A review of remote health monitoring based on internet of things

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ABSTRACT
Managing, diagnosis, prognosis, continuous monitoring, early detection, and preventing chronic diseases for patients and elderly people have been gained a crucial role nowadays. However, elderly people with chronic health conditions such as diabetes, cardiovascular disease, and mental diseases need special health care. With the help of the internet of things (IoT) technologies, remote health monitoring (RHM) helps patients, caregivers, and countries for improving healthcare services, such as medical file services, mobile healthcare (mhealth), telemedicine services, and sensing technology. Moreover, RHM aims to reduce hospitalized demands and costs. The main contribution of the proposed study is to review RHM studies based on IoT technologies. Moreover, the challenges and possible future trends of RMH are highlighted.

Keywords:
Diseases
Healthcare monitoring
IoT
Medical information
Sensors

1. INTRODUCTION
Currently, elderly, and aging people are increasing globally [1]. According to the reports of the world health organization (WHO), 30 years from now, i.e., in 2050, the proportion of the world’s elderly people, who are over 60 years old, will nearly double from 12% to 22% (2 billion). For example, nowadays, in Japan 30% of the population are already over 60 years old. This fact indicates a dangerous and important challenge for societies and countries [2]. However, real time and continuous disease monitoring lead to early detection of diseases and to increase the safety of the elderly people [3, 4].

Undoubtedly, elderly people with a chronic health condition, such as diabetes, cardiovascular disease, epilepsy, need special health care [5, 6]. Thus, remote health monitoring (RHM) can help patients, caregivers, and countries for improving healthcare services, such as medical file services, mobile healthcare (mhealth) telemedicine services, and sensing technology [7, 8]. Table 1 shows the importance and advantages of RHM [9, 10].

Recently, as a vision of the next generation of the healthcare industry [11], advanced trends in communication and technology aim to enhance healthcare and medical services [12, 13]. Internet of things (IoT) represents the revolution for the next technology era [14]. IoT aims to connect all healthcare objects, devices, services, and resources together using advanced networking technology [15]. Importantly, this application of the IoT is called internet of medical things (IoMT), which uses all medical connected resources to establish a medical
information network [16]. This network can be used for remote healthcare monitoring (RHM), rehabilitation systems [17], disease diagnosis [18], prognosis [19], detection [20], management [21], prediction [22], and prevention [23]. Importantly, IoMT in RHM applications is used to collect remote patient’s data (physiological and clinical measurements such as blood pressure, skin temperature, heart rate [24]) by smart connected devices and sensors over the network [25, 26]. The collected data are then transferred to be stored and analyzed in the cloud computing systems [27, 28]. Figure 1 shows a health care monitoring framework based on IoT [29, 30], while Table 2 summarizes the main characteristics of all possible sensors that are used in RHM.

### Table 1. The importance of remote health monitoring

| The Term                          | For Patients | Importance Level | For Caregivers | For Countries |
|-----------------------------------|--------------|------------------|----------------|---------------|
| Price                             | Less cost    | Less cost        | Comfort and make less crowded | Provide better health care services |
| Comfortability                    | Comfort      | Comfort          | Comfort and make less crowded | Cost-effective and Avoid emergencies |
| Mobility                          | Solved       | Continuous       | Continuous   | Provide better health care services |
| Continuity                        | Continuous   | Fast detection   | Fast detection | Provide better health care services |
| Speed                             | Fast detection of illnesses | Fast detection of illnesses | Provide better health care services |
| Quality                           | Better       | Better           | Better        | Better        |
| Medical intervention              | Early        | Early            | Early         | Avoid emergencies |
| Tracking and monitoring           | Real time and quick | Real time and quick | Provide better health care services |
| Convenience                       | Better       | Better           | Better        | Provide better health care services |
| Accessibility                     | Real time access | Real time access | Enhance treatment abilities |
| Disease Management                | Adequate     | Less medical errors | Enhance treatment abilities |
| Treatment accuracy                | Better       | Less medical errors | Enhance treatment abilities |
| Reliability and availability      | High         | Real time and continuous | Enhance treatment abilities |
| Resource utilization of medical centers | -           | Less             | Less maintenance cost, less crowded, and provide better health care services |
| Disease diagnosis                 | Better       | High data processing capabilities | Provide better health care services |
| Rehabilitation services           | Continuous, reliable, and fast | Accurate and remote monitoring | Less cost and provide better health care services |
| Duration time in medical centers  | Less         | less cost and less crowded | less cost and less crowded |
| Collecting, processing, and visualization data | Fast | Fast and high accuracy | Provide better health care services |
| Medical reporting and decision making | Reliable     | Smart            | Enhance treatment abilities |

