Blockchain based secure HL7 digital healthcare system

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1. Introduction

In many countries, especially in developing ones, the need for universally accessible solutions is in great demand. The use of mobile phones has become commonplace around the world, so making software solutions that can be easily accessed from mobile devices is a must. Also, in medical research, the use of questionnaires is a common practice, so the development of a solution that combines the need to use questionnaires with the easiest access to them is a natural step.

For the interoperability of medical data, the use of standards is an optimal solution to solve this problem. The HL7 standard [1] with his latest ISO/ANSI version HL7 FHIR [2] is a well-known standard used in software applications [3] for medical data interoperability.

Blockchain was conceived as a distributed database that implements a technology ensuring a tamper-proof validated list of time-stamped log entries (transaction records). The blockchain data structure is built on a chained blocks list [4]. Each block on the list contains a hash of its previous block. The concatenation of blocks creates the chain. The beneficial result is that historical transactions contained in the blockchain list can be viewed but cannot be modified, deleted or added without hash chain invalidation.

This paper will present a solution based on blockchain and HL7 FHIR standard which can be used to create questionnaires for collecting patient data. The first step is to create the medical data questionnaire. The questionnaires are saved in HL7 FHIR format, in Questionnaire resource. The answers are also saved in HL7 FHIR format, in QuestionnaireResponse resource [5]. The patients and medical staff data are also saved in HL7 FHIR format, respectively in Patient and Practitioner resources. As stated in the beginning, this software solution can be accessed from any device type.

The present work is the result of a research collaboration between researchers from University of Berkley, California, United States and University Politehnica of Bucharest, Romania, in the context of Smart Pandemic Initiative (available at http://spm.berkeley.edu/)from Berkley University in which both groups are present.

In the next section we will shortly describe the proposed application, and in the last

section we will present some conclusions and software application's future possible developments.

2. Proposed Solution

Our system presented here contains the following HL7 FHIR submodules which are part of Back End editor Logic - as presented in Fig 1:

1. Questionnaires module will help create and store questionnaires in HL7 FHIR format (HL7 FHIR Questionnaire). Results are stored in HL7 FHIR QuestionnaireResponse [5] resources.

2. QuestionnaireResponse module will help storing the answers in HL7 FHIR resources format.

3. Patient module will be used to create and save patient data in HL7 FHIR format.

4. Practitioner module is used to create and save data about practitioners (doctors, nurses, managers, etc.) in HL7 FHIR format.

We will present below (Fig. 1.) the main modules functionalities and outcomes.

When a new Questionnaire, QuesionnaireResponse, Patient or Practitioner resource is created, it is saved in the database respecting the HL7 FHIR standard format. The database is Multilanguage.

