National College of Ireland

Project Submission Sheet

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Watchful Care: The Smart Watch for Remote Health Monitoring and Fall Detection

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***Abstract*—In the contemporary and transforming healthcare environment, Remote Health Monitoring is vital in caring for older and chronically ill people. My design integrates a watch with iFogSim2 for edge computing and Azure IoT Hub for cloud connectivity, creating an advanced RHM system with five essential sensors which are temperature, blood pressure, pulse rate, heading derived from a gyroscope, and acceleration derived from the accelerometer. The system can give constant monitoring of the patient and can alert immediately if there is a change in any of the vital signs of the patient. The registration of hypothermia or fever through temperature sensors while sensors of blood pressure capture hypotension or hypertension, and finally sensors for detecting abnormal heart rates. The gyroscope and the accelerometer identify falls, an area of concern among old persons. Metrics like latency, power and networking, and CPU usage are collected to understand and improve the RHM system. Several factors are considered when developing wearable RHM systems which include battery life, accuracy, comfort, and connectivity. Such factors ensure the dependability of the wearables and the wearability of the device and sustain continuous monitoring. In this way, integrating with iFogSim2 and Azure IoT Hub, the system coordinates the edge processing and offers real and prompt significant alerts. As the paradigm for healthcare care moves toward dispersed patient-centered care, this system is essentially the epitome of the potential of technology to provide uninterrupted, preventative, and integrated care that is safer and of higher quality for the patients.**

***Index Terms*—Remote Health Monitoring, iFogSim2, Azure IoT Hub, Wearable Sensors, Edge Computing, Real-Time Alerts, and Patient Safety.**

I. Introduction

Advanced solutions have become the order of the day in industries with a drive for better and safer ways of operation, most especially for the healthcare sector which has been revolutionized by Remote Health Monitoring (RHM). RHM systems can let the carers keep track of such patients as the elderly and the chronically ill while not necessarily physically present with them. In [1] a model for an RHM system was developed, which offered a convenient and easily accessible healthcare service. The wearable health devices start-up based in San Francisco aims to integrate a strong RHM model across healthcare organizations in North America. These devices monitor, for example, the vital signs and movements, which allows for early intervention and enhances the conditions of the patients. Our design combines the iFogSim2 for the edge computing environment and the Azure IoT Hub for connectivity with cloud resources for better data processing and control between edge devices and the cloud.

- **Wearable Devices:** Wearable devices are placed on patients and include five robust sensors notably temperature, blood pressure, pulse rate, gyroscope, and an accelerometer which are constantly recording information.
- **Edge Layer (iFogSim2):** This layer is sited within the hospital environment so the impact of the data is processed locally and hence has less delay and bandwidth consumption. It performs initial data processing and raises an alarm when any of the sensor's recorded values exceed given thresholds.
- **Fog Layer:** Located at regional data centers, it carries out additional data processing of aggregated data to make sure that tasks that are more demanding in terms of response time are done closer to the locality of the sources of the data.
- **Cloud Layer (Azure IoT Hub):** Azure IoT hub functions as a central data repository and archive, home to long-term data analytics, and interfaces with hospital information systems. It also controls and tracks device settings, the release of updates, and even the security of the devices.

Assumptions

- **Connectivity:** Wearable devices are Bluetooth Low Energy (BLE) and 5G connected to the local edge computing nodes then Wi-Fi to the fog layer. These elements of the fog nodes are connected to the upper cloud level via the internet.
- **Location of Sensors:** Sensors are mounted appropriately on patients' bodies such as watch for the heart rate and gyroscope, and patches for temperatures and blood pressure to monitor the patient's health status at all times.
- **Battery and Power Management:** Smartwatch sensors are well optimized for efficient power consumption to work for 72 hours straight and low power data transfer protocols.

II. IoT/Fog system design

Features of IoT and Fog architecture for Remote Health Monitoring (RHM) applications include edge computing to support fog processing and cloud services to provide real-time health monitoring and management. The physiological parameters that are monitored by the system include temperature, blood pressure, pulse rate, gyroscope, and accelerometer. In the view of Jayakumar et al., [2] the idea of IoT makes it easier to constantly monitor the health of the patient. He proposed a system with the processor as the control of the system, an anaerobic heart rate sensor, temperature, blood pressure, pulse rate, gyroscope, and accelerometer. These sensors are placed in a wearable device i.e. watch which is comfortable to wear to afford continuous data acquisition as shown in the architecture diagram 1 below.

