A Comparative Study On Various Providers Of Wearable Wireless Sensor Products And Solutions (WWSPaS)

Final Report

Submitted to Dr. Maher Elshakankiri

Department of Computer Science

CS 890DH - Topics on Communications

Spring/Summer 2020

By

Tanu Nanda Prabhu - 200409072 - tnb735@uregina.ca

Regina, Saskatchewan

July, 2020

TABLE OF CONTENTS

TABLE OF CONTENTS 1

1 Introduction . . . 3

1.1 Health Care . . . 3

1.2 Wireless Sensor Network . . . 3

1.3 Internet of Things . . . 4

1.4 Open Connectivity Foundation . . . 5

1.5 IoTivity . . . 6

1.6 Libelium . . . 7

1.6.1 User Cloud Plans . . . 8

1.7 SHIMMER . . . 8

1.8 LoRaWAN . . . 8

2 Summary . . . 9

3 Related Work . . . 9

3.1 Data Model . . . 11

4 Proposed Solution / Discussion . . . 16

4.1 Comparison between OCF, IoTivity, Libelium MySignals, and SHIMMER . . . 16

4.2 Comparision between LoRa and GPRS . . . 18

4.3 Comparision between IoT4HC and GPRS . . . 18

4.4 Comparison between LoRa and other technology chip-sets . . . 19

5 Scope and limitations of the project . . . 23

6 Results . . . 23

7 Future Scope and Open ended problems . . . 24

7.1 Implementation of the blood pressure monitor using the OCF data model board with a blood-pressure sensor . . . 24
7.2 Human activity recognition . . . 24
7.3 Implementation of health monitoring using LoRaWAN . . . 24
7.4 LoRaWAN based e-health communication . . . 24
7.5 Libelium based e-health platform . . . 25
7.6 Health care resource model based on OCF on IoTivity platform . . . 25
7.7 Execution of wearable sensor systems in well-being and amusement . . . 26
8 Conclusion . . . 26
9 References . . . 27
10 Appendix . . . 30

Abstract

Wearable wireless body sensor networks are by far the most striking and trending domains in the field of computer science. Especially one of its applications such as health care is the most legatee of the Internet of Things (IoT) and wearable computing. In this research project, a detailed comparative study on various wearable wireless sensor products and solutions specifically on health care would be conducted. As we all know, the present era comprises many technological vendors, products, and solutions that are very prominent in healthcare. So out of many, the top three providers of wearable wireless sensors such as Libelium, SHIMMER, and OCF (IoTivity) framework along with LoRaWAN protocol shall be chosen for this study. Overall the detailed comparison between the implemented applications or models and the ones mentioned in the research will be thoroughly explored as the result.

1 Introduction

1.1 Health Care

Universally, the elderly populace is growing, and the general populace is getting older [1]. Because of the ever-increasing population, unknown diseases are putting more pressure on the health care systems. Infectious, deficiency, hereditary, and physiological, and the recently emerged virus (coronavirus) that has spread rapidly and killed thousands of people are just some diseases/viruses that have caused burdens for medical workers. Not only that, but a great extent of people also suffer from chronic illnesses. The Center for Disease Control and Prevention (CDC), says that every **"six in ten grown-ups in the United States has a chronic disease and four in ten grown persons have two or more chronic diseases"** [2].

1.2 Wireless Sensor Network

It is a network of devices (sensors) which remotely transmits data [3]. To be more specific, the data here can be a sample of humidity, temperature readings, blood and glucose levels, etc.[4]. The information is sent through various remote sensors called hubs using a gateway [4]. A sensor node can navigate autonomously or heavily influenced by humans [5]. Figure 1 delineates the design of the Wireless sensor network (WSN) model [5].

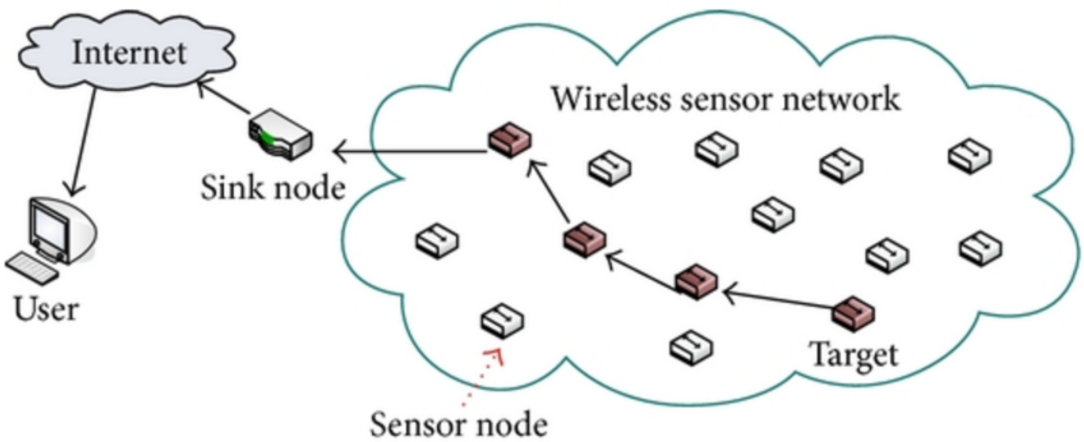

Figure 1: WSN architecture [5]

WSN was primarily used in military applications but was later extended to health care applications. Some implemented system models, for example, finger-worn ultrasound tests, virtual sign checking in emergency clinics, fall detection for elderly, and indoor versatile maturing have shown the capability of wireless sensor networks to empower early recognition of clinical disintegration through constant patient observation in medical clinics [6]. With the help of this innovation, individuals need not spend a ton of cash on medical services. They can monitor and improve their health status via the applications embedded with wireless sensors.

1.3 Internet of Things

A critical number of physical things are being related to the internet at a phenomenal rate, understanding the chance of the Internet of Things (IoT) [7]. IoT makes devices or objects intuitive and shares information. In the present era, almost every device is connected to the internet. This includes cellphones, coffee makers, washing machines, headphones, etc. In simple words, we can define IoT as connecting all various devices or gadgets that relate with all characteristics of many livings to the internet, singular for transference, prepotency, and relaying of information towards making the most productive decisions. The architecture of IoT is shown in Figure 2.

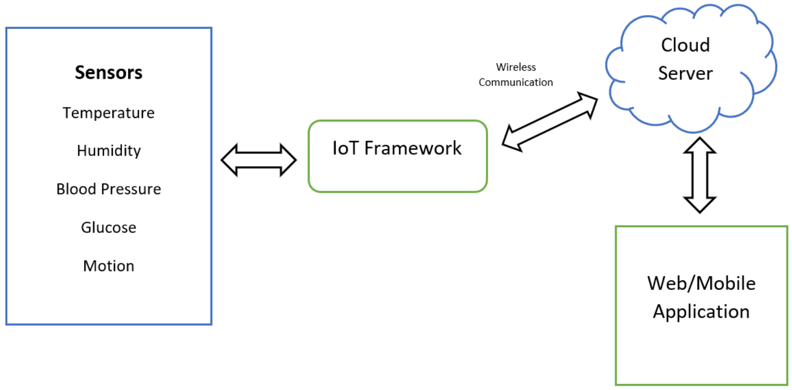

Figure 2: IoT architecture

1.4 Open Connectivity Foundation

Open Connectivity Foundation (OCF) is an open-source foundation devoted to guaranteeing a standard secure communication platform for customers, businesses, industries [8]. With the help of its open-source certification and implementation program, any devices irrespective of form factor, operating system, a service provider can use OCF. Figure 3 shows the building blocks of OCF. The OCF was founded in the year 2004 and has over 400 members altogether [9]. OCF has 5 different membership lists which include diamond members comprises of CISCO, Electrolux, Haier, Qualcomm, etc. [9]. Platinum members include Intel, Shaw, Mediacom, etc. [9]. Gold members include Lenovo, L&T Technology Services, Netgear, etc. [9]. Non-profit educational members include Kookmin University, KAIST, Seoul National University, etc. [9]. And the last but not the least basic member which include MediaTek, Microsoft, B&W Group Ltd, Nokia Networks, etc. [9].

