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Net!Works European Technology Platform

Expert Working Group on

Smart Cities Applications and Requirements

White Paper

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Executive Summary

Smart Cities gained importance as a means of making ICT enabled services and applications available to the citizens, companies and authorities that are part of a city's system. It aims at increasing citizens' quality of life, and improving the efficiency and quality of the services provided by governing entities and businesses. This perspective requires an integrated vision of a city and of its infrastructures, in all its components. A Smart City can be taken according to six characteristics: Economy, People, Governance, Mobility, Environment, and Living.

This White Paper identifies major topics of Smart Cities that will influence the ICT environment, as covered by Net!Works. Applications and requirements are grouped into 5 topics: Economic, Social & Privacy Implications; Developing E-Government; Health, Inclusion and Assisted Living; Intelligent Transportation Systems; and Smart Grids, Energy Efficiency, and Environment. Each of the topics is put into perspective according to its potential, challenges, technical requirements, and roadmaps.

All these domains raise new challenges in security and privacy, since users implicitly expect systems to be secure and privacy-preserving. One of the critical elements is which role(s) the city will take up as an actor within an increasingly complex value network. New players enter the market, actors shift their business strategies, roles change, different types of platforms emerge and vie for market dominance, technological developments create new threats and opportunities, etc. An element related to the trend of platformisation is cloud computing, which is increasingly helping the private sector to reduce cost, increase efficiency, and work smarter. One particular challenge relates to open data business models. Activities necessary for Public Sector Information provision can be identified.

The development of efficient and effective e-government is a prerequisite. Transnational authentication systems for citizens and businesses, agreed frameworks for data privacy, and the sharing and collection of individual and business data, are key. Smart Cities need to be able to integrate themselves into national, regional and international infrastructures. Although the implementation aspects depend strongly on the authorities of these infrastructures, European wide recommendations and directives will definitely contribute to accelerate the deployment of Smart Cities.

Health, inclusion and assisted living will play an essential role, since the demand for related services is rising, because ageing is changing disease composition. Requirements address a number of technologies, beyond the ones related to mobile and fixed networks. An integrated perspective on healthcare solutions for the near- to long-term can be foreseen, bridging a direct gap in between the health area and the technological development of communications (radio and network components).

The needs for mobility in urban areas result into a number of problems, such as traffic congestion and energy consumption, which can be alleviated by exploiting Intelligent Transportation Systems and further adoption of vehicle-to-vehicle and vehicle-to-infrastructure communication networks. The information being managed in this area can be relevant to other domains, which increases its potential. An effective deployment poses a number of technical, sociological, regulatory and economic challenges.

Smart energy grids are the backbone of the Smart City, a major requirement being to leverage energy consumption between the different producers and consumers. The successful combination of smart processes and technologies will enable energy efficiency and savings to be achieved in the residential and business markets. Intelligent systems and integrated communication infrastructure are highly demanded, which can assist in the management of power distribution grids in an optimised way. Smart grids are seen as a major opportunity to merge power and ICT industries and technologies.

In conclusion, in order to achieve the goal of Smart Cities, one has to develop quite a number of technologies in the area of wireless and fixed communications networks, and many research challenges are identified.

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List of Acronyms

3D	Three Dimensional
API	Application Programming Interface
CDMA	Code Division Multiple Access
DG	Directorate-General
EC	European Commission
EU	European Union
FTTH	Fibre to the Home
FW	Framework
GDP	Gross Domestic Product
GPS	Global Positioning System
ICT	Information and Communication Technologies
INFSO	Information Society
IP	Internet Protocol
IT	Information Technologies
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
LTE	Long Term Evolution
LTE-A	Long Term Evolution – Advanced
MAC	Medium Access Control
OECD	Organisation for Economic Co-operation and Development
PC	Personal Computer
R&D	Research & Development
SAA	Strategic Applications Agenda
SARA	Strategic Applications and Research Agenda
TV	Television
UMTS	Universal Mobile Telecommunications System
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

1 Introduction

Cities have quite an impact in the economic development of a country, being the "platform" where many people live and work, where services are provided to citizens in a wide range of ways, and where local government officials have a close contact with citizens. It is only natural then that ICT (Information and Communication Technologies) plays an increasing role in the life of both people and private and public entities that are part of a city.

The concept of Smart Cities is gaining increasingly high importance as a means of making available all the services and applications enabled by ICT to citizens, companies and authorities that are part of a city's system. It aims to increase citizens' quality of life and improve the efficiency and quality of the services provided by governing entities and businesses. This perspective requires an integrated vision of a city and of its infrastructures, in all its components, and extends beyond the mere "digitalisation" of information and communication: it has to incorporate a number of dimensions that are not related to technology, e.g., the social and political ones.

When looking at the potential impact that telecommunications, and the services made available by them, may have in cities, a number of opportunities, challenges and barriers can be identified. The deployment of these services implies that other sectors need to be brought to work together with the telecommunications one, hence, requiring that the latter is aware of a number of requirements and constraints, coming from the many applications made possible in a Smart City environment. This matter was recently addressed by the European Commission, via two strategic documents, i.e., the Digital Agenda [EuCo10a] and the 2020 Flagship Initiative [EuCo10b].

Several projects have been developed in Europe addressing Smart Cities in their various dimensions, e.g., [Smar11a], [Smar11b], and [SmSa11]. A total of 6 dimensions have been identified in [Smar11b], which describe the global perspective that is required in this area: economy (competitiveness), people (social and human capital), governance (participation), mobility (transport and ICT), environment (natural resources), and living (quality of life). Furthermore, in [KaLi09] the authors examine barriers to solve urban problems, presenting an approach on communities, and to turn problems into an opportunity to reduce costs, to improve services to communities, and to make cities smarter.

The intention of this White Paper is to identify major topics of Smart Cities that will influence the ICT environment, as covered by Net!Works. In order to provide a significant contribution for on-going discussions in the context of future target settings, e.g., for enabling platforms, co-operative research, and public funding, an analysis is provided here, centred on the following aspects:

- Potential
- Challenges
- Technical requirements
- Roadmaps

Based on the work of Net!Works, and on the past experience with eMobility's SAA (Strategic Applications Agenda) [eMob09] and SARA (Strategic Applications and Research Agenda) [eMob10], this White Paper on Smart Cities Applications and Requirements groups the various dimensions into 5 topics:

- Economic, Social & Privacy Implications
- Developing E-Government
- Health, Inclusion and Assisted Living
- Intelligent Transportation Systems
- Smart Grids, Energy Efficiency, and Environment

In the sections that follow, these topics are addressed individually.


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2 Smart Cities – the Economic, Social & Privacy Implications

2.1 Definition(s) of Smart Cities

While almost all cities (and municipalities and regions) want to be 'smart', there is no accepted definition of what this means in practice – be it in technological, developmental, or administrative terms. A Smart City is more than a digital city. A Smart City is one that is able to link physical capital with social one, and to develop better services and infrastructures. It is able to bring together technology, information, and political vision, into a coherent programme of urban and service improvements.

It is a mistake to think that making smarter cities requires just more investment in IT (Information Technologies) – what cities need to be able to do is to use IT as a means to deliver local (and national and EU levels) aims and objectives. The most important issue confounding efforts to make cities smarter is not the development of appropriate technologies per se, but to tackle the difficulties in changing organisations and existing ways of working to use these new technologies to deliver smarter cities.

The concept of Smart Cities has also been used in different ways: to describe a cluster of innovative organisations within a region; the presence of industry branches that have a strong focus on ICT; business parks; the actual educational level of the inhabitants of a certain city; the use of modern technologies in an urban context; technological means that increase government efficiency and efficacy; etc. A clear definition remains elusive.

The authors of [GFKK07], describing medium-sized European Smart Cities, define a Smart City by using six characteristics in which such a city "performs in a forward-looking way": Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living. They use these six concepts to describe specific factors that can be important when describing a Smart City, which are presented in Figure 1.

