Semantic Web Technogies for IoT-Based Health Care Information Systems

Emine Sezer, Okan Bursa, Ozgu Can and Murat Osman Unalir
Department of Computer Engineering, Ege University, 35100 Bornova, Izmir, Turkey
e-mail:{emine.sezer, okan.bursa, ozgu.can, murat.osman.unalir}@ege.edu.tr

***Abstract*— The IoT (Internet of Things), as the most popular trend in the next generation Internet technologies, has a variety of application domains, including health care. The healthcare domain is a big and significant area where people, different organizations and various institutions get services as well as provide services at the same time. It is one of the few areas that have a huge amount of domain knowledge. A significant part of this knowledge is composed of the data that is produced by the medical devices and sensors. This health data can be processed to monitor the health status of any person. In this paper, a semantic Web approach for IoT-based health care information systems is proposed. To transfer health data collected from IoT devices to smart devices and then from smart devices to the cloud platform without changing its meaning, the ontologies developed for medical devices and the health domain should describe this data. This way, health care services for the clinical domain can process the data according to the defined rules with the help of semantic rules and inference engines.**

Keywords- Internet of Things (IoT); Healthcare Information Systems; Healthcare; Semantic Web; Ontology.

I. INTRODUCTION

The improvement in Internet technologies allows people, devices, services and systems to be interconnected 24/7. Thereby, due to the rapid increase of the interaction between users and computer technologies with the advances in information and communication systems, intelligent ecosystems are needed. Internet of Things – IoT, which can be thought as one of these ecosystems, is a concept reflecting a connected set of anyone, anything, any place, any service, and any network [1]. IoT aims to exchange the data between all connected "things" to provide full automation with lots of benefits. Getting any data from anywhere at any time supports the analysis of different types of collected data in real-time, as well as over time. The first samples began to develop for IoT applications, such as smart cities, smart traffic control systems, waste management, security, emergency services, logistics and health care [2]-[6].

Health information systems are important application areas where IoT technologies can be used to provide more effective solutions. The healthcare domain is a significant domain, where people, different organizations and various institutions get services as well as provide services at the same time. It is one of the few areas that need a huge amount of domain knowledge. The important part of this knowledge is composed by the information that is gathered by the medical devices.

Remote patient monitoring activities can be carried out in a dynamic way as a result of analyzing the collected patient data from different devices so that many health care applications like monitoring of chronic diseases, elderly care, wellness and fitness programs can be followed and managed for sustainability. Regarding this aspect, medical, diagnostic and imaging devices and sensors which are used effectively for diagnosing, treatment and medication constitute the objects of IoT health care ecosystem. Blood pressure monitor, blood glucose meter, thermometer, and heart rate sensors can be given as examples for IoT in health care. The storage, querying and analyzing this health data, which is collected from these devices, can also be used to define required alarms with defining rules under certain conditions. These applications create IoT-based health care services that are expected to reduce costs, increase the quality of life with guiding the patient's experience, and also reduce the time spent from the perspective of health care providers.

In this context, ensuring consistency in the related terminology, sharing the data between devices and systems, and data exchange without losing its meaning during this sharing are extremely important elements that have to be provided by IoT ecosystems. For this purpose, the semantic Web technologies can be used to define the data that is collected from the IoT health care devices and sensors and also to define rules about IoT-based health care services.

In this work, the use of semantics and ontologies to share large amounts of distributed medical information is described to support interoperability between IoT-based health care information systems. In Section 2, the proposed model is introduced. Lastly, in Section 3, a brief conclusion is given with future works.

II. SEMANTIC WEB AND IOT-BASED HEALTH CARE INFORMATION SYSTEMS

Semantic Web is defined as the extension of the current Web where information is given in a well-defined meaning and leads to better collaboration between computers and people [7]. In semantic Web, the data about each real world concept as well as the data about concept relationships are described. So that, an information network is developed and by using this network, interoperability between systems, services, computer, and people can be achieved.

