Literature Review of Design and Implementation of a Wearable Sensor Network System for IoT-Connected Safety and Health Applications

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Abstract - *This paper is about a wearable sensor network system for Internet of Things (IoT) connected safety and health applications. For industrial workplace; safety and health of workers are important. Therefore, in the workplace, an IoT network system which can monitor both environmental and physiological can greatly improve the safety. To monitor environmental and physiological parameters, the proposed network system incorporates multiple wearable sensors. These sensor on different subjects can communicate with each other and also transmit the data to a gateway via a LoRa network. They forms a heterogeneous IoT platform with Bluetooth-based medical signal sensing network. The sensor node will provide an effective notification and warning mechanism for the users once harmful environments are detected. To provide data processing, local web server and cloud connection a smart IoT gateway is implemented. Gateway will forward the data to an IoT cloud for further data storage, processing and visualization After it receives the data from wearable sensors.*

Key Words: Wearable sensors; LoRa; Connected health; Safety; BAN.

1. INTRODUCTION

In recent years Internet of things (IoT) has become a promising technological paradigm and attracted many research interests. It is expected that there will be 26 to 50 billion Internet connected devices by 2020 and 100 billion by 2030 [1]. IoT can increase performance of wireless sensor networks (WSNs) particularly in environmental monitoring and healthcare applications. Users can easily view the real-time environmental and physiological data from web-browser or mobile applications at anywhere and anytime with the development of IoT. Wearable body area network (WBAN) is a special purpose WSN which is generally used in healthcare surroundings to monitor physiological signals that can improve the quality of life, and consequently health and wellness [2] [3].Example for this are, a wrist worn wearable system for photoplethysmogram (PPG) monitoring[4], a WBAN with motion and electrocardiogram (ECG) sensors for rehabilitation [5], also an edged-based WBAN healthcare monitoring system with heart rate checking [6]. Other than the healthcare applications, WBANs have also been used to monitor surroundings. For example, for safety applications, the work [7] monitors temperature, humidity, and ultraviolet (UV). Writers in [8] provide a wearable sensor network for inside environmental monitoring. For covering both environmental and physiological parameters monitoring, there is not much work. For instance, in chronic respiratory disease the work [9] continuously monitor the environment and health of the subject. For industrial workplace safety is very important specially for workers continuously changing working environments between indoor and outdoor. UV, ozone, carbon monoxide (CO) and particular matter (PM) are harmful to human health in outdoor environments. Solar exposure has been well recognized as the main cause of skin cancer in Australia. UV radiation is the factor of sunlight which is injurious. Lasting exposure to UV index level of 3 or above can cause skin cancer. UV contact is also a cause of eye diseases [11][10]. Other than UV, carbon dioxide (CO_2), smoke, CO, and Volatile organic compounds (VOC) are some usually indoor pollutants [12]. Warning sign of CO_2 poisoning, such as hearing loss, headache and rapid pulse rate, may occur to some occupants when the CO_2 level is above 600 ppm [13]. Consequently, it is indispensable to have a WSN system to observe both UV and CO_2 for industrial workstation