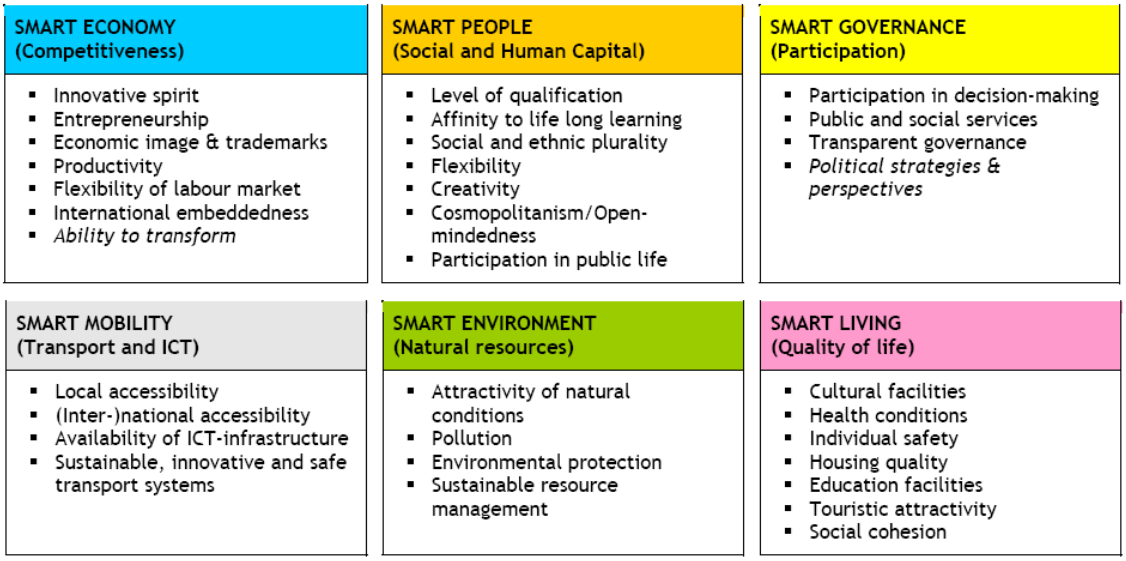

Figure 1 - Characteristics and factors of a Smart City (extracted from [GFKK07]).

This definition of domains and factors can serve as a good starting point for the crystallisation of the Smart Cities concept. The authors of [CaDN09], looking for an operational definition of Smart Cities, base themselves on the study mentioned above and propose their own definition: "*We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.*". While this definition remains broad, the Smart Cities concept does entail many diverging elements, which are all in some way captured by it.

Given the broad definition of the Smart City concept, and the wide array of domains it may impact on, its potential is equally broad. In its most basic and general interpretation, the idea behind a Smart City should be an increase in quality of life for its citizens and travellers. This goal can be reached by increasing efficiency and efficacy of government, developing environment-friendly applications, increasing mobility, providing better health services, stimulating economic prowess, etc. In order to reach these and many other goals, it is vital that a city intending to become smart clearly outlines them in policy making, then defines a strategy that is founded in research to reach them, and which role(s) the city should play, e.g., as a service facilitator/incubator, service provider, network provider, etc.

2.2 Privacy, security and trust

All the domains discussed in this White Paper raise new challenges in security and privacy, and although security is not the main selling point for most applications, users implicitly expect systems to be secure and privacy-preserving. If users deem a system as insecure or threatening their privacy, it will not be able to establish itself successfully in the market. Important social challenges stem from the necessity to adapt Smart City services to the specific characteristics of every user. A service has many configurations options, depending on user expectations and preferences; the knowledge of these preferences usually means the success or failure of a service. In order to adapt a service to the specific user's preferences, it is necessary to know them, and this is basically done based on a characterisation of that specific user. Nevertheless, a complete characterisation of user preferences and behaviour can be considered as a personal threat, so the great societal challenge for this, and for any service requiring user characterisation, is to assure user's privacy and security. Thus, in order to achieve user consent, trust in, and acceptance of Smart Cities, integration of security and privacy-preserving mechanisms must be a key concern of future research.

The overall priority must be to establish user confidence in the upcoming technologies, as otherwise users will hesitate to accept the services provided by Smart Cities. Although Smart Cities are not a new technology concept by itself, but rather denote the intelligent combination of currently established systems, new challenges arise in the area of security and privacy. These challenges can be classified into two aspects.

First, by interconnecting systems that serve totally different purposes (e.g., traffic control and energy management), and thereby creating a "system of systems", the complexity of such collaborating systems increases exponentially. As a result, the number of vulnerabilities in a Smart City system will be significantly higher than that of each of its sub-systems. Furthermore, the pure interconnection of two systems might open new attack vectors that have not been considered before, when securing either of the individual systems. Therefore, research into ways of handling the increasing complexity of distributed systems from the security perspective is required, which includes: cost-effective and tamper resistant smart systems or device architectures (crypto and key management for platforms with limited memory and computation); evolutionary trust models (i.e., trust is not static but dynamic, and associated values can change along time) for scalable and secure inter-system interaction; abstract and comprehensive security policy languages; self-monitoring and self-protecting systems, as well as development of (formal) methods for designing security and privacy into complex and interdependent systems; overall thread models that allow to take multiple sub-systems into account.

Second, the number of users, and the volume and quality of collected data, will also increase with the development of Smart Cities. When personal data is collected by smart meters, smart phones, connected plug-in hybrid electric vehicles, and other types of ubiquitous sensors, privacy becomes all the more important. The challenge is, on the one hand, in the area of identity and privacy management, where, for instance, pseudonymisation must be applied throughout the whole system, in order to separate the data collected about a user (which is required in order to provide high-quality personalised services) from the user's real identity (which is required for purposes such as accounting); this includes that the usage of addressing identifiers, such as IP or MAC addresses, for the purpose of identification must be avoided in future systems. On the other hand, security technologies, such as advanced encryption and access control, and intelligent data aggregation techniques, must be integrated into all systems, in order to reduce the amount of personal data as far as possible, without limiting the quality of service. For future research, work towards interoperability of different identity management systems, as well as automatic consideration of user's preferences, is required. The latter aspect goes along with the development of privacy policy languages, which allow users to express their preferences on service quality and data minimisation.

A study performed some years ago [CoWi07] recognised the importance of data privacy and personal identity among the aspects to be dealt with not only on technical grounds, but also concerning legal and communication aspects. Figure 2 shows a roadmap on how the technological development should be accompanied with these other aspects.

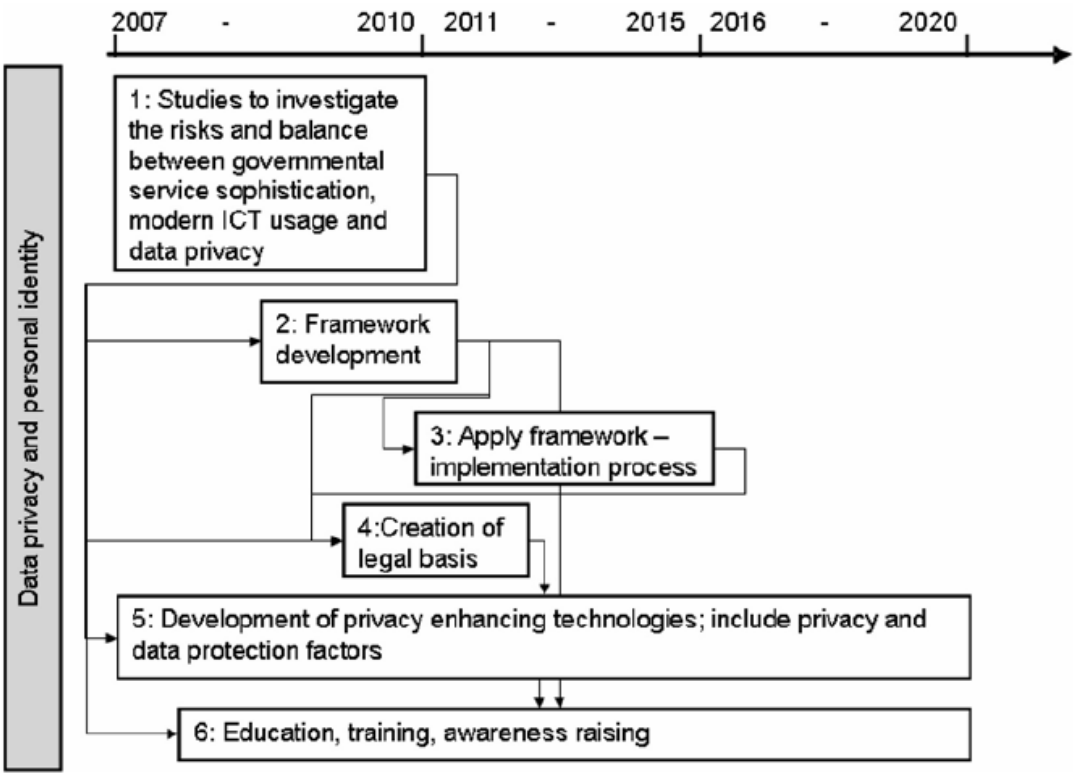

Figure 2 – Phased actions concerning data privacy and personal identity (extracted from [CoWi07]).

2.3 Business models, platformisation, interoperability and open data

One of the critical elements that will be of ever increasing importance for the Smart Cities of the future is which role(s) the city will take up as an actor within an increasingly complex value network. The ecosystems of mobile and fixed communications service provision are in a constant state of flux, as commercial and public entities aim to find strategic fits, while adapting their business models. New

players enter the market, actors shift their business strategies, roles change, different types of platforms emerge and vie for market dominance, technological developments create new threats and opportunities, etc.

