# Knowledge Management in Research Collaboration Networks

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***Abstract*— Advances in science and research have brought knowledge management and collaboration together around shared goals. Nowadays, they are quickly becoming a hallmark of high-performing corporations. The convergence and integration of knowledge management and networked collaboration has helped to harvest the benefits of diverse research teams. This paper presents a study related to this. It discusses about how creating a dynamic research collaborative network can positively influence the creation and management of acquired knowledge. Additionally, it addresses the role of Living Labs and Digital Innovation Hubs in creating different research fields and projects. Then, as result of such successful research collaboration through the use of an established Living Lab, some improvements in an ontology that has been used in the domain, was made. In relation to this, a scenario of CARELINK project that provides some unique services and technologies for People with Dementia is introduced.**

***Keywords*— *collaboration; knowledge management; research collaborative networks; Living Lab (LL); Digital Innovation Hub (DIH); People with Dementia (PwD)***

## I. INTRODUCTION

The contemporary world is faced with a higher variety of challenges than at any other time in human history. Although revolutionary advances in science, research, and technology provides people with more efficient solutions to better solve complex problems. Consequently, societies are challenged with how to manage the created knowledge of such productive outcomes. In this respect, emerging collaborative practices have brought into focus new approaches for dealing with such challenge.

Collaboration is a working practice that brings numbers of people to work together towards achieving common goals. Collaborative efforts, indeed, allow people to deliver smarter and more long-term solutions by leveraging joint energy, interests, talents, and resources. The fact is that collaboration between people is nothing new eventhough in today's modern world of proliferation of knowledge, information, and data, it comes to force. Furthermore, building on a foundation of collaborative team (who may have similar mindset, but different expertise) helps to harness the talent of team members, enhance effectiveness, promote individual skills, accelerate solution finding, increase job satisfaction, etc. [1]. Over recent years, large numbers of initiatives have been launched aiming to expand collaboration among diverse researchers. Research collaboration and working jointly with teammates provide broad range of opportunities for career, innovation, and learning across disciplines, sectors, societies, and nationalities [2]. Research collaboration can be undertaken in actual and/or virtual environments. In the case that the size of research team is big and team members are distributed, they can work virtually. Research collaborative networks can facilitate knowledge flow on the one side, and on the other can augment knowledge cross-fertilization and also team productivity. Currently, numerous research collaborative networks around the world are dedicated to work on different fields of study (e.g., health care, education, industry). In essence, research collaborative networks reap the benefit of wider public perspective and expertise by creating a powerful knowledge hub [3].

Regardless of the position and experience of members in a collaborative team, they all probably have valuable knowledge to share and/or receive. Knowledge refers to awareness and

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understanding of something such as, fact, object, idea, information, description, event, and way of doing things that gained via discovery, education, and experience [4]. Knowledge is considered as one of the most significant property to each organization, since it is power and can control the access to opportunities and advancements. It is note taking that we now face with the overload of knowledge that brings the necessity to manage it properly. The fact is that knowledge management aids to identify, obtain, assess, retrieve, distribute, and organize the knowledge and information of an organization for creating value and wealth. Knowledge management benefits people and organizations in different ways namely, by providing better services to capture and use the knowledge, reducing the time to reach the stored knowledge, spreading the gained knowledge throughout the entire organization, increasing the effectiveness of organization's operation, etc [5]. From this perspective Knowledge-Based Systems (KBS) have introduced and developed in order to create and promote the knowledge, information, and data from different sources. Furthermore, such systems allow capturing and utilizing the knowledge of human expertise to derive new knowledge, support decision making, and solve complex problems. Evidences show that KBS have enabled researchers to work at a higher level of expertise and enhanced the consistency and productivity [6].

Findings of several researches [7], [8] demonstrate that collaboration and knowledge management have mutual and complementary relationships, meaning that they feed and build upon each other. Collaboration can promote knowledge management, and knowledge management can drive organization collaboration. In general, collaborative systems open up the possibility to foster knowledge management, knowledge building, and knowledge sharing. Such systems provide productive places for potential and interested people to contribute in social interactions such as knowledge development. Hence, "the role of collaborative systems in our contemporary knowledge society is pervasive, both in people's public and private sphere" [9].

