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Embedded Management of Electronic Health Records

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Abstract – **One of the biggest challenges for IT in healthcare sector in the upcoming years will be to gather, maintain and search into geographically dispersed and unstructured clinical information. For years, many institutions are trying to collect, standardize and centralize this information into common storage in order to provide consistent health data. The project BioAGE presents a decentralized concept to link and build a virtual electronic medical record, stored on one or more distributed computers or embedded devices.**

Keywords – **electronic health records; ehr; grid computing; embedded; decentralized;**

I. INTRODUCTION

Modern medicine is probably the widest and most dynamically developing science with applications in fundamental biological sciences, such as anatomy, biochemistry, genetics, cytology, physiology; specialized activities, such as surgery, neurology, cardiology, oncology, ophthalmology; general practitioners and health management activities.

Today, the Health Informatics provides the automation of all these complex and heterogeneous activities by using variety of hardware and software solutions. As a result of the progress of this subject sector, the volume of information dramatically arises together with the requirements for processing, standardization, security, reliability and sharing. Furthermore, a significant part of this information remains unstructured and not portable. It is clear that without specialised tools for searching, crawl, access and virtualizes data, the medical information will become inconsistent and will be processed even more difficult [1].

Variety of examples can be given from different medical fields regarding issues that arise from the presence of dispersed, non-portable, heterogamous, and unstructured medical information. Such problems can also be found in EHR (Electronic Health Records), which should collect and present in consistent appearance the clinical information about the patients from different medical sources, such as centralised systems for clinical administration, content management systems (CMS), professional scanners, lab results, OCR data and more [2].

The information technologies, where a centralised database is used with computer connectivity in a local network, can automate and standardise particular medical activities in a single health facility. The technological boundaries of that type of solutions are quickly reached and exhausted, when the practise requires:

- Portability and fast deployment;
- Development of new medical activities performed on different storages and locations;
- Integration with existing professional systems;
- Data virtualisation, including controlled data sharing;
- Searching in geographically dispersed unstructured medical and operational information;
- Processing of distributed medical data and results.

The modern information solutions that can overcome the limitations, as mentioned above, can upgrade and connect the existing software, specialized embedded devices and the overall hardware infrastructure of one or more medical facilities in a grid or cloud.

These technologies could bring number of benefits. Some of those are mentioned here [6]:

- To achieve cost-savings during the expansion of the existing IT infrastructure;
- To increase efficiency and the performance of current medical activities;
- To improve the quality and the portability in the provisioning of medical services;
- To standardize and normalize the data from and to different external systems;
- To perform additional processing of medical information, such as fully text search in unstructured data, documents attached to the EHR, distributed medical image processing, etc;

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- To monitor and control the information access and the usage of systems by other system providers.

II. The Project BioAGE

A. Goals and Objectives

BioAGE is a project for developing of hybrid conceptual platform for parallel computations, which provides tools for building and deploying of computational data grid. This solution incorporates a number of standards and technologies for communication, grid computing and capabilities to work in embedded devices, such us ISO EN13606, OpenCV, and Erlang – a time-tested runtime system designed by Ericsson to support virtualized, distributed, fault-tolerant, soft-real-time, non-stop applications.

The platform is developed as a result of the execution of project BG161POO03-1.1.05-0152-COO01, sponsored by the European Union, Bulgarian Government and Binetix LLC.

The major goal of the project is to create collaborative environment where portable and embedded devices, different systems, functions and data can bring measurable results to a particular application field, like health informatics.

BioAGE provides the complete set of technology and programs for designing and deploying of computational and data grid, tools for developing new functions and connectivity, and number of options to integrate existing external systems into a common grid.

The scope of the project includes also few demonstrations of the capabilities of informational computational grid through different applications in the medical practice.

B. Applications and Deployment

BioAGE finds particular application in the field of healthcare for building virtual EHR to ensure their decentralized management and full-text search in structured and unstructured information, documents, databases and images associated with EHR.

The Grid is also used in medical imaging, in particular for the processing and analysis of images obtained by digital subtraction angiography by CT scans, MRI scanners, infrared cameras, apparatus for positron emission tomography, as well as different isotope studies [3].

Image processing and the provisioning of interim or final results, as part of the clinical information in an EHR, involves complex and time-consuming operations. Example of such operations is the amplification of the signal/noise ratio, contrast improving, contour and regional segmentations, bi-directional Fourier transformations, object recognition and comparative analysis of the results of regular surveys and observations of patients.

Users of the platform can be patients, doctors, and experts in hospitals, laboratories, pharmacies and other health care institutions which are authenticated by computers and that can receive access to information related to health records [5]. The information is managed by decentralized computers that can be connected in a common virtual infrastructure through Internet Protocol [4]. Information can be locally created, deleted, altered, or searched or globally summarized, synchronized and searched from any connected computer.

