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Faton Kabashi
University for Business and Technology, faton.kabashi@ubt-uni.net

Lamir Shkurti
University of Tetova, ls29773@seeu.edu.mk

Hizer Leka
University for Business and Technology - UBT, hizer.leka@ubt-uni.net

Vehbi Sofiu
University for Business and Technology - UBT, vehbi.sofiu@ubt-uni.net

Nazmi Misini
University for Business and Technology - UBT, nazmi.misini@ubt-uni.net

Internet of Things in Healthcare: A Review

Faton Kabashi[1], Lamir Shkurti [2], Hizer Leka[3], Vehbi Sofiu[4] and Nazmi Misini[5]

[1, 3,4,5] UBT, Higher Education Institution, Kosova

[2] SEE University, Tetovo, North Macedonia

Email: faton.kabashi@ubt-uni.net, , ls29773@seeu.edu.mk, hizer.leka@ubt-uni.net, vehbi.sofiu@ubt-uni.net, nazmi.misini@ubt-uni.net

ABSTRACT

In the current era, there is a requirement of a system with connected devices, persons, time, places, and networks, which is completely incorporated in what is called as Internet of Things (IoT). IoT is developed toward making the objects smart and connectable using recent development in miniaturizing and communication technologies. IoT can change the way human being live their life by making it their more convenient and smart. IoT has wide application domains one of them is healthcare. Healthcare is one of the application domains in IoT that draws enormous interest from industry, the research community, and the public sector. The development of the IoT in Health will greatly facilitate the process of patient's diagnosis and monitoring, with small IP-based wireless sensors implemented on the patient's body, his physiological parameters, such as blood pressure and heart rate, can be monitored remotely and continuously.

Over these years a number of advanced applications based on IoT have been proposed for the convenience of patients, doctors, and caregivers in the healthcare sector. In this paper, a review of IoT usage in healthcare has been presented. This systematic literature review has been conducted to determine the main application area of IoT in healthcare, most important technologies in IoT, related monitoring devices, and applications. Forty-four relevant papers, published between 2010 and 2021, were reviewed and analyzed. The results of this research improve our knowledge about IoT technology in the health sector and also encourage innovative use cases of this new technology in the health field.

KEYWORDS

Internet of Things, Healthcare, architecture in Healthcare, technology in Healthcare, applications in Healthcare

1. Introduction

The Internet of Things (IoTs) can be described as connecting everyday objects like smart-phones, Internet TVs, sensors and actuators to the Internet where the devices are intelligently linked together enabling new forms of communication between things and people, and between things themselves [1]. Internet of things (IoT) reflects the concept of connecting a set of anything, anywhere, anyplace and anytime for any service and through any network. Due to increase in embedded IoT devices in different objects, IoT has become increasingly widespread [2]. It allows devices to become smarter, stronger, more effective, and available in the future [3] [4]. This network is currently used in a variety of fields, such as manufacturing, banking, government, transportation, agriculture and, particularly, in healthcare system [4] [5] [6].

Today, thanks to widely available technologies such as communication technologies and smart mobile devices, IoT has become one of the hottest topics in all sub-fields [7] particularly in healthcare, with an estimated 40% of all IoT devices expected to be involved in healthcare by 2020 [8]. Due to the large size of the healthcare sector, it is difficult and costly to provide healthcare services for the patients. Today, IoT, as one of the most commonly deployed

innovation in e-Health, has decentralized healthcare services from healthcare centers to lateralized locations such as homes and workplaces [9]. Since the IoT affect the whole life sectors it's important to introduce the automation in nearly all fields especially the fields that affect human life directly. The IoT provides perfect solutions for wide range of applications such as smart cities, telemedicine, security, emergency management, industrial automation and control, health care, environmental studies and logistics [10] [11]. Medical health care and telemedicine represent the most important and attractive field for applying the IoT [12] [13].

