Internet of Medical Things (IoMT) - An overview

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***Abstract*—Internet of Things (IoT) plays a vital role in the field of healthcare. The development of smart sensors, smart devices, advanced lightweight communication protocols made the possibility of interconnecting medical things to monitor biomedical signals and diagnose the diseases of patients without human intervention and termed as Internet of Medical Things (IoMT). This paper portrays an overview of Internet of Medical Things based remote healthcare, tracking ingestible sensors, mobile health, smart hospitals, enhanced chronic disease treatment.**

***Index Terms*—Internet of things(IoT), Internet of medical things(IoMT), smart hospitals, ingestile sensors, mobile health, chronic disease treatment**

I. Introduction

The health of a human being is very important to lead a peaceful and successful life. According to the World Health Organization (WHO), health is a state of physical and mental fitness in the absence of diseases and infirmity. Healthcare is the process of maintaining or improving health with the help of prevention, diagnosis, treatment for illness and injury. Most of the conventional healthcare use manual management and maintenance of patient demographic data, case history, diagnostics, medication, billing, drug stock maintenance which leads to human errors and affect patients. Internet of things (IoT) based smart healthcare overcomes the human errors and helps the physician to diagnose the diseases more easily and accurately by interconnecting all the vital parameters monitoring devices over a network with a decision support system. The medical things which have the facility to transfer data over a network without demanding human to human or human to computer interaction are termed as Internet of Medical Things (IoMT). According to Gartner research and advisory company, 20.4 billion things will be connected to the internet [1] by 2020. Also, the worldwide market of IoT will reach 1.7 trillion USD by 2020 from 655.8 billion USD in 2014 with an annual rate of 16.9 percent [2]. This considerable amount of revenue includes developing IoMT platforms too. An IoMT platform is a smart system mainly comprises of sensors and electronic circuits to acquire biomedical signals from a patient, processing unit to process the biomedical signals, a network device to transmit the biomedical data over a network, a temporary or permanent storage unit, a visualization platform with artificial intelligence schemes to take decision according to the convenience of physician [3], [4] and the architecture of IoMT is shown in the Fig. 1. This article focuses IoMT based remote health monitoring, tracking ingestible sensors, smart hospitals, and enhanced chronic disease treatment.

II. IoMT based remote health monitoring

The main benefits of IoMT based remote health monitoring are the possibility to carry out regular tasks even though the patients are under continuous health monitoring and the advantage of low hospital bills. The conventional remote monitoring systems are making discomfort to the patients because of the size of the modules attached to the body and the frequent charging or replacement of batteries. Revolution of IoMT, resolves the above-mentioned issues by developing compact, ultra-low power sensor devices, and lightweight communication protocols. The remote health monitoring system mainly consists of a portable patient monitoring unit (PPMU) at the patient's home or at emergency medical service vehicles and real-time monitoring with a decision support system at the hospital. The portable patient monitoring unit mainly consists of sensors and electronic circuits which is capable of acquiring vital parameters such as heart rate, heart rate variability, pulse rate, respiration rate, systolic blood pressure, diastolic blood pressure, oxygen saturation, body temperature, body mass index, level of consciousness, muscular activation, total lung volume, height, blood glucose level, urine report, a processing unit to process the acquired data and a network device to uploads to the server for further analysis. The schematic diagram of PPMU in patient's home or in an ambulance is shown in Fig. 2. The condition of the patient can be viewed by using a graphical user interface by the physician. The general remote monitoring systems based on the diseases are discussed in this section.