## II. Innovation ecosystem framework

Innovation is a buzzword, and nobody agrees on what it really means. Given wide variety of proposed definitions, it can be simply defined as a process of turning a creative idea to solutions, goods, or services that are useful and can generate value. Innovation has been for long time the focus of attention for many organizations and businesses as it is a key success factor, it is major element in influencing strategic planning, it helps to stand out from competitors, it leads to wealth creation, etc. In the process of innovation might number of actors or entities participate such as, governments, academies, researchers, organizations, businesses, institutes, investors. Literature shows that the main features of innovation ecosystems determine different supporting structural basis that depend on various perspectives, as for example, self-organizing, co-creation, demand driven, application of IT and ICT technologies. Such characteristics are common with Living Lab (LL) and in larger scale with Digital Innovation Hub (DIH), where in which self-directed collaborators by establishing communication channels and utilizing tools and services will find effective solutions [10].

The CARELINK is an Active and Assisted Living (AAL) project and is co-financed by the European Commission (through Horizon 2020) and by internal countries budget until 2020. The CARELINK aims to create better quality of life for elderly people who suffer from dementia. AAL is an area where Artificial Intelligence (AI) can play an essential role, in particular, in the support of aging people. Thus, the creation of a LL that then supports a DIH in the area of AAL is complete aligned with the idea presented in this document.

Thus, the CARELINK project comes up with the objective to help People with Dementia (PwD) (who may affected from physical, emotional and economic constrains), their carers and families. The project also focuses on information sharing, training, and innovative solutions for involved community members. These solutionss are the following:

1. Design an innovative wearable tag for dementia patients at different disease progression stages that are suitable to their needs and the needs of the carers.
2. Design and develop a wearable and wireless sensor tag suite that is capable to provide proximity and location information for the wearer. It is low cost, robust, and energy efficient.
3. Design and develop a cloud-based platform to support personalized connected solutions to enable carers to monitor the proximity and location of patients and remotely interact with the system.
4. Develop an information suite that provides carers and families a general training course about dementia [11].

These solutions help to reduce the stress of cares, increase the survival rates of wandered patients, as well as develop communities that are care-based [11]. Therefore, an Innovation Ecosystem framework is proposed to guide the creation and implementation of such solutions.

The Innovation Ecosystem Framework that is illustrated in Figure 1, demonstrates the relationship between LLs and DIHs. To obtain positive results, it is necessary to have a healthy relationship between LLs and DIHs, as well as to share information between all respective agents (entities and services).

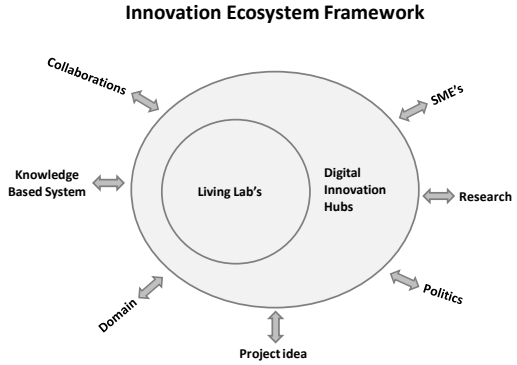


Fig.1. Innovation Ecosystem Framework

The proposed Innovation Ecosystem Framework is composed of following components:

***LL*** - is a user-centered, open-innovation ecosystem, often operating in a territorial context (e.g. city, agglomeration, and region), integrating concurrent research and innovation processes within a public-private-people partnership [12]. LLs place the citizen at the centre of innovation, and have thus shown the ability to better mould the opportunities offered by new ICT concepts and solutions to the specific needs and aspirations of local contexts, cultures, and creativity potentials [13].

***DIH*** - is an ecosystem that enables businesses to reach required knowledge, expertise and technology for testing and experimenting digital innovations relevant to their products, processes, or business models [14].

***Small and Medium Enterprise (SME)*** - is a term for segmenting businesses and other organizations that are somewhere between the "small office-home office" (SOHO) and medium size enterprise. European Union defined an SME as a legally independent company with no more than 500 employees [15].

***Research*** - is any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of a person, group, and/or society, and the use of this knowledge to develop new applications [16].

***Research Policy*** - allows financing of research ideas and projects which build on collaboration rather than single individuals' performance, and create arenas/systems (i.e., scientific conferences) for social interaction and networking, and support existing ones [17].

***Project Idea*** - is generated through different sources such as; customers, competitors, and employees. Occasionally the project ideas are discovered in a spontaneous way. However, to help in the creation of ideas at individual and group level are used techniques like brainstorming, Delphi Technique, and attribute listing [18].

***Domain*** - is an area of interest or a field of action, thought, influence, etc. In this study is about what the LL and DIH works on.

***Knowledge Based System (KBS)*** - is a form of AI that aims to capture and formalize the knowledge of human experts to support decision-making, like expert systems that relies on human expertise [19].