Modern medical care measuring devices such as blood pressure monitoring devices, blood glucose level monitoring devices, weight and motion sensors, and various wearable devices incorporate diverse communication skills. Basically they can create IoT networks that are implemented for home telemonitoring so that patients can be treated remotely or make the medical personnel aware of the patient condition regardless of the patients location [14]. As depicted in the Figure 1 recent IoT healthcare trends, healthcare networks powered by wireless technologies are expected to support real-time monitoring, emergency care, early diagnosis, an ailment of chronic diseases [15].

Figure 1: Recent IoT healthcare trends

Healthcare services based on IoT as a whole are expected to reduce costs, amplify patient care, and enrich the user experience [16][17].

This paper is organized as follows. The second section, showing the research methodology, in the third section is IoT in Healthcare, in the fourth section, applications of IoT in Healthcare is given. Finally, the fifth section will be summarized the conclusion.

2. Methodology

In this paper review, are taken into consideration the studies published between 2010 and 2021 in major online scientific databases, including Google Scholar, IEEE Xplore, Web of Science, Scopus, Elsevier, and Research Gate. The keywords used were IoT, Healthcare, and application in Healthcare. Thus, 44 documents including articles, books, and web pages were finally selected based on specific inclusion/exclusion criteria.

3. IoT and healthcare

The reliance of healthcare on IoT is increasing by the day to improve access to care, increase the quality of care and most importantly reduce the cost of care [18]. Personalized healthcare is based on an individual's exclusive behavioral, biological, social characteristics. This leads to superior outcomes with making healthcare cost-effective. A supportable service focuses on the early disease detection, and homecare rather than the exclusive clinical one. IoT can handle the care personalization services and can preserve a digital identification for every individual.

Various equipment are used in healthcare, to communicate and to make the omnipresent system-of-system [19]. The classifications of IoT based personalized healthcare systems are Clinical care and Remote monitoring [20].

3.1 Clinical care

Clinical care employs noninvasive monitoring IoT systems for hospitalized. This clinical care system uses sensors for collecting physiological information that to be stored and analyzed using the cloud. It delivers a continuous automated information flow, which improves care quality at a lower cost [18].

3.2 Remote Monitoring

There are people all over the world whose health may suffer because they don't have ready access to effective health monitoring. But small powerful wireless solutions connected through the IoT are now making it possible for monitoring to come to these patients instead of vice-versa. These solutions can be used to securely capture patient health data from a variety of sensors, apply complex algorithms to analyze the data, and then share it through wireless connectivity with medical professionals who can make appropriate health recommendations [18].

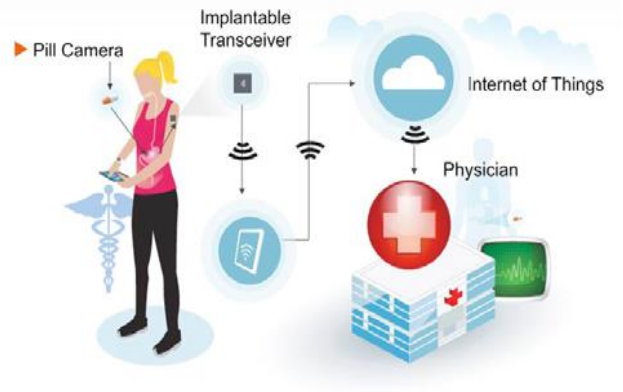

Figure 2: Remote patient monitoring [18]

4. Applications of IoT in Healthcare

In this part, we introduce several applications that are designed to give support to human and especially in the fields of health. According to reports submitted by P&S Market Research, there will be a compound annual growth rate (CAGR) of 37.6 percent in the healthcare Internet of Things (IoT) industry between 2015 and 2020. If one thing is certain, IoT has transformed healthcare in a variety of ways over the past several years and will continue to do so for years to come. [21].

