IoT-HEALTHCARE MONITORING SYSTEM WITH CAPABILITY TO DETECT ECG, BLOOD PRESSURE AND TEMPERATURE

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IoT-HEALTHCARE MONITORING SYSTEM WITH CAPABILITY TO DETECT ECG, BLOOD PRESSURE AND TEMPERATURE

by

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LIST OFABBREVIATIONS

ADC	Analog to Digital Converter
API	Application Programming Interface
ASIC	Application System Integrated Circuit
BAN	Body Area Network
Bpm	Beats per Minutes
CPU	Central Processing Unit
CSS	Cascading Style Sheets
ECG	Electrocardiogram
FDA	Food and Drug Admistration
FPGA	Field-Programmable Gate Array
FSS	Full Scale Span
GPS	Global Positioning System
GUI	Graphical User Interface
HPS	Hard Processor System
HTML	HyperText Markup Language
IoT	Internet of Things
IP	Internet Protocol
MAC	Media Access Control
Mbps	Megabit per Second
MQTT	Message Queue Telemetry Transport
MSPS	Millions of Samples per Second
SoC	System on Chip
PCB	Printed Circuit Board
PHY	Physical Layer
RFID	Radio Frequency Identification
WBAN	Wireless Body Area Network
WHO	World Health Organization

SISTEM PENGAWASAN PENJAGAAN KESIHATAN-INTERNET ENDA DENGAN KEBOLEHAN UNTUK MENGESAN ECG, TEKANAN DARAH DAN SUHU BADAN

ABSTRAK

Jangka hayat manusia semakin panjang berbanding dengan dulu. Penuaan penduduk menjadi satu cabaran untuk mencipta satu sistem pengawasan penjagaan kesihatan yang murah dan cekap. Pada masa yang sama, sistem pengawasan penjagaan kesihatan di pasaran tidak mempunyai fungsi komunikasi dua hala antara doktor dan pesakit. Sistem Permantau Kesihatan dengan Internet Benda telah dicadang untuk menyelesaikan masalah tersebut. Dalam kajian ini, satu sistem mengandungi prototaip sistem terbenam permantau kesihatan yang boleh mengukur elektrokardiogram, tekanan darah, denyutan jantung dan suhu badan telah dicadangkan pada DE1-SoC. Rangka kerja Internet Benda juga dimasukan untuk menyimpan maklumat di IBM Bluemix dengan serta-merta melalui Node-RED. Antara muka grafik pengguna di Web telah dicipta dengan mengguna http GET dan POST untuk memaparkan pengukuran dan nasihat daripada doktor. Sistem ini boleh membantu pesakit untuk memeriksa kesihatan masing-masing tanpa mengira masa dan tempat selain daripada bergantung kepada sistem pengawasan penjagaan kesihatan yang kompleks. Bagi doktor di hospital, mereka boleh memantau kesihatan pesakit dengan senang tanpa pergi ke tempat pesakit. Ketepatan bagi sistem yang telah dibina diukur dengan membandingkan pengukuran dari peralatan perubatan komersial. Purata ketepatan bagi penderia untuk mengukur suhu badan ialah 99.21%, 99.26% bagi denyutan jantung, 99.17% bagi tekanan darah tinggi dan 98.27% bagi tekanan darah rendah. Data daripada sistem dianalis untuk menjangka penyakit yang mungkin dihidapi dan keputusan telah dipaparkan pada laman Web tempatan. Masa yang diperlukan untuk menyimpan satu maklumat ialah 1.5 millisaat dengan menggunakan 100Mbps Internet. Sepuluh orang sukarelawan telah dipilih untuk menguji fungsi sistem

ini dan purata ketepatan bagi setiap penderia berjaya mencapai lebih daripada 95%. Kesimpulanya, sistem yang dicadang dalam kajian ini berfungsi dengan baik dan dapat memanfaatkan pesakit.

IoT-HEALTHCARE MONITORING SYSTEM WITH CAPABLE TO DETECT ECG, BLOOD PRESSURE AND TEMPERATURE

ABSTRACT

Life expectancy at birth increases compared to the previous year. Aging population has become a challenge to developing a low cost and efficiency healthcare system since there are limited medical resources. Besides, the healthcare systems on the market do not provide two way communication feature for doctor and patient. IoT-healthcare monitoring system is proposed to overcome these problems. In this study, a system consists of the prototyping of an embedded healthcare monitoring system which is capable to measure ECG, blood pressure, pulse rate, body temperature is proposed on DE1-SoC platform. The IoT-framework is included where the real-time data are stored at IBM Bluemix cloud platform through the Node-RED. Web GUI is created using http GET and POST to display the measurements and advice from doctor through Internet. The accuracy of the sensors for developed system are evaluated through comparing the measurement with the commercial medical devices. The average accuracy for each sensors to measure the health parameter are 99.21% for temperature measurement, 99.26% for pulse rate measurement, 99.17% for Systolic pressure and 98.72% for diastolic pressure. An analysis is carried on the measurements to predict potential disease and results are displayed on local web page. The time required for a sample data to successfully stored in cloud is 1.5 millisecond using 100Mbps speed Internet. Ten volunteers are invited to test the functionality of the system. Generally the measurements from the system have accuracy over 90%. As a conclusion, the functionality of the healthcare system in the study is proven and it is able to provide better healthcare service to patients.