A. Remote monitoring system for heart-related diseases

Monitoring related to heart is considered the most important one because the measured vital signs can reveal many illnesses that are hidden in nature such as arrhythmia. Generally, ECG electrodes will be attached to the chest of the patients to measure their physiological signals and after performing the

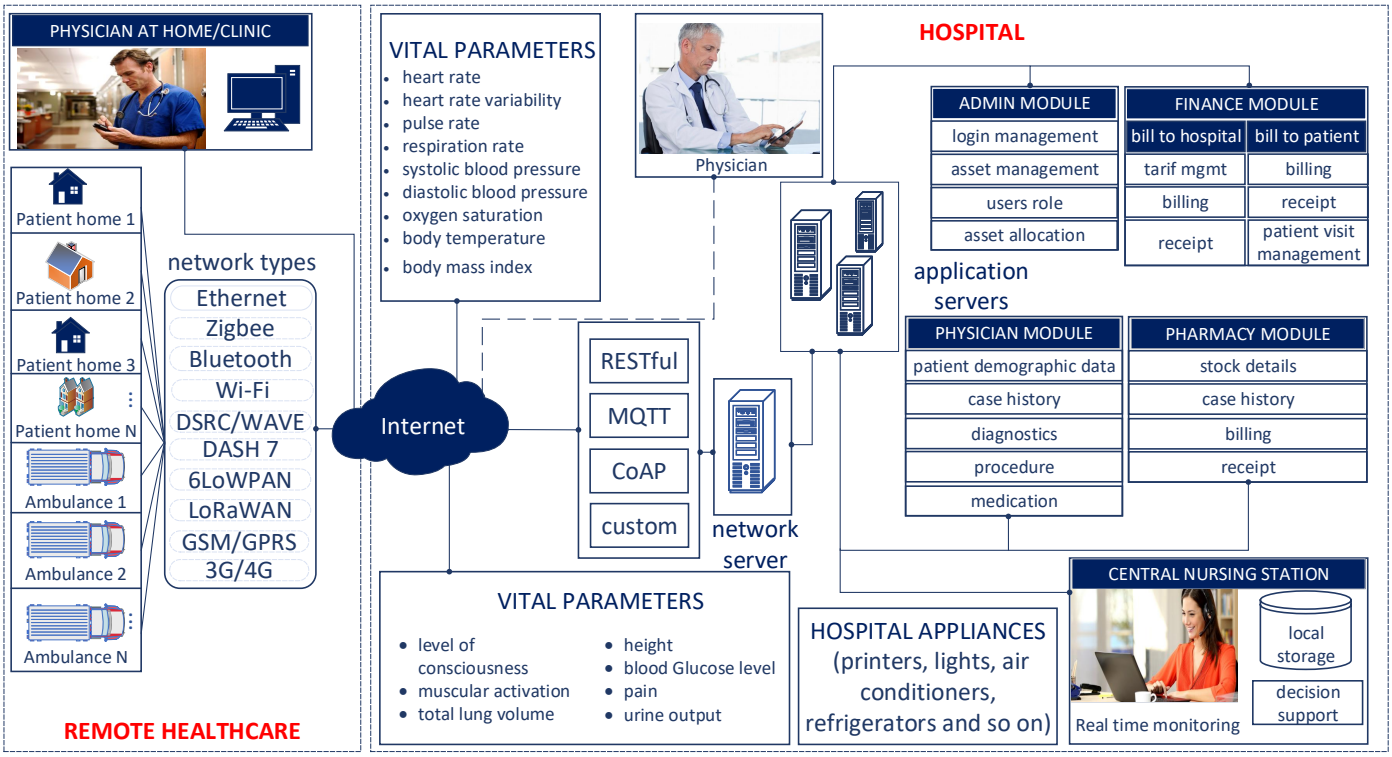

Fig. 1. Architecture of Internet of Medical Things (IoMT)