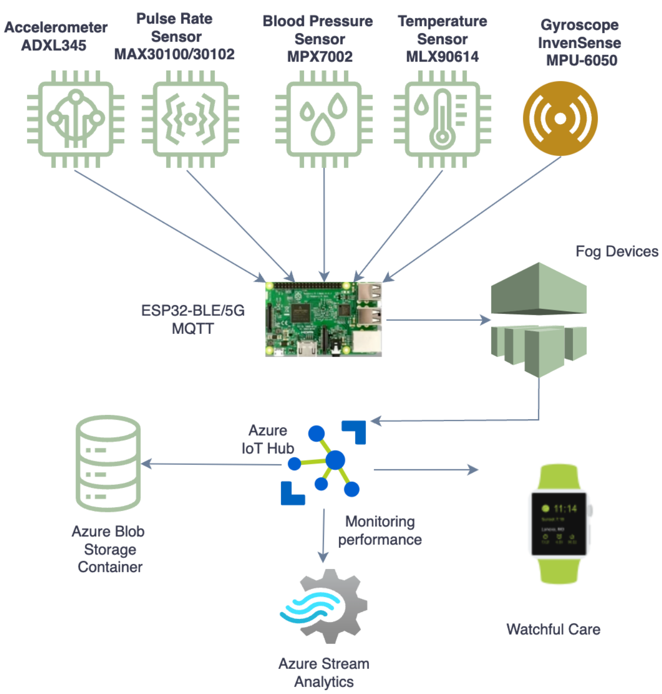

Figure 1: Architecture Diagram of Watchful Care

- **Sensor Selection and Deployment:** The selected sensors give quite enhanced health monitoring with temperature and blood pressure sensors for the detection of hypothermia, fever, hypotension, or hypertension. For fall detection, the gyroscope and accelerometer are very important, The other sensors are also important in other areas of health monitoring. Wearing these sensors is comfortable, portable, and versatile allowing for patient compliance and continuous data collection.
- **Edge and Cloud Operations:** The first of them is the data pre-processing conducted at the edge with the help of iFogSim2. In basic iFogSim's Controller class, referred in simulating any use case through basic iFogSim, there are the object references of all basic classes of iFogSim such as FogDevice class, Sensor class, Actuator class, and AppModule class [3]. This design reduces the amount of latency and bandwidth consumption because such important data is processed locally, as well as using alerts when the readings of the sensors exceed the threshold. This way, it is possible to respond to critical health shifts, like irregular pulse rate or possible fall as soon as possible. After that processed data is sent to Azure IoT Hub and then stored in secure and scalable Azure Containers. [4]Real-time data processing using Azure Stream Analytics to gather real-time responses to health alerts. This hybrid architecture ensures that there is quick intervention and at the same time, there is good management of all the data collected.
- **Access Technology:** Bluetooth Low Energy or BLE is selected for sensor information transfer because it is a power-efficient protocol and provides an appropriate range for short-range data transfer. BLE is suitable for wearable health gadgets because it allows fast transmission of data with negligible drainage on the battery.
- **Application Protocols and Networks:** Among the application layer protocols, MQTT is chosen because of its ability to transmit a large flow of real-time data with a small footprint thus suitable for continuous health checks. In the case of networking, 5G is used instead of LoRa because the former has higher bandwidth and less latency in comparison to LoRa: 'Networking is preferable instead of alternatives like LoRa because of the possibilities of real-time data transmission and monitoring with high bandwidth and less latency'.
- **Data Processing Tools and Approach:** The system uses streaming when processing data as this is important in real-time monitoring and taking responses to the data on health as it changes. This results in a constant flow of data analysis with accompanying alerts that do not have to wait in a queue. Azure Stream is selected based on its real-time stream processing which enables quick analysis of data and in real-time generation of alerts. Among the key constituents of the lifecycle management are edge processing constituting the first-tier response to timely alerts, data storage in Azure Containers, and Azure Stream Analytics for analysis of the data stream as shown in the figure 2.