Chapter 1 : INTRODUCTION

1.1 Research Background

In this modern era, one of the global challenges for humanity is health issues [2]. People are more concerned and interested in their health, fitness and wellness [1]. With the rapid development of healthcare system, the life expectancy at birth is increase compared to previous year. Life expectancy at birth is the average life expectancy of baby born at that year if mortality patterns at that time remain constant in the future. According to WHO, the global average life expectancy increase by 5 years between year 2000 and 2015 to 71.4 years old (73.8 years for females and 69.1 years for males). However, there is one human death across the global every one minutes [1]. According to a statistics reported by WHO, there are 12 million deaths occur worldwide each year due to cardiovascular disease [3]. The statistics from WHO highlights the critical situation of heart disease (41.8%) as the main contributor to the causes of death in Malaysia [4].

These millions of deaths due to cardiovascular disease can be avoided if they received treatment at the early stage of the disease. However, it is difficult to monitor patients' health every day. Doctor can only monitor and analysis patients' health condition when patients received treatment in hospital or have medical check-up. Once patients get discharged from hospital, doctor unable to monitor patients' health condition. At the same time, if the medical resources are limited in an area, patients have to make appointment or queue up at hospital to receive treatment. This is inconvenient to patients and lead to hospital overcrowding problem. Besides, patients might need to travel to hospital or clinic very far away from their home to receive treatment. This situation is inconvenient for those who live in the rural area especially patients who need to travel to hospital for regular medical check-up [5]. Therefore information and communication technologies are implemented in modern healthcare system to provide better health

service to patients.

Telemedicine is an example of modern healthcare system which make use of information and communication technologies. Telemedicine is a system that is able to provide and support healthcare service by using information and communication technologies when distance separates the user and doctor [6]. This mean telemedicine is able to provide healthcare service to user regards the time and location. Telemedicine also offer health service to bottom million peoples especially for those who are unable to have medical care due to limited medical resources [7]. Generally, there are two types of telemedicine available to user which are live communication type and store and forward type [44]. The live communication type telemedicine are similar to traditional face to face consultation which means it allows doctor and patient to see each other during treatment. Store and forward type telemedicine is able to collect patient's health parameter and transmitted to doctor in hospital. Live communication type telemedicine is unpopular compared to store and forward type telemedicine because its function rely on internet speed and video quality.

IoT-Healthcare Monitoring System is one of the examples of telemedicine. It has become the best solution for the limitation of healthcare system since cost can be reduced [8]. IoT-Healthcare monitoring system also able to monitor and control health condition without the need of withholding patients in hospital [9]. IoT- Healthcare Monitoring System provides convenient healthcare service to patients and make the diagnosis process become easier. IoT-Healthcare monitoring system is able to measure the vital sign like blood pressure, heart rate, body temperature, respiratory rate and etc using sensors. IoT-Healthcare monitoring system will store the vital signs measured by sensors to cloud as a record for further analysis by doctor. At the same time, these vital signs are important parameter that can assist in decision making during emergency. This is because the doctor

can directly know patients' health condition through the record without waiting for reply from other doctor who in charge for respective patients. Any suitable treatment can be taken immediately to save patients' life based on the record.

IoT-Healthcare monitoring system is able to benefit people that live alone by providing freedom and at the same time ensure they can stay away from the attack of disease and can protect their life. However, IoT-Healthcare monitoring system still not popular among patients. Most of the patient choose to visit to hospital instead of using the IoT-Healthcare monitoring system because the system only perform measurement on health parameter and stored the data to cloud storage. IoT-Healthcare monitoring system also does not provide a platform for doctor to interact to patients after the data is analyzed. This mean patients unable to know their current health condition even data is analyzed by doctor. They have to travel to hospital and have appointment with doctor in order to know their health condition. Therefore, IoT-Healthcare monitoring system is inconvenient to patients since it unable to diagnosis the potential risk based on the health parameter.

In this study, an IoT-healthcare monitoring system is proposed on DE1-SoC platform. This proposed system is able to measure health parameters like blood pressure, ECG signal, pulse rate and body temperature using sensor. The measured parameters will be stored in cloud storage and can be accessed by patients and doctors through a web page. At the same time, the system will provide an advice after analyzed the health parameters through the local web page. Doctors also able to give advices to patients after analyzed the data.

