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## Conference Paper

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25th European Regional Conference of the International Telecommunications Society (ITS): "Disruptive Innovation in the ICT Industries: Challenges for European Policy and Business" , Brussels, Belgium, 22nd-25th June, 2014

### Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Skouby, Knud Erik; Lynggaard, Per; Windekilde, Iwona; Henten, Anders (2014) : How IoT, AAI can contribute to smart home and smart cities services: The role of innovation, 25th European Regional Conference of the International Telecommunications Society (ITS): "Disruptive Innovation in the ICT Industries: Challenges for European Policy and Business" , Brussels, Belgium, 22nd-25th June, 2014, International Telecommunications Society (ITS), Calgary

This Version is available at:

<http://hdl.handle.net/10419/101421>

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# How IoT, AAI Can Contribute to Smart Home and Smart Cities Services - the Role of Innovation

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## I. Introduction

The urbanization of the cities will increase over the coming years and megacities will arrive with more than ten millions citizens. These megacities will have challenges such as create sustainable and cost efficient environments, enrichment of life quality for the citizens, and being able to handle non-static concepts that evolve over time. To address these challenges the latest information and communication technology (ICT) including its available services is needed. ICT offers a concept that fuels sustainable economic development and a high quality of life together with a wise management of natural resources. A valuable smart city ICT infrastructure must be able to integrate the smart homes into a coherent smart city concept. Vitale elements in this concept are Internet of Things (IoT), Clouds of Things (CoT), and Artificial Intelligence (AI).

The integration of a smart city, its embedded smart homes, and its offered service framework into a coherent ICT-based solution is the main focus of this paper. Thus, data from the smart homes will play a vital role in the development of innovative smart city services. In the near future it is expected that various kinds of home related data will be processed by an ICT-based infrastructure to provide intelligent community and personalized healthcare services.

ICT relates to the research areas that deal with adaptive AI, IoT, and CoT. These areas are developing rapidly in their own fields, but currently no research work that combines them with smart homes and smart cities has been done.

This paper will introduce a novel ICT concept that adapts and distributes the artificial intelligence between the smart homes and the smart cities. More specifically, the aim of this paper is to present a novel ICT-based infrastructure for future smart cities which comprises a collection of smart homes equipped with IoT's and an AAI system. The presented concept includes novel services for citizens and it seems to move the state-of-the-art for innovative smart city services into the next era, i.e. a new ecosystem. Furthermore we will investigate the relationship between ICT based infrastructure and innovation. The theory of innovation will be used to explain the phenomenon by which the technological and service innovation transforms existing cities into smart cities. We will demonstrate the innovative use of distributed IoT, CoT, AAI to solve problems in the area of social programs and healthcare, environment, energy and water, government, administration and public safety services.

## II. Smart Home

It is predicted that smart homes will have impact on our future life, i.e. they will provide services according to our preferences and they will act "intelligently". Smart homes provide services in the assisting and supervising areas such as: Ambient Assisted Living (AAL), i.e., support elderly to stay longer at home; telemedicine; and energy and pollution savings [1], [2]. In addition they are able to

assist with daily routines such as watering flowers, adjusting light and music level, controlling heating and changing multimedia settings according to user preferences and mood [3].

The smart home area are driven by consumers, AAL, entertainment industries, and green technologies [4], [5]. However, barriers exist in the form of technological limitations, high cost, inflexibility, and poor manageability [6]. At present, smart homes are still in their infancy, and they only exist in the form of laboratory experiments such as living labs.

From a technical point of view the smart homes are an extension of the home automation area. They offer remote and timer control of systems and embedded devices such as light, heating, ventilation, entertainment systems, appliances, etc., to improve comfort, convenience, energy efficiency, and security. Smart homes move beyond the home automation level, by adding extended behavior in form of context awareness and artificial intelligence. Thus, the smart homes build on the progressing maturity of the home automation area, the evolution of the Internet of Things, and the achievements in artificial intelligence technologies.

### **III. Smart City**

The urbanization of the cities is not expected to decrease over the coming years. Thus, megacities with more than ten millions citizens are no longer exceptional. These megacities pose some challenges in the quality of life for people and in form of city governance, i.e. sustainable solutions are needed. These solutions must address emerging requirements and could be provided by the concept of smart cities.

