Improving computing issues in Internet of Things driven e-health systems

Mirjana Maksimović
Faculty of Electrical Engineering
University of East Sarajevo
East Sarajevo, Bosnia and Herzegovina
e-mail: mirjana@etf.unssa.rs.ba

***Abstract*—The Internet of Things (IoT) progress shows a positive influence on all aspects of healthcare. Enabling access to high-quality healthcare to anyone, from anywhere are the main advantages of the IoT-driven e-health systems. Increasing numbers of medical devices and sensors and 24/7 monitoring of health parameters, consequently lead to enormous quantities and varieties of data. Having in mind the amounts of generated data and importance of on-time diagnosis and decision making as well as a significance of fast reactions in a case of detected abnormalities, transmitting all data to the Cloud for analysis may not be appropriate. For that reason, implementing a Fog computing, which realizes mini analytic processing centers at the edge of the network, appears as a better approach. This paper analyzes the manners and benefits of implementing Fog computing in the IoT-driven e-health systems. It is expected that the IoT and Fog computing together will revolutionize healthcare like nothing else before.**

***Keywords*—Internet of Things (IoT); e-health; Cloud; Fog computing**

I. INTRODUCTION

The right to healthcare is a fundamental right of every human being and includes anytime and anywhere accessible, available, acceptable and high-quality all medical services. Improving access to healthcare and quality of healthcare appear as one of the primary objectives of the modern society. The design of healthcare systems and their improvements are guided by the key human rights standards such as: universal access, availability, dignity, acceptability, non-discrimination, quality, transparency, participation, and accountability [1]. The recent intensive technology advancements have dramatically changed the healthcare of today. The Information and Communication Technologies (ICTs) have an impact on many aspects of healthcare, creating a new vision, namely e-health. The term e-health, sometimes called health information technology, encompasses the utilization of modern ICTs solutions to enable more accessible and high-quality healthcare when and where it's demanded.

The significant part in the realization of this vision has the Internet of Things (IoT). The IoT is a worldwide network of intercommunicating physical objects, devices or "things" that are connected to the Internet, controllable and available from anywhere, anyhow and anytime. As such, the IoT brings numerous benefits in diverse application domains (Fig. 1).

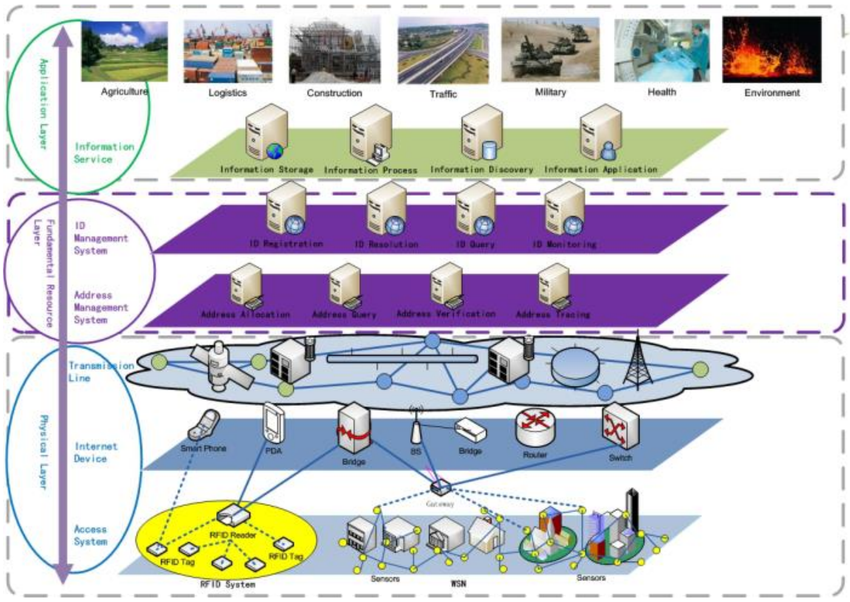

Figure 1. An IoT ecosystem: architecture and applications [2]

The IoT devices are embedded with electronics, software, sensors, and network connectivity, which enable sensing, collecting and exchanging information among each other, as well as with the environment, with or without human intervention. The realization of the IoT vision, connecting people and things, with anything and anyone, at anyplace and using any path/network and any service, requires dramatic changes in systems, architectures, and communications which should be: flexible, adaptive, secure, and pervasive without being intrusive [3].