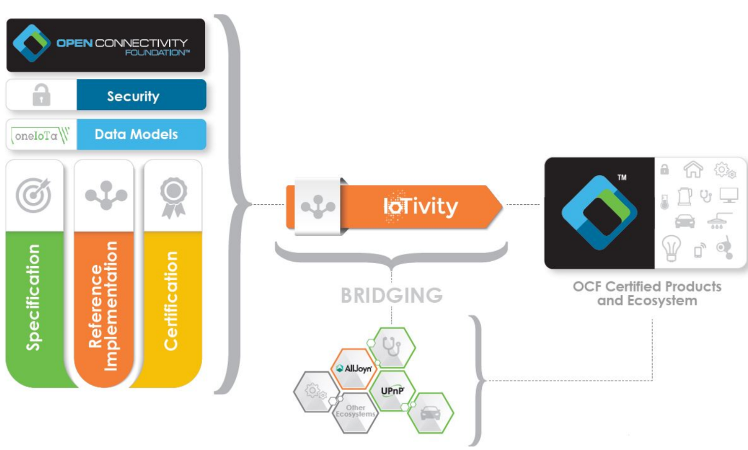

Figure 3: Building blocks of OCF [9]

OCF provides an online tool called **“OneIoTa”** to support the plan of interoperable gadget data models for the Internet of Things [8]. There are different data models such as heartbeat, blood pressure, glucose level, etc available in the OneIoTa repository. All these data model is freely available and is in the form of JSON files. Below is the JSON file for the Heartbeat [8].


```json
{
  "swagger": "2.0",
  "info": {
    "title": "Heart Rate",
    "version": "2019-03-04",
    "license": {
      "name": "OCF Data Model License",
      "url": "https://github.com/openconnectivityfoundation/core/blob/e28a9e0a92e17042ba3e83661e4c0fbce8bdc4ba/LICENSE.md",
      "x-copyright": "Copyright 2018-2019 Open Connectivity Foundation, Inc. All rights reserved."
    },
    "termsOfService": "https://openconnectivityfoundation.github.io/core/DISCLAIMER.md"
  },
  "schemes": [
    "http"
  ],
  "consumes": [
    "application/json"
  ],
  "produces": [
    "application/json"
  ],
  "paths": {
    "/HeartRateResURI": {
      "get": {
        "description": "This Resource describes the Properties associated with a person's heart rate.\n The unit, which is the default unit, is bpm.\n The
            heartrate Property is a read-only value that is provided by the server.\n When range (from \"oic.r.baseresource\") is omitted the default is 0
            to +MAXFLOAT.",
        "parameters": [
          {
            "$ref": "#/parameters/interface"
          }
        ],
        "responses": {
          "200": {
            "description": "",
            "x-example": {
              "rt": [
                "oic.r.heartrate"
              ],
              "heartrate": 80
            },
            "schema": {
              "$ref": "#/definitions/HeartRate"
            }
          }
        }
      }
    }
```


Figure 4: JSON file data model of heart beat [8]

1.5 IoTivity

IoTivity is also an open-source framework that actualizes the OCF guidelines by giving simple and secure communications to IoT devices. Each day more and more web-based devices/applications are coming online, adding to the ever-developing IoT [10]. Because of this security and reliability play a prominent role. The IoTivity venture was made to unite the open-source network to quicken the improvement of the system and administrations required to associate these billions of gadgets [8]. Figure 5 depicts the architecture of IoTivity [10].

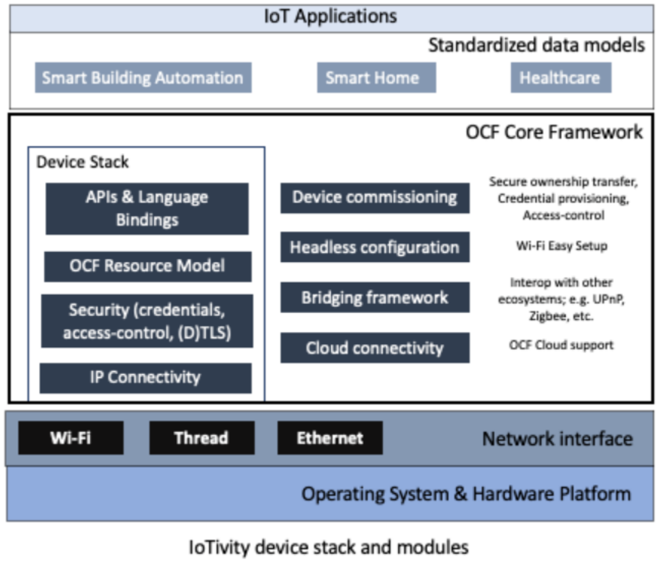

Figure 5: Architecture of IoTivity [10]

1.6 Libelium

Libelium is the producer of remote sensors for different applications, for example, brilliant homes, urban communities, medical care, etc [11]. It was founded in the year 2006 and is headquartered in Europe, with over 11-50 employees actively working. Alicia Asin, David Gascon are the prime founders of Libelium. There are several products such as waspmote, plug sense, smart parking, meshlium, Mysignals, mobile phone scanner. Figure 6 shows the ecosystem of Libelium [12].

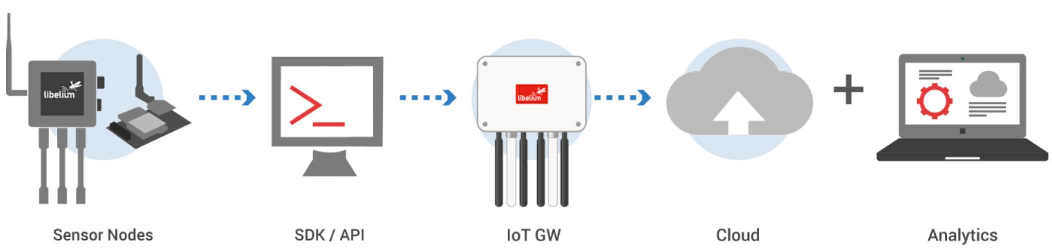

Figure 6: Ecosystem of Libelium [12]

The cloud partners of Libelium include Ericsson, Amazon web services, NEC, IBM cloud, etc. Similarly, its solution partners include Basen, eagle.io, Tata communications, etc. Libelium MySignals is an improvement stage for clinical gadgets and e-wellbeing applications. MySignals measures are over 15 different biometric parameters. Since it's open-source, we can add our sensors to build new devices. Some sensors include temperature, glucometer, blood pressure, body pressure, etc. With the help of its cloud services, the data gathered by MySignal sensors would be encrypted and sent to the owner's account. Data can be sent via Wifi or Bluetooth to the cloud for storage [12].

1.6.1 User Cloud Plans

	BASIC 99 €/year	*PRO 199 €/year*	*ELITE 499 €/year*
Usage	Platform Testing	Small development deployment	Professional development deployment
User Profiles	5	50	Unlimited
Departments	1	10	Unlimited
MySignals devices	1	1	1
Data Base Storage	0.1GB	2GB	6GB
Traffic I/O	2GB	5GB	15GB
Android/iOS App	Yes	Yes	Yes
Encryption Point to Point	Yes	Yes	Yes
Libelium Cloud Access	Yes	Yes	Yes
API Cloud	No	No	No

Figure 7: Cloud plans for users [13]

1.7 SHIMMER

The SHIMMER is a supplier of wearable remote sensor items and arrangements. It stands for **"Sensing Health with Intelligence, Modularity, Mobility, and Experimental Re-usability"**. It was founded in the year 2008 and is headquartered in Europe. Paddy White found it. Serves around 11-50 employees [14]. Some of their successful kits are Consensys Bundle Development Kit, Shimmer3 EBio Consensys Development Kit, Verisense Activity and Sleep Kit, etc [15]. Collaboration partners of SHIMMER are QTUG, Kinesis, NeuroLynQ, etc. [14].

