Alliance for
Internet of Things
Innovation

IoT for Smart Living Environments

Recommendations for healthy ageing solutions

AIOTI WG05 Smart Living Environments for Ageing Well

April 2019

Executive Summary

The objective of the Alliance for Internet of Things Innovation (AIOTI) is to enhance innovation and economic development in the Internet of Things (IoT) in Europe, and beyond when relevant.

The workgroup 5 of the AIOTI is focusing on Smart Living Environments for ageing well (SLEaw), and aims to build a dynamic pole for knowledge sharing in Internet of Things innovation for Smart Living Environments, acting as a bridge between initiatives that bring added value to healthy living. This workgroup should also identify and attempt to resolve market obstacles for IoT deployment in the Ageing Well domain.

To achieve this, the AIOTI WG5 has developed a strategy relying on 2 main objectives:

- Drive of the IoT uptake in Smart Living Environments for ageing well (SLEaw)

- Unleash the supporting technologies

This recommendation paper is built around these 2 strategic objectives, addressing the 3 following challenges, each of them discussed in the 3 main chapters of this report:

- Building a sustainable ecosystem for SLE for Ageing Well, around the technological and stakeholders requirements
- Driving Acceptance through market structuration, in increasing the acceptance of innovative IoT-based solutions for smart living environments for ageing well while impelling user needs and expanding the innovation coverage in the ageing well domain
- Demonstrating the IoT impact in ageing well, through architectures responding to stakeholders expectations, including proper security and privacy, implemented through different use cases.

This paper has been produced by a team of "AIOTI workgroup 5" members, coming from different fields of expertise, from academic research in sociology to semiconductor industry professionals, as well as medical practitioner, cybersecurity experts or start-up founders.

It also takes advantage of the contribution from active members of the ACTIVAGE project, an European Multi Centric Large Scale Pilot on Smart Living Environments for Ageing Well (the AIOTI WG5 did provide the background information and recommendations for the Internet of Things call on Large Scale Pilot). This is a real value-added of this report, considering the opportunity to share recommendations based on large scale experiments of Active & Healthy Ageing IoT based solutions and services, supporting and extending the independent living of older adults in their living environments, and responding to real needs of caregivers, service providers and public authorities.

The report also highlights best practices focusing on innovation and socio-economic impact, acceptance, business model and ecosystem sustainability like the "Neighbourhoods of the Future", a reference in terms of innovative co-creation processes.

In the first chapter of this report– Building sustainable smart living environments for ageing well ecosystem-, we explain "Smart Living environments for Ageing Well", basically an ecosystem triggered by the pervasion of IoT technologies within the services requested by elder people for active and healthy ageing (AHA). We go through selected initiatives.

- Beyond the usual statements related to population ageing, the report clearly indicates, that the purchase power of the pensioned people will globally decrease, while, in the meantime, a more technology-friendly population – currently the baby-boomers – is reaching the age of retirement, even if at general level, the relationships that older people have with IoT devices remains of course diverse. This is clearly a crucial factor for triggering a new kind of demand – personalized, affordable – for unmet needs, under the umbrella of "Smart Living Environments for Ageing Well".
- When defining the emerging "Smart Living Environments for Ageing Well", basically the intersection between Internet of Things technologies and the so-called Active and Healthy Ageing (AHA) services, the report mentions the necessary key levers for reaching their sustainability. A fundamental criteria is related to the IoT platform concept, actually the source of the data upon which business models for IoT-based Active & Healthy Ageing services are developed. The IoT platform technology should not be domain

specific and the report insist on the crucial role of interoperability to create a true IoT ecosystem, as it triggers the scalability in IoT.

- Based upon the experience of ACTIVAGE project, the report confirms that user needs, at the origin of IoT-based AHA services, require permanent updates obtained through continuous process of co-creation among all stakeholders in each local ecosystem, with particular emphasis on the participation of the assisted persons.
- More and more recommendations, coming from different initiatives, show that IoT technologies are instrumental to help older people stay in their home and live longer with a good level of safety and comfort because of their scalability that supports the increasing size of the target population. The concept of "domains of needs", with its associated use cases and based upon the reference Ageing Well initiatives around the world, including the ACTIVAGE project currently deployed, supports the creation of demand-driven experience in Smart Living Environments for Ageing Well.

The second chapter of the report - Driving Acceptance through market structuration - puts the focus on understanding the needs of the elderly, with the aim to manage them accurately and efficiently. It means, in the context of this report, understanding and defining, from a clinical, economical and customer perspective, how technology might impact these needs, which is of utmost importance, especially if we consider the dynamic nature of user needs in relation to emerging technologies. This chapter also addresses the current lack of performative power associated to the existing lack of evidence generated from Real World Evidence (RWE), and highlights how evaluation frameworks can demonstrate that IoT technologies can efficiently bring a combined added-value on quality of life and healthcare systems efficiency through innovative tools and models. The chapter presents, through two initiatives deploying innovative co-creation processes, best practices to address health and care needs of a person over their life course with life supporting technologies.

- Trust is a fundamental issue, and a common understanding of what it takes to go forward with IoT in an ethical then sustainable way is required
- Ethical & sustainable Design means on one side more control to the user, and it is implemented in the ACTIVAGE project through a "learning by doing" approach combined with a consultation process of all the different stakeholders
- It also means new ways of collaboration, to get a common vision across stakeholders from sectors that normally do not collaborate – such as housing, health, and ICT to mention those required to upgrade the Europe's built environment to meet the changing and evolving needs of older people. An example of a successful attempt to create this alignment is detailed, through the "Neighbourhood of the Future" experience.
- The dynamic nature of user needs - user needs as something that is established during the appropriation of new technologies - must be taken in account in relation to how new technologies are appropriated into existing social relations and care arrangements.
- it is also important to map future scenarios of using Smart Living solutions, as user needs and ethical issues are dynamic and change alongside with technological development and implementation
- Evaluation frameworks – whether they assess economic growth, sustainability or quality of life - must demonstrate that IoT technologies can help to measure the costs and the added-value of underlying technologies.

The last chapter of this report - Demonstrating the IoT impact in ageing well – is describing how technology is currently positioned as a solution to the ageing society. Technology is now at the heart of the prototyping of use cases, scenarios and services for Smart Living Environments for Ageing Well. The chapter explains the technology enablers for Active and Healthy Ageing services, from the underlying semiconductor technologies (sensors, microcontrollers, connectivity, security by design, artificial intelligence...) to the whole IoT movement, associated to a deep and continuous transformation in the way ageing people interact with their environments. The ACTIVAGE project has defined a reference architecture for IoT Platforms Interoperability allowing this movement to enhance this movement for the SLEaw domain. There is a strong focus in this chapter on the security and privacy concern, due to the IoT particularities which contribute to create a complex security challenge, especially in the case of SLEaw, where the main security concerns would be citizen-focused.

We also describe several experiments, among which two of them are currently deployed under the ACTIVAGE project. IsereADOM - ACTIVAGE Isère Large scale Deployment Site - is pioneering a disruptive business model, involving institutions (Hospitals, Senior Houses…) to promote Ageing in place. Equimetrix - implemented in ACTIVAGE Madrid deployment site - is an innovative solution increasing autonomy at home, actually the first clinical device measuring the state of balance by combining two highly relevant human motion descriptors: centre of mass and foot. Beyond ACTIVAGE experimentations – the different Reference Use Cases are all summarized in this chapter -, we pay a special focus on other experimentations illustrating how technology improvement can improve user or patient quality of life. A first example is related to the Internet of Medical Thing, with the experience brought by a General Practitioner within the hospital with a medical robot, used as a real organizational pivot of care, with the potential to extend this ability to daily life support thanks to Artificial Intelligence. It is interesting to observe the complementarity between these initiatives – for instance between the robot Charlie and the concept of "referent sentinelle" (concept duly explained in the report) of IsereADOM, demonstrating concretely that user needs must definitely be placed at the centre of innovation, but also highlighting the importance of enabling social and health care coordination.

We finally introduce an innovative quality of life concept, enhancing the impact of smart living environments for ageing well thanks to the effect of light on the circadian rhythm: Human Centric Lighting. Research in the key mechanistic principles for the biological clock – including the mechanism by which light can synchronize the clock - led to a Nobel Prize in Physiology or Medicine (Hall, Rosbash, Young - 2017).

- The chapter explores, from IoT designers' perspective, the ever-increasing toolkit of key IoT technologies, highlights their need and suggests solutions to conceive smart things adapted to the requirement of an ethical and sustainable IoT environment.
- New generation SLEaw will incorporate more powerful edge computing layer capabilities, due to the necessity of ensuring continuity of care when the target user leave home.
- Thanks to ACTIVAGE IoT Ecosystem Suite (AIoTES) Framework, ACTIVAGE architecture is designed to serve as common framework to build interoperable smart living solutions in the form of apps, software tools and services that can be deployed, extended and replicated across Europe.
- Core security technologies are not available "off the shelf". Securing IoT systems requires to rethink and redesign systems and reaching such objectives shall take time. Semiconductor companies can assist with end-to-end solutions by providing on-chip security, supplying comprehensive hardware and software services, including authentication, data encryption, and access management. Collaboration between semiconductor companies and application designers or network-equipment manufacturers, would also be helpful for the design of secure software.
- Concerning current IoT impact related to experiments for Smart Living Environments for Ageing Well, we highlight through 4 different projects - from robotics to personalized IoT kits and lighting – and more broadly through the presentation of the 11 Reference use cases of the ACTIVAGE project, how technology can support two important and specific objectives of Smart Living Environment for ageing well:

  ✓ Avoid and postpone hospitalization in optimizing patient follow-up at home, and intervening proactively for early detection of physical and cognitive deterioration

  ✓ Enable a better and faster return to their homes when hospitalization occurs by intervention programs supported by IoT based SLEaw

Table of Contents

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Table of Figures

1 BUILDING SUSTAINABLE SMART LIVING ENVIRONMENTS FOR AGEING WELL

1.1 User needs and societal needs

1.1.1 Ageing in Europe

The ageing of Europe, also known as the greying of Europe, is a demographic phenomenon in Europe characterized by a decrease in fertility, a decrease in mortality rate, and a higher life expectancy among European populations. There a big deal of informed reports that describe the phenomena of the Ageing in Europe, its causes and their potential effects on the global economy in the EU, on the Quality of Life (QoL) of European citizen, on the pension systems, health care systems and many more. The purpose of including this subsection in this papers is to set the overall context where IoT for Smart Living Environment for Ageing Well (SLEaw) will play its mayor impact, taking extracts from relevant documents, without entering into the social, policies and political analysis for which we refer the reader to the abundant bibliography on this matter.

The 2018 Ageing Report [EU-SG ECFIN 2018]

The 2018 Ageing Report, published in May 2018, shows that fiscal costs linked to pensions, health care and long-term care are expected to rise over the coming decades, as Europe's population continues to age significantly.

The long-term projections show where (in which countries), when, and to what extent ageing pressures will accelerate as the baby-boom generation retires and as the people in the EU are expected to live longer in the future. Hence, the projections are helpful in highlighting the immediate and future policy challenges for governments posed by projected demographic trends. The report provides a very rich set of information at the individual country level which covers a long time-span (until 2070), compiled in a comparable and transparent manner. The following are highlights from the report related to the economic and budgetary impact of population ageing.

- <u>Significantly lower working-age population projected for the EU over the coming decades</u>. The demographic projections over the long-term reveal that the EU is 'turning increasingly grey' in the coming decades. The total population in the EU is projected to increase from 511 million in 2016 to 520 million in 2070, but the working-age population (15-64) will decrease significantly from 333 million in 2016 to 292 million in 2070 due to fertility, life expectancy and migration flow dynamics. For males, the projected population in 2070 is lower than or close to the population in 2016 in all age cohorts between 0 and 64 years old (69 in women). Conversely, in all age cohorts of 65 years old and above (69 years old and above in women), the projected population in 2070 is higher than in 2016. Moreover, while in 2016 the largest cohort for both males and females is 45-49 years old, in 2070 the largest cohort will be 70-74 years old for women and 50-54 years old for men.

- The projected demographic old-age dependency ratio (people aged 65 and above relative to those aged 15 to 64) will almost double over the long-term. This implies that the EU would go from having 3.3 working-age people for every person aged over 65 years to only two working-age persons.

- The ageing of Europe's population will also have significant implications for its labour force. While the total supply of labour in the EU among those aged 20 to 64 is expected to fall by 9.6% between 2016 and 2070 (9.7% in the euro area), labour force participation rates are projected to rise from 77.5% in 2016 to 80.7% in 2070. This increase is particularly apparent among women and older workers in most of the EU Member States that have recently legislated pension reforms. The projections show an average increase of approximately 12.2 percentage points (pps) in the participation rate for men and slightly higher (16.2 pps on average), for women.

- Population ageing will increase pressure on public spending. The fiscal impact of ageing is projected to be a significant challenge in almost all Member States, with effects already becoming apparent over the course of the next two decades. Long-term care and health care costs are expected to contribute the most to the rise in age-related spending, increasing by 2.1 pps up to 26.7% of GDP. However, the public pension benefit ratio, which describes the average public pension in relation to the average wage, is projected to fall by 10.6 pps on average in the EU.

Some conclusions from the socio-demographic picture:

- Extrapolating from Figure 1.1, in 2018 the population of people of age between 65 and 90 is 48 million men and 52.5 million women. That is a total available market of 100 million persons, increasing up to 59 million men and 69 million women (e.g. a total of 129 million persons) in the study period.
- Buying capacity of pensioned people will fall in the long term by 10% compared as today, while public expenditure will be stable respect to GDP, meaning almost the same amount of revenue for more people
- The Baby Boom generation (those people born worldwide between 1946 and 1964) started entering in the retirement age from 2011. The oldest cohort is now in its 70th, when the demand of services starts growing. We must consider that in a large extent these people have been incorporated into the digital transformation of life in the last 20 years: Personal Computers massive use, internet, and mobile telephony. This is changing the landscape of education and technology use experience of targeted users versus the previous generation.
- An informed population with a better exposure to digital technology is consequently expecting more from affordable, personalized, effective and ubiquitous services that help Daily Life Activities (DLA).

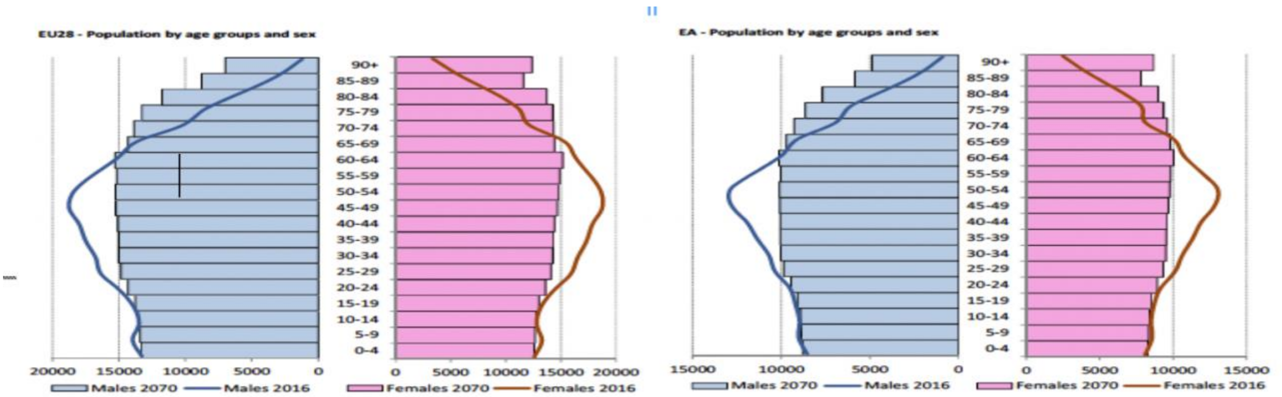


Figure 1.1: Population by age group and gender, 2016-70 (thousands). Source: Commission services, Eurostat

1.1.2 What are Smart Living Environments for ageing well?

Ageing poses therefore a crucial societal challenge. And technology is not only perceived as a brick of the solution to overcome these challenges, but also as an opportunity to achieve a “triple win”, according to the objective set by the EIP for AHA [EIPonAHA 2019], improving quality of care for elderly people, helping reduce the social burden and economical cost of the ageing population, helping caregivers to monitor the elderly as well as assisting them to age in place.

The application of Internet of Things technologies for the health and social care of senior people is set in the intersection of two broad domains. On one side, we have the DEMAND of SERVICES from senior people and their care givers, supporting them in extending their life living with independence, safety, security and quality, outside of any institutional physical and spatial restriction.

This domain is known with the name of ACTIVE and HEALTHY AGEING (AHA). Examples of AHA SERVICES are: continuous activity monitoring (to detect risk conditions or risk events), early detection of cognitive decline, social connection support, emergency detection, physical activity advisor and trainer, home rehabilitation trainer, companion for outdoors activity, tourist and leisure, booking services, and many more.

On the other side, we have the PHYSICAL SPACE where AHA services will take place and be delivered to senior people and caregivers. These physical spaces enabled through IoT and communication technologies are known with the name of SMART LIVING ENVIRONMENTS for Ageing Well (SLEaw). Examples of SLEaw are: smart home equipped with sensors for context and events detections, actuators for SLEaw driven interventions, user interaction devices, smart devices that perform automatic DLAs, Artificial Intelligence (AI) for continuous learning of living conditions and detection, communication networks, security and privacy protection, and more.

Other SLEaw are extensions of the smart home in public spaces like airports, train stations, governmental buildings, day care centers, public transport vehicles, private cars, shops, supermarkets, resorts and any space where a senior people can stay and receive local and global services.

Smart homes is not a new concept. It evolves from the definition of ubiquitous computing that, according to Mark Weiser, promotes the ideas of "a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network [M Weiser, 1991].

This visionary vision is nowadays becoming a reality with IoT enabling SLEaw.

Let’s see the key levers of this transformation, making possible to age in place.

1.1.2.1 IoT platform in SLEaw for ageing well

IoT is the crucial element providing the “smart” environment for the development of scalable applications and services connecting the physical world to the virtual world between objects, systems and people. The IoT platform is therefore an integrated physical/virtual entity system that enables the communication between the machines and devices and then the acquisition, processing, transformation, organization and storing machine and the sensor data. [M. Zdravkovic 2016]. The IoT platform components ensure that the communication between the device and the output is accomplished, that data is collected and formatted correctly and functions such as remote updates and access are facilitated.

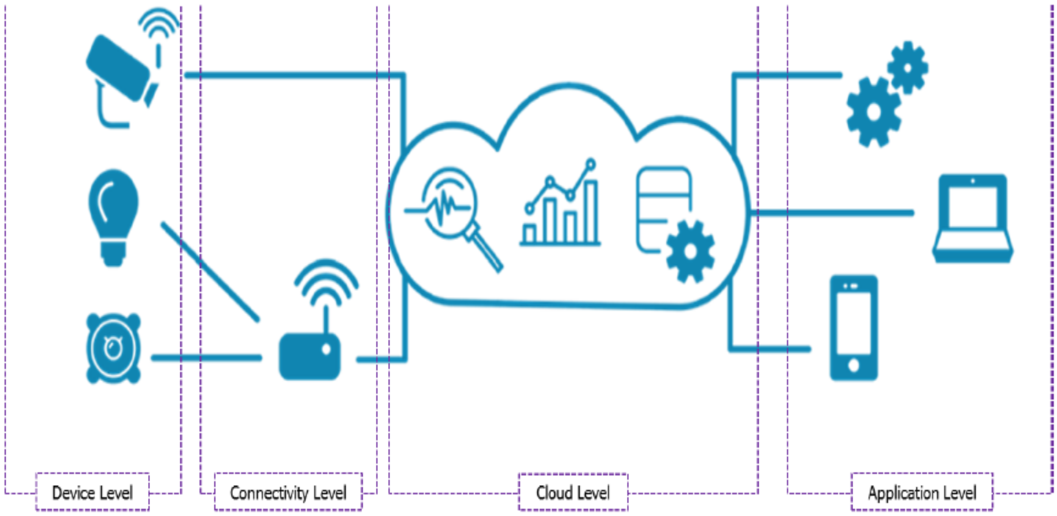


Figure 1.2 - IoT platform levels

The IoT platform is the key enabler for providing data, around which business models can be developed, like for instance IoT-based environments for ageing well.

The IoT platform is therefore the mean to gather and make sense of the data.

Below, a summary of the technologies used across the different levels of IoT platforms.

There are hundreds of IoT platforms in the market, from the ones provided by large multinational companies to open source projects usually supported financially by EU research and innovation programs. New platforms appear every day in the market, consequently, it is not straightforward to promote a single “domain specific” SLEaw platform, but rather a well-defined standard based interfaces across all layers, with the associated methods for interoperability across platforms. Therefore, IoT for SLEaw should be almost agnostic related to the Platform technology.