The coupling IoT and healthcare leads to the IoT-driven e-health solutions which have the power to completely revolutionize the healthcare industry. With the help of small, powerful and intelligent sensing devices, and the IoT concepts, availability and accessibility of healthcare are improved, more "personalized" systems are created alongside realized high-quality cost-effective healthcare delivery [3].

The increasing number of sensing devices used for healthcare purposes will generate a large amount of data. These data have to be processed accurately and on time in order to enable adequate diagnosis and care. Hence, it is essential to analyze, capture, search, share, store, and visualize large-volume, complex, growing health-related datasets [3]. Posting large quantities of data to the Cloud for analysis and storage is not practical, and it takes some time what can induce a negative influence in decision-making processes relating health. It is believed that current Cloud computing systems will not be capable of managing the total burden of data generated by IoT, and an adequate solution is seen in Fog computing. Fog computing is sort of a middle layer between the Cloud and the hardware and it reduces the quantities of data which needs to be sent to the Cloud by implementing more efficient data processing, analysis, and storage [4].

This paper represents the analysis of computing issues in IoT-driven e-health systems. Hence, the rest of the paper is organized as follows. The second section presents the fundamental characteristics of data produced by IoT-driven e-health systems and challenges for their processing and analyzing. The principles of Fog computing and how it can help in dealing with health-related data are shown in Section 3. The last section contains the concluding remarks.

II. IoT-DRIVEN E-HEALTH SYSTEMS: HOW TO DEAL WITH A LARGE AMOUNT OF VARIOUS HEALTH-RELATED DATA?

To realize the vision of IoT-related healthcare systems, the integration of IoT principles in e-health is essential. Hence, a variety of sensors, embedded in a device, internally embedded, wearable by users or stationary devices, are utilized to gather diverse patient medical data. These data are further processed, analyzed and transmitted wirelessly to medical professionals for further medical analysis, the remote control of certain medical treatments or parameters or real-time feedback (Fig.2) [3, 5, 6].

There are several estimations of the total number of IoT devices anticipated to be in operation by 2019, ranging from 19 billion to 40 billion devices. Regardless of the correct expected increase in the total number of IoT devices, the large-volume, complex and constantly growing datasets represent the future serious challenge. According to [7], an overall increase in health-related data will be about 48 percent annually, and the volume of healthcare data will grow to 2,314 Exabytes (10^{18} bytes) by 2020.

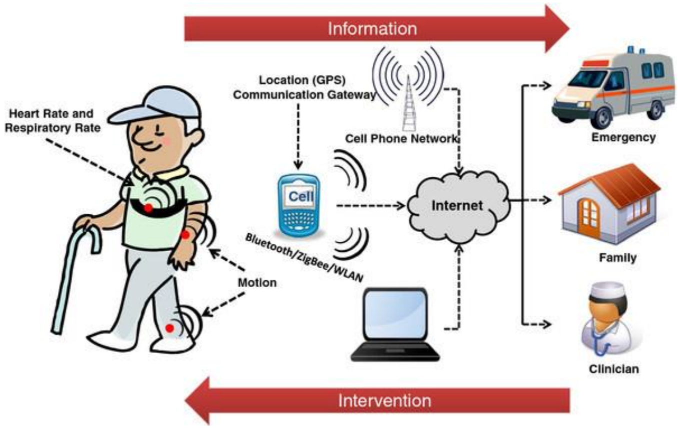

Figure 2. IoT-based e-healthsystem [2]

Alongside a voluminous nature of data, variety, velocity, value and veracity, are also the foundational characteristics of health-associated data. The IoT-based systems include medical and healthcare information such as: personal information, radiology images, personal medical records, 3D imaging, genomics, biometric sensor readings, etc. These data are classified into structured information (e.g. clinical data) and unstructured or semi-unstructured (e.g. office medical records, doctor notes, paper prescriptions, images, and radiograph films). The velocity of healthcare data increases with daily measurements and readings from medical devices, while high-quality data and its value are essential in making a diagnosis, predicting outcomes at earlier stages, making real-time decisions, promoting patients' health, enhancing medicine, reducing costs, etc [2]. Hence, a voluminous, rapidly growing, and mostly unstructured medical data are the consequence of increased digitalization, the continuous optimization of diagnostic laboratory and imaging sensors, increased monitoring with sensors of all kinds and so on, and represents one of the biggest challenges in healthcare systems nowadays. These data are usually stored in the Cloud while a variety of techniques and big data analytics are used to extract useful information, perform predictive modeling and make actionable decisions from the resulting massive volumes of high-dimensional observations [2].