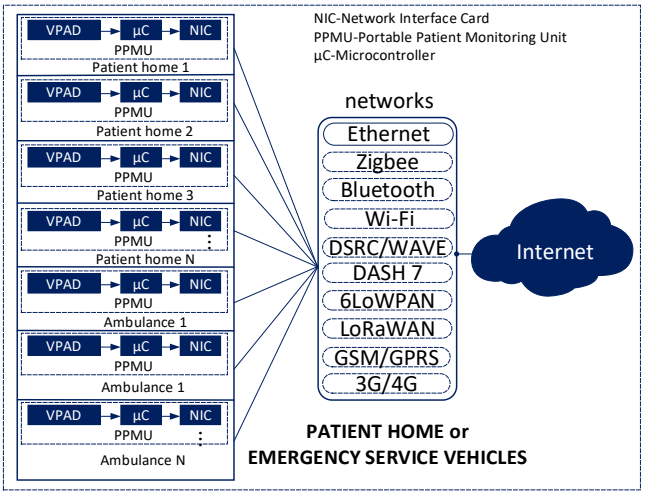

Fig. 2. Schematic diagram of patient home

required signal conditioning, digitizing and packetizing, the vital signs will be sent to the central server [5]. The server may be a remote server in the hospital or a cloud-based one. A mobile application or a web page will be designed to act as the GUI between the doctors and the server. The doctor will be able to see the patients status in real-time and can take action accordingly. Several research works are there which show the development of vital signal sensing nodes, having internet connectivity to provide the signal status in real-time. [6] - [7] presents an android based remote monitoring system which uses Pulsometer and Pedometer as sensors. A wireless body sensor and commercially off-the-shelf sensors-based ECG monitoring system for heart patients are presented in [8]. A platform dependent heart rate detection system that uses AMPED sensor is shown in [9] and a multi-parameter monitoring system with a defibrillator device is presented in [10].

B. Remote monitoring system for brain and neurological diseases

Applications of IoMT in the monitoring of brain and neurological signals opened a great comfort to the patients suffering from diseases such as Epilepsy, Alzheimers, Dementia, Stroke, and Parkinson, etc. Apart from this, IoT based systems are developed to monitor the behavior of psychiatric patients to enhance the research, which can be used to develop special approaches towards the patients [11]. The sensors using for acquisition are either contact-based or contact-less. EEG sensors, Galvanic skin response sensors, Wristwatches with integrated multi-sensors, Salivary Alpha-Amylase bio-sensors, Kinect with gesture recognition, Cameras, Plugwise sensors, etc are the commonly used sensors in the signal acquisition node [12]. Some of the important works in this category are cited here. To monitor the patients with neuro-degenerative diseases a camera-based system is developed with HC-V720

high definition camera to capture the movement of the patient [13]. A stress level monitoring based on the blood pressure measurement is presented in [14]. Textile based autonomic nervous system [15], a t-shirt with embedded sensors [16] and wireless sensor tag-based wristwatch [17] are some of the vital parameters acquisition devices used for remote monitoring of brain and neurological diseases.

C. Remote monitoring system for diabetic patients

Generally, patients who all are suffering from diabetic problems need to be checked their glucose level frequently to make sure that their diet is proper and their glucose levels are under control. Many devices are available in the market to provide the facility of finding glucose levels from their home itself. But, they are not providing a real-time monitoring with a doctor or a clinician. IoMT makes this possible by developing smart and low power nodes to measure the glucose level of the patients and make it available in real-time to the doctors through mobile applications or web applications. Some of the remote monitoring systems for diabetic patients are explained in the following section. A Bluetooth based glucose monitoring system is given in [18], the sensor node is paired with a smartphone via Bluetooth. The monitoring application in the smartphone is able to give the visualization of the measured values. A long-term monitoring system with an implanted sensor for glucose monitoring for diabetic patients is proposed in [19]. The glucose level of the individuals is updated to the remote server every 2 minutes. A near -infrared-based non -invasive glucose monitoring system is explained in [20]. Depending upon the variations of the received signal intensity from the NIR sensor, the glucose level is predicted in this system.