1.2 Problems Statement

WHO highlights the critical situation of heart disease (41.8%) as main contributor to causes of death in Malaysia. Majority of the cases are due to sudden cardiac death because no health monitoring system to monitor or check the heart rhythm consistently. Besides, most of the monitoring system only use heart beat to detect cardiac disease. ECG signal is the most important parameter to assist in diagnosis cardiac disease.

Most of the IoT-healthcare monitoring system measure vital signs and transmit to cloud storage for analysis. It does not provide any feedback or advice to user until doctor analyzed the data stored in cloud. There is also no platform for the doctor to inform the result to user through the system unless patients make an appointment with them.

1.3 Project Scope

The proposed IoT-healthcare monitoring system in this study is able to measure health parameters like blood pressure, ECG signal, pulse rate and body temperature using sensor. Besides, pulse rate of user can be obtained by extracted the R-R peak from ECG signal. Using the proposed system, user can just carry out the test at home and continuously monitor their health condition every day without going to hospital. A local web page is developed to display the parameter obtained by sensors. All the health parameters are stored in cloud and doctor or patients can observed the parameters through web page. Patients also can access to the web page to view their health parameter and advice from doctor will be displayed on the web page. Doctor can give comments on health parameters to patients through the web page after the data are analyzed.

Altera DE1-SoC which consists of Cyclone V SoC 5CSEMA5F31 is selected as the processing unit to interface with AD8232, LM35 and ASDXRRX015PGAA5 and a motor. Due to the limitation of network bandwidth and slow latency of network, sensor's data may lost when acquired by centralized system. Hence, combination of FPGA and

CPU make DE1-SoC suitable for IoT edge application since it allow DSP algorithms parallel implementation and high speed parallel processing. At the same time DE1-SoC also provide hardware for Ethernet networking to user via an external Micrel KSZ9021RN PHY chip and HPS Ethernet MAC function.

1.4 Objectives

1) To develop a portable healthcare monitoring system that is able to measure the ECG signal, blood pressure and body temperature with high accuracy.

2) To develop an IoT-framework healthcare monitoring system that allow doctor to give feedback to patients.

1.5 Thesis Outline

Chapter one discuss about the research background, problem statement, objective and project scope.

Chapter two is about literature review on IoT-Healthcare Monitoring System and related work to this system.

Chapter three discuss about methodology.

Chapter four present the result and discussion of this study.

Chapter five present the conclusion of study and its future development.

Chapter 2 : LITERATURE REVIEW

2.1 Internet of Things

Internet has become part of human's daily life. Concept of Internet of Things (IoT) has been introduced to assists and make daily life easier. European Research Cluster on the Internet of Things (IERC) defined IOT as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes, and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network"[37]. IoT provided a network for physical objects that embedded with sensors, actuators or computing device can exchange data among each object [10]. These exchanged data are available regardless the place and time by accessed to the facility or device that able to connect to internet.

The idea of IoT was proposed in the late 1990s [40] and become now has become a popular solution to improve human's life quality. According to Cisco, 25 billion devices will be connected to Internet by 2015 and will further increase to 50 billion by 2020. At the same time, this will create $14.4 trillion of value at stake for companies and industries [41]. Several companies like Intel, Google and Samsung had formed IoT division to implement IoT solution into their product. The development of smart gadgets, sensors, Radio frequency identification (RFID), cloud computing, embedded device and software challenge has help to connect the actual world with virtual world [41]. This make the application of IoT manage to implement in different sector like healthcare, transportation, industry and smart home [42] to realize the Smart City concept. Table 2.1 show the potential application of IoT in industry, environment and society which able to save the cost and more safety to human [41].

Table 2.1 Application of IoT:

Industry	Environment	Society
• Smart grid • Liquid presence • Tank level • Photovoltaic installations	• Natural disaster early detection • Water quality • Air quality • Water leakage	• Healthcare system • Smart parking • Traffic congestion • Waste management • Smart lighting

Healthcare Systems are rapid developed and smart health care is one of the key concept for the smart cities concept [11]. The IoT technology is implemented in healthcare system in order to reduce the cost and increase user friendliness. With IoT technology various distributed medical devices can be connected and can transmit the medical information to cloud [13]. This eventually allow IoT- healthcare system to monitor and assists patients' health easily. A doctor can remote monitoring a patient's health condition without holding patient in hospital. At the same time patients also no longer need to visit to hospital for regular check-up. This shown that IoT able to overcome the distance barrier which is the main problem for patients living in rural area. In recent years, many researches had been conduct to provide better healthcare service to citizens. Most of the IoT-healthcare system are makeup of three layer which are body area network, local gateway and cloud platform [14] as shown in Figure 2.1.

