Promela and Spin Formal Verification of an M-Health Medical Social Media System

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***Abstract*—The process of detecting and identifying errors early in the life-cycle of any software has many challenges. The tools used for model checking are however becoming more effective and usable because they are helping the identification of errors. This has empowered users to apply model checking to large-scale problems. The process of validating the model implementation is normally harder. We created a Promela model by using a model checker called Spin in order to verify the Medical Social Media System based on Social Oriented Networks by using M-Health technology and sensors in smartphones and bracelets for medical data acquisition, in order for it to be used in the healthcare sector in Iraq. For the Promela Model, we first described the behaviors of the Medical Social Media Systems via UML timelines. After that, we combined the UML timelines in state diagrams that were finally transformed into a Promela model and verified with the Spin model checker.**

Keywords—UML, Verification, and Validation, Promela, Spin, M-Health, Social Oriented Networks.

I. Introduction

The software is used in many systems, in all industry sectors, like healthcare, social networking, banking, and smart driving. Sophisticated technologies like mobile Sensors, Mobile Clouds Computing, and Mobile healthcare systems have a high grade of complexity.

To assure the correctness of the software, many complementary methods of verification have been used, like for example systematic testing of programs and early analysis of system design. However, verification activities are considered complicated and require a long time. Verifications are required though because of the intricacy of software systems and the fact that they have to adapt to requirements from various clients. Software verification affects the trustworthiness of systems and subsequently their economic status. [1]

One of the significant issues in software development is to guarantee that the conveyed product complies with its specification. Verification and validation are well-settled methods for assuring the quality of a product inside the general software development lifecycle. Usually, models are represented in a Unified Modeling Language (UML). Verification establishes that the model is accurate to the developer's conceptual characterization and specifications. Validation is defined as the way towards deciding how much a model or simulation is an exact portrayal of the reality from the perspective of the proposed employment of the model [2, 3].

This research proposes methods and strategies for the verification of a standardized system – a social network oriented towards healthcare. This healthcare system will provide a comprehensive platform for communication between different communities in the field of healthcare, where any user can register and enter his data via computer, smartphone, bracelet or different wearable devices. We planned to develop a standardized platform (social oriented network) that will provide an interface for doctors, people, and patients to access medical services and provide it as far as possible in Iraq. This social media system can be used from the personal computer or android mobiles. This system collects information like heart rate or blood pressure or others and taking into account security aspects. [4]

We planned to develop an integrated platform to Medical Social Media Systems which combined the social media and mobile health applications features, the project is concerned with the creation of an Improved Medical Social Media System based on M-Health targeted for the specific environment of Iraq, also we take into consideration that Iraq has specific challenges such as security issues and network infrastructure that is less developed as compared with west countries (in many parts is based on wireless networking), where the wireless network has a restricted coverage area at the moment in Iraq. The physical infrastructure is related to technology, hardware, medical operators and network needed to implement the M-Health. In this manner, there is yet a lot to be done in the sector of communication infrastructures to improve the spread of communications to cover most areas.

In Iraq, there are many challenges in expanding the Internet and improving the strategies of communications and there is no reasonable lawful status for the government's online information. A technical challenge may emerge from the compatibility issue of the mobile systems with the current m-health systems. This can affect healthcare workplaces which have legacy systems that may be hard to incorporate according to functionalities and information administration.

The Iraqi community has become more than 38 million people and only around 19% of them are using the internet, while the rest of people they prefer using cellular communication services. Compared to other western countries these are quite low levels. The mobile communications market in Iraq is more developed than the Internet, due to security issues in the country. Overall, the average download speed of public WiFi in Iraq is 3 - 5 Mbps, while the average in the USA and western countries may reach 40 Mbps.