D. Remote monitoring of fall detection of elderly people

A key application of IoMT can be observed in the field of fall detection of elderly people who are staying in their home and undergoing real-time health monitoring. A group of sensors including gyroscope sensors, accelerometer sensors, vibration sensors and single-channel or multi-channel cameras constitutes the data acquisition system. The sensors are interfaced with the appropriate micro-controllers and network processors to send the signals to the central server to establish the alarm system which provides the authorities to take actions according to the patients current condition. Some of the important works in this category are quoted in this section. A wireless motes-based fall detection system is presented in [21]. A local processing device with an accelerometer is used in [22] to get the movement of patients in their homes. Wheelchair oriented monitoring systems are developed in [23] to monitor the physical condition and movement of the patients in their homes. The clinician in the hospital or a home nurse can monitor the patients movements and they will be getting alarms whenever the patient falls down, unexpectedly. Apart from the primary monitoring task, many systems are having an additional sensor node setup for fall detection of the patients, especially for elderly patients. Accelerometer, breathing rate sensors [24] and Wireless wearable motes [21] are some of the sensors commonly using for the fall detection of elderly people.

III. Tracking of Ingestible sensors

Typically, a person will be in a healthy condition when he is getting sufficient nutrition from his food intake. It is important to find which food will provide sufficient nutrients to the patients. So, there is a need to analyze the process in the human digestive system. IoT is addressing this issue by developing ingestible sensors, which can be swallowed by a patient to monitor the complete information of the process in the digestive system. The pills can be tracked by a receiver or a smartphone via any of the standard wireless communication technology. Some of the research in this field is quoted here. Ingestible sensors are used to perform capsule endoscopy, in which the sensors can transmit the images of the interior part of the human body to the remote monitoring application software installed in the hospital systems [25]. The formation of different gases in the digestion process of human beings and animals can be measured using ingestible capsules [26].

A. Mobile health

Mobile-based health care is well established among the people because of the influence of smartphones in their day to day life. The era of mobile health is starting from the simple footstep counters to real-time physiological signal monitoring system. The wearable such as smart watches, smart t-shirt, etc can be paired with the smart-phones via Bluetooth or NFC to provide visualization of their vital signal status in real-time. Some mobile applications are sending real-time data to the hospital servers, so that specialized doctors can diagnose any abnormalities.

IV. Smart hospital

IoT plays a vital role to upgrade the hospital to a smart level. The initial step towards smart hospital is taken place by developing smartphone-based appointment registration according to the availability of doctor, mobile application-based inquiry and test result report, etc. Further up-gradation established by designing medical devices that are able to send real-time signals of the blood sugar level, ECG, blood pressure, etc to an information platform for diagnosis [27]. Highly expensive equipment in the hospital premise can be implanted with RFID chip to establish their tracking [26]. Another aspect of IoT in hospital is maintaining the stock in the pharmacy. RFID, sensors networks, wireless communication protocols, and embedded technology are enabling the development of smart hospitals with IoT.

A. Enhanced chronic disease treatment

Chronic diseases are diseases that cannot be cured but can be controlled. Patients under this condition require continuous monitoring and acute care to prevent them from critical conditions [5]. Continuous stay in the hospital only for the sake of monitoring can be avoided with the help of remote monitoring

systems. Holter based monitoring is the current accepted and approved method to perform remote monitoring of patients suffering from chronic diseases. But these methods are not able to make an analysis in real-time. So IoT based sensor nodes can be developed to measure the vital status of the patients and by using lightweight protocols, data can be sent to the cloud server. Artificial intelligence-based algorithms can be made to run in the cloud server to predict the accurate condition of the patients. Chronic disease monitoring is enhanced with the implementation of machine learning algorithms and a comparison of commonly using algorithms which are presented in [28]. A privacy-preserving arrhythmia prediction system is developed and verified in [29]. This system is able to achieve an accuracy of 96.63 percentage in arrhythmia prediction.