Figure 2.1: System Architeture of IoT Healthcare Monitoring System [14]

Body area network (BAN) is the fundamental layer of the healthcare system. BAN consists of wearable sensors, implantable medical sensors that able to measure vital sign

of the user and transmit the data to local centralized system [8]. Wireless body area network (WBAN) also refer as the part of BAN. Both BAN and WBAN have same function but WBAN use wireless technology to transmit measured data to central node. Local gateway is the middle layer for IoT-healthcare system and it can be microcontroller like Arduino and raspberry platform or other electronic device. Local gateway receive data from medical sensors and process it before send to the cloud storage. Local gateway also in charge to control and configure the sensor that interface to it. Lastly, cloud platform stored the data retrieved by local gateway and thus host the database. Healthcare service application can easily be implemented since it expose to application programming interface (API) [15].

E-Health using information and communication technology to support healthcare system [16]. WHO defines E-Health as "the cost effective and secure use of information and communication technologies in support of health and health related fields including healthcare, health surveillance and health education, knowledge and research." E-health concept was applied in to IoT healthcare monitoring system to overcome the distance barrier between patients and doctors. Through the information and communication technologies, the health parameters from patients are able to measure using wearable bio-sensor, non-wearable bio-sensor, implanted bio-sensor and other medical devices to provide health-related service. All the data obtained by the sensors or devices will be transmitted to cloud storage through wireless technologies. These data will be stored as medical record and analyzed by doctors. Figure 2.2 shows the sensors that available for healthcare system and the suitable position to attach on human's body.

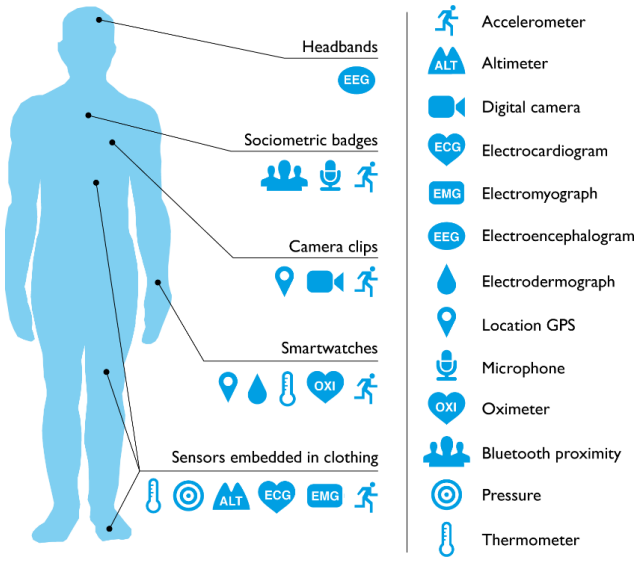

Figure 2.2: Potential Medical Sensors [17]

Wireless communication technology is one of the key element of IoT healthcare monitoring system. It is used to transmit the data from sensors to local gateway or direct to the cloud server. There are different type of wireless communication technology being used in IoT project which are IPV6 over Low-power wireless personal area network (6LoWPAN), Zigbee, Zwave, Message Queue Telemetry Transport (MQTT), and etc [36],[37]. IEEE 802.15.4 is a standard protocol designed for the physical (PHY) and media access control (MAC) layer which is the basic part for other standard like Zigbee and 6LoWPAN. Zigbee and Zwave both provide short range wireless communication at low cost and low energy consumption but using different frequency for frequency band. 6LoWPAN protocol combined the IPV6 and WPAN to provide better connectivity and compatibility. MQTT is a lightweight protocol to connect the sensors to server where the network is low bandwidth and high latency.

2.2 Vital Signs and Potential Diseases

Table 2.2 shows the Bio-Markers that available for IoT-healthcare monitoring system and their applicability to identify the patients' health condition related to common disease [8]. Pulse rate, respiratory rate, body temperature, and blood pressure are bio-marker that mostly use in healthcare monitoring system.

Table 2.2: Potential Bio-Marker to Detect Disease [8]

Bio-Marker	**Cardiovascular Disease**	**Chronic Obstructive Pulmonary Disease**	**Parkinson's Disease**	**Diabetes**
Galt(posture)	High	High	High	Undetermined
ECG	High	High	Some	Some
Respiratory Rate	High	High	Some	Undetermined
Skin Temperature	Some	Some	Some	Some
Surface EMG	Some	Some	Some	Undetermined
Sweating	Undetermined	Undetermined	Some	Undetermined
Blood Pressure	High	Some	Some	Some
Body Movement	Some	Undetermined	High	Undetermined
Blood Glucose	Undetermined	Undetermined	Undetermined	High

Electrocardiogram (ECG) signal is the most important bio-markers to identify patients' health condition since it is able to provide more information to doctor compared to pulse rate. ECG signal is an electrical signal that is generated by heart's activity [18] and can be measured by electrode attach to human's chest. Figure 2.3 shows the shape of the ECG signal. ECG signal is a non-invasive method for doctor to monitor the heart rhythm of patients because information like heart rate, heart beat regularity, strength and timing of the electrical signal can be interpreted from ECG signal. Therefore, most of the cardiac disease can be detected by analyses the ECG signal since abnormal heart rhythm can be easily observed through the ECG signal. Arrhythmia is a cardiac disease due to abnormal heart rhythm that can causes death if not received treatment earlier [19].

