Cloud Computing Enhanced Service Development Architecture for the Living Usability Lab

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Abstract. As life expectancy increases, so does the number of ambient assisted living (AAL) initiatives. These IT initiatives often traverse several research fields; from embed devices to multiple data streams analysis. Advanced processing and reasoning of such data streams poses a complex problem usually solved using local processing resources. This paper addresses this problem from a cloud computing perspective.

Keywords: Ambient Assisted Living, Cloud Computing, Living Lab, Telerehabilitation.

1 Introduction

Living Usability Lab (LUL) [1,2] is a joint academia-industry R&D initiative, started in January 2010, aiming at creating the conditions to develop and evaluate innovative services for the Elderly initiative of industry and research. Essentially, it is a living laboratory to test new approaches to the ambient assisted living initiative.

Nuclear to the project is its attention to usability, multimodal interaction, design for all and the exploration of new opportunities opened by next generation networks. Multimodality is essential to support intuitive and natural interfaces effectively humanized.

Considering the high demands on the overall AAL system quality and consequently on software and system engineering, user acceptance is an absolute necessity. Therefore, the early involvement of end users in the design process assumes a high importance to meet the actual needs of the future users in their daily life.

Although the importance of the user involvement and user participation in the design process has been recognized as essential, there is a need to further developments in the daily practice, through the use of innovative strategies. Living Lab is an emerging research methodology which includes the user involvement by taking into account the micro-context of their daily activities.

By addressing the scenario of elderly at home with these specificities, the project is in line with the most recent developments in the broad area of Ambient Assisted Living (AAL).

LUL is a living laboratory. One of the current projects in the laboratory is TeleRehabilitation [3].

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The main purpose of this paper is to present and discuss a possible research direction on LUL project where services and applications may embrace a distributed computing scenario. Given the current hype on cloud computing, and considering the benefits (scalability, processing, storage, etc.) arising from its usage, there is the need to understand how the LUL project can be adapted to integrate Cloud Computing on the production system. Furthermore, there is the need to understand the pros and cons of venturing through the cloud.

This is an essay paper about the usage of cloud computing services to enhance LUL. The main goal is to assess the pros and cons of adopting cloud computing. The extent of the externalization of LUL's system must also be considered.

2 State of the Art

Even though there are several AAL initiatives ([4-6] refer to recent work), few projects rely or are based on cloud computing solutions. However, there are a few exceptions worth mentioning. This section covers some of the approaches in production sites.

In [7] authors present an architecture for a Secured WSN-integrated Cloud Computing for u-Health Care. The cloud computing integration was necessary for faster, cheaper and more reliable processing of information.

Authors argue that large, heterogeneous and complex data processing and visualization can be computing intensive, especially for real time scenarios. Processing of raw sensors data, handling incorrect data, filtering information, combining different sensor data and display such information in a user friendly manner are but a few of the operations in place in the information workflow. The amount of sensors and information (environmental, imagery, video, audio) that can be monitored and cross compared at a given time, and considering the huge amount of information (hundreds of samples per second per device, burst frames, etc.) that such sensors represent, a huge processing power is required. This approach is also valid when considering that on top of such real time information, users require historical analysis, information data-mining, context awareness, ontologies processing and other high levels. In this case, the huge processing capabilities of cloud computing can be a key factor to achieve the desired performance and results.

The processed information is available to medical staff upon successful authentication.

In [8] authors present AMiCA, a multi-level layered architecture with intelligent reasoning and decision-making support. AMiCA pushes into the cloud the sensors' and context gathers' base communication line.

Both projects use cloud computing essentially for computing purposes.

3 LUL

The project's main concepts are the Home Site, the Specialist Site and the Main Server.

Home Site – it represents the location of the patient. It may be his home or his hospital room. Each home site may hold a set of resources available as services (temperature sensors, video camera, motion sensors, television, speaker, microphone, etc.).

Health professional (Specialist) Site – it represents the location of the specialist. A specialist is typically a doctor. The specialist site is usually his office. Each specialist site may hold a set of resources available as services acting as clients of the information sent by the home site's services.

LUL main server – it is responsible for maintaining a complete list of both specialists and homes registered in the system. For each registry, the server also holds a list of its available services. Along with basic registration functionality, LUL server is also responsible for maintaining a scheduler. Each scheduler event refers:

- Home identification,
- Specialist identification,
- List of allocated resources,
- Event start and end time.

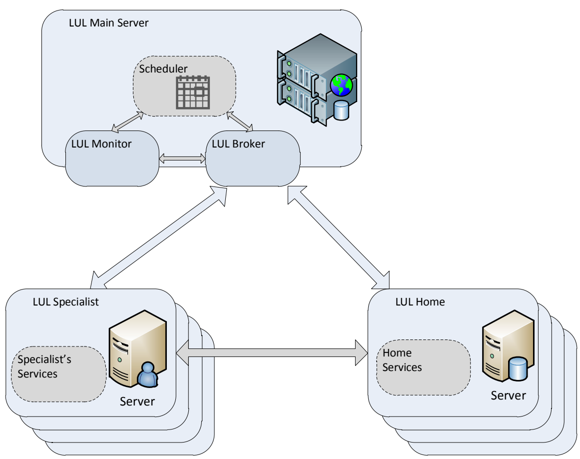

Fig. 1. LUL Remote assistance main blocks

Fig. 1 represents an overview of LUL's remote assistance building blocks. Based on the scheduling information, the LUL server is responsible for ensuring the communication between the LUL specialist and the LUL home. At the event's starting time, the LUL server informs both parties of which services should be started and sends them connection and configuration details for the session:

- Direct device to device communication addresses,
- Specific session and device configuration settings.

