Design of a FHIR interface for wearable healthcare devices

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***Abstract*—This paper designs a FHIR (Fast Healthcare Interoperable Resources) interface to provide a standard clinical data exchange for personal wearable healthcare devices, aiming at taking them as a part of remote medical services. In uploading, the agent converts the series of sensor readings, such as electrocardiogram, to the JSON-based standard format, divides it into several subparts if necessary, finds the references to relevant resources, and submits the request via RESTful API. For download, a Python client specifies the set of search parameters, gets the target resources from the server, converts them to the language-specific data structure, and hands over to the analysis module. Our testbed is implemented, making use of diverse FHIR tools including the FRED resource editor and the HAPI server.**

Keywords—FHIR standard, stream data resource, medical record sharing, data exchange mechanism

I. INTRODUCTION

The development of communication technologies allows us to build diverse Internet applications and more and more objects from a variety of domains are being connected. Particularly, the WWW makes those connected objects interact more conveniently and enriches our daily lives with smart services. In the meantime, personal medical records, formerly sealed mainly in each hospital information system, are to be open to patients and be exchanged between diverse organizations such as hospitals, institutes, emergency rescue services, and the like, definitely with strict security protection mechanisms and personal agreements. The well-designed sharing of clinical data allows patients to be treated in any hospital even though they are taking long-distance tours and a group of medical doctors belonging to different organizations to interwork with a common observation of patient data.

For the exchange of EHR (Electric Health Record), it is important to define a standard data format and this is carried it by HL7 (Health Level 7) with FHIR (Fast Healthcare Interoperability Resource). Here, the resource denotes the data format and related elements such as patients, organizations, conditions, observations, and the like. Moreover, built upon the web framework, those resources are seamlessly exchanged through a HTTP-based RESTful API with JSON or XML data representation as shown in Figure 1. In this figure, the CRUD interface means Create, Read, Update, and Delete operations and they are requested by web clients via POST, GET, PUT, and DELETE methods, respectively. In addition, each hospital has its medical record database, possibly within the private information system or external data cloud. The CRUD requests are mapped to this proprietary EHR database.

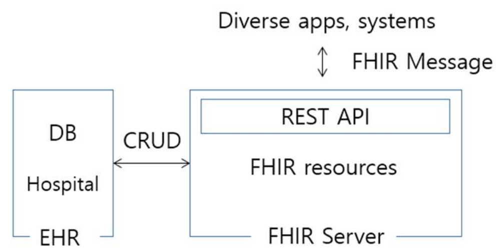

Figure 1 FHIR interface

In the meantime, FHIR resources are getting more diverse, while different stakeholders will interact via FHIR data exchange. Some participants will be empowered with artificial intelligence and big data analysis capabilities. Moreover, the spread of COVID-19 has prompted the penetration of remote diagnostics and the development of wearable medical devices for smart healthcare. The performance of such devices is much enhanced while the price is significantly cut down. They create a stream of periodically sampled values, such as body temperatures, ECG (electrocardiogram), and so on, while typically communicating with remote entities including data storage servers via wireless channels. Hence, it is necessary to efficiently convert from and to FHIR resources for more wide cooperation of medical services. In this regard, this paper scrutinizes the current FHIR resource definition for the ECG data set and designs the data exchange scheme for wearable monitoring devices.

II. DESIGN OF A DISPATCH MECHANISM

Figure 2 plots the data flow of our design. To begin with, the wearable device sends sensor readings to the data collector, and they are binary-valued and will be different from vendors. Receiving the sensor values, the collector converts them to FHIR objects, possibly using the preregistered encoder, and represents them with JSON. It invokes a POST method to store them in the data cloud. How to organize the medical record storage system is up to the policy of each institute. Actually, if

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we want to permit only the local upload, this FHIR interface can be omitted. The manager can update or even delete a specific record by issuing the corresponding FHIR method. Now, medical records can be retrieved by internal medical staff or external entities via GET methods The FHIR interface makes it possible to implement a strict information protection mechanism, recommending role-based access control. The development and security guidelines are well-designed in the SMART (Substitutable Medical Applications and Reusable Technologies) platform.

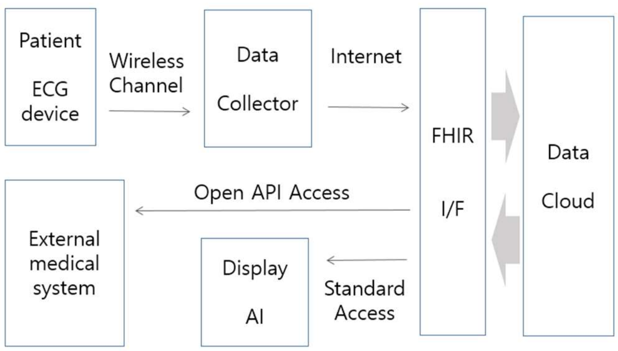

Figure 2 Flow of sampled data stream

Next, Figure 3 describes the relationship between FHIR resources related to the ECG streams. The JSON message created from the periodically sampled ECG values is handed over to the FHIR server. It will be a part of an observation resource which will also refer to specific patient and practitioner resources. References are actually numerical identifiers for a patient and practitioner(s). A medical staff member can access the detailed information on them via another query with those ids specified in the RESTful API request. The stored sensor readings can be analyzed by not only human experts but also AI-equipped machines, creating a diagnostic report resource and a condition resource. The condition resource has a more detailed set of clinical status fields for a patient associated with the ECG stream, including severity, onset time, evidence, timestamp, and the like.