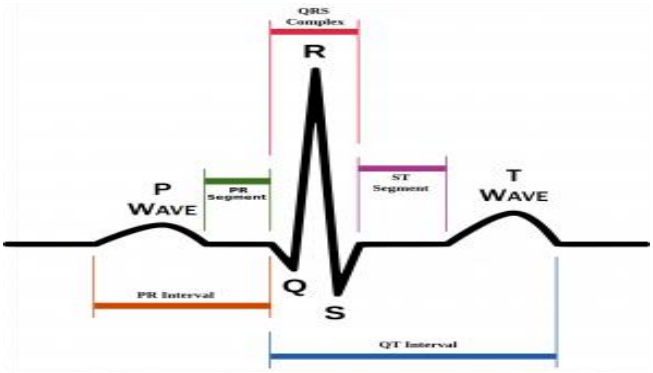

Figure 2.3: ECG signal [32]

Pulse rate is measurement of heart beat per minute (bpm) and it is one of the features that can be obtained from ECG signal. Every time when the heart pump blood, a beat is generated at the arteries which located close to the skin. Therefore, pulse rate also can be measured by counting the number of beat in arteries per minutes. Pulse rate of a person will be affected by his/her activity level, body position, body size and air temperature [33]. Pulse rate for a healthy person is between 60 to 100 bpm when he/she is resting during measurement. The abnormal pulse rate indicate that he/she may has Bradycardia (lower than normal range) and Tachycardia (higher than normal range). Table 2.3 shows the possible disease base on the pulse rate.

Table 2.3: Pulse Rate and Its Potential Risk

Pulse Rate (bpm)	**Potential Risk**
< 60	Bradycardia
$\geq 60 \; and \leq 100$	Healthy
> 100	Tachycardia

Heart pumps the blood into blood vessel and this will created blood pressure due to the force of blood that pushing against the wall of blood vessel. According to WHO, for a normal adult, his/her systolic blood pressure is less than120 mmHg and diastolic blood pressure is less than 80 mmHg. Systolic blood pressure is the pressure in blood vessel when heart beat while diastolic blood pressure is the pressure in blood vessel when heart relax. People with high blood pressure or also known as hypertension will have

higher risk to heart disease or stroke. Table 2.4 shows the range of blood pressure and their blood pressure category which recognized by American Heart Association [29].

Table 2.4: Category for Hypertension [29]

Category	**Systolic /mmHg**	**Diastolic /mmHg**
Normal	<120	<80
Prehypertension	120-139	80-89
High blood pressure (Hypertension) stage 1	140-159	90-99
High blood pressure (Hypertension) stage 2	>160	>100
Hypertensive crisis (emergency care needed)	>180	>110

Body Temperature of human varies due to the metabolism rate but 37 ℃ is accepted as a standard for a normal body temperature after Dr. Carl Wunderlich, recorded auxiliary temperature from 25000 people in the 1800s [20]. The 37 degree is an average body temperature and body temperature is considered normal once it is in between 36.1 to 37.2℃. Measuring body temperature is one of the diagnostic method and an important vital sign for disease like H1N1 [21]. Besides, once the body temperature of a person is exceed than the normal range by 1℃, he/she gets fever. According to WHO, Fever is a symptoms for dangerous disease like yellow fever which causes 215 death in Brazil (101 confirmed, 109 suspected, 5 discarded) from 1 December 2016 to 22 February 2017. A person is suspected to have fever if body temperature higher than 37.2 ℃ and Hypothermia if body temperature lower than 35℃.

Respiratory rate is a measurement of breath that a people takes within one minutes. Respiratory rates for a normal adult at rest is ranging from 12 to 16 breaths per minute. It is an important vital sign to diagnosis disease like chronic obstructive pulmonary disease, pneumonia and asthma. At the same time, the respiratory rate is increase as cardiac arrest

happened and will caused death [23]. Every year, there are more than 2 millions of children under 5 years old in developing world who die because of pneumonia [22].

2.3 Related Work

Hariprasad Anumala and Shiva Murthy Busetty [13] highlight that the recent healthcare system only consider wearable devices and medical devices as health relevant device. This paper attempts to use data from home smart appliance to monitor human's health condition and assist in health management. Table 2.5 shows the potential of home appliance that can be combined with IoT technology to function as medical device. According to [13], by analyzed the data received from home appliance, the system can determine the human's health condition. If he/she is unhealthy, the user's data will send to cloud server and advice will send to user. These data from home appliances can only use as reference to assist health management because data are compared to standard medical data to identify user's health condition. This may reported false result since the life style of humans are different for each country. The health parameters are better marker to assist in disease diagnosis.