Ontologies are very important for interoperability between systems. To provide full interoperability, the semantics of information have to be the same for all systems. Ontology presents format as an explicit specification of a conceptualization [8]. An ontology can be handled by machines and describes the definitions of these concepts and restrictions on possible interpretations between these terms to create a structure on the domain and how these concepts are related with each other [9]. In a certain domain,

 ISBN: 978-1-61208-507-4

ontologies which represent the knowledge of that domain provide interoperability to be connected with other networks.

There is a huge amount of information and data in the health care domain. In order to reuse health data for various purposes, it should be shared between systems and services. For that reason, ontologies are used as information bases for a common framework in health information systems.

IoT is the most popular trend of the next generation Internet applications with the promise of sharing the information from everywhere continuously and accurately in today's information systems. The current applications in this area are quite new. Health care is a domain that is expected to give personalized services with huge amount of data. Therefore, different opinions are available for developing IoT-based health care information systems which collect the heath related data from medical devices and sensors like blood pressure monitor, blood glucose meter, thermometer, oximeter and heart rate sensors that are used personally at their home on IoT platforms. The main purpose of these opinions is transferring the data form medical devices to smart devices and form smart devices to cloud without changing its definition, and in a secure way.

In the health domain, compared with the other domains, any new application or technology should be carried out very carefully to prevent mortal or permanent disability results. Thus, it is quite important to collect data in the most proper way, to store and to transfer this data in the most accurate and secure way while ensuring the patient privacy, to analyze this health data to help the health care providers to monitor the patient's status, and also to respond by giving proper alarms in emergency cases for quick and effective intervention.

IoT technologies are expected to be implemented to support each health service which offer different solutions for various health care applications. In the scope of the health domain, there is no standard that is currently developed to define the IoT-based health care services. However, there are some cases where the service cannot be separated objectively from a particular solution or application. Therefore, a service has a general level due to its structure and has a potential to be a building block for some solutions and applications. In addition, some changes for general services and protocols required in IoT frameworks may be needed in order to be functioning properly in health care scenarios. These include notification services, resource sharing services, Internet services, cross-link protocols for heterogeneous devices and link protocols for the main connections. Simple, safe and low power devices and services can be added to this list [10].

In Fig. 1, we show a model for an IoT-based health care information system which is supported with ontologies. Health data is collected from IoT medical devices and sensors and defined inside ontologies. Nowadays, with the rapid changes in advancing technology, there are small and practical medical devices that measure blood pressure, fever, blood glucose level, and etc. Transfer of this data collected from medical devices to smart phones, tablets or other smart devices and to the cloud platform by using the current Internet infrastructure is also another important research and application area [11]-[15].