Here are the IoT applications in healthcare:

4.1. Implantable Glucose Monitoring Systems

Diabetes is one of the most common disease affecting humanity. It is expected that by 2040, 1 in 10 adults will be diabetic (World Health Organization (WHO). Global Report on Diabetes 2016; WHO: Geneva, Switzerland, 2016). It causes the blood glucose concentration to increase (hyperglycemia) or decrease (hypoglycemia) due to improper levels of insulin hormone produced by pancreas.

Patients who suffer from diabetes can have devices with sensors implanted in them, just below their skin. The sensors in the devices will send information to a patient's mobile phone when his or her glucose levels get too low

and will record historical data for them too. This way, patients will also be able to tell when they are most likely to be at risk for low glucose levels in the future, as well as in the present. [22].

4.2 Activity Trackers During Cancer Treatment

Usually the right treatment for a cancer patient relies on more than just his or her weight and age. Their lifestyles and fitness levels also play a huge role in what the proper treatment plan for them will entail. Activity trackers track a patient's movements, fatigue levels, appetite, etc. Plus, the data collected from the tracker prior to treatment and after treatment has started will tell healthcare professionals what adjustments need to be made to the recommended treatment plan [23] [24].

4.3 Heart rate monitoring

Patients can wear devices that monitor their heart rates, and that can determine whether they have high blood pressure. Healthcare providers will have access to reporting of patient's heart monitor data when they need to pull it during checkups and exams. The wearable devices can even alert healthcare professionals when patients are experiencing arrhythmias, palpitations, strokes, or full-blown heart attacks. Ambulances can then be dispatched in a timely fashion, which can be the difference between life and death.

Heart rate monitoring, where the biometrics of each patient are independently monitored using specific threshold settings. Such monitoring system records the ECG Heart rate variability and reliability, respiration rate, activity level of the heart, body position. In addition, the vital signs such as the weight and blood pressure are remotely monitored using supplementary devices in conjunction. Generally, the heart rate monitoring system reports the rhythm to realize the cardiac role of impenetrable symptoms. Arrhythmia medication therapy is a further clinical applications the cardiac monitoring remotely at home or in the hospital [26].

4.4 Medical Alert Systems

In recent times, it has become necessary to have a system that constantly monitors a patient's heartrate and body temperature autonomously and then send an alert when readings are out of range to ensure healthcare is always provided on time. People are dying from heart related diseases like coronary heart disease, congestive heart failure, heart attack, and congenital heart disease especially the aged who need 24 hours monitoring [27]. Body temperature is a vital sign that medical professionals measure to help them determine the condition of their patients [28]. Medical Emergency Alert System (MEAS) is a wearable device that monitors the user's heart rate and temperature anywhere. Temperature sensors and pulse sensors are used to measure the respective values and display them on a screen for the user to see. These values are also sent to an application on an android device via Bluetooth and an alert is sent to confidants when measured values are abnormal [29].

4.5 Ingestible Sensors

An ingestible sensor or smart pill is one of the latest applications of IoT in healthcare. By using this technology the medication ingestion and adherence patterns of a patient and other useful health metrics can be measured. Non adherence with medication is a very complex and multidimensional healthcare problem which could result in significant complication and deterioration of patient health. This technology includes a system for detecting ingestion of a tablet or capsule. The system includes ingestible sensors embedded in tablets, a small wearable sensor patch, a mobile application and a portal. Once the pill reaches the stomach, a signal is transmitted, which is received by the sensor patch attached to human body. The signal is converted to digital record and then sent to the mobile

device of the patient and then to the cloud system where the doctors and caregivers can access the medical data using their portals [30].

4.6 Medication Dispensers

Medication nonadherence is a serious public health issue with the increase in chronic diseases [31] [32] [33]. To improve patient adherence, medication dispensers are often proposed [34] [35]. A medication dispenser is a device that delivers medication to the patient according to predetermined schedules; it is considered a very efficient device of improving medication adherence [36] [37].