Table 2.5: Potential Home Appliance as IoT Devices

Appliance	**Health Data**
Micro Oven	Food consumption data
Smart TV	Physical inactivity of user
Mimo	Temperature, sleep, breathing
Listnr	Baby's cry detection
Sproutling	Heart rate, temperature
Owlet Baby Care	Oxygen level, heart rate
Sensible baby	Movement, temperature, breathing
Withings Home	Analyzes local sound for signs of distress
Pacif-i	Temperature, Boundary check for kid
Emospark	Emotion text and content analysis
EAR-IT	Acoustic event detection

IoT-healthcare monitoring system not only assist on health management, it also manage to handle patient's medical record from papers into kilobytes of data in cloud. An IoT based In-hospital healthcare system was proposed by [24] to monitor patients' body temperature in hospital using LM35 temperature sensor. The reading from sensor is transmitted to Intel Galileo Generation 2 platform using XB24-B XBee S2 modules so that power consumption can be minimized. In this research, Intel Galileo Generation 2 platform acts as a local gateway and process all the data received from XB24-B XBee S2 modules. All the data stored inside the Intel Galileo Generation 2 platform and data are available by access the internet protocol address of Intel Galileo Generation 2 platform through internet enabled device that is connected to same local network. Therefore, doctor unable to access the system if he/she leave the hospital. At the same time, the memory storage of the Intel Galileo Generation 2 platform is limited and the previous records have to be deleted in order to store newest data.

R. Kumar and M. P. Rajasekaran [25] focus on hardware part of the healthcare system. In this paper, raspberry pi platform is used as gateway and this system is able to monitor body temperature, respiration rate, heart rate and patients' moment. Thermistors are choose to detect body temperature, ambient temperature and respiration rate. The heart beat sensor is constructed using Infrared sensor. This paper stated that once blood flow at measuring point then no reflected Infrared will be received by receiver of Infrared sensor. Hence, heart beat can be obtained by analyzing reflected Infrared. An accelerometer MMA7560QT is fit to patient's bed to monitor patient's movement. This paper proposed an IoT solution through registered the Raspberry pi platform to the website like dweet.io, IBM and developer.ibm.com. The Raspberry pi platform will act as a server to transmit the data to the website after connected to the website using registered MAC address. However, the IoT solution is no implemented on the proposed

system. The health parameters are only visible for user and these parameters are not fully utilize to assist in disease diagnosis. The diseases like Arrhythmia is unable to detect during earlier stage and may causes death.

Iuliana et al [10] perform a case study of e-health on K53 Tower System platform from Freescale Semiconductor Inc. The core for this family of microcontroller is ARM Cortex M-4 and it is suitable to use for application that require data acquisition. ECG, pulse oximeter, thermometer, accelerometer, and sphygmomanometer are proposed to interface with K53 Tower System platform to build a monitoring system. The data from medical sensors will be received by K53 Tower System platform and will be transferred to cloud storage, local computer or smartphone using Wifi, USB or Bluetooth. This medical information are able to help doctors or emergency department in disease diagnosis. This paper proposed new solution to IoT healthcare monitoring system which focus on prevention and effective intervention. The proposed system is no been evaluated and tested since authors do not implemented the idea into prototype. The performance and accuracy of the proposed system may different from the ideal system since the system may affect by factors like electromagnetic interference, humidity and surrounding temperature.

Zhe et al [26] proposed ECG monitoring healthcare system that directly transfer the data to cloud storage using wearable Wifi. This paper state that Wifi is better in coverage, data rates, terminal dependency and popularization. This system used cloud processing to ease the burden of smart devices and a web-based GUI is created. User can observe the historical ECG signal by selecting the start time and end time in control panel of the GUI. This system do not has backup data stored in microcontroller before transferring data to cloud. Therefore if Wifi connection is down then all the data is lost and the system no longer can monitor user's heart rhythm.

Amir et al [14] mentioned that most of the IoT-based healthcare system use local gateway as a bridge to connect sensor network and the cloud. The main role of local gateway in the healthcare system is to receive medical data from sensors using wireless protocols like Wifi, Bluetooh, Zigbee or 6LoWpan. Local gateway has potential to provide higher-level-service like local storage, data analysis, data filtering and etc. In this paper, authors proposed to apply the concept of Fog Computing in IoT -based healthcare system by utilizing the local gateway through forming a Geo-distributed intermediary layer of intelligence between sensor network and cloud. A prototype name UT-GATE is constructed using Pandaboard and Texas Instruments (TI) SmartRF06 platform integrated with CC2538 module and MOD-ENC28J60 Ethernet Module to support the study. Table 2.6 shows the latency result for the sensing to actuation loop by comparing the UT-GATE with other healthcare system.

