Real-time Multiagent System for Healthcarewith Temporal Behaviour of Agents

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Abstract--A real-time system is a system in which correctness of the system depends not only on logical result of computation but also the time at which the results are produced. Real-time system is formed by set of tasks characterized by deadline, a period, a worst-case execution time and assigned priority. When multi agent system is used in time critical environment it is called real-time multi agent system. In such environments, agents need to act autonomously for a common goal. These agents require real-time responses. A real-time agent is an agent with temporal restrictions in some of its responsibilities or tasks (hard real-time agent and soft real-time agent). A real-time multi-agent system is a multi-agent systemwhere at least one of its agents is a real-timeagent.The real time multi-agent systems are considered as useful tool for solving complex real time problems which require intelligence and real-time response times. Such system agents should have flexible, adaptive and intelligent behaviours to work in real-time environments. Healthcare domain is one of the real-time system where multiple agents work in coordination. The medical diagnosis system can be implemented with temporal behaviour of agents. The medical emergency can be implemented with hard real-time multi agent system and non-fatal diseases diagnosis is possible with soft real-time multi agent system as shown in case studies in paper. To implement this approach, the paper uses RT-MESSAGE methodology with SIMBA and ARTIS agent architecture.

Key words-- real-time system, agent, real time agent, agent methodology and architecture

I. INTRODUCTION

A Real-Time System (RTS) is a system in which the correctness of the systemdepends not only on the logical result of computation, but also on the time at which the results are produced. Real time system is a collection of tasks, a deadline, a period, a worst-case execution time and an assigned priority. A dead-line defines the greatest time interval in which the system can provide a response. Hard Real-Time System (HRTS), is a real-time system where the execution of a task after its deadline is completely useless. Systems of this kind are critical systems and if timing responses are not satisfied, this will result in severe consequences. In Soft Real-Time System (SRTS), the execution of a task after its deadline only decreases the quality of the task result.

When multi agent system works in real-time environment it is called real-time multi agent system (RT-MAS). The real-time agents will form such system. A real-time agent has temporal restrictions in some of its responsibilities or tasks. The RT-MAS can be implemented with all related temporal features.

RT-MESSAGE (Real Time-Methodology for Engineering Systems of Software Agents) is an agent-oriented methodology which covers the analysis and design phases of multi-agent system development. The use of UML throughout the entire development process of RT-MAS makes the approach easier to understand and manage. This makes the methodology much easier for developers to assimilate and use.

This methodology makes use of SIMBA (Multi-Agent System Based on ARTIS) architecture. SIMBA is set of ARTIS agents and their interactions. ARTIS agent architecture allowdevelopment of agents with strict temporal behaviour for hard real time systems.

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The methodology, RT-MESSAGE along with the architecture of SIMBA can be used for development of RT-MAS for health care domain. The scenarios can be identified where agents need hard time temporal behaviour or soft time temporal behaviour. With this approach medical RT-MAS can be used efficiently for various disease diagnosis and treatments.

A) RT-MESSAGE

It is the methodology used for analysis and design of RT-MAS. It proposes some models for analysis phase.

1) Organizational Model

As perthe requirements of real-time systems, this model helps to detect the entities that have temporal restrictions. In the model specification, the structural aspects of the organization are defined with behaviour of entities.

2) Goal/Task model:

This model attempts to answer the questions of why, who and how throughoutthe analysis process.Why refers to the goals that are defined for the system; who refers to the agents which are responsible for the goal fulfilment; how refers to the set of tasks which are defined to achieve the goals.At this stage it is possible to distinguish between hard goals, soft goals and normal goals.

3) Agent Model:

Agent model consists of a set of individual specifications of the identified agents and/or roles.This model defines real-time agents and roles with criticalor non-critical temporal restrictions.

4) Domain Model:

The domain model represents factual knowledge of the environment through the use of classical UML class diagrams. Some variable represents temporal information for complex real-time system.

5) Interaction Model:

This model represents the way in which the agents interchange information with other entities (and also with the environment). In the case of real-time systems, incorporating temporal restrictions in the specification of some interactions is important. So the interaction among the agents is represented with a specific deadline and expected quality.