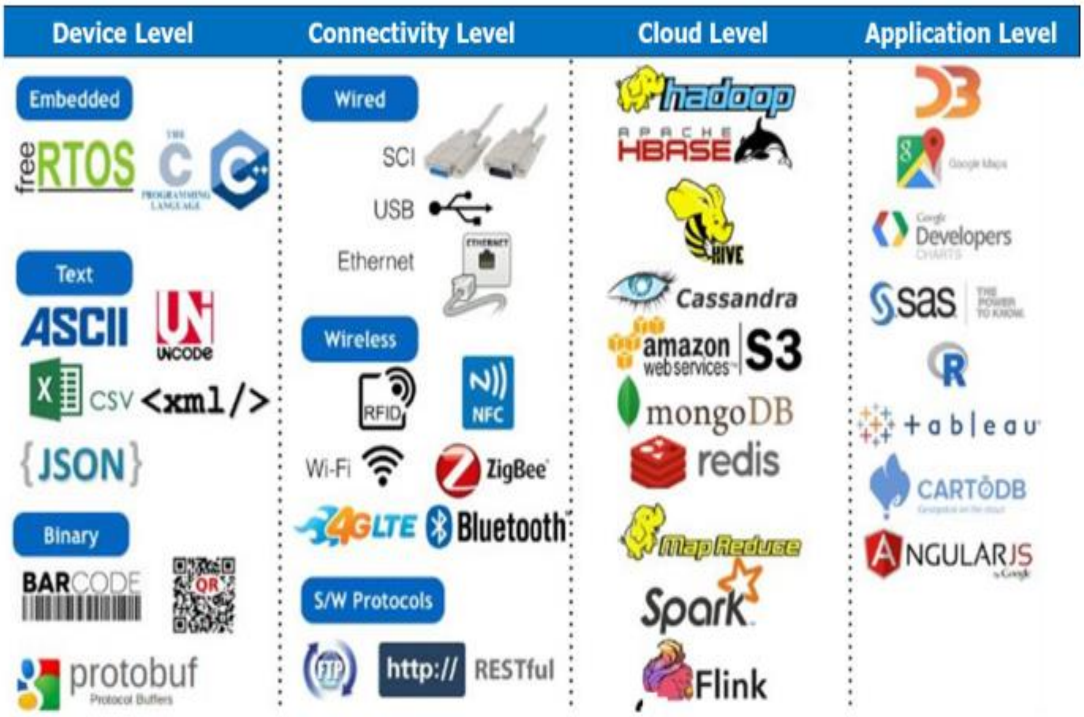


Figure 1.3 - Technologies by level of IoT platform

1.1.2.2 Interoperability: a “must” for a true SLEaw ecosystem

Today, the IoT market is growing and offering increasingly attractive applications but the lack of industry consensus on the use of open standards and protocols poses a major barrier to their diffusion.

In addition, current software development practice is the continued preponderance of ad-hoc approaches driven by industry needs, commercial interests, and market pressures, rather than scientific principles. It can be stated that “every IoT domain and every IoT vendor produces its own IoT platform”.

Different “vendor groups” can be found in different domains, while not a single vendor can be seen as having an “upper hand” in being positioned across all IoT domains. Unfortunately, without the definition of a common mechanism through which devices and applications can exchange information, regardless of their technological standard, brand or manufacturer, the IoT will never reach its full potential.

For these reasons, IoT challenges like research for standards, scalability, heterogeneity, common service description language, domain specific service discovery, integration with existing IT systems etc. have to be faced. Those topics are strongly related with the concept of interoperability.

Interoperability is essential to create a true IoT ecosystem because a single IoT platform alone will never be able to cover, just to talk about ageing well, the wide spectrum of potential use cases.

The International Organization for Standardization (ISO) has defined interoperability as the ability of two or more systems to understand, to use each other's functionalities and to give access to their respective resources.

The Healthcare Information and Management Systems Society (HIMSS) has also given its own definition of interoperability [HIMSS 2019]. HIMSS has described it as "the extent to which systems and devices can exchange data, and interpret that shared data. For two systems to be interoperable, they must be able to exchange data and subsequently present that data such that it can be understood by a user".

On a technical level, interoperability helps to reduce the time it takes to have useful exchange of information between providers. Some advantages highlighting the importance of interoperability are:

- Improved Efficiency: interoperability is designed to boost efficiency. When data is presented on a consistent basis no matter what the source is, it's easier for users to quickly get to the information they are looking for.
  • Safer Transitions of Care: continuity of care is crucial for patients, whether for chronic conditions or taking care of an acute situation with multiple health service providers. Interoperability enables safer transitions of care, which leads to better patient outcomes.
  • Can Help to Lower Costs: Interoperability means that more useful information can be shared in a timely manner. For instance, the data from a patient who recently had a blood test at his doctor's office might be immediately available during a transfer to the emergency room, saving time and cost as well as increasing efficiency at the hospital.

This means that interoperability will help the final users to work in mixed environments without facing the complexity of managing different technologies inside their organization's infrastructure, reducing the cost of buildings. In a worldwide view, users can make available on the network devices belonging to multiple vendors' technologies. This allows to implement scalability in IoT increasing the workflow efficiency in any environment connecting objects from anywhere to anywhere using different technologies.

Interoperability is surely the main challenge to be faced to achieve IoT full impact, due to the current absence of a widely accepted global standard for IoT, and the vast heterogeneity of IoT systems and elements, at all levels.

1.1.2.3 Applications and Services

Applications and services correspond to the service level of the IoT architecture. They exploit the results of the data analysis processed and stored in the cloud domain. The processed information is available to the users, as the application layer executes the applications in charge of monitoring and/or control the IoT system. Additionally, the level includes the use of statistical and optimization tools to refine, monitor, and analyses structured and unstructured data for enabling different services.

Methods and algorithms for Big Data management, collection and annotation are established within this domain. Statistical programming, text and data mining, Image and video processing, predictive models, machine and deep learning algorithms, optimizing and simulation and visual analytics are some significant examples of data formation.
In the next figure, we highlight the position of the different stakeholders, particularly the elder users in the IoT for SLEaw.

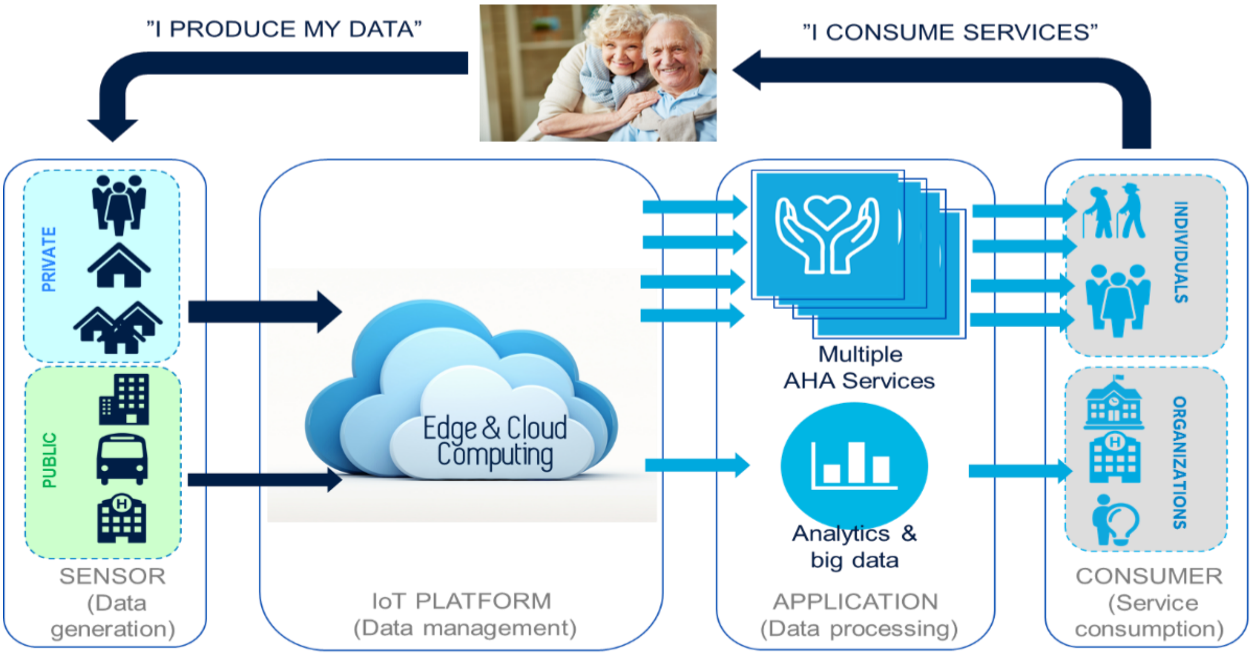


Figure 1.4. Elder users within the IoT for SLEaw ecosystem

We want to remark here a closed loop process on the valorisation of data across the whole stack. Indeed, 95% or more of the data is produced directly by the elder users or by the interactions with the environment. This has several implications with the management of the data, related to the property of the data, the privacy, the consent for the use of the data and so on, that we will not address here in this section. What is relevant is that when these data are used and transformed into services, these services are consumed by the same producers of data, closing the loop. Additionally, there are other consumers of aggregated data, normally anonymized data that are the organizations participating in the ecosystem.

1.1.3 Stakeholders, User needs & requirements in SLEaw for Ageing Well

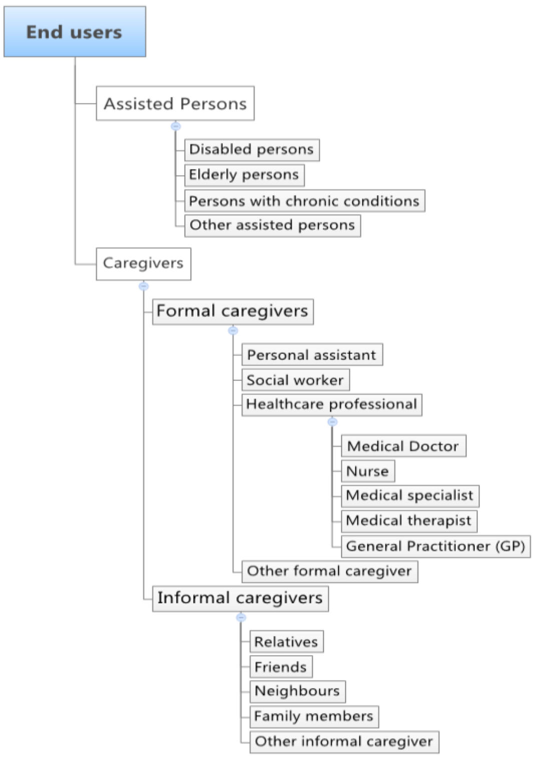
1.1.3.1 Stakeholders in SLEaw

The stakeholders are parties with an interest in IoT for AHA project. The primary stakeholders in a typical corporation are its investors, employees, customers and suppliers. However, modern theory goes beyond this conventional notion to embrace additional stakeholders such as the community, government and trade associations, just to mention some.

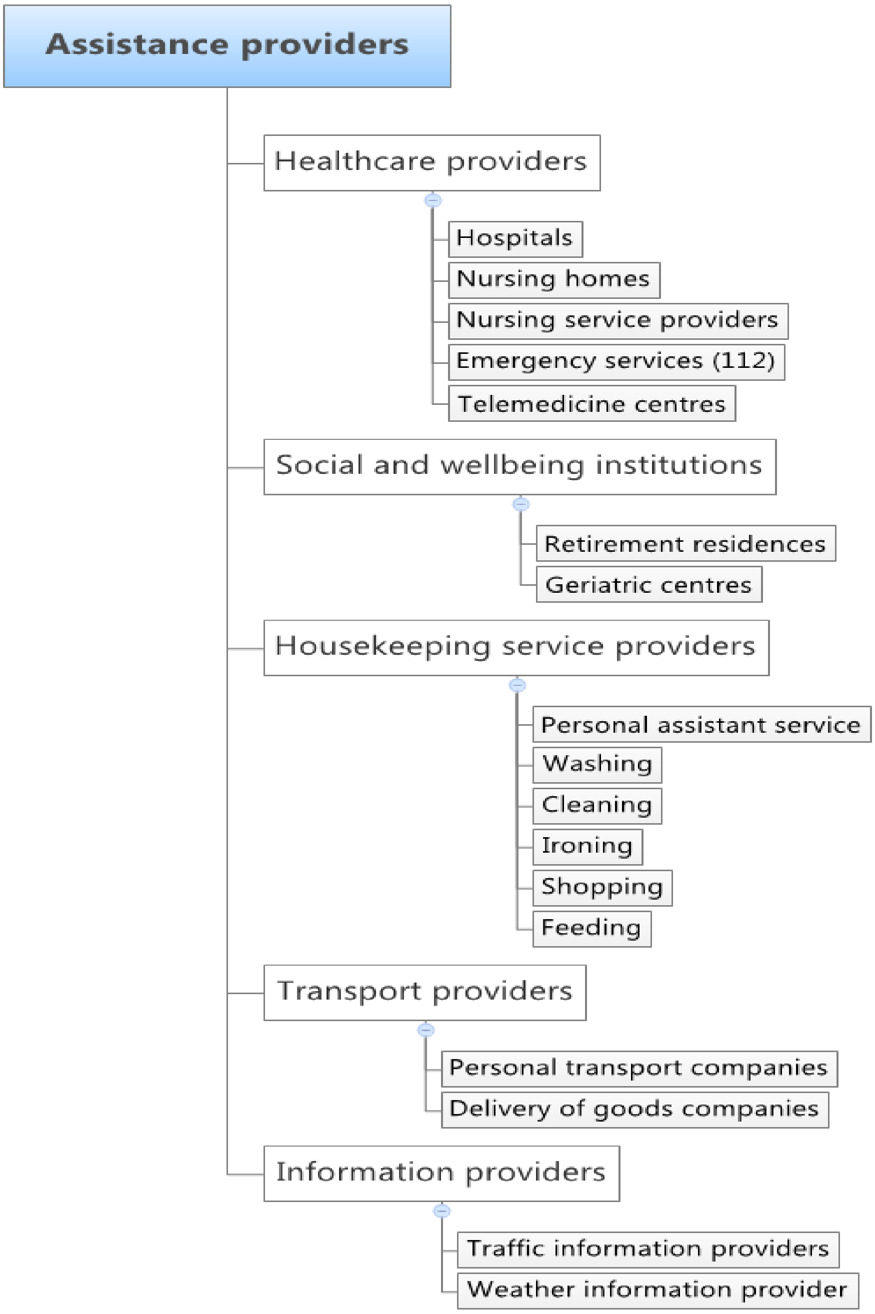
Identifying which people in the community are going to be involved in an IoT for AHA project and their level of influence implies analyzing the environment of intervention. To do this, it is necessary to explore who are the affected people, the problems that exist, what are the priority needs and their capacity to cope with them. Therefore, there is not a single universal list of stakeholders, but every project shall identify their own list of stakeholders, suitable and adapted to their own context.

At general level, the following taxonomy is defined for the classification of the identified stakeholders into 5 categories:

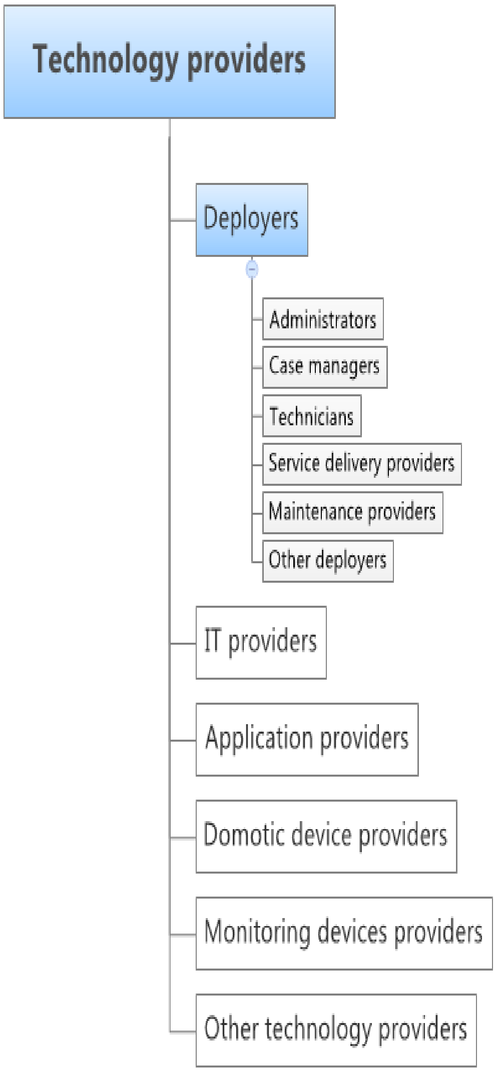
C1- End users: end users such as assisted persons which use installed IoT-based AHA applications and services and their caregivers



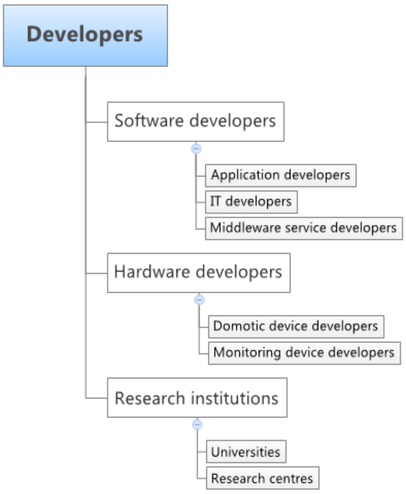
C2- Assistance providers: all kind of organisations that provide care at home or/and in elder care institutions



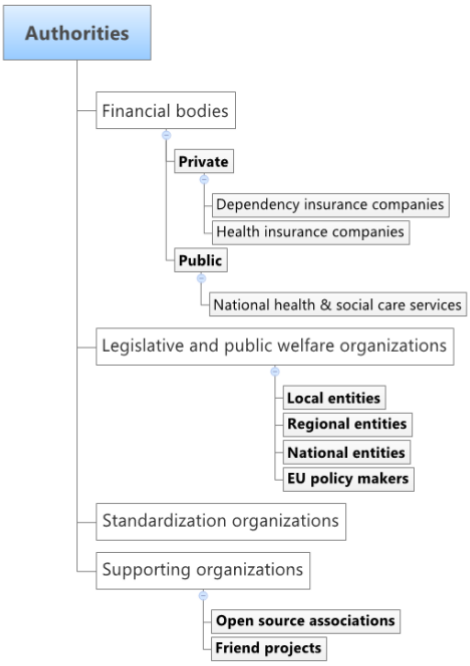
C3- Technology providers: IT manufacturers and vendors of products both hardware and software for end users and caregivers. Include technical service providers, responsible for installation, configuration, customization, and orchestration of integrated IoT solutions



C4-Developers: IoT solutions and technologies for SLEaw and AHA in form of both, hardware and software, who are the primary users of the IoT for SLEaw infrastructures



C5- Authorities and supporters: supporting organizations and authorities that deal with socio-economical and legal context of IoT for SLEaw, thus having an impact on the dissemination and uptake of IoT-based AHA solutions in their jurisdiction. Next figure outlines the 5 categories and subcategories of stakeholders in the IoT for SLEaw (AHA) domain.



The next table is an example of the more common profile, motivation and potential benefits for the main stakeholders identified above.

Stakeholder group	Profile	Motivation and goals	Benefits from IoT enabled AHA solution
Assisted person	Elder of more than 65 years leaving alone, with a partner or family members. Scale frailty between 2 and 6, with or without cognitive problems. Can receive assistance from formal caregivers at home or at a day care centre	Remain independent living at home, or any other solution chosen by them. Socialize and communicate and leave an active life. Feel safe	Feel safer at home and outdoors knowing that relatives have information about her wellbeing and potential risk situations. Exercise promotion and cognitive training. Socialize communicate in an easier and more effective way
Formal caregiver	Provide direct assistance to elder person at home or at a day care centre. Help when monitoring or exercising on frailties or cognitive training	Improve quality of service and obtain better results with clients. Attend more clients, optimise use of time. Improve self-organisation	Proactive mode of service enabled. Optimisation of use of time and resources. Quality control
Assitance Provider	Provide public or private social services for AHA.	Enlarge the portfolio of services. Adapt services to broader profile of clients. Enlarge clients reach. Reduce client acquisition and services costs. Need to provide reliable services protecting privacy in a cost-effective way	Become more competitive. Quicker adaptation to client's changing needs. Increase fidelity of the clients. Contribute to sustainability of the system
Technology provider	Provide IoT based AHA solutions and technology both software and hardware	Reach broader markets with solutions based on recognised standards, that can be used elsewhere	Can be integrated into IoT for SLEaw ecosystems and marketplaces
Governments	Draw the legal framework. Act at municipal, regional, national or European level	Sustainability of the health and social care	Driver and enablers of AHA market and ecosystem development

1.1.3.2 User needs and requirements for SLEaw: The example of ACTIVAGE[1]

User needs and requirements are not static definitions of necessities from people stereotypes and systems functionalities or performances specs. Moreover, both require permanent updates that are obtained through continuous process of co-creation among all stakeholders in each local ecosystem, with particular emphasis on the participation of the assisted persons. One of the larger attempts for the discovery and organisation of users' needs and requirements was done by ACTIVAGE large scale pilot, collecting information through user center design activities in the 9 deployment sites in Europe, involving the main stakeholders on each side: assisted older adults, formal caregivers, social service providers, technologies providers and governments. The next table is a summary of 58 user needs identified by ACTIVAGE in a single deployment site.

