Smart Home and Smart City Solutions enabled by 5G, IoT, AAI and CoT Services

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***Abstract* — in a nearby future 5G technologies will connect the world from the largest megacities to the smallest internet of things in an always online fashion. Such a connected hierarchy must combine the smart cities, the smart homes, and the internet of things into one large coherent infrastructure. This paper suggest a four layer model which join and interfaces these elements by deploying technologies such as 5G, internet of things, cloud of things, and distributed artificial intelligence. Many advantages and service possibilities are offered by this new infrastructure such as interconnected internet of things, smart homes with artificial intelligence, and a platform for new combined smart home and smart city services based on big-data.**

Keywords— 5G, smart cities, smart homes, internet of things, artificial intelligence, big-data.

I. INTRODUCTION

The growing research in and discussions of 5G connectivity – likely to arrive in a 2020 timeframe – is already changing many perspectives in the communications landscape. It changes the way we view Internet services and introduces the world of pervasive and always-connected mobile services. This includes services that are ubiquitous and available to everyone at almost every point in a given area, indoor or outdoor and dominated by machine-to-machine (M2M) connectivity with communications feature integrated into every-day devices in much the same way that a mains plug is fitted to most appliances.

One of the consequences of the pervasive and always-connected perspective as the coming together of two hitherto separated research areas 'the Smart Home' and 'the Smart City'.

'Smart Homes' have been an active technical research area in decades. From this perspective it deals with the technological enrichment of the living environment in order to offer support to inhabitants and improve their quality of life [1]. The roots have been in the home automation area, which offers remote and timer control of systems and embedded devices such as light, heating, entertainment systems, and appliances to improve comfort, energy efficiency, and security.

'Smart Cities' has developed to create a better sustainable and cost efficient urban environment. The idea has gained momentum with the realization that 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.

A future smart city 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) connected via pervasive and always-connected M2M communications (5G).

The connected IoT technology will integrate the Internet as we know it today (2014) into a multitude of things [2], [3], and 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 [3],[4].

The new dominating form of communication, M2M includes the challenge to make the IoTs context-aware, intelligent and able to communicate via IP, and combining them into a distributed system for the future smart homes and smart cities. They should be able to not only react to changes in the environment, but also perform AI-based reasoning to take into account the preferences of the user inhabiting the smart home. A lot of research is needed in this area [2].

The CoT is vital in the smart home and smart city contexts because IoT devices produce a huge amount of information that needs to be stored and processed. 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 [5].

Combining the pieces, a modern ICT based infrastructure must comprise technologies such as 5G, IoT, CoT and distributed AI. Especially, the AI part is challenging because it is embedded into the IoT context, which offers limited resources. Thus, an Advanced AI (AAI) system is needed for handling complex IoT patterns. This AAI system could be implemented as a distributed system which interfaces the AI systems embedded in: the IoTs, the smart homes, and the CoT services. Such an approach offers:

- The possibility to interconnect IoTs, coordinate activities, collect big-data, and offer complex services

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to the community, as well as to the individual smart home user.

- Scalability, it is easy to add new smart city members in the form of smart homes, upgrade and perform service to a distributed system, i.e. it scales well.
- Compatibility with the concept of smart grids supplying resources to a smart city.

II. 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 5G, big data, IoT, CoT, and artificial intelligence.

A. 5G

Even if the details of the future 5G systems are far from known or agreed upon yet, the overall qualities distinguishing it from the current systems including LTE Advanced are emerging in reasonably consensus in presentations from equipment manufacturers and academics [6], [7]. The challenge is no longer transfer capacity measured as bits / second, rather the focus will be on efficiently delivery in terms of services and experiences. The experience-oriented services will include that we are informed what we need, when we need it – based on a combination of user profiles and location; this information is delivered without delay and includes assistance to find what is relevant with an easy available possibility to decline or overrule the assistance. In essence 5G is the communications system that can finally achieve what has long been promised - anyone anywhere can get in touch with whoever or whatever – in a human-centric system that is meeting the user needs.

B. 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.

C. 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 [2], 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 [3].

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 [8], many of these will be IoTs.

D. 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 [9]. 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 [10]. 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.

The smart home building blocks for future smart cities are illustrated in fig 1. It comprises a collection of smart homes, which are equipped with IoT's. They offer services such as intelligent lighting, heating, security, and entertainment systems to its users. The individual smart home is equipped with an AAI system, which controls and processes its smart home services. By combining these AAI systems, using 5G to access the Internet and the CoT services, the ICT basis for a smart city is created as an Integrated Smart Home and Smart City (ISHSC).

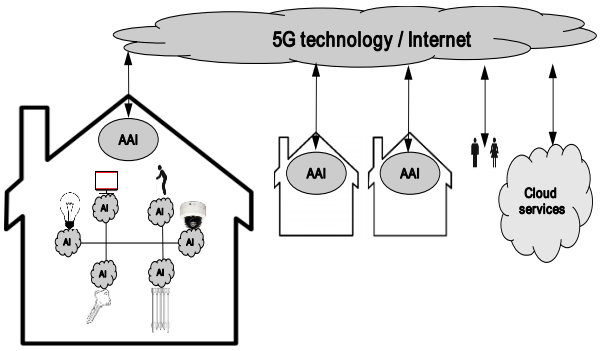

Fig. 1. AdvancedICT based infrastructure for future smart cities – the suggested Integrated Smart Home and Smart City based infrastructure

III. INTEGRATED SMART HOME AND SMART CITY - CHALLENGES AND VISIONS

The outlined ISHSC infrastructure integrates smart homes into a smart city concept. The IoT technology integrates the Internet into a multitude of things [2], [3]. 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 [3], [4].