Figure 1. Health care monitoring framework based on IoT

### Table 2. Sensing technologies used in RHM based on IoT

| Sensing technology              | Usage                      | Application                      | References |
|---------------------------------|----------------------------|----------------------------------|------------|
| Electroencephalogram (EEG)      | Brain signal activities    | Mental diseases                  | [31, 32]   |
| Electrocardiogram (ECG)         | Heart signal activities    | Heart diseases                   | [33]       |
| Electrooculography (EOG)        | Ophthalmological diagnosis | Retinal disorders                | [34]       |
| Electromyogram (EMG)            | Muscle electrical activity | Muscles diseases                 | [35]       |
| Body temperature sensor         | Body temperature measurement | Infection                        | [36]       |
| Blood pressure sensor           | Blood pressure measurement | Hypertension                     | [37]       |
| Heart rate sensor               | Heart monitoring           | Heart diseases                   | [38]       |
| Respiration rate                | Breathing and chest monitoring | Lung diseases                  | [39]       |
| Galvanic skin sensor            | Skin conductance           | Electrodermal activity           | [40]       |
| Blood glucose sensor            | Blood glucose measurement  | Diabetes                         | [41]       |
| Oxygen level sensor             | Blood-oxygen monitoring    | Blood diseases                   | [42]       |
| Inertial sensor                 | Motion acceleration        | Physical activity monitoring, tracking, and rehabilitation | [43] |
| Location sensor                 | Human activity             | Physical activity monitoring, tracking, and rehabilitation | [44] |
| Camera sensor                   | Human activity             | Physical activity monitoring, tracking, and rehabilitation | [45] |

The prime contribution of the proposed work is to review RHM studies based on IoT technologies. Moreover, challenges and possible future trends are also highlighted.
2. RELATED WORK

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition [1-3]. The description of the course of research should be supported references, so the explanation can be accepted scientifically [2, 4].

Nowadays, IoT plays a vital role in RHM to reduce hospitalized demands and the cost [31, 32]. Also, RHM aims to enable an uninterrupted and real time observation for patients and elderly people in order to diagnose, manage, and prevent disease [46, 47]. That includes:

a) Diabetic patients [41]
b) Heart diseases [48]
c) Cardiovascular diseases [49]
d) Blood diseases [50]
e) Mental diseases [51]
f) Arthritis disease [52]
g) Fall detection and prediction [53]
h) Activity detection and recognition [54]
i) Medication Management [55]
j) Rehabilitation [56]
k) Personal Fitness monitoring [57]

Next, Table 3 summarizes well-known works the literature for RHM based on IoT, where the sensing technology and the main characteristics of each work are highlighted.