Healthcare organizations often use virtualization and Cloud computing for manipulation, storage and use of such a complex data structure. Ideally, this "real-time analytics" could only take minutes, but in the life or death situation, it is unacceptable [8]. The additional problem with Cloud computing is bandwidth. A growing number of smart devices today are generating too much data to be sent to the Cloud for processing. The bandwidth is not adequate and costs too much [9]. Also, Cloud-based applications are typically widely distributed. The data are far away from the application logic and may be far away from the consumer. This may lead to latency and even reliability issues [10]. These challenges can be overcome by operating at the edge of the Cloud. In other words, the data are processed in smart devices where it is generated instead of routing everything over Cloud channels.

In this manner data processing is faster, the response time is improved while the need for bandwidth is scaled down. Consequently, costs are lowered and efficiency is enhanced [9, 11]. This approach is known as Fog computing or Fog networking and holds the potential to revolutionize IoT-driven e-health solutions and make them truly useful.

III. FOG COMPUTING AND ITS ROLE IN IOT-POWERED E-HEALTH SOLUTIONS

Fog computing adds a middle layer of computing power between the devices and the Cloud. In other words, it allows individual devices to conduct critical analytics and thus become processing nodes that can handle smaller, time-sensitive computational decisions without having to send all their data up to the Cloud. In this way, time from request to answer is significantly reduced and the link with the Cloud is free for larger-scale analytics work [8]. The smart gateway, shown in Fig. 3, is an example of Fog computing layer. By allowing real-time computing it minimizes the latency, provides location awareness and facilitates handling of the mobility requirements of the nodes [12].

It has to be highlighted that the Fog computing is not a replacement for Cloud computing. Fog computing vision retains the benefits of Cloud (e.g. agility, flexibility and distributed computing) while allowing communication of the data over the IoT devices much easier than Cloud [13]. Hence, Fog computing extends the Cloud computing paradigm at the edge of the network (Table 1) and it is developed to address applications and services that do not fit the paradigm of the Cloud, including [9, 13]:

- Applications that require very low and predictable latency;
- Applications in which thousands or millions of things across a large geographic area are generating data;
- Fast mobile applications; and
- Large-scale distributed control systems.

TABLE I. FOG NODES EXTEND THE CLOUD TO THE NETWORK EDGE [14]

	Fog nodes closest to IoT devices	**Fog aggregation nodes**	**Cloud**
Response time	Milliseconds to subsecond	Seconds to minutes	Minutes, days, weeks
Application examples	Machine to Machine communication Haptics (controlling technology using the sense of touch), including telemedicine and training	Visualization Simple analytics	Big data analytics Graphical dashboards
How long IoT data is stored	Transient	Short durations: perhaps hours, days, weeks	Month or years
Geographic coverage	Very local (e.g. one city block)	Wider	Global

The IoT-driven e-health system consists of various sensors within or on the human body as well as those attached in ambient surroundings. With the help of these devices, high-dimensional, high-velocity and high-variety health-related data is being generated on a daily base. Sending all that data to the Cloud and transmitting response data back requires a larger bandwidth, a considerable amount of time and can suffer from latency issues. Fog computing, creating an additional computing layer between sensors and Cloud computing (consists of the gateways and distributed databases) can get around these barriers [8, 15, 16]. This middle layer acts as a miniature data processing center that exchange data without the need for the Cloud. The sensed data is being analyzed at this level using various data mining techniques and data analytics. The found patterns are stored and unique patterns are transmitted to the Cloud alongside clinically relevant information extracted (Fig. 3). Hence, computations are performed only where the data originates: at the hospital or physician office that holds the patient record, while patient health data could be exposed to each device through a shared interface, using predefined authorization and user protocols [15].