The bandwidth given to customers by internet providers is low. Because Iraq demands transit of fees on Internet traffic, this makes the service very expensive for service providers, and they can't afford to purchase much capacity. There are few options available to users to get decent services because about 90 percent of traffic reaches end users in Iraq via wireless over congested, low-capacity frequencies, much of which is provided by private companies acting as a monopoly. The periodic power cuts and lack of interest in infrastructure development are some of the factors causing the high cost of Internet services in Iraq. Also, internet use is expected to grow among the younger. The positive correlation between the level of education and the use of the Internet indicates the need to use good strategies to develop the education sector in Iraq and motivate less educated users to use health care services on the Internet. [16]

The system will enable doctors to check the state of health of their patients as well as conduct integrated studies through user data and provide health and medical advice to patients. This healthcare application is aimed to make life easier for people and patients and save money and time, by eliminating the difference in the level of health services provided in Iraq, especially for areas away from the centers of cities, such as rural areas. It will also provide a safe and reliable application for sensitive data without any doubt of security threats [2].

We arranged the rest parts of the paper as follows – section 2 shows a pertinent literature review. Section 3 discusses the Promela Model and the verification results. In Section 4 we present the conclusions.

A. Unified Modeling Language (UML)

UML is a standards language for creating software schemas and can be used to view, indicate, build, and document the artifacts of a software system [5]. In the likewise way, software architects make UML diagrams to enable software developers to create their software. By understanding the vocabulary of UML, namely the elements of the diagrams and their significance, it is simpler to specify and understand a system and clarify the design of that system. For modeling an object-oriented software, the UML has developed a standard diagramming notation. [5, 6].

A UML model comprises of three main categories of model components, every one of them being used to make statements about various types of individual things inside the system that is modeled. These categories are:

- Classifiers: portrays a set of objects. The object represents as an individual having state and connections with other objects having its own properties.
- Events: depicts a set of conceivable occurrences. The occurrence is anything may happen and has some result with respect to the system.
- Behaviors: Consists of a set of potential executions. The execution is defined as a set of actions that might create and react to the occurrence of events, including getting and setting a state of the objects [7].

There are different kinds of UML Behavior modeling diagrams. In this Report, we are concerned with: use case diagram, sequence diagram and state diagram [5].

Figure 1 and Table 1 illustrate the major categories of modeling elements [8].

B. Promela and Spin

Promela (Process Meta Language) is defined as verification modeling language created by Gerard J.H. Promela programs are produced by the process, variables, and message channel. The processes are global objects that illustrate the collective entities of the appropriated system. The channels of a message may be declared as global or local – inside one process. Everything in Promela is bounded; for example, the channel size has to be finite. Also, Promela has no support for dynamic memory handling [9].

Spin is the favorite open source tool for model checking. Now it has become the most useful model checkers, in the programming sector and has a large collection of users in the academic and industry sectors. Spin is completely designed for distributed asynchronous software systems or analyzing the logical consistency of synchronous [10]. For a program written in Promela, by using Spin can check the correctness models by executing random or repeated simulations of executing the system, or it can produce a C code that implements a quick verification of the system state area. Through the simulations and verification stage, Spin has the ability to check for the lack of unspecified receptions, deadlocks, and code that cannot be executed. The verifier can be likewise utilized to illustrate the correctness of the system's constants and it can discover non-progress execution cycles. [11]

TABLE 1 MAJOR CATEGORIES OF MODEL ELEMENTS

UML Behavior Modeling	***UML Structural Modeling***	***UML Architectural Modeling***
Use Case Diagrams.	Class Diagrams.	Component Diagrams.
Interaction Diagrams.	Object Diagrams.	Distribution Diagrams.
State Diagrams.	Interfaces Diagrams.	
Activity Diagrams.	Packages Diagrams.	

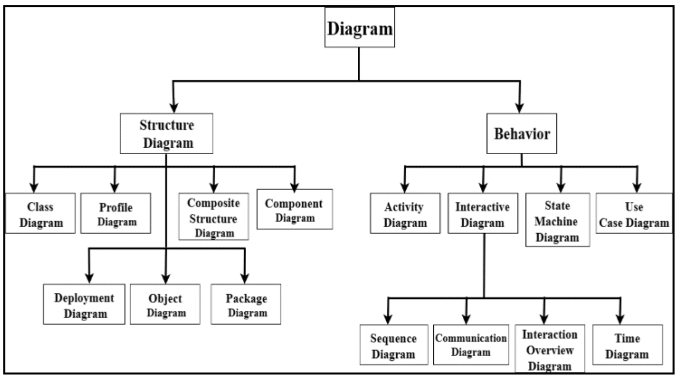

Fig. 1. Major categories of model elements.

