of three layers: 1) Sensor network, 2) Base station and 3) Care givers. Sensor network consist of sensors like ECG sensor, SpO_2 sensor, Glucometer, Thermostat, etc., which sense the parameters like heartbeat, amount of oxygen in the blood, the concentration of glucose in the blood, body temperature, etc. and are attached to the patient's body. Information sensed by that sensors are then transmitted to the base station via the wireless communication medium. Wireless communication may include technologies like Bluetooth, IEEE 802.15.4 (Mi-Wi, ZigBee) or Infrared to for wireless data transmission.

A base station is nothing but the node in a sensor network that is capable of gathering sensed data, performing some processing, and communicating with other nodes in the network. Received data are first stored, processed and visualize on a server. It controls information, pre-process it before sending over the network. The result of the analysis is then automatically sent to caregivers or to the respective relatives.

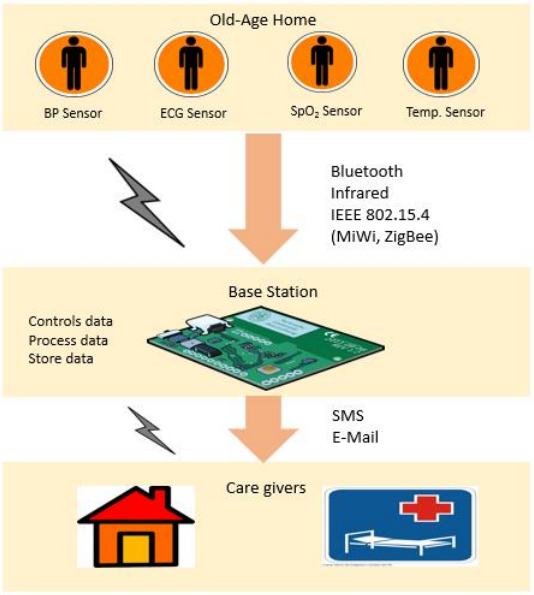

Fig. 1 Generalized architecture of CPS for health monitoring in old-age home

IV. SENSORS USED AT OLD-AGE HOME

Now-a-days thousands of medical sensors are available in a market for sensing patient's vital sign. Frequently used sensors in our daily life are explained in brief as below with its specification.

A. Glucometer

The approximate concentration of glucose in the blood is determined by the medical device named as Glucometer. It can be a strip of a glucose paper which is dipped into substance to test and compare to the glucose chart. Glucometer display the concentration of glucose in units of mg/dl or mmol/l. In an adult, a person not suffering with diabetes should have blood glucose of 70-100 mg/dL. Whereas in children younger than 5 years old 80-200 mg/dL, age of 5-11 should have 70-180 mg/dL and for 12 and older should have a glucose level of 70-150 mg/dL [14]. There are a wide range of glucometers available in the markets differs in a number of strips, number of lancets, measuring time, measuring range, and memory. Reading of the glucometer can be shared wirelessly with the iPhone or iPad as shown in Fig. 2. The OneTouch Verio Sync Meter from uses Bluetooth technology to send blood sugar test results to these devices wirelessly using the OneTouch Reveal™ mobile app. It offers several facilities like 14-day summary, high and low glucose alert, memory, rechargeable battery [15].

B. *Sphygmomanometer*

It is a medical device used to measure the blood pressure. Both systolic (maximum) and diastolic (minimum) blood pressure are measured by using this device. They are available in different shapes and sizes and have a compact design to fit over the wrist like a watch or fits to the arms. In adults, normal reading of sphygmomanometer in systolic and diastolic are 120 mm Hg and 80 mm Hg respectively [16]. Variety of Sphygmomanometers are available in the market, having difference in size of the LCD screen, irregular heartbeat detection, battery size, pressure units (mmHg or kPa). These devices also have a feature to send measurements via Bluetooth to another Bluetooth device.

Fig. 2 Sensors connected to the mobile devices

C. *ECG Sensor*

Electrical activities of the heart are recorded by means of ECG by using electrodes placed on the skin, which detects the small electrical changes in the skin arises from the heart muscles. ECG sensors are the medical devices that use technologies like Bluetooth and smart phones for cardiac rhythm monitoring. Specifications of these devices are frequency range, transmission range, battery, current drawn. The normal heart rate of an adult ranges from 60 to 100 beats a minute. If there is any abnormal change in the heart rate then these devices will alert respective caregivers.

