A Distributed E-health Model Using Mobile Agents

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***Abstract*—In this paper, a 3-layer agent-based model is proposed. The proposed model is supposed to be used as a general framework for e-health systems to facilitate health care processes. This 3-layer model consists of patient layer, clinic layer and central-hospital layer. These layers are hierarchically and horizontally related together. This relationship is defined in order to establish more accuracy in treatment recognition, quick treatment, and diagnosis. It facilitates the relationship between different parts of e-health procedure and reduces the workload and complexity to connect different interfaces. Mobile Agents technology is used to distribute the processing load as well as to support a more flexible peer-to-peer model, scalability and decentralization of control.**

Keywords–distributed; mobile agent; modeling; e-health; layer; workload.

I. INTRODUCTION

E-activities have been emerged as potential prospective trend in almost all aspects of human life. Some of them have become properly essential to control the huge amount of data and information produced during daily activities. At the same time, the introduction of e-Health represents the commitment of information and communication technologies to improve healthcare systems [1].

The E-health care indicates recording, measuring, monitoring, managing and finally delivering patient-oriented and specific-condition care services through Internet at the real-time.

E-health provides the interaction between a patient and healthcare institute, as well as institute-to-institute transmission of data or peer-to-peer communication between patients or doctors. Nowadays most healthcare institutes use computer systems for record keeping. Most of data being recorded would not be easy to understand for average patients, and they can be solely used directly by doctors and other practitioners. On-line tools may help patients to better understand their condition. Furthermore, it is of a great importance for a healthcare institute to manage, maintain, collect, and analyze the data received by doctors, practitioner and patients.

Several approaches have been proposed to integrate distributed information sources in a healthcare [2]. In one approach [3], the focus was on providing different teams across several hospitals with management assistance by coordinating their access to distributed information. The brokering architecture is centralized around a mediator agent which is responsible for allocating an appropriate medical team to an available operating theatre in which the transplant operation may be performed.

In this paper, the analysis is done across distributed system according to hierarchical and horizontal connections among the patients, the healthcare clinic, and the central hospital. We illustrate some benefits of these connections which lead to reduce the complexity of collaboration between some global queries and management of local entities. In order to have accurate queries and efficient analyses from distributed databases, a framework is required in order to support interoperability mechanism to identify and provide measures necessary to deal with the differences in database models. This makes use of a knowledge-based approach for information retrieval which can be provided by defining the entities and their relationships as well as agents' role.

The rest of this paper is organized as follows: Section 2 describes the agents reducing the complexity of the communication and facilitating the interaction between the layers in distributed environment. Section 3 explains the roles of multi agent system (MAS) in three layers and its efficiency in operating between layers, and also the interaction between layers with emphasizing the role of Object Request Broker (ORB) for being applied in client-server architecture. At the end of this paper, the conclusion and future work are presented.

II. MULTI-AGENT SYSTEM

A multi-agent system is a paradigm for understanding and modeling distributed systems, in which it is assumed that the computational components are autonomous; that is they are able to control their own behavior in the furtherance of their own goals. During the past decade, several agent architectures have been proposed to implement agent-based systems, and also a few efforts have been made to formally specify agent behaviors [4].

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However, there is little research on narrowing the gap between agent formal models and agent implementation; and of course this paper will not focus on implementation phase.

Because of their inherent characteristics, such as code and state mobility, network awareness, and intelligence, Mobile Agents are able to enhance distributed applications. Some of them include reduction of the network bandwidth use, distribution of processing, support for a more flexible peer-to-peer model, scalability and decentralization of control. In terms of processing and network bandwidth consumption, the use of mobile agent paradigm is justified when use of some remote resource applying traditional approaches as client/server paradigm are more expensive than use of the agent.

