Decentralised Approach to Provision of Home Services

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***Abstract*—This paper introduces an approach that addresses interoperability in AAL domain, the Decentralised Service Delivery Architecture. The approach was developed Within the Advanced Support for Independent Living; Human Lifecycle Approach in Senior Housing (Lily) project, funded in the Ambient Assisted Living Joint Programme. The approach has a decentralised architecture and therefore differs from traditional approaches where services are provisioned via central nodes as via service portals or hubs, dedicated home platforms or systems. The idea of the architecture is to use linked descriptions of samples of service-product continuum that can be discovered using certain criteria, and thus provisioned to inhabitants of intelligent environments. The paper describes the Smart Living concept under which the architecture takes a place, presents some particularities of the architecture and systems that utilise it - HoviMestari and VisAge, and introduces Integration Levels and service templates with respect to the architecture.**

I. Introduction

A Smart Home can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security, healthcare, education, communication and entertainment through the management of technology within the home and connections to the world beyond. [1],[2] A list of aspects relevant to human living may be extended even further by adding occupation, hobby, social interaction, variety of inclusions, etc.

The ageing population in many countries brings about more challenges to researchers and opens us new research fields. One of those is gerontechnology. "Gerontechnology is an interdisciplinary academic and professional field combining gerontology and technology. Sustainability of an ageing society depends upon our effectiveness in creating technological environments, including assistive technology and inclusive design, for innovative and independent living and social participation of older adults in good health, comfort and safety. In short, gerontechnology concerns matching technological environments to health, housing, mobility, communication, leisure and work of older people. Research outcomes form the basis for designers, builders, engineers, manufacturers, and those in the health professions (nursing, medicine, gerontology, geriatrics, environmental psychology, developmental psychology, etc.), to provide an optimum living environment for the widest range of ages." [3]. As it is seen in the definition, the Ambient Assisted Living (AAL) [4] domain and support for independent living have a direct relevance to this new research field.

There is a media that at these days penetrates all the intelligent environments and therefore may be considered for a variety of interoperability aspects. This is the Web. A vast number of consumer and professional devices that are able to access the web exist, and rapidly grow. Those devices may be used to form intelligent environments, or may be parts of the environments.

For example, smartphones are personal end-user devices that are essential in intelligent environments. Other essential devices are TVs and touch-screens that are widely used as front-ends of Smart Homes. An impact of web-enabled devices to industries is so big that governments have to reconsider their strategies, and new branches occur that merge some industries, like mHealth, for example [5].

II. Related work

A Wikipedia article about Gerontechnology lists more than a hundred platforms dedicated to elderly care in its most comprehensive version in French. Most of the platforms are proprietary and the only possible way to build an interoperable system is to use APIs provided by those platforms. A few projects are on the way to integrate existing AAL technological developments focusing on interoperability.

ReAAL project [6] is probably the largest EU-wide effort to develop interoperable AAL solutions – those are based on Universal Open Platform and Reference Specification for Ambient Assisted Living developed under the universAAL project [7]. Its idea of interoperability is more to build one common platform that supplement others than

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by opening it: 3 buses are used inside of the platform to exchange data but only one is open and accessible throw an API. The usage is focused on gathering hardware information from local devices such as domotic or health monitoring devices.

MEDIATE project [8] gather a connected e-Lio TV platform [9], a touch screen device VisAge [10], a website Hakisa [11], a tablet Eglu [12], and a smartphone James [13]. A methodology to make interoperability is to propose to the community an API to share messages (web-service API, P2P) about the state of elders on any topic (health, social, agenda), using open ontologies with RDFs description.

SONOPA project [14] allows platforms to exchange data from sensors on elders. Various existing platform are involved: Docobo [15], dedicated to health, VisAge [10], a smart display with PIR sensors Smart Signs [16], and an actioner device Abotic [17]. The Sonopa webservice API allows to gather data from sensors of elders and perform long term behaviour analysis. It includes data from door opener, cameras, and motion sensors.