C. M-Health

M-Health means freeing medical service devices from wires and location limitations. M-health is used to empower doctors and patients to use in a better way healthcare facilities. The M-health provides services like healthcare to areas far from centers, where it is difficult to obtain the same level of healthcare resources as in big cities. [12]

D. M-Health based on Medical Social Media Systems. Architectural Description

For the near future, the global M-Health market will be expanded to give wide health services to more people. [12]

We plan to create a unified software platform (Medical Social Media System) that will provide an interface for full interaction between doctors and patients or people. Figure 2 shows a general system architecture where users can register and enter their data via computer, smartphone, bracelet or wearable devices.

The system will enable doctors to follow up on the state of their health patients, but also to conduct integrated studies through user data and also provide health and medical advice to users. It will also collect medical information for different users like heart rate, blood pressure, weight, height, and calories.

These data can be collected during daily life activities, sleep time, etc., which helps to understand a person's health status and take into account security aspects [4] [13]. With regard to social media, one should note that there are health-oriented social networks like MedHelp, PatientsLikeMe, and HealthUnlocked which have become places for spreading and talking about healthcare information and best practice [14], [15]. However, they are not well integrated with mobiles and smart bracelets and they don't target the Iraqi environment, and despite the development of mobile health applications, it does not meet the needs of medical users. Therefore, we planned to develop an integrated platform to Medical Social Media Systems which combined the social media and M-Health applications features. There are not many medical social media targeting this specific environment.

Various advantages regard the execution and organization of healthcare in the Iraqi environment. The general advantages that are relevant for such a system for Iraq are: the capacity to reach rural and remote zones, increased cooperation between the patients and doctors, supporting the works and medical researches, mobility, and inward healthcare operations, sustaining healthcare sector specialists who observe and handle ongoing information regarding health.

The Medical Social Media System has two categories of users according to their needs.

- People and patients can search for a doctor before seeking medical advice; reading publications, articles and medical posts to increase their medical culture, and increasing awareness for disease prevention; send patient medical data and the analyses results to the doctor and schedule a doctor's appointment.

- Medical users (Doctors) can follow up on the state of their patients (regarding health) as well as conducting integrated studies through user data. Medical users can request health information for their patients, view their health histories and take advantage of the health information of the users to study the health status of a particular community or region and provide health and medical advice to users. Doctors can read the latest medical publications and articles and publish their articles and scientific research; also, they can choose the status of the privacy of articles: to be available to all or only available to doctors and specialists.

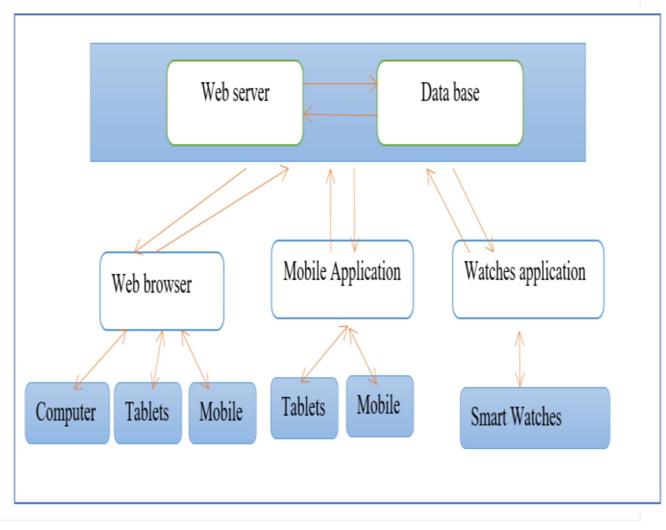

Fig. 2. Overall system architecture

II. The Verification of the M- Health System

This research uses UML modeling diagrams, Promela, and Spin to verify and validate the Medical Social Media System.

We performed the following steps:

a. The 1st step is to describe the timeline of use case diagram for the main used scenarios - see Figure 3 and to use them for the construction of corresponding state transitions systems.
b. The 2nd step is using a verification modeling language (Promela) for modeling the state transitions systems and a verification tool (Spin) to check for the absence of unspecified receptions, deadlocks, and code that cannot be executed.

