A SOA-Based eHealth Service Platform in Smart Home Environment

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***Abstract*—The increasing demand for a good healthcare quality has brought Information and Communication Technology to an important role in healthcare domain. The trend in decreasing number of formal healthcare workers gives further pressure to move non-urgent treatments to the patients' homes. However, delivering healthcare services to meet the changing needs of inhabitants in a smart home requires an open and flexible service creation and integration environment so that the modification of existing services as well as creation of new services can be achieved in a timely manner. This paper presents a vision of a logical integration platform in a smart home environment, integrating various devices and services by adopting the Service-Oriented Architecture paradigm to provide interoperability, modularity, and reusability of different service components.**

I. Introduction

Information and Communication Technology (ICT) is becoming more critical in the healthcare sector in many parts of the world as pressure for cost reduction and increasing quality of service are mounting. With the deployment of ICT systems within the healthcare domain, healthcare providers are able to provide remote patient monitoring and care. This will reduce the time required for patients to stay at the healthcare premises, promoting post-treatment at patients' homes. On the other hand, as the average age of the population is increasing considerably in major developed countries, policy makers have encouraged research and development projects of eHealth-related applications to meet the rising demand for healthcare and other social services for elderly at home.

Moving non-urgent care and treatments to patients' homes requires intelligent and networked sensors and actuators to be installed. Together with computer systems being deployed, the installed sensors and actuators transform the aforementioned homes to so-called smart homes. In addition, wearable and portable devices also play a big role in eHealth services, especially the ones closely related to tele-healthcare. These wearable and portable devices are attached to the monitored tenants when they are out of home. The computing resources in the smart home should be able to collect the data which are captured, and store them in either a local health-related data repository inside the smart home, a remote data storage service provided by third party cloud provider, or directly being sent to the healthcare provider.

Multi-layer architecture approach is commonly used in information gathering systems that involve various different sensors and actuators. To promote interoperability and manageability, Service-Oriented Architecture (SOA) [1] has been famous for several years as its loosely coupled nature allows integration of legacy and existing systems in a granular fashion that can easily accommodate changing needs. The introduction of SOA paradigm in a smart home for eHealth service delivery will create a unified way of combining and using data from various devices, providing a standard and easy way to develop and compose services.

This paper, which is based on an ongoing research project, proposes an overall architecture for home integration platform, integrating various devices and services in a smart home context to enable eHealth service creation and delivery based on SOA paradigm.

II. Related Work

With the increased average age of population in many developed countries, smart home environments play a bigger role for delivering eHealth-related services targeted to elderly people. One of the most important services is tele-healthcare, which can be achieved using advanced communication networks and Internet technologies. As each disease or pathology may generate its own set of requirements, ICT-based solution that allows the deployment of personalised and person-centric care process and tools is needed.

The authors in [2] developed a patient-oriented tele-homecare system that consists of five elements in its architectural design: Medical sensors and/or Body Sensor Networks (BSN), environmental sensors and home automation sensors network, a gateway, Web Services technology, Graphical User Interfaces (GUI).

The authors in [3] introduced non-intrusive and non-invasive monitoring and assistance to the elderly directly in their homes. A general framework is defined and a semantic model called Smart Home Ontology Model (SHOM) is proposed to perform autonomic decision-making in the U-Health smart home.

Pau et al. in [4] proposed a design of personal health system to be integrated with smart home services platform supporting home-based e-care by using a common media server. As the interactions between people and technology is of specific importance in home e-health applications, the system design takes into consideration the human factor guideline from European Telecommunications Standards Institute (ETSI).

Another tele-health system that is focused on monitoring patients at home was proposed in [5]. The system is designed based on the AILISA project [6], employing off-line model of communication by using emails for data exchange.

Another step was taken in [7] towards assistant tool for automatic assessment of the dependence of elderly at home by using non-invasive presence sensors.