The smart city concept is non-static and evolves over time, why no unique definition exists. In general, smart cities offer public and private services to its citizens, where these services are adapted to fit and suit the needs of the individuals. Thus, smart cities create sustainable economic growths and a high quality of life for its citizens. The smart city concept includes human capital, social capital, hard infrastructure, and ICT technologies to provide an attractive and sustainable environment. These points are driven by ICT technologies which offer a modern digital infrastructure, improved services by involving the citizens, using smart technologies, and openness by providing new transparent business models [7].

### **IV. Advanced ICT technologies for smart city development**

The future smart cities need ICT technologies as a core to be able to handle the innovative smart city challenges. These ICT technologies must incorporate a solid, sustainable and highly leveraged network which provides connectivity, smartness, security, and efficient energy management. In the following the main contributing technologies are discussed. They are big data, IoT, CoT, and artificial intelligence.

#### **Big data**

The use of IoT and other future internet technologies provides a huge amount of data, i.e. big data. These data need to be properly analysed and managed to extract patterns, which are useable for applications, services and integrated ICT approaches. Examples of services are public health, public information systems, city management, energy efficiency, transport, security and emergency services, waste management, and water management. Common for these services is that the data need acquisition, storage and processing on either a local smart city server or on a cloud processing platform. Processed data can be used for developing new services such as smart economy, smart governance, smart environment, and smart mobility. In this paper some of these services will be considered and discussed.

## **Internet of Things (IoT)**

The IoT is considered as the next big step in the evolution of the Internet. The EU Commission has written an IoT action plan for Europe [8], stating that IoT will drastically modify the way our societies function in the coming 5 to 15 years. A combination of Internet and emerging technologies like wireless communications, context awareness and embedded wireless sensor networks transforms everyday objects into intelligent and context-aware IoTs. Hence commonly known objects such as clothes, food packing, toothbrushes, etc. will be equipped with some level of Internet-addressable AI. Thus, these IoTs will offer context awareness and communication features, and they will share some level of pseudo-intelligence depending on their processing capability and consumed power limitation [9].

It has been predicted that 7 trillion wireless devices will be used by 7 billion people at 2020, i.e. more than a thousand devices for every human on the earth [10], many of these will be IoTs.

### **Artificial intelligence in smart homes**

The application area for AI covers a wide range of applications such as toys, scientific research tools, medical diagnosis and robot control. In addition, many of today's services are based on embedded AI, examples are self navigating vacuum cleaners, recommender engines, gaming engines, cars gearboxes, speech recognition, and industrial robots.

Smart environments in the smart home area need to implement context-aware services that are able to deal with daily activities, such as grooming, eating, drinking, taking medicine and cooking. These systems must be able to interface with hundreds or even thousands of sensors [11]. In addition, they need to be able to deal with voluminous and rich data, which is very challenging for the AI learning and prediction process [12]. In general, context-aware services are added to smart homes by using AI-based systems. These system need to be able to learn activities from users' behaviors, i.e., when the user move around and perform actions within the smart home. When these actions are learned, the system must be able to detect the "learning situation" with a high degree of probability and it must be able to perform the learned actions autonomously.

## **V. Existing smart homes and smart cities services**

### **Services in the smart homes**

The smart home services include services provided by the home automation area. Thus, services such as remote control of light, alarm systems, entertainment systems together with timer triggered services are included in the smart homes. However, smart homes provide an extra layer to the controlled home services by adding artificial intelligence, context awareness, and communication skills. By using this layer smart homes are able to offer more intelligent services and intelligently control items such as lighting, HVAC (heating, ventilation and air conditioning), appliances, security locks of gates and doors. Additionally, remote services such as programming the home theatre and the HVAC are possible.

