The Importance of Health Informatics in Public Health during a Pandemic
J. Mantas et al. (Eds.)

doi:10.3233/SHTI200586

Semantic Web of Things (SWoT) for Global Infectious Disease Control and Prevention

Arash SHABAN-NEJAD [a,1], Jon Haël BRENAS [b], Mohammad Sadnan AL MANIR [c], Kate ZINSZER [d] and Christopher J.O. BAKER [e, f]
[a] *University of Tennessee Health Science Center-Oak Ridge National Laboratory (UTHSC-ORNL) Center for Biomedical Informatics, Department of Pediatrics, College of Medicine, Memphis TN, USA*
[b] *Big Data Institute - Nuffield Department of Medicine, University of Oxford, Oxford OX3 7LF, U.K.*
[c] *Public Health Sciences, University of Virginia, Charlottesville, VA, USA*
[d] *School of Public Health, University of Montreal, Montréal, Québec, Canada*
[e] *Department of Computer Science, University of New Brunswick, Saint John, New Brunswick, Canada*
[f] *IPSNP Computing Inc., Canada*

Abstract. This paper reports on the early-stage development of an analytics framework to support the semantic integration of dynamic surveillance data across multiple scales to inform decision making for malaria eradication. We propose using the Semantic Web of Things (SWoT), a combination of Internet of Things (IoT) and semantic web technologies, to support the evolution and integration of dynamic malaria data sources and improve interoperability between different datasets generated through relevant IoT assets (e.g. computers, sensors, persons, and other smart objects and devices).

Keywords. Internet of Things, Semantic Web, Surveillance, Global Health, Interoperability

1. Introduction

Malaria is the most prevalent mosquito-borne disease worldwide, yet it is lethal, although preventable. According to the 2019 World Malaria Report [1], there were 228 million cases of malaria worldwide in 2018 with 93% of cases and 94% of deaths occurring in Africa. Data on malaria, generated by various sources, is currently stored in different formats in various geographical locations across diverse organizations, making it challenging to access, process, and use. Advances in information and communication technologies (ICTs) such as Internet use and mobile phones, smart devices, and Big Data analytics have provided opportunities for global health to improve health data exchange, delivery of health services, and employ novel surveillance methods for disease control

---

[1] Corresponding Author, Arash Shaban-Nejad, Centre for Biomedical Informatics, 492R-50 N. Dunlap Street, Memphis, TN 38103; E-mail: ashabann@uthsc.edu.

and prevention. In the recent years IoT assets have been widely adopted in health and clinical services as well as disease monitoring and surveillance [2, 3]. In addition, different types of sensors (e.g. for remote health monitoring (blood pressure and heart rate monitors and emergency notification systems) and GPS devices have been employed to generate epidemiological models of the spatial spread of infectious diseases. These provide explanatory and predictive patterns for the spread of a virus and measure the likely routes of infected persons and predict possible new outbreaks. Their use facilitates planning for preventive and therapeutic programs (e.g. vaccination). Some examples of the use of IoT to combat malaria and other infectious diseases [4] are; (i) Sensor- and SMS-enabled village water pumps (Rwanda, Kenya), (ii) GSM-connected refrigeration for vaccine delivery (Global), (iii) sensor-enabled "band aid" to monitor patients vital signs remotely (West Africa). One of the main challenges in using surveillance data is creating a mechanism by which such dynamic data, scattered in multiple heterogeneous data sources, can be consistently integrated and aggregated, shared, and analyzed to enable timely decision-making.

2. Methods and Results

The IoT assets have been utilized for malaria surveillance in various ways. Some of these include:

- Real-time satellite data collection, with focus on parameters such as temperature. pressure or other environmental indicators, remote sensing devices [5].
- Cell phone-based polarized light imaging [6].
- Tools for flight track analysis of Anopheles gambiae [7],
- Smart devices to capture data on travelers, data to quantify human movements, and displacement using mobile call detail records (CDRs) [4].
- Mobile phone surveillance to track and monitor malaria cases in remote villages (e.g. Botswana Mobile Device Surveillance) [8].
- Surveillance apps (e.g. Coconut Surveillance App - MEEDS, in Zanzibar for passive and active case detection) [9].

