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# The Nexus of IoT Devices and Healthcare Level 7 (HL7)

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***Abstract:*** The main goal of this study is to discuss the need for interoperability of Electronic Health Records (EHR) and Internet of Things (IoT) and highlight how the Health Level 7 (HL7) interoperability standard could be the solution to bringing the benefits of these disparate systems together for the benefit of all patients. This study conducted a thorough literature search and analyzed the EHR and HL7 critically. The results highlight that the health care industry is experiencing unprecedented changes, with a considerable increase in the use of electronic/automated systems that can make considerable improvements in the quality of life of patients around the world. However, to achieve such benefits, these systems need to be able to communicate freely with each other. Thus, more emphasis is made on improvising the health care systems such that they provide maximum benefits for the patients.

***Keywords:*** *HL7, IoT, healthcare, EHR.*

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## I. INTRODUCTION

Ever since the internet became a major force in communication around the world and computers became more commonplace, the medical industry has embraced them to some extent. For example, before EHR became a wide stream, doctors started looking at moving billing functions into their offices as billing software became more sophisticated and capable of handling the billing process [1]. This either greatly reduced or eliminated the cost of using outside services entirely, enabling doctors to continue to provide high-quality patient care while keeping their overhead costs low.

The next step in the electronic revolution was the move to EHR. While the shift to moving to bill into the local doctor's office was a relatively smooth one, motivated by reducing considerable costs of billing services, the move to EHR was another matter entirely [1]. As of 2007, according to Simon [2], it was reported that only 17.6% of medical offices had adopted the use of EHRs in the United States. The difference in adoption rates for EHRs may be related to the benefits such records provide. The Institute of Medicine (IOM) promoted the wide-scale adoption of EHRs to improve patient safety and health care quality. There may also be more significant obstacles to adoption of EHRs at the practice level.

Among the obstacles to EHR adoption noted by Simon et al. [2] was the fact that offices that were financially stronger and had more technologically-advanced practices were more likely to adopt EHR in their practice than those who were not. Two other major barriers to adoption were the high cost of implementing the new systems, and the loss of productivity that would occur as staff in the office had to learn the new systems. While it may seem that these problems were unique to the small medical office, the facts illustrate that major medical institutions were facing similar barriers to adoption.

While it would seem that medical centers and hospitals, organizations with considerably more finances, sophistication, and staffing would have an easier time adapting to the new technology, the facts indicate that this was not necessarily always the case. Concerns about the safety of EHR technology arose in larger organizations, with concerns of the vulnerability of personal health information to hacking, possible errors in software, and po-

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tential of litigation in the case of injuries due to the use of EHRs [3]. Another factor that thwarted widespread adoption of EHR at the medical center and hospital level was the considerable costs involved in adopting such systems. The federal government stepped in with financial incentives introduced in the HITECH Act, and this has largely fueled wider adoption of EHR systems with growth continuing as of this writing [4]. EHR is becoming more widely adopted, and this may bring benefits to patients in many yet-unforeseen ways.

### A. New Advances in Medical IoT

While much of the focus in the healthcare industry has been on the adoption and use of EHR to improve patient care and improve safety, another revolution has been occurring simultaneously in the healthcare industry. As Manyika et al. noted, with the advent of wearable sensors and portable monitors, IoT has potential to improve health outcomes substantially, especially when it comes to chronic diseases such as diabetes which exact a considerable toll both economically and on health and quality of life [5]. This potential has manifested itself in the healthcare industry in a number of ways.

For example, many patients who are elderly are at an elevated risk of falling, which could endanger their health can potentially cause serious injury [6]. Shubhankar, Pranav, Varun, and Chandrashekar report on an IoT sensor system that could dynamically monitor an at-risk patient and sound an alarm if the patient's posture or stance indicates that they are in imminent danger of falling [7]. If a patient in a long-term care facility were wearing such sensors, this would enable staff to rapidly respond to their room, providing needed assistance to prevent the patient from experiencing a harmful fall.

Another population that requires advanced surveillance is the population that suffers from cardiac disorders, which leave them prone to strokes or heart attacks. As Dey et al. reported, continuous monitoring is preferable to identifying and acting on risk factors for such occurrences [8]. However, Electro Cardio Grams (ECG), which are the most common devices used to detect heart abnormalities, generally involve placing electrodes on the body and attaching them via cables to monitoring equipment which monitors which detect and amplify electrical impulses that the heart emits, enabling detection of abnormalities.