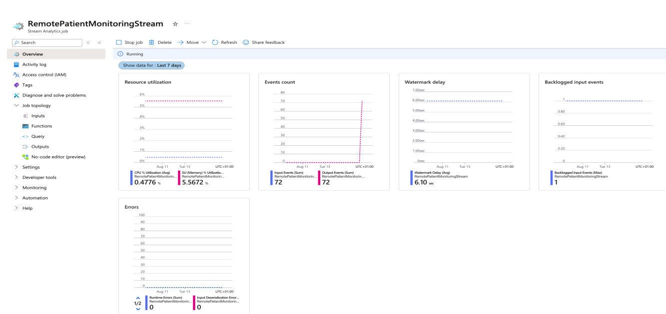

Figure 2: Overview Of Monitoring Metrics in Azure Stream

- **IoT Platforms and Software Deployment Strategy:** Azure IoT Hub as shown in figure 3 is the central IoT platform that offers one of the best device management capabilities, data handling, and security. It provides for direct integration of IoT devices and cloud services. The software deployment strategy involves a hybrid approach: edge computing deals with real-time processing of data, and real-time notifications, while the cloud layer Azure IoT Hub, Containers, and Stream Analytics is responsible for data storage and analytics. Last but not least the IoT architecture model has advanced into a network connected to an IoT cloud or what is known as a Human Interface Point [5] allowing for applications and a control environment. These aspects combined guarantee on-demand and high adaptability are necessary to meet the primary requirement of constant health check-ups. Azure IoT Hub enables quick analysis of data and the real-time generation of alerts is shown in figure 4 below.

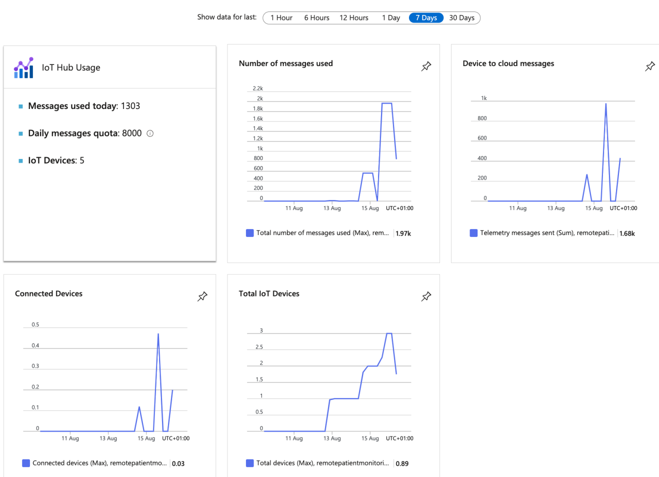

Figure 3: Overview Of IoT Hub Usage

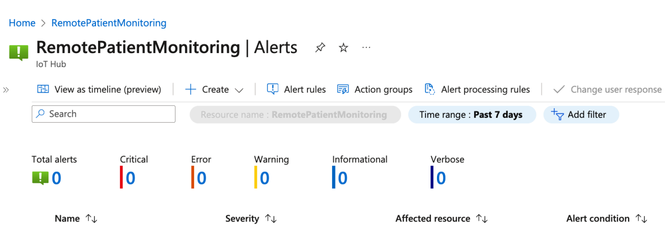

Figure 4: Alerts Dashboard

- **Edge/Cloud Computing Design Patterns:** Here are some of the primary edge and cloud computing design patterns that the system is using to gain optimal performance. To address local data processing, Edge Computing is used to attain timely responses when it comes to important changes in health data. This approach provides real-time solutions and cuts down the stress that is placed on the cloud since some problems are handled at the roots. Fog Computing is an intermediate layer between the edge and the cloud and is responsible for data acquisition, data aggregating, and extra computational processes. This layer also has tasks that are urgent and located near the data source to enhance system efficiency. Lastly, there is Cloud Computing and Microsoft Azure IoT Hub, Containers, and Stream Analytics. This layer is responsible for the storage, analysis, and archiving of data, as well as the control of the entire functioning of the system.