In design phase of the RT-MESSAGE for RTMAS following activities are performed:

- Number of agents is calculated,
- Types of agents are identified,

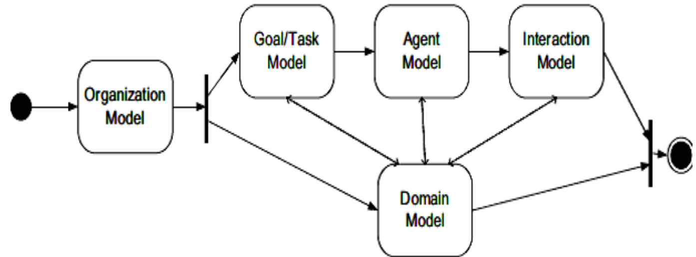

Figure 1.1: Analysis activity

- Internal structure of agent is defined,
- Communication protocols among the agents are defined,
- Agents are distributed among the physical nodes,
- Real-time agents' behaviour is scheduled according to communication protocols.

The RT-Message design process is divided in two parts: an architectural design and a low-level design. The architectural design takes place with following activities:

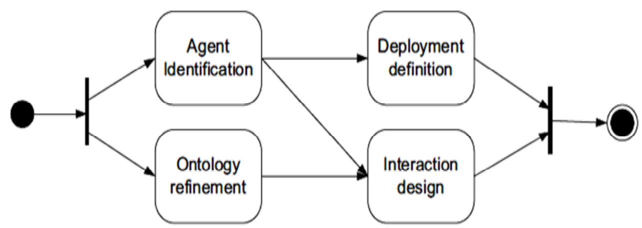

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Figure 1.2: Steps in architectural design
Source: Developing Real-Time Multi-Agent Systems

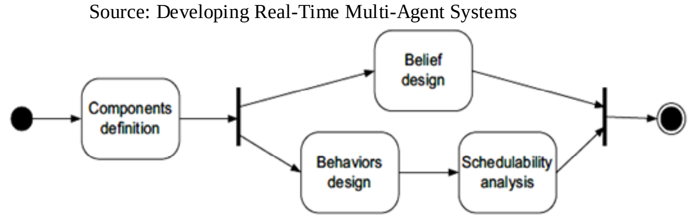

Figure 1.3: Steps in low-level design
Source: Developing Real-Time Multi-Agent Systems
(V. Julian and V. Botti)

In RT-Message methodology the real-time agents are designed using the SIMBA and ARTIS agent architecture.

B) SIMBA

SIMBAis a set of ARTIS agents and their interactions.It is an architecture for multi-agent systems to work properly in social real-time domains. The SIMBA architecture constitutes the ARTIS agent architecture for hard real-time environments. So hard temporal restrictions can be implemented with ARTIS agent. This set of agents controls the real-time environment with hard critical constraints. This architecture also supports integration of different types of agents for non-critical activities.

C) The ARTIS Agent Architecture:

This real time agent reacts to different scenarios in the environment in a dynamic and flexible way. The main features of ARTIS agent architecture are:

- It satisfies all the critical temporal restrictions of the system,
- Its adaptability and proactivity help to provide the best answer for the current environment status.

The ARTIS agent consists of following elements:

1. The sensors and effectors to interact with the environment.

2. The Communication Module (CoMo) to control the sending and arrival of messages.

3. In-agents: Set of internal agents to model behaviour to achieve goals. An in-agent is an internal entity that has the necessary knowledge to solve a particular problem.

4. A set of beliefs to represent domain knowledge relevant to the agent and the internal state.

5. The Control Module that is responsible for thereal-time execution of the in-agents that belongto the AA.The control module must implement different execution criteria for each agent. It is divided into two submodules: Reflex server and deliberative server.

Depending on temporal restrictions, in-agents are classified as critical or acritical. A critical in-agent is featured by a period and a deadline. The reflex server works for critical agents and deliberative server works at real time for both agents.