Nd Id	Description
ACT_Nd_01	Be able to choose how to live (at home, residence, co-housing, with friends…)
ACT_Nd_02	If living alone, need personal alarms or supervised guiding app for the public transport but be able to control that supervision
ACT_Nd_03	Continue active and sociable
ACT_Nd_04	Need to be creative, intellectual, cultural, to be happy
ACT_Nd_05	Need to have activities in cultural centers, library, dedicated to elderly
ACT_Nd_06	Need to be socially connected, friends
ACT_Nd_07	Need exercise promotion and brain training
ACT_Nd_08	Monitorize social activities apart from exercise or health
ACT_Nd_09	Security is essential in case of emergency (technical alarms)
ACT_Nd_10	Bigger displays to be able to see them (Accessible)
ACT_Nd_11	Secure and nice environment
ACT_Nd_12	More advanced teleassistance
ACT_Nd_13	Need more information on IT solutions
ACT_Nd_14	Not really care about intimacy or privacy, we accept it if we can choose
ACT_Nd_15	There is a risk on data protection but the services are more valuable
ACT_Nd_16	Don't want intrusive technology, only if they choose to have it
ACT_Nd_17	Solutions for general use like GPS are useful
ACT_Nd_18	The smartphone is the most valuable device
ACT_Nd_19	Need to check first the status of the user prior to sending a message to a relative
ACT_Nd_20	Need to provide the service when it is needed
ACT_Nd_21	Need to alert the user if he hasn't go out in three days, to motivate
ACT_Nd_22	Need to find the services in the gym near home, to normalise
ACT_Nd_23	To use the Equimetrix the user needs to be supervised by a person (caregiver)
ACT_Nd_24	If too advance age not all users will know how to use the tablet or smartphone
ACT_Nd_25	Brain training done without devices or with devices in the library
ACT_Nd_26	A videochat for groups of interest are useful to meet new people
ACT_Nd_27	Better voice and image than only written chat
ACT_Nd_28	Technology is useful but not every user knows how to use it
ACT_Nd_29	Need to monitor social activities
ACT_Nd_30	Not receive a service before it is needed
ACT_Nd_31	Cognitive decline is the main concern but mobility problems are the first detected
ACT_Nd_32	Users never assume that the time has come to leave their home, their families decide for them
ACT_Nd_33	Older adults tend to social isolation
ACT_Nd_34	The most useful services: home assistance, teleassistance, day centers, support products
ACT_Nd_35	Smart living environments - CO2 sensor, smart home and need to improve fall sensors
ACT_Nd_36	Lack of knowledge of technology and its benefits
ACT_Nd_37	Need to motivate users to go out home - group activities is the best option
ACT_Nd_38	Great satisfaction in learning to use devices
ACT_Nd_39	Technology very reliable, a single failure can produce a rejection forever
ACT_Nd_40	Balance training is a very useful solution
ACT_Nd_41	Not recognize the decline
ACT_Nd_42	Better acceptance of therapeutic solutions than others

[1] https://www.activageproject.eu/

ACT_Nd_43	It is very difficult to change the people lifestyle
ACT_Nd_44	Solutions for people who have had an active life and with restlessness
ACT_Nd_45	Need to act at the right time
ACT_Nd_46	Doctors and nurses should prescribe the active tasks
ACT_Nd_47	Customize services to improve the care model
ACT_Nd_48	Automatic learning of user routes and habits
ACT_Nd_49	To define the validation of the system and the UCs
ACT_Nd_50	To detect the user presence in an interesting point and to allow the interaction with the system to verify that it is right
ACT_Nd_51	Family members are involved in the promotion of active life
ACT_Nd_52	To know which users will attend events/activities
ACT_Nd_53	Anyone should performs cognitive trainings
ACT_Nd_54	Reliable authentication
ACT_Nd_55	Older adults need to feel that they continue to be useful
ACT_Nd_56	Older adults need monitoring with the intake of medicines
ACT_Nd_57	Older adults need to be reminded of doctor´s appointment
ACT_Nd_58	Older adults should never be left unattended when receiving home care assistance

For the formalization of requirements the “Atomic Requirements Shell” from Volere Methodology [Volere 2019] has been taken as a reference. All in all, the DSs have gathered a total of 357 unique requirements. The requirements are organised in 7 categories. The next figure shows the distribution of requirements across all categories.

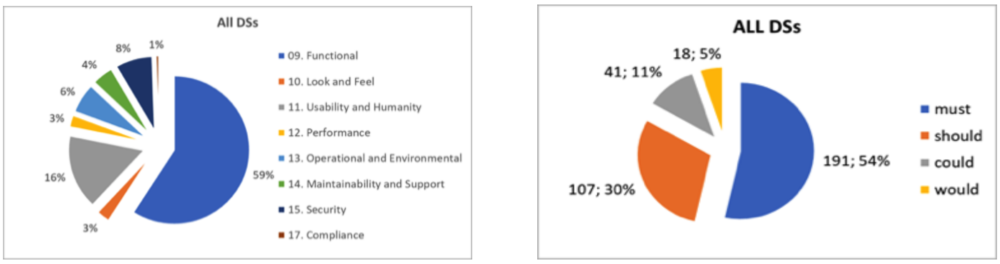


Figure 1.5. - Distribution of requirements through 7 categories
& valorization of relevance for stakeholders

Requirements from deployment sites surveys have been aggregated, and filleted the analogous ones keeping the highest priority. It resulted in 204 unique Smart Living Environment for Ageing Well (SLEaw) requirements. This list can be consulted in [ACTIVAGE D2.1, 2017] under request to project coordinator.

1.2 Existing Initiatives for building an IOT for SLEaw ecosystem

1.2.1 Studies and reports

A comprehensive analysis of the currently on-going initiatives and studies for the aging population is a challenging task. In fact, 110 European regions have identified Active and Healthy Ageing (AHA) as a smart specialization priority. Regional initiatives are then complemented by national and sectorial initiatives, including public policy actions, voluntary norms and service providers, etc.

This section points out some of the most significant initiatives related either to market studiesor projects programs addressing health, care, business model, Quality of Life improvement, maturity of ICT and/or assistance use cases.

1.2.1.1 Study on business and financing models related to ICT for ageing well[2]

This study - conducted by Ernst &Young and the Danish Technological Institute for DG CONNECT - started from the statement that business and financing models in smart living environment for ageing well were considered unsustainable and unprofitable, and aims to demonstrate that the ageing well market has the opportunity to grow exponentially based on a generic European business model for ICT and ageing well derived from 20 detailed case studies, taking in account the general European ageing well trends towards greater home care, commercial provision, cash transfers from the state to providers and carers, and greater reliance on informal carers and volunteers.

The study relies on the following key assumptions:

1) Technology should be an essential component of the use cases
2) Technology should evidence of benefits for the older adults
3) Technology should be innovative
4) Technology should be financially sustainable,
5) Technology should show evidence of cost efficiency
6) Technology should show evidence of being replicable and scalable

Major conclusions of the study highlight the next five points:

1. The most successful business cases are focused on the production of products and services which are generally off-the-self, using tried-and-tested technology.
2. Flexible partnerships and alliances between public institutions, SME's, industry and research institutions help to reduce risks and uncertainty.
3. Customer's segment identification needs to focus at least on such large regional or national scales, and should develop targeted customer strategies.
4. State funding and support should remain especially during the critical early stages of market development.
5. The financial strategy varies depending on the care regime and type of organizational set-up and market conditions, but all successful cases are typically highly innovative and adopt a multi-dimensional approach to generate revenue streams.

1.2.1.2 Analysis of Evidence from Social Innovation Good Practices across the EU: CARICT Project[3]

[2] https://ec.europa.eu/digital-single-market/en/news/study-business-and-financing-models-related-ict-ageing-well
[3] http://is.jrc.ec.europa.eu/pages/EAP/eInclusion/carers.html

The CARICT report provides an analysis of evidence from social innovation good practice across the EU. The aim of the CARICT project was to assess how, and to what extent, ICT solutions could play a role for informal carers across Europe.

According to the report, informal carers are assuming between 50 to 90% of the responsibility for the long-term care of elderly dependent people. However, their role is poorly recognized, their needs are unknown, and they have little access to the available formal services. Social, psychological and educational interventions are among the best strategies for informal carers to manage the pressure of care, and, taking this in account, new services enabled by technologies could support individuals more effectively and efficiently than traditional services.

The CARICT study results show the benefits that technology-enabled domiciliary care services can bring to the lives and health of elderly people and their informal carers, and to other care services and systems.

For instance, technology–based services for informal carers can positively impact on:

- The quality of life of the informal carers
- The quality of life of care recipients
- The quality of care provided by informal carers and privately-paid assistants, improving their knowledge of care, skills and competences.
- The cost of care for end-users, generating savings compared with ordinary services.
- The acceptability and accessibility of technology-based services

1.2.1.3 AIOTI-WG5 recommendation report[4]

This is a reference document initially produced by the AIOTI WG5 and published on October 2015. The aim of the document was to provide background information and recommendations for the Internet of Things call on Large Scale Pilot – Smart living environments for ageing well, part of the upcoming (at that time) H2020 Work Programme 2016 – 2017.

In this paper, AIOTI WG5 addresses the IoT support to the continuously growing population of elderly people in living longer, staying active and independent, and out of institutional care settings, while at the same time reducing the costs for care systems and providing a better quality of life for vulnerable categories of citizens.

In particular, WG5 focuses on two main issues - Elderly Care and Smart Home / Home Automation supporting technologies – that can be bridged by IoT.

In fact, IoT technologies are instrumental to help older people stay in their home and live longer with a good level of safety and comfort because of their scalability that supports the increasing size of the target population. Many of the propositions made by AIOTI through this paper were included in the official call for proposals H2020-IoT-2016-2017, Topic IoT-01-2016.
Activate large scale pilot initiative started from these recommendations.

1.2.2 Initiatives and projects

[4] https://aioti.eu/wp-content/uploads/2017/03/AIOTIWG05Report2015-Living-Environment-for-Ageing-Well.pdf

1.2.2.1 EIP on AHA[5]

The European Innovation Partnership in Active and Healthy Ageing [EIP on AHA 2019] is an initiative launched by the European Commission to foster innovation and digital transformation in the field of active and healthy ageing.

The concept of a European Innovation Partnership (an EIP) is of a partnership that can help strengthen EU research and innovation. A partnership brings together all the relevant actors at EU, national and regional levels across different policy areas to handle a specific societal challenge and involve all the innovation chain levels. The EIP on Active and Healthy Ageing was the first EIP created in 2011. It focuses on the active and healthy ageing of the people of Europe.

The EIP on AHA aims to promote healthy and active ageing. Its overarching target is to increase the average healthy lifespan of EU citizens by 2 years by the year 2020.

It pursues a Triple Win for Europe:

- Improving the health and quality of life of Europeans with a focus on older people;
- Supporting the long-term sustainability and efficiency of health and social care systems;
- Enhancing the competitiveness of EU industry through business and expansion in new markets

The EIP on AHA has its foundations on two main pillars: Action Groups and Reference Sites. The Blueprint, Innovation to Market (I2M) and MAFEIP are the three crosscutting horizontal initiatives that feed the EIP on AHA:

- The Blueprint aims to innovate health and care in Europe and is the follow-up of the EIP on AHA scaling up Strategy. It reflects the policy vision of the EIP on AHA partners. It is the channel for the EIP on AHA partners for giving and receiving policy inputs. A "back-and-forth" mechanism operates between the EC and stakeholders (policy makers and other key opinion leaders) to evolve, update and implement the Blueprint.
- I2M targets the scale-up of digital health and care solutions in a cross-border context. This horizontal action is part of the EC strategy on Digital transformation of health and care in the Digital Single Market.
- MAFEIP is the Monitoring and Assessment Framework initially developed in response to the EIP on AHA specific monitoring needs. See more about MAFEIP below.

1.2.2.2 MAFEIP (Monitoring and Assessment Framework for the European Innovation Partnership on Active and Healthy Ageing)[6]

The MAFEIP tool is a public and web based platform, developed by the Joint Research Centre – IPTS - of the EU Commission in close cooperation with the Commission's services and EIP on AHA partners.
The aim of the tool is to monitor the socioeconomic impact when implementing innovative solutions "to address the challenges of demographic change in Europe".

It particularly aims to combine the monitoring of 2 major objectives of the "Triple Win" strategy, which are:

- ➢ Enabling EU citizens to lead healthy, active and independent lives while ageing;
- ➢ Improving the sustainability and efficiency of social and health care systems;

[5] https://ec.europa.eu/eip/ageing/home_en
[6] https://www.mafeip.eu/

The value-added of the MAFEIP tool is its ability to provide an early assessment of the potential achievements versus the anticipated impact on deployed initiatives, in order to identify what drives initiatives efficiency to guide further design, development or evaluation, especially compared to standard practices.

1.2.2.3 ACTIVAGE LSP project

ACTIVAGE [ACTIVAGE 2017] is the winning proposal of the above mentioned call for proposal. ACTIVAGE objectives are very close and convergent with the proposed actions of the AIOTI in the SLEaw domain.

ACTIVAGE is a European Multi Centric Large Scale Pilot on Smart Living Environments. The main objective is to build the first European IoT ecosystem across 9 Deployment Sites (DS) in seven European countries, reusing and scaling up underlying open and proprietary IoT platforms, technologies and standards, and integrating new interfaces needed to provide interoperability across these heterogeneous platforms, that will enable the deployment and operation at large scale of Active & Healthy Ageing IoT based solutions and services, supporting and extending the independent living of older adults in their living environments, and responding to real needs of caregivers, service providers and public authorities

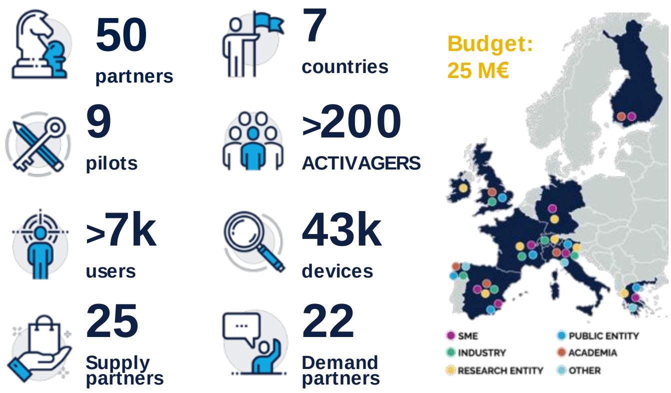


Figure 1.6. - ACTIVAGE in numbers

ACTIVAGE is designed as ONE multi-centric Large Scale Pilot across Europe.

ACTIVAGE brings UNITY of objectives, evaluation methodologies, and collaborations to achieve critical mass, and a single European platform to create and share evidence. 9 Deployment Sites (DS) rolled out in 7 countries join clusters of stakeholders in the Active and Healthy Living value network, working together within a geographical space (a city or a region - see the map). These clusters or AHA-Business Ecosystems are mainly composed by a cohort of users (older adults, caregivers and informal caregivers), service providers; health care/social care administration; technological infrastructures and technology providers (infrastructure, sensors, applications, etc.).

DSs deploy Reference Use Cases (UC) that address specific end-user needs, to improve their quality of life and autonomy. A single common interoperable ACTIVAGE IoT Ecosystem Suite (AIOTES) was built up that provides every DS with the capacity to build standard and interoperable IoT ecosystems on top of legacy IoT platforms, or communication and data management infrastructures. GLOCAL Evaluation Framework (Local KPIs and global KPIs) was designed and implemented to demonstrate and evaluate health & social outcomes and socio-economic impact from local up to a European scale, enabling effective exchange of experiences and cooperation among peers (e.g. users, providers, policy makers).

Use cases addressing the needs from the AHA perspective

ACTIVAGE focusses on “domains of needs” for the support of the older population and in order to create a demand-driven experience on the basis of the reference Ageing Well initiatives around the world. Figure below shows the domains of needs (on circles) and the Use Cases (UC) that will be deployed in the 9 DS involving up to 7.000 users.

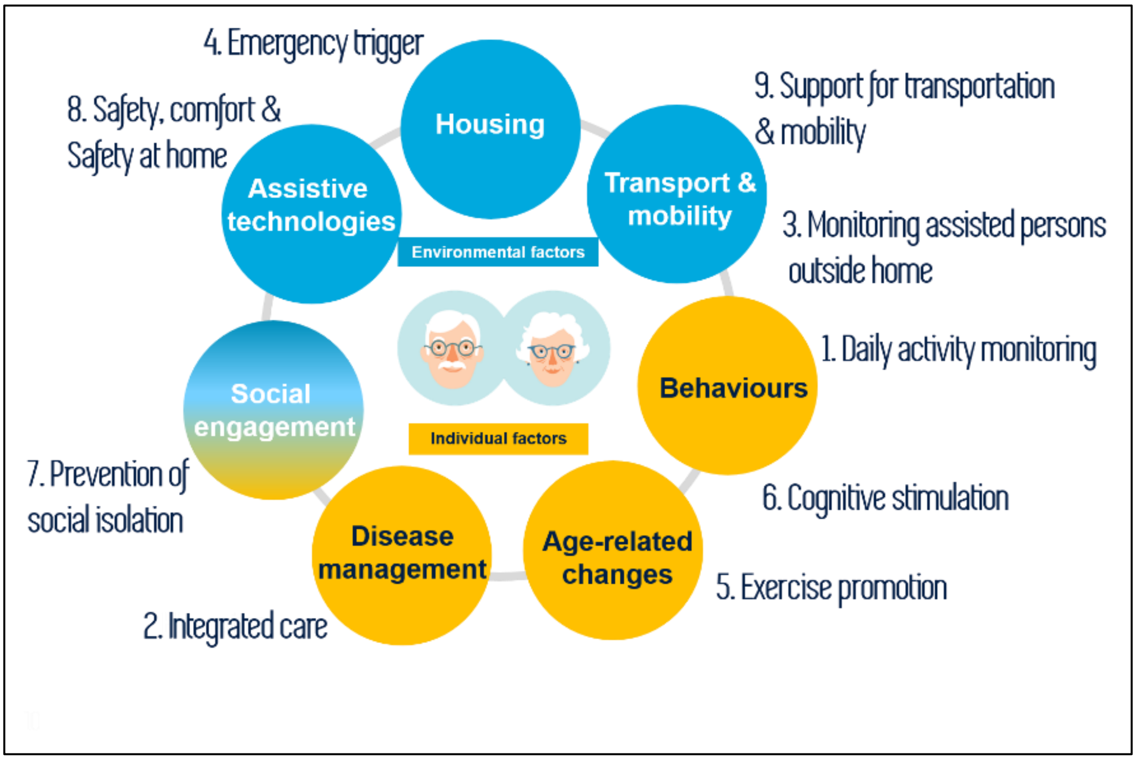


Figure 1.7. - Domains of user needs (bubbles) & corresponding Use Cases addressed in ACTIVAGE

2 DRIVING ACCEPTANCE THROUGH MARKET STRUCTURATION

2.1 User needs, societal needs & use case prototyping/co-creation

Understanding user needs of ageing population is a timely, urgent and strategic matter that concerns governments all over the world.

In the US, six market segments for opportunities in relation to the application of technologies for the support of the caregiving process for older people around Health and Safety awareness have been identified[7]: care coordination; support when becoming old; social well-being; caregiver quality of life; and daily essential activities.

In Japan, the Ministry of Internal Affairs and Communication[8] held the "Council for designing ICT solutions for the super-ageing society, where the intention is to keep population active despite of their age and keep people healthier for longer. They identify concrete innovation opportunities by developing life supporting technologies for daily living, including shopping, meal delivery and monitoring, improving ICT skills for work, including robots into daily life support.

In Australia, the "Ageing Well, Ageing Productively " program[9] highlights the need of working in the "interrelations of individual behaviours, general social, economic, cultural and environmental conditions and the efficacy of preventative, curative and rehabilitative models of interventions" as well as in "measuring and monitoring physical and mental functioning and age associated disabilities and the potential for preventing these".

In Europe, the Survey of Health, Ageing and Retirement in Europe (SHARE)[10], conducted through 5 waves of interviews covering up to 123,000 50+ aged individuals in 20 European countries from 2003 to 2015, represents a first-hand feedback on real needs and challenges for individuals in the ageing domain.

Age, gender, socioeconomic status, early retirement from work and social inequality are determinant for successful ageing, and present great variability across European countries and regions.

Another relevant initiative is the European Innovation Partnership on Active and Healthy Ageing (EIPonAHA)[11] that since 2012 has focused activities on understanding user needs in different Action Groups, determining the component for user empowerment or by developing guidelines for smart environment.

As an evolution, the "Blueprint on Digital Transformation of Health and Care for the Ageing Society", designed to guide the efforts of the EIP on AHA, by mobilizing investments and guaranteeing commitment of industrial players, regional authorities, professional and civil society organizations and multi-stakeholder platforms, has recently developed a framework that considers the health and care needs of a person over their life course (both person-centered and population-based dimensions), and is identifying corresponding technological solutions that target these needs.

In this direction, trust is a fundamental issue since the technological environment is characterized by different devices that must process and handle the data in compliance with user needs and rights. An intense discussion

7 AARP, Caregiving Innovation Frontiers. A universal need, a growing opportunity – leveraging technology to transform the future, January 2016. http://www.aarp.org/

8 Japanese Ministry of Internal Affairs and Communication (MIC): http://www.soumu.go.jp/english/icb/

9 Background information about the Australian Ageing Well, Ageing productively research program: https://www.nhmrc.gov.au/_files_nhmrc/file/grants/types/granttype/strategic/agingbac.pdf (accessed March 2016).

