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A Vision of Internet of Things based Health Care: Applications, Challenges and Opportunities

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Abstract – *The Internet of Things (IoT) is one of the most promising technologies for the near future. Healthcare and well-being will receive great benefits with the evolution of this technology. IoT has the potential to accurately track people, equipment, or specimens and analyze the data captured. With patients attached to sensors, vital signs and other biometric information can be monitored. Hence healthcare problems could be more rapidly diagnosed, a better quality of care given, scarce resources used more efficiently and cost of care reduced. This paper presents contribution of IOT in healthcare domain, application and future challenges of IOT in healthcare.*

Keywords – *Internet of Things, Health care, Ambient assisted living,Predictive analytics, Security, Privacy*

I. INTRODUCTION

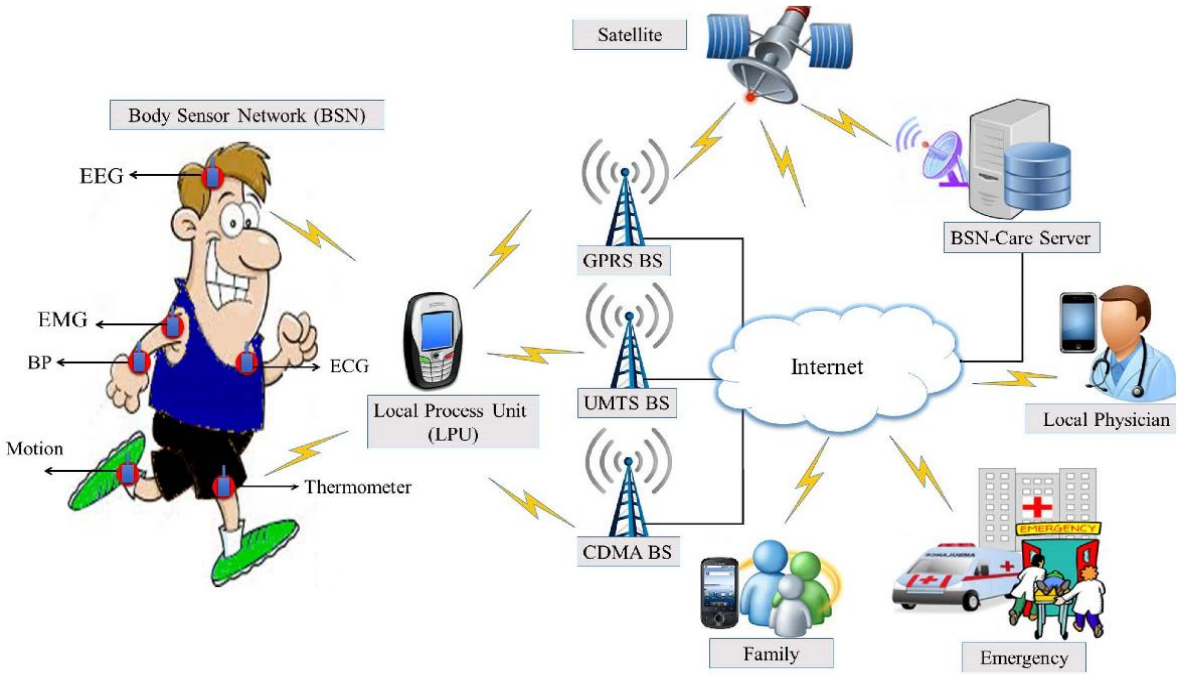
Healthcare is an essential part of human life. Unfortunately, the steadily aging population and the related rise in chronic illness is placing significant strain on modern healthcare systems [2], and the demand for resources from hospital beds to doctors is extremely high. Evidently, a solution is required to reduce the pressure on healthcare systems whilst continuing to provide high-quality care to patients. The Internet of Things (IoT) has been widely identified as a potential solution to alleviate the pressures on healthcare systems, and has thus been the focus of much recent research [3]-[5]. The IoT allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service[6]. IOT can bring multiple benefits to healthcare through the use of RFID tags, sensors/detectors, intelligent equipment, etc. Some of the benefits includes enhance the patient experience, improve workflow, optimize the use of scarce resources, and provide substantial cost savings. This paper explores the Internet of Things and its suitability for healthcare is highlighted. This paper also provides a comprehensive survey of applications of IoT based health care and also presents the challenges and opportunities associated with it.