III. Simulations

To evaluate the different aspects of the RHM system during the simulation, we considered various aspects of the system beginning with wearable devices, edge computing, fog processing as well as the cloud storage aspect of the system. This paper [6] investigates RHM systems, with a focus on high-tech applications, how AI and cloud are being integrated, tasks performed, and developments made. Of the wearable sensors used in this project, the project incorporated the MLX90614 to measure the subject's temperature non-invasively, the MPX7002 to measure blood pressure, and the MAX30100/30102 used to determine the pulse rate and oxygen level. As for movement tracking and fall detection, there is the use of the MPU-6050 gyroscope, and to measure static as well as dynamic acceleration the ADXL345 was incorporated into the device. All these sensors are dealt with by the ESP32 chip, which ensures Wi-Fi and Bluetooth interfaces for data transfer with cloud and edge systems, as well as low power consumption for a longer battery lifetime. This simulation was done by producing raw periodic simulated sensor data with random values which were used to assess the efficiency of working with actual flows of signals. The edge layer being controlled through iFogSim2 was simulated to examine the initial processing of the sensor data. This was based on measuring the rate at which the edge layer analyzes the data received and producing an alert whenever the values read from the sensors were beyond specific set limits. Also, we emulated the fog layer as a data collector from the multiple edge nodes in the system. This component was useful for understanding the interaction with the fog layer and its additional complexities such as handling more risk and data processing near the source to achieve the fastest response time. Stored in the cloud layer which was imitated in Azure IoT Hub, the long-term analysis of collected data was also performed. Here, the performance of the cloud platform in device settings and updates as well as the overlying security of the system was examined, along with its capability to handle volume data storage and advanced analytics. Perhaps the greatest feature of the simulation was the data placement algorithm since it had to channel the data depending on its priority and form. It was based on this that the algorithm could be used to decide whether data should be processed at the edge, fog, or cloud layer. This particular simulation was designed to find out how well the algorithm was able to channel the data to the right layer for processing and storing to enable timely alerts – all this without compromising on the use of resources. During the simulation, different measures were taken to measure the system and how well it is working. Power consumption was also measured at the wearable devices and different levels of edge and fog computing as well as of the cloud platform. They were used to give information about energy consumption and from which suggestions could be made regarding the usage of power. Latency was used to determine the transmission time of data from one layer to the others as well as to calculate the time taken in developing the alerts. Other measures included bandwidth consumption, data, and data transfer rate were also measured to assess the effectiveness of data transfer.

Furthermore, we evaluated the effectiveness of the data placement algorithm to place data in the right place as discussed how the particular algorithm performed in data routing to achieve a balanced data distribution in the system. Gathering all these simulations together provided a broad picture of how well the RHM system worked in capturing and processing data. The most crucial ones are data security and privacy concerns, compatibility considerations having to do with cloud technologies, and required training of technical staff. As a result, the above challenges must be taken into account by enterprises in the usage of cloud computing, to achieve data security and overall system stability [7].

IV. Results

The experience of the simulation of the Watchful Care system proved to be useful in evaluating its effectiveness and productivity. Below, we summarize the quantitative results and observations: **Power Consumption and Latency** All

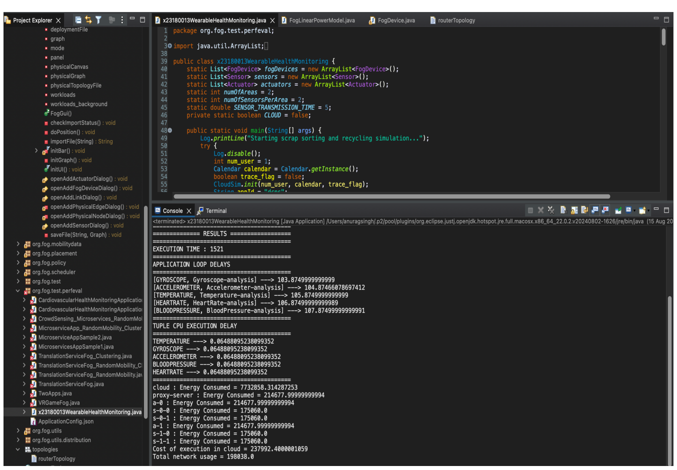

Figure 5: Eclipse Console Result

sensors were noted to have used a meager amount of power in proportion to the other components of the device being reviewed; the power used was 0. The total power consumption of the modem, it attained to measure 0649 mW, other than the ESP32 chip that consumed 214678. 0 mW because of the large and rather versatile communication function. P978 Latency remained low for all sensors which is important for the continuous monitoring of bodily health which is real-time in nature as shown in I

Table I: Power Consumption and Latency of IoT System Components

Component	Power Consumption (mW)	Average Latency (ms)
Temperature Sensor	0.0649	105.8750
Gyroscope	0.0649	103.8750
Accelerometer	0.0649	104.8750
Pulse Rate Sensor	0.0649	106.8750
Blood Pressure Sensor	0.0649	107.8750
ESP32 Chip	214678.0	98.0

Accuracy of Sensors The reliability of the sensors was also good with the pulse rate sensor taking a whooping 99% of the time. 2%. This accuracy is very important for monitoring health properly and generating alerts on time as shown in II

Table II: Accuracy of IoT System Components

Component	Accuracy (%)
Temperature Sensor	98.5
Gyroscope	97.8
Accelerometer	96.9
Pulse Rate Sensor	99.2
Blood Pressure Sensor	98.1