The integration of many clinical activities in e-health, requires a wide area of e-health monitoring in which most of the patients are usually mobile and situated in a low bandwidth, high latency, asynchronous transaction and unstable connection communication environment while servers are highly distributed and heterogeneous. For this paradigm Mobile Agent technology is more suitable as it provides a powerful and efficient mechanism to develop application for a distributed and heterogeneous environment. Mobile agent technology offers the possibility to execute duties in an automated way with minimal human intervention. It allows medical staff to concentrate their attention on other activities and consequently save valuable time of medical resources. Also, the medical team can be always accessible and their decisions are easily monitored by medical staff and Central Hospital.

The mobile agent in each machine interacts with stationary environment (e.g., service agents or other resources) to accomplish its task. The Central, the clinic, and the patient's PC are three stationary agencies which are supposed to provide an environment for the agents to interact in the system.

A principal goal is to overcome the difficulties of coordination and communication. The main challenge is to identify types of agents, their tasks, goals and interfaces. The types of the agents which are used in the whole system are presented in Table I.

In fact, there is a large amount of patients' data stored in lots of databases and not translated into any knowledge form which can be effectively suitable for consumers whether they are patients or medical practitioners. To customize this health information, they are required to be retrieved and translated into a suitable knowledge. In this model Analyzer Agent is supposed to perform such a task to retrieve appropriate information and convert it into knowledge-based information.

TABLE I. AGENT'S GOALS AND TASKS.

Agent type	Goals	Tasks	interfaces
Profile Agent	Complete patient's information. Update patient's health information.	Record user's application. Record user's preference. Record user's tasks.	Virtual medical team
Advice Agent	Care improvement	Bring medical suggestion to the patient	Patient
Query Agent	Obtain statistical information. Collect information from distributed DBs.	Carry and run a request through the system.	Clinic - Central
Analyzer Agent	Obtain an appropriate request and analyze data and convert it into appropriate information	Analyze data from information resource	Research team - Patient

There is a main resource in central hospital databases which is consisted of any necessary information about maladies, their drug's side effects, statistical information, etc. It will be easier for the agents to access the information and compare them with the decision made by e-health team; even in case of any collision or mistake, the system would alert and make the team aware.

A patient who decides to join electronic healthcare clinics will be continuously inspected by a virtual team. Each user is represented by a mobile agent, thus the virtual medical team is always available. Virtual team may consist of doctors, nurses, practitioners and any department (e.g., laboratory, radiography, etc.) being able to make a connection locally or globally (depending on their authority and their connectivity).

In fact, there is a dynamic virtual team which has been formed to response needs of any particular patient in any point of time. The patient will be assigned to the appropriate medical team by its Profile Agent. The Profile Agent representing the description of a patient, his situation and his health signs, will be sent manually or automatically to the healthcare clinic. At the clinic side, there must be a team or a doctor to advise the patient according to the received condition. Once the Profile Agent is received by clinic, the clinic agency verifies the authenticity of the received data to detect which parts are new or maybe changed. Thus it is able to update the information and dispatch necessary parts to the virtual team members. This procedure is shown in the Fig. 1.

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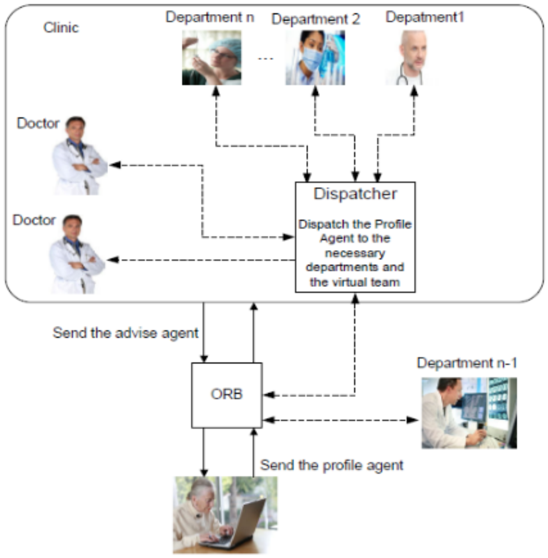

Figure 1. The patient's communication to the Clinic, its virtual team, and related department like laboratory, radiography, etc.