10 Survey of Health, Ageing and Retirement in Europe (SHARE): http://www.share-project.org/ (accessed March 2016).

11 Market Place of European Innovation Partnership on Active and Healthy Ageing: https://ec.europa.eu/eip/ageing/ (accessed March 2016).

among policy and regulatory bodies on how to define adequate best practices or regulation for data management in large IoT ecosystems especially when the data centers are cross-border has taken place in the last years: a report from EC[12] analysed and identified the characteristics of the IoT which might cause ethical & legal problems. An ethical behavior requires a) enforce the property rights on information; b) ensure the access to information; c) ensure the integrity of the information; and d) enforce the right to privacy[13]. The 5th Annual Workshop (2015) of the IGF Dynamic Coalition on IoT indicated the "IoT GOING ETHICAL" motto in order to get a common understanding of what it takes to go forward with IoT in a sustainable way-what "ethical" in the sense of IoT means. The authors[14] presented a new approach for users' interaction with the IoT, based on "Ethical Design" implemented through a policy-based framework which can give more control to the user. Similarly, the Security by Design and Privacy by Design approach have also confirmed the need for systemic approach in conceiving solutions that catch the dynamic essence of technology to assist older adults.

Existing guidelines and standards, such as ISO 9241_11-110, ISO 62366 [15][16][17]help developers to involve users in the design process at several steps of the development. Although the approach is called "user-centered", it is rather developer than user-driven, yet user involvement is segmented and limited.

Assessing user needs is a fundamental information that need participation of senior citizens, their caregivers and professionals in the evaluation of every AHA service, to be considered as part of a co-creation process where technicians, end-users, service providers, governments (payers) and other actors need to collaborate in order to create new evidence of the value of IoT enabled AHA.

Recently, the PROGRESSIVE project has tried to fill this gap by exploring standards in the context of ICT products and services with a focus on empowering older people in fields that relate to their active and healthy ageing. In relation to age-friendly housing, the recently started Homes4Life[18] project is looking into the development of a European Reference Framework and certification scheme for age-friendly housing. The framework will be based on an inspirational and realistic long-term vision of people's needs and requirements in a holistic life-course approach and help develop better living environments integrating construction and digital solutions where this is beneficial. This project recognizes as one of its central challenges that Europe's build environments and home and neighborhood levels need to remain flexible towards changing needs of European citizens across the life course, supported, where this is beneficial, by the possibilities of IoT. This is a fundamental challenge that came out loud and clearly during a Europe wide consultation process in 2016, the Neighborhoods of the Future Roadshow, which demonstrated that the design of age-friendly housing needs to start from a thorough understanding of the social life worlds of older people in their home and neighborhood environments. The final report with recommendations highlights a number of best practices in which this has been accomplished[19].

Among the most important results there is the recognition of implementing thorough and comprehensive co-production and co-creation strategies, in terms of effort to identify all the stakeholders and catching their opinion and input.

Understanding and defining from a clinical, economical and customer perspective how technology might impact needs is of utmost importance. Business-oriented methods like Running Lean Canvas help to better

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[12] Van den Hoven, J. (2013), Internet of Things Factsheet Ethics, http://ec.europa.eu/digitalagenda/en/news/conclusions-internet-things-public-consultation

[13] Valacich, J., Schneider, C., Information Systems Today. Managing in the Digital World, 4th Edition, Pearson Publishing House, Boston, 2010, p. 484

[14] Gianmarco Baldini, Maarten Botterman, Ricardo Neisse, Mariachiara Tallacchini, Ethical Design in the Internet of Things, Science and Engineering Ethics 2016,pp 1-21

[15] Secure WebOS Application Delivery Environment, availble at http://webinos.org

[16] Social AND Smart, available at http://www.sands-project.eu/

[17] Sensing, monitoring and actuating on the UNderwater world through a federated Research InfraStructure Extending the Future Internet, available at http://fp7-sunrise.eu

[18] http://www.homes4life.eu/

[19] https://ec.europa.eu/digital-single-market/en/news/final-report-recommendations-european-reference-framework-age-friendly-housing

define problems, objectives, and solutions. Focus groups and Persona help to determine and describe key stakeholders, to identify improvements, needs and requirements to be covered, and discuss issues of use of the technical system to be developed, revealing the functionalities that are more- or less desired, and the emotional or organizational problems related to these functionalities.

To further study user needs and transform them into a structured set of specified requirements, problem tree analysis such as the Analytic Hierarchic Process (AHP) help in structuring a decision problem, representing and quantifying its elements, and relating those elements to the overall goals. Once evaluations are done, experts discuss and comment the results generated, to gather insights and transform them into requirements and guidance for the development stage.

The result of this phase is a structured and balanced description of user needs, values and attributes that can be used as specifications for the implementation phase.

2.1.1. How to manage the need

The most innovative co-creation processes in Europe have been those defined by the Neighborhood of the Future (NoF) roadshow mentioned above, in terms of scenario definition, and by the ACTIVAGE project in terms of persona and user needs validation.

In the first case, the NoF roadshow engaged European stakeholders from different regions and sectors into a broad consultation process about the opportunities and challenges of concerted actions in the smarter age-friendly housing domain. Over the course of 8 month the roadshow included 10 interactive open innovation workshops that were organized in collaboration with local partners and that took into account regional and local particularities (a full report with details of the events and the main outcomes is available here).

The co-creation process laid out by the roadshow was tailored to address a key European challenge in relation to age-friendly housing – that the majority of Europe's built environment at home and neighborhood levels is not yet ready to meet the changing and evolving needs of older people. At the same time, updating Europe's built environments while making use of new opportunities from IoT would provide a major opportunity for Europe's housing and ICT sectors (in a 2015 ECTP report, the investment tasks was estimated to be more the 100 billion EUR for the construction sector alone). In order to realize this opportunity, however, concerted action would be required involving stakeholders from sectors that normally do not collaborate – such as housing, health, and ICT.

Utrecht University developed an innovative method for this consultation process, inspired by qualitative research methods from the social science. The main starting point for the roadshow were the many local and regional activities that already existed and that were probing into innovative ways for refurbishing homes and neighborhoods to make them better suited to changing demographics. These local initiatives typically were in an experiment or pilot phase and significant value were seen in engaging them in a co-creation process to explore what local project could learn from each other and how concerted action at the European level could support scale and impact. In other words, the roadshow was aimed at mapping a variety of local experiences, and extract from these experiences those insights that could, with support at the European level, lead to a new "business as usual" across the housing, IoT and health sectors (see Arentshorst & Peine 2018).

Methodologically, the co-creation process was designed as a bottom-up process. It revolved around a generic template for the open innovation workshops which was shared with the local partners that were given sufficient freedom to work with the template that would fit local circumstances, including the range of relevant stakeholders, the scope of ongoing initiatives, the particularities of the national and regional health care systems, the socio-economic circumstances of the housing sector, etc.

The template was also translated into different language so that the stakeholders could interact in their native language. Each of the local workshops, then, revolved around a particular theme and focus, summarized in the following table 2.1 that reflected the strengths of the local eco-systems. For each workshop, audio reports and extensive notes were produced, if needed translated, and then incorporated in an extensive database[20]; also, a summary report was produced for each workshop covering the main results. Through this process, we could identify the important overarching opportunities and challenges for the age-friendly housing domain, as experienced in the European eco-system.

Date	City & country	Partner organization	Focus / angle
7 April 2016	Brussels, Belgium	European Commission	Launch Event
11-12 May 2016	London, United Kingdom	Innovate UK, NatWest and Lansons	Finance, health & entrepreneurship
26 May 2016	Arnhem, the Netherlands	Foundation Kien & KIVI-Chair Architecture in Health	Small installation companies and their perspectives
16 June 2016	Bilbao, Spain	Tecnalia	Housing, buildings & urban environments
6 July 2016	Barcelona, Spain	Ethical Cities: Urban Innovation Forum	Urban design & inclusiveness
22 September 2016	Utrecht, the Netherlands	Economic Board Utrecht (EBU)	Construction, policy, entrepreneurship & EU dimension
27 September 2016	St. Gallen, Switserland	AAL-forum	Conference sessions
5 October 2016	Odense, Denmark	Copenhagen Institute of Interaction Design (CIID)	Opportunity-based design
19 October 2016	Genk, Belgium	Microsoft Innovation Centres	Health, Care homes & ICT
27 October 2016	Warsaw, Poland	Polish National Silver Economy Institute (KIGS).	Silver Economy, Smart by design & labels

Table 2.1: Overview of workshops and themes organized during the Neighborhoods of the Future roadshow (Source: Arentshorst & Peine 2018)[21]

[20] Atlas.ti was used to collect and analyse our data. Atlas.ti is a specialized software package for the analysis of qualitative data.

[21] Arentshorst, M. E., & Peine, A. (2018). From niche level innovations to age-friendly homes and neighbourhoods: a multi-level analysis of challenges, barriers and solutions. Technology Analysis & Strategic Management, 30(11), 1325-1337.

Three results stand out the came out of the roadshow and that informed further work on a European Reference Framework for Age-friendly Housing, as currently driven by the Homes4Life project mentioned above. First, further work on co-creating a common vision is needed that provides guidance across sectors and demonstrates the value of investing in the smarter age-friendly housing domain. Such a visions should depart, on the one hand, from a clear understanding of the social life worlds of older people; at the same time, it needs to be specific enough for various sectors and stakeholders to provide actionable knowledge. Secondly, existing initiatives and in particular the barriers and opportunities they face need to be the basis for identifying next steps for upscaling, mainstreaming and innovating in the age-friendly housing domain. This reemphasizes the need to follow a carefully design bottom up approach, while retaining a keen eye for overarching themes and challenges. Finally, and derived from the previous aspects, a clear set of indicators and measures need to be developed to evaluate the impact and value of investing into the age-friendly housing domain. These indicators and measures should be tailored to the specificities and needs of the sectors involved, pertinently the housing, IoT and health sectors.

In the second case, the ACTIVAGE is putting in place a co-creation process to define solutions with end-users for AHA and independent living based on IoT. This process is being performed through a "learning by doing approach", which complements a systematic approach based on reference frameworks and methods, such as the logic framework approach. This methodology follows a process in which the stakeholders are first identified for each of the Deployment Sites. This first step serves to determine who are the main stakeholders interested in the different deployed solutions. Subsequently, after identifying these potential interested parties, individuals belonging to these interest groups are contacted to begin a process of identification and formulation of needs. Once the needs of the different stakeholders have been gathered, a process of transformation of needs into requirements begins. Needs are reformulated in such a way that they are achievable and understandable by the personnel in charge of the development and implementation of the products and services. More in particular, they are "related to a product or service, and that the product or service must satisfy to get the right outcome and impact on users' quality of life". After evaluating which needs are implemented, it is necessary to evaluate to what extent the users and different stakeholders of the project consider them as satisfied and to what extent they think that services and solutions may include improvements for the future. This process is carried out through a set of personal interviews with key profiles selected from the different stakeholders involved.

Defining needs as those "related to a product or service, and that the product or service must satisfy to get the right outcome and impact on users' quality of life". However, such learnings must be turned into a systematic approach in order to reach systemic levels and be scalable.

2.2 Dynamizing user needs: An emerging field for IoT and Social Science and Humanities collaboration

In the European landscape, the potential role of the Social Sciences and Humanities (SSH) is increasingly recognized when it comes to understanding user needs, but probably more importantly the dynamic nature of user needs in relation to emerging technologies. In general terms, the H2020 funded CANDID project has recently published its PRIMER with recommendations about knowledge exchange between SSH and ICT experts[22]. Drawing heavily on insights from pertinent social science fields like Science and Technology Studies (STS) or consumption studies, this report highlights user needs as something that is established during the appropriation of new technologies, often in unexpected ways. It is an overriding message from the wealth of empirical studies into the "domestication" of new technologies that user needs do not linger around to be revealed as an input for design or innovation. Rather, they are gradually explored, established or declined once a technology becomes available for experimenting in real life settings. Dealing with users and user needs, therefore, is as much about rich and informed imaginaries about future uses as it is about identifying present user needs.

[22] https://candid.w.uib.no/2018/01/11/candid-primer-and-policy-recommendations-to-be-unveiled-at-concluding-conference-at-amsterdam-on-23-january

In relation to ageing and technology, available empirical insights into the dynamic relationship of user needs and new technologies have been summarized in what is increasingly called the co-constitution of ageing and technology approach[23]. Here, it is an important message that the existing approaches that focus on technology as interventions or solutions, and which often have their roots in the health science and medical interventions, need to be complemented with those focusing on co-creation and needs dynamism. This is particularly relevant in relation to the needs of older people, which are widely framed in terms of (static) medical or care needs in innovation policy and design circles[24], which can then be the basis for technological interventions. Empirical studies into real world uses and appropriations of IoT technologies, including care technologies, have time and again shown that such a focus on deficits does not reflect the richness of technology use by older people, and often creates acceptability problems. In that sense, more careful approaches might be in order that consider how the lives of older people are already permeated with digital technologies, and how new technologies are appropriated into existing social relations and care arrangements.

The potential of SSH and ICT collaborations in developing more nuanced co-creation approaches has been explored, for instance, in collaborative workshops of the AAL program and the Joint Programming Initiative “More Years, Better Lives”. This dialogue has further demonstrated that the needs of older people, like those of other age groups, are diverse, that some older people are highly digital literate while other are indeed late adopters or even laggards, and the technology use and needs change during the life course. Mapping these diverse relationships that older people already have with IoT devices, and exploring the role of such knowledge in design processes, is a main task that is explored and implemented in the project currently funded under the 3rd MYBL call[25].

What transpires from such approaches is a specific risk and opportunity for IoT innovations in the context of demographic ageing. On the one hand, many funding initiatives and policy programmes require new IoT “solutions” to focus on measurable medical or care problems – often those for which significant societal and economic costs have been established, and for which a clear RoI can be demonstrated. To this adds, that medical or care related needs are often the low hanging fruits that can be captured as requirement; they are easy to “parametrize”[26]. At the same time, the focus on these low hanging fruits positions older people as problematic (i.e., it further legitimizes and reinforces ageist representations of older technology user), and it limits the acceptability and meaningfulness of new technologies in the lives of older people.

"Hence, a new approach to ecosystem and trust building, based on dynamic and co-creative approaches to responsible research and innovation (Kiran at al. 2015; Kudina and Verbeek 2018) is needed. In contrast to more traditional approaches, such a framework would acknowledge that user needs and ethical issues like trust or privacy are dynamic and change alongside with technological development and implementation (rather than assessing new technologies in relation to a set of static and pre-defined ethical issues)."

In order to address user needs, it is thus not only important to understand how these needs are currently framed in relation to new IoT technologies, but also map future scenarios of using Smart Living solutions.

In practical terms, this means that it is crucial to (i) build a baseline scenario to map stakeholders’ initial position towards trust, (ii) initiate a prospective process to map future trust and value frameworks/scenarios in relation to

[23] Peine, A., & Neven, L. (2019). From Intervention to Co-constitution: New Directions in Theorizing about Aging and Technology. The Gerontologist, 59(1), 15-21

[24] Neven, L., & Peine, A. (2017). From Triple Win to Triple Sin: how a problematic future discourse is shaping the way people age with technology. Societies, 7(3), 26-37.

[25] https://www.jp-demographic.eu/calls/projects/

[26] Peine, A., & Moors, E. H. M. (2015). Valuing health technology – habilitating and prosthetic strategies in personal health systems. Technological Forecasting and Social Change, 93, 68-81

the new technology, and (iii) involve relevant stakeholders in eco-system co-creation to elaborate and articulate these positions as development moves forward.

Innovative frameworks to address the needs of older people in the design and implementation of IoT systems (this perspective is in line with recent EC work around responsible innovation, and the inclusion of SSH in particular) are needed, with the aim of creating a viable user-led innovation ecosystem of partnering healthcare professionals, industry players and end-users.

In order to dynamising user Needs through Responsible Innovation Framework, different aspects of the relationship between R&I and societal needs: public engagement, open access, gender equality, science, ethics, and governance, to provide an RRI framework and guidelines that will articulate stakeholders' needs on trust and privacy issues, aligned with IoT specifications. Based on Constructive Technology Assessment and RRI, experts recruit from relationships and established links from pilot sites, partners, and participating networks (among others: EIP-AHA key players, the RSCN, the Covenant for Demographic Change, UDGA, the ECTP), and engaged through focus groups and in-depth interviews to gather inputs.

Engaging with stakeholders in the project ecosystem, mainly consumers (elderly, patients, families) and health providers (informal and professional, home personal services, etc.) to elicit needs and preferences. Open innovation and co-creation workshops can be used to gather stakeholder requirements as input in the design, development, and implementation, aiming at eliciting and discussing future positions and needs of the extended stakeholders' network, with special attention to technology and to user specific criteria (e.g. trust, privacy, security, liability, accountability, accessibility & usability). The idea is to understand how relevant stakeholders envision technology advances and acceptance issues specifically in relation to the technology.

2.3 Expansion enablers

In the recent years there have been several initiatives that aims at accelerating the process of up taking and scaling up solutions that are working in a given context or scenario.

Pushed by regional healthcare system and municipalities, the Reference Site Network is an initiative that is being defining elements that favour scaling up within and across regions. In the Scaling up strategy, issued on early 2015 an approach on how to ensure implementation of innovative solutions for active and health ageing was presented. The approach focusses on two key elements "What to scale up", which includes identifying practices, projects and innovations to be scaled up; "How to scale up", which focusses on the methods of going to scale. There are also other examples of assessment frameworks that relate to specific types of innovation. For example, assessment tools have been developed by WHO-Europe together with the Healthy Cities Network in the area of age-friendly environments. Based on WHO/ExpandNet work, and the Partnership's work on the good practices catalogue and Reference Sites 'How to guide', the following framework for implementation of individual scaling-up is composed of three steps: 1) Planning the innovative service & setting up a system for change; 2) Organisational process and design choices; 3) Monitoring, evaluation and dissemination.

In the case of the ACTIVAGE project, each pilot has been selected according to the presence of all the relevant actors, that is, the supply and the demand sides, the payers and the prescribers. The project is moving to different phases, called the innovation path, which are incremental phases that will allow to increment the value and the maturity of the developed solutions, these are: DEMONSTRATE. Smart Living environments on each DS are deployed, instantiating the IoT ecosystem and UCs, providing AHA services to selected community of users, evaluating and demonstrating evidence and value to stakeholders. EXPAND. DSs cooperate bi-laterally or tri-laterally, allowing coherent, complementary replication of Use Cases, to generate evidence on the value of interoperability and standardisation at a European scale. GROW. DSs open to European external actors to incubate new UCs, technologies, solutions and BCs. Open calls will attract entrepreneurs and start-ups to implement innovative solutions using the mature DS's IoT ecosystem for testing, demonstration and initial market take-up. Calls will be also opened to other DSs that want to share experiences through bilateral exchange. In this phase, ACTIVAGE open possibilities to replicate best practices, transferring know-how, standards, tools and APIs, to facilitate the market growth of IoT solutions for AHA. SUSTAIN. The assets that guarantee the sustainability of the Business Models and exploitation plans beyond the project are created.

In the EIT Health, which is the most important initiative when it comes to innovation in Health, the Living Labs and Testbed initiative aims at providing services to innovation entrepreneurs in the health sectors. The network of EIT Health Living Labs comprises a wide variety of specialized high-quality facilities around Europe that accelerates the innovation of health products, services and processes.

In all these cases, KPIs that are focused on patient or citizen outcomes, health and social care system sustainability and economic growth, defined in the Triple Win Pillar of the EC, are being defined.

To meet the supply and the demand, the requirements and the solution, convergence between needs and KPIs is ultimately needed and this convergence should also take place among these initiatives. There are several institutions that are working in order to make it happen.

2.3.1 Dynamic assessment

The scaling-up and impact fundamentally depends on the creation of a viable and committed stakeholder ecosystem that aligns behind the proposed solutions.

In order to realize this, evaluation frameworks have to identify, monitor, quantify and assess the whole spectrum of the interventions related with a technology, and demonstrate that IoT technologies can help to measure the costs and the added-value of underlying technologies both on quality of life and healthcare systems efficiency. This way the existing lack of evidence generated from reliable Real World Data (RWD), the so-called Real World Evidence (RWE), which has been limiting the diffusion of value based solutions for management, treatment and prevention of diseases and conditions, will be overcome, thanks to the demonstrated benefit resulting from the data generation and sharing approach among stakeholders.

The IoT-AHA ecosystem operates as a multi-sided market: while the multi-dimensionality begins with two-sidedness (in which consumers and sellers meet on a platform), many of these markets might have even more sides. From the supply side, companies could be assessed through methods like the Entrepreneurial Performance Indicators developed by EUROSTAT[27] and the OECD covering their structure and performance, their productivity, business dynamics and job creation, and their wealth and therefore allowing to determine of entrepreneurial performance (i.e. regulatory framework, market conditions, access to finance, knowledge creation and diffusion, entrepreneurial capabilities and culture) in order to address job creation and economic growth.

From the demand side, tools like MAFEIP allow to assess cost-effectiveness of interventions and establish whether new technologies can provide the best value for money, or in other words, whether their use will ensure that limited healthcare resources are spent in the most efficient way.

Value for money of innovative technologies can be estimated through cost-effectiveness analyses, which require a systematic collection of both health benefits and resource consumptions occurring during the care process.

The data gathered through the ecosystem can facilitate the exploitation of the possibilities activated by a deeper integration of real-world evidence from different sources: cost-effectiveness analyses should be conducted from multiple angles: the perspective of the health authorities, to inform social decision-making and provide insights on whether the identified interventions provide good value for money. Secondly, the perspective of the

[27] Eurostat Entrepreneurship indicator programme https://ec.europa.eu/eurostat/web/structural-business-statistics/entrepreneurship/indicators

developers will be adopted with the aim to build business value propositions based on cost-effectiveness criteria, and to inform developers' strategies on pricing and product development. On the other hand, a Budget Impact Assessment (BIA), an economic assessment that estimates the financial consequences of adopting a new intervention, help to evaluate whether a high-value intervention is affordable. By conducting multiple analyses, a complete picture of the impact of the interventions can be provided at a micro, meso and macro level, proving the added-value of the underlying technologies to increase efficiency of health and care systems and to improved quality of life and health status for involved users and carers.