The problem, as Dey et al. point out, is that such systems are bulky and the attachment of electrodes often seriously impedes the individual who is being monitored from being fully mobile or active [8]. Another approach for long-term monitoring, a portable Holter monitor device could be used, but these are bulky as well. The most recent innovation in this area was the invention of an IoT device that utilizes Bluetooth and Zigbee to transfer information from sensors on the body to remote systems, where the data can be monitored, with any deviations being noted and attended to.

Another obvious area for remote monitoring via IoT devices is that of monitoring chronic conditions like diabetes. The Zigbee protocol is being utilized to monitor patients with diabetes [8]. Deshkar, Thanseeh, and Menon explain that several different options have been developed for remote maintenance and management of diabetes [9]. One solution in particular uses sensors on the patient's body, which communicate with an Arduino-IT microcontroller that translates and interprets the information, then sends information as appropriate to the patient's healthcare provider and/or EHR depending on the information received. If the patient's readings pass a critical threshold, the care provider can be emailed or even paged to notify them of the aberrant condition of the patient.

### B. EHR Systems and IoT

While both EHR systems and IoT devices have shown considerable advantages in use individually, there are definitely benefits where the two could be integrated into ways that could advance care for the patient [10]. However, integration on this level does require a certain level of communication between the disparate devices [11]. As Manyika et al. stated: "Interoperability between IoT systems is critically important to capturing maximum value; on average, interoperability is required for 40 percent of potential value across IoT applications and by nearly 60 percent in some settings" [5]. Luz, Masoodian, and Cesario [12] spoke to this need as well, noting: "there is also the underlying issue of the management and integration of health information from different healthcare providers and health programs, particularly in developing countries, where there is a need for ICT infrastructure and common standards for sharing and exchange of information". In order for IoT to work with hospital and doctor office EHRs as well as other systems, there must be a common form of communication between the disparate devices.

The healthcare industry has a common language that has been developed by Health Level Seven International (HL7) in order to create standards for exchanging information between different EHR manufacturers [13]. The purpose of establishing HL7 was to create an interoperable standard whereby different EHR systems could communicate information with each other. When an application is designed to write data for interchange using HL7, this facilitates communicating information across companies, systems, and countries.

## II. RESEARCH STRUCTURE

The research structure applied in this research into four parts. The first part is addressed the general overview of the EHR. The second part of this research is applied under the literature review of the EER, as well as what the scholars achieved and what problems they faced. The third part of this research discourses the modernity of EHR and the new advances that applied in the medical institutions through IoT. While, the last part mentioned in this research is the HL7 which has been taken as an example to illustrate the application technology in the medical and how it works and serves in the medical field.

## III. THE OVERVIEW OF HL7

Medical errors can cost between seventeen and twenty-nine billion dollars annually [14]. What is HL7 and how can it help reduce these costs? HL7 was founded in 1987 in an effort to provide standards for exchanging EHR [15]. Otherwise, HL7 defines as a message that is utilized to exchange electronic medical data inside various healthcare's applications [16]. The need for HL7 has grown exponentially since 1987. The United States government implemented Health Insurance Portability and Accountability Act (HIPAA) in 1996 and Health Information Technology for Economic and Clinical Health (HITECH) in 2009 [17]. These two laws have worked together rendering the need for medical standards were long overdue. Part of the goal of HIPAA was to use technology to help reduce costs. The HITECH act pushed medical facilities to automate more quickly, first by offering incentives, and, finally, by imposing fines.

The purpose of HL7 is to provide standards that allow medical data to be shared globally between multiple applications. The 7 in HL7 stands for the seven layers of the International Standards Organization Model (ISO): physical, data link, network, transport, session, presentation, and application [18]. HL7 was initially created to simplify application communications and collaboration. This began as a very tedious and complex coding effort, requiring costly and timely changes with every new application [18]. As of 2007, ninety percent of all US healthcare facilities and organizations in twenty-seven other countries were using HL7 to manage clinical data, government healthcare entities, and/or healthcare informatics. This may be considered one of the world's first Application Programming Interface (APIs). However, HL7 is not an application or set of code in and of itself, but guidelines on how to construct data. Applications written to align with HL7 make it easy to connect data across platforms, across companies, and across countries.

HL7 has grown so much so that there have been companies that create, maintain, and deliver HL7 interfaces for clients. There must be a sending and a receiving module for the data to transmit securely. Oftentimes, the data needs to be translated from its raw HL7 format, so the receiving and/or sending modules can understand the data. An interface engine may be used to aid in the translation. The interface engine gives an organization more control over its data by reducing other interfaces, reusing the internal data in other applications, simplifying the use of applications, allowing the entire system to be monitored in house, actively notifying system admins on premises. Using an interface engine on the information system to transmit the data from sender to receiver, reduces the cost it takes to build interfaces for each system. As systems are added to the process, the interface engine just needs to connect to it. It can link medical data, billing, prescription data, and any other system data on the network using the single-engine interface. It is a much smoother and cheaper method than creating an interface for each application added to the information system.