D. *Thermometer*

The thermometer is used to sense the human body temperature. Normal human body temperature is 37 degree Celsius. These sensors sense the temperature and send the information to mobile devices via Bluetooth or Infrared. An example of it is CorTemp sensor which is an ingestible body temperature sensor wirelessly transmits body temperature [17]. Another device is CorTemp data recorder which takes signals from CorTemp sensor and converts the signal into digital format, then displays and store the data in memory [18]. These sensors have specifications like measurement range and measurement accuracy.

TABLE I. MEDICAL SENSORS

Sensor/Medical Device	Purpose
Glucometer	Measure approximate concentration of glucose in the blood
Sphygmomanometer	To check the blood pressure
ECG Sensor	To record the electrical activities of heart
Thermometer	To measure the body temperature
Pulse Oximeter	Oxygen in blood
GSR sweating	Galvanic Skin Response
Breathing	Airflow
Accelerator	Patient's position
EMG	To record electrical activities of muscles

V. WIRELESS COMMUNICATION TECHNOLOGIES FOR DATA TRANSMISSION BETWEEN SENSORS AND BASE STATION

Wireless communication is the transfer of information between two or more points that are not connected by wires. In our system we require a short range wireless communication between various medical sensors and the base station. Most commonly used technologies for short range wireless communication are Bluetooth, ZigBee and Infrared transmission.

A. *Bluetooth*

It is a best wire-replacement communication protocol used to transmit voice and data at high speed using radio waves. It is basically designed for low-power consumption, with a short range and low-cost transmission. It is a packet-based protocol with a master-slave structure. One master node can communicate up to seven slave nodes in a piconet (ad-hoc network). It uses short wavelength in the ISM band from 2.4 to 2.485 GHz [19]. Applications of the Bluetooth are in headphone, handsfree headset, wireless speaker, mouse, keyboard, speaker and many more.

B. *IEEE 802.15.4*

It is a standard which specifies the physical layer and medium access control for low-rate wireless PAN. ZigBee, WirelessHART, MiWi, and Thread specifications are based on IEEE 802.15.4 standard [20].

C. *Infrared*

Infrared radiation is the region between microwaves and visible light in the electromagnetic spectrum. It is a wireless communication technology that conveys data through infrared radiations. It is suitable for short and medium range communication and control. Some of the applications of the infrared radiations are in thermography, night vision, tracking, heating, communication, environmental control system, navigation system, etc.

TABLE II. COMMUNICATION TECHNOLOGY

Communication Technology	Data rate/Bit rate	Transmission Range
Bluetooth	2.1Mbps	Class 3: <10m Class 2: 10m – 30 feet Class 1: 100m-328feet [21]
ZigBee	20 kbit/s-250 kbit/s	10m-75m [22]
Infrared	2400 bps to 4 Mbps [23]	Up to 30 feet [24]

VI. BASE STATION

For the base station, we can use any model of a low power credit-card-sized computer Raspberry pi. It has a variety of peripherals like SD Card storage, USB port, HDMI port, 512MB RAM, and interestingly 8 GPIO port for expansion. We can also connect a monitor, keyboard, and mouse to Raspberry Pi through HDMI and USB connectors and it can be used like a desktop computer. It support a number of Operating System like Linux (Pidora, Archlinux, and Raspian), OpenElec & XBMC, RetroPie, RISC OS, Firefox OS, and Android [25].

One can also use Arduino as a base station. It is an open source platform and it does not need a separate piece of hardware. The first Arduino was introduced in 2005 [26], with the aim to provide low cost to create device that interact with sensors and actuators. Till now 17 versions of the Arduino hardware had been produced [27]. Another device names MICAz, is also used for enabling low-power wireless sensor network. It has features like EEE 802.15.4 compliant RF transceiver, .4 to 2.48 GHz ISM band, 50 kbps data rate [28].

VII. GUI AT USER LEVEL

Vital signs from the base station is sent to the respective doctor or to the patient's relatives. They can view the information in a systematic manner by using any android applications, or software like Kst and MATLAB. These softwares are basically used in the data mining process.

Kst is the real-time dataset viewing and plotting tool. It is freely available and anyone can download it. It has inbuilt data analysis functionalities.

MATLAB is a widely used tool in research and engineering. Built-in graphics make it easy to visualize for the user. It allows implementation of algorithms, plotting of data, creation of interfaces, matrix manipulation, and interfacing with programs.

CONCLUSION

In this paper, we presented an architecture of a remote health monitoring system for an old-age home. We also gave the brief description about the sensors used in the old-age home to sense the vital signs. We highlight the short range, low power wireless data transmission technology to transmit sensed information from sensor to the base station. We showed

that Raspberry pi or Arduino can be taken as a base station. We note that simple and interactive user interface is required to view the data to the caregivers which achieved by android applications or by any data mining software like MATLAB, WEKA, RapidMiner, etc.

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