Lastly, in multi-sided markets a central role is given to open-platforms and standards embedding the demand and supply side. European-led platform could facilitate network externalities and economies of scale to increase the competitiveness of the European ICT industry generating synergies between the stakeholders and new viable business and financing models.

The impact of platforms can be measured with specific metrics (e.g. number of sellers, number of services, number of buyers, prices, number of orders per buyer, number of transactions, customer acquisition cost, and sellers acquisition cost).

2.3.2 Scaling up. Innovative procurement models for value-based healthcare

European Healthcare systems are planning to find the way citizens can adopt digital solutions to prevent suffering risks during their ageing process. Sustainability of such plans are tightly related with innovative procurement models based on risk sharing and Value-Based Healthcare. These two elements are intimately linked with a public-private partnership with European ICT industry, in particular with an ecosystem of SMEs and Startups that will join big industry to provide added value to the business proposition that can be test-proven and implemented through innovative procurement models and alliances.

Business models will be evolving and personalized according to the type of innovation and use cases demonstrated. Accordingly, value-based marketplaces (also defined as ecosystem transaction marketplace) would allow create a virtuous cycle between traditional IT companies and data market place for health and wellbeing. This way, the EU industry can be empowered with tools to build alternative economic and business models and scalable markets, on top of an interoperable novel infrastructure supported by a multidimensional and heterogeneous ecosystem in which people, technology, data, AI, and processes are driving EU leadership on digitalized innovative interventions

3 DEMONSTRATING THE IoT IMPACT IN AGEING WELL

3.1 Technological enablers in IoT for SLEaw

3.1.1 Underlying technologies embedded into the smart things

The connected physical things, also called « smart things », get the following specificities – « the embedded technology » - to be able to interact with their environment, e.g. to send or receive information using the internet:

- A smart thing has a “brain” to secure and process information
- A smart thing is connected to the outside world
- A smart thing can be enhanced through Artificial Intelligence (AI)
- A smart thing senses its environment and can act on its environment

These 4 specificities, combined, are the fundamental components of the IoT smart systems. Among the enabling factors of these smart systems, silicon technologies played – together with new materials and software, a crucial role. The technology embedded in the « things » owes a lot to Moore’s law, a reference in semiconductor research and development. The Moore law explains the miniaturization trend, which includes a cost reduction factor, authorizing to embed such an amount of technology into the smart things. “More than Moore, in which the needs for applications drive chip development, allows to expand the functionalities we find within these smart things.

The microcontroller – “the brain” - is usually the first choice of developers when designing a new application.

The microcontroller is responsible for acquiring the data or controlling a switch through a pre-defined instruction set.

An interesting angle, then, when looking at such kind of devices, is to ask the following questions:

What does an IoT application[28] developer need when developing innovative smart things and applications?

First, developers want a leading-edge, and preferably an industry-standard processor core. Since MCUs based on Cortex-M cores are supported by a large majority of major semiconductor suppliers, this architecture offers an open access to a large set of hardware and software vendors and is the most demanded in the market, especially in mobile applications, embedded intelligence and networking equipment, all related to IoT applications.

They want an easy to use Integrated Development Environment (IDE) enabling fast prototyping with leading-edge components that can quickly be transformed into final designs.

[28] https://www.st.com/en/applications/iot-applications.html

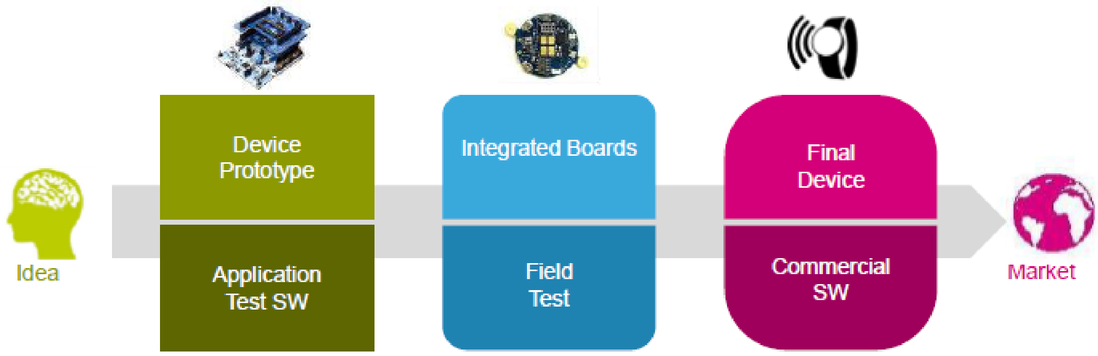

Figure 3.1. – Smart Thing Development continuity to final device (Source: STMicroelectronics)

They want a rich tool and software ecosystem to speed and ease development, saving time and effort by using software libraries and examples for all generic and standard functions, so they can spend more time on innovation where they can bring added value to their product.

This is typically what is offered by leading semiconductor companies. For example, the STM32 Open Development Environment (STM32 ODE)[29], based on the STM32 32-bit microcontroller family [30]proposed by STMicroelectronics, is an open, flexible, easy and affordable way to develop innovative devices and applications.

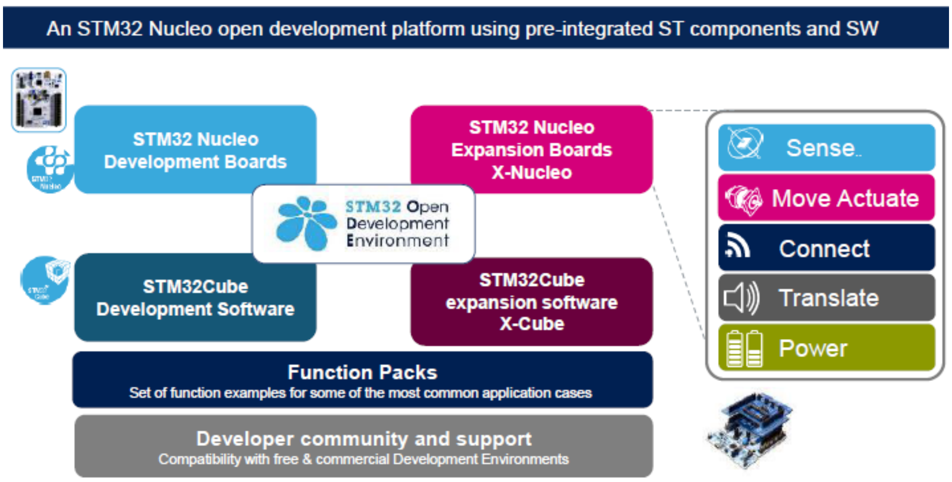

Figure 3.2. – Example of MCU ecosystem: the STM32 Nucleo open development platform

IoT Developers need a set of crucial extra functions, directly related, increasingly integrated into the "brain", e.g. the microcontroller, and essential to implement the system: connectivity, security and artificial intelligence (AI).

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29 https://www.st.com/content/st_com/en/products/ecosystems/stm32-open-development-environment.html

30 https://www.st.com/content/ccc/resource/sales_and_marketing/promotional_material/brochure/f0/93/da/5c/6b/31/4a/96/brstm32.pdf/files/brstm32.pdf/jcr:content/translations/en.brstm32.pdf

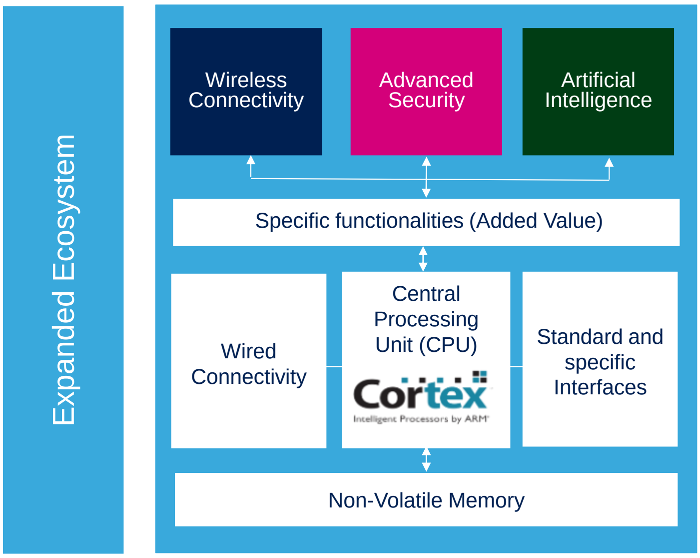

Figure 3.3. – Value-added functionalities around general purpose microcontroller

Concerning connectivity, IoT application developers want their smart things to communicate to users and with other smart things, increasingly via wireless connections that connect them to a personal mobile device (phone, tablet) or wider network that provides Internet or network connectivity. Below a summary of the main technologies used for connectivity:

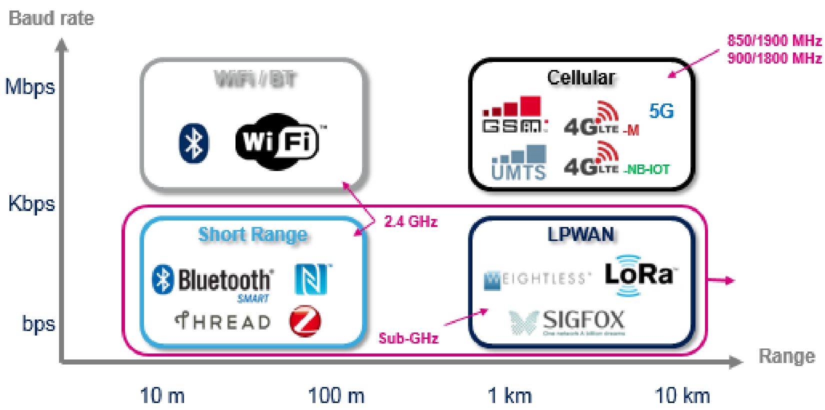

Figure 3.4. – Communication technologies overview

All the local connectivity provided by the communication technologies listed above will rely on the large-scale interconnectivity provided by the Internet Protocol (IP), the common language of data communication on the web. The IoT uses version 6 of the Internet Protocol (IPv6) which is still in limited use today but growing fast. IPv6 has the remarkable capacity to offer IP addresses for about 2,000 objects per square meter for the whole surface of the earth, oceans included!

IP, and IPv6 in particular will federate all the devices with various types of connectivity (wired or radio) and enable them to ‘talk’ to each other via gateways/routers. For example a 6LoWPAN local network can be based on an IEEE

802.15.4 or SubGHz network but already supports the IPv6 protocol. The same thing can apply to Bluetooth[31]: there are already developments to support IPv6 on top of Bluetooth radio.

We need such a large number of objects and IP addresses in Smart Living Environments because today each human-being has several connected devices (at least for the most advanced economies) - using some kind of local connectivity (such as Bluetooth) or longer range connectivity (such as LoRa[32]) - including smartphones, tablets, appliances, cars, home consumer electronic and even IP-connected light bulbs and electrical switches.

Low Power, Wide-Area Network (LPWAN) wireless technology enables low data-rate communications to be made over long distances by sensors and actuators for Internet of Things applications.

Three market trends are driving the growing need for LPWAN:

- Far-field low-power sensor grid
- The need to connect and manage your own devices
- Greener technology

Figure 3.5. - LoRa ecosystem

LPWAN offers much wider outdoor coverage than cellular, as well as deep indoor coverage. Additionally, it permits high-accuracy localization that is not based on signal strength (RSSI).This makes it very robust against multi-path and fading.

IoT application developers need to be able to address the security & privacy requirements to contribute to a more secure connected world. The ubiquitous use of mobile phones and wireless technology as well as connected devices in consumer and industrial segments has driven the evolution of the market with the introduction of a large range of new devices for Mobile NFC, Secure Driving, authentication and the broader IoT (utilities, Smart Home, Smart City, Healthcare,…).

Semiconductor companies can provide security “building blocks” to their partners, and therefore contribute to protecting everything from consumers’ personal information, including their financial, health, and location data for instance.

In order to cover the breadth of security demands of IoT applications, semiconductor companies like STMicroelectronics offer a scalable security-product portfolio ranging from the integrated security features in

[31] Bluetooth Special Interest Group: https://www.bluetooth.com/
[32] https://lora-alliance.org/

microcontrollers to the highest level of security based on secure elements[33]. The combination of a general-purpose microcontroller and secure element is also a solution which achieves the very highest security requirements for IoT applications.

Secure elements can be adjoined to general-purpose MCUs to deliver enhanced security or they can be used stand-alone for authentication or security in consumables; they cover a wide range of applications and use cases: confidentiality of transmissions to and from an IoT device over the network, gateways, IoT devices, and the smart grid market.

Figure 3.6. – Security by design (Source: STMicroelectronics)

The security topic being discussed in details in section 3.1.3 below.

AI on the Edge: smart things enhanced

Artificial Intelligence (AI) can be defined as a machine's ability to perform logical analysis, acquire knowledge and adapt to an environment that varies over time or in a given context.

AI uses an assembly of nature-inspired computational methods to address complex real-world problems where mathematical or traditional modeling have proven ineffective. Examples include a process that is too complex for analytical modeling or when a process contains some unknowns due to its intrinsic dynamic behavior. Many real-life problems, and typically Smart Living Environments for ageing well problems, cannot be described in exact terms and fall into this category, so they cannot be processed by traditional computing systems.

Artificial Intelligence uses an approximation of the way the human brain reasons, using inexact and incomplete knowledge to produce decisions and actions in an adaptive way, with experience built up over time. The basic concepts behind AI have been around since the 1950's but modern programming techniques (such as python), the availability of huge quantities of data, open-source tools for neural-network training, powerful computing centers and ever-improving embedded-processing systems are contributing to AI taking off as a world-changing technology today. AI is already being used in many different SLEaw applications today, such as:

- Super-smart computing-intensive AIs that help doctors make diagnoses by sifting through terabytes of patient data points to offer the best advice;
- In mobility, autonomous transportations that understand everything about traffic and help to keep drivers and other road users safe while making the journey more efficient;
- Personal voice assistants that are rapidly becoming pervasive to simplify everyday life.

[33] https://www.st.com/content/st_com/en/products/secure-mcus/authentication-secure-iot.html

- Chatbots, often indistinguishable from human operators, able to answer complex questions in real time;

This is only the beginning. The Internet of Things is enabling tens of billions of intelligent connected devices that will make our lives easier and make the environments in which we live and work safer and more efficient, often by providing more natural human-machine communication. The addition of AI capabilities to these Smart Things will significantly enhance their functionality and usefulness, especially when the full power of these networked devices is harnessed – a trend that is often called AI on the Edge.

Machine Learning (ML), as a subset of Artificial Intelligence, refers to techniques which enable machines to recognize underlying patterns and learn to make predictions and recommendations by analyzing data and experiences, rather than through traditional explicit programming instructions. ML adapts using new data and experiences to improve prediction performance over time.

Deep Learning (DL) is a subset of machine learning. It aims to learn data patterns and dependencies by using a hierarchy of multiple layers that mimics the neuron connections of the human brain and make up any deep neural network. Deep Learning techniques work with very large datasets by analyzing data, recognizing patterns and making predictions on next data points.

With Deep Learning, a computer can train itself with a large set of data collected for this purpose. The learning stage, in which the neural network learns to classify different patterns, may use data-sets labelled in advance, a process referred to as Supervised Learning. In the case of unlabeled data-sets the learning process is called Unsupervised Learning and during the training the neural network tries to cluster the data-set into groups with similar patterns.

In both cases the result is an Artificial Neural Network (ANN) that contains all the information necessary to carry out the task. The ANN uses the knowledge acquired in the training to infer data features from new incoming data. This is called Inference stage and can be deployed in embedded devices with memory and processing capabilities orders of magnitude smaller than the servers used to train the ANN itself.

Artificial Neural Networks are available in various types, topologies, and complexities to address a variety of problems across a wide spectrum of applications. They can exploit the data provided by the exploding number of heterogeneous sensors present in our Smart Living Environments (homes, cars, personal & care items,…).

If we consider a model where the raw data from all these sensors are sent to a powerful central remote intelligence, then we quickly see the escalation in required data bandwidth and computational capabilities in the Cloud. Especially if you consider processing audio, video or images from millions of end devices, not to mention the potential latency generated by such a centralized system.

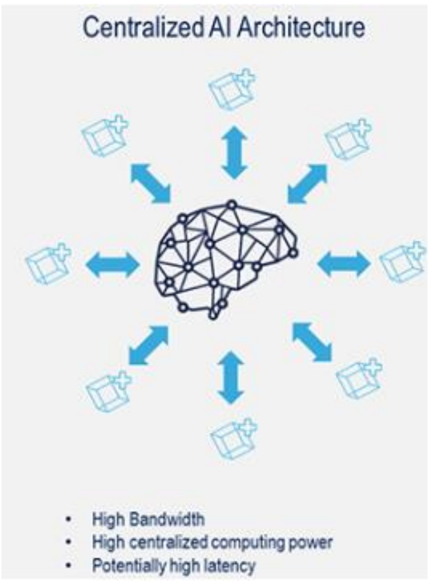

Figure 3.7. - Centralized AI architecture (Source: STMicroelectronics)

AI enables much more efficient end-to-end solutions by switching from a centralized to a distributed intelligence system, where some of the analysis done in the cloud is moved closer to the sensing and actions. This distributed approach significantly reduces both the required bandwidth for data transfer and the processing capabilities of cloud servers. It also offers data privacy advantages, as personal source data is pre-analyzed and provided to service providers with a higher level of interpretation.

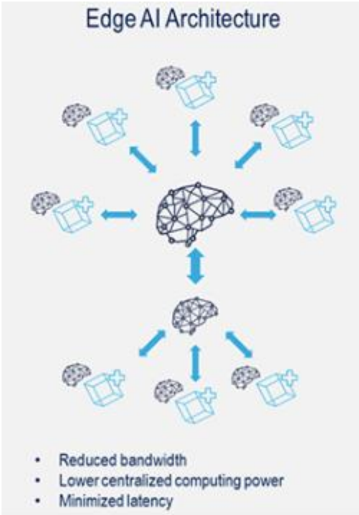

Figure 3.8. - Edge AI architecture (Source: STMicroelectronics)

AI and Deep Learning allow pure SW or mixed SW/HW low-power solutions to be deployed close to the sensor, enabling true edge computing.

While most microcontrollers today do not have the memory and processing power to run the learning algorithms needed to create Deep Neural Networks (DNNs), they can run the DNNs themselves – provided that the networks are optimized for microcontrollers.

In the future, nearly any device with a 32-bit microcontroller will be able to use AI techniques. More concretely they will be able to run DNN (Deep Neural Networks) that have been trained to do specific tasks.

For instance, STMicroelectronics has ported neural networks to its existing STM32 MCU portfolio and created a tool to do that optimizing of DNNs for a microcontroller, the STM32CubeMx.AI[34], part of the STM32 MCU software ecosystem.

The tool takes the pre-trained neural network model output from a broad range of the most popular AI frameworks (including Caffe, CNTK, Keras, Lasagne, TensorFlow, and Theano), and maps it to an optimized DNN that is adapted to the memory and processing-power capabilities of a microcontroller (see figure 3.9 below).

34 https://www.st.com/content/ccc/resource/sales_and_marketing/presentation/technology_presentation/group0/c1/23/94/03/3d/77/48/ca/AI_Edge_Computing_Paradigm_IoT_World_Asia_2018/files/AI_Edge_Computing_Paradigm_IoT_World_Asia_2018.pdf/jcr:content/translations/en.AI_Edge_Computing_Paradigm_IoT_World_Asia_2018.pdf

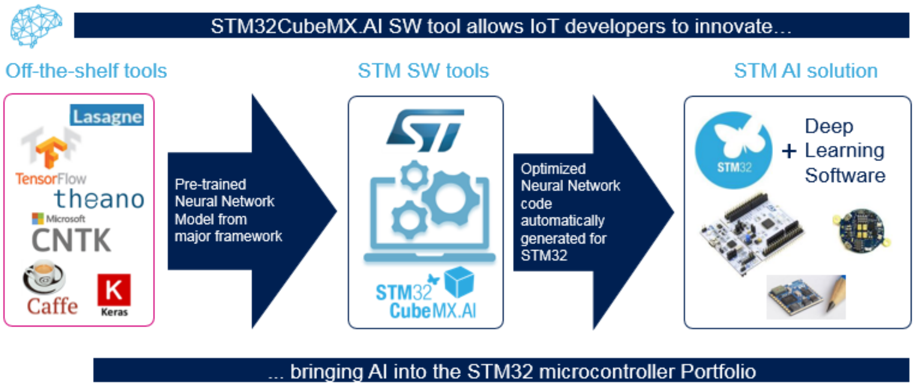

Figure 3.9. - Artificial Intelligence with STM32 microcontroller (Source: STMicroelectronics)

In an increasingly energy-conscious world, they want a device that is low power, with ultra-low-power (ULP) variants able to meet the most stringent power consumption requirements.

With the explosion of wearables and other small form-factor battery-operated devices we see on the market today, very low power consumption is probably one of the biggest concerns and technology challenges for product designers. Designers' objectives include important end-user experience considerations such as how often the device needs to be recharged and how long it needs to operate between charges. This can be days, months or even years for some IoT and in-body medical devices.