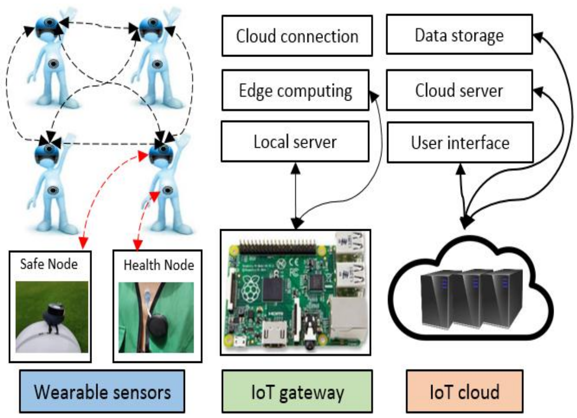

Fig. 1: The architecture of the proposed WBAN

Some physiological parameters of workers should also be monitored, to avert workers from being exposed to any risky and hazardous situations,. Body temperature and heart rate are the most considered parameters in WBAN based medical monitoring works. Temperature and humidity are the most commonly monitored parameters among different wearable environmental monitoring applications, Different wearable IoT sensor network system for connected safety and health applications is presented in this paper, which is suitable for industrial workplace. The system architecture is shown in Fig. 1The wearable network contains of numerous wearable sensor nodes which are capable of communicating with each other. Each person is equipped with two nodes: For environmental condition monitoring including ambient temperature, relative humidity, UV, and CO2, the first node is used, named as safe Node; For physiological signals monitoring including body temperature and heart rate, the second node named Health Node is used. For short range data transmission and LoRa for long range data transmission, two wireless technologies are utilized in our work including BLE Internet. Unlike [14], For an effective connectivity wearable sensors on different subjects are designed to communicate with each other. In addition, a smart IoT gateway is designed and applied to development, store and pass the data to cloud infrastructure. Observed data can be displayed from a local web server located in the gateway and a website in the cloud server. If any urgent condition is detected, the system can notify users by sending notifications to their smartphone

2. REVIEW OF SENSORS AND ACTUATORS

Presently we are emerging a complete wireless body-area net- work that is based on different frequencies in order to remove interference issues as well as to apply to different environments. We use MICS, WMTS and 433 ISM bands to sense signals from the sensors on the body. The aim in a WBAN application is to dedicate one sensor node to one physiological signal as described to remove placing wires on the patient body. However, there may be certain clinical applications that needs the checking of more channels of the same physiological signal simultaneously to provide a good quality screening More channels may be need when considering EEG signal for brain actions. We incorporate the UWB technology to achieve a high data rate wireless link [28] for the applications that require monitoring of more channels such as ECG/EEG/EMG, We also like to point out that we are working to interface our devices with IEEE 802.15.4 (ZigBee) and Wi-Fi links to shelter a large area of body-area network. The selection of wireless systems for sensor nodes will depend very much on the situation that the sensor nodes will be used.

The body-area system prototyping system presented in this paper uses a multi-hopping construction where the MICS band is used for collecting signals from sensors and WMTS is used to transmit the sensor records to remote stations letting a longer range checking. For a remote monitoring of several patients simultaneously, these frequency bands are internationally available and are permitted. The MICS band has a low emission power (25 μW, comparable to UWB) leading to a lower power consumption, and will thus offer one of the most appropriate transmission bands for medical sensor nodes [26,30]. Though a few events have been reported due to the interference from some local TV channels in USA, WMTS is still the most common band for wireless telemetry used in hospitals.

Hardware electronics and software programs are developed for three situations in the proposed WBAN as shown in Fig. 2. The first situation aims individual use in the medical center or can be used in home care. This wireless body-area network includes of sensor nodes, a CCU that communicates data to a local PC and then to a receiver position (i.e. remote PC) at a medical center. After finding the physiological data from a human body, sensor nodes communicate those data to the CCU via the RF link using the MICS band. The CCU then re-packages the data and communicates to the local PC. The data collected at the local PC is transported to a remote PC across the

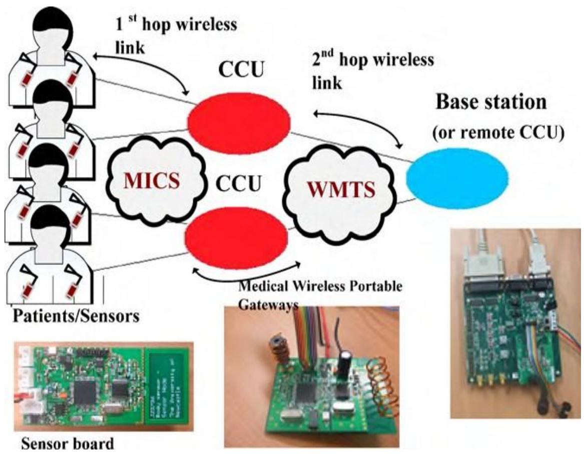

Fig. 2. A multi-hopping WBAN prototyping system for multi-patient monitoring.

