CHAPTER 3

Analysis of the Internet of Things capabilities in monitoring the physiological state and location of personnel on an offshore oil platform

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Abstract

This chapter explores the opportunities of using the Internet of Things (IoT) to ensure the safety of personnel on offshore oil platform. To this end, the IoT applications and technologies are analyzed for the monitoring of the physiological state and location of personnel. The chapter presents the opportunities of using IoT with cloud technologies, Big Data technologies, and artificial intelligence for system development which enables to monitor and, if necessary, to make appropriate decisions through systematic monitoring of the state of personnel based on expert assessment of deviation of real time parameters' values from the norm. The practical tasks related to the application of IoT technology in various fields of healthcare are explored. IoT Services and IoT Applications used in e-health are analyzed and classified. The risks and challenges arising from the implementation of IoT solutions in healthcare and posing a threat to both the physical safety of patients and the confidentiality of their personal data are identified.

Keywords

Offshore oil platform, expert assessment, IoT technology, IoT Applications, smart wearable sensors, Wireless Sensor Networks, e-health, IoT Services.

3.1 Introduction

In accordance with the thesis of the Concept of Human Development, "people are the real wealth of every state, and the development policy conducted in any field should serve them precisely", the protection and provision of health of human resources

 DOI: 10.21303/978-9916-9850-2-1.ch3

is among the priorities in all facilities [1]. Offshore oil platform (OOP) is a complex engineering facility designed for excavation of deposits in the seabed, and in the depth of ocean or other water basin and for the extraction of hydrocarbon raw materials [2].

Noticeably, the work of oil workers and gas producers is related to health risks. Early Preventive Medical checkup, Evaluation, Inspection and Review System is designed to minimize the risks. However, medical examination does not always guarantee that employees will be able to perform their professional activities during their shift (usually within two weeks in OOP). Analysis of emergency situations on oil platforms shows that most of them occur due to unexpected deterioration of health, critical fatigue and loss of consciousness of employees. In this regard, monitoring of employees, their health status (temperature, pressure and other physical controls), and location (space) are currently of great importance.

There are two main aspects of reducing the number of emergency situations (accidents, injuries, etc.), i.e., reducing the gravity center of the complications on the oil platform. The first aspect involves the development and perfection of technical tools and the support of the working environment, the prevention of their wear and, thus, the prevention of accidents on OOP. The second aspect is directly related to the safety of personnel, especially its physiological and psychological condition, behavior, performance on OOP and their geographical position, and professional activity. This means that, in addition to registering the equipment, raw materials and environmental parameters, it is important to ensure the proper evaluation of safety of the personnel. Despite the close interrelation between them, both aspects have their own scientific and technical specifications.

The subject matter of this chapter is the personnel and its physiological safety on OOP. The key point here is related to the human factor, the main reason for the tragedy is the personnel's insufficient instruction on emergency situations on the platform [3]. One of the chief ways to prevent the "dangerous behavior" of a personnel, or more precisely, the human factor on OOP, is a systematic monitoring of the physiological and psychological state of an employee and his/her geographical position at the place. With real time information, the level of risk and safety of each employee's health and psychological condition can be determined based on expert assessment. The Internet of Things, modern mobile technologies, the Internet of Medical things and numerous ICT technologies open up wide opportunities to strengthen security measures through the real-time monitoring of the health of personnel on OOP and systematic monitoring of the location of each employee.

The exploration of the possibilities of the Internet of Things to ensure the safety of staff on OOP requires first of all the study of the concept and the essence of the "Internet of Things".

3.2 The concept of "The Internet of Things"

The concept of the "Internet of Things" was first used by the English innovator in the field of technology Kevin Ashton in 1999 for the description of the system in which the objects of the physical world were connected to the Internet through transmitters. In the same year, the Massachusetts Institute of Technology established the Radio Frequency Identification (RFID) and Auto-ID Center, and respectively, the concept of IoT has gained a wide range.

The simple idea of the Internet is that surrounding objects or things (such as tablets, smartphones, fitness equipment, home appliances, clothes, cars, manufacturing equipment, medical equipment, medicines, etc.) can be equipped with miniature identifiers and sensors (sensitive devices) and can be connected to the Internet and to each other via wired and wireless (satellite, mobile, Wi-Fi and Bluetooth) connections [4, 5]. Availability of the necessary channels allows not only to identify and monitor the parameters of these objects by space and time, but also to manage them. Thus, the "Internet of Things" can be viewed as a global network infrastructure consisting of a large number of devices, interconnected through sensors, communication, networking and information technology [6].

From the information-communication point of view, the Internet of things can be typically written as a symbolic formula as follows [7]:

IoT=Sensors (Transmitters)+Data+Network+Services.

3.3 Definition of "The Internet of Things"

At present, the term "Internet of Things" does not have a single universally accepted definition in literature. Many definitions of IoT focus of its various aspects and features [7–9]. Some of them are listed below:

1. The Gartner analytical company interprets the "Internet of Things" as a network of physical objects based on technology that allows measuring the parameters representing the position of the physical objects as well as their environment, and using and transferring this data. The main aspect of this interpretation is that, despite the notion of "the Internet of Things", the things are often linked via the M2M (machine-to-machine) protocols rather than the Internet. In this case, it is focused on decisions based on the interactions of transmitters, sensors and other "iron" things without the participation of people [8].

2. The Internet of Things – Physical devices connected to the Internet – a global network of "things" equipped with data transmission facilities that enable sensors,

transmitters and data collection and share ("communicate" with each other). These facilities are connected with data management, control and processing center access tools [10].

3. The International Telecommunication Union defines the Internet for Thing as a global infrastructure for the information society, providing the opportunity to deliver more complex services by connecting physical and virtual objects based on existing and emerging ICTs [11].

Due to the rapid development of technology, various interpretations of IoT are given, however they are all based on the same concept. According to this concept, IoT is referred to the group of non-computerized devices, equipment, transmitters, and routine tools with computing ability and network access. Most of these devices usually referred to as "smart or intelligent devices" can process and utilize, analyze and share data with the minimal interference of human.

These things interacting and communicating with each other, and sharing information about the environment and responding to environmental processes without human intervention are predicted to be the most active participants of business, information and social processes in the future [12, 13].

3.4 Smart wearable IoT devices

At present, the continuously expanding market of health Internet of things have been applied in many healthcare sectors. Thus, many health centers around the world have been using smart clothes, gadgets for sensing data on key health parameters, climate control platforms in hospitals, applications for transferring health data to physician, and so forth. For interconnection of different devices with different applications, they are combined with different types of networks over the Internet.