HL7 organization, along with its CEO Charles Jaffa, MD, provided the HL7 standards fee-free. The desire was to make the intellectual property available free of charge worldwide, with the hopes of increasing usage. Offering the information free works to encourage other countries to use the standards [19]. The more entities using the standards, the more easily medical data may be connected and maintained. This offers a reduced cost to healthcare by reducing the cost of maintenance.

## IV. THE BENEFITS OF HL7

HL7 may not be needed in all healthcare organizations yet. However, as technology becomes more mobile and more prevalent in other countries, the need for HL7 will continue to grow [20]. Globalization is a buzzword that helps describe the medical industry and the need for HL7. Even though an entity may have no need for HL7 up front, it is suggested that HL7 is adopted as the standard regardless. There will be a point in time when every medical institution will have a need for HL7. Getting started on it from the ground up positions a medical facility in the front of the line. It will be easy to connect with other applications and share data. Most entities that reject HL7 standards, or put them in a low priority category, does so as a result of technology.

It goes without saying that sharing medical data across multiple applications, reduces time and money. It also provides efficiency and consistency. Medical testing will not have to be done at every medical facility. The testing may be transmitted from one location to another using HL7. There is no need to create individual standards. That part is done and removes the time and cost of planning and building standards. Using eHR and HL7 proves to be a benefit for maintaining a patient's medical history. Drug interactions, allergies, surgeriesall of these things may be shared with anyone using the HL7 standards. The benefits and the needs continue to grow and will continue to expand to different facets and countries [21]. There's also the treatment consistency. Certain symptoms may result in specific diagnoses. This information may be stored in electronic format and quickly and accurately shared with HL7. This also allows medical personnel to share their knowledge and experiences [22].

HL7 is a set of standards used globally to allow healthcare related applications to communicate and share data. HL7 is ISO compliant and uses Extensible Markup Language (XML) to help identify pieces of data. The HL7 board agreed to provide the standard information free globally, hoping to encourage a broader adaptation. HL7 reduces costs by reducing, and, sometimes eliminating, redundancies. Sharing patient data with multiple entities removes ambiguity in all facets of healthcare: testing, medicating, billing, scheduling, demographics, etc. Although HL7 started as an in-house tool to help connect applications, it has grown to a point where there are companies providing the service or the interface engine. Interface engines are excellent tools to use as a single point of connection for all applications within an institution. Interface engines are less expensive way to connect different applications. It reduces the complexity of recoding for each application added and allows a single point of maintenance for all connections. Adding an interface engine to the HL7 information system is an ideal setup to keep costs down. As technology continues to grow, develop, and become more relied upon for daily tasks, HL7 will continue to refine and improve the maintenance and sharing of medical data.

## V. HL7 MESSAGES ENCODING METHOD

Explaining it briefly, HL7 uses XML to create a standardized schema [23]. An example of XML coding in HL7 is the use of the <FN> tag, which represents the first name. When the data stream contains a string delineated by <FN> both the systems sending and receiving HL7 data know that this data string is the first name and interpret it as such into their own systems. This nomenclature is set, meaning that regardless of the underlying system being in English, Spanish, German, or French, the underlying HL7 schema remains the same. This allows for complete interoperability between systems.

Several types of the HL7 messages define to hold various types of electronic medical data to the patient, such as; "the ADT messages type is used for patient's patient administration information" [16]. The inner structure building of HL7 messages application, each frame or structure is applied as an agent, assigned on a particular task, and each agent on a multi-agent platform. Through this platform, persons and diverse in character or content systems can be exchanged and participation patient's electronic data.

Message converting into a coding form depict of how HL7 messages are initialized data from one application to others. Edidin et al. divided the message transmitted into two different types of encoding for HL7 2.x version; first type is Delimiter-based encoding, and second type is XML encoding [16]. Furthermore, HL7 V3 uses XML to map out the data (messages) for applications to read and utilize. XML acts as a map to specify where each piece of data is located. Perhaps a patient's first name would be located in <FN> tags. Using HL7 would place that particular tag in a particular location in the code. An interface engine or some other system would act as a legend of sorts to identify what that piece of data represents. It is pushed to the receiver and whether the receiver speaks English, French, German, or Spanish, the data is understood due to the HL7 standards and XML mapping [23].