V. Conclusion

An overview of IoMT based remote monitoring systems, tracking ingestible sensors, smart hospital, mobile health and IoMT based enhanced chronic disease treatment methods have been studied and presented in this manuscript. Security and privacy are the serious concerns which restricts the consumer level usage of IoMT.

References

[1] A. S. El-Wakeel, J. Li, A. Noureldin, H. S. Hassanein, and N. Zorba, "Towards a Practical Crowdsensing System for Road Surface Conditions Monitoring," *IEEE Internet of Things Journal*, vol. 5, no. 6, pp. 4672–4685, 2018.

[2] Y. Mehmood, F. Ahmad, I. Yaqoob, A. Adnane, M. Imran, and S. Guizani, "Internet-of-Things-Based Smart Cities: Recent Advances and Challenges," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 16–24, 2017.

[3] J. T. John and S. J. Ramson, "Energy-aware duty cycle scheduling for efficient data collection in wireless sensor networks," *IJARCET Volume*, vol. 2, 2013.

[4] S. Ramson and D. J. Moni, "A case study on different wireless networking technologies for remote health care," *Intelligent Decision Technologies*, vol. 10, no. 4, pp. 353–364, 2016.

[5] S. Vishnu, S. J. Ramson, K. L. Raju, and T. Anagnostopoulos, "Simplelink sensor network-based remote monitoring of multiple patients," in *Intelligent Data Analysis for Biomedical Applications*, pp. 237–252, Elsevier, 2019.

[6] L. P. Malasinghe, N. Ramzan, and K. Dahal, "Remote patient monitoring: a comprehensive study," *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 1, pp. 57–76, 2019.

[7] T. Szydło and M. Konieczny, "Mobile devices in the open and universal system for remote patient monitoring," *IFAC-PapersOnLine*, vol. 48, no. 4, pp. 296–301, 2015.

[8] M. V. Ramesh, S. Anand, and P. Rekha, "A mobile software for health professionals to monitor remote patients," in *2012 Ninth international conference on wireless and optical communications networks (WOCN)*, pp. 1–4, IEEE, 2012.

[9] A. F. Otoom, E. E. Abdallah, Y. Kilani, A. Kefaye, and M. Ashour, "Effective diagnosis and monitoring of heart disease," *International Journal of Software Engineering and Its Applications*, vol. 9, no. 1, pp. 143–156, 2015.

[10] T.-H. Tan, M. Gochoo, Y.-F. Chen, J.-J. Hu, J. Chiang, C.-S. Chang, M.-H. Lee, Y.-N. Hsu, and J.-C. Hsu, "Ubiquitous emergency medical service system based on wireless biosensors, traffic information, and wireless communication technologies: Development and evaluation," *Sensors*, vol. 17, no. 1, p. 202, 2017.

[11] Z. W. Adams, E. A. McClure, K. M. Gray, C. K. Danielson, F. A. Treiber, and K. J. Ruggiero, "Mobile devices for the remote acquisition of physiological and behavioral biomarkers in psychiatric clinical research," *Journal of psychiatric research*, vol. 85, pp. 1–14, 2017.

[12] K.-Y. Lam, N. W.-H. Tsang, S. Han, W. Zhang, J. K.-Y. Ng, and A. Nath, "Activity tracking and monitoring of patients with alzheimers disease," *Multimedia Tools and Applications*, vol. 76, no. 1, pp. 489–521, 2017.

[13] B. Abramiuc, S. Zinger, P. de With, N. de Vries-Farrouh, M. M. van Gilst, B. Bloem, and S. Overeem, "Home video monitoring system for neurodegenerative diseases based on commercial hd cameras," in *2015 IEEE 5th International Conference on Consumer Electronics-Berlin (ICCE-Berlin)*, pp. 489–492, IEEE, 2015.

[14] V. S. Dhulipala, P. Devadas, and P. T. Murthy, "Mobile phone sensing mechanism for stress relaxation using sensor networks: a survey," *Wireless Personal Communications*, vol. 86, no. 2, pp. 1013–1022, 2016.