Let's note that various types of health Internet of things are referred to the large number of intellectual devices that are easily accessible in our daily lives. They are smart wearable Internet of things.

Today, there are numerous body-worn wearable devices that measure human physiological parameters [14]. Wearable biomedical transmitters are the subset of devices measuring human biological parameters. Wearable IoT technologies are typically rigid or flexible, based on ordinary electronics, and are designed for low power consumption. They are able to control the patient's parameters in a natural environment and an arbitrary environment, and to transmit signals and information.

In the market of the health Internet of things presents various wearable technologies installed on the transmitters that are categorized as "smart clothes" (head covers, space suits, helmets, jackets, trousers, coats, socks, etc.) and "smart things" (glasses, watches, rings, bracelets, sticks, bandages, lens etc.) [15].

"Smart Clothes" can be used to sense and analyze the data related to the physical activity of a person, to control vital health indicators. They can control the state of people working in hazardous conditions, and monitor the location of the patients and their place of residence in emergency situations, and to observe fatigue levels of an oil man, pilot, driver, etc.

"Intelligent things" (gadgets or devices) may include body-worn transmitters, the objects to monitor vital health indicators, to track the location of the staff on SP, and the applications or objects (e.g. smart box for ampule/pills) reminding the stuff, as well as the healthcare personnel observing their physical state (both physicians), smart devices for real-time monitoring of critical health status, transmitters for tracking and transmitting geolocation data.

Let's note that each wearable smart gadget has certain functional capabilities and is intended to address specific issues.

This allows classifying the wearable IoT for their functional capabilities and relevant applications.

Essentially, wearable medical IoT can be grouped as follows:

1) IoT for monitoring, diagnostics, treatment, care and rehabilitation of personnel;

2) IoT for supporting healthy lifestyle of staff, including their daily physical activity and physical condition;

3) transmitters for tracking staff displacement.

First-group devices include measuring and analyzing one or more vital indicators and parameters (cardiac frequency, ECG, arterial pressure (smart tonometer), sugar rate (smart glucometers), respiratory rate) characterizing the functioning of the cardiovascular system, and the transmitters for drug control.

Second-class wearable devices are designed for continuous monitoring of the level of human agility (SP employee), and shows the data, pulse rate, distance traveled, calories consumed, and so forth sensed from accelerometers. The sensed data can be transmitted to the employee's smartphone or computer as well as to the medical personnel (physicians) who treat them. The applications specifically designed for the calculation of various human health indicators provide advice to users when they detect abnormalities in these indicators, and notify the healthcare personnel in critical situations (insult, heart attack, epilepsy, etc.) and for emergency medical intervention.

Third-class mobile devices can be used successfully for tracking the location of people at high-risk areas, including people from vulnerable categories (elderly, children, people with psychological illnesses).

3.5 Smart IoT Applications

Success of IoT depends on the applications that improve the daily life of a person. The requirement for the use of certain applications is the presence of transmitters for the transmission of the relevant data set. IoT applications are software applications or software systems designed to handle specific issues [16].

IoT applications play an important role in e-health and are directly used by users and patients. In addition, they enable tracking and monitoring the health of people working in other areas, including those of specific risks. IoT applications supporting one or more health indicators at the same time are shown below.

Glucose level sensing. Blood sugar monitoring enables detecting blood glucose level and nutrition plan, activity, and the time to take medication [17].

At present, IoT-based health monitoring systems are being successfully implemented. However, modern IoT-based continuous monitoring systems for sugar levels are not numerous and existing systems also have some restrictions. In [18], using IoT, the architecture for glucose level monitoring system is developed. The system provides actual information about the amount of glucose in blood, including body temperature and contextual data (e.g. environmental temperature) in realtime mode in a timely or affordable format to the users (patients and physicians).

The authors of the article [19] offer the configuration for *Internet of m-health (m-IoT)* for non-invasive real-time monitoring of glucose providing IPv6-connectivity with medical service providers (physicians) based on the transmitters mounted on the patient's devices (gadgets).

The article [20] introduces a model for sugar monitoring system based on IoT networks comprising the devices for blood collection and glucose level measurement modules, including mobile phones or computers for data transfer.

Electrocardiogram monitoring (ECG). ECG is one of the methods of simple, palliative and informative diagnostics of heart disease. The method is based on the recording of electrical impulses that occur in the heart and its graphic writing in the form of extensions on the special paper film. ECG reflects numerous variations of the certain parts of heart in the form of extensions [21].

In recent years, various studies have focused on the use of IoT in ECG monitoring. IoT technologies are now thought to be quite promising for the acquisition of maximum amount of information related to the activities of cardiovascular system, including ECG monitoring [22, 23]. The article [24] offers IoT-based system for real-time authentication of heart function. The system records the electrical activity of the heart and sends this data to the data analysis center, which detects ECG errors and evaluates the patient's condition. Another article [25] develops a complex of algorithm for practical detection of ECG signals in IoT environment for continuous monitoring of ECG. In [26], IoT-based applications are developed to write and monitor of ECG, to measure heart rate and provide the graphical description of the heart rhythm, and then to send these data to the databases and web servers. ECG collecting devices cover the transmission of data on the frequency of heart attacks and *Arduino* micro-controllers. The software is written in MATLAB and C^{++} programming languages in order to process and analyze ECG and download it into the database and Web servers.

A new generation *Nuubo*, offering a wireless and remote platform for heart monitoring, is of great interest. This Spanish company produces, manufactures and sells a wearable medical technology portfolio for the diagnosis and rehabilitation of cardiovascular diseases. These tools are based on the ECG wireless remote monitoring platform and incorporate patented biomedical electronic tissue technology (electronic smart tissues), which uses digital technology called **BlendFix Sensor** [27].

The advantage of *Nuubo* series transmitters is that they can be installed on a daily basis. Smart *Nuubo* shirt is equipped with special devices that control the vital condition of the patient and his/her movements. The shirt records ECG, transmits the sensed data through wireless network to the server for analysis, where special software can define the abnormal parameters. The transmitters installed in the shirt regularly collect parameters such as heart rate, arterial pressure, and body temperature. Shirt-mounted transmitters use a GPS network for connectivity and ensure recording of people on the move (moving throughout the OOP) [27].