1.8 LoRaWAN

It stands for **"Low Range Wide Area Network"** also known as LPWAN (Low Power Wide Area Network) technology which provides low power and cost device-to-device communication in densely populated residential locations [16]. It provides long-range communications in noisy environments. LoRa which is **"Long Range"** operates at the physical layer of the OSI model, works on unlicensed bands such as **"EU 868 MHz and US 433 MHz"** [16]. But the LoRaWAN operates at the MAC (Medium Access Control) layer, uses FSK (Frequency Shift Key) technique for modulation [16]. The outline of LoRaWAN engineering is depicted in Figure 8 [16]:

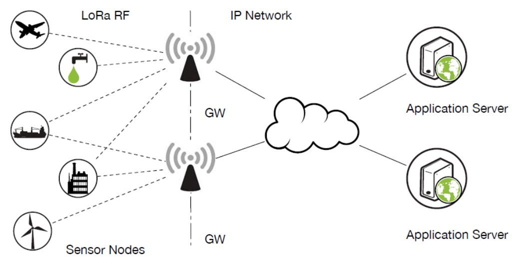

Figure 8: LoRaWAN architecture [16]

2 Summary

This final project report is a detailed comparison between various wireless sensor networks, products, and solutions in healthcare. The methodology proposed would be a detailed comparison of different models, products, and solutions of body sensor networks. These are Libelium, SHIMMER, OCF(IoTivity), and LoRaWAN protocol. As these are different technologies, products, and solutions a side-by-side comparison is significantly hard because different innovations would be done in different fields. Every research implementation in this field would be thoroughly explored and compared also a future scope would be provided for every comparison. Different research papers (references section) are being referred to as proposing a comparative study. It would be really hard to choose the best one, because all these technologies work well in different environments. The advantages and disadvantages of each product and technological solutions would be listed. With the help of this detailed comparative study, others can choose the right product or solution when they build, develop, or deploy the product of their choice.

The final report is organized as follows, section 3 talks about the related works, whereas section 4 talks about the proposed arrangement/system alongside results. The scope and limitations of the project is discussed in section 5. Section 6 discusses about the result. Section 7 provides the recommendations and future scope. The section 8 provides the conclusion of the report. Section 9 and 10 are references and appendix of the report

3 Related Work

H. Cha and J. Jeon et. al [8] implemented the blood pressure monitor using the OCF data model [8]. The main reason for using OCF was to prolong its data models available from its 'OneIoTa' repository which is open source and free to download. Shown below is the data model specification table.

Data Model Name	Blood Pressure
Published in	RAML
Type	JSON
Format	Swagger
Compatible with	OCF Restful architecture

Figure 9: Data Model Specification table [8]

Below is the JSON format of blood pressure data model along with the RAML API downloaded from the OCF repository:

```
{
  "id":
"http://openinterconnect.org/iotdatamodels/schemas/oic.r.bloodpressure.json#",
  "$schema": "http://json-schema.org/draft-04/schema#",
  "description" : "Copyright (c) 2017 Open Connectivity Foundation, Inc.
All rights reserved.",
  "title": "Blood Pressure",
  "definitions": {
    "oic.r.bloodpressure": {
      "type": "object",
      "properties": {
        "systolic":   {
          "type": "number",
          "minimum": 0,
          "readOnly": true,
          "description": "Systolic blood pressure"
        },
        "diastolic":   {
          "type": "number",
          "minimum": 0,
          "readOnly": true,
          "description": "Diastolic blood pressure"
        },
        "map":   {
          "type": "number",
          "minimum": 0,
          "readOnly": true,
          "description": "Mean Arterial Pressure (MAP)"
        },
        "unit": {
          "type": "string",
          "readOnly": true,
          "enum": ["mmHg", "kPa"],
          "description": "Blood pressure unit"
        }
      }
    }
  },
  "type": "object",
  "allOf": [
    {"$ref": "oic.core.json#/definitions/oic.core"},
    {"$ref": "oic.baseResource.json#/definitions/oic.r.baseresource"},
    {"$ref": "#/definitions/oic.r.bloodpressure"}
  ],
  "required": ["systolic", "diastolic"]
}
```

a) JSON file data for blood pressure [8]

```
schemas:
  - BloodPressure: !include oic.r.bloodpressure.json

traits:
  - interface:
      queryParameters:
        if:
          enum: ["oic.if.s","oic.if.baseline"]

/BloodPressureResURI:
  description: |
    This resource describes the properties associated with a person's
Blood Pressure.
    The unit is a single value that is one of mmHg or kPa.
    If the unit Property is missing the default is a millimeter of mercury
[mmHg].
    The BloodPressure and unit Properties are read-only values that are
provided by the server.
    When range (from oic.r.baseresource) is omitted the default is 0 to
+MAXFLOAT.

  displayName: Blood Pressure
  is: [ interface ]

  get:
    description: |
      Retrieves blood pressure of an object.
    responses:
      200:
        body:
          application/json:
            schema: BloodPressure
            example: |
              {
                "rt":      ["oic.r.bloodpressure"],
                "id":      "unique_example_id",
                "systolic": 110,
                "diastolic": 85,
                "unit": "mmHg"
              }
```

b) RAMPL API for blood pressure [8]

Figure 10: JSON file and RAMPL API for blood pressure [8]

As seen in the above JSON code, blood pressure data has two important parameters **systolic** and **diastolic** with values **110** and **85**, respectively [8]. The measurement unit is mmHg or kPa. The value of 200 shows successful communication between the server and the client [8]. IoTivity can be installed on Windows and Ubuntu and different platforms. Here IoTivity was used only to create a server that is primarily used for measuring transmitted health care data and client which is used to receive data from the server. Similarly, Libelium MySignals was used to develop a prototype with its available sensors such as blood pressure monitor, glucometer, body temperature, scale.

T.Amartuvshin et.al [17] implemented the human activity recognition using **SHIMMER 2A** wireless sensor platform. Here the 2A platform comprises sensors, data storage, communication, connection capabilities. Show below is the specifications of the SHIMMER 2A platform [17].

Platform Name	Shimmer 2A
Core	MSP430 MCU
Bluetooth	Yes
Accelerometer	iMEMS tri-axis MMA7260Q
Software Operating System	Tiny OS

Figure 11: Shimmer 2A platform specifications [17]

Block diagram of the SHIMMER baseboard is as shown below [17]:

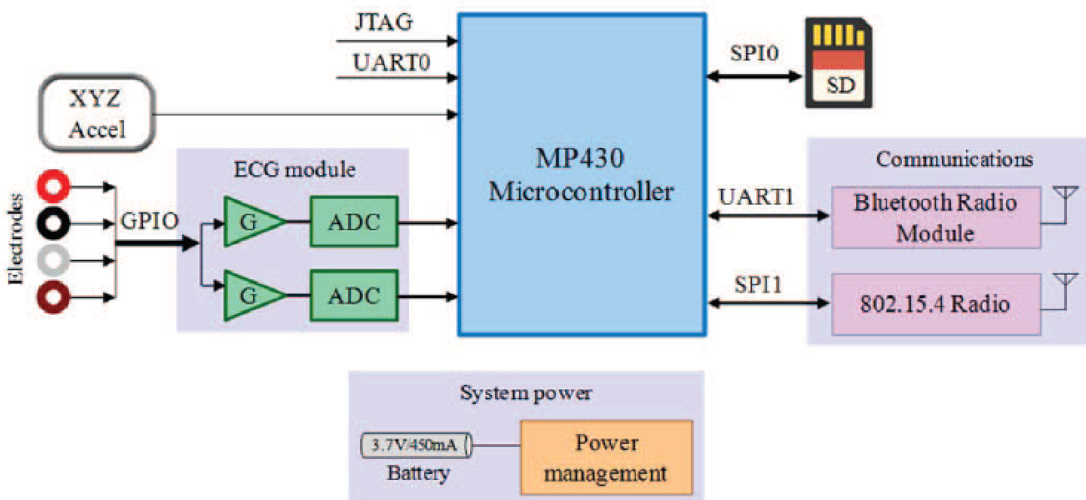

Figure 12: Shimmer 2A platform [17]

The only reason that the accelerometer is being used for measuring the patient's body movements. Similarly, the ECG (electrocardiogram) is primarily used for recording the heartbeats (activity).