NITICS project [18] is quite similar with the objective to perform long term behaviour analysis. It includes data from, motion sensors, health monitoring devices such as blood pressure, and data from indoor localisation. Existing platforms gathered in the project: Eeleo [19] , eclexys [20], and VisAge [10].

III. Smart Living

In spite of a great number of implementations of Smart Homes - home platforms [6] developed in research circles and home solutions available on markets, interoperability [21] between home solutions is still a great challenge. This gets even more complicated when intelligent environments are observed from a higher level of immersion, which is beyond the residential home, like Smart Communities and Smart Cities – which brings to a concept of Smart Living [2] that essentially assumes all the aspects of human living affected with technologies.

A number of systems and applications that affect to human living is enormously huge, many pretend to be smart/intelligent, and more are to come. Some systems or set of systems form complete spaces that are often referred as smart. Among those are: smart home, smart hospital, smart library, smart campus, etc. Fig. 1 shows some of manifestations of Smart Living that are grouped by domains.

Regardless of the domain, technological challenges in all of those manifestations are the similar. Those are the following:

- Generation of data and information
- Infrastructure
- Information Management
- End-user terminals and interfaces
- Best Practices and Adoption

Smart Living may be considered as a large smart space that consists of smaller smart spaces with other smart spaces – nested and intersected. It means that technological solutions addressing the above-mentioned challenges may be reused across the smart spaces. Following this idea may reduce a number of interoperability problems that isolated systems have.

Such shared communication media as Web, common data models, and generic service processes are enablers of an architecture proposed in this work.

Fig. 1. Manifestations of Smart Living

IV. Systems utilising the decentralised approach

A. HoviMestari and UbiquitousHomeEnvironment

HoviMestari [22][23] is one of the front-ends that targets people of different ages and abilities to make life easier at home by simplifying everyday tasks and activities. It has a reusable modular architecture allowing delivery of a variety of services through an original user interface designed for TV, mobile, and touch-screen devices.

Ubiquitous Home Environment (UHE) [24][25][26] is a user-centric set of systems that serve users in domestic space and expands its services to other spaces in order to facilitate the Smart Living concept. A primary goal of the HoviMestari as the UHE front-end is to be an interface for home services supporting independent living [27].

As it is seen from the definition, the UHE is a fragment of the ultimate ubiquity, which is bound to a domestic environment. There may be a number of systems that form the environment, all having any number of devices, nodes, entities, and things. Systems may be categorised by complexity (ranging from dumb home appliances that do not

have any connectivity through sophisticated Smart Home implementations); by autonomy (ranging from embedded demotic systems through autonomous robots); and in a number of other ways.

The UHE systems typically expose and utilise a variety of services: internal - platform/system overhead services, generic - platform/system reusable services, and front-end services – those, that are directed to users. Front-end services are exposed via end-user devices, and may be provided by systems, or provisioned with via the systems. For example, a Smart TV may provide a video-recording service, but video-on-demand services may be provisioned via the Smart TV.

Within the Advanced Support for Independent Living; Human Lifecycle Approach in Senior Housing project, funded by the Ambient Assisted Living Joint Programme, a one-year field trial with third-age end-users and primary caregivers was launched in the spring 2014.

The following services were proposed for the field-trial:

- Local weather forecast
- National news
- Local newspaper news
- Local events information
- Public transportation schedules
- Drawing tool
- Memory-developing game
- Bible audio-book
- Church services
- Video-guided exercises
- Radio
- Audio
- sonami – natural sound samples
- Maps
- Calendar
- Local restaurant menu
- Local supermarket offers
- Help request

The test group of users was supplied with a limited version of the HoviMestari installed to such end-user terminals as 7” Tablet PCs.