Table 2.6: Latency Result

Latency of the sensing-to-actuation loop	**using Wi-Fi (ms)**	**using BLE (ms)**
Fog-based (locally via UT-GATE)	21	33
Cloud-based (remotely via the Cloud)	161	176

Min et al [27] proposed a new generation smart clothing integrated with ECG, respiration, heart rate, body temperature, and blood oxygen sensor is proposed to replace traditional wearable medical sensors. Authors have highlighted that this smart clothing is convenient, comfortable, washable, highly reliable and durable from traditional wearable medical sensors. Besides, data processing module, storage module and wireless communication module also part of the important components integrated in smart clothing. Non waterproof sensors and modules are able to remove from smart clothing before washing. Smart clothing can measure vital sign from user, analyzed the data and activated the alarm if user is in un-health condition. It also will transfer the data to local

gateway like smartphone through Bluetooth and later will upload to cloud storage. An apps is used by smartphone to display data from sensors.

M. S. Mahmud et al [28] prototyped a wireless healthcare monitoring system, “Smart Case” that able to measure ECG signal in real time. This system replace the existing ECG sensor module with a dry electrode which attached to a smartphone case. The signal from electrode is filtered using bandpass filter and a notch filter before amplified by high gain amplifier. This amplifier will send to RFduino and ECG’s features are extracted before transfer to smartphone using Bluetooth. This system also provided an emergency button that able to trigger an alert with GPS location and voice message to the emergency contact of user. Smartphone is used to receive and display the data obtained by sensor with an android app. This system unable to connect many sensors since it is limited by Bluetooth technology. Only one device can connected and transmit data to smartphone at a time.

J. Qi et al [43] had studied several research that focus on monitoring human’s physical activities since physical inactivity is the fourth leading risk factor for global mortality according to WHO. Generally, the research studied are combination of sensing layer, network layer and analysis layer. The sensing layer consist of wearable sensors and smart phones which able to recognize human’s physical activities through recorded specific data from human. The wireless communication technology like RFID, Bluetooth and Zigbee are implemented in network layer to transmit data to analysis layer or shared the data among sensors. In analysis layer, temporal segmentation, feature extraction and machine learning algorithms are developed to perform analysis on the data received. Large volume of data is recorded during monitoring and might not enough memory space to store the data.

2.4 System on Chip FPGA (SoC FPGA)

The advent of semiconductor technology allow integrated circuit designers to integrated more functions into a chip and created SoC. SoC is a silicon chip that integrated with difference functions like high speed logic, memory, analogue to digital converter and etc. The term of SoC is often refer to Application System Integrated Circuit (ASIC). At the past, these functions were realized through combine difference components on a printed circuit board (PCB). However, SoC able to provide same features with lower cost, faster, smaller physical size and better performance [34]. Figure 2.4 shows the comparison between SoC and traditional system on a PCB.

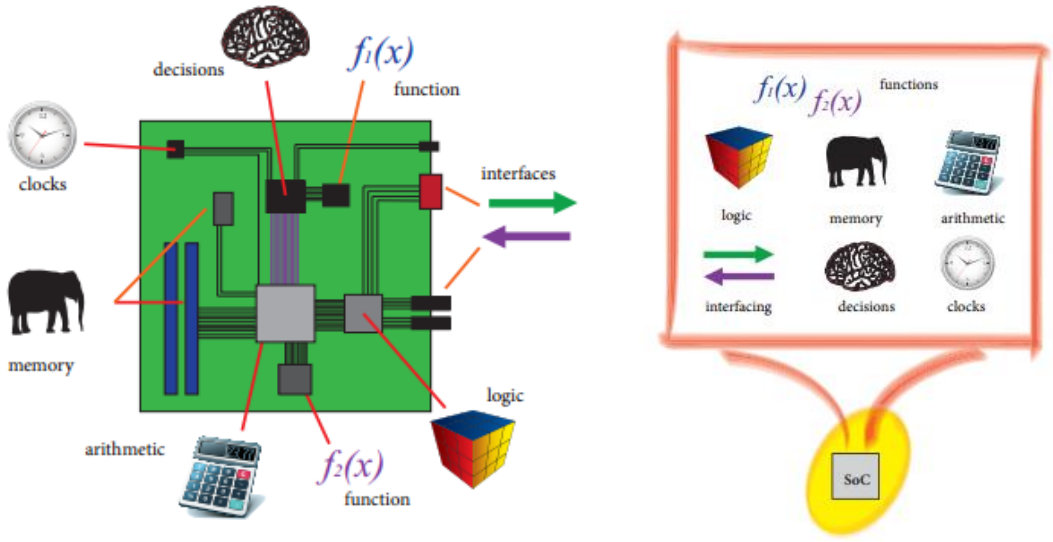

Figure.2.4: Comparison between SoC and Traditional System on a PCB [34]

At the same time more costs have to invest in order to keep up with Moore's Law. The fixed function semiconductor or single purpose semiconductor will soon become unpopular due to grow in advance semiconductor cost and even more in coming process technology. The ASIC based SoC required longer development time, higher cost and lack of flexibility. This has limited the ASIC based SoC and make it only suitable for high-volume market where no future upgrades are required like tablets and smart phones. These limitations have motivated a new SoC solution which implemented on a programmable FPGA [35].