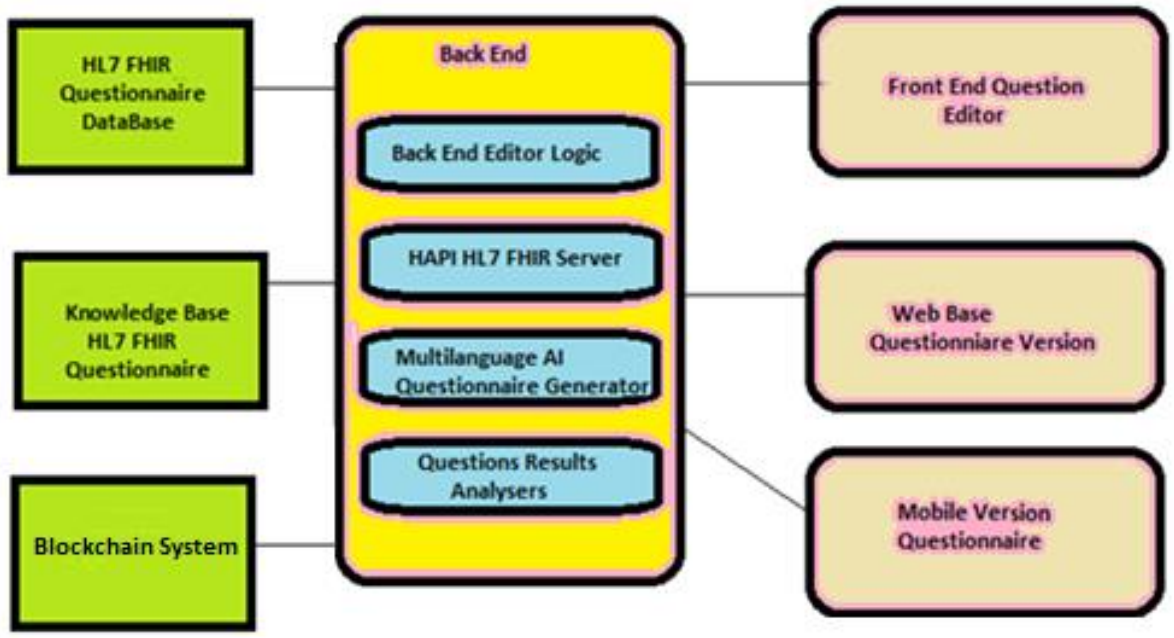

Fig. 1. HL7 based questionnaire functional architecture (generator and editor)

The back-end consists of different subcomponents, such as Multilanguage database, the artificial intelligence (AI) questionnaire generator, question results analyzer. After the questions are edited and skip logic is applied, the back-end will get the data, parse the data and save them in the database. The same approach will be used with the other resources created in the front-end, respectively with the patient and practitioner.

Another component of the back-end is the Multilanguage AI Questionnaire Generator. This component will generate questionnaires based on patterns created. Like the first type of questionnaires, this will have skip logic applied and it will be saved in the database using the HL7 FHIR format. Skip logic is a feature that allows users to jump to different questions (skipping some of the questions if necessary) based on the answers given by the users.

Based on the answers collected from the patients, question results analyzer will retrieve the data from the database, analyze it and send it to the front-end to be displayed.

HL7 FHIR Questionnaire Database stores the information in HL7 FHIR format. Knowledge Base HL7 Questionnaire stores information such as questionnaire patterns for AI generator and other intelligent relevant information.

Blockchain System assures the saving of relevant information related to the questionnaire and its results in the blockchain and also the interoperability (to the HL7 FHIR) component to other medical systems. It manages all aspects concerning traceability and adds the needed security level of a medical system.

Bellow we will detail more on the web interface and its link with HL7 FHIR.

The "Create forms" module

In order to create a form, the user has the ability to create questions and choose the expected answer type (free text, date, multiple choice, single answer). In Fig. 2. are presented the first mandatory data: the form name, the question, the answer type.