In this case, different conditions will be supposed depending on the structure of the clinic and their Network Structure. For example, the sub-sections of the clinic including laboratory, radiography, etc. are connected to the same authority (their connection are locally authorized) or maybe it is needed to connect other clinics with help of a broker to connect the entity A (from one clinic) to the entity B (another clinic).

The system is able to bring the team members together even if they are separate of each other. As mentioned earlier, some agents are defined to do system's tasks. Some of them are intelligent and able to analyze and verify the patient's information or team advices (As it has been mentioned in Table I).

Agents learn how to simplify choices according to pre-defined data rules and user-based information [5]. As a matter of fact, the rate of human errors in this area is not negligible; for instance in order to be sure of drugs consumption or their side effects, the patient can send an Agent to receive additional information on that special case. In fact, the patient does not know how it works. The only thing that the patient deals with is the interface and the result. This scenario promotes the use of mobile agent in order to decrease network usage.

This system could be used for different reasons including long-term care, homecare, clinical search studies and public health reporting [6].

III. LAYERED-BASED MODELING

In this paper, 3 layers are defined interacting with each other: the patient layer, the clinic layer and the central hospital layer. These layers are hierarchically and horizontally connected together. This relationship between layers is defined in order to establish more accuracy of treatment recognition, quick patients' treatment, and malady recognition, and also to facilitate the relationship between different parts of e-health procedure. As a scenario, both connections may be verified in details. If a patient is under cares of e-health, the doctor will visit the patient and it can be called a hierarchical connection. The receptor fills referral form and then sends it to the clinic's database (DB) and the latter will organize a new record for the patient. This is the beginning point of the patient - healthcare clinic interactions. After that, depending on patient's situation, an appropriate e-health team will be organized. At the same time, a horizontal connection between clinics or departments can be set in order to allocate the e-health team for the patient. A horizontal connection shows the same range of information interaction which is accessible for whole e-health team. Patient's information for each part of the virtual team appears in a specified interface. According to the responsibilities assigned to each section, some information or prescriptions are added to DB and they are shared with other parts to be more observed. Horizontal connection plays an important role for e-health team. Quick access, easy connection and quick changes of information by e-health team is the major role of a horizontal connection and it can lead e-health team to have a personalized application because in spite of being strongly related to the structure, it does not have any relation to the interface.

The access of each part of e-health team to the patient's information does not have any overlapping and each part can add its information when it is allowed to do.

A specific software is embedded on both sides (patients and e-health team) with two different interfaces. On the patient side, the patient or some tool such as an electronic health device or a portable device being able to interact with the patient's PC can be applied to control and measure some health parameters. The embedded software can analyze the data prepared at patient side and then the result will be sent as a Profile Agent which transmits health parameters of the patient to the clinic.

The interaction between client and server with different interfaces, program languages, hardware platforms, Operating Systems, location, etc. poses a great concern that how we can encounter with all of these parameters in the server side. A programming model acting as a middleware between clients and servers is needed. Object Request Broker (ORB) is a middleware from which a client can request a service without knowing anything about the servers which are present on the network. ORB provides the participating system with a consistent interface by wrapping each software entity in the framework in order to enable them to collaborate [7]. Various ORBs receive the requests, forward them to the appropriate servers, and then give the results back to the client. The structure of the ORB as well as the relationships of the system is shown in Fig. 2.

Interoperability means the ability of diverse systems to work together accurately. They must be able to exchange data and information in an effective, accurate and continuous way. Core problems with which e-health system faces are lack of interoperability, common standards and common architecture for their health information exchange.