II. HEALTH CARE AND THE INTERNET OF THINGS

The Internet of Things remains a relatively new field of research, and its potential use for healthcare is an area still in its infancy. As per the definition of Gartner [1], "Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment". The Internet of Things has capabilities to connect D2M(Device-to-Machine), O2O(Object-to-Object), P2D(Patient-to-Doctor), P2M(Patient-to-Machine), D2M(Doctor-to-Machine), S2M(Sensor-to-Mobile) and M2H(Mobile-to-Human). It intelligently connects humans, machines, smart devices and dynamic system which ensure the effective healthcare and monitoring system, medial asset monitoring and medical waste management system. For example, wearable bands on patient's wrist can track pulse, blood pressure, red blood cell counts, glucose and cholesterol level and constantly send the reports to doctors smart phones as well as reminders to take the medication, walking, etc to patients smart phones.
The emergence of the IoT in health care is important for two reasons

1. Advances in sensor and connectivity technology are allowing devices to collect and analyze data that was not accessible before. In healthcare, this means being able to collect patient data over time that can be used to help enable preventive care, allow prompt diagnosis of acute complications and promote understanding of how a therapy (usually pharmacological) is helping improve a patient's parameters
2. The ability of devices to gather data on their own removes the limitations of human-entered data—automatically obtaining the data the doctors need, at the time and in the way they need it. The automation reduces the risk of error. Fewer errors can mean increased efficiency, lower costs and improvements in quality.

2.1 Architecture of IoT in Health Care
An infrastructure composed by wireless body areanetwork, personal server using intelligent personal digitalassistant, and medical server tiers for healthcaremonitoring system is illustrated in Figure 1.



The data input from patients can be collected through various sensors such as BP Monitor, ECG monitors, Motion monitors, EMG Monitors, etcand processed by applications developed for a user terminal, such as computers, smart phones, smart watches or, even, a specific embedded device. The user terminal is connected to a gateway through short coverage communication protocols, such as, Bluetooth low energy (BLE), Bluetooth, or 6LoWPAN (IPv6 over Low Power Wireless Personal Area Networks) over the IEEE 802.15.4 standard. This gateway connects to a (clinical) server or cloud services for data processing and storage. Physician can access the data in clinical server and share their feedback and give general suggestions to the patient.It also alerts hospital staff and family members if any abnormality is detected. Patients' data can also be stored in a health information system using electronic health records and, when the patient visits a medical doctor, he/she can easily access the clinic history of the patient[11].

III. IoT BASED HEALTHCARE APPLICATIONS

The IoT plays a significant role in a broad range of healthcare applications, from managing chronic diseases at one end of the spectrum to preventing disease at the other. This section presents some ofhealth care applications along with the usage of IoT concept and their benefits.

3.1 Wireless patient monitoring

This application is for remote surveillance of patient vital functions through the use of internally and externally located patient devices. As opposed to discrete interactions, the provision of healthcare is moving to a model where information is being transmitted and shared in real time between individuals and caregivers. This is especially relevant for chronic disease management such as hypertension, diabetes, coronary heart disease, asthma. Examples: Wirelessly monitored pacemakers and automatic defibrillators

3.2 Mobile system access

This application is based on the mobile technologies that enable remote/virtual access to current clinical systems such as electronic health records [EHRs], picture archiving and communication systems [PACS], etc. All the medical system can be automated with easy to use mobile app interface. This application of technology in healthcare is referred as e-Health. If the mobile is used as monitoring and delivery of healthcare, the application area is termed as m-Health. Examples: Websites, portals, mobile apps[8].

3.3 Medical devices

This application is used to capture and track key care compliance and disease management data. Mainly these are used as fitness solutions for tracking of patient activities. Smart diagnostic devices are used for capturing the data from the sensors for further analysis by doctor. Google glass is under research for possible use as medical devices to perform assisted surgeries and recording, etc. Examples: digital glucometers, blood pressure devices, pedometers, wearables – fitbits, google glass, etc.

3.4 Virtual consultation (telemedicine)

This application is based on the remote connectivity that enable virtual care consultation, education, medicine delivery and therapy procedures. In some countries appointments and wait times are getting longer. Through virtualization, the

majority of routine care can happen within minutes and even seconds. The remote diagnostic screening has become common in some countries and markets. Examples: Tele-consultations, mobile video solutions

3.5 Ambient assisted living (AAL)

This application is based on IOT that supports care of elderly or debilitated patients. It helps to extend the independent life of elderly individuals in their place of living in a convenient and safe manner. These services mostly come up as wearable for monitoring the elderly patients without the need for manual intervention. The vital signs data from the elderly care is acquired from the monitoring devices and transmitted to a standard mobile device which acts as a network node for transmitting the real-time data to the doctor. The information can be used to give medical assistance to the needful person and in case of higher abnormalities, the nearby efficient hospitals can be alerted and thus the hospitalization costs can be reduced through early intervention and treatment Examples: Personal emergency responses systems (PERS), video consultations, activity monitoring and fall detection.