Devices can now be implanted in a patient that dispense medication in steady doses throughout the day. Patients will be notified when they need to refill their medications. Doctors can also be informed of missed doses during routine visits.

4.7 Asthma monitor

Now there are wearable intelligent asthma monitors intended to identify the signs of an asthma attack prior to its onset, helping to handle it until the attack gets worse. Asthma Detection and Monitoring (ADAM) is an example of this type of Asthma Monitor [38] [39].

4.8 Blood pressure (BP) monitoring

For the moment, several IoT Healthcare based devices, wearables capable of measuring blood pressure, are beginning to be offered on the market, offering the possibility of monitoring BP every time and everywhere [40] [41].

These devices encompass high-precision blood pressure monitoring, automatic wireless synchronization with your smartphone, compatible with heterogeneous smartphone operating systems, instantly sharing results with friends, family, or doctor, tracking physical activities and daily diet as part of your overall health.

4.9 Oxygen saturation monitoring

Blood oxygen saturation (SpO2) is one of the vital parameters of survival that is potentially used in patients, and newborn health monitoring, etc. [42].

4.10 Fitness Applications

Fitness, an application field helpful for a huge market interested in exercising, provides immediate performance feedback about an individual's heart rate, body temperature, oxygen uptake, and aerobic and anaerobic exercise [43].

There are various fitness products on the market which calculate exercise, steps and other data [44]. Therefore, connected objects that make self-tracking possible during everyday life will improve the fitness and physical wellbeing of individuals.

Conclusions

In this paper, a review on IoT usage in healthcare has been presented. The article presented a review of the latest IoT based healthcare applications. IoT in healthcare is one of the most noteworthy technology trends. IoT has potential to change the way of human living standards especially from the healthcare point of view. Healthcare driven IoT systems thus has the potential that would allow healthcare providers to give optimum quality healthcare

service to their customers also predict their health problems at early stages reducing mortality rates. In the long term, the deployment of IoT in health can improve productivity, enhance the quality of life, and contribute to poverty alleviation and overcoming health inequities.

This paper is a current review of the application of IoT technologies in healthcare and related monitoring devices and applications. The results of this research improve our knowledge about IoT technology in the health sector and also encourage innovative use cases of this new technology in the health field.

REFERENCES

[1] G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, "Smart objects as building blocks for the internet of things,"Internet Computing, IEEE, vol. 14, pp. 44-51, 2010.

[2] K.J. Singh, D.S. Kapoor, Create your own internet of things: a survey of IoT platforms, IEEE Consum. Electron. Mag. 6 (2017) 57–68.

[3] J. Cubo, A. Nieto, E. Pimentel, A cloud-based internet of things platform for ambient assisted living, Sensors. 14 (2014) 14070–14105, https://doi.org/10.3390/ s140814070

[4] M. Bhatia, S.K. Sood, A comprehensive health assessment framework to facilitate IoT-assisted smart workouts: A predictive healthcare perspective, Comput. Ind. 92–93 (2017) 50–66, https://doi.org/10.1016/j.compind.2017.06.009

[5] W.-T. Sung, K.-Y. Chang, Health parameter monitoring via a novel wireless system, Appl. Soft Comput. J. 22 (2014) 667–680, https://doi.org/10.1016/j.asoc.2014.04.036.

[6] L.J.B. Andrews, L. Raja, A study on m-health inline with the sensors applying for a real time environment, J.Stat. Manag. Syst. 20 (2017) 659–667, https://doi.org/10.1080/09720510.2017.1395186.

[7] L. Catarinucci, D. De Donno, L. Mainetti, L. Palano, L. Patrono, M.L. Stefanizzi, L. Tarricone, An IoT-aware architecture for smart healthcare systems, IEEE Internet Things J. 2 (2015) 515–526.

[8] D.V. Dimitrov, Medical internet of things and big data in healthcare, Healthc. Inform. Res. 22 (2016) 156–163.