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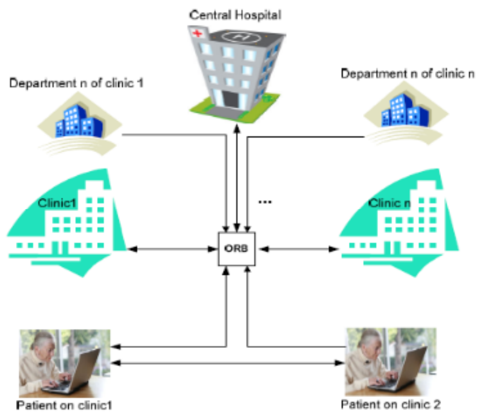

Figure 2. Role of ORB and structure of whole system

Since public health agencies rely on multiple systems, it is a hard task to provide a common framework for all relevant parties. Moreover, a middleware is required to connect different sides in order to omit dependency on various applications and different architectures of information exchange.

Although common standards such as Logical Observation Identifiers Names and Codes (LOINC), Health Level Seven International (HL7) have been recognized as long term important factors, at present time it is unknown how they shall be implemented. Moreover, their implementation needs huge amount of funding. So beside of this action, this paper suggests a middleware called ORB in order to establish a connection between client side, server side, and other different sections in different levels of authorities across healthcare monitoring team, departments, knowledge-based resources, etc.

Up to now, the system has established a hierarchical connection from the patient side (client side) to the healthcare team (server side). Diagnostic team sends some request to the main resources of the central hospital in order to obtain information from the knowledge-based data server. The analyze agent is responsible to obtain necessary information and convert it into appropriate knowledge-based information all are to be transferred by the ORB. Sometimes the doctor wants to know the patient's health information, so the system creates an Agent to retrieve the appropriate information from different parts such as radiology or laboratories; therefore, the doctor will not conflict with these complexities of the system and its procedures. There are other facilities on this system that allow the patients to communicate directly with each other. In fact the system can find some patients which are engaged in the same diseases. This can be a mental help for the patients and their relatives.

A) Patients

The patient or the electronic health care tools import data on the patient side interface and submit it by producing an agent containing the data and its respective function to have more interaction with the clinic. In the next step, this data is sent to the ORB. The ORB recognizes the agent type and invokes the appropriate function to save the data in the related clinic's DB. The data is detected by practitioners or medical teams on their screen and they diagnose the patient's status. If they want to prescribe the patient, the system will make an Advice Agent which will be sent to the patient's PC.

The patient's PC generates different agents to perform the tasks, like Profile Agent as described above or Query Agent that the patient uses it to access the medical information collected by Analyzer Agent. To make sure of the medical process and getting some reports, the system needs to make Query Agent and make use of pre-defined knowledge to analyze and send back the result.

The Analyzer Agent can update its information using basic information, the result of a patient's care, advices of doctors or some new information which has been added to the knowledge-based resources.

B) Healthcare Clinic

Once a patient connects to the e-health system, he/she will be assigned to appropriate departments and be advised by a virtual team. The virtual team may need to work separately instead of being together in a place.

The Profile Agent consists of different parts which must be divided in order to be analyzed in different departments and to be observed by a virtual team. The dispatcher is responsible to check Profile Agent and distinguish each section. As the virtual team and departments are not necessarily in the same place, the dispatcher must use two different connections to transfer appropriate data to appropriate department, local connection and global connection. Global connection refers to a connection established with the help of the ORB, while local connection does not need the ORB for applying the connection.

Clinics can use the other clinics' information via the ORB. For the sake of security and safety, there should be some different accessibility for the personnel who want to achieve this information. In this procedure, the clinic will introduce itself to the ORB and also define its role. The ORB will verify the Agent received from the first clinic and also define the accessibility of the request depending on its role. Then it will negotiate with the second clinic to verify the permission of accessibility. If the second clinic confirms the accessibility, appropriate information will be sent back to the first one through Query Agent.