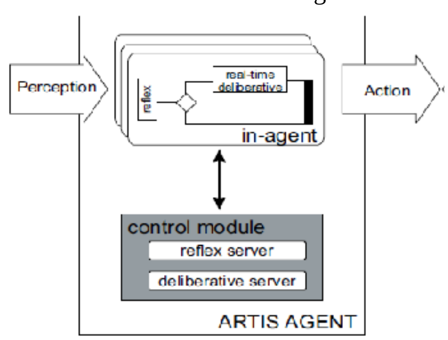

Figure 1.4: ARTIS agent Architecture
Source: Developing Real-Time Multi-Agent Systems(V. Julian and V. Botti)

SIMBA communicator agent consists of Agent Management Specification (AMS) and Directory Facilitator (DF). A Directory Facilitator (DF) provides yellow-pages service to the agents involved and an Agent Management System (AMS) maintains the addresses of agents registered in the platform. SIMBA platform works with multiple ARTIS agents and a mediator agent which integratesthe DF and the AMS services. This mediator agent is the SIMBA interface with agents that do not follow theARTIS agent architecture.

As shown in figure 5, SIMBA platform consists of multiple ARTIS agents and a mediator agent which implements DF and AMS services. The mediator agentprovides SIMBA interface.

D) Agent's Temporal Communication:

An **in-agent** is an ARTIS internal entity that has the necessary knowledge to solve a particular problem. This in-agent is also an agent with additional features as:

- **Reactivity**: periodically looks for changes in its environment.
- **Collaborative performance:** Each **in-agent** has to solve a particular sub-problem, but all the **in-agents** of a particular **AA** cooperate to control the entire problem
- **Hard real-time activity:** Each in-agent must have a deadline and a period which enable it to work in environments of this kind.

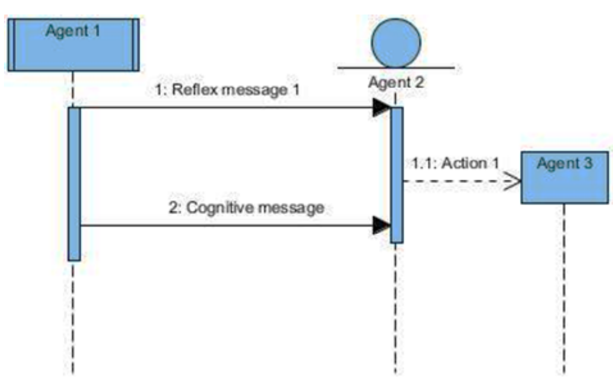

Figure 1.6: in-agent communication

The in-agent communicates with three steps:

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1. **Reflex level**: Here, in-agent assures minimum answer for a particular problem within short bounded time.
2. **Intelligent or cognitive level**: Here, in-agent calculates a reasoned answer through a deliberative process.
3. **An Action level**: It carries out the corresponding answer for implementation.

For each interaction, the in-agent has to decide between reflex answer and a more detailed answer at cognitive level. This decision depends on the time available to calculate a better answer before deadline.

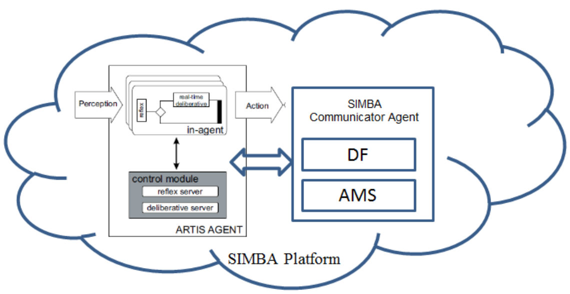

Figure 1.5: SIMBA platform

The agent communication based on time can be used in different domains. Using such agent communication, agent can take different decisions which are uncertain. Intelligent decision support system for healthcare need increased timeliness in making decisions, improved consistency in decisions, improved management of uncertainty, and formalisation of organisational knowledge. Several applications of the agents for healthcare can use temporal behaviour in following fields:
i) Medical data management, ii) Decision support systems, iii) Planning and resource allocation, iv)Remote care.