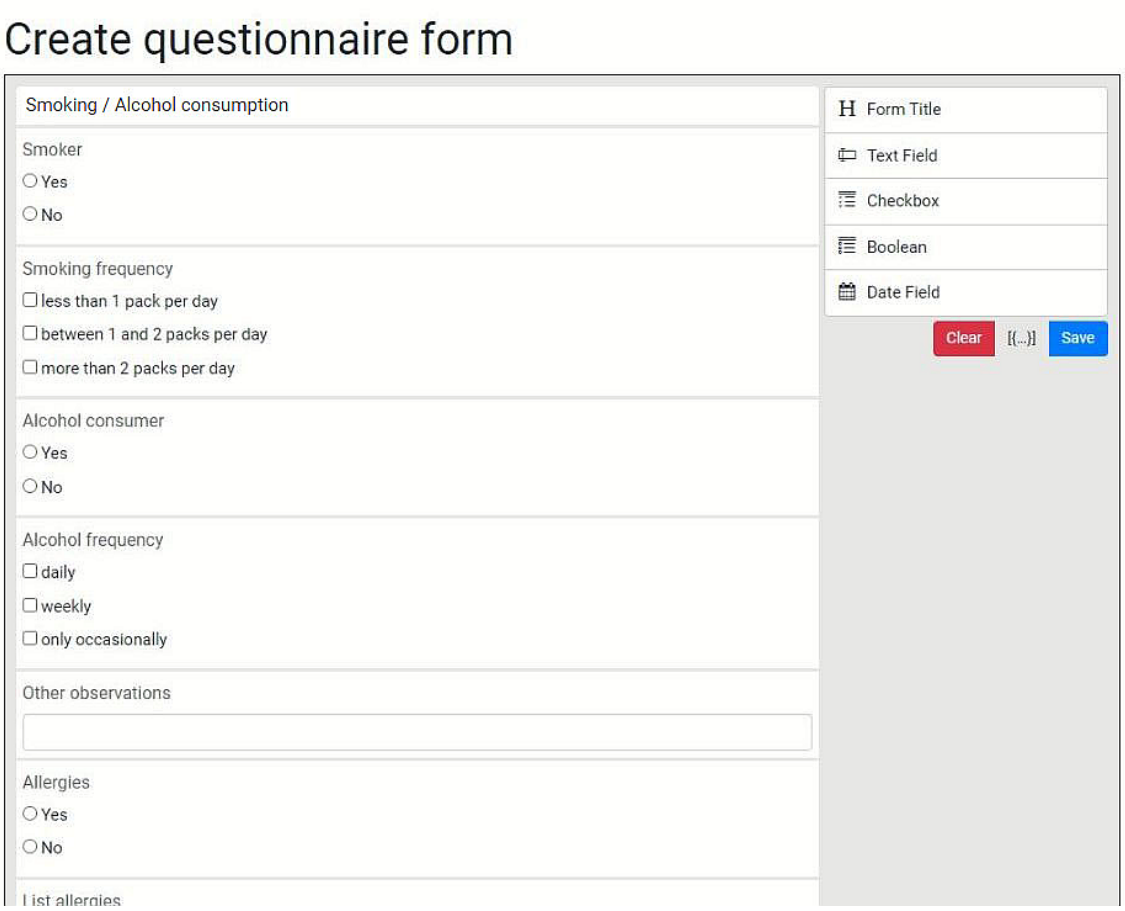

Fig. 2. Create a questionnaire form (named e.g. "Smoking / Alcohol Consumption")

The module interface is based on the JQuery formBuilder library. It facilitates the possibility of creating forms using a drag and drop interface. After creating the form and saving it, JQuery formBuilder creates a JSON file that uses the HL7 FHIR format and it will be saved in the database.

In the following you will find the JSON structure of a basic question.

```
{
     "linkId": "1",
     "text": "Smoker",
     "type": "boolean"
   }, {
     "linkId": "2",
     "text": "Smoking frequency",
     "type": "choice",
     "enableWhen": [ {
       "question": "1~1#",
       "answerBoolean": true
     } ],
     "answerOption": [ {
       "valueString": "1 pack per day"
     }, {
       "valueString": "between 1 and 2 packs per day"
     }, {
       "valueString": "more than 2 packs per day"
     } ]
```

```
}
```

where:

- *linkId* is the id of the question
- *text* represents the question content
- *type* is the type of the question (Boolean, choice, free text, etc.)
- *enableWhen* defines the skip logic of the question
- *answerOption* defines the possible answers to a question of choice type

The "Form display" module

This module is used to collect answers. Depending on the rules set out in the skip-logic module, some questions will be disabled. These will be available if the answers set in the logical skip module are chosen. Saving the answers is done in json format, according to the HL7 FHIR format.

In the following you will find the JSON structure of an answer.

```
{
      "linkId": "1",
      "text": "Smoker",
      "answer": [ {
        "valueString": "true"
} ]
}, {
      "linkId": "2",
      "text": "Smoking frequency",
      "answer": [ {
        "valueString": "between 1 and 2 packs per day"
     } ]
}
```

where:

- *linkId* is the id of the answer
- *text* represents the question that is answered
- *answer* represents the value chosen by the respondent (or the text entered in the text field)

Fig. 3. presents a questionnaire that is submitted for collecting answers.