Heart rate. The frequency of heart rates is characterized by the number of rates in the same time and measured in bits per minute. The frequency of heart rates is substantially dependent on context, i.e., it increases after physical exercises and can change due to stress, insomnia, illness and drug intake. The frequency of heart rates is also affected by age and genetics. IoT-based ECG monitoring systems incorporate the measurement of heart rate and pulse rate, as well as the diagnostics of multi-channel arrhythmias, myocardial infarction, and so forth. In healthy people, the frequency of heart rates and pulse are equal [24, 25].

Blood pressure monitoring. Blood pressure is referred to the Withings in the arterial vessels. The blood pressure in arteries, veins and capillaries differs and is one of the main indicators of the functional status of an organism.

High blood pressure is a risk factor for the development of insidious, cardiovascular, and chronic renal failure; thus, it is important to systematically monitor and check the effects of treatment. At present, there are a large number of different devices, including mobile devices, to measure blood pressure.

The relevance of the problem is that blood pressure-measuring devices and a set of mobile phones supported by NFC (Near Field Communication) have to be related so that they will make up a part of blood pressure monitoring on IoT networks. Performance of the blood pressure measuring devices depends on the model connecting them with a mobile computing device (for example, *Apple*), which realizes wireless data transmission [28]. The article [29] proposes a device equipped with the apparatus for blood pressure measuring with communication modules for collecting and transmitting blood pressure data in IoT networks. The article [30] offers IoT-based Intelligent Terminal, which identifies the location of the wearable apparatus for blood pressure monitoring.

Body temperature monitoring. Body temperature monitoring is an integral part of health care. This indicator is a vital parameter for homeostasis support [31].

Traditional method of temperature measurement through mercury thermometers has been recently replaced by more reliable and inexpensive wire and wireless sensor transmitters for the determination of health status. To determine body temperature, the article [19] provides an example of the realization of m-IoT concept, which uses transmitters installed on *TelosB Mote* platform. Another article presents IoT-based architecture for temperature control system [32]. FID module and body temperature control module are the key components of the system responsible for the temperature recording and its transmission in the system.

Smartphones for the development of IoT Solutions in healthcare. Recently, smartphone-driven transmitters have been developed. This enhances the essence of smartphones in the development of IoT technologies. Various hardware and software products that transform smartphones into a universal health device have been developed [33]. Modern smartphones support a large number of health applications (diagnostic, reference, commentary, analytical, etc.) [34]. Health applications also use numerous wireless transmitters running on algorithms to analyze images [35].

Smartphones include effective diagnostics of asthma, cystic fibrosis, allergic rhinitis, as well as monitoring of vital indicators as heart rate, blood pressure, respiratory rate, and so on [34]. Health applications for smartphones offer solutions that are not too expensive for both the patient and the wide user audience. Today, there is a tendency of using multifunctional applications to interact with several sensor devices as of *ZephyrLIFT* series, while the first health applications were designed to interact with one transmitter.

Applications for geographical location tracking. At present, there is a growing need for solutions that enable each person to track the trajectory of traffic and notify the emergency response service immediately about hazardous situations. Modern mobile devices are equipped with information on their geographical location. For example, *Corvus-Tracker* for *Android* operating system is designed to track users' mobile devices. This application sends information about users' geographic location to the monitoring system server. The system is also capable to send SOS signals to the specified phone numbers. The complementary function of the system is to create a geographic area, run within a given time, combine several users in one group, and visualize the system data for the user [36]. Applications for "smart" items' tracking are also widespread. Thus, applications supporting Global Positioning System (GPS) provides operational information to the relevant medical personnel about the location of the users (including those with special risks, as objects, children, elderly people, mentally handicapped people, etc.) through pre-installed sim-cards.

Nowadays, modern systems providing the identification of real-time location system (RTLS) are available. Actually, GPS is considered to be the most important RTLS. This satellite-connected navigation system is able to find objects anywhere on the Earth in different weather conditions. The basic principle of the system is to determine the geographical location by measuring the time of receipt of synchronized signals from antenna satellite navigation in any point of the Earth and of the space. This feature of the GPS can be used for the identification of the location of medical part of the ambulance, patients, physicians, as well as the staff on OOP, and for the acquisition of the information on the location [37].

3.6 Technologies used in Medical IoT

The IoT concept for healthcare is realized through a range of technologies. A brief description of these technologies is shown below.

The instruments that constitute the basis of IoT and allow the integration of physical devices into the digital world include *RFID* technologies and *Wireless Sensor Networks (WSN)*.

RFID technologies are based on the use of microcircuits that collect information from the devices mounted on the machine or chips installed on the devices. RFID technology enables the transmission of identifiable information wirelessly to the meters via microchips. RFID meters allow identification, monitoring and control of any object automatically integrated with RFID [38].

RFID technologies can be used in IoT to track the movement of staff on OOP. By integrating IoT technologies with e-Health solutions, it is possible to assign RFID to each staff member on OOP and to send data to the center. This allows the staff to access electronic health records, and the sent data is stored on the Health Center database. The physician gets access to health records of a specific person by scanning the RFID tag [39, 40]. RFID tag can register any person on OOP or the specific business areas of the platform. This is especially important in extreme situations to get accurate information about people on OOP and their location.

Wireless Sensor Networks *(WSN)* or *Ubiquitous Sensor Networks (USN)* constitute a technological basis for the realization of the concept of the Internet of things [41]. *Wireless Personal Area Network (WPAN)* is a distributed network of unserved miniature electronic devices (sensor nodes) that provides collection of data about external environment parameters and transfer them to the processing center based on retranslating them from node to node. All transmitters are linked with interconnected radio-channels located in the air, water and water surface, and inside the body.

Wireless Body Area Network *(WBAN)* is a wireless computer network which is wearable and wearable on body. These devices can be mounted and implanted into the body, mounted to the body in certain conditions, or installed in clothing (e.g. in a pocket) and carried items (e.g., in a bag) that people wear in different places. *WBAN* system can use wireless network as a gateway to reach greater distances. The wearable devices can be interconnected through the Internet via the gateways. Thus, health workers can access the information online regardless of the patient's location [42].

3.7 IoT based medical data transfer technologies

At present, networking combinations with different forms and able to operate from different distances, and requiring different powers open wide possibilities for IoT. They may include wireless personal area networks (WPAN), Wi-Fi networks, wireless mesh networks, cellular networks, extremely broad-band networks, and satellite-connected networks.

IoT are grouped into near and remote activity segments. The near business segment mainly covers the devices linked with connection channels through the use of unlicensed radio communication technologies (Wi-Fi, ZigBee, Bluetooth) covering 100 meters or fixed as a local area network (LAN), PLC (Power Line Communication). The remote activity segment covers the devices connected through cellular networks, unlicensed low-band radio communications technologies (such as *LoRa*, *Sigfox*) or satellite technologies.