To achieve ultra-low power operation it is essential to optimize the microcontroller architecture and key features for energy efficiency. The MCU must use minimal power for all its computational functions and also be capable of handling the peripherals around it very efficiently in order to optimize the energy budget. Unfortunately, the technology for digital circuits works against chip designers, as the power consumption of the MCU scales with the square of the operating Voltage. Lowering the voltage reduces power but also reduces the computing speed measured in DMIPS (Dhrystone Mega Instruction Per Second. A measure of the number of instructions -in millions- the MCU can execute, generally the higher the better), due to the slower switching speeds of internal gates. So, special measures need to be taken during the product development of our ultra-low power MCU families to maintain good computing performance versus current consumptions.

The Embedded Microprocessor Benchmark Consortium (EEMBC, www.eembc.org), an industry alliance to define microprocessor performances, has defined a set of tests, under the name of ULPBENCH™, to independently benchmark the ULPMark. In general, the higher the ULPMark, the better.

IoT designers can now draw upon an ever-increasing toolkit of effective silicon sensors and actuators, along with the sensor-fusion technology. These sensor technologies are the “hubs” for “augmented” applications and are radically redefining the user interfaces.

Each sensor and actuator is attached to a microcontroller.

A sensor transforms interesting, useful energy into electrical data. By contrast, an actuator transforms electrical data into interesting, useful energy. Both belong to the transducer category, actually a category gathering devices that change energy from one form into another form. Sensors[35] are here to collect data, Actuators to execute actions.

[35] https://www.st.com/en/applications/sensing.html

Figure 3.10 – Human beings are equipped with sensors

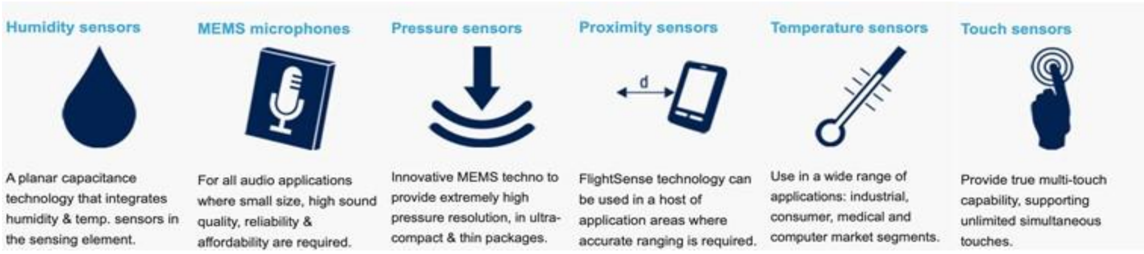

Figure 3.11 – Examples of MEMS & sensors covering a full spectrum of applications for IoT (Source: STMicroelectronics)

To put it simple, the IoT would not be possible without sensors and actuators. Tremendous progress was made, during the last 10 years/since the "consumerization" of the micro-electro-mechanical systems (MEMS) in the mid-2000, in developing compact, accurate, low-cost silicon sensors and actuators.

From tiny silicon cameras to miniscule sensors that measure motion such as linear or angular acceleration or pressure, temperature, humidity, and light to understand the environment, IoT designers can now draw upon an ever-increasing toolkit of effective silicon sensors and actuators, along with the sensor-fusion technology.

These sensor technologies, e.g. gesture-based, voice-based and touch/proximity-based are radically redefining the user interfaces. They are the "hubs" for "augmented" applications, for smarter environments, like smart environments for ageing well.

We can summarize these "sensor hubs" in the figure below:

Figure 3.12. – Sensor Hubs for Augmented Applications

(Source: STMicroelectronics)

3.1.2 The IoT movement: IoT for SLEaw architecture

We could define Internet of Things, to complete our list of definitions, as" a continuous movement, allowing an infinite number of new possibilities – whether these possibilities are related to products, services, business models, actually in most cases to both of them- and associated to a deep transformation in the way humans interacts with objects".

The Activage project is an illustration of this IoT movement in Smart Living Environments for Ageing Well.

3.1.2.1 IoT Functional architecture for SLEaw

This generic functional architecture proposed by ACTIVAGE follows the IoT Reference Architecture (HLA) functional model described by the AIOTI-WG3 [4] which is compliant with ITU-T Y.2060 IoT Reference Model, OneM2M reference architecture and IIC's Industrial Internet Reference Architecture (IIRA), and it considers specificities of the AHA domain.

The Figure below describes the fundamental elements that we take into account when implementing a full SLEaw for AHA services.

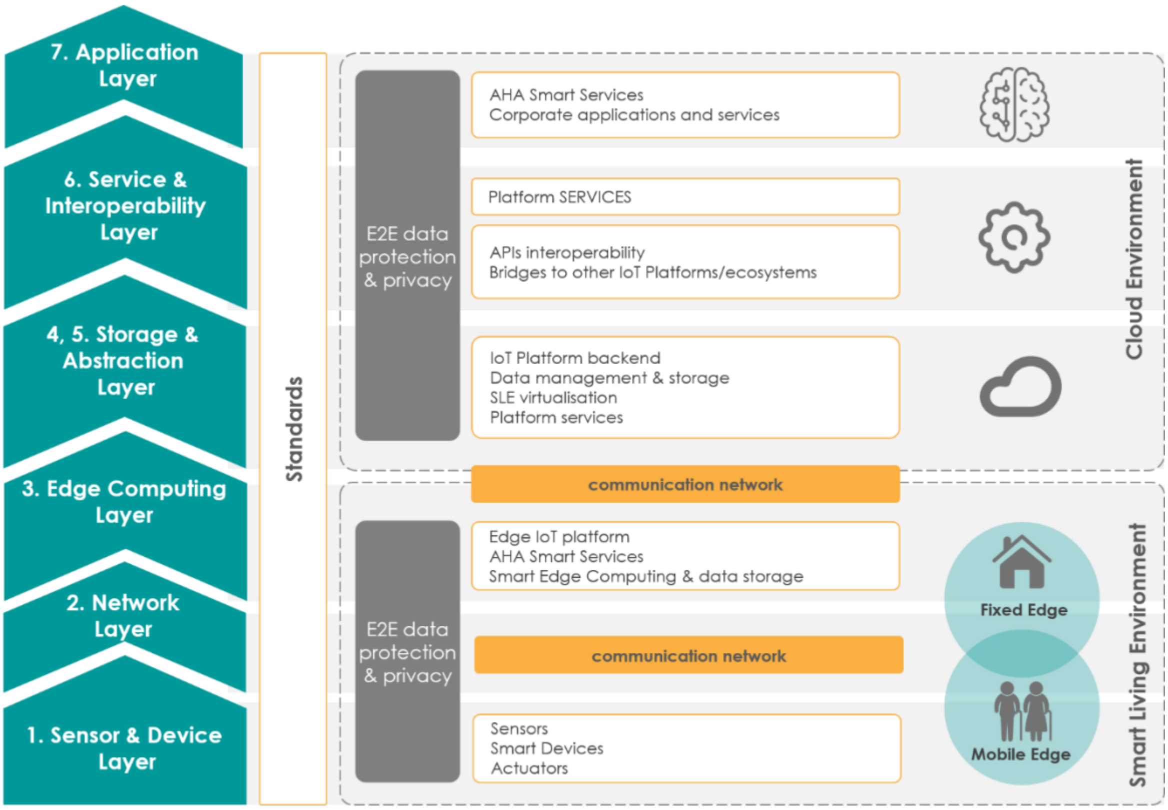

Figure 3.13. - Functional reference architecture for IoT for SLEaw based on AIOTI standard

The sensor and device layer, at the edge of the network, is the domain where the smart things interact with the physical world. At this Level the data are generated through various IoT sources, the smart things.

These smart things can be a device sensing data (named "sensor") from the Physical word or a device controlling the parameters of the devices (named "actuator") interacting with the Physical world.

As explained above, a smart thing can sense, monitor and react to its environment, securely processing the information it collects, protected from threats and intrusions, then communicating the results to other smart objects while managing its power consumption.

These sensor and actuator nodes (also known as "Connected objects" or "Smart things") are basically constituted by a sensor element, a processor and a connectivity element (in general wireless transceivers supporting BT/BLE, ZigBee, ZWave, … protocols).

In the AHA domain, we can observe the following categories in the sensor and device layer:

- Physical space sensors: they detect the context of a person living in the SLEaw. For example: location/presence (of persons @SLEaw), environment (temperature, humidity, smoke, light, sound/noise, movement …).
- Medical devices: normally they measure physiological condition and data from the user's body. For example: BP, SPo2, Body Weight, Heart Rate, ECG, …. Normally these devices shall be certified, although they might by purchased in a pharmacy.
- Smart devices: complex apparatus that normally are equipped with sensors, processing capabilities, user interaction, actuation and communication. For example: a cognitive/physical training and rehabilitation device, a treadmill, a gait monitoring device,… . Home appliances that feature those characteristics and can be considered smart device and used in AHA context.
- Wearable devices: they have different form factors that enable occasional or permanent wear attached directly to the body or apparel like shirt, belt, pendant or shoes. Consumer wearable devices like smartwatches and wristbands include more than one sensor, including physiological measurements like Heart Rate, SPo2 and blood pressure. Normally they are not certified as medical device product. There are medical devices that have the form factor of wearable devices, for example patches and smart textiles harness that records ECG, heart rate and movement.
- Actuators: nowadays, they are devices used in home automation and environment control. Intervention (i.e. actuation) over the person is a field of big potential for growth in the coming years in the SLEaw evolution. Robots are the key devices that will take care of intervention directly over the human being body or performing actuation functions.

The network layer acts as a communication and networking layer, where data coming from the smart things are compressed and aggregated, with the required security, and transferred via the internet to the cloud domain. This Level includes all the hardware and software within network that facilitates any type of connection with the cloud. Currently, the Communication network layer mostly uses BLE, although there is an important challenge of interoperability that should be solved at gateway level, since most of sensors and wearable vendors use proprietary protocols for data transmission over the BLE.

The Edge computing layer

New generation SLEaw will incorporate more powerful edge computing layer capabilities. There are reasons for this, (explained in section 3.1.1.4. for what relates to underlying technologies) but no limited to:

- Reduction of data transmitted to the cloud
- Data analytics performed in the edge
- Mobile edge environment: follows the person when moving away from home
- Quicker reaction by the SLEaw to risk situations and quicker intervention
- Enhance of security, data protection and hence data privacy implementation within a secure SLEaw

We have to consider here the concept of mobile edge. This rise up by the necessity of ensuring continuity of care when the target user leave home. Mobile edge is normally performed in a personal (user's) smartphone application that has to ensure the same level of data protection and confidentiality as the fixed one. Moreover, the mobile edge shall provide connectivity to open public SLEaws that was mentioned above.

The cloud environment is in charge to provide the network infrastructure (switch/Router) and servers to store the – big – data received from the gateway domain through the internet.

The hardware infrastructure of the cloud is mainly dedicated to provide internet access and to store the data. The requirements for cloud-based databases are reaching a new level in terms of data volume, variety, velocity and veracity. The software infrastructure purpose is related to data analysis, databases, and cloud management.

Services and interoperability layer

At cloud level, we have to remark the presence of the semantic (recommended) interoperability layer (SIL). This concept is introduced and developed by ACTIVAGE as a solution to provide interoperability across different IoT platforms working as backend of the whole system, and then as an extension to provide interoperability with external platforms. This layer is very specific for SLEAWs as it aims at providing services (i.e., tools) for data management, security, data access control to upper layers applications, data analysis, big data and over the all, independence from the below IoT platforms through the semantic interoperability sub-layer. This is presented in details in the following section (3.1.2.2)

The application layer is where the output should be sent. It exploits the results of the data analysis processed and stored in the cloud domain. This is the service level of the IoT architecture. The processed information is available to the users, as the application layer executes the applications in charge of monitoring and/or control the IoT system. This level includes smart devices, sensors, different type of smart components, mobile apps or an internal system and forms that the data will be sent. Additionally, the Level includes the use of statistical and optimization tools to refine, monitor, and analyse structured and unstructured data for enabling different services.

Methods and algorithms for Big Data management, collection and annotation are established within this domain. Statistical Programming, Text and data mining, Image and video processing, Predictive models, Machine and Deep learning algorithms, Optimizing and Simulation and Visual analytics are some significant examples of data formation.

3.1.2.2 ACTIVAGE IoT large scale pilot Architecture

The ACTIVAGE project, from its starts, has worked towards implement the idea of innovating the Active and Healthy Ageing (AHA) sector by both, designing solutions introducing IoT technology and by using IoT technology to improve current healthcare services.

ACTIVAGE has implemented the full reference architecture, described in the section above (3.1.2.1 – figure 1), but in particular layers 4, 5 and 6 which consist in the core of the interoperability feature of ACTIVAGE, i.e. the AIOTES framework. In this way ACTIVAGE proposed the total decoupling between the applications: i.e. AHA applications providing services to senior people and caregivers, from the backend IoT platform complexities and variability in design, and standards used.

ACTIVAGE has defined a reference architecture for IoT Platforms Interoperability. This architecture aims to build general approaches to face the interoperability in a universal way with the objective of serving as common framework to build interoperable smart ACTIVE AGEING solutions that can be deployed, extended and replicated at Deployment Sites[36] across Europe.

The IoT Platform Layer in ACTIVAGE architecture

The IoT technology enables to connect all kinds of things to the network and develop applications to control and manage these things using Internet transfer protocols. All the intricacies of enabling connectivity, services and cloud for these devices is the task of the IoT platform whose main role is to be a mediator between the sensors and edge computing and application layers. Hence, platforms connect all kinds of things ensuring seamless integration with the network and develop applications to control and manage these things. An IoT platform is also

[36] Deployment Site: geographical region where Smart Living Environment based on IoT technologies are deployed that support and sustain active and healthy ageing ICT services for senior citizen.

often referred to as IoT middleware, which underlines its functional role as that of a mediator between the hardware and application layers.

The Platform Layer contains the platforms that are part of the ACTIVAGE Project, namely, FIWARE, SOFIA2, universAAL, OpenIoT, SENIORSOME and IoTivity. The motivation that gives rise to the grouping of platforms in a layer is the objective of interconnect various platforms so as to achieve an IoT LSE ecosystem across 9 DS. The challenge consists of communicating with each other the six platforms that are part of the project in a current landscape characterized by a lack of interoperability.

IoT platforms are very fragmented; the majority of existing and emerging IoT platforms access to their data and devices in a very heterogeneous way. In order to be able to access and retrieve data from any of the IoT-Platforms it is necessary to develop the Interoperability Layer. This layer serve as a bridge between the platforms, working as an abstraction layer and allowing the connection between the devices (at the bottom of the architecture) and the application (on top of the architecture). Thus, one service will be able to be replicated in any deployment site across Europe or it will be use more than one platform in a particular deployment site at the same time regardless of the selected platform.

ACTIVAGE IoT Ecosystem Suite (AIoTES) Framework

It Consists of a set of software techniques, tools and methodologies for semantic Interoperability, privacy and data protection, and security between heterogeneous IoT Platforms and Active and Healthy Ageing applications, services and solutions.

The schema below summarizes the main different software components of AIoTES:

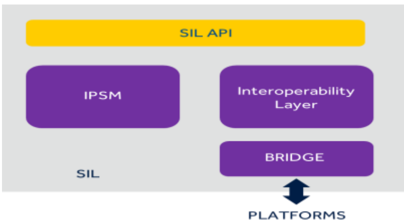

Figure 3.15. – Semantic interoperability (Source

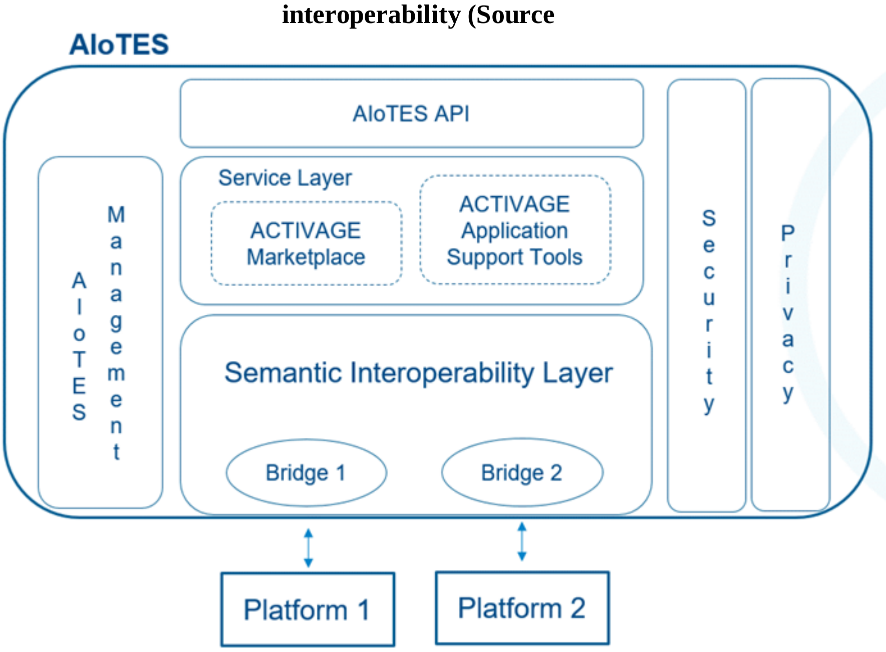

Figure 3.14. – AIOTES main internal components

The AIoTES Framework is made up of six main components, highlighted in Figure 6:

1. The Semantic Interoperability Layer is the element that provides interoperability among platforms and allows other elements of ACTIVAGE to communicate with any platform through a common API. The Interoperability layer has been proposed as a solution to overcome the lack of interoperability among the existing IoT platforms. Each platform has different standards and data formats. For these reasons, interoperability, data sharing and communication among platforms is considered one of the most arduous challenges in IoT.

This component provides an abstraction layer at middleware level, which will be connected to all the IoT platforms deployed in the ACTIVAGE Project. This layer, that is a middle element among the IoT platforms and ACTIVAGE, will allow the communication and information sharing among those platforms and ACTIVAGE (e.g. collection of data from AHA sensors).

SIL is mainly composed by three blocks:

- Interoperability Layer at syntactic level
- IPSM (Inter Platform Semantic Mediator) that provide the actual semantic interface
- SIL API

2. The ACTIVAGE Application Support Tools (Tool Kit) provides an easy way for using the various functionalities of the main AIoTES components that will help developers towards implementing new AIoTES-compliant applications by also hiding low-level technical details, in order to automate the development and deployment process as much as possible.
3. The ACTIVAGE Marketplace is a deployment tool, one very close to the users as it is intended for any online user, deployment site or general healthcare professional, third party adopter, existing and potential developer, individual or business entity to develop, provide and obtain applications build for AIOTES. The ACTIVAGE Marketplace functionalities include basic services for registering users, publishing and retrieving offerings and demands, search and discover offerings according to specific user requirements as well as lateral functions like review, rating and recommendation
4. The AIoTES API offers a homogeneous access to the AIoTES features. It is the layer of connection of AHA applications and services
5. The AIoTES Management provides mechanisms, tools and helper contents to make proper use of the Semantic Interoperability layer (SIL) in addition to help with the fully integration of the AIoTES Framework.
6. The security and privacy protection are crucial components of the AIoTES Framework since they span across all the above layers and components and guarantee both the protection of sensitive information of users and, also to comply with ethical and legal requirements for privacy and confidentiality.

ACTIVAGE architecture is designed to serve as common framework to build interoperable smart living solutions in the form of apps, software tools and services that can be deployed, extended and replicated at deployment sites across Europe. In other words, to allow future support of any additional platforms and services as far as they comply with defined interoperability framework and standards.

3.1.3 The security issue in IoT for SLEaw

The IoT refers to an “infrastructure in which billions of sensors embedded in common, everyday devices […] are designed to record, process, store and transfer data”. In the current state of things, it is based on several existing technologies such as RFID, Near Field Communication (NFC), sensors and actuators, wireless, communications machine-to-machine, the ultra-wide band, Routing Protocol for Low power etc. Thanks to the recent advances in miniaturization and the falling costs of electronic devices, the Internet of Things suddenly became relevant for several new hardware-powered services designed as solutions to societal challenges such as population ageing, energy rarefaction. In the IoT, objects are potentially inter-connected with other objects and with broader networks like the Internet. This creates new risks, in particular to the confidentiality, authenticity and integrity of data exchanged between objects. For instance, an unauthorized access to any device of your personal sphere can reveal a lot of information about you: health, relations, behavior and location. In SLEAW, a corrupted data can prevent incident process treatment from performing properly, potentially leading to critical situations for residents. The strong impact the IoT can have on cyber-physical systems pushes security to the main stage and makes it a key point of the potential IoT success and adoption by end-users.

ICT development has shown in the past that security is sometimes overlooked during the design phase, and its integration late in the product development phases causes technical difficulties and increasing costs, and can greatly reduce the quality of the associated systems. Given the particular nature of IoT systems with respect to “traditional” ICT systems, it is essential that the original design elements of an SLEAW’s IoT comply with privacy and security as much as with all user requirements.

3.1.3.1 Particularities of the IoT

Current definitions of an IoT depict a system of (inter)connected objects from applications as diverse and complex as automotive, domestic appliances, mobile phones, health care to critical infrastructure management. In the case of SLEAW, trends either follow the concept of the “Internet of existing Things” where we must interconnect existing devices using current infrastructures to that of the “Internet of every Thing” (we shall also talk about the “Internet of future Things) where new devices and new technologies need to be deployed.