1.5 Research Objectives:

The research objective is to explore health care domain as real-time multi agent system and to compare temporal behaviour of agents in hard real-time scenario and soft real-time scenario with the help of some case study.

II. LITERATURE REVIEW

Real-time multi agent system for healthcare domain supports intelligent decision support system (IDSS) for intensive care to help doctors to decide about the best care to provide their patients. Such system is expected to reduce medical errors, to fasten clinical interventions and to provide better care by having the required information at the right place, at the right time. Temporal agents with their properties like intelligent, autonomy, reactivity, and proactivity are well suited for dynamic, ill-structured, and complex environments such as an Intensive Care Unit (ICU), diagnosis of diseases, treatments for fatal and chronic diseases etc. There are some medical multi agent systems which can have temporal behaviour of agents and they can be enhanced into real-time multi agent systems.

A) *Clinical Diagnosis System*(Shibakali Gupta, SripatiMukhopadhyay, 2012)**:**
The agent oriented clinical diagnosis system (CDS) can take care of every stage of patient such as initial check-up, treatment, and report for the patient. And the CDS algorithm is capable to handle the system very efficiently. It is intelligent medical diagnosis system. Using the knowledge base and collaborative, co-operative intelligent agents with a multi-agent platform, CDS provides a communicative task-sharing environment.

B) *mHealth with THOMAS approach* **(**Roberto Centeno, Moser Fagundes, Holger Billhardt, Sascha Ossowski, 2010**):**This system supportsmobile medical emergency management in an urban areausing THOMAS approach. THOMAS is set ofMeTHods, Techniques and Tools for Open Multi-Agent Systems. This system works for all types of medical emergencies. The application provides services and decision support to the different actors (patient, emergency centre, ambulances, hospitals, etc.) involved in emergency assistance processes. The organisational paradigm provides a straightforwardapproach to model the functioning of complex application domains. The THOMAS platform facilitates the integration of non-active entities as web services, so it introduces the concept of Service-oriented Multi agent systems.

C) *CASIS* **(**Wan-rongJih, Jane Yung-jen Hsu, Tse-Ming Tsai, 2006**):** CASIS **(**Context-Aware Service Integration System**)** is an event-driven service-oriented and multi-agent system framework whose goal is to provide context-aware healthcare services to the elderly resident in the intelligent space. CASIS framework allows remote caretakers, such as concerned family members and healthcare providers, to closely monitor and attend to the

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elder's physical and mental well-beings anytime, anywhere. The smart environment interacts with the elder through a wide variety of appliances for data gathering and information presentation. The environment tracts the location and specific activities of the elder through sensors, such as pressure-sensitive floors, cameras, bio-sensors, and smart furniture. Meanwhile, the elder receives multimedia messages or content through speakers, TV, as well as personal mobile devices. The caregivers may access the elder's health and dietary information through any Web enable device like a PC or PDA.

D) *OHDS* (Hadzic, M., Chang, E., & Ulieru, M., 2006): It is ontology-based holonic diagnostic system. It is a system that supports the doctors in the diagnostic, treatment and supervision processes of the evolution of new epidemics, based on the exploration of all data for each case. OHDS combines the advantages of the holonic paradigm with multi-agent system technology and ontology design, for the organization of unstructured biomedical research into structured diseaseinformation. Ontologies are used as "brain" for the holonic diagnostic system to enhance its ability to structure information in a meaningful way and share information fast. A fuzzy mechanism ruled by intelligent agents is used for integrating dispersed heterog knowledge available on the web and automatically structuring the informatio adequate ontology template.

E) *MobiHealth* **(2004):** Itis an innovativ agent platform for Body Area Ne (BANs). It provides plug and play connectivity. It enables monitoring, s and wireless transmission, by means G gathers vital signals data coming fr BAN of the patient. The system helps b monitoring of patients at home. Vital are measured and are transmitted alor audio and video to healthcare providers. The MobiHealth servic application platform enables mon g, storage and transmission of vital signs data coming from the patient BAN. The platform supports flexible personalization of services.