The success of IoT technologies is built mainly on their "interoperability", which refers to "the ability of two or more systems (computers, communication devices, networks, software, and other information technology components) to interact with one another and exchange information according to a prescribed method in order to achieve predictable results" (ISO/IEC [10]). IoT by its nature is an integrated set of several devices communicating within a network and exchanging data and information with each other to achieve a common goal. Although many approaches tend to improve structural and syntactic interoperability, achieving semantic interoperability remains an ongoing challenge for IoT systems.

We are employing tools and techniques from knowledge representation and semantic web in combination with IoT to create a Semantic Web of Things (SWoT) [11] platform that uses the interoperable IoT-based surveillance data along with the domain (here malaria) knowledge for effective malaria control and prevention. We aim to provide an integrated semantic platform (Figure 1) that can be accessed by multiple users (e.g. researchers, epidemiologists, and public health practitioners) for real-time monitoring, tracking, and analysis of datasets generated by different IoT assets operating in different platform and protocols with different levels of complexities. For maintaining the interoperability between different data sources and devices we employ the Semantics, Interoperability, and Evolution for Malaria Analytics (SIEMA) framework [12, 13], along with a graph-based formalism [14] for managing changes within dynamic distributed sources.

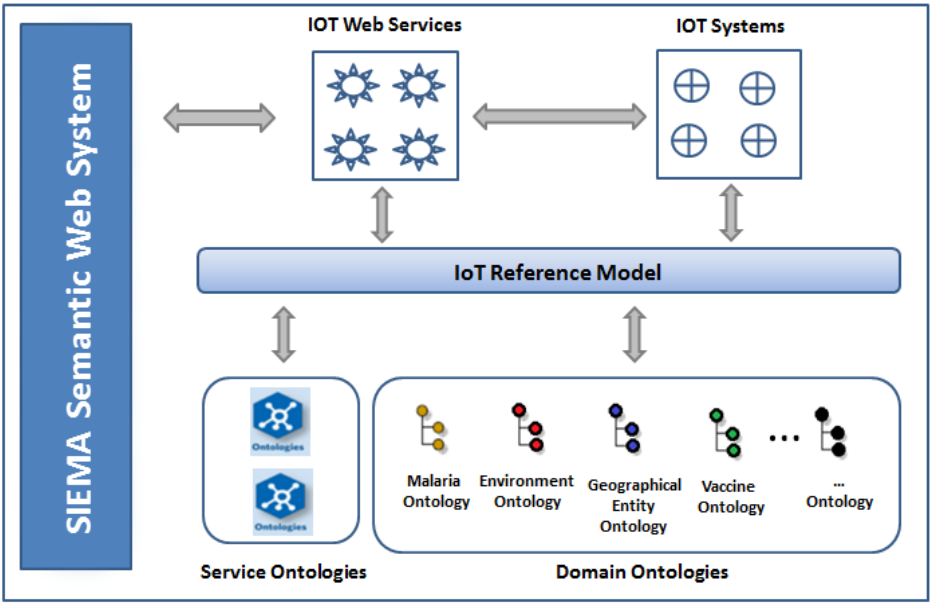

Figure 1. A schematic representation of the semantic web of things for malaria surveillance.

SIEMA deploys the IoT web services that access and manage distributed IoT devices, sensors, and systems. The semantics to define interactions and interoperability between the IoT systems and services are supported by a series of domain and service ontologies and their communication is managed through an IoT Reference Model (IoT RM) [15] that provides the concepts and definitions on which IoT architectures can be constructed. The ontologies can provide a shared common understanding of the IoT devices, their missions, resources, functionalities, and the domain they are working in. SIEMA can assist in discovering and deploying context-appropriate web services in a dynamic environment.