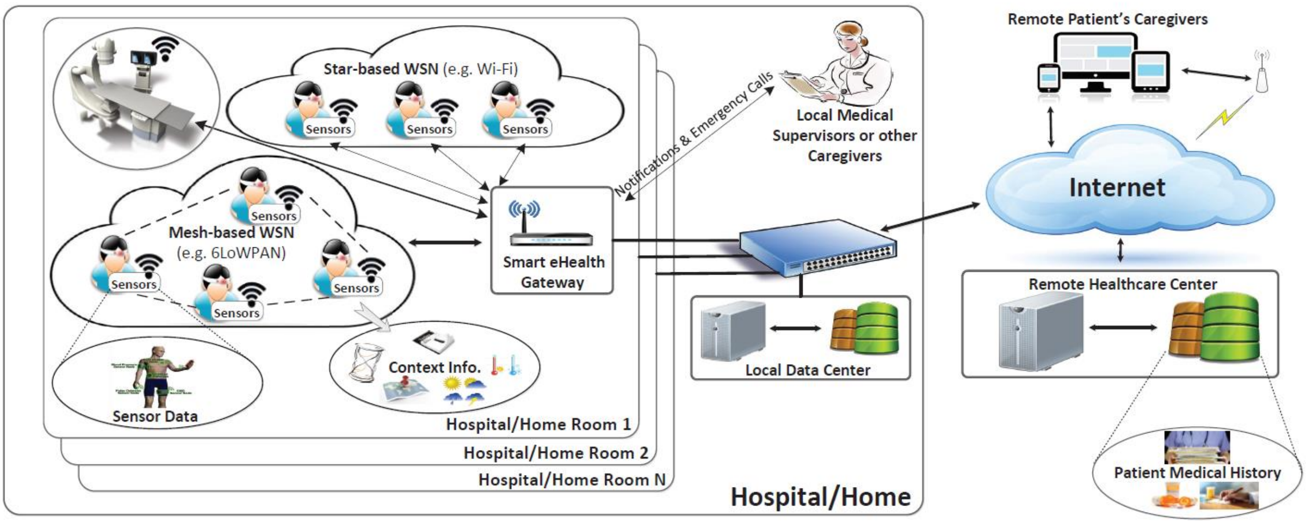

Figure 3. Fog computing in IoT-based e-health system [12]

Implementing the concept of Fog computing in IoT-powered e-health systems, the smart gateway as a middle layer between IoT-connected medical devices and sensors, and Cloud, enable applications of advanced data mining techniques, distributed storage, and notification service at the edge of a network [16]. Turning devices into their own mini-analytics centers, the Fog computing offers big benefits for healthcare:

- Fog layer easily deals with challenges such as heterogeneity of devices and data sources, interoperability and bandwidth while connection of health data from disparate organizations is enabled through the IoT;
- Splitting big data to sub data in the Fog layer leads to the easing data manage and process. In addition, it is simpler to extract useful key information when the data are processed in smart devices where it is generated.
- Fog layer enables real-time and online analytic even in event of loss of connectivity or poor connection with the Cloud;
- Having in mind that the latency is highly associated with proximity, moving the applications and services close to the end users contributes to significantly reduced latency. Hence, Fog computing implies less congestion and faster real-time interaction what enables instantly alerting healthcare providers in a case of emergency.
- Data privacy is easier to be provided since Fog computing separates the public and private data.

IV. CONCLUDING REMARKS

Healthcare, as almost every other aspect of our lives, has not been immune to technology advancements. The evolution of the IoT has completely revolutionized healthcare industry, especially monitoring and delivering of healthcare. At the same time, a great number of diverse IoT-connected medical devices and sensors create an escalating volume of health-associated data. Instead of sending all these data to the Cloud, implementing a miniature data processing centers that exchange data without the need for the Cloud has been shown as a better approach. Problems with the bandwidth, a considerable amount of time, and latency in a case of Cloud computing utilization justify the implementation of Fog computing. The benefits that Fog computing offers (low latency, low bandwidth, heterogeneity, interoperability, scalability, security and privacy, real-time processing and actions) are of immense importance in health monitoring and delivering healthcare. Moving powerful processing, currently only available in the Cloud, to the edge of the network, Fog computing holds the potential to make IoT-driven e-health systems reliable, simpler, scalable, and exceptionally high performance. However, Fog computing will not totally replace the Cloud computing. Complementing each other they will be a powerful tool to achieve numerous benefits in various aspects of the healthcare domain.