This existing complexity increases exponentially, when considering the involvement of cities as actors in the value network, with all the agencies and domains they entail, and the potentially large differences between cities themselves. When discussing the creation of Smart Cities, one must remember that is trying to facilitate the development of thousands of urban areas across Europe; they bring together a wider range of different institutions (emergency services, health, planning, education, economic development, etc.) that are trying to deliver a range of complex and different services to citizens and businesses, within a variety of national, regional, state and local political and administrative structures. These urban areas are at radically different stages of technological, political and administrative development; these differences in administrative and technological maturity will both shape and constrain the ability of individual cities to become smarter.

In this tumultuous field, cities have to explore closely which roles they want to take up in these new value networks, as various options exist, centred around two axes: the network and the services. As far as the networks are concerned, the trend of cities aiming to offer ubiquitous coverage of different technologies (WiFi, WiMAX, FTTH, etc.) to its inhabitants seems to be subsiding, after several failed experiments around the world. However, one can expect that the focus on the network side will shift to Wireless Sensor Networks, allowing for the connection among locations, everyday objects, and devices. Such ubiquitous connectivity needs to be facilitated (e.g., by building sensors into new and existing city infrastructures), and has to be supported by relevant services and applications (potentially in all the domains identified in this White Paper).

Apart from infrastructure, high-quality services will be the focal point in all the domains in the years to come. From a business model perspective, similar questions arise as to the role of the city as an actor, or even as a platform. In the last decade, one has assisted to the surge of platforms, not only as coordination mechanisms between agents, but also acting as a driver for innovation. Even if the most popular ones are situated around the offers of mobile vendors, platforms have a long standing in the computer industry, with examples such as Wintel (Windows and Intel), as well as in other sectors. Platforms provide a combination of constraints, value propositions, and revenue sharing mechanisms, aimed at maximising network effects and creating a virtuous cycle. However, despite of the extraordinary success and popularity experienced by some platforms, the public sector has been very slow in translating this concept into its own specific context, and implementations are limited to a few low-impact experiments. Cities should carefully decide on their strategy with relation to platforms, depending on the policy goals they wish to achieve, as many approaches (technological development, subsidies, public-private partnerships, open data provision, etc.) are possible, each with different consequences. The roles of intermediaries, the impact of decisions on platform strategies, and their potential direct and indirect “cost” recovery, should be thoroughly studied, before a city decides on an approach to service creation and distribution.

An element related to the trend of platformisation is cloud computing, which is increasingly helping the private sector to reduce cost, increase efficiency, and work smarter. From a business perspective, cloud computing is a key concept to enable a global ecosystem, where organisations are able to be more competitive. The sharable and the on-demand nature of cloud computing are compelling for today’s highly distributed yet collaborative-driven workforce.

In the context of this ever-increasing complexity and platformisation, interoperability between systems will be exceedingly important. One could envisage a flexible, secure, and open communication platform, which could also be referred to as middleware, allowing different systems to share information, enabling the creation of services that combine data, and spanning the different domains described in this White Paper. Standardisation is clearly an important task, affecting all levels of middleware implementation, assuring transparent and reliable interfaces to the middleware, as well as interoperability between products and services across very different domains. Thus, interoperability and standardised ways of communication between systems is an important research subject, crosscutting all Smart City domains.

One particular challenge in the context of Smart Cities relates to open data business models. As services become pervasive and ubiquitous, the matter of opening up databases will become more important. Open Data is hardly a new concept, its origins being easily traced to Open Science data, a fairly common practice among scientists (its translation to governmental data is credited to Edd Dumbill in the 2005 XTech conference, acknowledged by the OECD [OECD04], and supported by Tim Bray and Tim O'Reilly in 2006 [BrRe06]). Cities will have to decide to what extent they want to share information with third parties, such as application developers or commercial companies, without losing a competitive advantage, or worse, violating the privacy of its inhabitants. In general, services and applications that leverage user information provide higher quality experiences when such information is used in a balanced way, e.g., when its benefits outweigh the "costs" (of sharing private information); however, it is an exercise in balance, which can have a negative impact on the service uptake if it is not achieved. Transparency towards the end user on how his/her information is being used, with clear opt-in options and secured environments, has to be the starting point when providing services that leverage personal data.

The use of open data as described in EU's Public Sector Information directive is an opportunity to trigger innovative Future Internet enabled services in Smart Cities. The Public Sector Information re-use and utilisation of open data introduces a paradigm shift that will impact many people working in public administration. This change covers not only processes, but also alters our understanding of the role of public authorities, and thus, the role and perceived importance of its employees. It is understandable that different stakeholders might only reluctantly embrace these concepts, and that they might strive to find arguments against them. Public Sector Information re-use will help creating a better and more efficient public administration, as well as opening new ways for the administration, the general public and the commercial sector to be involved in societal processes.

The following activities are necessary for Public Sector Information provision and re-use: improving communication about the advantages and boundaries of open data; analysing current skills in the public sector, identifying necessary expertise, and bridging any existing gaps with external support and internal capability building; adapting existing information producing processes in the public sector, so that regular provision of data to according platforms becomes routine; creation of easy-to-use guidelines for public authorities on how to start with data provision; achieving most easy comparability and comprehensibility through furthering meta-data and data standardisation; alleviating retracing of the data sources, by developing an attribution schema and enabling a data source to sign published data; and supporting the publishing of more fine granular data through mechanisms for automatic anonymisation or pseudonymisation of data sets.

3 Smart Cities – Developing E-Government

3.1 An Approach to Smarter Cities

Eighty per cent of Europe's population already lives and works in cities of more than 10 000 people. Cities are the key pathway to delivering better and more effective e-government, and to the delivery of a range of EU and national economic and environmental objectives.

The development of efficient and effective e-government is a prerequisite for the development of Smart Cities. E-government applications and technologies must be able to address the fundamental questions of how cities work, how they are organised, and how they can be made to work in more intelligent ways for citizens and businesses. A Smart City will be able to bring together technology, information, and political vision into a coherent programme of urban and service improvement. The development of Smart Cities will affect thousands of urban areas across Europe, which are at very different stages of technological, political and administrative development: these differences in administrative and technological maturity will shape and constrain the ability of individual cities to become 'smarter'.

The lack of horizontal and vertical integration across the various e-government and urban initiatives in EU states, and the relatively low level of interest shown by many national authorities, limit efforts for the systemic development and implementation of local e-government. One needs a coherent integration of related interventions across policy fields and administrative structures, to facilitate the development of Smarter Cities. The adoption of technologies that make cities smarter and provide better e-government will require significant organisational and structural changes, on the part of both the cities themselves and the institutions that work with cities.

3.2 Priorities and challenges

Cities will take different paths and become smarter at different speeds and in different ways. However, there are a number of technologies that will be required for the underlying infrastructure that is needed to help support this process. Fundamental technologies that are key to the development of the Digital Single Market, such as authentication and privacy, are key to the development of e-government in Smart Cities. The development of transnational authentication systems for citizens and businesses, the development of agreed frameworks for data privacy, and the sharing and collection of individual and business data, are key. Citizens and businesses will need standardised ways to identify themselves electronically to networks, applications, and service providers. Robust political and policy frameworks are required to address common privacy issues associated with the use and re-use of personal data across Europe.

Standardisation and interoperability are key requirements for the widespread adoption of technologies and services to provide e-government at the city level. Cities need to be able to integrate new services and technologies with their existing services and infrastructure – this requires the development of open and common approaches, based on the development and use of shared and public APIs (Application Programming Interface), which support the continuous development and evolution of Smart Cities.

Cities will need to be able to better integrate wireless networks. European cities are currently characterised by heterogeneous wireless access technologies, provided by a diverse range of operators. Smart Cities will integrate wireless technologies and operators, making provision seamless

and transparent. Many cities already have fragmented, partial coverage of wireless networks: the next step will be to find ways to help these public and private networks to converge or integrate into city-wide networks, which will require both technical developments and regulatory changes.

Cities will increasingly move from being service providers to platform ones. This will cover both the development and integration of wireless networks that bridge multiple providers and multiple communication technologies, and the development of infrastructures to facilitate more active and smarter urban networks and applications. By creating these platforms and applications, Smart Cities will provide an infrastructure that enables the development of a broad range of public and private applications and services.

