Sleep Monitoring System

Megha Kumari[1], Goutam R [2]
[1,2] Atria institute of technology

Abstract- *Obtrusive sleep apnea (OSA) is one of the sleep disorders because it has a direct impact on the quality of life. It has many side effect. Therefore, a real-time monitoring of this disorder is a critical need in healthcare solutions. There are several systems for OSA detection. Nevertheless, even with the promising results that this system provide provides, this do not act upon all the treatment. For these reasons, this research presents an innovative system for both to detect and support of treatment of OSA of elderly people by monitoring multiple factors such as sleep environment, sleep status, physical activities, and physiological parameters as well as the use of open data available in smart cities. Our system architecture performs two types of processing. On the one hand, a pre-processing based on rules that enables the sending of real-time notifications to responsible for the care of elderly, in the event of an emergency situation. This pre-processing is essentially based on a fog computing approach implemented in a smart device operating at the edge of the network that additionally offers advanced interoperability services: technical, syntactic, and semantic. On the other hand, a batch data processing that enables a descriptive analysis that statistically details the behavior of the data and a predictive analysis for the development of services, such as predicting the least polluted place to perform outdoor activities. This processing uses big data tools on cloud computing. On the other hand, a batch data processing that enables a descriptive analysis that statistically details the behavior of the data and a predictive analysis for the development of services, such as predicting the least polluted place to perform outdoor activities*

Keywords- Internet-of-Things, big data, interoperability, sleep monitoring, health monitoring, open data, fog computing, cloud computing..

I. INTRODUCTION

Over the years, we human beings experience changes in our bodies and in our lives. One of these changes is the alteration of sleep that occurs with age. [1] In particular, obstructive sleep apnea syndrome (OSA) is one of the most common and dangerous respiratory disorders that occur during sleep. OSA consists of the obstruction or partial blockage of the upper respiratory tract for at least 10 seconds and that prevents proper oxygenation of the blood, even over 20-30timesan hour of sleep. According to number of interruptions per hour and by using the apnea-hypopnea index (AHI), OSA can be classified into 3 categories from higher to lower severity; if these interruptions occur between 5 and 15 times per hour as. ‘‘mild’’ , if these interruptions occur between 15 and 30 times per hour as ‘‘moderate’, and if these respiratory interruptions occur more than 30 times per hour as ‘‘severe’’ . In this work, an architecture of an OSA monitoring system based on the Internet of Things (IoT) and Big Data is proposed. The three-layered architecture integrates Fog and Cloud Computing capabilities to support both diagnosis and treatment of sleep apnea by creating of various services including remote monitoring, real-time alert notifications, data analysis and information visualization. The proposed system envisions assisting health professionals in medical decision-making.

II. LITERATURE SURVEY

Zhu et al. [2] proposed an automatic system for the long term monitoring of the quality of sleep of the elderly in a residence. The system uses a piezoelectric transducer placed under a mattress to measure the heart rate, respiration, and the parameters of the body movement of older adults at the time of sleep. The collected data is transmitted to database servers through the Internet. Similarly, a non-intrusive system for quantifying sleep quality was proposed by Nam et al. [3] The system was equipped with multimodal sensors, which included a three axis accelero meter and a pressure sensor. Multimodal sensors monitor various physiological parameters, such as the respiratory rate , the heart rate, and the body activity, as well as the posture of older adults during sleep. The data collected from the system is transmitted over a wireless network of sensors based on ZigBee technology to a portable recording device and to a PC.

III. SYSTEM ARCHITECTURE

[4] The IoT layer obtains and aggregates the data from multiple heterogeneous sources and transfers them to the fog layer. Fog layer provides the basic functionalities to offer seamless connectivity and interoperability between the different heterogeneous devices involved in the system. This layer is also responsible for the pre-processing of the sensor data necessary for detecting possible adverse events for older adults relating to OSA and to react in real-time by sending notifications to those responsible for the healthcare of the elderly people so that they can receive immediate help. The

data from the fog layer is stored, processed, and analyzed at the cloud layer using generic enablers provided by IoT platforms and algorithms based on Big Data, in order to discover new knowledge and thus, support medical decision-making. Finally, the results of the processing can be visualized in a web application through a graphical user interface (GUI), which converts the analyzed information into rich content to guide the treatment of the OSA.