Figure 3 illustrates the main used case diagrams for the simulation system and Figure 4 illustrates the sequence diagrams for Scenario 1 and 4, while Figure 5 illustrates the state diagram for the Medical users (Doctor) which is part of the simulation system. Those scenarios are Register and Login, Publish and Share Posts, Search Doctor, Friend, and Posts, Display Profile, Request Medical Advice, Write Medical Report.

Figure 4 shows a sequence diagram specifying the object interactions coordinated in the time sequence. It describes the objects and classes implied in the scenario and the sequence of messages interchanged between the objects needed to carry out the operation of the scenario. In this figure there are two scenarios, the first one is for the sequence diagram using the New Registration and Login and the second one is using Request Medical Advice and Write Medical Report.

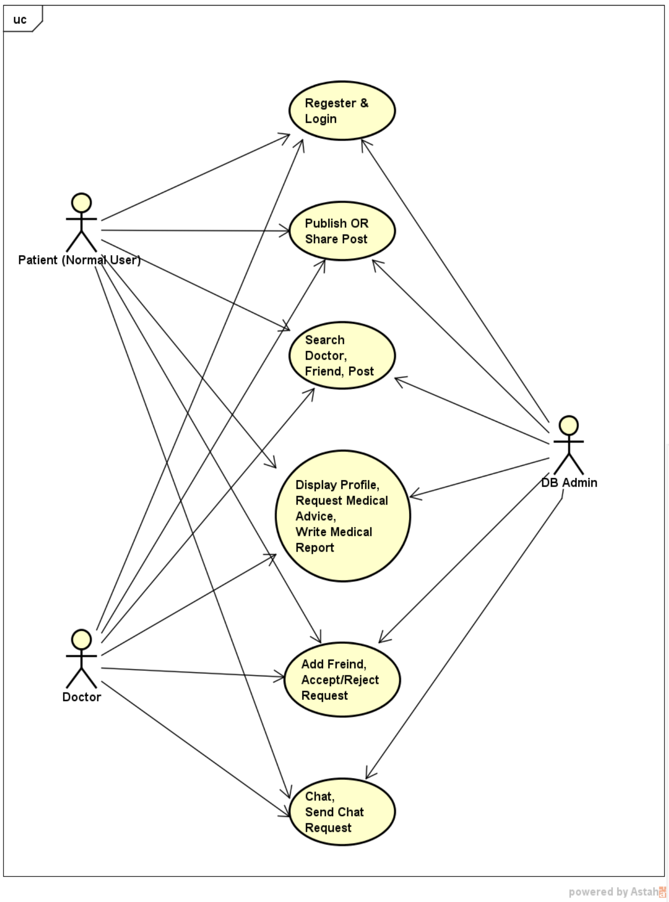

Fig. 3. The use case diagram for the simulation system

We combined the relevant scenarios in states diagrams- see them in figure 5. For each entity from the UML timeline, a state transition diagram was constructed. The process of construction is as follows: each event (sending or reception of a signal) means a transition in the state diagram between two states. In the case in which the scenarios differ as behaviors, several transitions between the two states were constructed. Below, we put a state diagram for the Medical users (Doctors) entity.

After that, we constructed the Promela program for the states diagrams. For each diagram, we have a process. Below, we put some relevant code for the Medical users (Doctors) part of the simulation system that will explain some main ingredients of the system.

```
proctype Doct() {
            byte countX41 = 1;
             ……
DOCT5:
     do
     :: (countX41 == 1) -> countX41 = 0; atomic {
                        Doct1_adm1??Accept;
            }
     :: (countX41 == 0) -> countX41 = 2; atomic {
         Doct1_adm1??Rewrite_UserName_And_Password;
            }
     ::(countX41 == 2) ->break;
             od;
            goto DOCT6:

DOCT6: …
```

It can be seen that in the initial state there are two possible receptions of two different signals (Return Accept and Rewrite User-Name and Password). After that, the process goes to the next state and so on. It can be seen that it is quite a one-to-one correspondence between the state transitions diagram and Promela code.