Cities and urban networks will need to become increasingly active, aware, and smart, compared to current passive and intelligent networks. The current system of fragmented and passive information networks will need to be replaced by active, integrated networks that are able to link citizens, businesses, governments, and infrastructure. Standardised technologies and infrastructures that are necessary to provide personalised and location-based services need to be developed – this includes solving the technical challenges of developing location frameworks and integrating wireless offerings, while also developing the knowledge infrastructure and ecosystem that are necessary to provide the content needed by citizens, travellers, businesses, etc.

3.3 Roadmap

The development of Smart Cities requires a pragmatic approach to technological development and deployment that is based on open standards and interoperability, which is vendor neutral and focused on the needs of cities, citizens, and businesses. Technologies need to be deployable, and supported by sound business models.

Smart networks and infrastructures need to be developed in order to exchange information from person to person, from people to machines, from machines to people, or from machines to machines. Only by developing robust, shared solutions can one develop cities that are smart, and which are able to increase innovation, improve the quality of life, and raise standards of living.

Smart Cities need to be able to integrate themselves into national, regional and international infrastructures, e.g., to share location data about businesses or development land, or to establish the marital status of citizens. The development of data and service standards, ensuring application interoperability and data exchange are key to this. Institutional and organisational processes need to be developed, to facilitate the shared development and deployment of e-government applications across cities.

The development of open data and data sharing is also a requirement for the development of e-government in Smart Cities. Public data needs to be made open and accessible, through the establishment and use of a repository of definitions and taxonomies that makes data consistent throughout Europe. This will provide a standardised foundation for developers to use and re-use government content – including address and location service information, data, maps, transport information, timetables, etc.

Although the implementation aspects depend strongly on national, regional and local authorities, European wide recommendations and directives will definitely contribute to accelerate the deployment of Smart Cities in their e-government perspectives. Studies for the increase of trust in e-government in Europe have been conducted [CoWi07], and a roadmap has been established, Figure 3, but plans extend beyond Europe, and, e.g., Japan [JaGo10] has also a calendar that impacts on the usage of ICT in e-government, Figure 4.

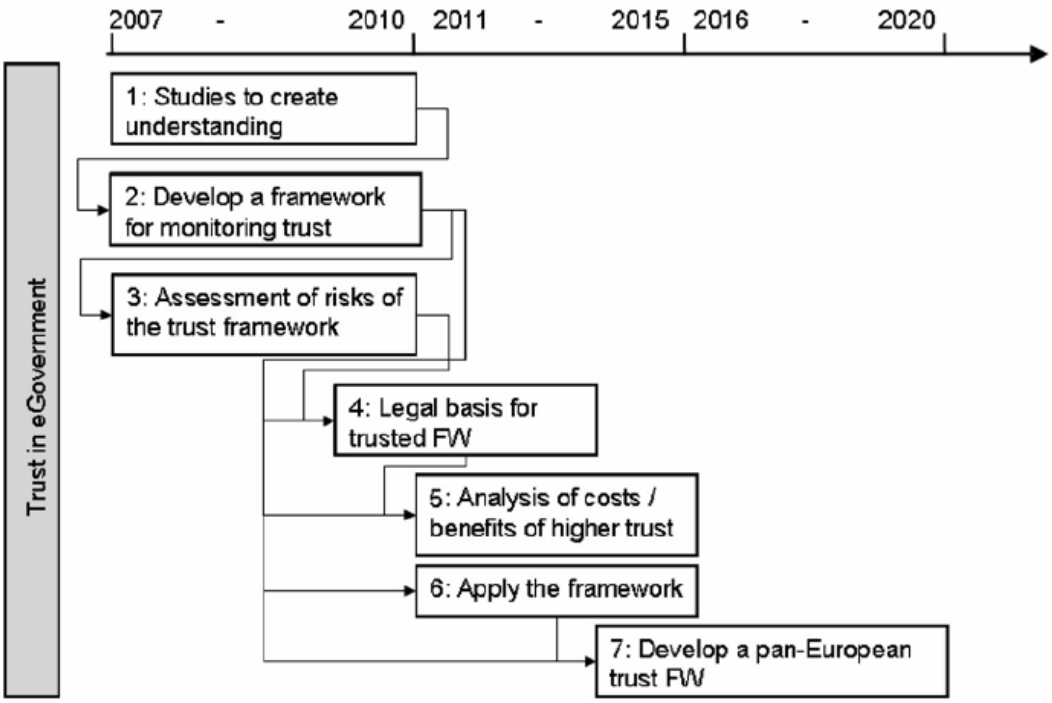

Figure 3 – Roadmap for the increase of trust in e-government in Europe (extracted from [CoWi07]).

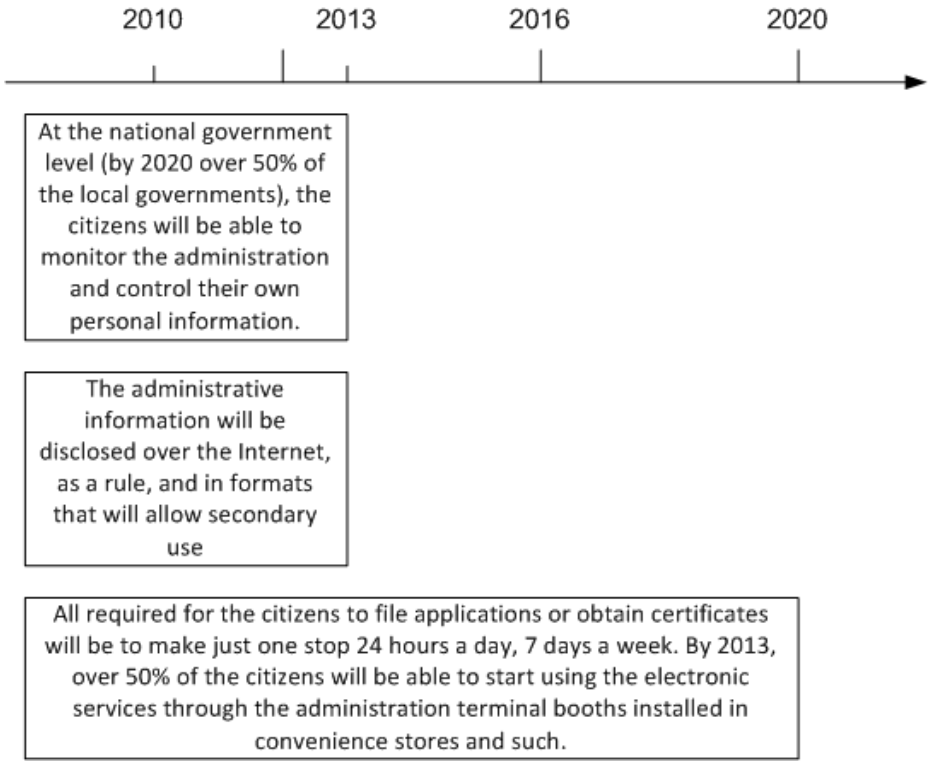

Figure 4 – Roadmap for the introduction of e-government in Japan (extracted from [JaGo10]).

European-level regulation will be a key driver for the adoption of 'smart' urban technologies, particularly for the development of new urban infrastructure and new buildings. Developing technical and regulatory frameworks to drive improvements in existing infrastructure (e.g., through improving energy efficiency) will be a key challenge for policy makers.

4 Smart Cities – Health, Inclusion and Assisted Living

4.1 Application

The world's population is aging, while it is getting sicker at the same time. By 2050, the number of people in the 60+ category will reach 2 billion, while half of the developed world is projected to become chronically ill [UnNa07]. A recent study revealed that local hospitals and access to healthcare facilities were cited among the most important features for city inhabitants [Phil10], while ICT plays an instrumental role in bringing unique responses to these needs. Many existing and potential technologies under development for the maintenance and/or supervision of health and wellbeing offer a great promise, ranging from health monitoring services and falls detection to "lifestyle monitoring" (detecting changes in behaviour patterns) [BBBC00]. Within this realm, research in ICT platforms for elderly and people with chronic diseases test ideas of generic health monitoring platforms, addressing people with chronic conditions, [Chro11], [Hear11], and assistive mobile devices, [Enab11], among others. Smart Cities need to incorporate these aspects into their overall structure and roadmap.

Current trends in personal health systems, enabled by the advances in ICT, biomedical engineering, healthcare technologies, and micro- and nano-technologies, can greatly contribute to the need for better health care and wellbeing solutions. Personal health systems offer pervasive solutions for health status monitoring, through vital signs measurements performed by bio-sensors, which will be exploited for the prevention and/or early diagnosis of harmful situations. Furthermore, efforts to support independent living encompasses social and medical assistance in the home or at an institution, in the form of face-to-face contact or assistance via tele-care services, in the shape of assistive technologies, personal monitoring, etc. One can consider three categories: health; enhancing digital literacy, skills and inclusion; and assisted living.