SoC FPGA is introduced and it has potential to serve in different market since it is programmable. SoC FPGA integrated microprocessor and FPGA into a single platform to provide better performance, flexibility and reliability. SoC FPGA combines the control capability of a microprocessor and parallel processing capability of FPGA to solve the limitation of ASIC based SoC. There are 3 sets of SoC FPGAs available on market which are Altera SoC, Xilinx Zynq 7000 EPP and Microsemi SmartFusion2. In this study, the DE1-SoC platform from Altera SoC family will be focused.

DE1-SoC platform combines the dual-core Cortex-A9 embedded cores with programmable FPGA logic for ultimate design flexibility and allow user to leverage the power of tremendous re-configurability paired with a high-performance, low-power processor system. According to Intel FPGA (previous called Althera), DE1-SoC platform integrates an ARM-based hard processor system (HPS) tied with the FPGA fabric through a high-bandwidth interconnect backbone. The hardware provided by DE1-SoC platform are high-speed DDR3 memory, video and audio capabilities, Ethernet networking, and etc.

2.5 IBM Bluemix IoT Platform

IoT allows multiple smart devices to connect to each other via Internet and generated huge amount of data. The method to acquire, store, process and integrate the data has become a huge challenge for developers to make use of these data to achieve their goal. According to survey done by Business Insider, there were 44% global IoT project managers agreed that the main challenge faced in collecting and analyzing data from their IoT project is too much data to analyze effectively. The result of the survey is shows in Figure 2.5. Cloud Computing is the solution to overcome the challenge in data management since the service on Cloud Computing environment able to consume data on-demand, analyze data and send control action in real time. There are at least 49 IoT cloud platform are available to developers and suitable for the application like healthcare,

transportation and manufacturing. In this study, IBM Watson IoT Platform (https://internetofthings.ibmcloud.com) will be focused.

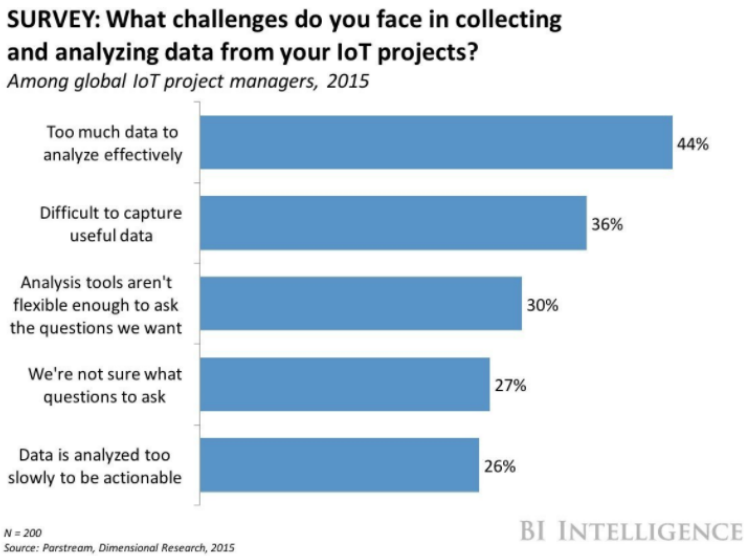

Figure 2.5: Survey from Business Insider [38]

IBM Blumix IoT platform assists developers to solve problems and drive business value through its applications, infrastructure and services. It allows the developers to design and manage Web or mobile application easily. IBM Blumix IoT platform allow connection from devices like Arduibo, Intel Galileo and etc through MQTT messaging protocol. IBM Blumix IoT platform also associated with NoSQL, Dash and Time Series database. Ademir et al [39] had proposed an Industrial Exhauster using Arduino platform as sensor node while a Rasberry Pi function as local gateway. The data from sensors was formatted in JSON representation and transmitted to IoT application through MQTT messaging protocol. The IoT application was implemented using Node-RED and hosted in IBM Blumix. The IoT application also exposes a RESTful API so that data can be queried and consumed by other applications.

2.6 Summary

Several wireless protocol are used to communicate with the local gateway but there are some limitation. Although WBAN is more user friendly but the power source is limited its performance and affected the sensors' accuracy since battery is used. At the