III. RESEARCH DESIGN

A) Example for Soft Real-time Multi agent System for Healthcare Domain:

Consider the Context-Aware Service Integration System (CASIS), which provides context aware healthcare services for elderly residents in intelligent space, and allows remote caretakers, to closely monitor and attend the elder's well-being anytime, anywhere. Due to technology there are no limitations of "geographical distance" between the elders and their caregivers to achieve higher quality elder care. The environment tracks the location and specific activities of the elder through sensors, such device like a PC or PDA. Context-aware computing enables the environment to respond at the right time and the right place, to the elder's needs based on the sensor data collected.

Many elderly people face difficulty for taking care of their health. Let us assume the patient aged above 70, lives in his home town by himself. Additionally, the patient can be a diabetic and needs to test his blood glucose level several times a day.In such situations, physicians request the patient to keep a record of the test results, which are reviewed during the monthly check-ups.

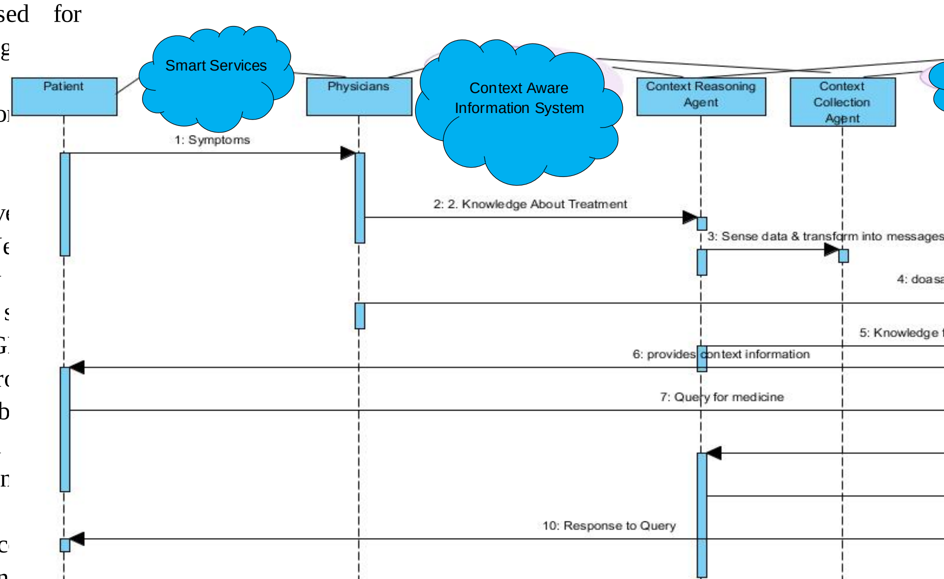

Figure 3.1: soft real-time scenario for chronic diseases

Since the situation comes under the category of chronic diseases, Patient requires routine medication, which may be adjusted periodically by his physician according to his health conditions.

Patient may forget to take his medicine on time. Sometimes, he may get confused about the prescribed dosage. In order to keep his diabetes under control, the doctor suggests patient to follow a strict diet with meals designed by his dietician. Additionally, the patient may feel his diabetic diet overly restrictive. As a result,

he tends to make poor food choices. However, there is no way for his dietician and family to monitor patient's dietary behaviour. For such scenario, real-time multi agent system will work perfectly with following services:

1. **Smart Services:** The elders can interact with a variety of intelligent interactive objects in a typical home environment. For example, the Smart Floor can be deployed for location tracking,

2.Context-Aware Information Services: The elders may receive timely and personalized information services. Using an event-driven calendar, CASIS may generate voice reminders for taking medicine.

3. **Healthcare Services:** CASIS works as a gateway for healthcare professionals to get updated and aggregated bio data on the elder's health conditions.

Following agents will work in real-time environment to provide services of CASIS:

1. Context Collection Agent: It gathers raw sensing data and transforms it into XML format before sending messages. Context Collection Agent also collects the personal preference and ontology data.