[15] M. Kozlovszky, L. Kovacs, and K. Karoczkai, "Cardiovascular and diabetes focused remote patient monitoring," in *VI Latin American Congress on Biomedical Engineering CLAIB 2014, Paraná, Argentina 29, 30 & 31 October 2014*, pp. 568–571, Springer, 2015.

[16] P. Casacci, M. Pistoia, A. Leone, A. Caroppo, and P. Siciliano, "Alzheimer patients home rehabilitation through ict advanced technologies: the altruism project," in *Ambient Assisted Living*, pp. 377–385, Springer, 2015.

[17] A. Karakostas, G. Meditskos, T. G. Stavropoulos, I. Kompatsiaris, and M. Tsolaki, "A sensor-based framework to support clinicians in dementia assessment: The results of a pilot study," in *Ambient Intelligence-Software and Applications*, pp. 213–221, Springer, 2015.

[18] M. Ali, L. Albasha, and H. Al-Nashash, "A bluetooth low energy implantable glucose monitoring system," in *2011 8th European Radar Conference*, pp. 377–380, IEEE, 2011.

[19] J. Y. Lucisano, T. L. Routh, J. T. Lin, and D. A. Gough, "Glucose monitoring in individuals with diabetes using a long-term implanted sensor/telemetry system and model," *IEEE Transactions on Biomedical Engineering*, vol. 64, no. 9, pp. 1982–1993, 2016.

[20] K. U. Menon, D. Hemachandran, and T. Abhishek, "A survey on non-invasive blood glucose monitoring using nir," in *2013 International Conference on Communication and Signal Processing*, pp. 1069–1072, IEEE, 2013.

[21] R. Paoli, F. J. Fernández-Luque, G. Doménech, F. Martínez, J. Zapata, and R. Ruiz, "A system for ubiquitous fall monitoring at home via a wireless sensor network and a wearable mote," *Expert Systems with Applications*, vol. 39, no. 5, pp. 5566–5575, 2012.

[22] D. Naranjo-Hernandez, L. M. Roa, J. Reina-Tosina, and M. A. Estudillo-Valderrama, "Personalization and adaptation to the medium and context in a fall detection system," *IEEE transactions on information technology in biomedicine*, vol. 16, no. 2, pp. 264–271, 2012.

[23] E. C. Pinheiro, O. A. Postolache, and P. S. Girão, "Dual architecture platform for unobtrusive wheelchair user monitoring," in *2013 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, pp. 124–129, IEEE, 2013.

[24] G. Sannino, I. De Falco, and G. De Pietro, "A supervised approach to automatically extract a set of rules to support fall detection in an mhealth system," *Applied Soft Computing*, vol. 34, pp. 205–216, 2015.

[25] M. R. Yuce and T. Dissanayake, "Easy-to-swallow antenna and propagation," *IEEE Microwave Magazine*, vol. 14, no. 4, pp. 74–82, 2013.

[26] L. Yu, Y. Lu, X.-L. Zhu, and L. Feng, "Research advances on technology of internet of things in medical domain," *Jisuanji Yingyong Yanjiu*, vol. 29, no. 1, pp. 1–7, 2012.

[27] S. H. Almotiri, M. A. Khan, and M. A. Alghamdi, "Mobile health (m-health) system in the context of iot," in *2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW)*, pp. 39–42, IEEE, 2016.

[28] A. A. Samoilov, D. V. Telishev, and I. V. Pyanov, "Application of heart rate variability methods to the tt-intervals and st-segments durations," in *2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, pp. 1928–1931, IEEE.

[29] J. Son, J. Park, H. Oh, M. Bhuiyan, J. Hur, and K. Kang, "Privacy-preserving electrocardiogram monitoring for intelligent arrhythmia detection," *Sensors*, vol. 17, no. 6, p. 1360, 2017.