3.1 Data Model

The sensor data can then be accessed on a mobile phone. With the help of this, the device can understand the movement of the patient's body such as running, walking, skipping as shown below [17]. SHIMMER 2A can monitor and record the ECG of the patient's activity, it keeps on monitoring continuously with high accuracy by allowing users to access the data on their wireless device.

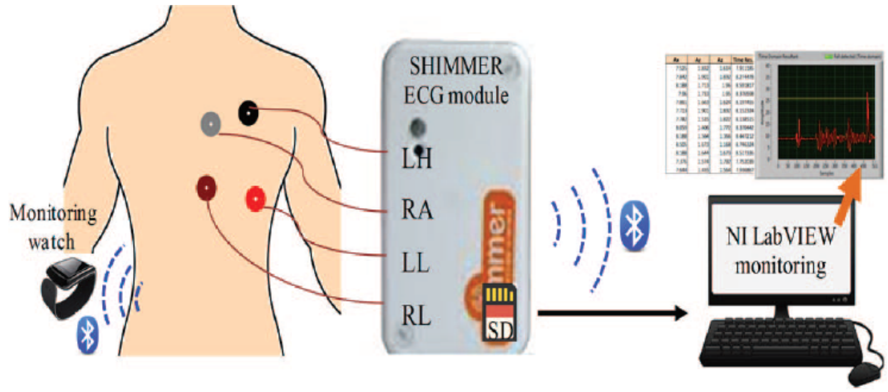

Figure 13: Block diagram of the data model [17]

Afef Mdhaffar et al [18]. implemented an e-health monitoring system (along with temperature, glucose monitor) in rural areas via LoRaWAN [18]. The low power wide area network (LoRaWAN), is a low-power cost and enables secure communication between the sensors implanted to the patients and the dashboard or the user interface at the doctor's side. The authors use IoT4HC (Health Care) architecture because they believe all the existing works use relatively high communication links, and the connection is not secure. Shown below is the architecture for IoT4HC [18].

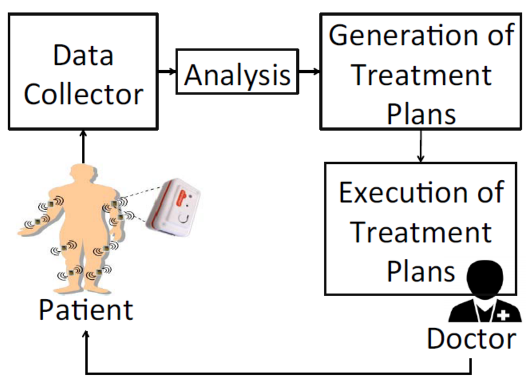

Figure 14: Architecture of IoT4HC [18]

The data collector collects the data from the embedded sensors on the patient's body. The analysis component gathers the data from the collector and generates diagnosis reports which then would be to provide generation treatment plans by the generation treatment plans component [18]. Last, the created reports are approved and executed by specialists. The IoT4HC depends on the LoRaWAN convention: a highly efficient communication protocol. The security of LoRaWAN is much better than the traditional GSM because it houses symmetric encryption based on AES IEE E802.15.4/2006 along with a 128-bit key. The below figure shows the based e-health monitoring framework [18].

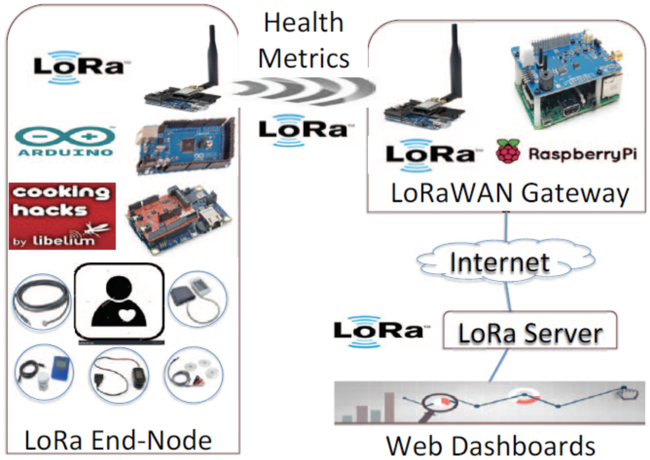

Figure 15: LoRaWAN based e-health monitoring system [18]

As seen in the above figure 16 the LoRa end node comprises e-health sensors, a shield, along with Arduino Mega microcontroller, LoRa transceiver [18]. All the transceivers, sensors, and the shield are designed by Libelium.

Bo Dong S et al. [19] implemented wearable sensing networks for human mobility and activity analysis [19]. Bo Dong S et al. investigated and thought about the consequences of a solitary sensor framework [19]. A multi-sensor game plan that was utilized to follow the imperativeness. This system used 3 inertial measurement unit (IMU) sensors [19]. They attached these to the user's/patient's thigh, wrist, and ankle as seen in Figure 16 [19]. These three locations resulted in the highest accuracy. Both Mercury and SHIMMER wearable wireless platforms were used [19].

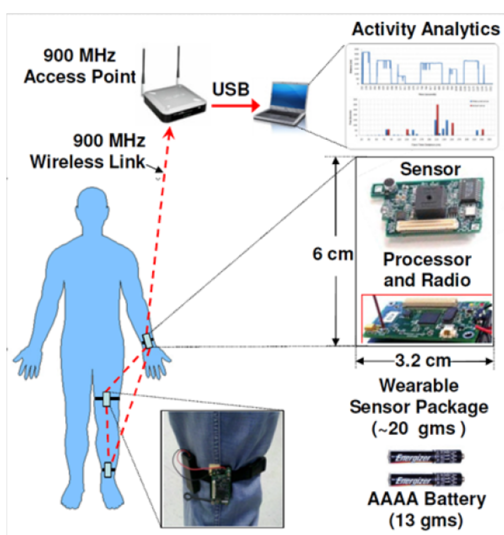

Figure 16: Activity analysis using wearable sensor networks [19]

Joo-Chul Lee et al. [20] implemented the healthcare resource model on the IoTivity platform [20]. ETRI and Samsung electronics proposed the health care model in July 2015 under CoreTech WG [20]. The goal is to empower the medicinal services use cases, and making specific courses of action and contraption profiles that address the openings against social protection requirements in existing subtleties and standards [20]. There are ten gadgets and thirty two asset models and two standards such as Open Interconnect Consortium (OCI) healthcare resource and health care device developed by HCTG shown below [20].