B. VisAge

VisAge [25] is a social network for older people and carers. It uses cloud infrastructure dedicated and terminals at home of older people. It is made of a connected touch screen with sensors (camera). As a personal TV, it broadcasts information to the screen, and gathers feedback from the activity of the elder. The screen broadcast programs (also called services or apps) automatically without requiring any motivation of the older person, among a hundred of them. Themes of services include health monitoring, prevention, physical activity, nutrition, sleeping advices, food delivery, entertainment or games. The large panel of services are co-developed with customers such as local shops, insurances, or local authorities. These customers want their program to be broadcasted to the largest number of users, whatever their terminal is at home, a connected TV or a tablet.

The VisAge system relies on a framework to broadcast e-services through the older person’s terminals. The user’s terminal is composed of a touch screen that is always on. The screen displays content from e-services. E-services can be hosted anywhere on the Internet. For example, distant e-services can show local weather or deal with fall prevention, serious game for health, social interaction, telemonitoring, or connecting people to other people. Registering a new e-service that an older person would be allowed to subscribe to, or be subscribed to by a helper, requires OAuth and web-service WSDL function access. Examples of functions accessible through the web-services are as follows [25]:

- setUserWall allows an e-service to write on the ‘wall’ of the elder and share information with other e-services.
- getUserLastActivity returns the last e-services broadcasted.
- getUsersSeeingMe returns the social network persons accessing a user’s information.
- getActimetry returns the activity diagram of an elder so that, for example, a service can interrupt itself if the user goes away.
- setServicePriority sets the priority of the e-service itself. A service with a (normalised) high priority at a given time will have more probability to be displayed on the screen. For example, for an e-service showing an RSS-feed [28], if fresh news arrives, the service can increase its priority.

In the VisAge system, a broadcasted content is adapted using unintentionally given information, gathered from the older users. For that purpose, a built-in camera is used to monitor activity of users when content is shown on the screen [25].

V. DECENTRALISED SERVICE DELIVERY ARCHITECTURE

A. The architecture

The aim of the Decentralised Service Architecture is to simplify service provisioning by establishing interoperability between information systems of retailers, service providers and content suppliers and such system-frameworks as the HoviMestari or the VisAge. The idea of the architecture is to abstract whenever it is possible from the low-level technical interoperability to interoperability via such the high-level media as the Web.

The over-the-web interoperability may be achieved by using principles of the Linked Data [29]. Those samples of service-product continuum [30] that stakeholders would like to offer, need to be annotated with RDF [31] or RDFa [32] in accordance to the Best Practices for Publishing Linked Data [33]. Thus, service and product descriptions will be added to a huge mass of metadata available on the Web, particularly to a layer of Linked Data. It means that a variety of software systems, agents and bots may run queries and discover products and services using specified criteria (such as geographical location, time, and many other), and proposed them to inhabitants of intelligent environments – basically any smart spaces of the Smart Living concept. Fig. 2 shows a general overview of the architecture.

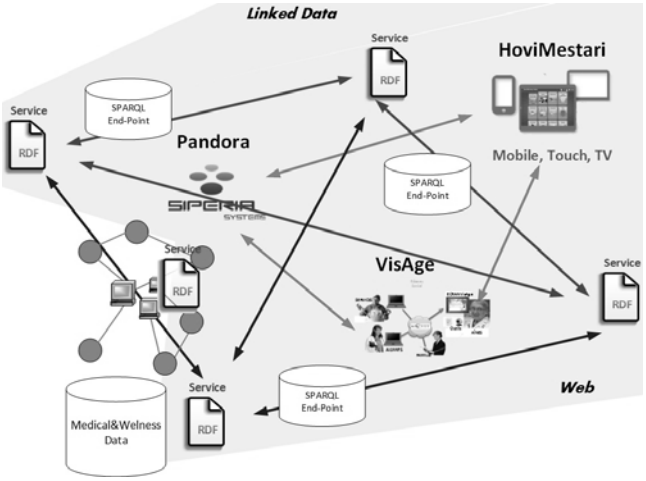

Fig. 2. Decentralised Service Delivery Architecture

In accordance to the architecture, service and product descriptions may be retrieved from publicly available RDF storages and SPARQL [34] endpoints, and/or collected to local storages of systems/applications. That may be applicable at different levels, from low-profile sensor networks where motes are able to work with simple RDF-based data models, till web architecture where web portals exchange information using sophisticated data models. Using generic technologies and data models simplifies information exchange with EHR/EMR systems since it does not require developing of dedicated interfaces.