Most controlled homes uses smart phones to interface the user with their service. An example is remote control of the lighting in the home. However, handling hundredths of devices this way requires a highly complex user-interface even on a smart phone with interface technologies such as NFC and WiFi. A more user-friendly approach is allocating artificial intelligence, context sensing, and communication ability in the consumer devices. An example could be a microwave oven that downloads cooking recipes direct from the manufacturer's server and then take care of the cooking process. Another example could be an air conditioner which learns the preferred climate from the user's preferences and then adapt its behaviour accordingly [13].

Some existing smart home appliances, which include internet connections, are:

- LG's Smart Oven
- LG's smart refrigerator – Smart-Grid-Ready
- Whirlpool Wi-Fi Smart Appliances
- GE's demand-response refrigerator - can make adjustments to its settings based on peak-time price signals from the utility.
- LG Smart Washing Machine with Wi-Fi/NFC Tag-Smart Diagnosis

The smart household appliances will benefit from developed Smart Grid technologies such as two way communication. Using a two way communication between the consumer's appliances and the utility provider facilitate new services like grid energy saving in peak hours by regulating its working hours. An example is a washing machine that monitors the electricity price and regulates its washing cycle to optimise the costs according to price variations communicated by the energy supplier.

Web connected appliances are used in existing solutions; nevertheless, the key issues is to supply services that are based on this connectivity. These services in conjunction with new technologies will extend the smart homes beyond the homes into the area of connected homes, i.e. part of a smart city. Emerging technologies like CoT facilitates this development by providing means for linking and integrating the smart homes into a global internet based concept.

Adding the new dimensions of entangled smart homes provide new connected services such as ambient assisted-living, environmental monitoring for seniors, in home fitness and weight management. An example is residential security where devices such as video camera and multiple sensors can track motion, temperature, air quality, vibration, sound, and other kind of activity. Data from these devices are intelligently filtered and evaluated by the smart home artificial intelligence system.

### **Services in smart cities**

Smart cities mainly focus on city planning and resource management, i.e. presently smart city applications are used for optimizing services rather than providing service personalization. In addition, service optimization and personalization are defined by the Forrester Research group as a collection of smart computing technologies. These can be applied to the seven critical infrastructure components of a smart city, which are: administration, education, healthcare, public safety, real estate, transportation and utilities [14]. The service personalization viewpoint is used in various pilot service projects which have been initiated in many smart city projects around the world and it is recognized as providing benefits to city systems.

#### *Environmental monitoring and public safety*

A selected set of services that provide safety and a high quality of life for the citizens are discussed in the following. Firstly, a service that monitors critical infrastructure, material conditions, vibrations in buildings, vibrations in bridges and historical monuments is needed. Secondly, an environmental service which monitors temperature and air quality is important. Thirdly, intelligent traffic and transportation services are needed to monitor the level of vehicles and pedestrians to optimize driving and walking routes. This optimization must include intelligent and weather adaptive systems like street lights, etc. Finally, intelligent detection and treatment of garbage and rubbish levels in containers can be used to optimize the trash collection routes.

#### *Society and social programs*

In smart cities the vision is to increase citizens' quality of life, and improve the efficiency and quality of the services offered by governing entities and businesses. These services focus mostly on e-inclusion and e-participation. However, it is expected that innovation chains can be generated by improving the ICT in the public sector. Generating innovation chains will accelerate social innovation and improve the local ecosystems. An example is performing network tracking in a local area. This generates a sort of "augmented neighbourhood" where traditional channels of social interactions are

supplemented with some virtual communication channels. These provide new services such as formation of new groups, new forms of social association, and new local events [15].

A few examples of city services which can enhance living, working, studying, and travelling conditions are: smart neighbourhoods [16], services created by citizens for the citizens, based on open public data [17], 3-D visualisation and promotion of local recreation facilities on an interactive map of the city [18], tourism information through mobile devices using visual and interactive experiences [19], community energy management system [20], and smart urban space [21].

### *Healthcare*

Applications of new ICT technologies in smart cities enable new services in the health care area. Focusing on telemedicine where patients are diagnosed and monitored at home environment provides a better end-user experience. [22]. Other examples are faster emergency response; consistent tracking and monitoring of elderly, disabled, and chronically ill patients.