Device Name	Device Type (rt)
Activity Trader	oic.d.activityTracker
Blood Pressure Monitor	oic.d.bpm
Glucose Mete	oic.d.bpm
Heart Rate Monitor	oic.d.hrm
Pulse Oximeter	Oic.d.sleepmonitor
Scale	oic.d.scale
Sleep Monitor	oic.d.sleepmonitor
Smart Watch	oic.d.watch
Strength fitness equipment	oic.d.fitness
Thermometer	oic.d.thermometer
Peak Flow	Tbd
Body composition Analyzer	Tbd
Strength Fitness	Tbd
Bike Power Meter	Tbd
Bike Speed Cadence Sensor	Tbd
Crank Torque Frequency	Tbd
Continuous Glucose Monitor	Tbd
Muscle Oxygen Monitor	Tbd
Patient Position Sensor	Tbd
Airflow Sensor	Tbd
Galvanic Skin Response Sensor	Tbd
Electromyography Sensor	Tbd

Friendly Name (informative)	Resource Type (rt)
Activity	oic.r.activity
Blood glucose sensor	oic.r.blood.glucose
Blood pressure sensor	oic.r.blood.pressure
Body Fat	oic.r.body.fat
Body height	oic.r.body.height
Body mass index	oic.r.bmi
Body metrics	oic.r.body.metrics
Body position	oic.r.body.position
Body site	oic.r.body.site
Body temperature	oic.r.body.temperature
Body water	oic.r.body.water
Body weight	oic.r.body.weight
Breath	oic.r.breath
Continuous glucose monitor	oic.r.cgm
Cycling computer	oic.r.cycling.computer
Cycling power	oic.r.cycling.power
Cycling speed cadence	oic.r.cycling.speedcadence
Distance	oic.r.distance
Electromyography	oic.r.emg
Fat free mass	oic.r.ffm
Forced expiratory volume 1	oic.r.fev1
Galvanic skin response	oic.r.gsr
Heart rate	oic.r.heartrate
Muscle oxygen saturation	oic.r.muscle.oxygen.saturation
Oxygen saturation	oic.r.blood.oxygen.saturation
Peak expiratory flow	oic.r.pef
Repetition	oic.r.repetition

Figure 17: Health care devices and resources from OCI [20]

Implementation of the e-health care with detailed specifications is given below:

IOT Platform version	IoTivity 1.0.1
Client hardware	Android smartphone
Server hardware	Arduino Due + BLE (Bluetooth Low Energy) shield + e-health kit sensor platform
Connectivity	BLE
Health care resource	Body temperature (oic.r.body.temperature), Oxygen saturation (oic.r.blood.oxygen.saturation), Blood glucose sensor (oic.r.blood.glucose)
Health care device	Blood pressure, heart rate and pulse oximeter

Figure 18: e-health implementation specifications

The prototype of the implementation structure is depicted in Figure 20.

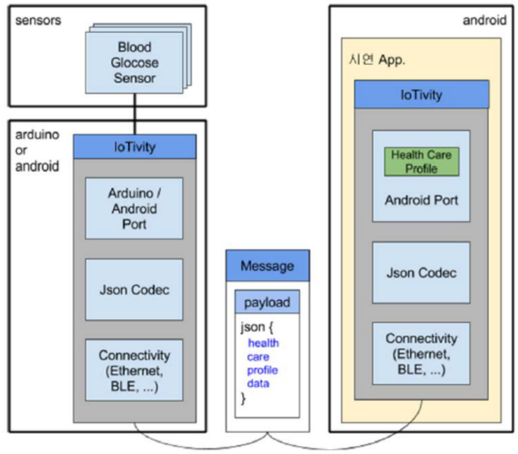

Figure 19: Prototype structure of healthcare resource [20]

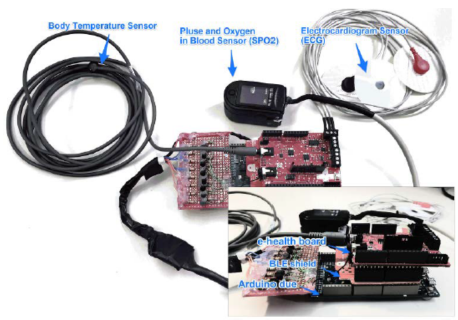

Figure 20: e-healthkit shield [20]

M.Talha Buyukakkaslar et al. [21] implemented LoRaWAN as an e-health communication technology. The data transmission for healthcare, or critical health care data in disaster environments, was investigated [21]. The data frame transmission of LoRaWAN is also being tested in healthcare. Theoretically the data rate (DR) is calculated by three important parameters.

- **Spreading factor (SF)** : Used to ensure the quality of service [21].
- **Bandwidth (BW)**: Range of frequencies, measured in hertz (Hz)
- **Coding rate (CR)**: Code rate at the forward error correction is the extent of the information stream that is helpful [21].

Altogether this can be written as [21]:

$$DR = SF \times \frac{BW}{2^{SF}} \times CR$$

The node development of LoRaWAN is given below in Figure 21. Arduino UNO is used as the baseboard, RFM95 chipset, LoRaWAN "Class A library stack" is also used [21]. Our end-hub is fit for transmitting LoRa outlines with predefined recurrence and SF values [21].

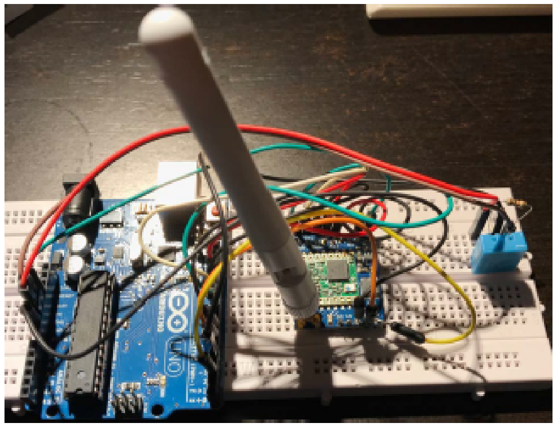

Figure 21: LoRaWAN node [21]

4 Proposed Solution / Discussion

The discussion of this project is done by a detailed comparison of the implemented and researched wearable sensor networks products and solutions discussed above.

4.1 Comparison between OCF, IoTivity, Libelium MySignals, and SHIMMER

Implementation of the blood pressure monitor using the OCF data model board with a blood pressure sensor. A blood pressure sensor is present in the MySignals Kit. Rather than comparing side by side, the comparison would be done by exploring the concepts, products thoroughly listing advantages, disadvantages, and the future scope. Firstly, let's see the advantages of the above implementation.

- With the help of these frameworks (IoTivity and OCF), can be effortlessly broadened and connected to other applications such as home applications (smart), transport applications or devices, etc. without drastic customization/transportation issue.
- The IoTivity was operated on OCF's standard data modeling, which is an official OCF reference specification implementation.
- Since because of the open-source nature of the OCF vault, any available data model can be easily edited and downloaded.

Below shown are the disadvantages of the above mentioned implementation:

- **Platform Compatibility issue**: Arduino Micro-controller is not supported by IoTivity. Arduino is utilized as the primary stage for Libelium MySignals.

- **External Shield**: An alternate option can be installing it to another operating system such as Linux, Ubuntu, etc. and then transport it to Arduino. For this successful porting an external shield should be used such as Raspberry Pi to Arduino shield.

- **Voltage level difference**: Arduino UNO and the Raspberry Pi 3 operate on two seperate voltages 5 and 3.3 V [8]. Hence to maintain the balance between them 3.3-5V bidirectional level shifter was used. The primary motivation behind utilizing a bidirectional level shifter was to arrange the voltage level contrast [8].

- **Bluetooth connectivity issue**: Also, Bluetooth (BLE) connectivity was also not supported, but since the code was open source, we could easily modify the OCF standards and make it compatible.

- **Selective operation**: Additionally, Bluetooth (BLE) availability was likewise not upheld by OCF, but only devices with three different protocols such as constrained application protocol, user data gram protocol, internet protocol operation only could be authenticated and certified.

Using shimmer 2A platform to implement human activity recognition [15]. Firstly lets see the advantages of using SHIMMER 2A platform of the above implementation:

- **Direct-To-Host data transfer**: With the assistance of this, we can without much of a stretch exchange the information from SHIMMER's smaller scale SD (Secure Digital) card to unload.

- **Expansion connectors**: The connectors of the SHIMMER board expands which allows all the baseboard hardware versions to work with internal and external sensors.

- **Tiny OS**: With the help of this software the application can be migrated via a compile time flag.