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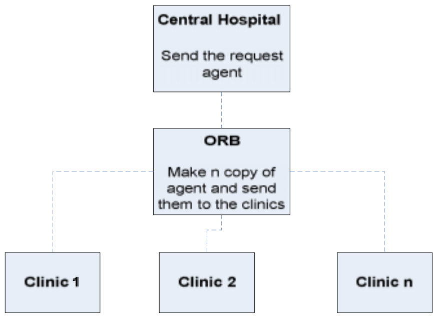

Figure 3. Role of Query Agent and Analyzer Agent to analyze the information received from Clinics.

C) Central

In a periodic sequence, central hospital makes a Query Agent to retrieve information of clinics' DBs. The central hospital can analyze this data and convert it into statistical information usable by research teams; for example, medical diagnoses, procedures, allergy information, medication, patient histories, eligibility data, and so on.

The central will analyze the patient's data and the clinic's one; the final output is statistical information. This knowledge-based information is useful for the clinics and research teams. Analyzing the patient status, based on the illness, amount of drugs' consumption, age, data gained from some tools or patients itself, etc. will be useful for the healthcare clinics to achieve some new medicine research and also to provide better patients' care.

It is necessary for the system to know which user is on-line or off-line and where they are. The central also analyzes and monitors the queries and the functions which are being interacted among the users and the healthcare clinics through the ORB. A global observation mechanism is needed to monitor and analyze the status of these entities [7].

Fig. 4 explains the functionality of the Query Agent and the Analyzer Agent in pseudo codes. In fact the role of Query Agent and Analyzer Agent will be detected according to their interoperability and their functionality.

The Query function can be divided into different Query functions. It means that a query may want to retrieve information from many resources or make another query from another resource by receiving especial information. The whole information will save in Result. After that the Analyzer Agent processes the data which has been received by many resources. In fact it will compare the information with the knowledge of the main resource, and it can report the appropriate information to the requester.

```
QueryAgent()
{
make child Query (variable type, query type); /* "variable type" is the type of some information parameters required to obtain the appropriate information for example what are the causes of the X disease.*/
Result=Query (variable type, query type); /* Result of the query according to its purpose is reserved in "Result" */
if (Analyzer==true) {
Result=AnalyzerAgent(Result); /* the Query Agent can invoke the Analyzer Agent – the Analyzer Agent can analyze the information which has been taken by the Query Agent from different part such as laboratory, patients, doctors, etc. */
Return Result;
}
}
AnalyzerAgent()
{
Info=Obtain (variable type); /* "variable type" is the type of some information parameters required to obtain the appropriate information.*/

Check if (variable type is reported before) {
Info=Obtain (title); /* the necessary title which are more related according to their subject and titles */
}
Result=Compare (Info with pre-defined knowledge); /* the obtained information with pre-defined knowledge and make some statistical report in a file */
Save (variable type);
Save (Result);
Return Result;
Pre-defined knowledge:
According to the variable type, will detect some necessary information around the title of the query and some related titles (it can make use of previous queries which were used before and will compare all of them)
}
```

Figure 4. Pseudo code of the Query Agent and the Analyzer Agent

IV. CONCLUSION AND FUTURE WORK

This paper introduced a framework for an e-health system to facilitate health care processes. A layered-based system and ORB are used to reduce the workload and the complexity of the connection among different interfaces. Mobile Agent is used for distribution of processing, support for a more flexible peer-to-peer model, scalability and decentralization of control. Generally speaking, there are some specific applications which run on this platform:

- Health records
- Telemedicine
- Tele monitoring
- Agent-based transition of data
- Decision support
- User identification
- Information accessibility in mobile state

Moreover, a common set of rules and standards should be established for information exchange, interoperability and making sure of data quality which could be a part of our anticipated research. Our future work will focus on analyzing the protocols between layers, adding some intelligent agents to facilitate some tasks and more about the security of agent implementation.

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