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 advanced communication 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 [2].

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 handled in a new communication concept.

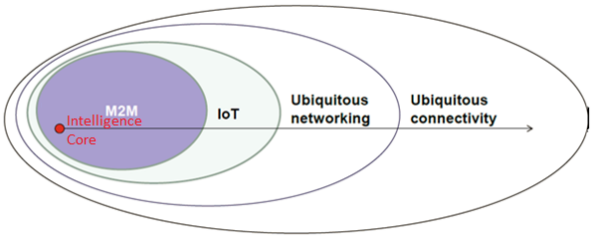

Fig. 2. 5G communication concept for ISHSC (based on a presentation by Ramjee Prasad GISFI, Bangalore Dec 2012)

Using CoT in this setting 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 interconnected by the Internet. For smart cities combining IoT and CoT is crucial, as this allows IoT data to be processed and stored [5].

This advanced ISHSC infrastructure presents a number of challenges apart from development of a 5G system. The IoT devices present challenges as they need to communicate with each other (M2M communication); they need to communicate with the cloud services which collect big-data, and they need to process complex data using AI. To handle these challenges including the huge amount of data involved, 5G technologies are needed. Firstly, the M2M communication requires scalable and opportunistic radio facilities like cognitive radios (5G) which are able to allocate bandwidth dynamically, able to handle high interference levels, and able to save power by adapting resources dynamically Secondly, uploading big-data to the cloud services requires considerable bandwidth with a minor delay, i.e. it must be possible to offer extracted big-data services in real time. 5G technologies are foreseen to support this. Lastly, processing complex data using AI is challenging because it is allocated on the resource constrained IoT devices. Hence, in order to handle complex IoT patterns an Advanced AI (AAI) system is needed. This AAI system can be implemented as a distributed interface between the IoTs, the smart home AI systems, and the AI systems offered as cloud services, where CoT is the integrating technology.

A detailed overview of this system and its 5G communication concept is provided in Fig. 2. Focusing on an "IoT" device it includes an "intelligent core" and a "M2M" communication interface. The "intelligent core" is a resource constrained device which offers AI processing capability and a "M2M" interface which handles 5G based IoT communication. Hence, the communicating IoTs, the smart home servers, and the cloud services constitute an "ubiquitous network" which offers "ubiquitous connectivity's".

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.

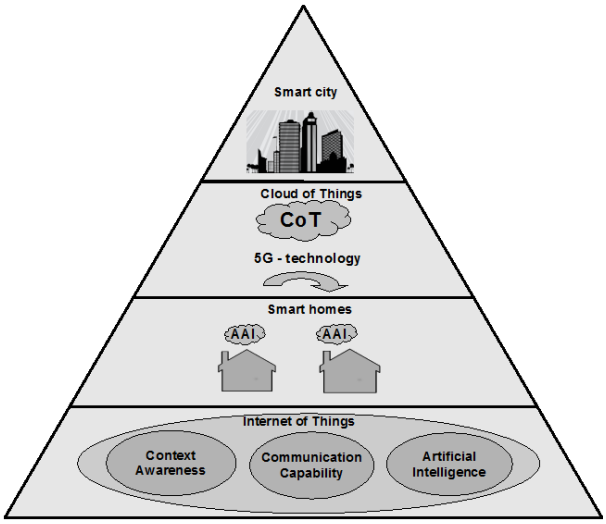

Fig. 3. The suggested ICT-based infrastructure and its four layers

Fig 3 illustrates the suggested elements in the ISHSC infrastructure. 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 distributed AAI system. By combining these AAI systems, using 5G communication and the Internet and the CoT technologies (layer 3), a smart city ICT-based infrastructure is created (layer 4).

The suggested infrastructure includes a number serious of challenges in communication technologies, security, privacy, costs, usability, and user involvement. Meeting these challenges, however, can initiate the smart city as an engine of transformation and a generator of solutions. The entangled smart homes provide a platform for new connected services based on multiple sensors which can track motion, temperature, air quality, vibration, sound, and other kind of activities. Data from these sensors can be filtered intelligently and evaluated by the smart home AAI.

A host of new ISHSC services are likely to emerge on areas as environment, energy and water; government, administration and public safety; traffic and social programs and healthcare.

In environment, energy and water potentials for automated handling and adaptation of the resource scheduling are opened including resource scheduling offering, e.g., 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 to provide local and global savings.

In government, administration and public safety services apart from refinement of conventional e-government, e.g., a system may 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. Further, 'un-normal smart home behaviour' may be followed and alarm given to neighbours, police, security companies, etc.

Intelligent traffic systems (ITS) may be taken to a new level by combining real-time traffic information and user needs/ requests for transportation to regulation traffic and offer transportation.

A multitude of ISHSC services are likely to be developed in the area of social programs and healthcare with examples such as: common information servers (CoT based) which update automatically based on observations, shopping recommended and organized, looking after children, pets, etc., social relationships are recommended (like LinkedIn), unusual behaviour monitoring like detecting an elderly person has fallen , and health staff is informed in the area of telemedicine, etc.

IV. CONCLUSION

The suggested ISHSC infrastructure is based on a four layer model incorporating emerging advances in 5G systems, Internet of Things, Clouds of Things, and Advanced Artificial Intelligence. It 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.

These potential developments presuppose solutions to a row of socio-technological challenges including diverse areas such as 5G communication technologies, distributed AI, CoT based services, security, trust and privacy. Solutions to these will require huge research efforts using innovative principles, strategies and methods. The outlined infrastructure is inherently a user centric system that will provide a platform for a new eco-system based on new socio-economic structures.

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