- **Wireless Data Streaming**: As mentioned earlier, the SHIMMER 2A base board is equipped with Bluetooth module named RN-32, which can be connected to the MCU MSP430. This can be possible with the help of serial connection. [15]

The baseboard of the SHIMMER 2A provides three different types of sensing capabilities such as kinematic, physiological and ambient. There are three channels of ADC which are used to connect to the micro control unit. The ECG provides a low power auto calibrating CMOS amplifier.

Implementation of health monitoring via LoRaWAN (IoT based). The advantages of implementing LoRaWAN rather than GPRS are:

- **More Range**: The total area covered by LoRaWAN is around 33 square kilometer, when it is placed on a altitude of 12 meters.

- **Power consumption efficient**: The power consumption of LoRaWAN is atleast 10 times lesser than traditional GPRS 3G/4G. The average power consumption of LoRaWAN is 148.6 mA where as the GPRS is around 2000 mA.

- **Low installation and Infrastructure cost**: The cost of the LoRaWAN is very less compared to the GPRS. The infrastructure cost of LoRaWAN is 10 times cheaper than GPRS. Also LoRaWAN provides secure communication.

- **Low Idle mode**: The idle mode of IoT4HC is 4.7 mA, where as the idle mode of the GSM is around 20 mA. Shown below is the comparision of both LoRaWAN and GPRS.

4.2 Comparision between LoRa and GPRS

	Average Range	Energy Consumption (mA)	Minimum Hardware Cost	Maximum Data Rate
LoRa	60 km	Idle mode: 2.8 mA Continuous receive mode: 14.2 mA Send mode 38.9 mA	Transceiver: 10 \$ Gateway: 250 \$	50 kbps (downlink) 50 kbps (uplink)
GPRS	60 km	Idle mode: 20 mA Continuous receive mode: 130 mA Send mode 2000 mA	Transceiver: 50 \$ Gateway: 10000 \$	85.6 kbps (downlink) 14 kbps (uplink)

Figure 22: LoRa versus GPRS comparision [17]

4.3 Comparision between IoT4HC and GPRS

	IoT4HC using LoRaWAN protocol	**GPRS (General Packet Radio Service)**
Power Consumption	**148.6 mA**	**~2000 mA**
Current Consumption (Idle Mode)	**4.7 mA**	**~20mA**

Figure 23: IoT4HC versus GPRS comparision [17]

The disadvantages of IoT4HC is as shown below:

- **Small frame size**: Collection of data would be represented as a small frame size of 256 bytes. And the need to send frequently this may overflow the frame.

- **Continuous data**: The IoT4HC cannot send continuous information (medical). The continuous medical information in this case would be ECG, EEG

Implementation of LoRaWAN based e-health communication. As we all know that LoRaWAN operates at the MAC layer uses multiple frequencies. There are three main categories of LoRaWAN:

- **Class A**: Supports bidirectional communication. The communication takes usually between gateway and an external device. Fully asynchronous and use lowest power.

- **Class B**: Extension of class A, includes scheduling for down-link messages from the server. Bidirectional and synchronous with latency.

- **Class C**: Extension of A, by keeping the get windows open except if they are emitting. Bidirectional and lowest latency.

All LoRaWAN gadgets must execute class A, though B and C are expansions to the detail of A gadgets [23].

Class	Description	Latency	Direction	Battery consumption
Class A	Must be supported by all the nodes. DL after TX	High latency	Bi-directional	Most energy efficient
Class B	Slotted communications synchronized with beacon frames	Low latency	Bi-directional	Efficient with controlled DL
Class C	Devices listen continuously, DL without latency	Very low latency	Bi-directional	Least efficient

Figure 24: Categories of LoRaWAN

4.4 Comparison between LoRa and other technology chip-sets

LoRa stands for low range, uses on chirp spread spectrum (CSS) modulation. The advantages of LoRa modulation are [24]:

- Adaptable transmission capacity and frequency [24]

- Consistent envelope/Low-force

- High strength
- Multipath/blurring Safe
- Doppler safe
- Long range ability
- Upgraded system limit

Unlike its advantages, LoRa is quite expensive when compared to other technological chipsets. Building a LoRaWAN end-hub with no sensors as of now requires $35 and a total GW costs from $200 to $800 contingent upon indoor or open air. The below-shown table shows the wireless chipset cost comparison:

Technology	Chipset Cost	Range	Data Rate
Blutooth LE	$3.69	10-100m	2Mbps
WiFi (2.4 GHz)	$2.08	10-100m	433Mbps
Zigbee	$4.80	10-100m	20-250kbps
LoRa (868Mhz)	$8.90	2-15km	300bps-50kbps

Figure 25: Comparison between LoRa and other technologies [18]

Libelium based e-health sensor is improvement with ECG for body area networks [25]. Libelium that permits Arduino clients to peruse and gather biometric data by utilizing 10 various sensors that incorporate electrocardiogram (ECG). The advantages in terms of security would be:

- The unit utilizes AES 128 bits for ZigBee and WPA2.
- WiFi is utilized in the correspondence layer
- HTTPS(secure) convention is utilized in the application layer
- An outer cloud is utilized to store the information for all time or can be sent to client's advanced cell for perception

The methodology used for the MFBSG algorithm is shown below in the form of a flowchart

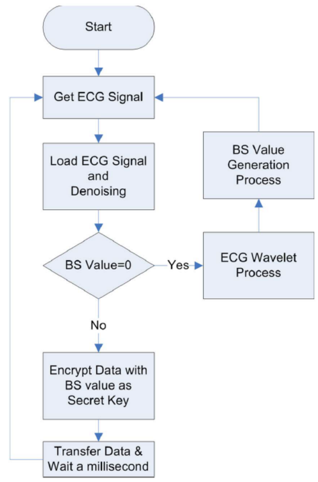

Figure 26: MFBSG algorithm process flowchart [25]

Below is the pseudo code of the implementation [25].

```
import eHealth
import ECG-MFBSG

# routine runs once when press reset
void setup() { Serial.begin(115200); }

# The routine runs in loop forever
eHealth.getECG();
load ECG signal();
Refine ECG signal();
detect ECG fiducial points by using discrete wavelet
transforms();
Generate BS value;
loop() {
        eHealth.getECG();
        if (BS value available)
        Encrypt based on ECG BS();
        Else generate BS;
        print/transfer(encrypted "ECG  v a l u e );
        delay (1); // millisecond wait
}
```

Figure 27: Improved algorithm of MFBSG [25]

Introduction of a new healthcare resource model the OCF and the IoTivity platform us being used [20]. The healthcare resource model/e-health kit comprises the IoTivity client/server application on Arduino. The sensor values were derived from the human body, and the three different types of sensors used were body, pulse, and oxygen (SPO2), electrocardiogram sensor (ECG). Shown below is the specifications of the model

IOT Platform version	1.0.1
Supported connectivity	Wi-Fi, Ethernet, BLE, NFC
Supported devices	Rich and Lite devices
OS	Linux, Android, Arduino, Tizen
Architectural model	RESTful resource-based architectural model
License	Apache 2.0
API layers	Two – Core API, Service API • **Core API** – Resource registration, lookup, query for resource value, monitor resource value • **Service API** – resource encapsulation, resource container, things manager, resource hosting, resource directory

Figure 28: Specifications of health care resource model

Usage of wearable sensor systems in wellbeing and diversion [22]. IMU (Inertial Measurement Unit) is one of the main and most commonly used types of sensors in the WSN. These have been extensively used in the military since 100 years because it collects different types of data such as gyroscope, magnetometer, and accelerometer. In the health care field, the IMU captures a near plot among solid and undesirable conduct.

For the activity monitoring system the Mercury along with the SHIMMER platform is used. Here the two disadvantages of Mercury platform with Shimmer is:

- **Platform incompatibility**: Mercury platform is not compatible with SHIMMER
- **No Pairing**: The Mercury platform cannot be paired with SHIMMER

On the other hand the SHIMMER platform has advantages over other platforms such as:

- **Less weight**: The SHIMMER along with Mercury weighs only **ten** grams
- **Less area**: The area occupied by SHIMMER is less than **ten square centimeters**
- **Increase ideality**: In view of less region it is utilized as a drawn out gadget contrasted with different gadgets.