After this step is completed, the monitoring features of the LUL server will continuously assess the established connections and may signal the broker to restart all or any service that fails during the event.

Fig. 2 represents the complete set of communications amongst services, broker and monitor. Before any session may take place, both home and specialist services must be registered in the broker. This registration process results from a direct communication between the services and the broker. Each device registers its connection endpoints, capabilities and security requirements.

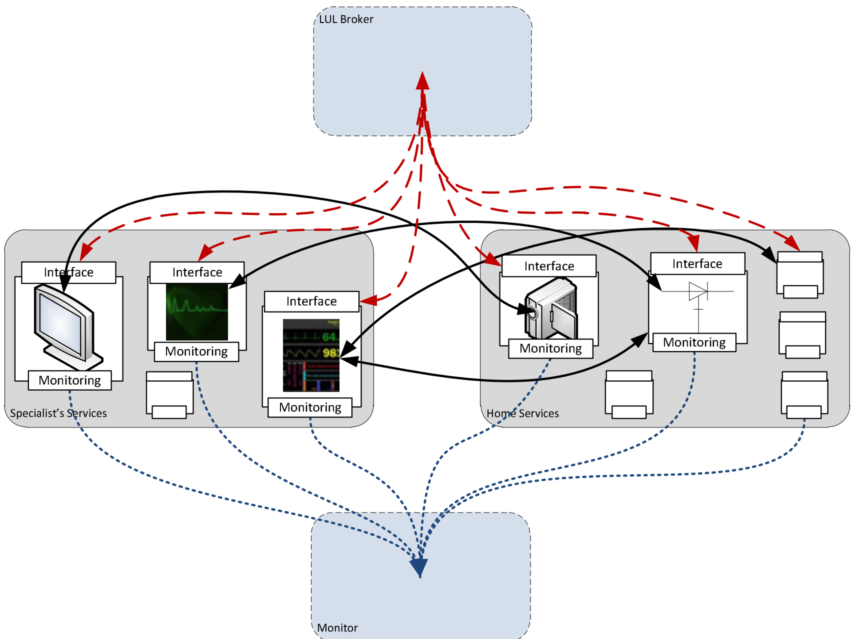

Fig. 2. Communication amongst services

To start a session, both parties (specialist and home) must already be connected to the LUL main server. This initial connection ensures their readiness for the session. Pending request from the specialist regarding an upcoming event, the broker initiates a work session between the services. During this process the broker sends configuration and crossed endpoints details downwards the services. This may be compared to a traditional doctor's appointment: at the designated time, the patient arrives at the doctor's office and waits for its turn (connection phase); on its turn, all the required specialist services can be used to diagnose the patient (session start phase).

Depending on the service's features, one service may establish one or more connections simultaneously with other services. For instance, a sensing service may be connected to two different display services on the specialist side; or a monitoring display service may be connected to more than one sensing service.

As stated, after this initiation phase, each device pushes activity status information to the monitor.

3.1 Deployed Services

Each service may aggregate a set of devices. These are abstracted by a common interface layer that is also responsible for the communication with the LUL server. An independent monitoring layer is also responsible for sending status information to the LUL server. Fig. 3 illustrates the generic service architecture.

This architecture ensures that for a given service, regardless of the number, type or complexity of the devices, the way that the service communicates with others follows a specific and single protocol. This enables the services to evolve and replace devices by others with better features without disrupting the outside communication layer.

Service interface and monitor communicate with the LUL Main Server using web services. The service-to-service communication may or may not use web services. As an example, the home video service and specialist video display, upon registration and successful connection, send and receive the video stream using Real Time Protocol.

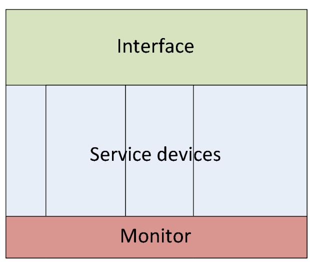

Fig. 3. Generic service architecture

The first service developed aims at making available inside the home and remotely the data gathered by a set of sensors developed by one of the project partners, named BioPlux [9]. For its inclusion, a generic sensor service was developed. The service was developed to be independent of the sensors to be used. The Plux Bio Sensor can be used as any other type of sensor that can appear in the future. The list of currently deployed services include a sensors' service implementation, a specialist sensors display service, a home video service and a specialist video display service.

3.2 LUL @ Cloud – Future Architecture

As with the projects presented in the state of the art section, more advanced usage scenarios require more processing and storage capabilities. To overcome this situation, we propose the off-site processing of all services involved in LUL: Main Server, Specialist Server and Home Server. This way all services may communicate primarily with the off-premises infrastructure.