Data processors are belonging to private spaces of intelligent environments, that functionality belongs to intelligent systems, and there may be some private RDF storages and file storages. Data processors operate with Linked Open Data, and private data, that is a part of user profiles or linked to those.

As the Lily project outcome, the GoodRelations [35] model dedicated to e-commerce is proposed to be used to describe products and services. This model was found [36] to be the most suitable for the purpose due to its nature, and utilisation of widely-adopted vocabularies. Such NoSQL database engine as mongoDB [37] and OpenRDF Sesame [38] framework are used to store and process service-relevant data, search criteria, profiles, templates, and required overhead information.

B. Integration Levels and Service Templates

Since some of the services that may be provisioned via such systems as the HoviMestari or the VisAge are generic, and do not require to be integrated into smart spaces, Integration Levels are introduced.

Integration Level 0 means that the system is not aware, who is the user. Therefore the system may be used by any unidentified user, and does not have to be integrated into the smart spaces. No personal services are possible in this case, while only generic ones, are offered. Those generic services may be classified as informative, that have only one-way information flow – from a service provider or content supplier to a requester [26]. Examples of such services are the following: weather forecast, RSS feeds, infopages, persistent multi-media content, etc.

Integration Level 1 means that the system is aware of the user and makes a personalisation of services possible. Integration with smart spaces is required, since user profiles typically handled by the smart home platforms are used to keep essential user data (e.g. name, contact information, address, location, sizes of shoes and clothes, generic personal preferences) and service-specific data along with personalisation data (that is formed based on a history of use, and service-specific personal preferences). Such integration may be performed with the software, and does not require any specific configuration.

Services implemented in accordance to Integration Level 1 may be interactive – request-response model allowing purchase orders using a single customer ID from a single household, or fully-interactive – advanced version of previous, allowing purchase orders using multiple customer IDs from multiple locations, taking into account a variety of preferences and customizations [26]. Shopping, appointments, communications – are among such services.

Integration Level 2 is a further developed integration. The system is aware of the user, and complicated services can be configured. Those services may require additional installation and configuration settings of communication protocols and equipment (e.g. sensors, Bluetooth access points), software and hardware platforms, which support a functionality of services provisioned in accordance to the architecture. These kind of services are classified as ultimate [26]. Integrated home automation systems, and such sophisticated services as Safety Navigation [39] are examples of ultimate services.

A summary of description of Integration Levels is collected to the Table I. A use of a dumb profile with Integra-

tion Level 0 is required for those systems implementing the architecture that are assumed to be able to work with user profiles and higher integration levels.

TABLE I. INTEGRATION LEVELS

	Integration Levels:		
Properties:	**0**	**1**	**2**
System is aware who is a user	No	Yes	Yes
User profile is used	No/ Dumb	Yes	Yes
Personalisation	No	Yes	Yes
Customisation	Possible	Possible	Possible
Type of services	Informative	Interactive	Ultimate
Examples of services	Weather forecast RSS feeds info-pages persistent content	Shopping appointments communications	Home automation safety navigation transportation
Development effort	Relatively low	Average	High
Extra requirements	No	Interoperability with information systems of involved stakeholders	Domestic installation and maintenance

To simplify a development of services, and automate a service provisioning, service templates were developed. They are used in a similar way as operational templates. Service templates may be used at Integration Levels 0 and 1, but not all services may be implemented in accordance to the service templates yet. The templates are built as a result of observation of similar functionality required by certain services. For example, a process of making an appointment with a dentist is similar to a process of making an appointment with a car service company. Among service templates are the following: RSS reader, appointment maker, purchase maker, and some other.