The connectivity between computers is not mandatory.

C. Solution Architecture

The Grid has SaaS (Software as a Service) architecture and it is dynamically built by interconnected nodes (computers, servers, mobile and other embedded devices). The design of the nodes allows them to operate on different hardware platforms and operating systems. Due to the service nature of the entire solution, all resources in the grid, such as interfaces to external systems, unstructured files and documents, intersections and unions from data bases, extra developed functionality, can be:

- categorized and represented in unified format;
- accessed, exchanged and ultimately used in a controlled way from all nodes in the grid;
- utilized and scheduled simultaneously, in accordance with particular business needs and practical scenarios.

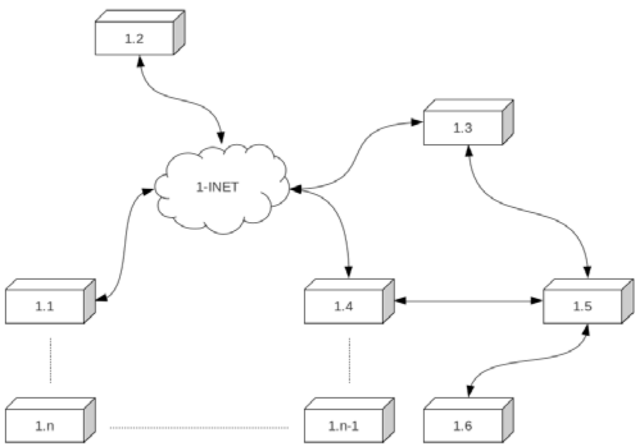

Fig. 1. Embedding computers, servers, and portable devices into a common grid solution.

The Node is managed by a special program called *Agent*. The Agents control the execution and the exchange of algorithms and data between the nodes in the grid and its users.

Fig. 1 depicts exemplary system architecture for decentralized management of electronic health records realized through BioAGE, which consists of nodes 1.1, 1.2, ..., 1.n-1, 1.n, which build virtual infrastructure and within it are the users of the system - patients at home or in public places, experts, doctors and specialists in hospitals, laboratories, pharmacies and other health-care institutions. The connectivity between nodes 1.1, ..., 1.n is not mandatory, but can be achieved by one or more connections by using appropriate transport Internet Protocol (TCP, UDP, SCTP), in local computer network as well as in the public Internet cyberspace 1-INET [4].

The Agents dynamically and asynchronously optimize the executed requests and their content, thus balancing the performance of complex parallel tasks in the grid, reduce traffic between the nodes and ensure the timely delivery of interim and final results.

Due to its hybrid design, the BioAGE technology enables the integration of existing embedded devices, applications and algorithms in a distributed, competitive and geographically distributed computing environment.

D. System Components

Fig. 2 shows components that describe an Agent of the grid and must be present in the composition of each node of the model system for the decentralized management of electronic health records.

This node consists of a component for managing communication with Virtual Infrastructure 2.1, component for managing of queries and results 2.2, component for managing of data for EHR 2.3, component for rights management 2.4, component for identification and authorization 2.5 and components for data management from external system sources 2.6.1, 2.6.2, ..., 2.6.n.

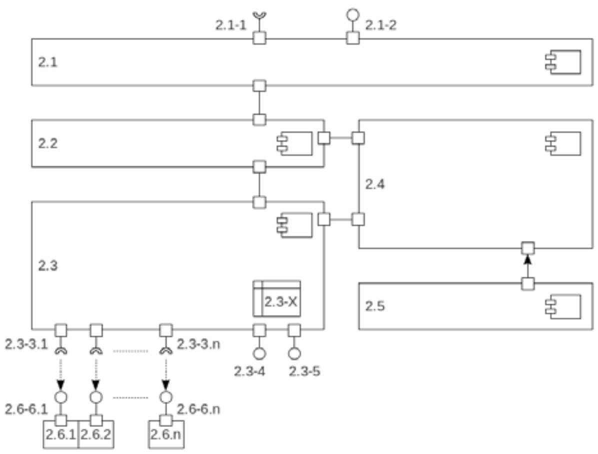

Fig. 2. Embedded Components within BioAGE's node.

At the example, the system will operate in the following manner:

On one hand, each node 1.1, ..., 1.n operates, by functioning as a component to manage data for electronic health record 2.3 can locally create, delete, modify, search, format and summarize the information available in the system external sources.

For this purpose XML structure, aligned with ISO EN13606, is used 2.3-X, by which are described and managed the data, using the control components 2.6.1, ..., 2.6.n and by active interfaces 2.3-3.1, ..., 2.3-3.n accordingly associated with interfaces 2.6-6.1, ..., 2.6-6.n. with the help of programming interface 2.3-4 the users manage the summarised information with 2.3-X, and by using the programming interface 2.3-5 they can expand and change the shape of 2.3-X, to activate or deactivate some of the components for external data management 2.6.1, ..., 2.6.n.