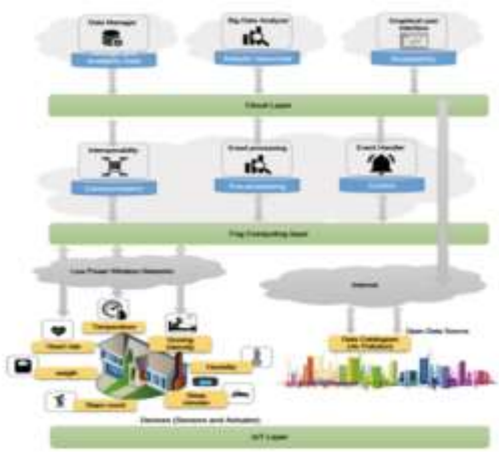

Fig:1 System Architecture

IoT Layer

The IoT layer is the foundation of the entire system since it acquires data from different heterogeneous sources through different wireless networks; IoT nodes located in the elderly person's house , mobile devices worn by the elderly ,and open data from smart cities .[5]The IoT nodes and mobile devices are constituted by sensors that measure different parameters such as the sleep environment, the sleep state, physical activities, and physiological parameters. Additionally, the IoT layer uses parameters related to air pollution which are available in the open data catalog of smart cities, taking competitive advantage over previous works, that focus exclusively on physiological parameter monitoring. All the parameters have been selected because they have a direct relationship with the OSA and/or a high impact on the progress of the treatment of this syndrome, and they influence the QoL of the elder. On the other hand, wireless networks allow for the transmission of data to the fog layer through low-power wireless technologies

Fog Layer

The fog layer enables interoperability of the heterogeneous sources of the data and the pre-processing and knowledge generation of them by a fog computing approach. In fog computing, a set of edge devices are placed in between the sensing devices and the cloud in order to extend the cloud resources to the edge of the network with the aim of achieving improved performance by networking, storage, processing capabilities, and so on, close to the end devices. In this work, the fog layer consists of a Smart IoT Gateway where IoT protocols, control, notifications, and data pre-processing services are integrated. The fog layer includes the following main modules: Wireless communication and interoperability, an event processor, and an event handler as shown in Fig. 2.

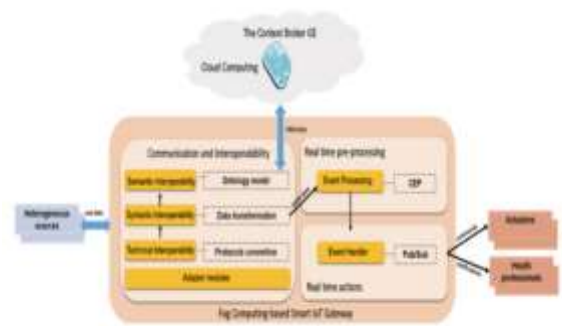

Figure 2:Fog Layer Architecture

Cloud Layer

Cloud computing is currently the preferred paradigm to undertake large storage, computation-intensive data process and analysis tasks, due to its maturity and scaling capabilities, as they allow services to grow and shrink in-line without degrading, which greatly eases the burden of smart devices. This layer is responsible for efficiently managing, storing, and analyzing all the data collected by the system. Given that the system is closely related to the health status of elderly persons, the availability and analysis of the data are necessary to support medical decision-making. For this, this layer includes the following functional modules: data manager, Big Data analyzer, and web application.

Data Manager

Data Manage reacts as a central repository and is responsible for managing and providing access to information coming from the fog layer. The generic enabler, GE Context Broker Orion, also provided by the Fiware platform, is used as the Data Manager. Interfaces that allow for the registration, update, and elimination of these entities ,as well as for the retrieval of context data to any authorized party in consuming this information such as services or applications, through Publication/Subscription operations as shown in Fig. 5. In our system, the Big Data analyzer (detailed below) subscribes to the Data Manager to obtain the online information.