***Collaboration*** – refers to organizations and/or individuals that work together, and share their sharable resources to achieve a common goal [20].

The fact is that collaboration in research is fundamental to explore, create, and develop new ideas and solutions. Research Collaboration (RC) refers to collective efforts of researchers who work together to achieve a shared goal for producing new scientific knowledge [21]. RC mainly leads to improving the knowledge skills, and scientific qualifications, which researchers can't easily and perfectly obtain it alone. Additionally, RC gives rise to the generation of new ideas as result of communication and discussions with other collaborators [17]. Taking this into account, LLs and DIHs, can provide a suitable foundation for RC.

## III. APLICATION

The knowledge that is transferred through a LL may has a significant impact on the development of solutions, because the combined views of different perspectives often lead to direct improvements in the creation and development processes, in the products specifications, and in the commercial approach taken. It enables the acceleration of such results' projects contributing to out-of-the-box enhancements, also made possible mainly by the open access and knowledge sharing environment provided.

An example of the impact that this kind of knowledge transfer approaches can create, is demonstrated by the strategic partnership of the CARELINK project and an existent LL called "Internet of Things Open Laboratory".

A direct result of the initial meetings, besides the dissemination of both projects visions and goals, was an informative communication of the IoT development state, across the European Union zone, and Portugal in particular. The motivation of using Low Power Wide Area Networks (LPWANs) such as cellular based technologies like LTE-NB1 (also referred to as NB-IoT) and LTE-CAT M1, and non-cellular based, like LoRa and Sigfox, in IoT deployments, is creating an expansion in new hardware solutions that can leverage the benefits of lower power consumptions and higher radio signal penetration, to deploy devices with up to 10 years of autonomy, and with better coverage and smaller sizes.

An example of these improvements can be verified by the changes to CARELINK ontology model for energy management profiling that is depicted in the iterations resulting from the meetings in the mentioned Open Lab.

In Figure 2, an excerpt of the CARELINK ontology model is presented, with the "before" on the left side and the "after" on the right side of the image. The main changes before mentioned are highlighted in the red boxes. The ontology is comprised of 7 primary classes, of which 3 are depicted (represented in yellow boxes): "Device", "Energy Profile" and "Component". The other 4 classes are used in accessory with the previous classes and managing data elements that were not influenced or changed as a result of the knowledge transfer. Device "limitations" was added to "Device" class list of properties (represented in green boxes), to reflect the technical and physical constrains to the knowledge management of the device operations. "Protocol Status" was added to the "Energy Profile" to indicate the current communication protocol in use. "Component" received some changes as "ECG", "EMG", "GSR", "RF" and "Cellular" were eliminated (due to changes in the overall applicability of the sensors in the use case scenario that required fewer components consuming energy and space used for the miniaturization of the device) or replaced in favor of the more specific communication protocols: "LTE-NB1", "LTE-Cat M1", "LoRa", "Sigfox", "GSM" and "GPRS". These are morphological changes to the knowledge representation that

have a positive impact in software and hardware development and optimization.