IoT are assembled into two groups for distant and remote data transfer. Today there are various wearable devices that support medical sensors to collect data. Most of these devices provide connection at a near distance. This can be a link between nodes or sensor nodes, or a gateway aggregating the data from sensors.

If the data is required to be transmitted to the nearest distance, the device can use a Personal Area Network (PAN), as well as wired USB interface presented with wireless data transmission technologies such as *BLE (Bluetooth Low Energy)*, *ZigBee*, and *6LoWPAN*.

LAN can be used when the data is partially transmitted at a far distance (e.g., within a clinic or hospital). Wired local networks are often built on *Ethernet* and optical fiber technologies, while the wireless ones are built on *Wi-Fi* technology. *WiMax*, *LTE*, etc. are used for the organization of a global network (Wide Area Network, WAN) [43].

Over the past two years, the technology has been developed to connect low-powered devices to *LPWAN* [44].

Data transmission speed and energy consumption are the key factors for the choice of cellular technology in specific cases. *BLE*, *ZigBee*, *Z-Wave* are used in limited-powered devices and comprises the use of gateways for data aggregation and sending them in IP-network [5].

IoT uses the BLE and ZigBee technologies for data transfer at a close distance.

Bluetooth LE technologies. *Bluetooth* is a wireless technology that provides the data transmission between the devices that are not too far away from each other. This technology allows the communication between the devices within the coverage of 10 m. One of the significant advantages of *Bluetooth LE* is its low power consumption and extreme low power consumption in sleep mode. In other words, the device "sleeps" at 99 % of the time and "awakes" for a short period of time, shares data and "re-sleeps" again. In general, *BLE* is very advantageous in medical applications. It is safe and has low bandwidth, low latency, low power consumption and resistant to hindrances. This standard is recommended for the design of wearable healthcare systems.

Bluetooth 5.0 is the newest generation of *Bluetooth*, allowing for data sharing between devices at a distance of up to 200 meters and at a rate of 4–12 megabytes/s [45].

Wi-Fi technologies are designed to provide access to wireless broadband networks for high-speed data transfer. The networks can be expanded without interlayers and wire through *Wi-Fi*, with access to network and mobile devices. Within the Wi-Fi zone, several users can access the Internet on a computer, laptop, tablet, phone, etc. may be included in [46].

ZigBee (6LoWPAN) technologies. *ZigBee* is designed to create wireless personal networks (WPANs) using small-size radio transmitters with little power. *ZigBee* technology is oriented at the applications capable to operate separately and securely for a long time during high-speed data transmission [47, 48].

ZigBee is used in bio-transmitters for medical diagnostic devices, medical equipment, and for the monitoring of the condition of athletes, including the personnel operating at high-risk sites. In this case the maximum transmission speed accounts for 250 kb/s. *ZigBee* consumes low power operating in sleep mode. Devices can be enabled by pressing the button, working with the timer, and so on. "Sleeping" devices switch back to "sleep" mode as soon as the data is transmitted and they get the confirmation on the receipt of the package by the main line. The disadvantage of *ZigBee* technology is often due to the fact that it is not used on smartphones, although *BLE* is used. Therefore, the use of ZigBee technologies in fixed locations is recommended.

ANT+technology is a wireless communication standard designed to transmit information between ANT+ supported devices [7]. This standard uses the frequency used by Bluetooth, supports up to 30 meters distance, and is implemented through special chips allowing the data transmission between devices. The standard is intended for house use and medical application. This standard is used by *Philips*, *Samsung*, *Sony*, *HbbTV*, *France Televisions*. Its main advantages include low energy consumption, thus the ANT+ connection uses 70 % less energy than *Bluetooth*.

3G/4G LTE (Long Term Evolution) and 5G technologies. 3G is a third-generation mobile communication technology, providing a set of services combining both high-speed mobile access technologies with data transmission channels, as well as Internet-based services. 3G networks work within the range of decimeters and centimeters, and transmit data at speeds of up to 3.6 mbit/s.

4G LTE is a fourth-generation mobile communication technology, designed for high-speed wireless data transmissions in data-driven mobile devices and other equipment. The objective of 4G LTE is to increase speed and transmission capabilities using modulation methods and digital signal processing, as well as the reconstruction and simplification of IP-based network architecture, which will significantly reduce delays in data transmission in regard to 3G-architecture networks.

5G is the next generation mobile communication technologies, which involves the creation of a network that practically enables connecting almost everything. The transition to global standard 5G NR (*New Radio*) will ensure a new mobile broadband connection for smartphones (tablets) in 2019. These devices sense the information from transmitters in the human body and send them to the network for general use [42, 49].

NFC technologies *(Near Field Communication, NFC)*. In recent years, near field high-speed wireless technology has also improved significantly and allows data exchange between devices at a distance of about 10 centimeters. NFC technologies were primarily intended for the use on digital mobile devices. This technology is a simple expansion of contactless standards that connect interface smart cards considering it a single device. The NFC device supports the communication with a smart card and other NFC devices, which can work with existing contactless card infrastructures [8].

NB-IoT technologies *(Narrow Band IoT)* is a new generation of cellular connection standards for telemetry devices for low-scale data exchange (2016), designed to connect a wide spectrum of autonomous devices, including medical devices to digital network connections [50]. Since NB-IoT is protected and supports a large number of devices and transmission at a great distance, it is very convenient for healthcare applications.

Transmitters. The development of transmitters is one of the main incentives for the expansion of the ICT application. Transmitters measure the physical data and convert them into raw information. This information is then stored digitally, and useful for analysis and processing.

Miniaturization of sensors has allowed them to integrate into "smart" devices, with the latter being able to record data, analyze the data, and allowing them to be transmitted over the Internet. The size of modern transmitters can range from one millimeter to tens of centimeters. At present, the work is underway to further reduce the dimensions of transmitters to ensure high comfort within the human body. Transmitters are fastened to the body in a variety of ways, and combined with the basic headset (often with a smartphone) via wireless technology, such as via *Bluetooth*, *ANT+*, *ZigBee*, etc.

Transmitters have to work perfectly and autonomously for the full realization of IoT capabilities, i.e., transmitters must be systematically fed. Solution of the problem should be sought from the environment: the methods of generating electricity from vibration, light and air flow [51]. Many achievements have already been done in this area. Scientists have announced the utilization of commercial nanogenerators – the chips that transform the movement of the human body (even one finger) into electrical energy, which avoids the use of battery and electrical sockets [52].

