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Semantic interoperability for big-data in heterogeneous IoT infrastructure for healthcare

Farhan Ullah[a], Muhammad Asif Habib[b], Muhammad Farhan[a], Shehzad Khalid[c], Mehr Yahya Durrani[d], Sohail Jabbar[b,*]

[a] Department of Computer Science, COMSATS Institute of Information Technology Sahiwal, Pakistan
[b] Department of Computer Science, National Textile University, Faisalabad, Pakistan
[c] Department of Computer Engineering, Bahria University, Islamabad, Pakistan
[d] Department of Computer Science, COMSATS Institute of Information Technology Attock, Pakistan

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ABSTRACT

Interoperability remains a major burden to the developers of Internet of Things systems. It is due to IoT devices are extremely heterogeneous regarding basic communication protocols, data formats, and technologies. Furthermore, due to the absence of worldwide satisfactory standards, Interoperability tools remains imperfect. In this paper, we have proposed Semantic Interoperability Model for Big-data in IoT (SIMB-IoT) to deliver semantic interoperability among heterogeneous IoT devices in health care domain. This model is used to recommend medicine with side effects for different symptoms collected from heterogeneous IoT sensors. Two datasets are taken for the analysis of big-data. One dataset contains diseases with drug details and the second dataset contains medicines with side effects. Information between physician and patient are semantically annotated and transferred in a meaningful way. A Lightweight Model for Semantic annotation of Big-data using heterogeneous devices in IoT is proposed to provide annotations for big data. Resource Description Framework (RDF) is a semantic web framework that is recycled to communicate things using Triples to make it semantically significant. RDF annotated patients' data and made it semantically interoperable. SPARQL query is used to extract records from RDF graph. Tableau, Gruff-6.2.0, and Mysql tools are used in simulation in this article.

1. Introduction

Internet of things (IoT) is a combination of diverse, smart objects which have sensing capabilities and identified by Radio Frequency Identifier (RFID) technology. Specifically, the integration of sensors, RFID tags, and communicating technologies build the foundation of IoT. IoT interconnects real world objects as smart objects which can sense each other according to the environment. It addresses the traceability, visibility, and controllability of smart objects. There are many applications of IoT e.g. environmental monitoring (Pavithra & Balakrishnan, 2015), Healthcare service (Nugroho, 2015), inventory and production management (Agra, Christiansen, Ivarsøy, Solhaug, & Tomasgard, 2016), food supply chain (Zhao, Fan, Zhu, Fu, & Fu, 2015), transportation and logistics (Qu et al., 2016), smart cities (Misra, Rajaraman, Dhotrad, Warrior, & Simmhan, 2015), smart homes (Ghayvat, Mukhopadhyay, Gui, & Suryadevara, 2015), security system (Han, Jeon, & Kim, 2015), firefighting system (Grant, Jones, Hamins, & Bryner, 2015) and mining production (Hu, Ding, Wu, Cao, & Zhang, 2015).

In spite of its broad spread emergence, IoT is still in its infant stage and has big scope for research in a variety of issues like interoperability standards, scalability, heterogeneity of different devices, domain specific service discovery, integration with existing IT systems and so on. In IoT, one specific issue is interoperability among smart devices to interconnect and communicate heterogeneous devices to form a *cost-effective* and *easy to implement the* network. Low-cost interoperability among smart objects is a vital aspect for IoT. Smart mesh backbone gateways (Linksys WRT54GL and Soekris net5501) are developed for smart cities which provide low-cost interoperability (Avelar et al., 2015). The solution of interoperability will help the customers to continue working in a mixed environment in nearer future. It will solve the complexity of an organization's infrastructure, reduce the cost of buildings and help in supporting diverse infrastructure. In parallel to it, energy aware algorithms are required to ask from users for routing their packets on wireless or IEEE 802.11 mesh network. Thus, it will save the energy of smart objects (Avelar et al., 2015). IoT increases the workflow efficiency in any environment and connects smart objects from anywhere to anywhere using heterogeneous devices.

* Corresponding author.
E-mail addresses: farhankhan.cs@gmail.com (F. Ullah), drasif@ntu.edu.pk (M.A. Habib), farhansajid@gmail.com (M. Farhan), shehzad_khalid@hotmail.com (S. Khalid), mehryahya@ciit-attock.edu.pk (M.Y. Durrani), sjabbar.research@gmail.com (S. Jabbar).

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Interoperability related issues can be solved with the development of commonly accepted standards. All smart objects from multiple vendors should operate on common standards. If we can mix IoT into existing IT infrastructure, then it will solve many issues like protocol using, packet size, encryption/decryption algorithms, and so on. Functioning smart objects to existing Internet Protocol version 6 (IPv6) configuration may be expensive because it is hard to embed RJ45/WLAN port in every smart object but IoT Industry is now working on roaming the IoT standards to existing IPv6 and Ethernet standards to ensure the interoperability with legacy protocols. IP for Smart Objects (IPSO) (www.ipso-alliance.org) stimulates IPv6 as a distinctive identification for discovering, accessing and communicating the smart objects (Chen, Doumeingts, & Vernadat, 2008). Interoperability issues can be solved through different vendors' collaboration. Collaboration is needed between enterprise modeling societies that are developing business-oriented architecture and software engineering companies that are working on IT oriented solutions (Chen et al., 2008). The same issues can also be solved if communicating smart devices are semantically interoperable. It gives the detail about the structure of transferred data. Communication among smart objects is semantically understandable (Ambrosio & Widergren, 2007; Xiao, Guo, Da Xu, & Gong, 2014). Robust infrastructure is required for interoperability to fit any device from multiple vendors. The consumer must feel free to use any device from any vendor, and on the other hand, the vendor should care of consumer reliance.