[9] Farahnaz Sadoughia, Ali Behmaneshb,∗, Nasrin Sayfouric, Internet of things in medicine: A systematic mapping study, Journal of Biomedical Informatics 103 (2020) 103383.

[10] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Aves and and D. Boyle, "Real-World Design Constraints", From Machine-To- Machine to the Internet of Things, pp. 225-231, 2014.

[11] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Aves and and D. Boyle, "M2M to IoT – An Architectural Overview", From Machine- To-Machine to the Internet of Things, pp. 61-77, 2014.

[12] M. Gigli and S. Koo, "Internet of Things: Services and Applications Categorization", Advances in Internet of Things, vol. 01, no. 02, pp. 27-31, 2011.

[13] Bandyopadhyay and J. Sen, "Internet of Things: Applications and Challenges in Technology and Standardization", Wireless Personal Communications, vol. 58, no. 1, pp. 49-69, 2011.

[14] L Margarida R Tarouco et al. (2012). Internet of things in healthcare: Interoperatibility and security issues. IEEE International Conference on Communications (ICC). Available at: http://dx.doi.org/10.1109/icc.2012.6364830

[15] Navod Neranjan Thilakarathne1, Mohan Krishna Kagita2 and Dr. Thippa Reddy Gadekallu, The Role of the Internet of Things in Health Care: A Systematic and Comprehensive Study, Volume-10, Issue-4 (August 2020), https://doi.org/10.31033/ijemr.10.4.22

[16] The Internet of Things for Health Care: A Comprehensive Survey. Available at: https://ieeexplore.ieee.org/document/7113786, accessed June 2020

[17] Technology Networks. (2020). Using the internet of things to fight virus outbreaks. Available at: https://www.technologynetworks.com/immunology/articles/using-the-internet-of-things-to-fight-virus-outbreaks-331992.

[18] David Niewolny. 18 Oct 2013. How the Internet of Things Is Revolutionizing Healthcare, Freescale Semiconductors