The first complexity within the IoT comes from its heterogeneity: IoT refers to an ecosystem of interconnected objects, going from sensors embedded into everyday-life devices to complex Supervisory Control And Data Acquisition (SCADA)-like infrastructures, through the use of smart phones and tablets… with different constraints in terms of protocols used, power consumption and communication interfaces.

Another particularity of the IoT is the scale of deployment: we are here concerned with billions of connected objects and any approach that shall be deployed in such a context shall be able to scale efficiently both in terms of technical feasibility and cost. The security services and resistance to attacks inherent to the IoT devices must also be able to scale with the large number of appliances and services that shall be deployed, given that they will become more and more accessible to hackers or malicious applications.

A third aspect that is a clear trademark of the IoT is the bargaining value of the data being collected and manipulated by the IoT devices. The latter can allow to collect, either directly (like monitoring one’s location, health etc.) or indirectly (like learning about one’s SLEaweping or working hours by simply having access to one’s electricity consumption), information about individual end-users. This can not only have a serious impact on how privacy issues are managed at societal and judicial levels but also at economic and business levels. As shown so far by social media champions, end-user data and profiles are valuable information that can be monetized whether to advertisers or insurance companies.

The above particularities contribute in making of IoT a complex security challenge, linked to the fact that it is extremely difficult to have one threat model addressing all security concerns with expected societal and economic impacts. In the particular case of SLEAW, and smart health in general, the principal security concerns would be citizen-focused. The devices used should not only be safe for the SLEAW resident but they must also guarantee the confidentiality and integrity of his data in transit or at rest and at best protect the user’s identity. The ability of the service providers to undertake secure actions, based on the confidentiality, the authenticity and the integrity of the operations and data, shall also be a major concern. The core components or constituent elements of an SLEAW composing an IoT infrastructure can be identified as

- The node which is a low power device basically composed of sensors, a small computing machine and a communication (often considered to be wireless) interface. Depending on the application, such a node can be embedded into a tamper resistant packaging. The node may also be fitted with an on-chip mechanism for energy harvesting in order to power itself.

- The gateway manages the interface between several nodes belonging to one same “Area Network” and the external connected (internet) world for aggregation and transmission of data.
- The server which may be “located” within a cloud infrastructure and which is responsible for the supervision/management of the associated network of gateways and nodes and the control and access to the network.

3.1.3.2 Security challenges

One way of dealing with the issue of security in the IoT is to consider the latter as a conglomerate of different “vertical” applications whether it is for smart health, smart vehicles, smart factories etc. Due to the specificities of these different use cases, specific dedicated security architectures have to be specified and implemented for each of those architectures. One striking observation that can be made for all those applications is that any disruption in the security chain of any of those applications can lead to large scale security problems (in terms of persons/victims affected, in terms of geographical spreading of the problems and their consequences etc.) leading national security issues even for infrastructures that are not primarily identified as critical infrastructures (like energy or distribution networks, lighting etc.).

However, doing such a security engineering work relies on the fact that the core security technologies are available “off the shelf”, which is far from being the case today. The ubiquity of smart devices without physical protection and surveillance makes them easy preys to hardware and software attacks. These objects can be stolen, counterfeited and corrupted. Without specific countermeasures, the data stored on these devices would then be accessible, including cryptographic data that would provide access to other sensitive data. Moreover, wireless transmissions, could be easily eavesdropped. The security challenges of the IoT must be first addressed by looking at its constituent building nodes. The underlying paradigm is that by deploying secure, low power and functionally efficient nodes, secure, safe and resilient infrastructures can be built.

Trust in the connected nodes: A first issue to be addressed is that of the trust in the IoT nodes, i.e. to what extent one can trust a given node to be whatever it claims to be or whatever it claims to be doing. To achieve this intrinsically, research work has been carried on the hardware authenticity and integrity of integrated circuits. One of the objectives here is also to provide a scheme that covers for the overwhelmingly complex and growingly uncontrollable supply chains of ICs that shall be used in the IoT.

Confidentiality, Integrity and Authenticity: IoT nodes are expected to provide the ‘classical’ security services of data Confidentiality, Integrity and Authenticity (CIA). There are cryptographic solutions to deliver services of CIA, but these are often computation-intensive and memory-greedy. They are not necessarily adapted to the stringent power and die size constraints of IoT nodes. Elliptic curves cryptography could provide a level of security similar robust cryptography asymmetric classic with the advantage of being inexpensive in terms of resources (memory, calculation and bandwidth). On this aspect, low power cryptographic hardware accelerators for asymmetric cryptographic algorithms like Elliptic Curves Cryptography must be designed. Conversely, further research has to be pushed to find new elliptic curve parameters better suited to the IoT and taking into account the 20+ years of research in ECC security since the NIST curves were published.

Privacy: Privacy shall be “by design”. In general, integrating security features into an existing system can become very complex, sometimes impossible, and often increases the cost of the final product significantly. A more efficient approach is to take into account those security requirements at the early beginning of a project and integrate them in the design and development phase. It requires developing tools and mechanisms allowing privacy-by-design in the network. IoT technologies are emerging and promised to a bright future, this is the opportunity to think and design the security from the foundations. Investigation must be done around secure implementations of Pairing Based Cryptography which is up to now the only cryptographic tool able to guarantee user privacy in a connected world.

Low power and deployment: IoT devices are often simple low power sensors or actuators. They should then run protocols – including security protocols – that are lightweight, though providing an appropriate level of security. For example, entropy harvesting can be generated by using sensors, channel and battery information as entropy sources, in order to locally generate random numbers used in security protocols. Moreover, Elliptic Curve Cryptography can provide lightweight security for such low power sensors. Usually, such sensors are autonomous and deployed at a large scale. A few thousands sensors can be deployed and therefore the security must be managed in a hierarchical way. In the latter cited example, one of the aims was to easily isolate and potentially revoked nodes that may have been tampered with, without any impact on the functionality and the security of the entire.

Management of heterogeneous systems: More than the different hardware capabilities of each node, the diversity in terms of constraints added by each type of network link involved in a communication session is a problem. The approach until now has been to establish "hop-to-hop" security. For instance, every packet received from a node is decrypted in the gateway then re-enciphered before to be sent to the server; with this approach gateways handle clear-text information and this may not be acceptable. In opposition to the "hop-to-hop" security, the third challenge for IoT security is to design new "end-to-end" security schemes. This means that the information will be secured from the sensor to the server without being deciphered anywhere else than at the destination. The challenge is now to design security features in protocols, new protocols must be designed in order to be compatible with Internet one and with the low computation capabilities of IoT nodes.

The main difficulties with deploying security for the IoT come mainly from the heterogeneity of this "system of systems", lack of standard for security and inter-device communications, lack of off-the-shelf trusted IoT devices and tools (respecting all power, size and security constraints) and lack of appropriate business models (`low end' devices will potentially be communicating with `high end' ones…). Despite all those difficulties, securing IoT systems is not an option but a must. To overcome some of those hurdles, systems have to be rethought and redesigned and reaching such objectives shall take time. For that matter, one approach is to split the IoT into two categories representative of the technical security solutions that can be deployed.

3.1.3.3 Short term: Internet of existing things

In the short term, we should look at what we call the Internet of existing Things (IoeT) which is an IoT deployed using already existing technologies that have to be adapted and upgraded to address the different security & privacy issues of confidentiality, authenticity and integrity:

- Efficient, extremely low power implementations of cryptographic algorithms, either based on existing schemes like ECC or the AES, or by searching for more efficient algorithms based on Light Weight Cryptography. No matter which algorithms are chosen, their implementations have to be inherently resistant to physical attacks (side channel information leakages or sensitivity to fault injections.
- Low cost (or inherent) tamper resistant designs and designs resistant to physical (side channel and fault) attacks.
- Efficient key generation and storage realizations like technologies based on Physical Unclonable Functions (PUFs).
- Efficient key management procedures for exponentially growing infrastructures with the corresponding personalization model.
- Adapting the low level IP protocols to suit IoT requirements like it is already the case with the IPv6 Low power Wireless Personal Area Network (6LoWPA)
- Efficient data fusion and management on the server side (coined into Artificial Intelligence those days) to predict system disruption and implement adapted and fast system healing and recovery from attacks.

3.1.3.4 Long term: Internet of future things

In the long term, we will look at the Internet of future Things (IofT) where systems can be completely rethought in order to use new technologies like

- Pairing Based Cryptography (PBC) that can solve the key management issue for a scalable IofT through IBE for example. One of the major issues for existing secure systems is the distribution of cryptographic keys. The way of dealing with this issue is the use and deployment of a Public Key Infrastructure (PKI) where certificates have to be managed and checked for every connected object by a Trusted Third Party. PKI infrastructures are relevant for today's networks made up of hundreds of millions of computers but shall not scale efficiently for tomorrow's billions of connected objects. Due to that, new cryptographic techniques, and the associated infrastructures, shall have to be deployed and one such technique could be based on pairing algorithms where the identity of the device can be directly used as the encryption key for an asymmetric cryptosystem.

- Homomorphic encryption for secure and private data management and storage on the server side. Homomorphic encryption refers to a cryptographic scheme whereby arithmetic and Boolean operations can be performed directly on the encrypted data without needing to decrypt data, especially if homomorphic-friendly light weight cryptographic algorithms can used on the node side to enforce end-to-end security.

3.1.3.5 Taking things into perspective

Securing the IoT ecosystem is a multiple level problem. Once secure, low power and trusted nodes are deployed, the communication protocol among them has to be adapted for efficient authentication and management schemes: in particular when it comes to managing billions of cryptographic keys, current existing cryptographic schemes (whether it is symmetric key cryptography with the 'risky' deployment of shared keys or public key cryptography with the complex management of certificates,…) fail to fulfil the IoT requirements. New cryptographic schemes like Identity Based Encryption (IBE) might offer a cost efficient solution, especially if we look at the level of Internet of Things & Services (IoTS) but this would involve deploying new tools and security paradigms.

Semiconductor companies can assist with end-to-end solutions by providing on-chip security, supplying comprehensive hardware and software services, including authentication, data encryption, and access management.

Some are able to use their own products to provide comprehensive solutions, and collaboration between semiconductor companies and application designers or network-equipment manufacturers, would be helpful for the design of secure software.

3.2 IoT Experiments in SLEaw for ageing well

The following experiments demonstrate, thanks to the IoT, how technology can support two important and specific objectives of Smart Living Environment for ageing well:

- ✓ Avoid and postpone hospitalization by optimizing patient follow-up at home
- ✓ Enable a better and faster return to their homes when hospitalization occurs

To illustrate these 2 objectives, we first present 2 experiences based on the technology enablers presented in the section 3.2.1 of this chapter, and currently implemented in the ACTIVAGE project.

The first one – IsereADOM – aims to bridge the different stages in elderly person's life to limit the loss of autonomy and avoid unnecessary re-hospitalization.

The second, Equimetrix, shows how IoT platforms and interoperability are enabling robot-mediated neurorehabilitation.

We present in a third section the whole reference use cases currently implemented in the ACTIVAGE project.

We conclude IoT Experiments in SLEAW for ageing well with a last section related to 2 innovative approaches making environments for ageing well smarter, focusing on quality of life whether the users are ageing in place, in institutions, or facing hospitalization.

3.2.1 Examples of Activage project use cases

3.2.1.1 IsereADOM: a Modular and personalized Ageing in place IoT experience

ACTIVAGE Isère Large scale Deployment Site aim to create and evaluate a continuum of care that combines human and technological assistance,.

This experiment strengthens IsereADOM running experimentation by offering new services based on connected digital objects. IsereADOM is a project led by the Isère Department in partnership with France's national pension fund (CNAV), the public deposits and consignments fund (CDC), the Auvergne Rhône-Alpes regional health authority (ARS), the Rhône-Alpes regional health and retirement financing body (CARSAT) and supplementary retirement funds (AG2R La Mondiale and APICIL). The project receives European Union funding. A consortium of companies Altran, Inter Mutuelles Assistance (IMA) and Orange Healthcare was awarded the project contract.

Three areas of service offer are experimented and assessed within the IoT-enabled IsereADOM experiment ("DS ISERE"):

- A 7/7 open phone platform addressed to all Isère inhabitants will offer a range of home-based services. The website provide access to all information and directories of medical, social, homecare helpers, tradesman and shop keeping services, etc.
- A new organization for the coordination of all care provider named "Sentinelle processus". Using a digital tablet and specific software to collect and centralize socio-medical information. The information is accessible by home and health care professionals, hospitals, etc. The "referent Sentinelle" plays a pivotal role in supporting the beneficiary: detecting warning signals "at the right time", to readjust, when necessary, the assistance needed by the person.
- An offer of connected objects and telemedicine equipment. Prevention and monitoring of the elderly person to enable rapid intervention, when necessary and emergency, and to prevent deterioration phenomena. This offer of care will be coordinated for 600 people belonging to 4 groups in 4 areas of the Department (urban, outer-urban, mountain and rural). Objective: to monitor and compare the health status of 600 people benefitting from this system, including connected objects, with 600 non-equipped people.

Moreover, the most suitable financial model will be assessed within the framework of a public-private partnership.

The focus of ACTIVAGE ISERE Deployment site is to propose and test a modular personalized IoT Kits to enhance safety, comfort and social link to enable elderly to stay autonomous at home as long as they wish. The concept is to follow persons evolving needs along the ageing stage and support carers' intervention to detect early sign of fragility, prevent loss of autonomy, and avoid unnecessary hospitalization.

DS ISERE has planned to integrate 3 panels embracing the 3 main stages of ageing in a life's course in order to best accompany persons and adapt to their life plan and its development. The aim is to develop and assess an adaptable and adaptable solution that creates bridges between the different moments in an elderly person's life, limits loss of autonomy and combines human and technical assistance.

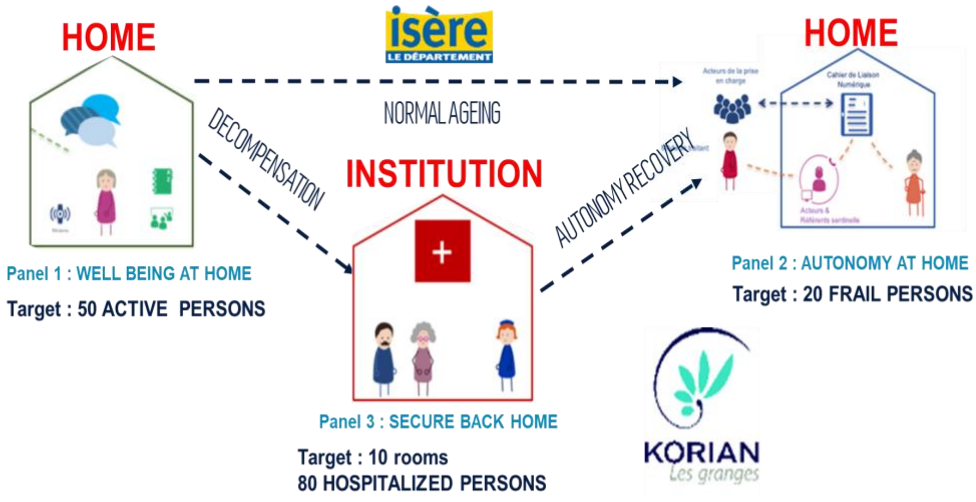

Figure 3.16. – 3 panels for 3 stages of ageing (Source: ACTIVAGE DS ISERE)

The project targets 3 stages of ageing:

A modular and adaptable IoT solution has been co-designed and refined with all the stakeholders to fulfil the needs of the different situation and population targeted. Three main services have been designed:

1. Service 1: “Living well at Home” propose to active elderly person, an evolving, personalized service offer combining human support and technical aids, which enables independent retired people to implement a prevention approach in anticipation of loss of autonomy at home.

2. Service 2: “Autonomy at Home” propose personalized support integrating the monitoring of the person evolution through vigilance indicators (digital solution allowing automatic monitoring of vigilance indicators). This will allow adapting homecare through the "sentinelle organization” based on medico-social data exchange between health and social services providers, doctors and social worker. The goal is to propose personalized support for persons at risk in order to anticipate deterioration and rupture situations, thereby avoiding hospitalizations, limiting loss of autonomy, etc.

3. Service 3: “Secured back home” is proposed in follow-up care and rehabilitation hospital. The beneficiaries are patient hospitalized after an accident of life (stroke, repeated traumatic or non-traumatic falls, post-op convalescence, cardiac decompensation, moderate cognitive disorders) and for which a return home is foreseeable and foreseen.

ACTIVAGE will propose suitable technical assistance in addition to human assistance:

- To enhance the patient's quality of life and autonomy.
- To improve the patient's safety and follow-up in his/her room through a reinforced work organization.
- To allow monitoring of patient progress to motivate him/her during his/her rehabilitation period.
- To objectivize patient progress to determine the best moment for a return home.
- To prepare the return home: patient support in appropriating technical aids by integrating these solutions into rehabilitation.

Adaptable IoT solution architecture for the individual home and institution have been design to be compliant with GDPR regulation (figure below) . The modular KIT include 10-20 IoT equipment depending on the user needs and home configuration.

The French ACTIVAGE deployment site has chosen to rely on the sensiNact open interoperability platform made available in open source via the Eclipse community. Used in various European projects for smart city and smart home applications, sensiNact aims to manage the heterogeneity of communication protocols and devices deployed and to provide access to data collected in synchronous and asynchronous modes.

Two instances of the sensiNact platform (sensiNact-pi and sensiNact-server) are deployed on the internal network as detailed below. The sensiNact-pi instance is installed on a local concentrator. This sensiNact instance collects the data produced by the sensors (presence, door contacts, air quality sensors, power consumption measurement, water consumption measurement in the shower, pedometer, etc.).

The sensiNact-server instance is installed on the ACTIVAGE server accessible. The sensiNact-server instance allow data background history in the database, publication of AHA (Active and Healthy Aging) services, and publishes an API (Public Interface Applications) for data consumers:

Interoperability with the other European IoT platforms is ensured through the development of a generic sensiNact-InterIOT bridge integrated into the SIL Semantic Interoperability Layer of the ACTIVAGE Suite - AIOTES.

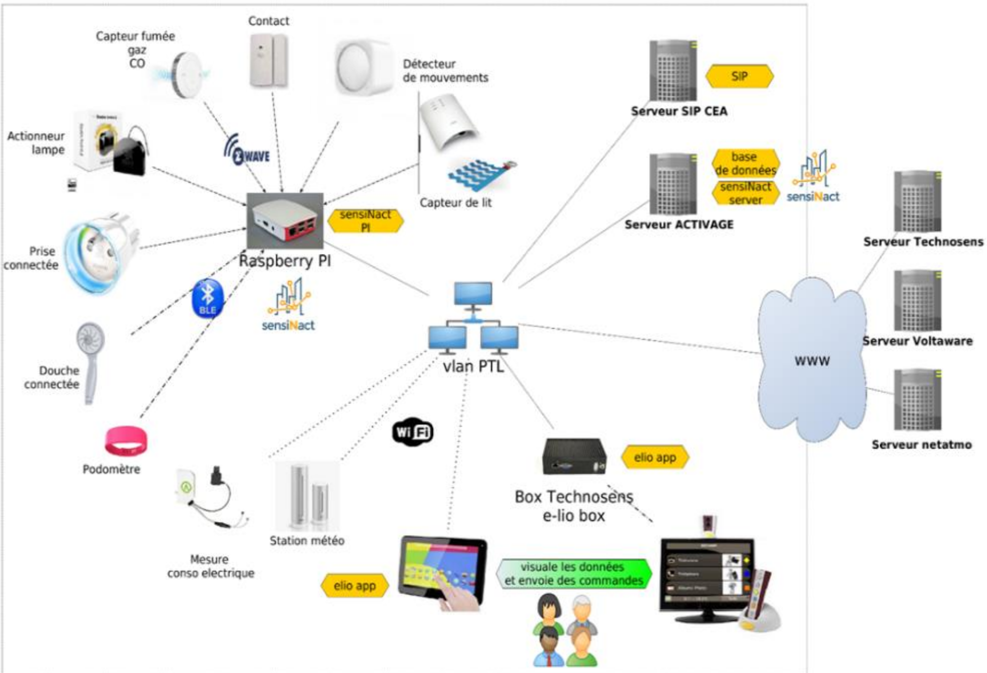

Figure 3.17. - ACTIVAGE Isère deployment site: Smart home modular secure architecture

(Source: ACTIVAGE)

3.2.1.2 The interoperable IoT platform as an enabler for robot-mediated neurorehabilitation

Due to adverse events occurring during life, hospitalisation happens which in some cases need neurorehabilitation. Neurorehabilitation is generally a very complex and challenging task involving ‘successes’ and ‘failures’ (setbacks). Neurological patients typically report having ‘good days and bad days’, which affect performance, motivation and stamina. Among others, psychological problems and chronic fatigue are major consequences which also impact behaviour/participation in rehabilitation/self-management. There is an actual and growing societal need for new technologies that have the potential to improve the efficiency of neurorehabilitation and relieve some of the pressure on the health systems (WHO 2011, Intercollegiate Stroke Working Party 2012). Robotics is well suited for precise repetitive labour and – for example – its application in neurorehabilitation has been very successful (Kwakkel 2009, Marchal-Crespo et al. 2009, Norouzi-Gheidari et al. 2012). This is one of the main reasons why the rehabilitation robotics market has tripled in the last five years.