In a similar way, we constructed the rest of our Promela code. After we had constructed the code, we analyzed it via simulations. We performed around 65 simulations and the Promela model was checked for deadlock using Spin. The system reached the 'free of errors and deadlocks'. In figure 6, there is part of a trace from the simulations performed with Spin.

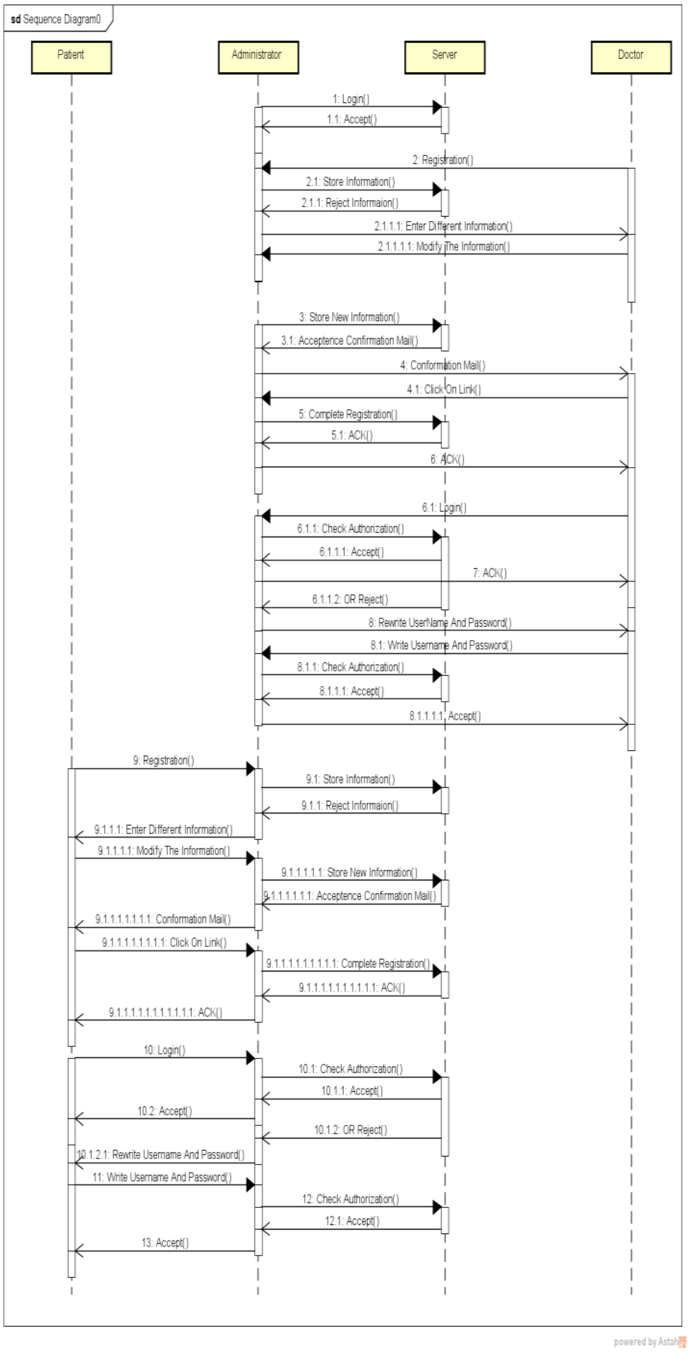

Figure 4 (a). The Timelines diagram for simulation system scenario 1 (New Registration and Login)