This prototyping system uses two medical standards: MICS for short distance and WMTS for long distance wireless communication respectively. network in a medical center or through Internet if the patient is at a different site than the medical center.

In the second and third situations, more than one patient shares a CCU box. The CCU can either be linked to a local PC in the room (Scenario-2) or it can transmit data wirelessly to a remote CCU box that is devoted to a PC via another wireless link (e.g. WMTS (600 MHz)). In the last case, the CCUs act as transportable wireless gateway devices (e.g. middle devices) and therefore the system will practice a multi-hopping wireless networking.

The preparation in the last scenario can be used for one or more rooms in a medical center. A network between sensors and CCUs, another network between CCUs and a base station, and the last communication is between base stations (This is mainly a LAN joining).Organizing a complete wireless medical system in a hospital environment needs monitoring of a few hundred patients. With this article we discuss issues related to the application of such a large-scale body-area network and introduce techniques that suit well for an application in hospitals.

The present and described body-area network projects have mainly focused on the scenario. We have mainly been interested in a WBAN system which deals with the implementations Two pieces of software are shaped in this project. The software exist in at the local PC is named GATEWAY. The job of GATEWAY is to collect data from the CCU through RS232/USB2 cable and forwards it to one or more remote PCs using TCP/IP sockets over an Ethernet network. The software residing at the remote PC is called as BSN application. The BSN application gathers data from the local

PC, understands and stores them onto the remote PC to be examined later by health professionals. The base station (i.e. the remote PC) is capable of showing all the received data on a graphical user interface (GUI) and is also capable of storing all the data in the database system of a medical center .The MICS regulations need that the output power of any terminal must be kept under 16 dBm and is not planned for long-range wireless connections [24,26]. To enable a long-range communication, a WMTS link operating in the 608–614 MHz band 2 We have used both wired USB and RS232 connections. USB has a faster data communication and removes the requirement of holding data in the base station is used between the CCU and the base station letting for a much longer range. This suggests that the intermediate CCUs must be able to work both at MICS and WMTS frequencies, providing a link between the nodes and the computer.

The CCU remains in close range with the patient and may be devoted to their belt for example when it is for separate use. The minimal wireless distance for the MICS linkage is about 10 m. The WMTS link goals a distance more than 100 m.

2.1 Sensor nodes and CCU hardware designs

We progress our individual sensor nodes to detect and transmit the physiological signals . Appearances of these physiological signals are got from the public area available on the Internet. Most physiological signals have small amplitudes and frequencies in nature, and inhabit a small information bandwidth. At such low frequencies and low amplitudes, some difficulties inherent to circuits need extra care. For a trustworthy information transmission it is essential that the interface electronics in the sensor nodes notice the physiological signals in the presence of noise and increase the signal-to-noise ratio (SNR) of the noticed signal for a better processing by the subsequent blocks of the sensor nodes. Sensor nodes are planned to be small and power efficient so that their battery can last for a long time. They gather the signals from a human body which are usually weak and coupled with noise. An amplification/filtering process is exploited first to increase the signal strength and to eliminate the unwanted signals and noise. Then an Analog to Digital conversion (ADC) stage is hired to convert the analog body signals into digital for a digital signal processing. The digitized signal is treated and stored in a microcontroller. The microcontroller will then pack the data and transfer over the air via a wireless transceiver. Fig. 4 displays the hardware implementation of our sensor nodes and the block diagram.