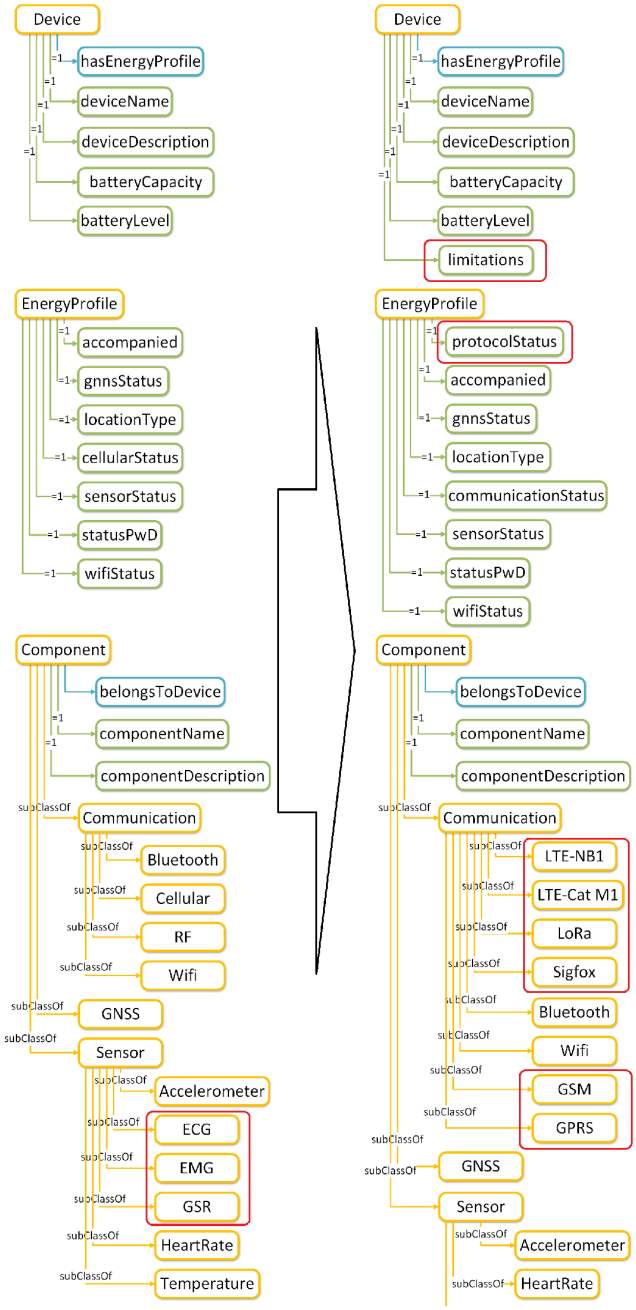


Fig.2. An excerpt of the CARELINK ontology model

A substantial improvement of the model is resulted from this collaborative work that represents an unquestionable added value. It facilitates the access to such kind of LLs for such research interactions. Thus, the authors started a process to build a LL to support PwDs with the idea to later integrate it in DIH, similar to the ecosystem framework presented in Figure 1. Therefore, the next section describes the fundaments taken to create such LL from CARELINK.

## IV. A PROJECT TO BUILD A LL TO SUPPORT PWD AND ITS LATER INTEGRATION TO A DIH

As mentioned above, LL is defined as a physical or virtual environment where anybody can conduct research and discovery on different fields of study, then experiment and test the scenarios, and lastly evaluate, develop and apply the ideas, product or services. LL is indeed an open-innovation ecosystem in which wide variety of activities can be carried out from different perspectives and through different methodologies [22]. Generally speaking, in order to build and develop a LL some key components and principles are essential. From both environmental and methodological perspective, the key components are addressed in follow:

- *User* - represents the individuals who participate in activities.
- *Application environment* - represents the context in which users collaborate together.
- *Technology and infrastructure* - represent the ICT technologies that facilitate collaboration among users.
- *Methods, strategies, and standards* - reflect the applicable methods, strategies, and standards within/for LL environment.
- *Partners* - share the resources to achieve the common goal of LL.

Furthermore, the key principles that make possible operations in LLs including; value, influence, sustainability, openness, and realism. These principles play important role to define what counts as a LL toward providing the foundation for design of its operations and assessing the value of LL operations [23].

LL has applications in different domains such as health care. Additionally, LL can actively contribute in different stages of research, development, and even in innovation development process including; exploration, designing, testing/evaluating, and implementation [24].

In this context, the proposed LL for CARELINK can support and facilitate the testing and deployment of both the prototype and its system in the target community. On the other hand, it can increase the impact among the community that is addressed in the developments namely, patients and carers, technical developers and researchers, and industry and marketers that may have interested in selling the product which are produced by the project.

It is worth mentioning that CARELINK is committed to design and develop a low-priced system for monitoring location, proximity, and biometric of PwDs. It intends to introduce some adopted devices and services suitable for specific requirements of PwDs and their carers. The CARELINK team also attempts to design and develop wearable devices (at first stage, in the form of wristband and necklace) with competitive features and potential market usage for PwDs at different stages of the disease. Additionally, the CARELINK will also provide some smart solutions to effectively manage the wandering caused by dementia.

The reason of establishing a LL is because it is real-life research environments that may be used to tackle innovation challenges in all kinds of fields. For example, The European Network of LLs (ENoLL) is the network of open and citizen-centric innovation ecosystems encompassing innovation experts, policy makers, academics and citizens. In ENoLL, countries worldwide share their expertise and knowledge about different fields of study. Many projects have been already funded in this network. As an instance, in the Innovate Dementia project, four LLs within Eindhoven, Liverpool, Krefeld and Geel/Antwerpen/Heusden-Zolder/Diest work together to develop and test social and technical innovations for people living with dementia. In this, many stakeholders including: PwDs, carers, health care institutes, local authorities, universities, and business partners contributed to a research for relevant innovation that support PwDs at their home [25].