Participation in society, a healthy lifestyle, and good healthcare system are determinants of a healthy living. New technological advancements in the area of health, such as remote monitoring solutions, which can serve as a bridge between the hospital and the home, could enable cities' inhabitants to monitor their condition at home, ensuring that, when they get ill, they will be supported along the entire patient pathway (diagnosis, treatment, and long-term disease management).

Inclusion is concerned with minimising all barriers to learning and participation, whoever experiences them and wherever they are located in Smart Cities. Applications include: improving quality of life of users with digital content, taking multilingualism and cultural diversity into account; ensuring seamless access to ICT-based services, and establishing appropriate framework conditions for the rapid, appropriate, and effective convergence of digital communications and services; monitoring Smart Cities, through data collection and analysis of the development, availability, and use of digital communications services. Furthermore, the needs of people with physical impairments have also to be taken into account, and the way ICT will be used in Smart Cities must consider these needs.

Increased use of ICT among elderly people, the technologies used to be elderly friendly, and encourage elderly people to use the services, are also among the needs in this area. The main problems ageing people are facing when living independently are reduced physical abilities and isolation. Ageing well is also about independent life, and continued active and satisfying participation in social life and work. Independent living is the ability for elderly people to manage their life style in their preferred environment, maintaining a high degree of independence and autonomy, enhancing their mobility and quality of life, improving their access to age-friendly ICT, and personalised, social integrated, and health care services. A social problem is the creation of an economically sustainable model for the assistance of elderly people, and for their physical and psychological independence and wellbeing. The potential of ICT to support innovation in this area is large, and several applications and

services already exist, which can be directly applied to this context. The major hurdle in this domain is the lack of familiarity of elderly people with such new services and technology, which so far has excluded them from the benefit of a diffuse information and communication network.

It is expected that a better access to ICT in the public sector can generate innovation chains, such as:

- *Increased use of social networking applications*: at present, elderly people are not using social networking application and are considering them with diffidence, hence, ICT emerges as an excellent opportunity to increase social contacts and reduce the sense of isolation.
- *A better quality of life for elderly people and their relatives*: geographical localisation and positioning allow for elderly people to visualise the position of people that are relevant for them, such as friends, relatives, and caregivers; services based on these systems will increase elderly people's control and social contact within their living area, thereby, increasing physical and social activity in their life, reducing the social distance between them and their neighbours, and reducing their feeling of loneliness and isolation.
- *New opportunities for elderly people to circulate their own knowledge*: elderly people are a resource for the community in which they live, and their personal knowledge and their skills could be valuable for many people around them; not only can they help each other, but they can also transmit their knowledge (e.g., cooking, gardening, knowledge of local history, etc.) to others.
- *Personalising home assistance to independent seniors*: provision of an integrated system of assistance, wherein (functional and psychological) support to elderly people could be provided in a shorter time and by the appropriate people.
- *New business opportunities also for private companies and service providers*: by using geographical information systems to support services that are relevant for independent senior people, private companies and public services can provide more personalised services, while increasing elderly people confidence in the new services.
- *Local ecosystems that accelerate social innovation*: the activation of a tracking network in a local area generates a sort of "augmented neighbourhood", in which the traditional channels of social interactions are backed up by virtual channels of communications supported by the new services; on this ground, new groups, new forms of association, and new local events can be created.

4.2 Potential

The demand for healthcare is rising, because ageing is changing disease composition, with a rise in chronic diseases [AkTs09], which treatment now accounts for around 70 to 80% of healthcare costs in Europe, and at the same time, the number of healthcare professionals declines. Furthermore, healthcare systems are likely to face substantial challenges in the future, with public expenditure on healthcare likely to grow by 1.5% of GDP across the EU by 2060. In this context, the provision of healthcare services using immediate applicable innovative ICT is seen to be one of the elements helping the containment of healthcare delivery costs [AkTs09], while maintaining the expected levels of quality of care and safety [STSD07]. According to [ITU10], ICT for health is driven by governments to expand healthcare coverage, cut down unnecessary expenses, ease burden for traditional healthcare, and keep fairness of healthcare condition and facility in different areas. The impact on Smart Cities is undisputable.

4.3 Challenges

The challenges can be summarised into three different categories: Social, Market and Business, and Technical. The grand social challenges include: social communication, access to public and private services, healthcare assistance, policy and ethics, and safety of people living independently; use of ICT as the basis for increasing elderly people's socialisation opportunities; informal help exchange or a local exchange trade system. Market and business opportunities address: a revolutionary value chain to show relations within the ecosystem; new business opportunities, also for private companies

and service providers; a Go to Market plan, which has to include product distribution chain/channel; economic and financial aspects, such as the pricing strategy, product life cycle, public demo together with a launch venue, beta customers, early field trail, and attracting venture capital for scaling-up. Finally, the grand technical challenges encompass: geographical localisation and positioning; interoperability and maintenance of connectivity context, while residing on a mobile device and traversing multiple networks (e.g., cellular and WLAN, among others); pervasive borderless middleware platforms; configurable, adaptable, secure frameworks, and decision support systems.

A broader view can also be taken. Recent changes in society demand for new specific services. Such changes include an ageing society and ageing workforce, increasing life expectancy, changing family forms with an increase in people living alone. New challenges relevant to these changes have to be faced, such as chronic and degenerative diseases, addictions, obesity, depression, etc. The use of pervasive healthcare systems raises several challenges regarding energy, size, cost, mobility, connectivity, and coverage. Since these systems and services are to be used by beginners or moderately ICT literate users, it is of high importance to build them around user-friendly platforms, reducing complexity through better design.

More recently, there has been interest in the ethical implications of in-home monitoring of the elderly. A discussion in [MPWA07] notes the responsibility of researchers and technology developers to consider the needs and limitations of older adults regarding their interface with technology. In-home monitoring technologies must be used with precaution, taking user communities into account, as well as end user needs, and safety and privacy concerns (enabling users to be aware of what kind of data is being transmitted, and to whom). Following the above, personal data security and location privacy are considered to be some of the most important future challenges. Furthermore, related to challenges within the field of ICT security aspects, one of the main challenges in this key area relies in the trustworthiness of the gathered physiological parameter information. The main challenge in the area of hospital consultation and emergency scenarios is secure delivery of medical quality (multimedia) data over wireless channels, while the enhancement of the main functionalities in terms of speed and data compression are also considered important. The main challenge for assistive technologies is offering independence and autonomy to senior citizens and people with disabilities; legal, ethical and regulatory issues need to be addressed, since there are still uncertainties about the liability of healthcare services providers.

The following questions still need to be answered: Who are the most relevant actors in elderly people's and people with disabilities' independent life? How is the daily life of those actors organised? What are the most relevant interactions between those actors, and how and when in their routine are those interactions placed? What are the emerging needs from those actors? What kind of knowledge and familiarity do elderly people have on the technologies to be used? How is the approval by competent authorities? What are the ethical and privacy policies scenarios? What technologies are available for the pilots, concerning, e.g., tracking technologies and geographical information systems, and visualisation hardware? What are the technologies elderly people are already familiar with?

4.4 Technical Requirements

ICT in health is one of the key areas of change in the health and social services sector. Mobile technologies are among those that enable, in particular, new services that could lead to a dramatic change in health organisations and healthcare delivery practices. These could be defined as the emerging mobile communication and network technologies for healthcare systems, including sensors, WLANs, satellite, and current and future cellular mobile systems.

Biosensors and other new medical technologies reduce costs dramatically, and lead to do-it-yourself home care. Recent advances in image and wireless video transmission will enable remote diagnosis also in wireless and mobile scenarios (e.g., ambulances). Furthermore, smart phone devices, tablet PCs, Web TV sets, and video and audio analysis techniques are currently going through major

revolutions, changing the way people are accessing information and communicating. A recent study by Gartner [Gart10] forecasts that worldwide downloads in mobile application stores will pass 21 billion by 2013. Among the technical requirements that are associated to the wide adoption of health related ICT technologies, one can identify data security, devices connectivity and interactivity, power requirements for devices, end-user interface problems, among others.

The key technical requirements to be addressed in this domain are: security (encryption, authentication and authorisation), service discovery, scalability and survivability, persistence, interworking, community-to-community application messaging propagation, auditing and logging, location information sharing, and application service migration.

4.5 Roadmaps

The developments for the coming years, focussing on the aforementioned challenges, are the basis for the roadmap for preventive health diagnostics, health care and lifestyle management. The future challenges are usability issues, such as user friendliness, privacy of data, human-computer interaction, unobtrusiveness of systems, practicality of the proposed solutions, systems to secure the independence of the users, and ergonomics to increase the functionality that users need, which are important factors in the design of such systems. In order to enable the ease of use of such systems, there is a need to make wireless diagnostic and disease management systems more intelligent, using trends from the artificial intelligence discipline. Machine learning smart-phone systems using advanced sensors that gather data about the physical world, such as motion, temperature, or visible light, together with machine learning algorithms that analyse sensor data to enhance the healthcare services, are recommended to produce patient predictive computer-based models of diseases integrating medical and environmental data.