2. **Policy Control Agent** This component contains a set of rules and ontologies that relate to user policies, which has access control of personal information, e.g. daily schedule and health status.

3. **Context Reasoning Agent:** This agent is an inference engine that reasons from the context knowledge.

4. **Context Visualizer**: This provides the interface for users to access and query context information.

The sequence diagram fig 3.1 shows how the above mentioned agents will coordinate and communicate for CASIS in the scenario of chronic diabetic patient.

This scenario is considered as soft real-time scenario because intelligent agents like smart services, context aware information system and healthcare services will save necessary data for particular patient and will become active when needed by physicians or context reasoning agent.

B) Example for Hard Real-time Multi agent System for Healthcare Domain

Consider the typical medical emergency case: It starts when a patient calls the emergency number, asking for assistance. The call is received by an Operator, who gathers the initial data from the patient. Then she forwards the call to a Medical Doctor, who assigns the resources to process the request. Technicians do this task by considering availability of ambulances, distance and time to reach the patient, type of resource (ambulances with different capabilities and available resources). Finally, according to the patient condition, she is transported to a hospital.

For above scenario, the agents identified are: patients, emergency communicator, physicians, ambulances and hospitals. These agents collaborate with each other in order to obtain their goals - to provide medical treatment to patient as fast as possible. The performance of the whole system depends strongly on the efficiency and effectiveness of this collaboration and interactions among the agents. So the intelligent agents can come in scenario as below:

1. **Emergency Centre Finder:** this service finds the responsible emergency coordinator for a given location.

2. **Medical Record Store:** it allows agents to store and retrieve patients' medical history information through user name and password.

3. **Ambulance Finder:** This service is an internal service for the emergency-coordinator centre. The service finds an ambulance for a particular patient, considering his position, his symptoms, etc.

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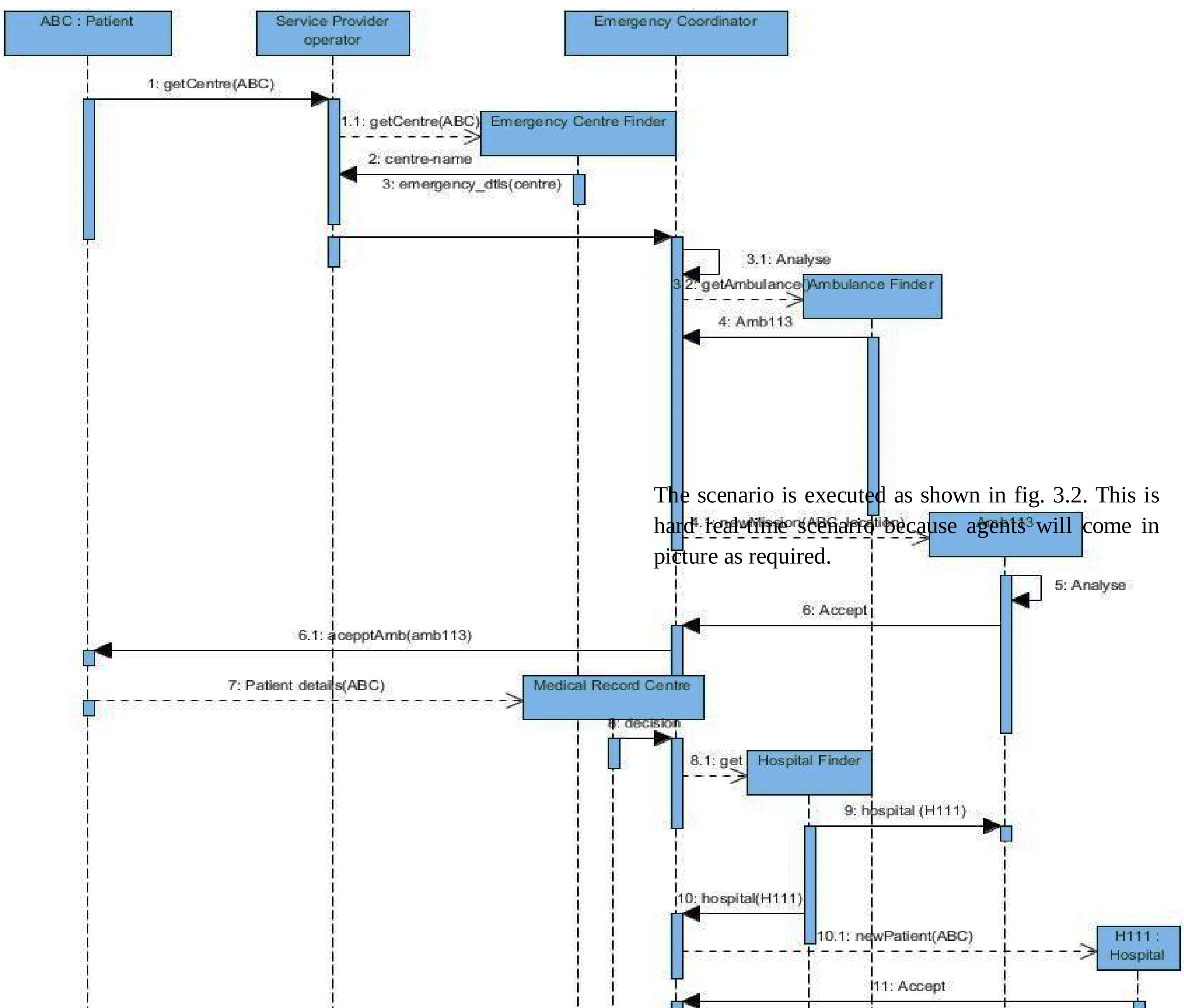
4. **Hospital Finder:** this service is similar to ambulance finder service. The service is able to find a hospital taking into account the patient's position, symptoms, availability of specialists, availability of bed etc.

