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The use of standards in embedded devices to achieve end to end semantic interoperability on health systems

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ABSTRACT

Nowadays, an approach to improve the quality of medical services is the semantic interoperability, and to achieve it, physiological transducers descriptors and data from physiological transducers need to be shared and understood in the same way by Medical Information Systems (MIS), the importance of the physiological transducers in medical environment and at home healthcare monitoring is growing; they provide physiological data, such as body temperature, glucose level, blood pressure, among other parameters to improve medical services. This is the reason why this work proposes the integration of HL7 V3, a standard of Health Level 7 (HL7) family and a second family of standards named IEEE1451; the latter manages smart transducers and the definition of Transducer Electronic Data Sheets (TEDS). To achieve semantic interoperability, a message template is proposed which includes date, physiological transducer sample, basic TEDS, transducers template identifier, a link to the complete TEDS, among other important features from physiological samples. As a case of study here, the HL7 V3 - IEEE1451 TEDS message defined by the template is sent by an application implemented on a network gateway NXP's Tower System to a remote server recipient. This way, the main contributions of this paper are: i) the design and implementation of a message template that integrate HL7 V3 and IEEE1451 standards into an embedded gateway device NXP's tower system; and ii) a testbed based on embedded devices to show that it is possible to achieve end to end semantic interoperability.

1. Introduction

Technological advances in wireless networks, electronics, and microprocessors have enabled the development of smart transducers; which consist of a data processing unit, and a communication interface [1]. A transducer is a device that interprets parameters or detects events in its surroundings; it also provides signals that can be analyzed. In this paper the interest is in physiological transducers, which are used in the medical environment to collect physiological variables in humans, such as body temperature, heart rate, blood pressure, glucose level in blood, among others [2,21]. Besides, transducers are characterized by high heterogeneity in the methods used to deliver data in raw format, or in processed readings in different units of measurement [3]; this presents great challenges to achieve interoperability between Medical Information Systems (MIS).

The term *Interoperability* is defined in [4] as the ability of two or more information systems and their components to exchange and use information. There are different types of interoperability: technical, syntactic, and semantic, among others. This article focuses on semantic interoperability through Health Level 7 (HL7) family standards and IEEE1451.

Syntactic interoperability ensures conservation of healthcare information based on data structure, while semantic interoperability allows us to interpret exchanged medical data in the same way [5]. This allows exchanging data with other applications, including medical information acquired through devices of electronic context data acquisition (transducers).

HL7 family standard provides a set of syntactic rules and suggestions for using semantic elements to exchange health information. The family of standards IEEE1451, describes the characteristics of smart transducers and Transducer Electronic Data Sheets (TEDS), which contains information about the transducers, such as the calibration procedure for a particular measuring system [6].

By combining the use of the two families of standards mentioned above, a template that generates a message called HL7 V3-IEEE1451 TEDS is proposed, which provides to MIS the ability to handle samples from physiological transducers, as well as the capacity to understand data contained in the message, thus achieving semantic interoperability.

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Obtaining and understanding data in the same way in the target system enhances the quality of the process in which its analysis is involved.

2. Brief review of HL7 standards

HL7 family standards [7,8], uses messages and documents called artifacts to exchange data; created from a health care event, called trigger events [9]. The most relevant HL7 family standards are described in the following paragraphs:

- HL7 Version 2 (HL7 V2) is a messaging standard that enables the exchange of clinical data, it is characterized by using the separator pipe "|" to delimit text within a message. HL7 V2 is considered the workhorse of electronic data interchange (in the clinical domain) within the HL7 family of standards; it is the standard is it the most used healhcare worlwide. A work developed under this standard version is shown in [10].
- HL7 Version 3 (HL7 V3) is based on a methodology for the exchange of clinical information that generates messages and electronic documents, which follow the format of the structure of extensible markup language (XML). HL7 V3 defines the Reference Information Model (RIM), which allows it to offer syntactic and semantic interoperability because it defines the structure of the artifacts.
  Derived from HL7 Version 3 messages, it is possible to generate documents, as defined in Architecture of Clinical Documents (HL7 V3 CDA) where the structure and semantics of clinical documents must be followed to achieve clinical information exchange.
- HL7 Fast Interoperability Resources in Health (HL7 FHIR) combines the best features of HL7 V2, HL7 V3, and HL7 V3 CDA. This standard to name its artifacts uses the term resources, instead of messages and documents as the HL7 V3 standard. HL7 FHIR mainly follows the structure of XML format and the JavaScript Object Notation (JSON) format.

HL7 V3 was selected by this research because: it follows the XML format; which provides a more flexible way to exchange information. Another reason why the HL7 V3 standard was chosen was because its artifacts base their structure on templates, as mentioned in [11]. In this article, a new template based on the selected standard is proposed, which includes the Basic TEDSs as mentioned in and [12,13].