Figure 3: Data Manager

Big Data Analyzer

is able to process and analyze the data coming from the fog layer, as well as the open data catalog available in smart cities. To do this, the analyzer implements four modules: data integration, batch processing, machine learning, and services

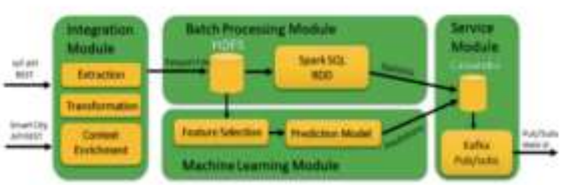

Figure 4: Big Data Analyzer

- -The data integration module allows for the data combination, which comes from the fog layer and the smart city open data
- The batch processing module provides storage and the processing of the data which were merged in the integration module
- The machine learning module exploits the data stored in the batch processing module through pre-processing and prediction tasks in order to provide a prediction service for the places with less pollution in the city
- The service module provides temporary information storage for both the descriptive analysis and the predictions made and a publish/subscribe mechanism for access to this information by the applications

IV. TESTBED IMPLEMENTATION

In order to evaluate the functionality of the proposed system, in this section, we first detail the implementation of each component used in the different layers of system architecture

Mobile App

developed for the Android operating system consists of several classes built using android studio; the physical activity class to manage the weight and step count readings, the sleep class to manage the minutes of sleep and heart rate readings; and the local database is used to temporally store data in the smartphone. The android application reads the minutes of the sleep/wake state and number of steps, heart rate records and also takes weight records of a wristband Fitbit Flex 2, a Heart Rate Monitor PM235 and an A&D Medical Precision Body Weight Scale, respectively. These wearable devices are wirelessly connected to a smartphone through a Bluetooth connection.

Smart IoT Gateways

The smart IoT gateway prototype has been implemented using a Raspberry Pi 3 model B as equipped with a 1.2 GHz Quad-Core ARM Cortex processor, 1 GB of RAM, and which is permanently connected to an electrical power supply and located in the elder's room. The Raspberry uses several communication modules to allow the interoperability of heterogeneous devices working with different wireless communication technologies. For instance, X Bee 2mW Wire Antenna S2 ZigBee communication module is configured as a coordinator device in order to acquire sensor data sent by the LM393 sound sensor. In Addition, the gateway integrates a 6LowPAN module (by the combination NUCLEO-L152RE based on ultra-low-power microcontroller and IDS01A5 board) configured as an edge router in order to collect the information from the temperature and humidity sensor HTS221, which is integrated on the IKS01A1 STM32 board. Furthermore, a tunneling-virtual network adapter is configured on the edge router to translate IPv6 packages to IPV4 and vice versa by using the tunslip6 tool running on the Contiki OS.

Servers

Three types of servers that provide different functionalities were implemented using virtualization technologies running on a private server. The server had the following hardware features: a FUJITSU server with an Intel Xeon E3-1220 v5 3.00 GHz CPU with 64 GB of memory.

V. CONCLUSION

QoL has become a need in society that will continue to be even more important if we consider that in the future the number of older adults will represent more than 14% of the world's population. OSA is one of the diseases that most compromises the QoL of the adults who suffer from it and causes important complications that can affect their health. The continuous monitoring and the processing of multiple parameters related to OSA will lead to the alerting of health professionals, emergency centers caregivers, and relatives of adults at the right time so as to be assisted on time, in order to improve their QoL, and in some cases, even preserve their lives. Innovative technologies such as IoT and Big Data have been gradually developed to create intelligent and pervasive systems focused on the healthcare of adults and, in general, on medical care. More precisely, IoT can be used as a tool to support the monitoring and control within a health ecosystem, whereas data analysis technologies can be used to support decision-making. A system based on a 3-level architecture for supporting real-time monitoring of OSA in elderly people and guiding their treatment has been proposed and implemented. The system is implemented using heterogeneous and non-intrusive devices, IoT protocols, components of standard platforms, low-power technologies, big data technologies, and fog and Cloud computing approaches

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