Three types of information are relevant to be captured in remote health monitoring [8]: physiological parameters (health), environmental parameters (comfort), and Activity of Daily Living (ADL). For health monitoring in smart home environments, wireless sensor networks (WSN) technology is becoming more important for gathering data from the patients due to the decreasing cost of miniature sensors, wireless networking technologies, and embedded microcontrollers. A design of wireless body sensor system for monitoring patients physical activities at home is described in [9]. Accelerometers are used for demonstration purpose to measure different types of human movements.

The aforementioned related work mostly focused on the creation and delivery of healthcare services to the patients at home for specific purposes and scenarios without much attention to integration, interoperability, and modularity of different service components. This paper proposes an integration platform for integrating different devices and services in a smart home environment based on SOA concept.

III. Towards Service Oriented Architecture Paradigm

SOA has been a famous buzzword for several years, and the fundamental concept behind it has been adopted very rapidly until recently, especially using the Web Services [1] technology. Web Services technology promotes interoperability between various software applications running on disparate platforms by employing open standards and protocols. In addition, it also supports the reuse of services and components which further increases the speed of service creation.

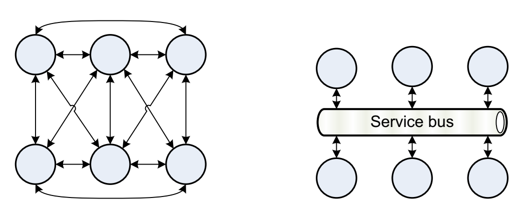
As SOA has been proved well suited for tackling interoperability issues by separating implementation logic and the interface of a service, SOA is envisaged to have a significant impact when applied to eHealth services in the smart home context. Furthermore, since the SOA concept promotes the reusability of existing services, new and tailor-made healthcare services can be provisioned in a timely manner.

In a smart home environment, sensors and actuators play vital roles for monitoring and controlling home conditions, tailored to meet the inhabitants' needs. With eHealth services becoming more pervasive, medical sensors are required to be installed and used in the smart home to deliver eHealth services. Most of these devices may not be owned by the residents of the home, but rather provided by healthcare service providers (e.g. hospitals) with a wider scope of business processes which leads to the notion of *Device as a Service* (DaaS). A device placed by a healthcare service provider in a smart home usually serves a specific purpose which might be considered as a service to the user. This, however, limits the full potential of the corresponding device as the data produced or captured by the device can potentially be used by other services in the smart home. A common data collection mechanism is required, and further, a common interaction platform between devices is necessary to be present in the smart home.

The traditional Web Services technology approach uses a point-to-point mechanism between a service provider and a service requestor (consumer). This may work well when a small number of devices are present. With an increasing number of new devices being installed in the smart home, a centralised management system is beneficial to be deployed. This can be achieved by introducing a logical smart home service bus that supports event-driven SOA. A technology called Enterprise Service Bus (ESB) [10] existed within the SOA domain which can be used to tackle this issue. An ESB provides the implementation backbone for an SOA, acting as a hub between different services. It provides a loosely coupled, event-driven SOA with a highly distributed universe of named routing destinations across a multi-protocol message bus. Applications in the ESB are abstractly decoupled from each other, and connected together through the bus as logical endpoints that are exposed as event-driven services. In general, an ESB has four major functions: message routing, message transformation, protocol mediation, and event handling.

A. Point-to-point vs. service bus considerations

Point-to-point Web Services approach is straightforward and simpler to be deployed. But with the increased number of applications (or in general: services) being introduced in the smart home, this can potentially create management and integration issues. The point-to-point way of integration, which is mainly used for synchronous communications, could not avoid the tight-coupling between the sender and the receiver of messages being exchanged. If the receiver is down, this approach may fail the entire system if message handling is not considered thoroughly. On the other hand, a centralised service bus approach seems more promising to handle the integration task in a smart home setting, avoiding direct contacts between communicating services which remove the hardwiring between service producer and service consumer. This allows integration of services to follow the publish-subscribe model where a receiver subscribes to a topic and receives messages whenever a sender publishes messages to that particular topic. Fig.1(a) and Fig.1(b) show the general comparison of the two SOA approaches.