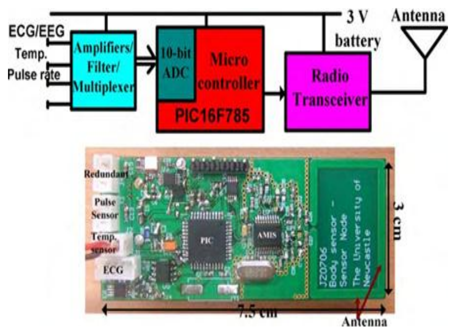

Fig. 3. An example of sensor node hardware designed

In our system we designed sensor nodes that can calculate up to four body signals for a single patient. One node is committed to one of continuous physiological signals such as ECC, EEG or EMG. Four sensor nodes electronics (i.e. 4-channel) are built on a mutual PCB board so that some electronics can be used interchangeably

3. REVIEW OF GATEWAY IOT SYSTEM

This section is about the main suggestion of this work consisting into the design of a Smartphone-based Gateway solution for IoT interoperability, through a unified smartphone-centric application able to backing multi standard, multi interface and multi technology transportations. According to this vision, we first provide a high level explanation of the proposed software architecture and then we further describing some important employment aspects.

3.1 System Architecture

Figure 1 shows a future communication situation in which the widely available and powerful smartphones, already present on the market, can show a vigorous role in our daily life helping us in different circumstances. The proposed smartphone- centric software architecture can use different communication technologies to intermingle with several human situations by obtaining data coming from different IoT devices and providing them to specific user-oriented services through Internet and Cloud connections.

The foremost challenge of this communication architecture is, for sure, the continuous integration and interoperability of such variegate communication standards, already supported by different IoT and sensor devices specifically designed for specific purposes at different times.The IoT devices (i.e., Smart Tv, air conditioners, video projectors, printers...) are based on standard Wi-Fi communication interface by focused on the communication technology,; many therapeutic recent devices backing the ANT+ [16] standard; routine IoT devices are mostly based on Bluetooth SMART [17] and NFC [18] whereas the ecological sensors, whose machinery is less modern than the other ones, make use of ZigBee [19] high level statement protocol based on the IEEE 802.15.4 standard is an example. The integration, coordination and interoperability of such different communication protocols and standards represents the main problem to be addressed in order to fully realize the exciting IoT vision by actually taking benefits from the potential offered by modern smartphones equipped with multiple radio interfaces.

3.2 Software Architecture

In this segment we define the software construction of the smartphone-centric mobile gateway application that is mostly created by i) a Management GUI through which the user can acquire notifications coming from IoT devices and modest sensors, ii) a Group Communication and Management Brain (CCMB) able to obtain and evaluate data from different interfaces. In certain the CCMB module is consist of three main logical blocks that can interact with each other as shown in Figure 5

- The reception and transmission of messages over the air, and manages the radio duty cycling is handled by the Communication block . It is possessed of a sequence of decoders for arriving packets and a series of encoders for outgoing packets. Each message received or sent is initially handled by the radio controller that offers a mutual interface on a specific radio adapter that can be vigorously loaded to support numerous communication technologies like Bluetooth SMART, ZigBee, NFC, etc.

Fig. 4. General communication architecture

- By creating periodic timers when the remote sensing operation is required by a specific user the IoT Device Management block acts as an interface to the IoT devices, or it may just take a reading on the IoT devices. The controller within this block can handle different types of of sensors irrespective of their hardware specifications through the suitable interfaces. This guarantees modularity and efficiency. The controller also uses a Buffer Pool to store the readings that become obtainable for the signal block processing. The BufferPool consists of a set of circular buffers and offers two mechanisms for information access;

  i) By using specific getting functions for information recovering;

  ii) By using hearers to get notification when new information from the sensor devices are available. Finally, the Device Registry comprises a list of each active device to connect to in order to receive information.

- In charge for the management of the interaction between the IoT device Management and Communication modules is done by the Coordinator Manager block, which derives from [20],; moreover, it contains a check on the structures that can be used by the network of IoT devices and an event contributor.