A concept which connects and combines data from the smart homes with data from the smart cities is still lacking. This suppresses the usage of the coherence and synergy which are implicitly embedded in these data. Using these in a combined way provides the opportunity to achieve a higher level of smart home performance. So the question is how we can integrate the various sets of heterogeneous data in a way that creates new services for citizens'. This challenge will be elaborated in the followings.

## **VI. Future smart cities, their challenges and visions**

It is generally accepted that long-term sustainable solutions are needed in the world where the resources are scarce, the population grows, and the lifestyle involves increasing resource consumptions with the consequences of resource shortage and climate change. A way to deal with these challenges is by focusing on a smart infrastructure for the most resource consuming cities. Basically, these cities support the citizens, their activities, and their homes, i.e. a smart city is a complex entangled system. Smart cities must address these challenges by integrating citizens and the smart homes into a unified and coherent concept [23], i.e. a smart city must include a smart home concept.

As discussed, to create a better sustainable and cost efficient environment the smart cities need the latest information and communication technology (ICT) and its services. Modern ICT communication infrastructure fuels sustainable economic development, a wise management of natural resources and a high quality of life. Using ICT in a smart city context provides personalized health care, intelligent community services, and green ecosystems among other things.

So to make the smart city the engine of transformation and a generator of solutions a modern ICT-based infrastructure is needed. This infrastructure must integrate smart homes into a smart city concept and must include technologies such as Artificial Intelligence (AI), IoT and Clouds of Things (CoT).

The IoT technology is expected to integrate the Internet into a multitude of things [8], [9]. Thus, commonly known objects such as clothes, food packing, toothbrushes, etc. will be equipped with some level of Internet-addressable AI, context awareness and communication features. Based on these technologies IoT's will provide some level of pseudo-intelligence depending on their processing capability and consumed power limitation [9], [24].

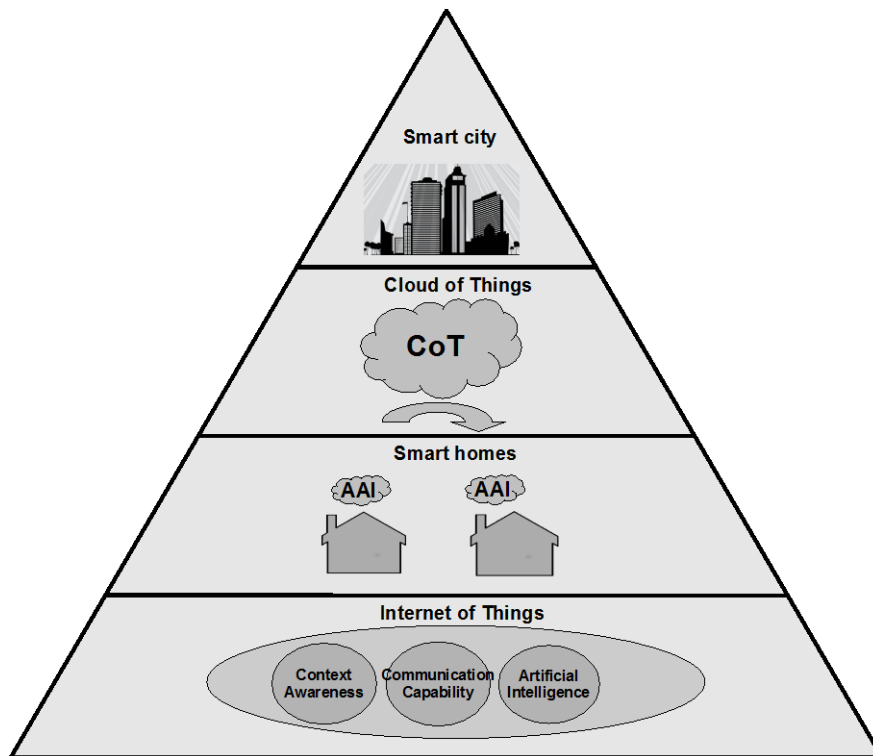
In a future perspective this development will provide useful coupling between people, things and between things themselves. Especially the context-awareness, the artificial intelligence, and the communication skills will pave the way for IoT's to become an important part of the future smart homes and smart cities. In the smart home context the IoT's contribute to make the home smart by sensing their context, reflect over their usage, and communicating this knowledge to the smart home

management system. Thus, the IoT's contained in the smart homes capture contextual information that describes the ongoing activities. By using artificial intelligence to analyze the provided information the smart homes are able to learn the user's behaviour and offer new services according to our preferences. A lot of research is needed in this area [8].