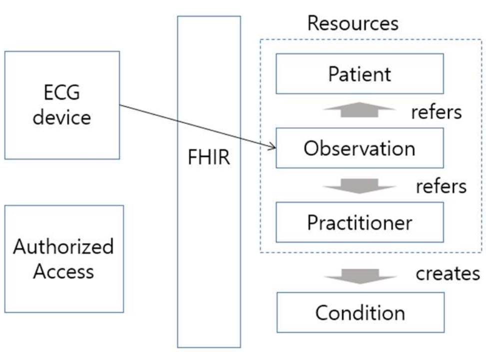

Figure 3 Resource relations

An observation resource for ECG values is endowed with a specific code as shown in Figure 4. It includes references to patient and practitioner, effective time instant, and component. Due to the limitation in the size of a component field, the stream is split up to 3 subparts, while each of them is given a numerical code as shown in Figure 4. Each subpart consists of a base value, sampling interval, scale, and dimension, followed by a series of measured values. In case a single component cannot cover a whole set of sensor readings, it is necessary to build an entry object with multiple components. This resource is exchanged as a form of bundle resource.

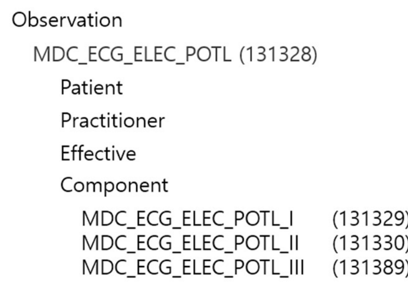

Figure 4 ECG-related observation resource

III. TESTBED IMPLEMENTATION

A FHIR client can be implemented by means of diverse ways as long as they support a JSON message exchange mechanism with the FHIR data model specification. Here, it's quite complex to make a JSON message for a clinical record as it must include detailed information fields with a given hierarchy. However, the FRED editor, developed by SMART Health IT, helps us to easily make a JSON message according to the FHIR object definition as shown in Figure 5. We can select the top-level resource such as observation, add some fields we want, and specify their values, possibly with data types. Then, the message will be generated and exported as a text file. In the figure, fields of observation id, code, effective, and component are added and their values are input. The FHIR client can submit this JSON message either by simply issuing the curl command or by developing an application in a programming language, such as Python, which supports HTTP access to the target server.

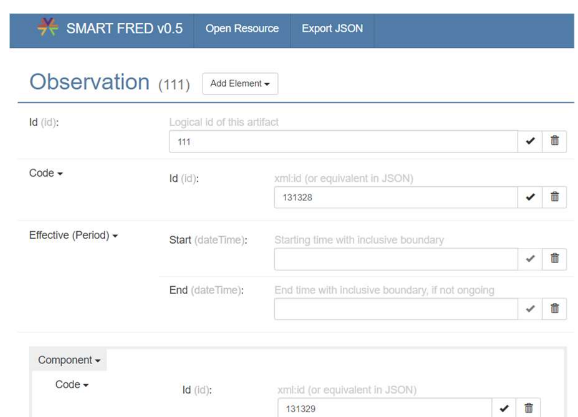

Figure 5 FHIR request builder

The stored ECG stream can be retrieved also via the FHIR interface. Currently, we don't have enough data streams, so our client program retrieves the stream from the HAPI server, which allows us to test diverse FHIR applications and contains plenty of sample resources uploaded from many users for different purposes. The stream is retrieved mainly for analysis purposes, so as for doctors to make a diagnosis. Hence, we implement the client with the Python language, which provides a rich set of visualization and analysis libraries such as *matplotlib*, *scikitlearn*, and the like. The client invokes a GET method with the specification of query parameters including patient id and EGC resource code. The HAPI FHIR server returns the target resource as a form of JSON objects, which are converted to the Python dictionary. Receiving the response, the client merges subparts, when necessary to restore the original data stream, and conducts a predefined analysis procedure. After all, Figure 6 shows the sample ECG stream plotted by using the Python library.

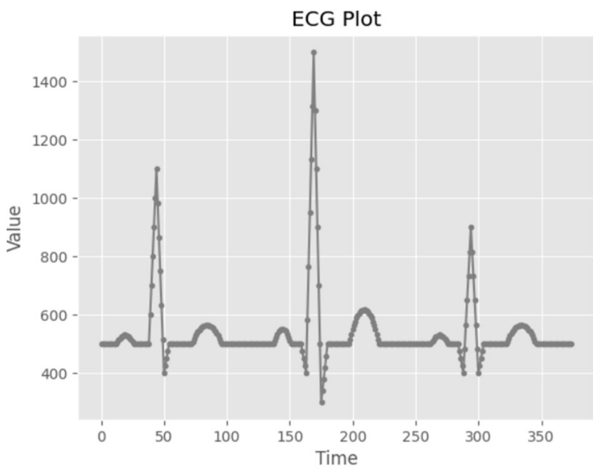

Figure 6 FHIR retrieve and plot

IV. Conclusions

In this paper, we have examined the FHIR resource definition for the stream data and designed a FHIR client which can interact with the server according to the standardized data representation. The most important part is the mapping of privately defined data format to the common data model. The designed mechanism can systemize the data sharing process between diverse stakeholders, not restricted to medical staff members, while making it possible for a variety of personal wearable healthcare devices to the clinical domain for more convenient and affordable medical services.

As for future work, we are first planning to develop an access control mechanism in the FHIR server to protect sensitive personal medical records. In addition, as we believe that the emergency rescue system is also an important coworker of the FHIR system, we will extend the coverage of FHIR resources to this area, using the past EHR in the rescue operation.

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