(a) (b)

Fig. 1. (a) Point-to-point approach; (b) Service bus approach

Although the service bus approach may provide a better centralised mechanism for integrating various devices and services in the smart home environment, an additional layer between service producer and service consumer is expected to give an extra overhead and increased latency, especially when compared to the point-to-point approach. With this trade-off in mind, both approaches can be beneficial to be incorporated side-by-side in the home integration platform, forming a hybrid architecture.

B. Service composition

Service composition becomes essential when full potential of different devices' functionalities are spotlighted to give value-added benefits to the inhabitants in a smart home. In ESB, different services can be called by using the mediation flow mechanism, where mediation flows are committed as a transaction or rolled back. Traditional Web Services approach has a standardised Web Services Business Process Execution Language (WS-BPEL) technology [11] to call different services, also providing transactionality. In general WS-BPEL approach of service composition is well-suited for stateful process with complex logic. It has container activities such as while loops which ESB misses. ESB's mediation flow is generally more suited for message processing since it supports message routing, transformation, and protocol mediation. Both approaches are envisaged to play their own parts in different smart home services integration scenarios.

IV. Home Integration Platform Architecture

Integration of different devices and services in the smart home environment is necessary so that collaboration among devices and services is made possible for offering services beyond the basic utilisation of each device or service. To achieve this, a logical home integration platform is needed as a logical central point of contact for all communication among devices and services. This platform should accommodate event-driven message handling as well as service creation and composition capabilities. In addition, the platform should also follow standard-based interoperability best practices by utilising open standards to further avoid vendor lock-in. A local database or data repository connected to the home integration platform is required to store captured or produced data from different devices and services. A general high-level overview of an architecture for eHealth smart home integration platform is depicted in Fig.2, which shows an example of an external environment connected to the smart home environment.

Since healthcare services in the smart home will most probably be provided by healthcare service providers, the smart home environment should have connections to the healthcare service providers. The connectivity to the external environment is provided by using Internet technology. It is possible that many point-to-point connections are established between the home integration platform in the smart home to various healthcare service providers. Fig.2 refers to Norwegian national health network in which the Core Electronic Health Record (EHR) is proposed to be deployed in the near future, hence, it shows only a connection between the home integration platform with the national health integration platform.

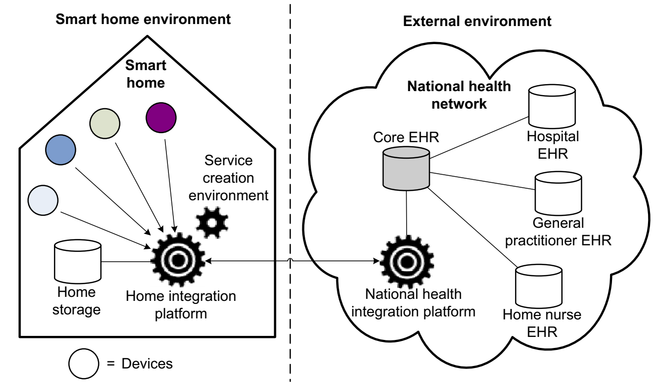


Fig. 2. eHealth smart home integration high-level overview

Fig.3 shows the general architecture of the proposed eHealth smart home integration platform.

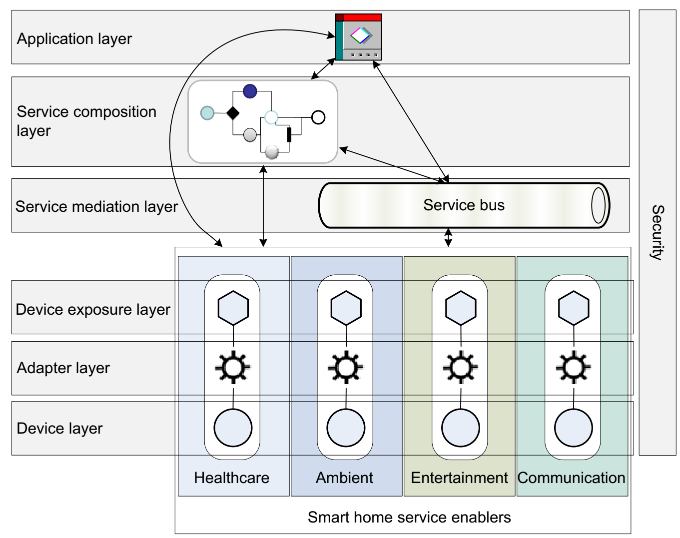


Fig. 3. eHealth smart home integration platform architecture

The architecture of the platform follows a multi-layer approach, consisting of six main layers described as follows.