The first type of message transmitted during encoding HL7 messages is Delimiter-based encoding; is a cornerstone of defining data fields of variable lengths and disassembles the data by utilizing delimiter. The message frame of HL7 delimiter-based encoding includes the whole data over different components. The different components are *delimiters, segments, fields, data types*, and *escape sequences* [16]. Delimiters are the major components throughout the HL7's messages. Segments in HL7 messages include diversified segments, appears for each segment special data, for instance *laboratory results, patient's details, visiting the patient, patient's insurance*, and so on. Nevertheless, the patient's details should be grouped into different fields. In turn, these Fields carry on the message details. Data types contains following up the details key; *position, length, data type, optionality, repetition, patient's name, ID patient's number*. Escape sequences is defined as "allows you to have special characters in the HL7 message text that are not allowed normally; such as, delimiter characters can be included in the message field by using an escape sequence" [16]. The second type of message transmitted during encoding HL7 messages is XML encoding, or XML schemes. The agent receives HL7 notices of a particular events encoded by

XML form the messages deduction, throughout the events type; it distributes the incoming events into a favorable event line [24]. Herein HL7 gives XML scheme for each version which is propped by HL7 2.x.XML version. Follow the instance in the Fig. 1 below is the XSD scheme encoding [15].

```
<!--
   v2.xml Message Definitions Version v2.4  - ACK
   Copyright (C) Sun Microsystems. All rights reserved.
-->
<xsd:schema
   xmlns:xsd="http://www.w3.org/2001/XMLSchema"
   xmlns="urn:hl7-org:v2xml"
   xmlns:hl7="urn:com.sun:encoder-hl7-1.0"
   targetNamespace="urn:hl7-org:v2xml" xmlns:jaxb="http://java.sun.com/xml/ns/jaxb" jaxb:version="2.0">

   <!-- include segment definitions for version v2.4 -->
   <xsd:include schemaLocation="segments.xsd"/>

   <xsd:annotation>
 <xsd:appinfo source="urn:com.sun:encoder">
    <encoding xmlns="urn:com.sun:encoder" name="HL7 v2 Encoding" namespace="urn:com.sun:encoder-hl7-1.0" style="hl7encoder-1.0"/>
 </xsd:appinfo>
   </xsd:annotation>
```

Fig. 1. XSD scheme encoding

The scheme file for ‘message structureID.HTML’ as described by [16] “a set of many files in HTML format containing a short description of the message and links to the corresponding schemes”. Moreover, >message structureID<.xsd “a set of many schemes each containing the schema definition for a specific message structure specified by message structureID”.

Other schemes show in Fig. 2, *segments.xsd file* encompasses all segments definitions, *fields.xsd file* encompasses all fields definitions, *datatype.xsd file* encompasses all data type definitions, *butch.xsd file* consists of a definition of butch, and the last scheme *messages.xsd file* also includes the definitions of messages all together.

```
    <!--
 MESSAGE ACK
    -->
    <!-- .. groups used in message ACK -->
    <!-- .. message definition ACK -->
    <xsd:complexType name="ACK.CONTENT">
        <xsd:sequence>
            <xsd:element ref="MSH" minOccurs="1" maxOccurs="1"/>
            <xsd:element ref="MSA" minOccurs="1" maxOccurs="1"/>
            <xsd:element ref="ERR" minOccurs="0" maxOccurs="1"/>
        </xsd:sequence>
    </xsd:complexType>
    <xsd:element name="ACK" type="ACK.CONTENT">
        <xsd:annotation>
            <xsd:appinfo source="urn:com.sun:encoder">
                <top xmlns="urn:com.sun:encoder">true</top>
            </xsd:appinfo>
        </xsd:annotation>
    </xsd:element>
</xsd:schema>
```

Fig. 2. The segments.xsd file

## VI. CONCLUSION AND RECOMMENDATIONS

As this study noted at the outset, the healthcare industry has recently undergone considerable changes with the introduction of EHR systems which have enabled healthcare providers to have considerably more information at their fingertips regarding each patient. These systems, while slowly adopted, have become a mainstay of healthcare around the world. As a result, patients are getting better care and having better outcomes.

The advent of IoT devices was also discussed. IoT devices have multiple applications and can help protect patients at risk of falling, provide detailed surveillance of heart patients, and provide ongoing monitoring and information sharing with care professionals caring for patients with diabetes. These are just the tip of the many applications that IoT devices could perform in the healthcare industry. Hence, this domain is open for further exploration.

### Declaration of Conflicting Interests

This work is an original contribution of the author who declares that there is no conflicting interest involved.

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