To obtain reliable and trustworthy information, the system has to consider both the integrity of the transmitted data between the sensor and the doctor‘s reporting unit via diverse entities (end-to-end integrity protection), and the validation that sensors and reporting unit are executed in a trustworthy and not manipulated state. Those demands can be enforced by hardware and software, e.g., by trusted computing technologies. This challenge does only consider attack or manipulation attempts on the transmission path or the entities itself (sensor and reporting unit). The manipulation of the sensor‘s environment to (intentionally) falsify recorded sensor data has to be tackled by a second challenge that considers plausibility checks on the sensor data.

The challenge related to ICT security aspects has to be ensured by a manageable access control management system, to ensure that only authorised persons (e.g., doctors, relatives, and clinic personnel) are allowed to access the data, and ensures that the data is protected to achieve confidentiality. Users should manage authorisation. Dedicated authentication and logging mechanisms have to support the access control enforcement. The challenge in this approach is that access control architecture has to consider both the decentralised storage of data at a medical practice, and the comprehensive access control mechanisms and enforcement that concern all parties that could have access to that data. That means that, even if data is locally stored in a medical practice, the access control system has to approve data usage according the current access permissions.

Wireless transmission of multimedia medical data is a challenging application area, due in particular to the high quality requirements of medical video, the bandwidth limitation/error prone characteristic of the wireless channels, and real-time requirements of most of the services in this area. In order to keep the required quality, lossless compression techniques are usually considered when medical video sequences are involved, resulting in huge amounts of data for transmission. When transmission is over band limited, error prone channels, lossless compression is not possible, and a compromise should be made between compression fidelity and protection, and resilience from channel errors and packet loss. The quality level achieved in a low-bandwidth system is acceptable, in some cases;

although due to the high compression ratios and to the effects of the wireless channel, such systems are of interest for a first diagnosis or emergency scenarios, a second diagnosis being usually required.

The most recent broadband wireless access technologies, including WiMAX, UMTS, CDMA2000, and LTE, allow a broader bandwidth, which provides the means to make multimedia tele-medical applications reliable, by maintaining good quality levels. The proper exploitation of such novel technologies, and the development of tailored tools for medical video compression and transmission over these systems, is one of the main challenges in the area. The trend towards even more bandwidth demanding 3D medical digital imaging adds interest to such a challenge.

Future developments will also see an increased use of satellites, particularly in situations such as natural disasters and emergencies, and where the existing infrastructure is poor or non-existent. Thanks to the specific properties of satellites, including the ability to oversee and monitor large parts of the continent, they are likely to play an important role in a future unified European system of eHealth.

The challenge for offering independence and autonomy to senior citizens and people with disabilities could be addressed by: locating services and guiding people with heterogeneous disabilities at places like museums, airports and shopping malls; developing customised and accurate platforms to exchange homogeneous data among different devices, services and healthcare personnel; developing easy to use, highly reliable, unobtrusive, low power and transparent technologies and devices in order to gain users' confidence. The implementation of stress detectors and face recognition applications utilising emotion recognition techniques is expected to meet the expectations and cognitive capabilities of end users.

Contributions to innovation that will boost wellbeing and personalisation services are expected in several areas, such as intelligent agents, ambient intelligence, smart shirt sensory architecture and wearable sensors for activity monitoring, and in-home and domotic sensors. The challenge now is not to invent new devices, but to make any service adaptive to the conditions of the users and the device there are using. In this way, one should start talking about equality and design for all.

Japan [JaGo10] has a calendar that impacts on the introduction of ICT for healthcare, Figure 5.

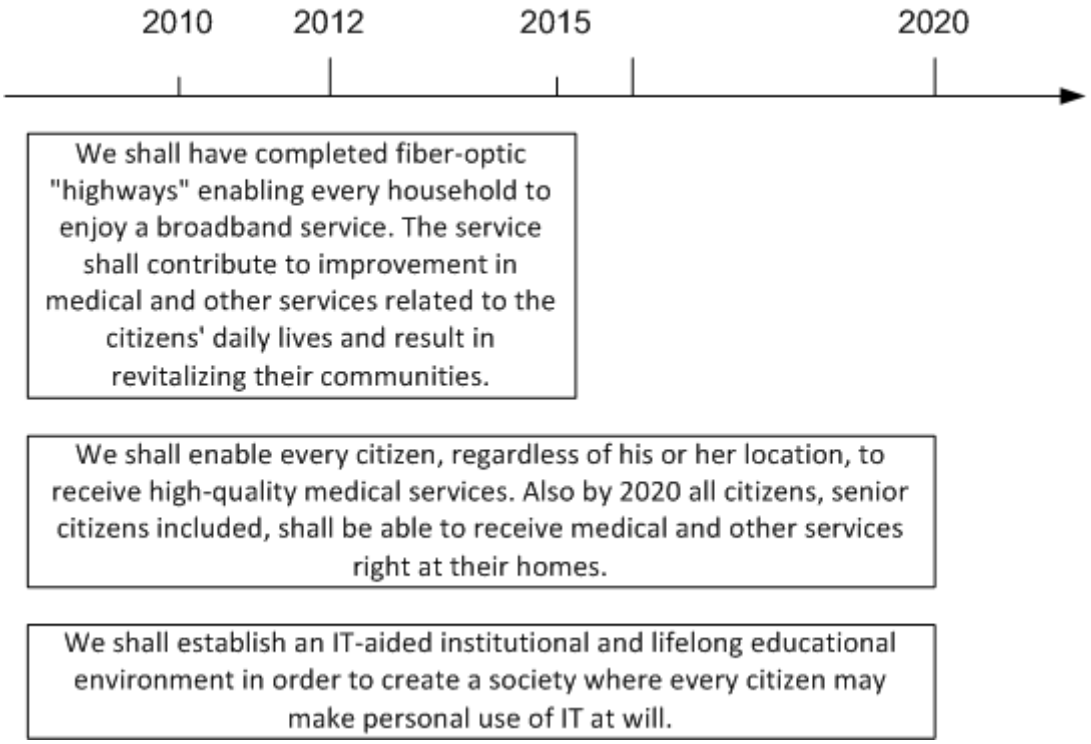

Figure 5 – Roadmap for the introduction of ICT in health care in Japan (extracted from [JaGo10]).

In Europe, an integrated perspective on healthcare solutions for the near- to long-term views has been presented by [EPOS09], Figure 6. Some of the enabling technologies are directly related to communications, bridging a direct gap in between the health area (within Smart Cities) and the technological development of communications (radio and network components) in the years to some.