Today, rehabilitation robotics is one of the fastest growing segments of the robotics industry. It is dominated by European companies that can deliver highly innovative solutions with strong scientific basis and exceptional quality of manufacturing. Based on the market size and needs, it is projected that the compound annual growth rate (CAGR) in the near future will be between 20% and 50%. (Curtiss ET, et al. 2014).

However, the market penetration is currently limited to the segment of well-funded hospitals, which are innovators and early adopters of advanced rehabilitation technologies. The main impediments for state of the art systems are fragmentation of treatment modalities, incompatibility of the independently developed devices and high diversity of use procedures.

The rehabilitation market needs technologies and services that enable independent manufacturers to make interoperable devices that can be seamlessly integrated into a heterogeneous Robotic Rehabilitation Systems (RRS). The manufacturer-independent modularity will be achieved through an appropriate architecture that ensures consistent user experience, structured information sharing and reasoning services that support more efficient rehabilitation workflow.

For the last decades, rehabilitation devices are envisioned to be part of IoT ecosystem, guided by the mission to facilitate the use of multiple (today single actor) rehabilitation robotic systems with higher robustness to inaction of any specific actor, thus to promote the use of robot-mediated neurorehabilitation in the semi-structured multi-actor environment of hospitals, outpatient facilities, and finally in patients' homes. Such IoT platform would empower the users, increase the system autonomy and reduce "no value-added" dependence from specialist healthcare professionals (HCP). Based on pervasive system monitoring, patient assessment and interlinked knowledge it would provide decision support in therapy planning, system personalisation and dynamic adaptation to patients state, supporting all actors to reduce the risk of errors.

More specifically IoT based technologies offers to:

a. Increase the autonomy of multiple-actor rehabilitation (robotic) systems from the task level to the therapy session level by:
- Automating the parameterisation of individual exercises
- Providing personalized exercise sequences for the entire therapy session
- Providing the possibility of tele-presence and tele-rehabilitation

1.

b. Provide synergetic therapy thru multiple rehabilitation robotic systems by:
- Having a centralized therapy planer based on a DSS
- Using multi-scale prediction models parameterised through Big Data Analysis

2.

c. Increase multiple-actor performance and robustness accounting for identified user needs for:
    - The patient, through automated personalisation of the system based on automatically assessed patient status and available base of knowledge
    - The lay user, by allowing system configuration through goals and preferences with interactive decision support, thus enabling operating with minimal technical knowledge
    - The professional user, by minimising overhead of manual and administrative task and extending systems autonomy

Several EU projects (ACTIVAGE, POLYCARE, RUBICON, BUTLER, RGS2) and National projects (HYPER, TeleICTUS, AMADEO, TELEREHA, TEREHA) are investigating how rehabilitation technologies can be combined with Information and Communication Technologies.

The ACTIVAGE project, through its "cognitive stimulation" and "exercise promotion" use cases, is demonstrating how initial standalone rehabilitation devices (e.g. balance assessment and training) connected to an IoT ecosystem (AIOTES in this case) can improve quality and efficiency of care.

The ACTIVAGE IoT Ecosystem Suite (AIOTES) offers several key underlying technologies (device layer, services and interoperability layer, as well as service layer, see section 3.1.2 above) which already support the collection and processing of home and/or medical data.

AIOTES platform was therefore a very good candidate to facilitate the integration a of neurorehabilitation device (see Equimetrix, figure 3.8). Equimetrix[37] is the first clinical device measuring the state of balance by combining two highly relevant human motion descriptors: centre of mass and foot related information (base of support). Its connection to the AIOTES platform only required to implement a new device bridge following those steps:

- Identify data to be sent
- Model Ontology according to data (extending existing ontologies whenever applicable)
- On the device side:
    - Registration of a context publisher in AIOTES and user authentication
    - Data serialization using JSON (based on the ontology).
    - Event publisher to the bus context using web requests and AIOTES REST-API.
- On the platform side:
    - Design Context events, and generate context event templates for REST API
    - Design and implement auxiliary components (for user log on, log management, and additional local data management).
    - Build local server (with REST-API, CHe and all previous components) and deploy
    - Connect local server to cloud server (using AIOTES components)
    - Connect dashboard to cloud server (using AIOTES components specific for SPARQL REST querying

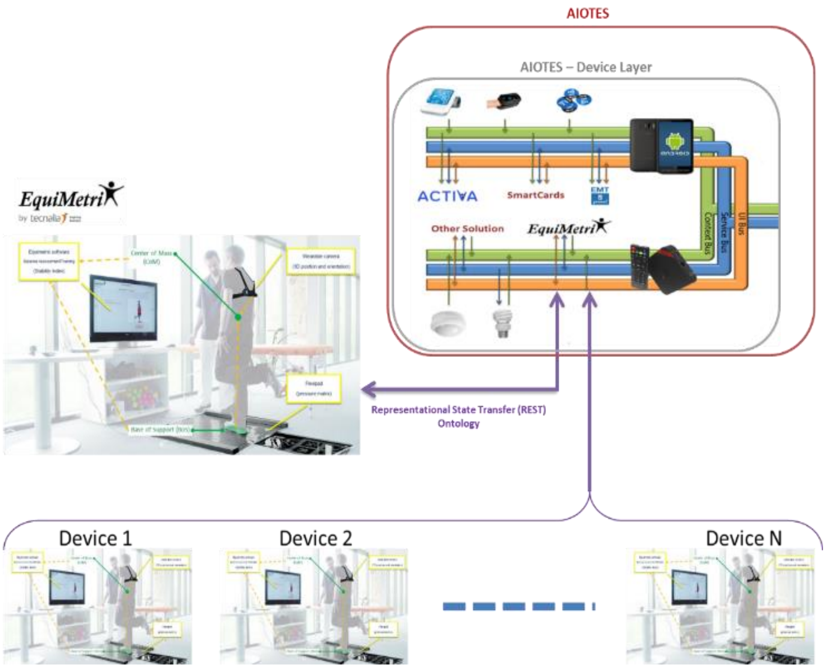

Figure 3.18. - Equimetrix balance assessment and training devices connected to AIOTES platform

(Source: ACTIVAGE)

In the context of the ACTIVAGE project, several Equimetrix devices have been deployed in Madrid social care facilities, all of them connected to the AOITES platform. It offers the healthcare professionals with an overview of the progress made by each patient, information about the attendance/adherence to the training program. For the patients, they can together with the therapist visual their progress if requested, they can also perform training sessions in another location where the Equimetrix device is located. To summarise, AIOTES has shown to be a modular IoT ecosystem that eased the integration of a non-conventional device (for neurorehabilitation) which,

[37] https://www.tecnalia.com/images/stories/Catalogos/EQUIMETRIX_ENG.pdf

when connected, amplified the quality of service and user experiences compared to a standalone/non-connected Equimetrix device

3.2.1.3 ACTIVAGE Reference Use Cases: a replicable plan for long-term sustainability

A bottom-up approach has been followed to analyze currently deployed local Use Cases aiming to identify Reference Use Cases (RUC) and to define a systematic approach to describe IoT Services provided in the 9 European Deployment Sites and that could be exchanged.

A list of 11 RUCs have been identified (see table below) and defined through several iterations with the different stakeholders involved in the 9 European Deployment Sites.

The purpose of the RUCs is to reliably collect the implementation of the different pilots and serve as a guide so that any person interested in Smart Living Environments for Ageing Well can clearly understand the way in which users benefit from the technology proposed by the ACTIVAGE project, and therefore support replicability and long-term sustainability.

List of the 11 Activage Reference Use Cases

Reference Use Cases	Generic Services	Examples of IoT Devices
Daily activity monitoring	Home occupancy & Behavioural patterns monitoring	Motion sensors, door opening sensors, Gateway, Samsung Gear fit 2 smart watch
Integrated care	Collaboration Home-Hospital	Wearable ECG, Blood Pressure Meter, Scale and Coagula-meter, Gateway
Health parameter monitoring	Vital signs monitoring – Self assessment	Smart pill dispenser Weight scale, blood pressure meter, Glucose meter
Emergency trigger	Tele-assistance (Fall detection, Panic button, Detectors…)	Smoke detector, CO detector, Gas detector and Emergency button Samsung Gear fit 2 smart watch
Exercise promotion	Games to assess and train individuals' balance Guided exercises prescribed by formal caregivers Monitoring of evolution and motivation in practice	Smartphone , tablet, Pedometer, Balance, Nutrition platform PC, Kinect, tv screen Equimetrix and windows PC
Cognitive stimulation	Brain Training Games	Smartphone/tablet, Dashboard
Prevention of social isolation	Communication and social activities	home hub gateway, motion sensors, door sensors, electrical sensors Display, Tablet / TV-Webcam+ phone/remote control
Safety, comfort and safety at home	Adjusting the environment according to user mood or needs control of domestic risks	Homes sensors & actuators (gas, flood, energy and water consumption), presence sensor and automations, door contact, and bed sensors + lights & outlets tablet

Mobility monitoring & advice for active mobility	Motivation, information and alerts Access to information concerning trip time, distance travelled, average travel speed and trip segments	Motion sensors, door opening sensors, Gateway
Notification of abnormal situations	Home and mobility monitoring based on user behaviors	Motion sensors, door opening sensors, Gateway
Support for caregivers	Planning Optimization (time control, task scheduling) , interactions and assistance following detection of abnormal patterns in the home - alert to inactivity/deviation	web platform for control and management of information as well as analytics software

3.2.2 Further horizons for IoT in Smart Living environments for Ageing Well

The ACTIVAGE large scale pilot assumptions related to IoT pervasion were to use proven technologies. However, since the use cases are deployed (see RUC above), they must be envisaged as an opportunity to facilitate the wide implementation of sustainable innovation services for smart living environments for ageing well, subject to many initiatives and rapidly advancing technology. This report illustrates it through two examples below.

3.2.2.1 Internet of Medical Things in the hospital: a vision from the practitioners

The vision behind doctors when requiring technology support – here more particularly Internet of Medical Things and Robotics - is fundamentally, when considering ageing, to allow our fellow citizens to live better and longer at home.

Major chronic diseases are requiring the use of IOT and Robotics. Whether we are talking (just to name these 2) about chronic respiratory diseases, responsible for the loss of 5 million disability-adjusted life years (DALY) in the EU or Cardiovascular diseases (CVD), responsible for the loss of 26 million disability-adjusted life years (DALY) in the EU, the monitoring of these chronic diseases is currently carried out by health professionals in a traditional way by their current materials most of them not being connected.

Doctors and nurses are globally very keen to adopt the technologies of the Internet of Medical things, they do well understand the need for prevention and for a precise, personalized monitoring in a framework where data security and privacy is guaranteed.

The obstacles, nowadays, are rather within institution organizations and related to the social support needed to support the prevention and carers efforts. How to manage efficiently the information, until the market transformation provide a seamless data integration?

Enabled thanks to the IoT, the medical robot position itself as an organizational pivot of care, and in this aspect, to connect the dots with an experience mentioned previously in this chapter – e.g. IsereADOM - can for instance be a great assistant to the "Referent Sentinelle" (see 3.2.2.1 IsereADOM: a Modular and personalized Ageing in place IoT experience). The medical robot is a secure digital central hub for patients for the medical staff under the monitoring of the nursing teams. It supports several nurses' activities, providing an educational role towards patients, and therefore allow patients to get a better understanding - through some assisted monitoring- of their own therapeutic conditions.

Below some typical examples of medical robots capabilities related to major chronic diseases, whose expansion is associated to the current ageing trend:

1. Vital signs checker: blood pressure meter, oximeter, thermometer, weight scale
2. Hospital's software interface, the patient file, the patient's risk alarm center with automatic call to the nurse from the activated orange code (green / orange / red), direct call to the doctor and nurse at the red code
3. Visio communication support via a touch screen (between the patient and his nurse, his doctor and his family), interactive modules for the patient (administrative, activities, menus, medical bot chat ...)
4. Authentication and geolocation of patients
5. Teleconsultation for nights and weekends at the foot of the bed of patients hospitalized or retirement home.

For instance, Charlie (a medical robot currently in experimentation at Bichat hospital) allows this interface, being at the service of the patients and the caregivers, without any aim to replace them but to relieve them and help them in their task of monitoring, carrying charge, geolocation of patients, medical content broadcast, video interface with families, telemedicine with doctors sometimes in other units and allowing to respond to any emergencies.

Figure 3.19.: Charlie, a medical robot currently in experimentation at Bichat hospital

Charlie will be deployed in the medium term at home as part of a home hospitalization and eventually, when AI enabled, in each home as a medical assistant.

In the last two decades effort has been made to enhance social care services through robots. The purpose is to provide advanced assisted living services via general-purpose robot as an autonomous interaction device that is able to access all available knowledge and cooperate with digital appliances in the home. In this sense autonomous mobile robots offer several advantages compared to (stationary) existing AAL solutions:

1. Robots represent a familiar metaphor for most persons. Thanks to sensor augmented user interfaces, human computer interaction are becoming more and more natural.
2. Robots are supporting the adoption of assisted living applications
3. Robots are flexible. In case of a crisis, the robot can localize the person and provide help.
4. Robots can increase privacy versus stationary sensors.

3.2.2.2 Human Centric Lighting: enhancing quality of life with light

Background to Lighting and Digitization

The lighting industry has seen a variety of developments in the type of technologies we have available from incandescent light bulbs, to fluorescent lamps, to Light Emitting Diodes (herein LEDs). LEDs contain a solid-state object (a semiconductor) that emits light through electroluminescence, hence the name solid-state lighting (SSL) is also used. With its introduction, the LED light source has revolutionized the lighting industry and opened many new opportunities not possible with previous technologies.

LED based digitalization of light allows for intelligent lighting control which can make indoor and outdoor environments more attractive and functional. It should be noted that the ability to get the right light, at the right place, at the right time is very much dependent on the lighting and system design, i.e. the ability to position the right luminaries in the right place and to enable a user adapted lighting control. Through its digital technology, SSL allows the light output to be controlled in a precise manner, adapting to changes in the users' needs as well as in its own performance.

From the users' point of view, smart lighting systems (with sensors, advanced data processing and control loops and interoperability with e.g. entertainment, security, or building management systems) allow light to dynamically be adapted to the needs of the users. This system approach needs to address the issue of interoperability with other systems (e.g. building management systems, smart city infrastructure) from the start and needs to be open for the ever more advanced digital advantages like intelligent maintenance and information transfer. Smart lighting could use sensor data to assure that the right lighting is provided where and when needed.

Research shows that lighting can have an impact on the health, well-being and performance. The effects of light on the circadian rhythm have been studied by scientists and industry over the years. The research in this field led to the joint award of a Nobel Prize in 2017 in Physiology or Medicine to Jeffrey C. Hall, Michael Rosbash and Michael W. Young "for their discoveries of molecular mechanisms controlling the circadian rhythm." This prize recognizes the importance of circadian rhythm for mankind.

Throughout the day, people are exposed to different types of lighting, depending on the location, activity performed and surroundings. Traditional electrical light lacks the ability to mirror the intensity, timing, color and dynamics of natural light. Human Centric Lighting (herein HCL) can supplement natural daylight.

Defining Human Centric Lighting

The term Human Centric Lighting (herein HCL) has been defined by Lighting Europe and the IALD as being lighting which supports health, well-being and performance of humans by combining visual, biological and emotional benefits of light.

These are benefits for the users of light, such as patients, residents, and staff in hospitals and nursing homes, and residents in private homes can benefit from adequate lighting in their private environment. The benefits differ per application area.

- Visual benefits include: good visibility, visual comfort, safety, orientation
- Biological benefits include: alertness, concentration, cognitive performance, stable sleep-wake cycle
- Emotional benefits include: improved mood, energize, relaxation, impulse control

Light has the ability to improve cognitive performance, it can energize, increase alertness or ease relaxation. It can improve mood, as well as stabilize the sleep-wake cycle of people. Therefore, it can be understood that light impacts people's well-being and performance. In fact, the true value of light lies in the combination of excellent visual, biological and emotional effects of light.

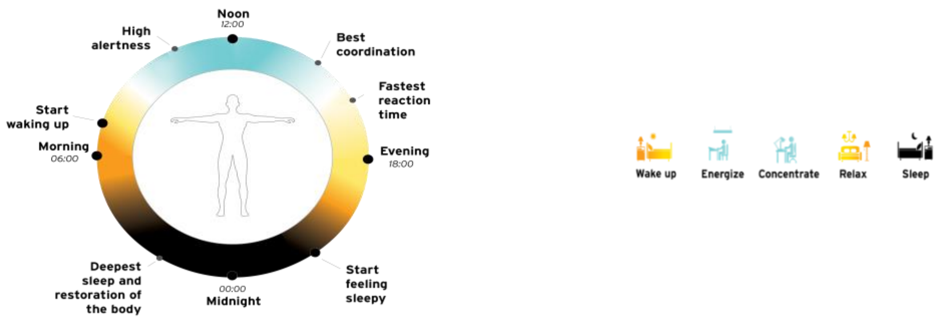

Figure 3.20 – The effects of light

Specific example of application field: Healthcare

The LightingEurope infographics on HCL and Healthy Buildings illustrate the different application fields where it is important to identify the amount and type of light needed in order to improve the health, well-being and performance of people. For the purpose of this paper, the application field that will be focused on is the healthcare sector. The healthcare sector/application field requires special consideration as inhabitants are either sick, chronically ill, disabled or have age-related problems in basic daily activities. They may be with or without visual problems, frailty, movement disorders, Sleep disturbances or memory and cognitive problems. Light can play a very prominent role in improving the quality of life for these individuals. Encouraging more use of outdoor spaces has a major impact if used in association with suitable lighting indoors. The eye's health (lens transmission, pupil size and reflex) can be measured and assessed. Accurate information is important for vision (glare, acuity) and non-image forming function (Sleep-wake timing) and has to be taken into consideration for lighting solutions.

The temporal 24-hour light-dark exposure becomes very important for the repair and regeneration of cells, because cell cycles are dependent on strong signals from the body clock, whose activity is influenced by light quality, intensity and timing. Therefore, personalized dynamic light settings for each room in hospitals and care homes should be propagated. For example, dynamic light can include a dawn simulation, a cool light color temperature that fluctuates with warmer color temperature over the course of the day, and an absence of cool color temperature in the evening. Furthermore, in a hospital, if possible, a patient should be allowed to adjust light levels in the room by shading daylight, dimming ceiling lighting from cool to warm color temperature and having localized lights for reading or getting up at night. A conclusion that can therefore be drawn is that patients should be able to control the light levels in the room and the color temperature. This will support the healing process and enhance quality of life for the patients. There are several technical and content enablers that could support HCL.

<u>Technical enablers for Human Centric Lighting are especially</u>:

- intelligent lighting (including sensors and controls to support dynamics)
- tunable white (at least tunable in light intensity and color)
- personal control (allowing personal settings depending on age, gender, chronotype, preference and activity)

The presence of one or more enablers however, does not guarantee that a lighting system in an application space is truly "Human Centric". The evidence that the actual lighting system in that application delivers the benefits remains the key requirement to claim HCL.

Further steps

This paper is a consolidation of the current actions in which the AIOTI workgroup 5 is involved at the current stage to drive the IoT uptake in Smart Living Environments for ageing well.

In short, there is definitely the emergence of a solid IoT for SLEaw ecosystem. Market acceptance of IoT-based solutions in the Ageing Well domain is spreading, but still needs more performative power.

Initiatives like ACTIVAGE, actually an “in progress” umbrella for establishing a solid and sustainable IoT for SLEaw ecosystem, are currently demonstrating that IoT can make a positive impact in Ageing Well and contribute efficiently to the Triple Win.

These ageing well initiatives, through the demonstration of the technological enablers and of the sustainability of IoT-based solutions, will enhance the diffusion of IoT innovation, suggesting the key IoT technologies for the better and quickest possible acceptance as long as they are taking in account the several “categorical imperatives” discussed in this paper, e.g. “interoperability”, “co-creation”, “domain of needs”, “trust” or “ethical design”.

The AIOTI workgroup 5 will continue to deploy its strategy. In this paper, we focused on investigating in technological & operational dimensions as well as on the acceptance, sustainability & expansion criteria of IoT-based solutions.

As per our strategy and action plan, our next step is of course to continue to support the demonstration of the efficiency of the IoT-based environments for ageing well. This is also to demonstrate the sustainability of IoT-based solutions, in order to impel new business model capturing the socio-economic value of digital innovation investments in Smart Living Environments for Ageing Well and to provide an evidence based roadmap for implementation.

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About AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT Innovation in Europe, bringing together small and large companies, start-ups and scale-ups, academia, policy makers and end-users and representatives of society in an end-to-end approach. We work with partners in a global context. We strive to leverage, share and promote best practices in the IoT ecosystems, be a one-stop point of information on all relevant aspects of IoT Innovation to its members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of IoT Innovation in society.

AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies. We also put them in practice in vertical application domains with societal and economic relevance.

AIOTI is a partner for the European Commission on IoT policies and stimulus programs, helping to identifying and removing obstacles and fast learning, deployment and replication of IoT Innovation in Real Scale Experimentation in Europe from a global perspective.

AIOTI is a member driven organisation with equal rights for all members, striving for a well-balanced representation from all stakeholders in IoT and recognizing the different needs and capabilities. Our members believe that we are the most relevant platform for connecting to the European IoT Innovation ecosystems in general and the best platform to find partners for Real Scale Experimentation.