IoT platforms. An IoT device is interconnected via the Internet protocols for data transmission between each other. IoT-platforms provide bridge services between sensors and data transmission networks.

The most popular companies in the IoT platform market may include:

– Amazon Web Services;
– Microsoft Azure;
– ThingWorx IoT Platform;
– IBM's Watson;
– Cisco IoT Cloud Connect;
– Salesforce IoT Cloud;
– Oracle Integrated Cloud;
– GE Predix.

3.8 IoT and other technologies

The development and use of IoT potential will be possible in its interaction with other technologies.

Cloud technologies, Big Data tools and techniques, artificial intelligence technologies should be mentioned here first.

Cloud technologies. The IoT system generates a large amount of data to be stored, processed and shared. Clouds in the universal architecture of IoT have three main functions:

– data collection and storage (transmitters' indicators), and their accessibility. The devices with transmitters collect giant volumes of data; the latter ones are stored in the clouds for further processing and analysis;

– data analysis. Cloud services provide data review, cross-connections detection, and important data extraction, including transformation of transmitters' indicators for remote data exchange and decision-making. Real-time analytics (analytic processing), including the analytics implemented after packet mode data collection in wide intervals. In this case, machine learning and data acquisition algorithm and technology play an important role;

– providing execution commands: IoT systems refer to data in different directions, along with transmitting the transmitters' indicators, and ensuring that the commands are securely activated from the cloud.

In addition, cloud solutions perform administrative functions such as managing the records of device and users' logs, performing the protocols of use, monitoring of server status and reporting [53].

Big Data is one of the most important technologies that complements IoT and provides tools and techniques for large, diverse, different sized and unstructured data processing. The use of IoT also increases the number of large data in e-health [54]. Anyone in need of regular medical supervision and wearing a transmitter is the generator of infinite large numbers of digital anamnesis. Thus, one of the most important issues for the development of new medical technologies is the solution of large data generated by IoT transmitters. Modern medical technology allows scanning a body for only a second, whereas the whole human body is scanned for 60 seconds. This means that after appropriate examination, 10 GB of data will be sent to disease archive in the form of unprocessed images and electronic reports. Moreover, the volume of data on the electronic health record (EHR) of an adult patient will account for more than 2 TB.

The development of specific analytical tools aimed at working with medical data is very important for the solution of big data problem in medical IoT. Today *Hitachi Clinical Repository's* solutions are very successful in the market [55], these solutions allow processing the results of the examination and the raw medical data from various sources, and obtaining the necessary information.

Artificial intelligence technologies. Several researchers and developers offer creating "sensitive Internet objects" by transferring artificial intelligence to the "objects" and communications networks. They state that IoT system should have the features of "self-configuration, self-optimization, self-protection and self-healing" in the future [56]. The "smart" things are estimated to be "smarter" due to context dependence, large memory, and extensive processing capabilities, as well as ability to think [57].

The Internet of Things generates a huge amount of data; however, the real problem is the timely and precise processing and analysis of this data. The analytical capabilities of artificial intelligence applications on servers that handle data obtained or served to the IoT networks can provide fast and adaptive data collection. The combination of IoT and artificial intelligence technologies will enable the development of "smart" and "connected" machines to interact with each other and to make decision with the without or minimized participation of a human in general.

3.9 The Internet of medical Things

One of the most important areas where IoT technologies can significantly benefit society is e-medicine. Special terms as "the Internet of medical things" (IoMT) or "the Internet of things in medicine" are already used for this field. Almost all segments of medicine have recently been in the focus of IoT researchers and creators, and these technologies are being applied in solving a number of practical issues. As a result, many applications and service areas have emerged.

Large-scale research and experiments on the integration of IoT innovations into medical practice demonstrate the wide potential of this technology in the field of healthcare. Undoubtedly, the prospects for the expansion of the IoT segment are currently determined by the needs of the medical field. The main reason for this is the possibility for mass and direct interactions between people and electronic devices. Consequently, according to *Allied Market Research* forecasts, the market for medical *IoT* devices (gadgets) and *IoT* applications is estimated to grow to 136.8 billion USD in 2021 [58, 59]. Currently, the average annual growth rate of the IoT market is 12.5 %, and the number of high-tech services, applications and systems in the field of healthcare is predicted to increase in the near future. Market development is also driven by increasing availability of medical gadgets and increasing user awareness of medical innovations.

IoT technologies allow medical institutions to increase the efficiency of work, reduce the time of stay in the stationary mode, monitor the patients' health by providing new services, receive and analyze additional information about the course of treatment, and get consultations from the best doctors. Remote health monitoring provides prompt control of medical indicators, reduces the cost of medical care and simplifies the relationship between the doctor and the patient.

IoT devices, various sensors and analytical applications working with them are involved in solving a number of administrative management, logistics and treatment-diagnostic issues. The global connectivity of the Internet of Things allows collecting, processing and effective use of various types of medical data related to security, diagnostics, therapy, treatment, medicine, management, finance, daily activities, and etc. [60, 61].

Below are some practical issues successfully solved in a number of medical spheres with the use of IoT technologies [62–65].

Administrative management. IoT technologies have great potential in solving the following problems in the administrative management segment of e-medicine:

– patient control and monitoring of his/her health condition (temperature, pressure and other physical indicators);

– real-time monitoring of the location of doctors and patients in a medical institution (this allows for their urgent call in emergency situations, i.e., an operation or a procedure);

– monitoring of environmental parameters, climate control in the medical institution and wards, monitoring of internal climate conditions in the medical institution to warn about exceeding the limits of certain indicators (for example, temperature, humidity, oxygen concentration, etc.);

– management, monitoring of the status and condition of medical equipment, drug stock, used materials, etc. in medical institutions and pharmacies;

– automation of inventory work, automatic reporting on the intensity of use of medical equipment and information technology equipment.

The IoT devices used in solving the problems under consideration are deployed in hospital refrigerators, ice chambers, wards, corridors or other places of the medical facility.