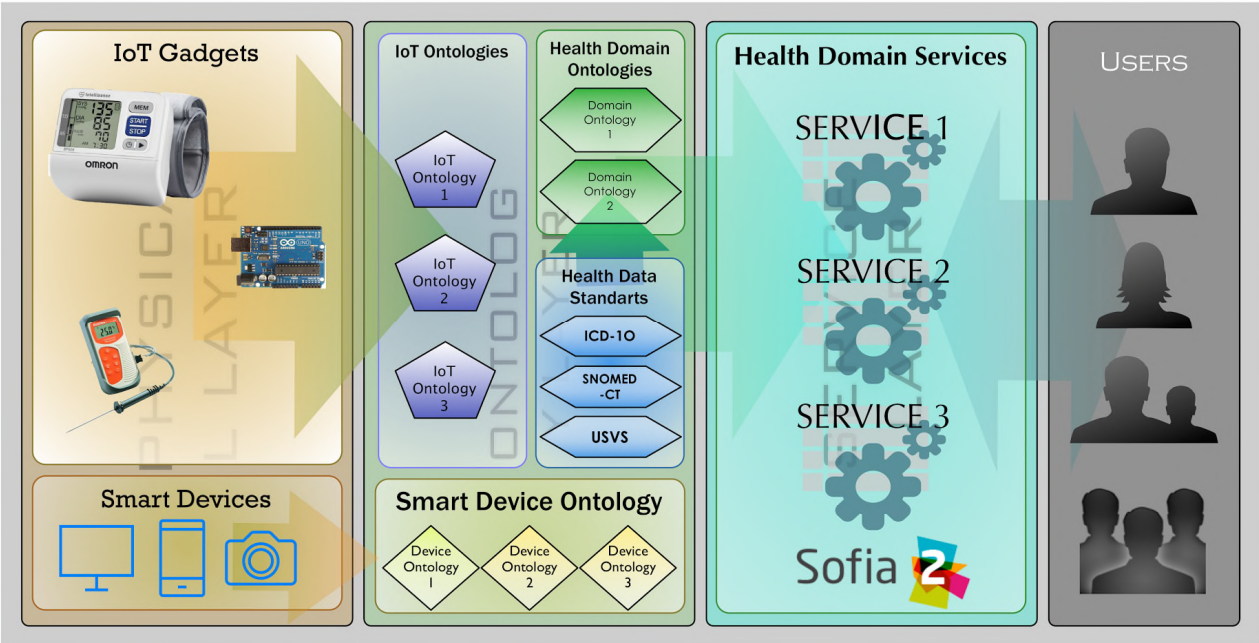

Figure 1. The proposed semantic web model for IoT-based health care information system.

 ISBN: 978-1-61208-507-4

Proper patient care can be done by reliable health data. To transfer the health data without losing its semantics, we are proposing to define health data with ontologies. For this purpose, first of all, ontologies for medical devices and sensors that produce health data have to be developed. Ontologies developed for these IoT devices describe the data not only by its measurement value, but also its relationships with the other data sources and also with descriptive properties like where and when it is produced.

The described health care data should be related with the clinical domain knowledge where it is needed to monitor the patient's health situation. In that case, the specific health domain ontologies like Vaccine Ontology, Infectious Disease Ontology or Blood Test Ontology are needed to process collected health data [16]. Also, to be able to share data between different health information systems, in other words in order to reuse the health data, the health data standards like SNOMED-CT [17] and ICD 10 [18] should be supported by these health domain ontologies. The interoperability between information systems is achieved by using general information descriptions and describing data with its semantics.

After the data is transferred to the cloud, the health care services can provide proper information or services by using the inference and role engines that are offered by semantic Web technologies to the health care providers and clinics.

To describe the overall system interaction, a sample scenario is given. A person who had a heart attack is discharged from the hospital and his responsible physician is supposed to measure his blood pressure twice a day. His physician also defines some limiting values and rules for his measurements. If a measurement exceeds the defined limit, the system requests to make measurements more frequently, such as once an hour. However, if the measurements reach the alarm levels, the system should give an alert. The physician is informed quickly with a message or a call, and also with the health institute that is the nearest one to the patient's location. If the patient specified a person to be informed in emergency situations for himself, the system should also give information to that person. The system should be adaptable and self-driven to different situations.

III. Conclusions and Future Works

In this work, we propose an IoT-based health care information system model which uses semantic Web technologies to describe the domain and device data and also to define rules to make proper inferences to execute health care services. In this model, the health data collected from any medical device or clinic is meant to be reused and shared not only at the point where it was produced, but also on other authorized services, devices and people by using semantic Web technologies. Thus, interoperability between information systems can be achieved.

To implement the proposed model, an application domain area from the health care is determined, primarily. The medical devices, sensors, diagnostic and monitoring devices used in that domain are determined as IoT objects. For the application domain, the health care services are determined and then the information needed for these services is defined. With the goal of interoperable devices and systems and also reusable health care data, IoT device ontologies and specific health domain ontologies should be developed. The developed ontologies will be integrated with Sofia 2 platform. Sofia 2 (Smart Objects for Intelligent Applications) was developed as R&D Artemis project by 19 stakeholders such as companies like Nokia, Philips, Fiat and Acciona from the European Union [19]. It is widely used in IoT applications, works on Eclipse platform [20] and is an open source platform. Sofia 2 platform is defined as a layer that provides seamless interoperability between different devices and systems. The data handled from IoT devices will be stored on Sofia 2 platform that offers big data storage by describing the defined ontologies.