5 Scope and limitations of the project

There is nothing in this world that stands is perfect. Likewise, there are some limitations to this project. But before let us see the scope of the project. This project provides a detailed comparison between the existing and implemented wearable sensor networks products and solutions. The scope is limited within the research boundary. Because there might be more implementations that would have been done in the field of healthcare but would have not come into the light. For example, on the official website of Libelium they have implemented a technology that helps to fight novel coronavirus. But this is not officially declared in any research paper. This is one of the limitations of the project. We need to broaden the scope and go beyond and try to compare and find the best solution. Another limitation would be comparing more research works because in this report there were 7 different works altogether comprising of different wireless products and solutions were compared in terms of health. Furthermore, research in the field of healthcare must be done. Because innovations in healthcare are an ever-increasing thing. We need to build such innovations devices self-monitoring devices to keep ourselves fit and not spend a ton of cash on health care.

6 Results

As this is a detailed comparative study between different products and solutions of wearable wireless sensor networks providing the best or the worst product or the solution is certainly improbable. Rather for every specific model or implementation, the comparison is done internally to choose the best platform, connectivity, or boards. The comparison results for every research implementation can be found in section 4 and correspondingly the future scope and recommendations of these innovations can be found in section 7. Because the result not just depends on the which is the best platform when it comes to choosing between Libelium baseboards and SHIMMER baseboards. The result would totally depend on the application. If we are building an e-health care system and we need more features in terms of cost, size, and speed, and storage. In this case, the Libelium boards outperform the SHIMMER platform because it provides MySignals cloud services which is very cheap and easy to use because of its dashboard functionality. On the other hand, if we want to incorporate sensors for healthcare then the SHIMMER platform provides a 3D accelerometer, blood pressure sensor, glucometer at reasonable prices. To find a detailed comparison refer to the above section.

7 Future Scope and Open ended problems

Below given are the recommendations, future scope and open ended problems for the implementations discussed in the proposed solution section 4.

7.1 Implementation of the blood pressure monitor using the OCF data model board with a blood-pressure sensor

As a future extension, an alternate number of OCF applications independent of areas can be worked in IoTivity. Because of the missing BLE feature, an alternate option would be using SHIMMER 2A or any higher versions, because the base version of SHIMMER provides BLE connectivity, and it is powered by MSP430 MCU which is way more powerful than ATMEGA 328.

7.2 Human activity recognition

As a future scope, rather than performing a multiple test, the base data for the testing can be extended by using one of the data models from the OCF repository. Also, an extended feature such as an alert notification system can also be added, in case if the patient falls down then an automatic call or message should be given to the caretakers. Also to store all the data the Libelium Mysignal cloud environment can be used since it is one of the cheapest and provides lots of features compared to other cloud environments.

7.3 Implementation of health monitoring using LoRaWAN

As a future scope, rather than using a LoRaWAN module for sending continuous medical data, we can use GPRS such as 4G, which is expensive, but this can send continuous data. We must also implement the IoT4HC in urban areas because not all people are rich and the internet connectivity is good in urban areas. A dashboard must be enabled because often patients would like to keep updated about their health, and they can monitor it regularly rather than an experienced person look over it.

7.4 LoRaWAN based e-health communication

As a future scope, rather than using a LoRa module for sending continuous data transmission, we can use LoRaWan conveying little estimated sensor information for significant distances or then again thick urban regions. LoRa is more expensive than LoRaWAN. But LoRaWAN as an LPWAN innovation that gives remote availability inside long ranges utilizing low vitality

7.5 Libelium based e-health platform

As a future scope instead of using a generic cloud, which leads to security issues, using a Libelium MySignals is the best option. MySignals cloud is best known for security and less cost. When it comes to choosing the best algorithms between EVFDT (Enhanced Very Fast Decision Tree) or MFBSG (Multiple Fiducial-points based Binary Sequence Generation) shown below are the results.

No. of Instances	Attack Detection Accuracy in %	
	EVFDT	MFBSG
10,000	95.7	96.4
20,000	96.8	97
30,000	97.6	98.5
40,000	98.1	98.7
50,000	98.8	99.1

Figure 29: EVFDT versus MFBSG algorithm [25]

As the number of instances increases such as for 50,000 instances the accuracy of MFBSG is around 99.1%. Choosing this would be the best option.

7.6 Health care resource model based on OCF on IoTivity platform

As a future scope, we can inculcate the wireless BLE connectivity for the e-health kit. The BLE 4.0 provides low vitality utilization and extensible information trade structure. The two potential ways to deal with help heterogeneous availability condition are:

- **Implementing a common network layer**: Maintaining a common network layer is very significant. One of the best recommendations is IPv6 (Internet Protocol with an address size of 128 bit).

- **Implementing application protocol**: This is a faster technique to send merchant's things into the market, in any case it is in opposition to the principles of OCF and we have to consider completing help for each system advancement in the IoTivity stage. To assist this technique with BLE, additional custom GATT-based profile for OCF transport is required

7.7 Execution of wearable sensor systems in well-being and amusement

As a future scope using Mercury with SHIMMER would be significantly hard because of platform compatibility. We must hope that the Mercury platform vendors will reduce the battery size and also reduce data collection. Because the more the data collection the bigger the battery. Alternative option would be using ZigBee with WSN. The goals of ZigBee is similar to that of Mercury. The ZigBee WSN contains an arrangement of IMUs that are similarly outfitted with sEMG sensor center points which give significant muscle development data for reclamation.

8 Conclusion

This paper has presented a comparative study or review of wearable wireless sensor products and networks specifically on health care. The different body sensor network providers were Libelium MySignals, Shimmer the frameworks such as IoTivity, OCF, and the protocols such as LoRaWAN were studied in depth. This final project report also comprises results from the midterm report (Half of the comparison was done in the midterm report and the other half is done in this final report). However, this is a detailed comparison between implemented and researched applications so there are no best and worst answers to choosing different frameworks, providers, or protocols. But as a whole for choosing the platform if the application is implementing a health monitoring system, then according to the study conducted the SHIMMER 2A platform performs better than Libelium MySignal Arduino Uno. Similarly, for implementing the protocol resulting in low cost, secure then LoRaWAN is the best option compared to GPRS. Also to access the data model, the OCF repository is the only and the best option available. Also, in the appendix section, a small snippet of python code is provided to convert the JSON code (data model) to CSV (Comma Separated Value) format.

9 References

[1] "Ageing", Un.org. [Online]. Available: https://www.un.org/en/sections/issues-depth/ageing/. [Accessed: 26- Jul- 2020].

[2] "Chronic Diseases in America — CDC", Cdc.gov. [Online].
Available: https://www.cdc.gov/chronicdisease/resources/infographic/chronic-diseases.htm. [Accessed: 26- Jul- 2020].

[3] I. Khan, F. Belqasmi, R. Glitho, N. Crespi, M. Morrow and P. Polakos, "Wireless sensor network virtualization: A survey," in IEEE Communications Surveys Tutorials, vol. 18, no. 1, pp. 553-576, Firstquarter 2016, doi: 10.1109/COMST.2015.2412971.

[4] "Introduction to Wireless Sensor Networks Types and Applications". ElProCus - Electronic Projects for Engineering Students, from https://www.elprocus.com/introduction-to-wireless-sensornetworks-types-and-applications/ [Accessed: 26- Jul- 2020]

[5] Ryu, Ji Irfan, Muhammad Reyaz, Aamir. (2015). "A Review on Sensor Network Issues and Robotics. Journal of Sensors". 2015. 1-14. 10.1155/2015/140217.