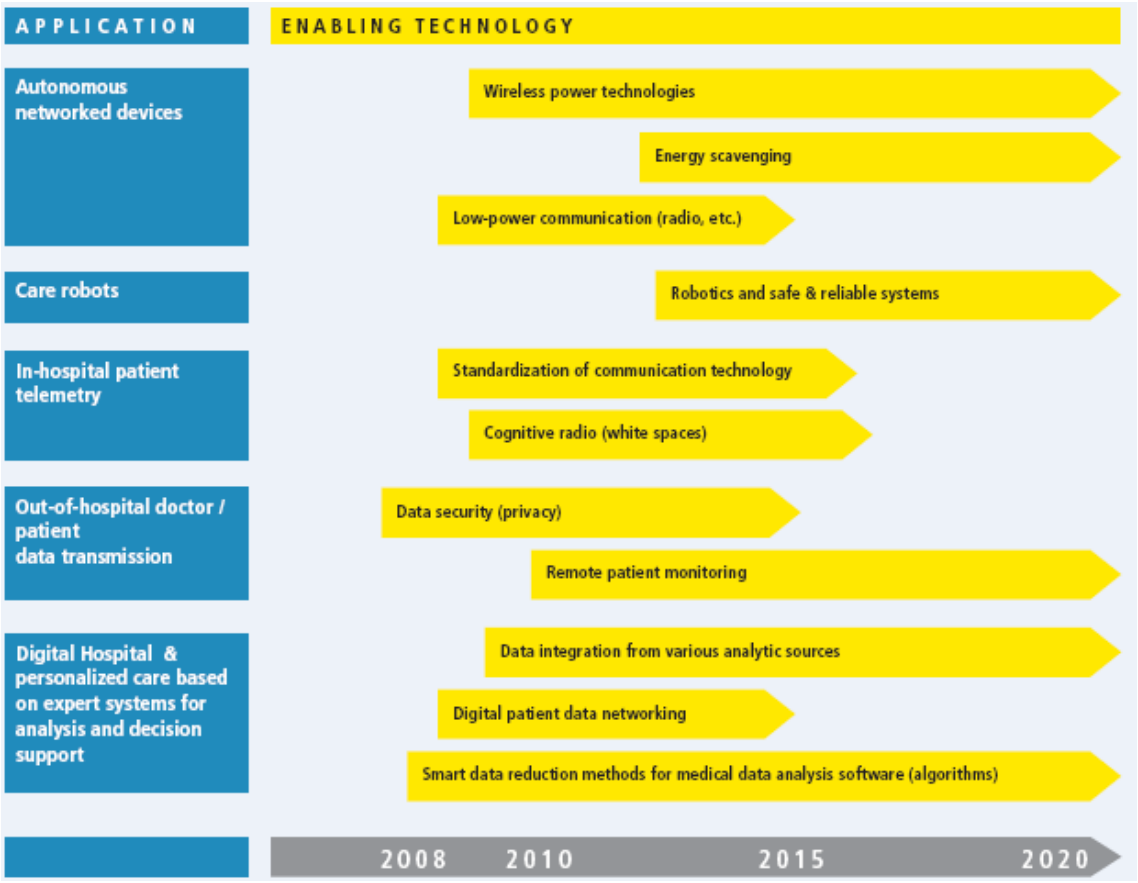

Figure 6 – Integrated healthcare solutions timeline (extracted from [EPOS09]).

5 Smart Cities – Intelligent Transportation Systems

5.1 Application

As previously mentioned, currently, 80% of the European population live in urban areas. Their mobility needs often result into a number of problems, such as traffic congestion, increased pollution levels and/or greenhouse gas emissions, or excessive travelling time and energy consumption. These problems can be largely alleviated by exploiting Intelligent Transportation Systems (ITS) and further adoption of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication networks, in Smart Cities.

More precisely and from the ICT viewpoint, applications should cover the following requirements in order to guaranty sustainable Smart Cities: reducing the mobility needs for both individuals and goods; optimising trip planning and management, transport mode selection and allowing seamless multimodality; impacting the overall behaviour of the drivers in the long term; improving the vehicle manufacturing process to directly include Smart Cities considerations; increasing the vehicles passenger and goods capacity; and enabling more efficient transport networks.

As an example, public parking spaces could be more efficiently managed, by guiding drivers to nearby free parking places (e.g., they could be displayed on portable or car-mounted devices), which requires accurate location information. By lowering the average time needed to find a public parking place from 15 minutes (estimated time in downtown Barcelona) to 12 minutes, the associated reduction in terms of CO_2 emissions would be of 400 tons/day. Besides, the provision of multi-modal travelling support (bus, taxi, train, plane, etc.) to citizens is instrumental to minimise traffic congestion problems. To that aim, platforms allowing transportation system operators, urban districts and passengers to effectively and securely share information are needed in Smart Cities. Distributed Urban Traffic Control systems capable of tracking cars location in real time, and adapting traffic management to current and predicted conditions, are instrumental too, which could be used, for instance, to set up fast lane corridors for emergency services (e.g., ambulances, police or fire brigades). Complementarily, dynamic carpooling systems [CoVi09], or the ones developed in the WiSafeCar project [WiSa11], provide a means to optimise the utilisation of transportation systems for commuters living in nearby places and sharing a common destination. Currently, the challenge is to go beyond static systems where routes are planned in advance, and make them advantageous for occasional travellers too.

5.2 Potential

A widespread adoption of ITS in urban areas has a tremendous impact on citizens' quality of life. On the one hand, traffic congestion can be reduced, and on the other, a number of energy-related and environmental problems (e.g., pollution and energy consumption) can be alleviated as well. Interestingly, a more efficient use of energy resources is one of the Grand Societal Challenges identified in the Innovation Union flagship of the European Commission [EuCo10b]. Besides, in DG INFSO's Digital Agenda [EuCo10a], it is acknowledged that R&D and innovation policies should be re-focused "in areas where Europe has a lead market potential, e.g., health, green mobility, smart grids & meters and energy efficiency". Moreover, the EU i2010 Intelligent Car Initiative [InCI10] indicates that intelligent systems embedded in car or in road infrastructure along with V2V and V2I communication systems should primarily target: (i) traffic congestion problems (10% of the road network is affected daily by traffic jams) and their associated costs; (ii) energy efficiency and pollutant emissions (road transportation accounts for 83% of the energy consumed by the whole transport sector and 85% of the

total CO_2 emissions); and (iii) safety issues (the cost of over 40 000 fatalities and 1.4 million accidents in the EU represent 2% of the EU GDP).

Interestingly, the information being managed by the aforementioned ITS systems and applications could be relevant to other domains. For example, data on traffic congestion patterns could be correlated with the concentration of pollutants, and this, in turn, with the impact of respiratory diseases in a given geographical area.

5.3 Challenges

An effective deployment of ITS in urban areas poses a number of technical, sociological, regulatory and economic challenges. At the technical level, it is often necessary to deploy large communication networks (e.g., Wireless Sensor Networks for the management of public parking spaces), which raises some concerns on the scalability of the proposed solutions when it comes to, e.g., conveying information to a central server for further processing. Besides, the adoption of service platforms capable of dealing with heterogeneous devices collecting different types of data, each of them holding individual vendor requirements, constitutes a technical challenge as well.

The availability of accurate location information is also challenging, due to the fact that, in dense cities, urban canyon effects often result into an insufficient number of visible satellites, and/or severe multi-path propagation this leading to poor signal quality. Therefore novel hybrid satellite/terrestrial positioning techniques need to be investigated, where signals from terrestrial communication systems are effectively exploited in scenarios when not enough satellites are visible [FeND10].

Cost-efficient and self-configuring road traffic management systems allowing for reductions of journey times, fuel consumption and pollution can be developed, on the basis of an appropriate combination of V2V and V2I communication technologies. The main technical challenge here is the real-time exchange of data among vehicles and roadside infrastructure.

In order to offer better alternatives to the user, multimodal public transportation information should be integrated within the itinerary results. Guaranteeing security and privacy along with effective user authentication mechanisms is key as well. Besides, the system has to be scalable in order to adapt to different business models and interact with other transportation providers, both public and private.

On a more practical side, protocols and algorithms successfully tested in lab conditions often exhibit poor performance in large-scale deployments: lower data throughput, data-link degradation, unstable multi-hop links, etc. Many of these problems can be fixed at the networking layer, but this comes at the cost of reduction in battery lifetime. To avoid that, it is crucial to test technology on large-scale testbeds (as in the SmartSantander project [SmSa11]), and conduct extensive field trials before undertaking commercial deployments. This encompasses measurement campaigns in order to assess the availability of satellite/terrestrial signals in urban areas.

In order to provide city council's staff with corporate network support in streets (e.g., for police patrols) or other generic city services (e.g., lighting, automatic watering, and waste collection) in a more efficient manner, some municipalities are deploying city-owned communication networks (e.g., based on Wi-Fi or WiMAX). Typically, such networks are progressively deployed (e.g., due to budgetary constraints), which impacts, for instance, on the performance of routing schemes and route stability. Hence, additional research is needed on network optimisation methods, experimental characterisation and monitoring of data traffic, and definition of troubleshooting strategies from network edges.

A challenge under the responsibility of the public administrations is to foster, publicise and convey the benefits that such technologies and applications will bring to citizens. Besides, the impact on the public opinion is clearly linked with the selection of applications (e.g., monitoring CO_2 emissions) needed to illustrate Smart City concepts. From the citizens' viewpoint, there are also some concerns with respect to the handling of personal data by public administrations (i.e., privacy issues) or about technology being used mostly to punish driving and parking faults, rather than to improve their quality

of life. Hence, it is also a challenge to stimulate technology acceptance since early deployment phases, or to fight the selfishness of the peers to share, gather, and work on collected information.

5.4 Technical Requirements

As a summary of the previous section, a non-exhaustive list of technical requirements encompasses: the provisioning of flexible, scalable and self-optimised networks; dealing with heterogeneity (support of different sensor and actuator technologies, radio interfaces, etc.); effectively exploiting location information, guaranteeing real-time exchange of data where needed; and providing security, privacy and authentication mechanisms.

5.5 Roadmaps

Nowadays, a number of standardised short-range wireless technologies (e.g., 802.15.4) are already available for deployments in Smart Cities. In addition, the 802.11p standard was finalised in 2010. The on-board installation of cards by car manufacturers is expected to ramp up in the coming months.

Besides, a number of EC-funded projects, such as ICT-EXALTED [EXAL11] or ICT-LOLA [LOLA11] are aimed to investigate the adaptation of existing and future cellular systems (LTE, LTE-A) to the requirements associated to machine-to-machine communications arising in such scenarios.