Medical diagnosis. Medical diagnostics involves various measuring instruments as the potential of IoT in this field is infinite. Currently, in addition to the "traditional" visualization (for example, ultrasound, magnetic resonance and computer tomography) and laboratory diagnostic methods, the field of clinical diagnostics is widely applying transmitters for measuring many clinical indicators (for example, heart rate, arterial pressure, pulse, brain activity), as well as micro-transducers and nano-sensors for the assessment of clinical biomarkers. Today, nano-sized biochips are already being used in laboratory conditions, which allow ultra-sensitive analysis *in vivo* (*lat. "in living"*), or rather, "inside a living organism or inside a cell" [66]. Significant progress identifies cancer biomarkers and infectious microorganisms through molecular diagnostics. For example, a unique biosensor developed by Swiss researchers, which is only one centimeter long, is implanted under the skin and measures glucose, cholesterol, toxins, etc. in the blood. By transmitting the information about the amount of above listed to the patient's phone, it allows patient to monitor this amount continuously. The device is charged with a special patch attached to the patient's skin. Wearable, implantable and absorbable sensors monitoring various vital signs are connected to the patient's smartphones and can also directly "communicate" with the treating physician.

Remote monitoring. Remote monitoring through IoT is an integral component of modern telemedicine systems and telemetry. Thus, wearable transmitters allow doctors to remotely monitor the patient's important vital functions, analyze the real time data and predict changes in their health conditions. At present, diagnostic complexes are available with transmitters for remote monitoring of heart rate, body temperature, blood pressure, blood sugar level in diabetics, and for real time processing of breathing functions.

The signals from the transmitters are sent to the patient's mobile device, to the monitors of the staff and treating doctors. The analysis is performed and conditions related to life-threatening situations are formed being supervised by a doctor. The patient himself/herself can send an alarm signal about his/her condition to the server from the phone interface [67].

The use of IoT technologies enables remote monitoring of the physical condition of workers in hazardous facilities and making decision regarding the provision of appropriate and immediate medical assistance. Vests with a set of transmitters already recording the electrocardiogram (ECG), arterial pressure and a number of other parameters, with the ability to record the ECG and transmit it to the medical center using *General Packet Radio Service* (GPRS), as well as diagnostic complexes composed of mobile phones identifying the coordinates of the employee (patient) in a life-threatening situation have already been developed and tested [68]. The processing of received data by specialists enables the real time monitoring the situation of workers in dangerous zones, assessing the situation and responding to it immediately. Radio Frequency Identification (RFID) technologies, RFID tags track the movement of employees, determine their location in special risk facilities and warn about entering a prohibited zone.

Drug therapy. Drug therapy is one of the medical spheres where the use of IoT will bring great benefits. Today, micro-transmitters embedded in pills have already proven themselves to be effective in the monitoring of medication intake, helping to control medication intake and compliance with the prescribed schedule. Such implants can "connect directly" to both the patient's smartphone and the treating doctor. Currently, devices monitoring the correct use of drugs and making reminders about their regular intake are widespread in the market.

Proteus Biomedical (USA) develops miniature microchips that are part of the pill [69]. When the pill is swallowed, the microchip entering the body creates enough potential to transmit the signals of the person's movement to the ECG and through radio channels to a small receiver attached to the abdominal wall.

The receiver collects the signals from the swallowed pills and then transmits them to the server or the doctor's computer. Detailed information on the use of such a chip-pill is provided in [70].

Philips develops an "intelligent pill" (*iPill*), which is a tiny device composed of a microprocessor, battery, radio receiver, pump, and a container for medicines [35, 71]. This device "releases" the drug exactly where it is required.

When an "intelligent pill" enters a human body, it determines the necessary dose by minimizing the harmful effects of the drug. The "electronic brain" in the *iPill* consists of control chips and transmitters, as well as a tiny pump regulating the temperature and acidity. The microprocessor processes the sensed data and transmits a voltage to the "pump" releasing the necessary amount of medicine at the current moment. The *iPill* can be programmed to deliver medication at set intervals.

Treatment and care. *IoT* has a great potential in treating and caring for patients both in the healthcare facility and at home. The expansion of the IoT segment in healthcare, and regularly sending the patient's health indicators to the treating physician responsible for the monitoring the patient's health status through transmitters, has made it possible for many people to live more comfortably. The clinic's staff analyzes each patient's health based on the requirements of the relevant technology, determines his/her needs and teaches him/her how to use IoT-enabled devices. The application of IoT in the field of patient monitoring in operating rooms, other emergency rooms, separate intensive care and post-operative care units has a great potential. In this case, transmitters can be used to measure a wide range of clinical indicators (heart rate, arterial pressure, pulse, brain activity, etc.). Customized IoT platforms with health data analytics enable medical personnel to monitor the condition and alert them to the need for medical intervention.

IoT solutions focus more on preventative care at home rather than emergency care. The use of appropriate technologies reduces the cost of medical services by reducing the demand for emergency services and visits to hospitals.

3.10 IoT Services and Applications in medicine

Currently, IoT technologies open up wide opportunities for the development of the following services and applications in the medical segment:

1) to increase the quality and efficiency of medical assistance service;

2) to perform collection, analysis and interpretation of various types of data;

3) to improve real-time decision-making;

4) to constantly monitor the health status of patients with dementia and chronic diseases or preventive intervention;

5) to create favorable conditions for the development of customized and personalized medicine, etc.

Research shows that there is no standard definition of an IoT service in the medical context. IoT technologies are expected to proliferate, each providing a large number of medical solutions, providing a variety of medical services. However, in exceptional cases, the service may be objectively separated from a specific solution or application [72]. In addition, it should be noted that the common services and protocols essential to the IoT infrastructure may require minor changes in the functionalization of the healthcare scenarios which they belong to. These include alerting service, shared resource access service, Internet service, cross-switching protocols for heterogeneous devices, and aggregation protocols for basic connectivity. Note that services are aimed at their creators, whereas the applications are used directly by users and patients.

Fig. 3.1 presents IoT-based medical services and applications that are currently more available and widespread.

IoT services in medicine are defined by:

1. Public healthcare. The rapid growth of healthcare expenditure has been a challenge for most countries of the world. In many developed and developing countries, the trend of population aging, "lifestyle diseases" (obesity and diabetes, memory problems, arthritis, etc.), a significant increase in patients with chronic diseases are considered the main factors of the extensive development of the medical care system [73].

Because of the policy in the field of public health, i.e., the traditional reactive health care model is now giving way to a preventive one. The latter involves monitoring the health status of people and predicting its change, preventing the development of diseases. The e-medicine technologies referred to in this model, especially IoT-based technological solutions, provide remote diagnosis, remote monitoring of chronic patients, monitoring of health status and, as a whole, achieve cost reduction in the healthcare system [20].

2. Mobile healthcare Internet. The mobile health (*m-Health*) industry comprises the medical data generation, collection and sharing through mobile and wireless devices.