[19] Nilanjan Dey, Amira S. Ashour and Chintan Bhatt, Internet of Things Driven Connected Healthcare, © Springer International Publishing AG 2017, DOI 10.1007/978-3-319-49736-5_1
[20] Mikhail Simonov, Riccardo Zich, Flavia Mazzitelli. Personalised healthcare communication in Internet of Things.
[21] Amine Rghioui, Abdelmajid Oumnad, Challenges and Opportunities of Internet of Things in Healthcare, International Journal of Electrical and Computer Engineering (IJECE) Vol. 8, No. 5, October 2018, pp. 2753~2761 ISSN: 2088-8708, DOI: 10.11591/ijece.v8i5.pp2753-2761
[22] https://www.psmarketresearch.com/market-analysis/internet-of-things-in-healthcare-market.
[23] Thomas Diaz, Alicia M., ed. (November 2017). "Continuous Glucose Monitoring". Hormone Health Network. Endocrine Society. Retrieved 24 August 2018.
[24] Shcherbina A, Mattsson CM, Waggott D, et al: Accuracy in wrist-worn, sensor-based measurements of heart rate and energy expenditure in a diverse cohort. J Pers Med 7:3, 2017.
[25] Evenson KR, Goto MM, Furberg RD: Systematic.Review of the validity and reliability of consumer-wearable activity trackers. Int J Behav Nutr Phys Act 12:159, 2015.
[26] Bourge, R.C., Abraham, W.T., Adamson, P.B., Aaron, M.F., Aranda, J.M., Magalski, A., Jessup, M.L.: Randomized controlled trial of an implantable continuous hemodynamic monitor in patients with advanced heart failure: the COMPASS-HF study. J. Am. Coll. Cardiol. 51(11), 1073–1079 (2008)
[27] World Health Organization [Internet]. Cardiovascular diseases (CVDs), 2017. [cited 2018 October 28]. Available from: http://www.who.int/news-room/factsheets/detail/cardiovascular-diseases-(cvds).
[28]https://www.hopkinsmedicine.org/healthlibrary/conditions/cardiovascular_diseases/vital_signs_body_temperature_pulse_rate_respiration_rate_blood_pressure_85,p00866.
[29] Benjamin Kommey, Seth Djanie Kotey, Daniel Opoku, Patient Medical Emergency Alert System, Volume 12– No.17, December 2018, https://www.researchgate.net/publication/329681918.
[30] H. Hafezi, T. L. Robertson, G. D. Moon, K. Y. Au-Yeung, M. J. Zdeblick and G. M. Savage, "An Ingestible Sensor for Measuring Medication Adherence," in IEEE Transactions on Biomedical Engineering, vol. 62, no. 1, pp. 99-109, Jan. 2015.
[31] World Health Organization, “Adherence to long term therapies: evidence for action,” http://www.who.int/.
[32] R. L. Ownby, “Medication adherence and cognition: medical, personal and economic factors influence level of adherence in older adults,” Geriatrics, vol. 61, no. 2, pp. 30–35, 2006.
[33] Pan American Health Organization, “Poor adherence to longterm treatment of chronic diseases is a worldwide problem,” Revista Panamericana de Salud Publica ´ , vol. 14, no. 3, pp. 218– 221, 2003 [48] Benjamin Kommey, Seth Djanie Kotey, Daniel Opoku, Patient Medical Emergency Alert System, Volume 12– No.17, December 2018, https://www.researchgate.net/publication/329681918
[34] e-pill, http://www.epill.com/medtime.html.
[35] W. W. Changa, T. J. Sungb, H. W. Huanga et al., “A smart medication system using wireless sensor network technologies,” Sensors and Actuators A, vol. 172, no. 1, pp. 315–321, 2011
[36] J. Dunbar-Jacob and M. K. Mortimer-Stephens, “Treatment adherence in chronic disease,” Journal of Clinical Epidemiology, vol. 54, no. 12, supplement 1, pp. S57–S60, 2001.
[37] P. A. Frick, L. Lavreys, K. Mandaliya, and J. K. Kreiss, “Impact of an alarm device on medication compliance in women in Mombasa, Kenya,” International Journal of STD and AIDS, vol. 12, no. 5, pp. 329–333, 2001

[38] Rhee H, Belyea MJ, Sterling M, Bocko MF. Evaluating the validity of an automated device for asthma monitoring for adolescents: correlational design. J. Med. Internet Res. 17(10), e234 (2015).Crossref, Medline, Google Scholar.
[39] Rhee H, Miner S, Sterling M, Halterman JS, Fairbanks E. The development of an automated device for asthma monitoring for adolescents: methodologic approach and user acceptability. JMIR Mhealth Uhealth 2(2), e27 (2014).Crossref, Medline, Google Scholar.
[40] F Lamonaca et al. (2019). An overview on internet of medical things in blood pressure monitoring. IEEE International Symposium on Medical Measurements and Applications (MeMeA) DOI: http://dx.doi.org/10.1109/memea.2019.8802164.
[41] S Hameed, F Idris Khan, & B Hameed. (2019). Understanding security requirements and challenges in internet of things (IoT): A review. Journal of Computer Networks and Communications, 1–14. DOI: http://dx.doi.org/10.1155/2019/9629381.

[42] Y Jie Fan, Y Hong Yin, L Da Xu, Y Zeng, & F Wu. (2014). IoT-based smart rehabilitation system. IEEE Transactions on Industrial Informatics, 10(2), 1568–1577. DOI: http://dx.doi.org/10.1109/tii.2014.2302583.

[43] Swan, M. (2012). Sensor mania! the internet of things, wearable computing, objective metrics, and the quantified self 2.0.Journal of Sensor and Actuator Networks,1(3), 217-253.

[44] Vermesan, O., & Friess, P. (Eds.). (2014).Internet of Things-From Research and Innovation to Market Deployment(pp. 74-75). River Publishers