1) Device layer: This bottom-most layer consists of various devices in the smart home which are used for providing data to the platform. These devices can be controlled by the three upper-most layers of the platform. The majority of devices in this layer are sensors, although for entertainment integration use cases this may not likely be the case. Devices in this layer are not necessarily physical devices, but any data source which may provide usable information to smart home applications.

2) Adapter layer: This layer is responsible for translating a service operation call from the adjacent upper layer to a native API call of a device. For incoming data from the lower layer, this layer is responsible for transforming incoming data format to the suitable format of the upper layers, including callbacks to applications. The adapters can be implemented in the device itself if it has the capability to be programmed, otherwise a separate box with listeners to incoming messages from the device should be used. If a mediation layer is used, such as the ESB, specific message translation functionalities of the mediation layer's components can be used as adapters.

3) Device exposure layer: This layer is responsible for exposing the functionalities of devices from the bottom-most layer in a standard way to promote interoperability between service provider and service consumer. This layer wraps the underlying details of functionalities from the devices and acts as an interface to the service consumer. In the traditional Web Services approach, this layer's role is mainly played by a description language called Web Services Description Language (WSDL).

4) Service mediation layer: This layer is responsible for mediating communications between service consumer and service provider in SOA environment, playing the role of service broker. ESB technology is an example that suits well in this layer.

5) Service composition layer: This layer provides the capability to combine and link existing services, either atomic or composite services, creating new services. Service composition can be seen in a part-of sense where a larger part encapsulates services and exposes itself as a service, or in a sequencing sense where invocation order of existing services is defined. WS-BPEL is a commonly used language for Web Services composition.

6) Application layer: This upper-most layer acts as a host to applications created in the smart home environment, encapsulating different logics for providing direct services to the inhabitants. The main intelligence in the smart home is envisaged to be residing in this layer by making use of the underlying service enablers and/or composite services from these service enablers.

7) Security layer: This vertical layer is responsible for handling security issues across different horizontal layers. Different security approaches may be applied to different layers depending on the required level and type of security by each layer's implementation.

The three bottom-most layers in this architecture form the smart home service enablers which provide basic functionalities to be used for creating applications in the upper-most layer. The service enablers are categorised to four different groups in the smart home as follows.

1) *Healthcare service enablers:* This service enabler category consists of basic services within the healthcare domain in the smart home such as electrocardiography.
2) *Ambient service enablers:* This service enabler category consists of basic services for gathering information and controlling the surrounding condition such as temperature.
3) *Entertainment service enablers:* This service enabler category consists of basic entertainment-related services in the smart home such as controlling entertainment devices.
4) *Communication service enablers:* This service enabler category consists of basic communication-related services in the smart home such as making a phone call.

This architecture provides freedom to the application developers either to use service enablers per se, combined the application with composite services, or rely on the mediation layer's specific functionalities such as the mediation flow for sequencing the invocation of services. By deploying this architecture, it is envisaged that devices and services will be easier to be integrated in the smart home, and new services can be produced faster to meet the inhabitants' demands.

V. Conclusions and Future Work

The SOA paradigm provides positive impacts in service creation and integration realm. Interoperability, modularity, and reusability are among the most important aspects of SOA that have changed how application development in general works. It is also foreseen to give positive contributions in the smart home service integration domain. In this paper the idea of adopting SOA to support eHealth services integration in a smart home setting was described and a generic logical integration platform architecture was proposed. Specific scenarios related to eHealth service creation and delivery are planned to be devised in the advancement of this work.

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