REFERENCES

[1] Nesri, “What is the Human Right to Health and Health Care?,” [Online]: https://www.nesri.org/programs/what-is-the-human-right-to-health-and-health-care

[2] Opentechdiary, “Internet of Things,” 2015. [Online]: https://opentechdiary.wordpress.com/tag/internet-of-things/

[3] M. Maksimovic and V. Vujovic, Internet of Things based e-health systems: ideas, expectations and concers, Chapter in the book Handbook of Large-Scale Distributed Computing in Smart Healthcare (in press), Springer, 2017.

[4] Westbase Technology, “Fog Computing vs Cloud Computing: What’s the difference?,” 2016. [Online]: http://www.westbaseuk.com/news/fog-computing-vs-cloud-computing-whats-the-difference/#sthash.5j0QkbxG.5HRRJSNc.dpuf

[5] D. Niewolny, “How the Internet of Things Is Revolutionizing Healthcare -White Paper,” 2013. [Online]:

https://cache.freescale.com/files/corporate/doc/white_paper/IOTREVHEALCARWP.pdf

[6] D. Lake, R. Milito, M. Morrow, R. Vargheese, “Internet of Things: Architectural Framework for eHealth Security,” Journal of ITC Standardization, Vol. 3 & 4, pp. 301–328, River Publishers, 2014.

[7] K. Corbin, “How CIOs Can Prepare for Healthcare ‘Data Tsunami’,” 2014. [Online]: http://www.cio.com/article/2860072/healthcare/how-cios-can-prepare-for-healthcare-data-tsunami.html

[8] J. Bresnick, “How Fog Computing May Power the Healthcare Internet of Things,” Healthanalytics, [Online]:

http://healthitanalytics.com/features/how-fog-computing-may-power-the-healthcare-internet-of-things

[9] N. Joshi, “Why is fog computing beneficial for IoT?,” 2016. [Online]: https://www.linkedin.com/pulse/why-fog-computing-beneficial-iot-naveen-joshi?articleId=8166335329880272527#comments-8166335329880272527&trk=sushi_topic_posts_guest

[10] D. Linthicum, “3 ways to improve cloud performance, Infoworld,” 2012 [Online]: http://www.infoworld.com/article/2615188/cloud-computing/3-ways-to-improve-cloud-performance.html

[11] B. Marr, “What Is Fog Computing? And Why It Matters In Our Big Data And IoT World,” 2016. [Online]:

http://www.forbes.com/sites/bernardmarr/2016/10/14/what-is-fog-computing-and-why-it-matters-in-our-big-data-and-iot-world/#686925e34971

[12] A.-M. Rahmani, N. K. Thanigaivelan, T. N. Gia, J. Granados, B. Negash, P. Liljeberg, H. Tenhunen, “Smart e-Health Gateway: Bringing Intelligence to Internet-of-Things Based Ubiquitous Healthcare Systems,” in Proc. of Annual IEEE Consumer Communications and Networking Conference (CCNC’15), pp. 826-834, 2015, USA.

[13] P. G. Vinueza Naranjo, M. Shojafar, L. Vaca-Cardenas, C. Canali, R. Lancellotti, E. Baccarelli, “Big Data Over SmartGrid – A Fog Computing Perspective,” SOFTCOM Workshop, pp. 1-6, 2016.

[14] Cisco, “Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are,” 2015. [Online]: https://www.cisco.com/c/dam/en_us/solutions/trends/iot/.../computing-overview.pdf

[15] H. Dubey, “Fog Data: Enhancing Telehealth Big Data Through Fog Computing,” In Proceedings of the ASE BigData & SocialInformatics 2015 (ASE BD&SI '15), New York, USA

[16] T. N. Gia, M. Jiang, A.-M. Rahmani, T. Westerlund, T. Liljeberg, H. Tenhunen, “Fog Computing in Healthcare Internet-of-Things: A Case Study on ECG Feature Extraction,” IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing (CIT/IUCC/DASC/PICOM), 2015