Hence, the system will consider intelligent agents and active agents and scenario will be as follows: Assume the person staying in suburbs of Mumbai starting chest pain suddenly. He already had a history of cardiac treatment previously. The *patient* calls to emergency number for *ambulance*. The *emergency operator* with the help of *medical record store* will find patient history. According to current symptoms, the *emergency operator* will take the help of intelligent agent *emergency coordinator* and they will call *ambulance finder*.

The agent *ambulance finder* will locate the ambulance in that geographical area with needed equipment. The *ambulance* agent accepts the mission and reached to *patient*. Till that time *ambulance finder agent* will communicate with *hospital finder*. The *emergency communicator* with the help of *hospital finder* will try to find out suitable hospital which will be closer with the specialists and bed available. The ambulance will take the patient to the hospital directly.



The scenario is executed as shown in fig. 3.2. This is hard real-time scenario because agents will come in picture as required.

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IV. IMPLEMENTATION

To implement the system, it is necessary to implement every agent of the systemon a software platform. The multi-agent platform used in SIMBA offers social frame to place the different ARTIS agents that constitute the SIMBA multi-agent systemto be developed. The SIMBA platform provides following services:

1. It offers a communication environment which allows for the sending and receiving of messages among agents.
2. The platform supports a subset of FIPA interaction protocols and includes the AMS (Agent Management System), the DF (Directory Facilitator), and the ACC (Agent Communication Channel)
3. SIMBA is a distributed agent platform and can be executed in several hosts.
4. ACL messages should be platform-independent.

A development tool called InSiDE (Integrated Simulation and Development Environment) is used during the implementation process of every ARTIS agent. The prototype of ARTIS agent can be made with this visual toolkit.

For intelligent agents implementations web services can be used. E.g. in above hard real-time scenario to implement agents ambulance finder or hospital finder, Google Map web services can be used.

V. CONCLUSION

SIMBA architecture with ARTIS agent architecture supports real-time multi-agent system architecture. This is applied to solve problems in social real-time domains.

The examples show that temporal agents in real-time multi agent system handle soft real-time communications and hard real-time communications. Temporal agents can give reflex response for hard real-time scenario and reflex and cognitive response for soft real-time scenarios. Such system can support all types of medical emergencies.

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