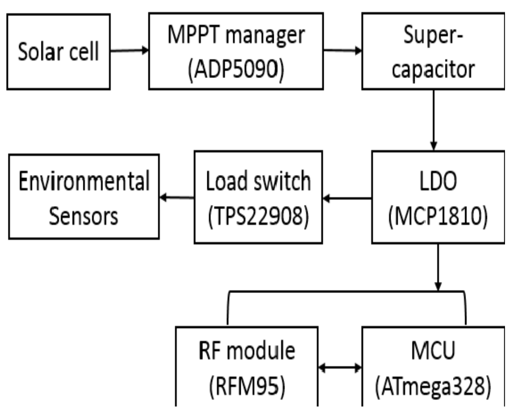

Figure 5. The block diagram of the wearable node.

4. REVIEW OF WEARABLE SENSOR NETWORK

Wearable sensor nodes are typically connected in wireless body area networks (WBAN) to canopy physiological factors, like body skin temperature, photoplethysmogram (PPG), or electrocardiogram (ECG). Other than the medical signals, they can be organized to monitor environmental conditions around the human body as well, such as in the security application and environmental monitoring applications Such a wearable sensor system can also offer invaluable and useful information about the environmental effect on subjects' health. People can also get a deeper understanding of their native micro-environment [8]. A wearable system is not only restricted to personal use, it can also be installed on a bicycle, car, and animal to form a wearable or mobile wireless sensor networks. For example, a mobile node is connected on bicycle for environmental monitoring. The power supply of sensor nodes is a main challenge for autonomous wearable sensor nodes, because many devices need regular battery replacement or charging. The system has to be low power consumption and adopt energy harvesting [4], [10] to allow long-term operation and minimize the human interaction of the wearable sensor node,. There is a need for an well-organized and effective energy harvesting module, which can address this power supply problem. There are several choices for energy sources, like thermoelectric, piezoelectric, micro-magneto-electric, or photoelectric harvesting techniques [11]. Solar energy offers the highest power density among these with high output voltages [12], [13]. The disadvantage is that the solar energy will disappear at night and this should be considered in the power management unit of a sensor node. This paper is about a self-powered wearable IoT sensor network, named as WE-Safe IoT project, for safety environmental checking. Each sensor node contains of a micro-power manager, a sensing unit, and a wireless module. The micro-power manager is intended to harvest energy both indoors and outdoors to enable a continuous energy supply for the sensor node. The total sensor node is low power consuming 5.6 _A in sleep mode. The data collected is communicated to a gateway via a long-range LoRa wireless technology. The entire system construction is shown in Fig. 6. The suggested network offers an effective solution for safety environmental applications.

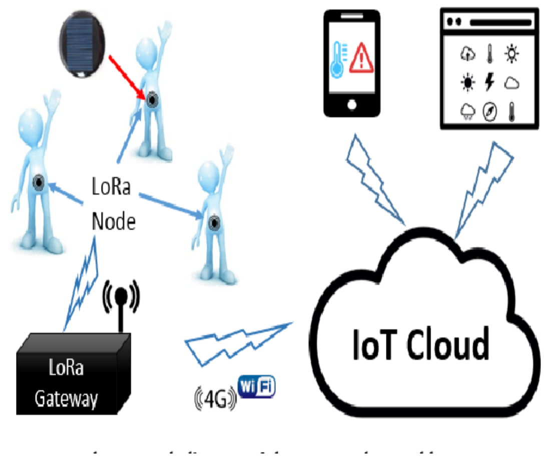

Fig6 . The network diagram of the proposed wearable sensor

5. CONCLUSION

In this paper, we present an IoT network system for connected health and safety applications for industrial outdoor workstation. The arrangement is able to monitor both physiological and environmental data forming a network from wearable sensors attached to workers' body and provide priceless information to the system operator and workers for safety and health monitoring. Features such as sensor node hardware and software design, gateway and cloud implementation are described. In our future works, variety of environmental and physiological sensors can be combined to the system to suit different workplaces. A smartphone-based IoT gateway can be developed to reduce the need of the fixed location gateway.

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