By using component 2.3 each node can globally process queries for full-text searching, comparing, summarizing, tasks execution and synchronizing the contents of the medical record with connected computers or mobile devices in the virtual infrastructure through the program interface 2.3-4 with the help of the connected to 2.3 component for managing of queries and results 2.2 and the associated with 2.2 component for communication management 2.1.

III. Practical Scenario

Practical scenario for the usage of the system, which describes real situation of its industrial application, is as follows:

When a patient is visiting at a GP a medical exam is performed. The doctor uses system for the decentralized management of electronic health records through their portable tablet 1.4, which originally is not connected to another node. The component for management 2.3 is preliminary set to save the data of the health record to an external system file, which is managed by appropriate XML structure 2.3-X, activated exemplary interface 2.3-3.4 connected with 2.6-6.4 and exemplary component for managing of specific external files 2.6.4, the program interface is used for tuning the preliminary settings, 2.3-5. The doctor saves the information from the exam in the patient health record the trough program interface 2.3 4 by creating or updating locally on their PC a file that contains ambulatory sheet with personal patient information, details from the consultation and medical direction for further examination in hospital or a lab [4].

According schedules medical direction, the patient goes to a designated hospital to another expert who also uses the system from their PC and 1.5. On this node, the component 2.3 is set to manage electronic data file in an external system database (DB), which is governed by another independent XML structure, exemplary interfaces 2.3-3.5 and 2.6-6.5 exemplary component for managing of DB 2.6.5. The expert from the hospital accepts the patient and successfully connects their computer to the GP's computer by the component 2.1 and communication interface 2.1-1 The embedded devices 1.4 and 1.5 already build new virtual infrastructure. With the help of component 2.3 and the interface 2.3-4, the expert in the hospital sends a request from 1.5 to the infrastructure in order to find the electronic health record of the patient. The request is processed by 2.2 and the result is summarized by the component 2.3, thus the expert receives detailed information for the medical direction from the portable tabler 1.4.

The information is synchronized and save by 1.5 in appropriate manner in the local DB with the help of component 2.6.5. The expert updates locally the patient's EHR with the results from the medical examination in the hospital, but realizes that it is necessary to perform further analysis at an independent laboratory. The medical expert modifies the data of patient's EHR by using interface 2.3-4, as supplementing it with instructions for laboratory testing and sends new query for specialized examination in a laboratory using the help of components 2.3, 2.2 and 2.1. The computer 1.5 makes successful attempt automatically to connect to other computer in the lab. A specialist in the lab also uses the system for EHR from a PC 1.6. By the communicational interface 2.1-2, he/she accepts the incoming connection from 1.5.

The virtual infrastructure already consists of three nodes that are connected as follows: 1.4 with 1.5 and 1.5 with 1.6. On the computer 1.6, component 2.3 is set to govern the data for EHR in different to the system external file, which is managed by third independent XML structure, exemplary interfaces 2.3-3.6 and 2.6-6.6, and exemplary component for managing specific external files 2.6.6.

The specialist sends search and summarization request of patient's EHR to the virtual infrastructure, as a result he/she receives information from 1.4 through 1.5 for the patient's data and the performed medical examination by the GP and information only from 1.5 about the results from the test performed at the hospital, as well as the instructions for additional lab testing of the patient. The specialist locally modifies the data in the patient's EHR by the interface 2.3-4, as the supplements it with the results of the requested earlier lab test. The GP sends request towards the virtual infrastructure. After analysis of he received information from 1.4 and 1.5, he/she adds locally to file the final history of the clinical condition of the patient.

In the example scenarios for usage of the system for decentralized data management of electronic health records (EHR) all requests for search and summarization, as well as data updating and the format of the file are always controlled by the rights management component 2.4 and the associated to it component for identification of authorized users 2.5. The communication and the authentication are secured by standard transport protocols TCP/IP and RFC 4510/4511.

IV. Conclusion

BioAGE project presents an innovative method for decentralized management of electronic health records by the by existing software and hardware infrastructure with integrated tools for full text search in structured and unstructured information.

The advantages of such a solution are that it automatically builds electronic health record information distributed on one or more computers and portable devices without requiring the presence of a central server. As a result of this, data can be summarized on the visits to various doctors, from expertise conclusions and analyses made in geographically distant laboratories conducted treatments in hospitals, for medicines nomenclatures stocks, knowledge bases, and to perform processing for the purposes of medical diagnostic imaging.

Additionally, by the virtual infrastructure it is ensured the continuity of services provided for data management, comprehensive protection against data loss, autonomy of the medical records on individual users or institutions and to automatically include new computers, devices and resources with which to update and supplement the health records with new relevant information.

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