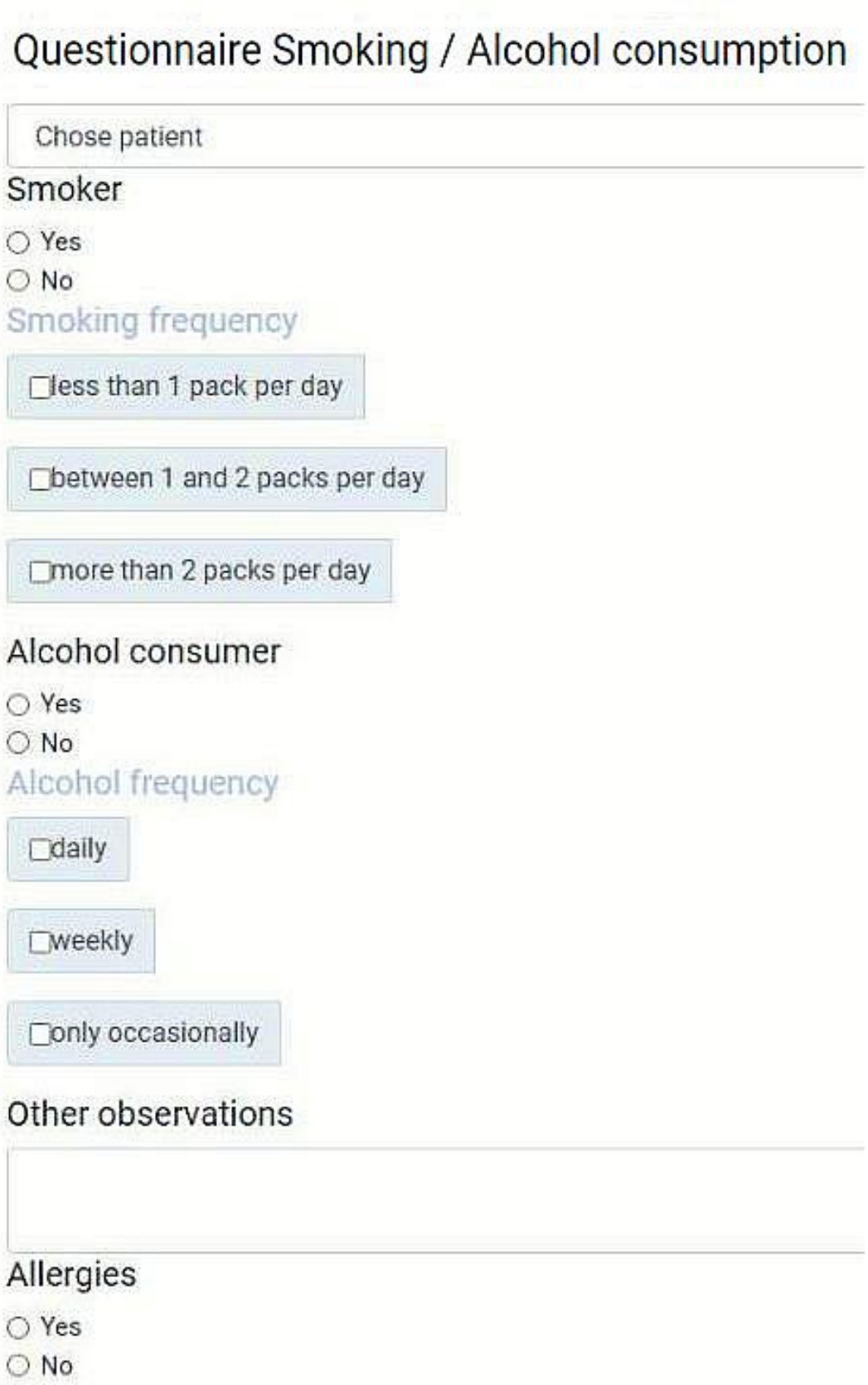

Fig. 3. The ready to use questionnaire "Smoking / Alcohol Consumption"

3. Conclusions

The software application we propose is based on HL7 FHIR standard for the creation of different resources (questionnaires, patients, practitioners). In the first part of the application development we focused on the components regarding the creation of questionnaires, patients, practitioners, as well as the data analysis of information collected using questionnaires.

The present work comes from a research collaboration between researchers from University of Berkley, California, United States of America and University Politehnica of Bucharest, Romania. The research mixed work is conducted in the context of Smart Pandemic Initiative (available at http://spm.berkeley.edu) from Berkley University in which both groups are present.

The next step in the development of the application will be the components regarding natural language processing (NLP), namely text to speech and speech to text processing. Also, an AI module will be implemented to create questionnaires and analyze the results. For security purposes and to ensure the data integrity in the database, blockchain technology will be used.

Another direction for our system extension is to collect patient data from sensors (for example physical activity data or heart rate data from mobile phones) and to generate Patient Generated Data (PDA) or to use existing disease questionnaires for Patient Reported Outcomes (PRO). The different data types (such as PDA, PRO, and data from user defined questionnaires) can be analysed through an artificial intelligence (AI) engine for better diagnosis and treatment. Those are some development directions for this work.

References

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