As discussed, the IoT's embedded in the smart homes produce contextual information, which is intelligently processed by the smart homes. However, taking the next step by combining the smart homes into one large organic unit provide basis for developing new services and new infrastructures where the smart homes are the knowledge suppliers. Hence, using CoT to integrate the smart homes into a smart city concept creates new sustainable service opportunities, creates a basis for improving the quality of life for peoples, and it forms new ways of implementing city governance. In this vision the CoT technology is a vital player because it handles the huge amount of information produces by the IoT devices. In simple terms a CoT is a pool of resources and calculation capabilities accessible through the Internet. For smart cities combining IoT and CoT is crucial, so that IoT data can be processed and stored [23].

An ICT-based infrastructure which is suitable for future smart cities must comprise technologies such as IoT, CoT and distributed AI. The AI part is challenging because it is allocated on the resource constrained IoT devices. Hence, in order to handle complex IoT patterns a more Advanced AI (AAI) system is needed. This AAI system could be implemented as a distributed interface between the AI systems in the smart homes by using Internet and CoT service technologies. Such an approach offers:

- A possibility to interconnect smart homes, coordinate their activities, collect big-data, and develop new services to the community, as well as to the individual smart home users.
- An efficient approach that makes it possible to add new smart homes to the smart cities as an ongoing process.
- The ability to upgrade the smart homes and implement new service offered from cloud based repositories.
- A system that adapts to the concept of the smart grids, which supplies resources to the smart cities such as electricity, water, and sewerage.
- The benefits of centralizing all the big-data information on few cloud servers. This offers easy access to all information and the opportunity to develop new services by analyzing and processing the distributed pre-processed (anonymous) big-data from the cloud servers.



**Fig. 1. The suggested ICT-based infrastructure and its four layers**

Fig 1 illustrates the suggested ICT-based infrastructure for future smart cities. At layer 1 (the bottom layer) it contains a collection of IoT's which directly interacts with the users. Contextual information from these is collected in the smart home systems which learns and predicts the user's behaviour and preferences (layer 2). Based on this they offer services such as intelligent lighting, heating, security, and entertainment to its users. The smart home services are controlled and processed by its AAI system. By combining these AAI systems, using the Internet and the CoT technologies (layer 3), a smart city ICT-based infrastructure is created (layer 4). The suggested ICT-based infrastructure offers advantages in the smart city areas "environment, energy and water", "government, administration and public safety", and "social programs and healthcare".

Firstly, the suggested ICT-based infrastructure offers a multitude of services in the area of social programs and healthcare. Examples of these services are: AAI offers common information servers (CoT based) which update automatically based on observations, AAI recommends and organizes common shopping, AAI schedules activities such as looking after children, pets, etc., AAI recommends social relationships (like LinkedIn), AAI detects unusual behaviour like an elderly person has fallen, AAI monitors behaviour and informs caregivers in the area of telemedicine, etc.

Secondly, in the area of environment, energy and water the suggested ICT-based infrastructure offers automated handling and adaptation of the resource scheduling by using the interconnected AAI and the CoT systems. Resource scheduling offers coordination of electricity suppliers and consumers. This improves the reliability, efficiency, economics, and sustainability of the production and distribution. Likewise sustainable resources like rainwater, solar based heating, wastewater, and power production systems can be coordinated by the interconnected AAI system to provide local and global savings.

Lastly, in the area of government, administration and public safety services can be offered where taxes are directly related to the resource consumption and the monitored pollution level by using the collected big data that are saved on the cloud servers. In addition, the suggested ICT-based infrastructure can watch for un-normal smart home behaviour and e.g. alarm neighbours, police, security companies, etc.



The suggested smart city ICT-based infrastructure has some challenges in the form of security, privacy, costs, usability, user involvement, and the fact that the AAI does not exist. However, these are manageable with today's technological capabilities.