[6] J. Ko, C. Lu, M. B. Srivastava, J. A. Stankovic, A. Terzis and M. Welsh, "Wireless Sensor Networks for Healthcare," in Proceedings of the IEEE, vol. 98, no. 11, pp. 1947-1960, Nov. 2015, doi: 10.1109/JPROC.2015.2065210.

[7] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," in IEEE Communications Surveys Tutorials, vol. 17, no. 4, pp. 2347-2376, Fourthquarter 2015, doi: 10.1109/COMST.2015.2444095.

[8] H. Cha and J. Jeon, "OCF Healthcare Proof of Concept (PoC) on Libelium MySignals," 2017 European Conference on Electrical Engineering and Computer Science (EECS), Bern, 2017, pp. 356-364, doi: 10.1109/EECS.2017.73.

[9] "OCF Membership List", Open Connectivity Foundation (OCF). [Online]. Available:
https://openconnectivity.org/foundation/membership-list/ [Accessed: 26- Jul- 2020].

[10] "IoTivity Architecture — IoTivity", Iotivity.org. [Online]. Available: https://iotivity.org/about/iotivity-architecture. [Accessed: 26- Jul- 2020].

[11] "Products — Libelium", Libelium.com. [Online]. Available: http://www.libelium.com/products/. [Accessed: 26- Jul- 2020].

[12] "Ecosystem", Libelium.com. [Online]. Available: http://www.libelium.com/partners-ecosystem/.

[Accessed: 26- Jul- 2020].

[13] "MySignals Cloud — Libelium", Libelium.com. [Online]. Available: http://www.libelium.com/cloud-services/mysignals-cloud/. [Accessed: 26- Jul- 2020].

[14] "Customers — Shimmer Enterprise Customers", Shimmersensing.com. [Online]. Available: http://www.shimmersensing.com/services/customers/. [Accessed: 26- Jul- 2020].

[15] A. Burns et al., "SHIMMER™: An extensible platform for physiological signal capture," 2015 Annual International Conference of the IEEE Engineering in Medicine and Biology, Buenos Aires, 2010, pp. 3759-3762, doi: 10.1109/IEMBS.2010.5627535.

[16] M. T. Buyukakkaslar, M. A. Erturk, M. A. Aydin and L. Vollero, "LoRaWAN as an e-Health Communication Technology," 2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC), Turin, 2017, pp. 310-313, doi: 10.1109/COMPSAC.2017.162.

[17] T. Amartuvshin, D. Erdenechimeg, N. Chuluunbaatar, T. Enkhbaatar and D. Enkhzul, "Preprocessing techniques for daily healthcare device using SHIMMER™ wireless sensor platform," 2016 11th International Forum on Strategic Technology (IFOST), Novosibirsk, 2016, pp. 558-562, doi: 10.1109/IFOST.2016.7884179.

[18] A. Mdhaffar, T. Chaari, K. Larbi, M. Jmaiel and B. Freisleben, "IoT-based health monitoring via LoRaWAN," IEEE EUROCON 2017 -17th International Conference on Smart Technologies, Ohrid, 2017, pp. 519-524, doi: 10.1109/EUROCON.2017.8011165.

[19] Bo Dong and S. Biswas, "Wearable networked sensing for human mobility and activity analytics: A systems study," 2016 Fourth International Conference on Communication Systems and Networks (COMSNETS 2016), Bangalore, 2016, pp. 1-6, doi: 10.1109/COMSNETS.2012.6151376.

[20] J. Lee, J. Jeon and S. Kim, "Design and implementation of healthcare resource model on IoTivity platform," 2016 International Conference on Information and Communication Technology Convergence (ICTC), Jeju, 2016, pp. 887-891, doi: 10.1109/ICTC.2016.7763322.

[21] M. T. Buyukakkaslar, M. A. Erturk, M. A. Aydin and L. Vollero, "LoRaWAN as an e-Health Communication Technology," 2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC), Turin, 2017, pp. 310-313, doi: 10.1109/COMPSAC.2017.162.

[22] Olson JS, Redkar S. "A survey of wearable sensor networks in health and entertainment". MOJ App Bio Biomech. 2018;2(5):280–287. DOI: 10.15406/mojabb.2018.02.00082

[23] "Classes", The Things Network. [Online]. Available: https://www.thethingsnetwork.org/docs/lorawan/classes.html. [Accessed: 26- Jul- 2020].

[24] "AN1200.22 LoRa™ Modulation Basics - MAFIADOC.COM", mafiadoc.com. [Online]. Available: https://mafiadoc.com/an120022-lora-modulation-basics$_5 9c455b21723ddcdf4b9782c.html$. [Accessed: 26-Jul- 2020].

[25] K. Saleem, H. Abbas, J. Al-Muhtadi, M. A. Orgun, R. Shankaran and G. Zhang, "Empirical Studies of ECG Multiple Fiducial-Points Based Binary Sequence Generation (MFBSG) Algorithm in E-Health Sensor Platform," 2016 IEEE 41st Conference on Local Computer Networks Workshops (LCN Workshops), Dubai, 2016, pp. 236-240, doi: 10.1109/LCN.2016.053.

10 Appendix

The JSON file can be found here. It is open source and freely downloadable.

```python

from . import json
from . import import pandas as pd

# Loading the json file from the system
data = json.load(open('/content/data.json'))

# Converting the json file to the data frame
dataframe = pd.DataFrame.from_dict(data, orient="index")

# Saving the generated data frame to the CSV file
dataframe.to_csv('datamodel.csv')
```

Code Listing 1: Converting the json data model (Heart rate) into a CSV file

On executing this program the JSON file would be automatically converted to the a CSV file as shown below:

	0
swagger	2.0
info	{'title': 'Heart Rate', 'version': '2019-03-04', 'license': {'name': 'OCF Data Model License', 'url': 'https://github.com/openconnectivityfoundation/core/blob/e28a9e0a92e17042ba3e83661e4c0fbce8bdc4ba/LICENSE.md', 'x-copyright': 'Copyright 2018-2019 Open Connectivity Foundation, Inc. All rights reserved.'}, 'termsOfService': 'https://openconnectivityfoundation.github.io/core/DISCLAIMER.md'}
schemes	['http']
consumes	['application/json']
produces	['application/json']
paths	{'/HeartRateResURI': {'get': {'description': 'This Resource describes the Properties associated with a person\'s heart rate.\n The unit, which is the default unit, is bpm.\n The heartrate Property is a read-only value that is provided by the server.\n When range (from "oic.r.baseresource") is omitted the default is 0 to +MAXFLOAT.', 'parameters': [{'$ref': '#/parameters/interface'}], 'responses': {'200': {'description': '', 'x-example': {'rt': ['oic.r.heartrate'], 'heartrate': 80}, 'schema': {'$ref': '#/definitions/HeartRate'}}}}}}
parameters	{'interface': {'in': 'query', 'name': 'if', 'type': 'string', 'enum': ['oic.if.s', 'oic.if.baseline']}}
definitions	{'HeartRate': {'properties': {'heartrate': {'description': 'This Property describes the heart rate in bpm.', 'type': 'integer', 'minimum': 0, 'readOnly': True}, 'rt': {'description': 'The Resource Type.', 'items': {'enum': ['oic.r.heartrate'], 'type': 'string'}, 'minItems': 1, 'uniqueItems': True, 'readOnly': True, 'type': 'array'}, 'n': {'$ref': 'https://openconnectivityfoundation.github.io/core/schemas/oic.common.properties.core-schema.json#/definitions/n'}, 'if': {'description': 'The OCF Interface set supported by this Resource.', 'items': {'enum': ['oic.if.s', 'oic.if.baseline'], 'type': 'string'}, 'minItems': 1, 'uniqueItems': True, 'readOnly': True, 'type': 'array'}, 'range': {'$ref': 'https://openconnectivityfoundation.github.io/IoTDataModels/schemas/oic.baseresource.properties-

Figure 30: CSV file of the data model