VI. ETHIC AND TRUST CONSIDERATIONS

Trust is an important consideration that is required at early stages of implementing the Decentralised Service Delivery Architecture. It assumes a quality of data, but also some aspect that are relevant to business behaviour of stakeholders. In addition to that, the more services will be provisioned in accordance to the architecture – the more difficult it will be to manage them. For example, in large cities, a number of restaurants near certain locations may be significant, and basic criteria will discover them all. Thus, basic criteria are not sufficient. Additional criteria may be used, based on historical data of user behaviour, personal preferences, etc.

Additional criteria are typically stored to user profile. User profiles are certainly limited when they are formed using the smart spaces user data only. A bigger share of personal activity on the Web may occur in the outside of smart spaces, using traditional web application and services. Even more, some parts of personalisation, or even dedicated personal data may require to be stored in certain repositories outside of smart spaces.

For example, national health registers store personal medical data, while some part of it may be available and can be used to form personal profiles. Therefore, there is a need for technologies that allow exchanging data between profiles, or simply linking them, taking into account security and privacy considerations. For that signing linked data graphs and modern trust models [40] may be used.

The linking of data raises ethics issues that need to be carefully considered. These issues regarding privacy and data protection must be taken into account when planning the services infrastructure. No sensitive data, and health record data is sensitive, can be used without the explicit, voluntary, and freely given informed consent of the person in question. National privacy legislation must be carefully considered in the planning stages.

VII. CONCLUSION AND DISCUSSION

For online retailers, service providers and content suppliers a use of decentralised architecture means marketing and business exchange channels with an unlimited potential [36]. With non- to low-effort, exposing open data to the web allows promoting of own products without limitations of search engines and dedicated web portals operating with monetary business processes demanding an obvious effort.

Utilisation of open standards of Linked Data technologies opens opportunity to any application/system developers that would be able to bring solutions operating with information about products and services that are not discovered via dedicated APIs that differ from vendor to vendor, but freely available on the Web and discovered in a generic way.

At the same time, arranging interoperability between systems and applications at high levels using well developed data models allows overcoming a complexity of interoperability at low levels – relevant to hardware specifications, communication protocols and data formats.

Smart Living concept unites smart/intelligent solutions that form variety smart spaces that affect to human living by any mean. The concept admits a level of abstraction where common communication media and many similarities relevant to service processes at higher levels, and data models and lower levels of a provisioning stack may be observed.

Integration Levels position different service provisioning models that may be developed with a different development

effort. Service Templates simplify development processes by applying generic procedures that unify functionality of similar services.

By the end of Lily project it is still possible to observe some barriers that may make more difficult an implementation of any demanded services using the Decentralised Service Delivery Architecture.

First barrier is a status of the architecture that at this moment may be considered as work in progress due to a lack of annotated in a proposed way samples of service-product continuum, particularly from retailers, service providers and content suppliers at some locations is observed. As it is the case with many other application areas of linked data on the web, the architecture may excel under a condition of a critical mass of discoverable resources available. Involvement of local stakeholders that may be interested to provision their services via such systems as the HoviMestari or the VisAge, and a use of transformation tools that would allow processing of data formalised in accordance to different data models may help to achieve the critical mass.

The other barrier is a small number of available service templates. The more service templates will be developed – the more services may be provisioned in an auto-mated way in accordance to Integration Level 1. It may be possible to design unified templates for very sophisticated services using modern modelling tools. Some of the services may be so complicated that will remain to be Integration Level 2 services. More service templates may be developed by analysing Smart Living use-cases and developing generic scenarios.

Decentralised service delivery architecture does not address all the technological challenges of the Smart Living concept. It does not imply generation of data and information as well as end-user terminals and interfaces, allowing that remain at a service level – even though service templates are used to build GUIs. It dies imply infrastructure, information management, and best practice and adoption. The future work is all about developing of the architecture future, addressing those aspects of these challenges that are not covered yet.

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