Summing up, the suggested ICT-based infrastructure uses the resources intelligently and coordinating their usage across the smart city. This lowers the resource consumption. Thus, it creates a cost efficient environment and it improves the sustainability by optimizing the environments for the citizens to live in, it provides a high quality of life, and it provides a wise management of the natural resources.

## **VII. Innovation**

Smart City and smart home concept are taking an important role in innovation trends. Artificial Intelligence, Internet of Things and Clouds of Things will contribute to the smart city/home services developments.

An important attribute characterizing a great part of smart city/home innovation is its growing complexity. Some innovations in a smart city/home are seemingly incremental, involving new combinations of existing technologies. Some innovations represent a new approach to service development and are based on the new technologies.

The terms radical and incremental innovation are often used to describe the degree of innovativeness of a service, product, process or business model.

Incremental innovation is often described as an improvement and exploitation of the existing technologies, services and business models. Radical innovation aims to create a new product, service or technology which solves a need that the market had not previously expressed, or which had not yet been seen as solvable, which results in transformation of existing markets or creations of new ones. New products or solutions are based on an invention or an insight that is ahead of its time and of the market. Often, radical innovation is technology driven, starting from a new technology, looking for an application [25].

In the context of smart city and smart home services and infrastructures, radical innovations will be often aimed at driving the performance frontier rather than serving under-served or unserved markets like in the case of disruptive innovation.

The fast development of ICT technologies is enabling the emergence of many new applications and the redesign of traditional systems towards smarter solutions.

In practice, many innovations in smart city/smart home are a mix of different types of innovations. Even though incremental and radical innovations generally result from different processes and require quite different strategies, both activities need to be executed within smart city/home concept (figure below).