Information that is common among smart objects needs to be a common accepting of QoS (Quality of Service), sequencing and time. Interoperability algorithms should care of time synchronization and sequencing (Ambrosio & Widergren, 2007). Deficiency of standards for interoperability is a big question in IoT. Now vendors making devices conferring to domain specific and which can be used for some special commitments according to surroundings. Interoperability has the issue of worldwide heterogeneity because IoT devices are highly diverse. Devices from several vendors have different methods for semantics and syntactic interoperability methods, so there will be semantic and syntactic errors. It will be difficult to add a new device in IoT network without semantic ambiguity. Syntactic conflicts among IoT devices means they have different message format (Ambrosio & Widergren, 2007). In health care domain, it can deliver high worth care to patients when every device works in "interoperable environment". In health care industry, it programs the hospitals that will observe the patients by physicians remotely. It will afford fast access to patient's records from diverse IT storage systems placed anywhere.

In this paper SIMB-IoT model is proposed which offers semantic interoperability for big data among heterogeneous IoT devices. Two datasets were used for the analysis of big data. One dataset contains diseases with drugs details and the second dataset contains drugs with side effects. Different symptoms of diseases collected from IoT sensors and under the supervision of physician, SIMB-IoT model suggests the drugs with side effects details. Further, A Lightweight Model for Semantic annotation of Big-data using heterogeneous devices in IoT is proposed to provide annotations to data. RDF is used to offer semantic interoperability among physicians and patients using heterogeneous IoT devices. SPARQL query is used to find hidden patterns in the graphical database.

This paper is mainly divided into 5 sections which are Literature Review, IoT-based Semantic Interoperability Model (IB-SIM), Semantic annotations of data using heterogeneous IoT devices, experiments and results, and conclusion and future work respectively.

2. Literature review

IoT smart objects from diverse vendors can be incorporated in health care environment to support physicians and patients remotely. Physicians can observe their patients anytime, anywhere and can change treatment when required. In Santos et al. (2016), authors used Intelligent Personal Assistant (IPA) as software agent in IoT device for a physician to give real-time information about the observed patients. The AMBRO mobile gateway gathers information from different IPA devices and then take schedules. It empowers interoperability among different IPA devices. The AMBRO device uses the only definite operating system and does not incorporate with any other operating system such as iOS or Windows phones. Semantic web technologies are capable tools for this commitment to share data and interchange their services resourcefully, which interconnect a significant number of smart devices with heterogeneous abilities. In Yachir et al. (2016), the authors proposed a semantic model for the narrative of smart things using ontologies and description judgments to allow semantic interoperability. This semantic model still requires additional empirical evaluation to improve the service classifications for semantic interoperability among smart objects. There is a need to gather information about crop growth observing and irrigation judgments support through smart objects.

Jayaraman et al. (2015) proposed an OpenIoT platform used for digital agriculture use case (Phenonet). To enable semantic interoperability, the OpenIoT platform used ontologies to signify Phenonet domain ideas to collect a smart collection of information, annotation and validation procedures. A scalable and intelligent IoT architecture is required for the upcoming era to assist discovery of environmental sensors and interoperation semantically and syntactically. Desai et al. (2015) proposed semantic web permit architecture to afford interoperability among smart things. The Semantic Gateway as a Service (SGS) combined semantic web technologies to enable communication between protocols such as XMPP, CoAP, and MQTT. The ontologies are used for semantic reasoning to provide semantic interoperability among interactive posts. Though there are different methods settled for semantic interoperability for IoT devices, there is still a lack of proper methodologies for interoperability in technology and standard data presentation of data.

Girard, A. and M. Serrano the proposed SEG 3.0 approach to unifying, merge and provide semantic interoperability in IoT domain. The SEG 3.0 arse from ontology engineering and its key advantage is to mix heterogeneous data collected from different smart things. The authors applied SEG 3.0 methodology in three different use cases; In M3 context to assist developers to scheme semantic-based IoT applications, the VITAL EU project for smart cities and the FIESTA-IoT EU project for semantic interoperability. For the filling level of performance among low-power heterogeneous networks, there is a requirement of interoperability protocols standards. To link this gap, the author defined in (Fotouhi, Čaušević, Vahabi, & Björkman, 2016) structures of different protocol stacks such as Bluetooth, Bluetooth Low Energy, IEEE 802.15.4, ZigBee, 6LoWPAN and IEEE 802.15.6. Moreover, authors proposed the planning of generic protocol stack that interconnects with multiple radios and with different protocols concurrently, irrespective of IP-based or non-IP-based systems. Mingozzi et al. (2016) proposed an innovative identical platform designed to take account of context-awareness functionalities and exposed how such tasks can be exploited to mechanize search and selection of things through natural language. It is presented that context can be used on *things services* to mining knowledge through semantic perception in smart homes.

Todays' smart headsets have vast connectivity and sensing abilities for helping body area networks and physiologic sensors. Common standards are the controlling essentials to empower interoperability between Machine-to-Machine (M2 M) in IoT. (Pereira et al. (2016) suggested the design of ETSI M2 M gateway, combined with libraries to ease the distribution of IoT applications with condensed development budgets. Its performance exposed by computing the smartphone's CPU and Memory usage and battery lifetime. Jayaraman et al. (2016) proposed an architecture for data processing in IoT cloud environment that backing semantics interoperability. Google Cloud and Microsoft Azure were used as a multi-cloud environment with OpenIoT architecture. Shariatzadeh et al. (2016) used IoT notion in the factory to make it computerized. Data transfers from heterogeneous IT environment to