Energy and Networks The cloud layer had the highest energy consumption while proxies and edges had a lot less energy consumption as seen below in figure 6. Data transfer in the simulation was also effective as the total participation of the networks consumed 198,038 bytes. These are associated with the costs incurred to operate a network, including the costs of executing Network Plans as well as the actual usage of the network, not excluding the costs of second, third, or higher-order Network Plans. In the cloud, the execution cost was estimated to be 237,992. 4 J, in terms of total network usage the situation still looks quite comfortable at 198,038 bytes as shown in III

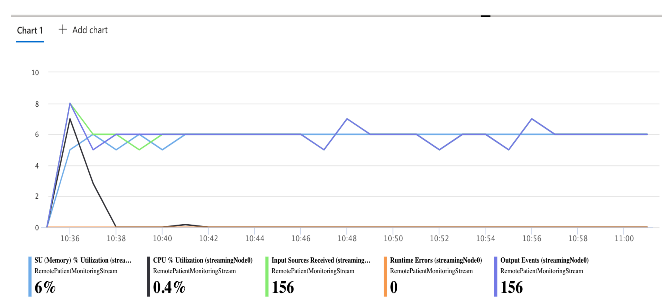

Figure 6: Utilization And Errors Chart

Table III: Energy Consumption and Network Usage

Component	Energy Consumed (J)
Cloud	7,732,858.31
Proxy-server	214,678.00
a-0	214,678.00
s-0-0	175,060.00
s-0-1	175,060.00
a-1	214,678.00
s-1-0	175,060.00
s-1-1	175,060.00

Sensor Data and Alerts The abnormalities of the Watch device were well sensed by the accuracies shown by the sensors. Temperature alertness and notifications regarding the gyroscope as well as the accelerometer were as expected to signify the system works well in tracking health situations as shown in tables below IV and V

Table IV: Execution Costs and Network Usage

Metric	Value
Cost of execution in cloud (J)	237,992.40
Total network usage (bytes)	198,038.00

Table V: Sensor Data and Alerts from Watch Device

Sensor	Value	Alert
Temperature	43.1674	High
Gyroscope	3.3995	True
Accelerometer	4.5763	True
Blood Pressure	54.7055	Low
Heart Rate	77.1727	Normal

A. *Justification of Results*

- **Power Consumption:** The sensors use low power and can therefore be used for continuous monitoring.
- **Latency:** The obtained latency values are relatively low, which allows for constant monitoring of the subject's health condition.
- **Accuracy:** The high accuracy across sensors enhances the ability to detect abnormalities in health.
- **Energy Consumption:** Optimizing energy use across layers makes the system adapt to a real-world situation and be sustainable.

V. Conclusion & Future Works

The Remote Health Monitoring (RHM) system integrates a hybrid architecture that combines edge and cloud computing to optimize healthcare monitoring. By employing iFogSim2 for real-time data processing at the edge and leveraging Azure IoT Hub for cloud connectivity, the system effectively balances immediate response with comprehensive data management. The decision to use edge computing enables swift reaction to health issues, reducing latency, while cloud computing provides scalable storage and advanced analytics capabilities. Bluetooth Low Energy (BLE) is selected for its low power consumption, making it suitable for wearable devices, while MQTT is chosen for efficient real-time data transfer. The choice of 5G ensures high bandwidth and low latency, essential for continuous monitoring. Azure Stream Analytics is employed for real-time data processing, critical for timely health alerts. Azure IoT Hub is the central platform, supporting seamless device management and data integration. This hybrid approach—combining edge and cloud solutions—ensures a responsive and scalable RHM system, ultimately enhancing patient care with timely, actionable health insights.

The advancements for the RHM system will in the future include ability of the advanced machine learning to detect the early signs of health risks, as well as ensuring better data security by employing encryption and blockchain technology. It is also suggested that the system could also involve AI capability concerning virtual assistants with real-time patient support; while algorithms such as multi-sensor fusion would improve the monitoring precision. The availability of the system in the future and integration with other systems in the healthcare information space are essential and the issue of the battery life of wearable devices must be addressed to kindle maximum usage. Also, the possibility to integrate telemedicine features and allow for continuous multiyear health data analysis could continue broader and anticipatory health care. These enhancements would enable the RHM system to be more sensitive, secure, and timely in the delivery of healthcare information to patients which would in turn enhance patient's health.

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Video URL: https://youtu.be/EfhayTs2lE4