Considering each deployed service (sensor, camera, speaker, etc.) as an agent, it is possible to automatically propagate its information throughout the off-premises infrastructure. LUL's sites are equipped with fast next generation networks, making the migration from local servers to cloud based servers almost seamless from the communications and latency point of view. Even when considering the nationwide adoption of such project, Portugal has one of the fastest and most widespread fibre optical commercial offerings in Europe [10], meaning that the cloud computing approach will still be valid.

In this scenario there is no need to install extra computational power at the Home site or at the Specialist site, meaning that the deployment of the project itself into new Home Sites becomes cheaper and therefore easier to adopt.

Fig. 4 presents the new block and its interaction with the existing infrastructure. Local server instances are eliminated in this approach. The only precondition is that all services are able to communicate remotely.

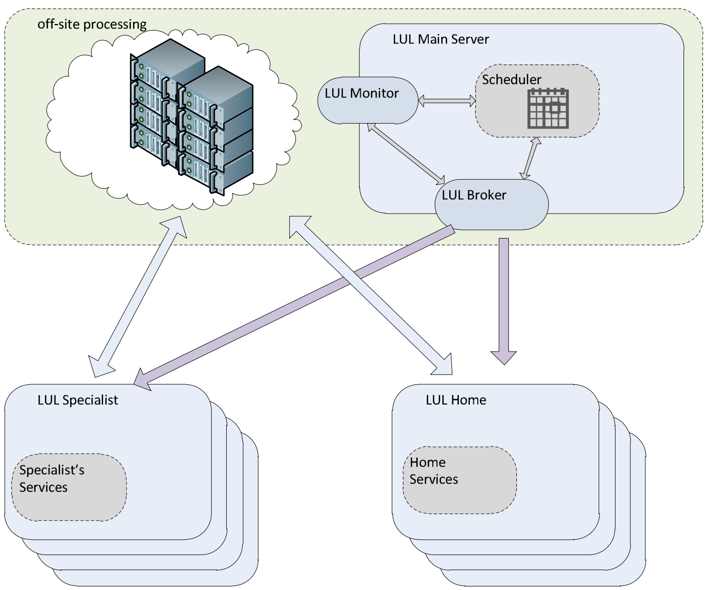

Fig. 4. LUL @ Cloud proposal

The main interactions are still present: at the starting time of an event, the LUL Main Server initiates both the Specialist devices and the Home services. Information flow however, differs from the initial architecture. Information datasets start being pushed from the Home site and consumed at the Specialist site, always traversing through the cloud. The fact that the information datasets all pass through a common location, allows that, for example, a single Home site information stream be directly consumed by several Specialist services, without having to send a duplicate stream from the Home site (information upload) and without the needing of multicast routing. If several Specialist services require a particular stream, then it should be directly downloaded by the requiring services.

The monitoring module, currently running in the LUL Main Server, may be modified to also listen to the streams passing through the cloud. In this case, the traffic added due to monitoring on either Specialist or Home Site would be null.

A simple but effective solution for the data stream is the use of ROS [11], a cloud enabled Robot operating system. ROS is composed by a set of basic information flows consistent with message parsing, organized in a series of topics. Each topic has one or more publishers and zero or more subscribers. Agents (in our case services) push information to the topic and the subscribers get the pushed information.

On top of this first service layer (ROS), the management layer (Main Server) commands the agent's (Site's Services) activity. Their monitoring can be made using the topic/publisher/subscriber use case.

3.3 Discussion

Services and applications in use can be compute intensive, especially at the specialist site, when trying to analyse lengthy patient data records, or when making real time processing of complex information. This off-site processor cloud computing executing based environment means that both peak and off-peak usage can be automatically handled by the cloud, further alleviating the overall cost of running this project.

From the Health professional point of view, the off-site processing element can be interpreted as a Home site with very powerful hardware available. From the Home point of view, the off-site processing element can be interpreted as a regular Specialist that needs access to the information.

Adding to LUL telerehab scenario a ROS based messaging scheme enables the reduction of server equipment on the home site and on the specialist site. Nevertheless, due to the anonymous messaging architecture, special care must be taken to ensure data safety, integrity and confidentiality. . One negative aspect of ROS is that publish and subscribe are anonymous, meaning that it has to be the overall system to guarantee data safety and confidentiality.

An advantage of this scenario is the possibility to rapidly have multiple reasoners analysing the streams passing through the cloud, with no additional cost (in terms of power, resources or bandwidth) from either the Home site or the Specialist site. These high level modules could then be used to trigger warning alerts when certain conditions are be met, or to actively enforce services (on both sites) to perform a given task.

4 Conclusions

This paper presented an overview of LUL's telerehab project, with special focus on the further development of it architecture. This development must consider the need for more processing resources as well as for more resources and services available. Cloud computing was chosen as a common platform to use when replacing the connections for the main server, the health professional site and the home site.

This paper briefly outlines the cloud computing scenario on AAL systems and proposes a new AAL cloud computing approach based on ROS's messaging system.

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