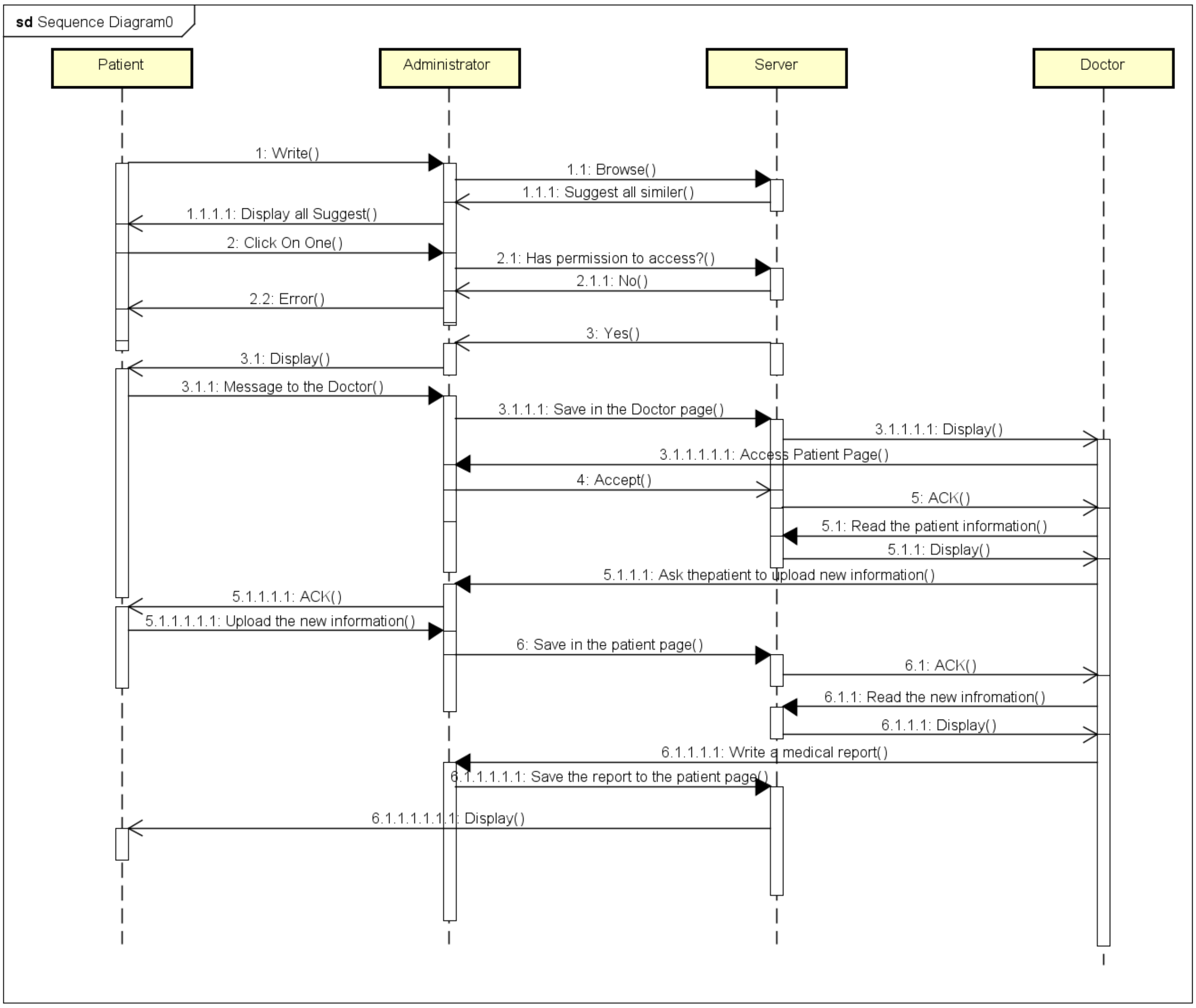

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Fig.4 (b). The Timelines diagram for simulation system scenario 4 (Request Medical Advice and Write Medical Report)