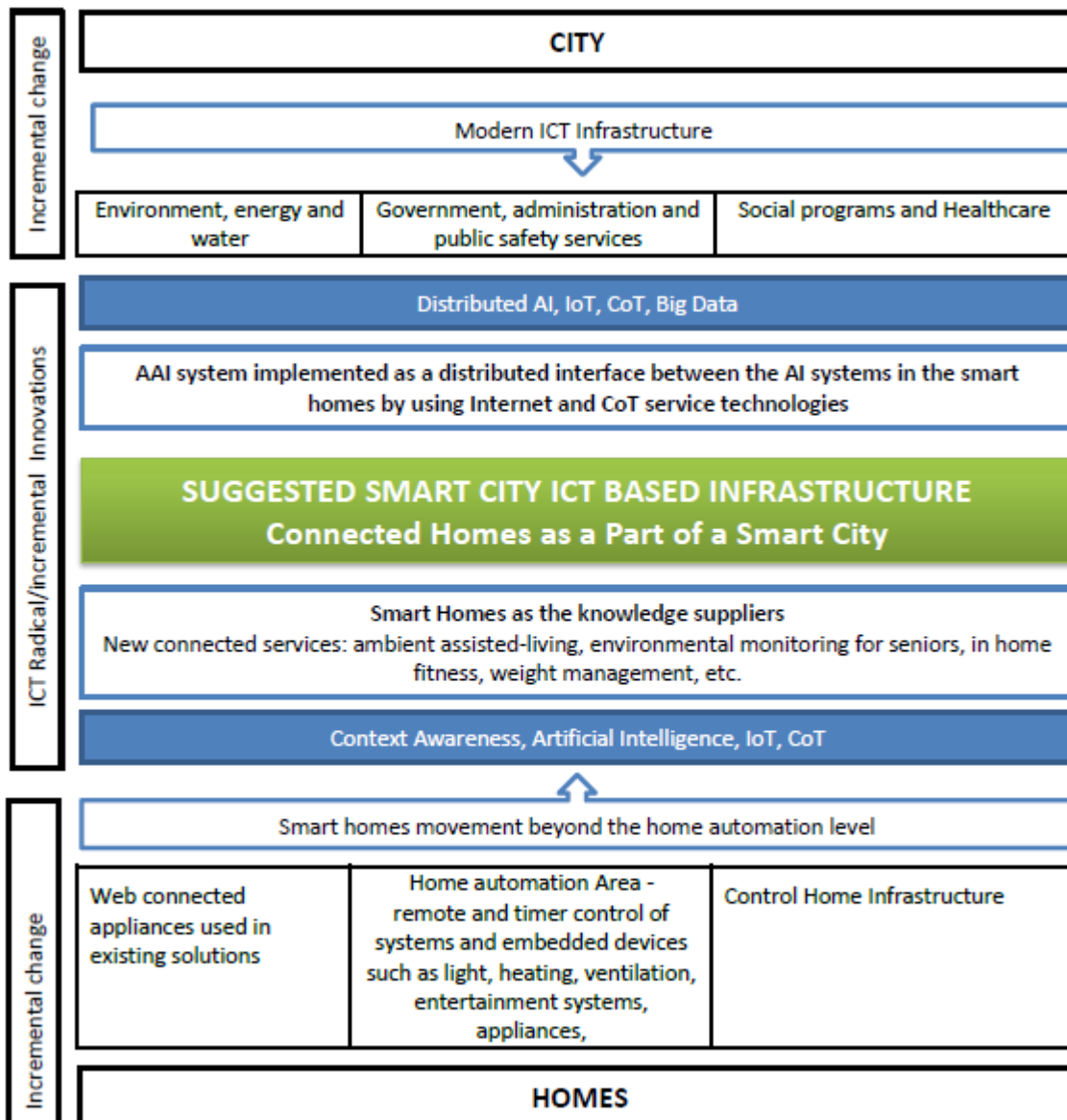


Fig. 2 Innovative Smart City based infrastructure – Connected homes as a part of a Smart City

The innovation process in a smart city and smart home can be also seen from the perspective of Schumpeter innovation theory as the succession of invention, innovation and diffusion. Looking at the smart city and smart home needs, the concept of services has increasingly become important to many fields, including environment, energy and water, government, administration and public safety, social programs and healthcare. In this context CoT, IoT, AAI in a smart city context provides personalized health care, intelligent community services, and green ecosystems among other things.

Most innovations take considerable time to become accepted. Therefore new smart city/home solutions are still in the stage of the early development.

## **Conclusion**

It is concluded that new strategies, processes and visions are needed to cope with the population growth and the related challenges that are expected in future cities.

In a smart city context many different services can be offered by deploying an ICT-based infrastructure. However, an ICT-based infrastructure needs new combinations of existing technologies and it requires new service development approaches, why the role and impact of innovation in smart cities need considerations.

A beneficial ICT-based infrastructure and its four layers model have been discussed in this paper. It incorporates the recent advances in ICT and its embedded important elements such as Internet of Things, Clouds of Things, and Advanced Artificial Intelligence. These elements constitute the infrastructure that interfaces the elderly people, the smart homes and the smart cities. Hence, by combining smart cities and smart homes, we have provided an ICT-based infrastructure that supports the entangled connections between citizens, smart homes, and smart cities. This infrastructure offers many advantages and new service possibilities. Firstly, it is able to interconnect Internet of Things in the individual smart homes in an intelligent way by deploying AI. Secondly, it scales well and offers easily adaptation to new technology and services such as smart grids. Lastly, the smart city Cloud of Things offers the possibility to centralizing distributed data into a few big-data storages by deploying new combined smart home and smart city services.

The presented ICT-based infrastructure provides a new platform for services. It mainly focuses on services in the areas of social programs and healthcare; environment, energy and water; and the area of government, administration and public safety.

Deploying a new ICT-based infrastructure requires considerations about the used innovative principles, strategies and methods. Thus, it has been found that the innovation process of integrating homes and cities into one unit requires incremental principles for providing new combinations of existing technologies and new services to the homes and the cities respectively. Nevertheless, even though incremental and radical innovations generally use different processes and require quite different strategies, it has been found that both activities are needed to combine the smart homes and the smart city into one concept.

In a future perspective the ICT-based infrastructure has some challenges in the form of security, privacy, costs, usability, user involvement, and the fact that the embedded AAI does not exist. However, these are manageable with today's technological abilities.

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