3.6 Ingestible sensor

The ingestible sensor is the sensor based technology swallowed as a pill. It is made of ingredients found in food and activated upon ingestion. These ingestible devices are noninvasive and hence are very attractive for customers. With widespread access to smart phones connected to the Internet, the data produced by this technology can be readily seen and reviewed online, and accessed by both users and physicians. The outputs provide invaluable information to reveal the state of gut health and disorders as well as the impact of food, medical supplements, and environmental changes on the gastrointestinal tract.

3.7 Personalized medicine

Currently, the healthcare delivery is based on population statistics. Patients are separated into groups defined in various ways but usually by similar symptoms or by the results of basic lab tests (like cholesterol levels). These groups are then treated with drugs that may help many people, but not all of them, and often only a fraction of them.Personalized medicine will enable customization of drugs and effective drug combinations based on the specific person's genes.

3.8 Predictive analytics

The use of predictive analytics in healthcare will benefit from the merging of different data repositories, which has the trends of food & lifestyle habits. The more we know about an individual or population, that is, the bigger the picture, the more precise the predictions will be. These models can be customized based on the data points, to a specific patient or group of patients that ultimately leads to more precise and effective treatments that are bound to improve the overall efficacy of the healthcare system while at the same time reducing costs [7].

IV. IoT HEALTHCARE CHALLENGES AND OPPORTUNITIES

Many researchers have worked on designing and implementingvarious IoT-based healthcare services and on solvingvarious technological and architectural problems associatedwith those services. Still there are several challenges and open issuesthat need to be carefully addressed. This section brieflyexplains some of the significant challenges in the integration and management of IoT in health care[9].

4.1 Scalability

As the number of IoT devices has increased gradually, more devices are getting connected to the global information network. Therefore, the system which stores and analyses the information from these IoT devices needs to be scalable and securable.

4.2 Heterogeneity

Health care devices are diverse in nature, ranging from full-fledged PCs to wearable wrist watch. Such devices vary in terms of their accuracy, performance, power, memory, and embedded software. Therefore, the challenge lies in designing a system that can accommodate all categories of devices.

4.3 Interoperability

Technological standards on most areas are still fragmented. These technologies need to be converged. This will help to establish the common framework and the standard for the IoT devices. As the standardization process is still lacking, interoperability of IoT with legacy devices should be considered critical.

4.4 Security and Privacy

In a healthcare environment, it is essential that a patient's health information is readily accessible to authorized parties including doctors, nurses, special9ists, and emergency services. It is also essential that the patient's sensitive health data is kept private. Therefore, IoT in healthcare should ensure Confidentiality, Integrity, and Availability of patients' personal data. Stringent policies and technical security measures should be introduced to share health data with authorized users, organizations, and applications.

4.5 Lack of government support

The government and the regulatory bodies like FDA should come and play an active part in bringing up the regulations by setting up the standards committee for IoT devices for safety and security of the devices & people.

4.6 Technology transition

Healthcare organizations can modernize their existing devices and sensors for smart resources by incorporating IoT approaches into the existing network configuration. Therefore, a seamless transition from the legacy system to an IoT-based configuration is a major challenge. In other words, there is a need to ensure backward compatibility and flexibility in the integration of existing devices.

4.7 New diseases and disorders

Although there are many healthcare apps and new apps are being added to the list every day, the trend has been limited to a few categories of diseases. R&D activities for new types of diseases and disorders are essential, and the discovery of methods that can make the early detection of rare diseases is challenging one.

4.8 Computational limitations

IoT health devices are embedded with low-speed processors. They simply act as a sensor or actuator. Therefore, finding a solution that minimizes resource consumption and thus maximizes security performance is a challenging task.

4.9 Memory limitations

Most IoT healthcare devices have low on-device memory. Such devices are activated using an embedded operating system (OS), system software, and an application binary. Therefore, their memory may not be sufficient to execute complicated security protocols.

4.10 Energy Limitations

A typical IoT healthcare network includes small health devices of limited battery power (e.g., body temperature and BP sensors). Such devices conserve energy by switching on the power-saving mode when no sensor reading needs to be reported. In addition, they operate at a low CPU speed if there is nothing important to be processed. Therefore, designing an energy-aware security solution is challenging.

V. CONCLUSION

The Internet of Things enables health organizations to lift critical data from multiple sources in real-time, and a better decision-making capability. This trend is transforming healthcare sector, increasing its efficiency, lowering costs and providing better patient care. In this paper, we provided an overview of IoT services and technologies in healthcare. A number of research challenges also have been identified, which are expected to become major research trends in the next few years. We hope that this work will be useful for researchers and practitioners in the field, helping them to understand the huge potential of IoT in medical domain and identification of major challenges in health care IoT.

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