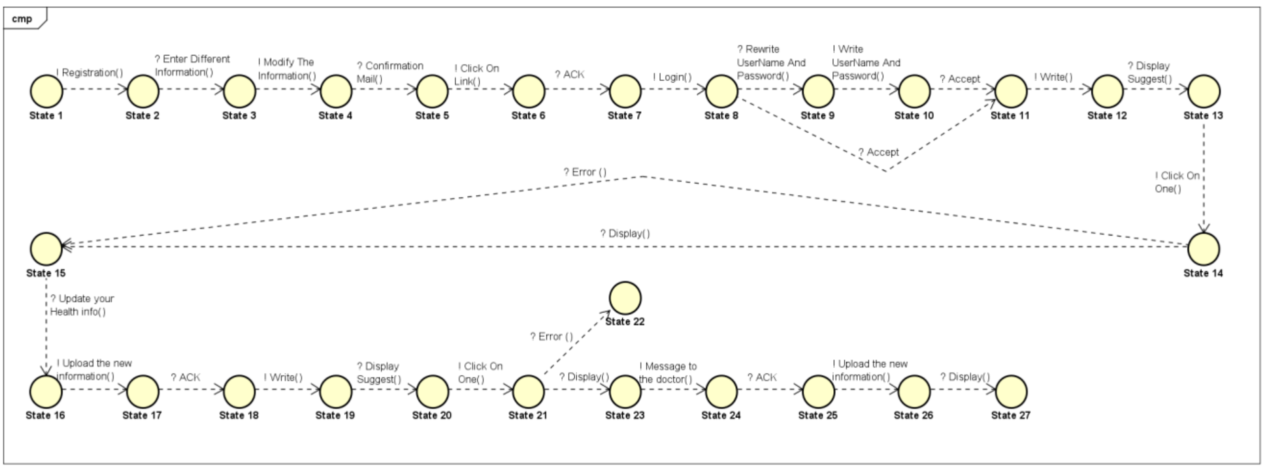

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Fig. 5. The State diagram for the simulation system (Doctor)

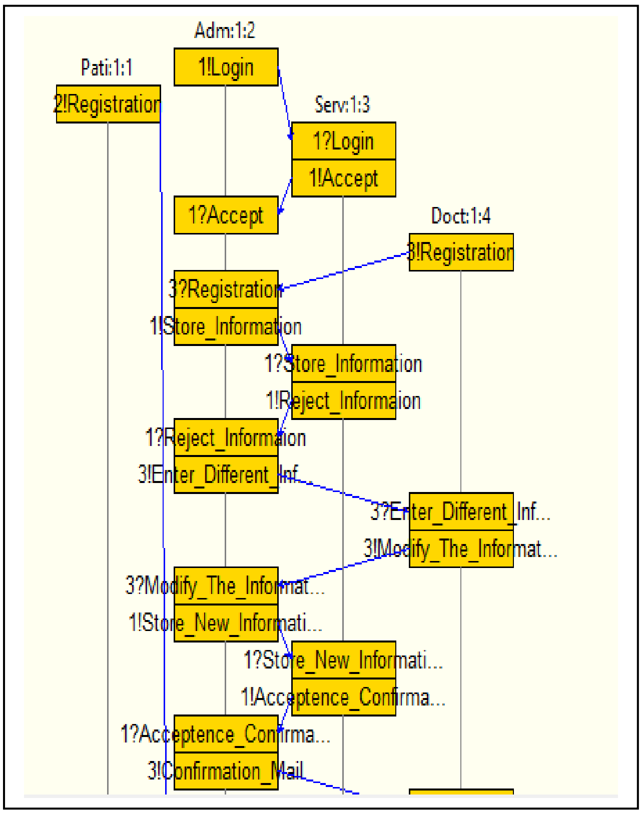

Fig. 6. A simulation trace using Promela and Spin

III. Conclusion and Future Work

We planned to develop an integrated platform to Medical Social Media Systems which combined the social media and M-Health applications features. There are not many medical social media targeting the Iraqi environment so we wanted the application to have the capacity to reach rural and remote zones, increase cooperation between the patients and doctors, supporting the works and medical researches, mobility, sustaining healthcare sector specialists who observe and handle ongoing information regarding health. The application would be similar to a social media system and could be used from the personal computer or android mobiles.

After a challenge in the software development process, we aimed to detect errors in the software lifecycle. The purpose of the paper was to introduce a formal verification and validation in order to verify the Medical Social Media System based on Social Oriented Networks by using M-Health technology.

We used a Promela model from UML interactions using the Spin model checker to verify the properties of the Medical Social Media System and to simulate the execution.

We also modeled the main scenarios of a Medical Social Media System and after we unified them as a state transition diagram that we further used for building a Promela model that was simulated with the tool Spin. We performed around 65 simulations until we could not find further errors.

Further work is to implement the system and test it under different conditions.

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