According to [72, 74], *m-Health* consists of mobile computing complex, wearable transmitters and communication technologies for providing medical services. The theoretical foundation of the mobile Internet of Things (*m-IoT*) is a new model of healthcare connectivity. According to this model, *6LoWPAN* will be integrated into the advanced *4G* network for future *m-Health* Internet services. At this time, attention should be paid to the specific aspects determining the importance of direct interaction with people in the course of monitoring, diagnosis and treatment of *m-IoT*. These aspects should be considered in *m-IoT* architecture designing for e-medicine, solving context-dependent problems and ecosystems.

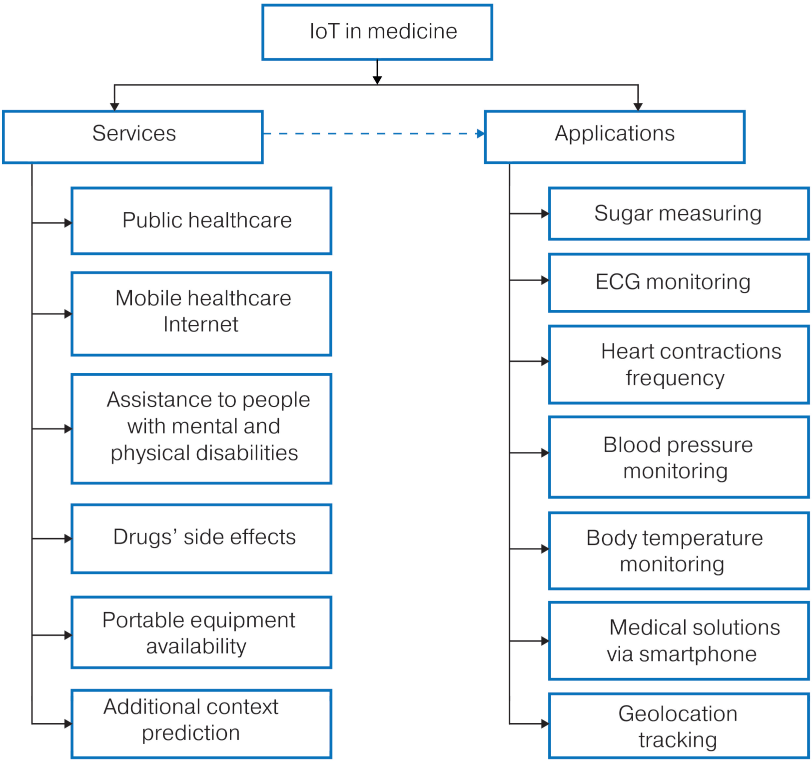

Fig. 3.1 IoT services and applications in e-medicine

3. IoT technologies for supporting the elderly. IoT technologies supporting the living environment it covers are designed to provide special services to the elderly and disabled. The essence of this technology is to ensure the independent life of the relevant category of people through modern technologies, especially IoT. Remote monitoring systems and transmission of alarms are designed to prevent potential dangers as falls, illness, etc. *GPS* transmitters installed in "smart" vehicles track the movement route of patients with limited mobility, activate the warning system in case of falls and exceeding the location boundaries, and the information panel shows their location. An open, secure and flexible platform based on IoT and cloud computing, which supports the surrounding environment, is described in [75].

4. Drugs' side effects. The World Health Organization concludes that the side effects of drugs are harmful to the body, dangerous, unintended reactions when taking certain doses of drugs used by a person for the prevention, diagnosis and (or) treatment of a disease, as well as for the correction and modification of physiological functions [76].

Side effects of drugs are revealed in the following cases:

1) after taking the first drug;

2) as a result of long-term drug intake;

3) in the process of taking two or more drugs together – in this case, the relevance of the effects of each drug to specific clinical situations should be evaluated.

A personalized system for drug availability verification using IoT is proposed in [23]. Mobile devices identify medications directly through contactless connections or barcodes. The suitability of the drug for the patient is checked with the help of an intelligent pharmaceutical information system organized from a database (description of drugs, active ingredients, side effects) and a knowledge base (rules for detecting allergies or adverse reactions to the drug).

This system checks the drug compatibility with the patient's electronic medical history, in particular with the allergic profiles of certain drugs. The use of such system in special risk facilities, including OOP, is of great importance for checking whether the drugs to be taken by the employees during the early elimination of health problems are useful or not.

5. Availability of wearable facilities. Ensuring IoT excellence is a complex task. Thus, its solution practically requires a revision of all issues, from the general architectural principles of the existing identification technologies that make up the modern Internet, the management of networks, to the provision of human rights and security. Today, a large number of different wearable transmitters have been developed for a wide range of medical applications, especially medical care based on wireless sensor networks. These transmitters are promising enough to provide relevant services in the IoT environment. Wearable devices can provide a set of functions realized based on the architectural principles of IoT. This necessitates the integration of existing transmitters into wearable IoT products. Researchers and developers dealing with the integration problem face many challenges related to the heterogeneous character of medical transmitters. In this context, mobile devices require a special service called accessibility. Already today, due to such a service, there are many applications for IoT based on wireless sensor networks scenarios. Thus, the IoT environment proposes solutions based on the use of mobile and wearable devices such as smartphones, tablets, smart-watches, wristbands to monitor a person's physiological state, systematically control the physical activity, etc. [77, 78]. The listed aspects make it necessary to use the latter on OOP.

6. Context recognition. One of the ways to improve the efficiency of IoT applications is to implement a context recognition service. The device's knowledge of its environment, its users, as well as the application context (for example, generating a location map to automatically display the user's current location) filter data and adapt to the application. The more contextual information an IoT device has, the more probably the necessary information will be automatically presented to the user.

When collecting contextual data through clinical transmitters, it is important to consider relevant temporal and spatial characteristics. If these characteristics do not coincide, the data reading can be confusing. Context can also play an important role in determining the security, confidentiality, performance, and availability requirements of transmitters' networks. This continues to be an area of active research [79].

Over time, the Internet of Things will enable us to receive more information from web services and nearby physical transmitters and share them with other devices. Consequently, the accuracy of received data and made decisions will increase. Future devices will be "smarter". The development of context-dependent systems, which operate in different ways depending on the context, provides an opportunity to respond adequately to the situation [80]. Developers of context-dependent medical systems in the IoT network base require the context prediction service to provide possible contexts. A predictive context framework for providing medical services is developed in [80], and an application of predictive context for remote medical monitoring in the IoT environment is presented in [81].

7. IoT Applications in medicine. The success of IoT depends on applications improving people's daily lives. A prerequisite for the processing of certain applications is the availability of transmitters for sending the appropriate data set. IoT applications are the programs or software systems designed to solve a specific problem [17].