| Literature | Contribution | Sensing technology | Highlights |
|------------|--------------|--------------------|------------|
| [58]       | Automatic diagnosis of heart diseases using IoT | Body area sensor network (glucose level, electroencephalogram (EEG), electrocardiogram (ECG), electromyography (EMG), respiration rate, oxygen level, and temperature) | A framework based edge computing and deep learning called HealthFog is developed |
| [59]       | RHM for heart rate based on IoT | Pulse rate sensor | RHM prototype based on cloud computing is developed using Arduino UNO, raspberry Pi 3 |
| [60]       | RHM for cardiac based on IoT | ECG | Diagnosis of the heart disease using ECG monitoring |
| [61]       | Regular monitoring of arthritis disease based on IoT | Wearable sensor gadgets and uric acid sensor | Diagnosis of joint inflammation |
| [62]       | IoT recognition and monitoring elder people at home | Accelerometer sensor | Monitor of human physical activities |
| [63]       | IoT monitoring elderly health and sleep patterns | Wearable wrist-worn activity sensor | Unobtrusive monitoring of circadian activity and sleep patterns |
| [64]       | IoT based health care monitoring and tracking system | GPS and GSM | Continuous monitoring of physical activity |
| [65]       | IoT based real time system to locate an Alzheimer’s patient | GPS module | Real time health monitoring and tracking. |
| [66]       | Smart phone RHM application for patients with Alzheimer's disease | Smartphone | Real time and continuous tracking system are presented |
| [67]       | IoT based smart depression diagnosis | Smart phone | High fidelity prototype is developed |
| [68]       | IoT mental disorder tracking | Mobile cellular | Depression index service using the knowledge-based crowdsourcing |
|            |              |                    | Self-diagnosis |
|            |              |                    | Tracking the patient in the outdoor environment |
|            |              |                    | Scalability and power efficiency |
| Literature  | Contribution                                                                 | Sensing technology                                                                 | Highlights                                                                 |
|------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| [69]       | IoT stress disorder monitoring                                                | Heart rate sensor, 3-axis accelerometer, temperature sensor, and altimeter        | • Posttraumatic stress disorder diagnosis and monitoring                  |
|            |                                                                              |                                                                                   | • Temperature control, aromatherapy, and auditory therapy capabilities     |
|            |                                                                              |                                                                                   | • Efficient for reducing depression                                         |
| [70]       | IoT mental and behavioral disorders platform                                  | Murata bed sensor                                                                  | • Designing a digital platform for collecting data for mental health studies |
| [71]       | IoT based health monitoring                                                   | Piezoelectricity sensor                                                            | • Flexibility and high privacy                                              |
| [72]       | IoT based smart healthcare monitoring                                         | Temperature, heartbeat, GPS, glucose level, blood pressure, and Kinect camera       | • Big data analytics in healthcare                                          |
|            |                                                                              |                                                                                   | • Smart health monitoring, and energy harvesting                            |
|            |                                                                              |                                                                                   | • Smart health monitoring with big data analytics and energy harvesting      |
|            |                                                                              |                                                                                   | • Qualifying the IoT devices used for the healthcare system, aggregation, and processing of real-time data |
| [73]       | IoT wearable sensors for health monitoring                                   | Temperature, humidity, pressure, and light                                         | • Low-power wearable sensor node for environmental IoT applications        |
| [74]       | Fall prediction and detection prototype                                       | Tri-axial accelerometer                                                            | • Patient-specific single sensor and low cost                              |
| [75]       | Fall detection technique based on IoT                                        | Tri-axial accelerometer                                                            | • The accuracy of the proposed method is 95.53%                             |
| [76]       | Energy efficient fog-assisted IoT system for monitoring diabetic patients     | Glucose level                                                                      | • Remote and real time monitoring                                          |
| [77]       | Design and development of a non-invasive smart and pervasive mobile solution for diabetic patients | Glucose level                                                                      | • Self-management support tool within a smart digital companion            |
| [78]       | RHM for or diabetes patients based on IoT and big data analytics              | Blood glucose                                                                      | • Early detection of Diabetes system is presented                           |
| [79]       | RHM for or diabetes patients using IoT                                        | Glucagon and insulin                                                               | • Tracking system-based cloud computing is proposed                         |
| [80]       | Wearable Sensors for human activity monitoring                               | -                                                                                 | • A review of activity monitoring of humans based on wearable sensors is presented |
| [81]       | Pattern recognition models for detecting behavioral and health-related changes in a patient | Heart rate, temperature, glucose, and respiration                                  | • Continuous monitoring in an assisted living environment                   |
| [82]       | IoT-cloud based wearable ECG monitoring system for smart healthcare          | ECG                                                                               | • Visual and timely ECG data capabilities                                  |
| [83]       | Smart rehabilitation system based on IoT                                     | GPS                                                                               | • Feasibility, rapidity, and effectiveness of the proposed system           |
| [84]       | Remote rehabilitation monitoring embedded system based on IoT                | Bendable force sensors                                                             | • The advantages of the proposed system are, simple, flexible, cheap, unobtrusiveness, and low power is consumed |
| [85]       | Physical activity recognition from smartphone accelerometer data             | Accelerometer                                                                      | • Accurate predictions could be made for offline activity recognition      |
| [86]       | Detection of daily activities and sports with wearable sensors               | Accelerometers and GPS                                                             | • Hybrid classifier (tree structure and artificial neural networks)         |
| [87]       | Activity detection and classification using different sensor modalities (Data fusion) for real-time and autonomous monitoring | Inertial sensors                                                                   | • Data fusion with multiple classifier system                               |
After studying and reviewing several studies about RHM based on IoT, it can be found that the proposed topic is considered as a hero nowadays and still in its infancy stage. However, more efforts and contributions are still needed to tackle the challenges and gaps.

2.1. Challenges and future trends

This section summarizes the main challenges and the possible future trends for RHM based on IoT [93-109]:

a) Usability: patients and elderly people may not engage with sensors and recent technologies. Moreover, wearable sensor should be designed in comfortable shape for the wearer.

b) Cost: advanced sensors, security protocols, network infrastructure, and compatible systems may carry a huge cost.

c) Data Security: protecting patient’s data from hacking and stolen is a challenging issue.

d) Integration and standardization: build a medical network with medical devices is a challenging task.

e) Data acquisition: noise, uncontrolled environment, sealing, sensor placement and position, and size of the sensor may lead to difficulties in data collecting.

f) Feature extraction: obtain valuable diagnostic information from wearable sensor data is very crucial. However, high accuracy and high-performance feature extraction methods should be developed.

g) Big data problem: real time and continuous monitoring lead to produce huge mass of data. However, big data analytics and protocols have to be developed for dealing with huge mass of collected data, even approximately.

h) Safety: wearable sensors with batteries may lead to skin problems.

i) Power consumption: Sensors have a limited power capacity.

3. CONCLUSIONS

Currently, elderly and aging people are increasing globally. Thus, the use of novel advanced technology in healthcare industries has critically required to enhance medical services for those people. RHM with the help of IoT technologies offers remote and continuous monitoring for patients and elderly people. Moreover, RHM aims to enable a continuous and real-time monitoring to diagnose, manage, and prevent disease. The proposed review study highlighted RHM based on IoT studies. Finally, challenges and future trends of this emerging topic are also discussed and highlighted.

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