References

[1] S. M. R. Islam, D. Kwak, M.D. H. Kabir, M. Hossain and K. S. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey", IEEE Access, Vol. 3, pp. 678-704, 2015.

[2] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Avesand, and D. Boyle, "From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence", Amsterdam, The Netherlands: Elsevier, 2014.

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

[4] K. Romer, B. Ostermaier, F. Mattern, M. Fahrmair, M., and W. Kellerer, "Real-time search for real-world entities: A survey", Proc. of IEEE, 98(11), pp. 1887-1902, 2010.

[5] D. Guinard, V. Trifa, V., and E. Wilde, "A resource oriented architecture for the Web of Things", in Proc. Internet Things (IOT), pp. 1-8, 2010.

[6] L. Tan, and N. Wang, "Future Internet: The Internet of Things", in Proc. 3rd Int. Conf. Adv. Comput. Theory Eng. (ICACTE), Vol. 5., pp. 375-380, 2010.

[7] T. Berners-Lee, J. Hendler, O. Lassila, "The semantic web". Scientific American, 284 (5), pp. 34-43, 2001.

[8] T. Gruber, "Toward principles for the design of ontologies used for knowledge sharing", Technical Report KSL93-04, Knowledge Systems Laboratory, Stanford University, 1993.

[9] M. Uschold, "Knowledge level modelling: Concepts and terminology", Knowledge Engineering Review, 13(1), pp. 5–29, 1998.

[10] K. Vasanth and J. Sbert. Creating solutions for health through technology innovation. Texas Instruments. [Online]. Available: http://www.ti.com/lit/wp/sszy006/sszy006.pdf. [Retrieved: September, 2016]

[11] S. Imadali, A. Karanasiou, A. Petrescu, I. Sifniadis, V. Veque, and P. Angelidis, "eHealth service support in IPv6 vehicular networks", in Proc. IEEE Int. Conf. Wireless Mobile Comput., Netw. Commun. (WiMob), pp. 579-585, 2012.

[12] A. J. Jara, M. A. Zamora, and A. F. Skarmeta, "Knowledge acquisition and management architecture for mobile and personal health environments based on the Internet of

 ISBN: 978-1-61208-507-4

Things", in Proc. IEEE Int. Conf. Trust, Security Privacy Comput. Commun. (TrustCom), pp. 1811-1818, 2012.

[13] P. Lopez, D. Fernandez, A. J. Jara, and A. F. Skarmeta, "Survey of Internet of Things technologies for clinical environments", in Proc. 27th Int. Conf. Adv. Inf. Netw. Appl. Workshops (WAINA), pp. 1349-1354, 2013.

[14] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey", *Computer Networks,* 54(15), pp. 2787-2805, 2010.

[15] M. Hassanalieragh, A. Page, T. Soyata, G. Sharma, M. Aktas, G. Mateos, B.Kantarci, and S. Andreescu, "Health Monitorin and Management Using Internet-of-Things (IoT) Sensing with Cloud-Based Processing: Opportunities and Challenges": In Proceedings of the 2015 IEEE International Conference on Services Computing (SCC'15). IEEE Computer Society, Washington, DC, USA, pp. 285-292, 2015.

[16] O. Bursa, E. Sezer, O. Can, M. O. Unalir, "Using FOAF for Interoperable and Privacy Protected Healthcare Information Systems", Research Conference on Metadata and Semantics, Springer International Publishing, pp.154 - 161, 2014.

[17] SNOMED-CT, http://www.ihtsdo.org/snomed-ct [Retrieved: September, 2016]

[18] ICD 10, http://www.who.int/classifications/icd/en [Retrieved: September, 2016]

[19] Sofia2, SOFIA2 IoT Platform: Technical View, [Online]. Available: http://sofia2.com/docs/SOFIA2%20-%20Technical%20-%20IoT%20Platform%20(oct%202014).pdf [Retrieved: September, 2016]

[20] Eclipse, https://eclipse.org/ [Retrieved: September, 2016]

 ISBN: 978-1-61208-507-4