IoT applications play an important role in e-medicine, directly used by users and patients. They track the location and health of people in other spheres, including special risk facilities. Below are the IoT applications supporting the vital medical indicators of a person, in this regard, to monitor the health status of employees on OOP, to detect their health problems up to the point of "emergency care" and to eliminate them by providing early assistance:

– *determining the amount of sugar*. Blood sugar monitoring detects the patterns of blood level changes and planning nutrition, activity, and medication timing [18];

– *ECG monitoring*. By recording the electrical activity of the heart in real time, an IoT-based system for identifying the heart's activity is proposed, which assesses the patient's condition in time and transmits the detected ECG errors to the data analysis center [25]. An algorithm complex for detecting ECG signals at a practical level for continuous ECG monitoring in the IoT environment is developed in [26]. Applications designed for ECG recording and monitoring, heart rate measurement and heart rhythm graphic representation, and subsequent data transfer to databases and web servers are proposed in [27];

– *heart rate*. Heart rate is characterized and measured by the number of heart beats per minute. The frequency of heart contractions depends significantly on the context, i.e., it increases after physical exercises, and changes by stress, lack of sleep, illness and drug intake [25, 26];

– *arterial pressure monitoring*. Arterial pressure is a blood pressure measured in the arteries. The threshold of blood pressure in arteries, veins and capillaries is different and one of the main indicators of the functional state of the body;

– *body temperature monitoring*. Body temperature monitoring is an integral part of medical care. This indicator is a vital parameter for maintaining homeostasis [32];

– *smartphones in the development of IoT solutions in medicine*. Transmitters controlled by smartphones have appeared in recent years. This increases the importance of smartphones in the development of IoT technologies. Medical applications for smartphones offer inexpensive solutions for both patients and a wide user audience. Early medical applications were developed for interaction with one transmitter, whereas now, there is a trend to develop multifunctional applications interacting with several sensor devices.

Smartphones are a successful tool for monitoring the health status and location tracking of employees on OOP and transmitting alert information to the employees and relevant officials on OOP.

8. Applications for geolocation tracking. Currently, there are mobile devices that monitor the patient's movement trajectory and alerting the emergency response service in case of dangerous situations, and they are equipped with information about their geolocation. For example, *Corvus-Tracker* application of the *Android* operating system, designed for tracking users' mobile devices. Applications for tracking "smart" things are becoming more widespread.

Modern systems for real time reporting geographic location in make it possible to find relevant objects. This feature necessitates the use of those systems to locate personnel on OOP and to alert people when they enter (or attempt to enter) restricted facilities.

3.11 IoT in medicine: risks and challenges

Analysts believe that medicine and healthcare will be the most widespread segment of *IoT* in the following five years. The main demand factor for this technology is the ability to establish direct contact with patients in the process of diagnosis and treatment. However, this factor directly connecting the *IoT* to the human body creates threats to his/her health, sometimes even fatal consequences, and conditions specific risks. On the other hand, the global connection, which collects, processes and automatically links a large amount of personal information, makes high demands on data security and protection of personal data, confidentiality [82–84].

Below are some of the risks and challenges arising during the implementation of medical IoT, which pose a threat to both the physical safety of patients and the confidentiality of their personal information:

– the risk of breaking the system delivering drugs installed in the human body, injecting a fatal dose for the patient into the system, not introducing the drug into the body in time;

– attacks on the transmission of the patient's vital health data collected on the monitor to the doctor's office via the network, the risks of system hacking, information theft;

– attacks on personal gadgets connected to IoT (remote control of cardiac pacemakers, diabetes support system, contact lenses supporting infrared vision, etc.);

– the problem of protecting data security and confidentiality as a result of the mobility and complexity of IoT;

– problems and requirements of personal data protection in the IoT environment capable of tracking and automatically linking a large amount of personal and individual data;

– high requirements for the guarantee of information security and confidentiality of patient data for IoT solution providers in healthcare (this leads to the increase in the price of IoT products and a decrease in their availability in the market);

– importance of identifying research on the security and confidentiality of IoT solutions for healthcare and proposing a more reliable security model;

– necessity of careful analysis of encryption technologies before using information received from wireless sensor networks or other networks in order to protect information during IoT implementation;

– uncertainty of data security and confidentiality issues in IoT, their legal interpretations;

– lack of unique standards and protocols of data transfer, which complicates the integration and cooperation of devices of different manufacturers in the IoT industry;

– technological challenges related to the transition to the *IPv6* protocol in the development of IoT and the energy supply of billions of new transmitters;

– presence of a psychological barrier such as patients, doctors and other medical professionals not trusting the machine providing IoT services in making important decisions;

– generation of the huge volume of data in the base of IoT solutions exceeding the volume characteristic of big data;

– traditional conservatism of patients and medical professionals, which is one of the main obstacles for the application of modern technologies.

These risks and challenges make it necessary to adopt appropriate programs and develop procedural rules and take security measures for the implementation of IoT solutions.

3.12 Conclusion

IoT technologies allow collecting and processing relevant data, analyzing them, and detecting potential problems along with the monitoring of the health and location of the personnel on OOP. Thus, the data received from smart devices during a certain period of time allows building the behavioral patterns of the personnel on OOP and providing the staff with clinical information based on the discrepancies recorded through expert assessment by the health monitoring results. One of the trends promoting the realization of these capabilities is the gradual reduction of the size of the connecting devices, which enhances the capability of wearable devices to be implanted to the human body. In this case, microscopic transmitters installed in the human body (inside) and body-worn devices allow the collection of objective information and the control of the treatment process (at any point of the world). This increases the probability of the provision of medical care before undesirable and unpleasant situations occur.

Today, many countries recognize that IoT is capable to radically change human resources management in the world as a whole, as well as in certain areas, particularly those at risky sites. Unquestionably, many countries are developing the strategies and guidelines for installing IoT technologies at special risk sites (coal mines, mines, oil platforms, etc.), and conducting research on different segments of IoT. Based on IoT applications and services, monitoring the health of people on OOP and tracking their location will detect the problems arisen in their condition before "emergency care", eliminate them with early medical intervention, and prevent undesirable situations that may occur due to the human factor. Therefore, the use of IoT to protect the health of employees on OOP requires a deep understanding of the essence of these technologies, changing the views of consumers, relevant officials, and medical professionals regarding its benefits, and preventing their traditional conservatism, and the presented article will be beneficial in this field.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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