Therefore, the idea is that CARELINK through such LL increases its visibility, importance, and specially impact on stakeholders who are in this domain. In the second phase the idea is to integrate the LL in a DIH focused in AAL to open the work to a bigger community and to integrate other projects active among participants.

DIH also provides companies the opportunity to collaborate with private and public sectors to more access to common technical services, research data, and human capital helping. Thus, those companies become more competitive in terms of business processes, products or services as well as access to the latest knowledge and also expertise [26].

Building and developing a DIH like this follows pre-established requirements related to: creating awareness, creating needed ecosystem and networking, developing business plan, prototyping and concept validation, testing and evaluation, developing suitable incubator/accelerator, developing market intelligence, funding and financing, managing, developing skills for education, and business development [27].

There isn't any particular DIH that focuses on AAL in Europe, and because one of the partners proposing such LL integrated in a DIH is coordinating a relevant project in the health area [28], it has high potential to be successful. Just to compare, there are several other active EU initiatives and projects that are shaping the pan-European network of DIHs, for example: ICT Innovation for Manufacturing SMEs [29], Smart Anything Everywhere [30], Open Data [31], Robotics [32], Photonics [33], HPC [34], and EIT Digital [35].

The EU initiates ICT Innovation for Manufacturing SMEs (I4MS). For example, it links SMEs, startups, and mid-caps with European DIHs, who are supporting firms to test and adopt the innovative and latest introduced digital technologies. Since its launch in 2013, I4MS has enabled more than 300 innovative experiments that connect SMEs, startups, and mid-caps with European DIHs to speed up their digital alteration and transformation with aid from DIHs.

In CARELINK project the idea is to create a LL at a first instance for supporting the dissemination and exploitation of the project results to impact on the society, particularly PwDs. Later use such LL as a lever to the creation of a DIH in a more wider domain of the AAL, which as shown above can be supported by a big H2020 project to then reach other actors as public authorities to establish new synergies and opportunities in line to the social inclusion as supported by AAL. These solutions contribute to progress and consequently to the creation of spin-offs and start-ups which has impact in the global economy.

Due to expecting definitely a stronger impact of the project in the community, this idea has the entire support from the CARELINK consortium. This is also in line with the strategy of European Commission in relation to the area of Digital Single Market, which foresee the creation of DIHs to support such digitalization.

Finally, the Portuguese National Initiative on Digital Skills, INCoDe.2030 is also foreseen under their strategy fostering Portugal as a LL for experimentation of new developments. It clearly states that Portuguese innovative sectors should be promoted as "LLs" for new experimentation at a global level.

The findings of this study will be as future work employed in SHYFTE project (that aims to develop the skills of Industry 4.0) [36]. The key target in this project is to develop a new skills framework that may integrate competencies of all the partner countries in four main pilots: (i) Industrial engineering and management, (ii) Software Engineering and big data analytics, (iii) Wireless networks analytics, and (iv) Artificial Intelligence, to boost the job market by introducing innovative learning and teaching methodologies. The project, therefore, is planning to build Skills 4.0 LABs or Learning centers of excellence in those Asian Partner's HEI to enable each of them to become the referral center in their respective countries and disseminate the results of the project nationally and regionally.

On that account, the proposed LL and DIH in this study will be potentially utilized as research-based, practice-based, open-innovation, and knowledge-transfer forum for the partners in SHYFTE project through such Skills 4.0 LABs or Learning centers.

## V. CONCLUSIONS

The proliferation of knowledge management and collaboration, and the continuation of their incorporation has opened new avenues to link up with global research networks. It has not only help to develop scientific researches, collaborative learning, and improve productivity in effective ways, but also promoted innovative approaches in introducing and developing new technologies and services. In this journey, open innovative ecosystems such as LLs and DIHs have had a role to play. In such dynamic, productive, and networked environments the confluence of thoughts fosters effective knowledge building, sharing, and development. On that account, this case study relies on multiple sources of evidence and benefits from the prior development of theoretical propositions. So that, various methods of data collection and analysis (e.g., observation, interviews, in-depth investigation, and consulting) were used. As a result, by taking the advantages of research collaboration, the proposed ontology in this work and its related knowledge were to some extent

improved. Proceeding on this track, the CARELINK project is planning to establish, in an initial phase, a LL to reap the benefits of potential researchers and assistive tools and introduce unique technologies for PwDs. In the subsequent steps and as future work, by expanding the size of activity and integrating the LL with a DIH, it expects to make a strong link between industry and this academic project. It is worth mentioning that these facilities can be then used for other similar projects.

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