3. The IEEE1451 family of standards

A smart transducer defined by the IEEE1451 family of standards provides the necessary functions to generate a valid representation of an acquired or controlled physical variable. The IEEE1451 family standards enable transducer manufacturers to build interoperable elements, achieving connectivity between transducers and microprocessors [14]. The family of standards divides the parts of a system in Network Capable Application Processor (NCAP) and Transducer Interface Modules (TIMs). If NCAPs manufacturers and TIMs comply with the rules defined by the IEEE1451 family of standards, it makes them interoperable [15], see Fig. 1.

The EEE1451 family standards are formed by the following work groups:

- IEEE1451.0-2007 Defining common functions, communication protocols and TEDS formats.
- IEEE1451.1-1999 Network Capable Application Processor Information Model.
- IEEE1451.2-1997 - Transducer Communication Protocols for Microcontrollers and TEDS templates.
- IEEE1451.3-2003 Digital communication and TEDS distribution template for multiple separate transducers, one processor on a single pair of wires.
- IEEE1451.4-2004 - Mixed-mode (analog-digital) communication protocols and TEDS formats.
- IEEE1451.5-2007 Wireless Communication Protocols and TEDS formats.
- IEEEP1451.6 - A transducer and a standard closed loop controller for operation in a network environment of intrinsically safe cascading network, with multiple controllers in each level.
- IEEEP1451.7 Standard test for Interfaces for Smart Transducers, Sensors and Actuators-Transducers; to Radio Frequency Identification Systems (RFID), Communication Protocol and TEDS formats.

The work proposed in this article focuses on the IEEE1451.3 and IEEE1451.5 standards, with plug and play capabilities to analog transducers provided through the use of TEDS, containing relevant information for a device or measuring system.

4. Related work

In 2006 Kim et al. [16], introduced option of integrating the HL7 and IEEE1451 families of standards. They described the IEEE1451.1 standards to the IEEE 1451.4 standard; and the basic characteristics of the HL7 family of standards. This article also explains an implementation of the IEEE1451.1 standard in a case using IBMs Spac-Sungil as publisher and SPAC-hwan as the subscriber; the authors of this paper developed the publish-subscribe protocol with a personal computer mounted on a single board printed circuit (SBPC); the authors stated that, at the time of development, there was no connection between NCAP developed in the SBPC and the Smart Transducer Interface Module (STIM).

In 2009, Kim et al. [13] studied the possibilities to achieve interoperability between IEEE1451 and HL7 V2.5 standards by using physiological transducers; where measurements of physiological parameters of patients are sent for processing to a Personal Digital Assistant (PDA). Some of the processing skills are: calibration, feature extraction, the decision on patient status; processed data is sent to a hospital or emergency center. In this paper the authors describe the data structure of a message HL7 V2.5 and the IEEE1451 standard TEDS template. In 2015, authors of [10] developed a smilar work but using IEEE11073 and HL7 standards.

Lee et al. [12] proposes a system for monitoring home health care, based on an exchange framework of clinical data between HL7 artifacts and monitoring devices compatible with the IEEE1451 standard. The authors considered developing a middleware, as intermediary software between the HL7 standard running on a personal computer, and the IEEE1451 standard on a PDA. In this article the following conclusions were reached: the HL7 standard can be readily applied on the personal computer architecture and some mobile devices, but is more difficult with embedded device implementation ; the latter assertion encouraged the proposal in this paper, its main contribution being to demonstrate the feasibility of implementing the use of HL7 V3 and IEEE1451 standards integrated into a template to be used in embedded devices.

Related aforementioned work used the HL7 V2.5 standard; for its part Baird et al. in [17] describe the implementation of a template using the HL7 V3 standard to request and retrieve information from sensors associated in a gateway device, which contains HL7 web service methods to manage information showing that the use of an HL7 V3 standard and data from transducers is feasible.

Using embedded devices Ramirez et al. in [11], proposed the design of a digital device handling the data from sensors and sending it to the cloud. Data acquisition is comply with IEEE1451.0, IEEE1451.1, IEEE1451.5 standards and Health Level 7 (HL7) on the application layer. Their contribution is the embedded device called "gateway" able to receive data from wireless technologies like Wireles Sensor Networks or Bluetooth (IEEE802.15.4 and IEEE802.15.1 standards respectively), and send it to Internet through WiFi or Ethernet data networks (IEEE802.11 and IEEE802.3 standards respectively).

The authors of [18], emphasizes on achieving semantic interoperability across multiple electronic health records (EHRs), through ontologies and Model-driven Engineering techniques. Also, they propose to