3. Discussion

Our proposed framework aims to improve decision making for malaria control and prevention by increasing the interoperability between malaria data sources and relevant IoT-based surveillance devices and reducing the time for data harmonization and integration. In the near-term, we will generate a registry of discoverable services using Valet SADI [16] to ensure the interoperability of IoT assets and to support dynamic data integration while considering the evolving nature of data sources coming from multiple devices.

Acknowledgment

This research has been partially supported by Melinda and Bill Gates Foundation and Microsoft Research Inc. through Azure Research Award CRM:0518540.

References

[1] World Health Organization. World Malaria Report 2019. Geneva; 2019. License: CC BY-NC-SA 3.0 IGO.

[2] Zhu H, Podesva P, Liu X, Zhang H, et al. IoT PCR for pandemic disease detection and its spread monitoring. Sensors and Actuators B: Chemical 2020;303: 127098.

[3] Santamaria AF, et al. An IoT Surveillance System Based on a Decentralised Architecture. Sensors (Basel) 2019;19(6): 1469.

[4] Biggs P, Garrity J, LaSalle C, Polomska A, Pepper R. Harnessing the Internet of Things for Global Development. ITU/UNESCO Broadband Commission for Sustainable Development, Geneva, 2016.

[5] Contribution of remote sensing to malaria control. Med Trop (Mars) 2015;69(2): 151–159.

[6] Pirnstill CW, Coté GL. Malaria Diagnosis Using a Mobile Phone Polarized Microscope. Sci Rep. 2015;5: 13368.

[7] Spitzen J, Spoor CW, Grieco F et al. A 3D Analysis of Flight Behavior of Anopheles gambiae sensu stricto Malaria Mosquitoes in Response to Human Odor and Heat. PLoS One 8(5): e62995.

[8] Chihanga S, et al. Malaria elimination in Botswana, 2012–2014: achievements and challenges. Parasit Vectors 2016;9: 99.

[9] Coconut Surveillance App, Retrieved on May 15, 2020. https://coconutsurveillance.org/history.

[10] ISO/TR 16056-1:2004(en), Health informatics — Interoperability of telehealth systems and networks. Retrieved on May 15, 2020. https://www.iso.org/obp/ui/#iso:std:iso:tr:16056:-1:ed-1:v1:en.

[11] Jara AJ, Olivieri AC, Bocchi Y, Jung M, Kastner W, Skarmeta AF. Semantic Web of Things: an analysis of the application semantics for the IoT moving towards the IoT convergence. Int. J. Web and Grid Services 2014;10(2/3): 244–272.

[12] Brenas JH, Al Manir MS, Baker CJO, Shaban-Nejad A. A Malaria Analytics Framework to Support Evolution and Interoperability of Global Health Surveillance Systems. IEEE Access 2017;5: 21605–21619.

[13] Al Manir MS, Brenas JH, Baker CJ, Shaban-Nejad A. A Surveillance Infrastructure for Malaria Analytics: Provisioning Data Access and Preservation of Interoperability. JMIR Public Health Surveill. 2018;4(2): e10218.

[14] Brenas JH, Strecker M, Echahed R, Shaban-Nejad A. Applied Graph Transformation and Verification with Use Cases in Malaria Surveillance. IEEE Access 2018;6: 64728–64741.

[15] Bauer M, et al. IoT Reference Model. In: Bassi A. et al. (eds) Enabling Things to Talk. Springer, Berlin, Heidelberg, 2013.

[16] Al Manir MS, Riazanov A, Boley H, Klein A, Baker C. Valet SADI: provisioning SADI web services for semantic querying of relational databases. In Proc. of 20th International Database Engineering & Applications Symposium, IDEAS '16; Jul 11-13 (2016), p. 248–255.