As for the availability of user devices, the number of Smart Phones equipped with GPS, Wi-Fi and cellular connectivity has steadily increased over the last years, and it is expected to continue to grow.

Finally, city regulations regarding in-street installations (e.g., info-panels, sensing devices, and communication equipment) should be carefully monitored, since this has an impact on the corresponding deployment strategies.

Although many technologies not related to ICT are foreseen in the development of the automotive sector [EPOS09], [EESG10], one can see that wireless communications and networks play a major role in this area as well, Figure 7, Figure 8.

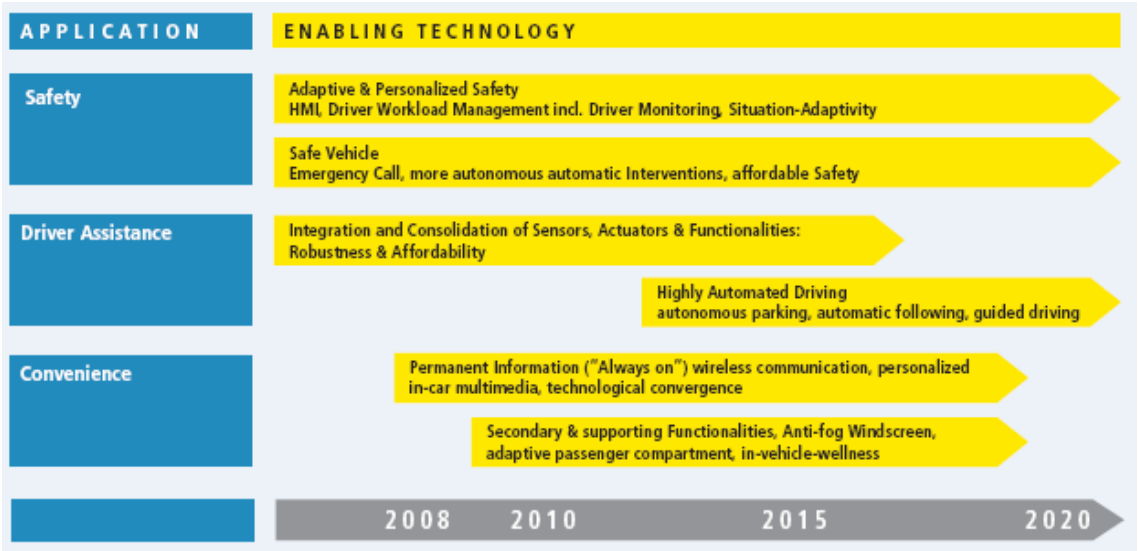

Figure 7 – Developments priorities in the automotive industry (extracted from [EPOS09]).

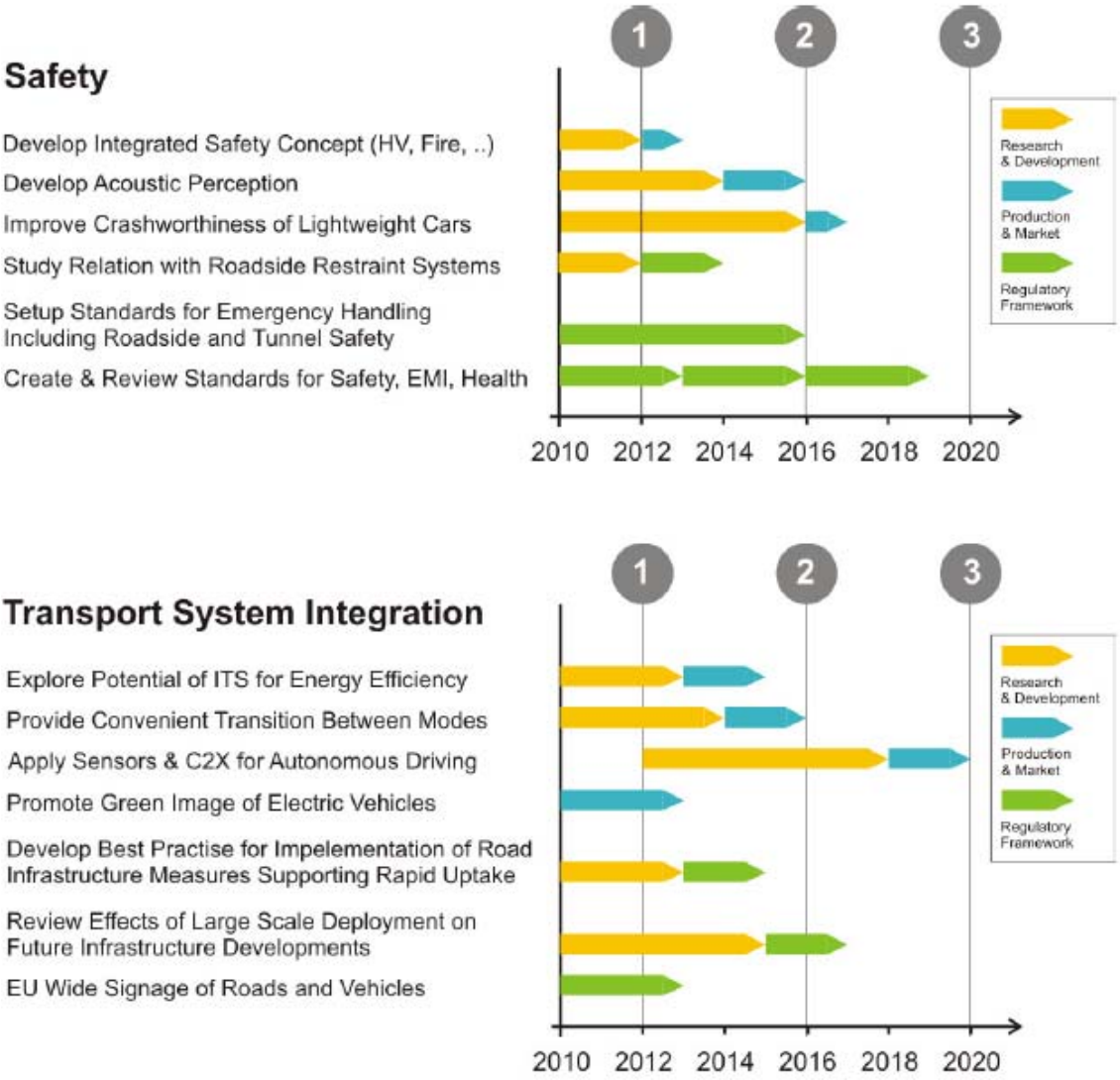

Figure 8 – Goals in safety and transport system integration (extracted from [EESG10]).

6 Smart Cities – Smart Grids, Energy Efficiency, and Environment

6.1 Application

Smart energy grids are the backbone of the Smart City, and will be responsible for the intelligent management and operation of energy networks in cities, by utilising the potential for shift between thermal and electrical loads. Furthermore, the integration of decentralised renewable energy sources into existing energy grids brings up some major technical issues that have to be treated. The interaction between advanced communications infrastructure, mathematical modelling techniques, and numerical simulation environments is a powerful tool in this research area. This also holds for the potential storage capacity for both electrical and thermal energy within energy networks, which can be achieved by intelligent demand side management.

A major requirement in Smart Cities is to leverage energy consumption between the different producers and consumers, which directly translates into reducing the pollution generated by today's cities and the emerging mega cities. To fully understand the complex interaction between the city and its energy management systems with all components at different urban scales (grids, buildings, supply technologies, and consumers), it is crucial to be able to unlock the full potential of smart grids. Therefore, a more holistic approach with a special focus on the interaction of all incorporated system elements is needed.

The successful combination of smart processes (e.g., demand side/response management and real-time consumption management) and smart technologies (e.g., smart meters and intelligent home energy management devices) will enable energy efficiency and savings to be achieved in the residential and business market. In fact, intelligent systems and integrated communication infrastructure are highly demanded, which can assist in the management of the electricity distribution grids in an optimised, controlled, and secure manner.

6.2 Potential

According to on-going international discussions, society is facing a worldwide climate change, which calls for an effective low-carbon policy and highly efficient energy technologies in the very near future. Dramatic CO_2 reductions have to be achieved, in order to prevent the gradual increase in global average temperature caused by fossil fuel combustion. Consequently, a change of the worldwide energy mix moving towards a smart integration of renewable energy sources (photovoltaic, geothermal, wind, biomass, etc.) into our energy networks is of crucial importance for achieving the ambitious targets for CO_2 reduction. Based on this measure, the reliance on imported fossil fuels could be decreased enormously, leading to improved energy reliability in Europe in the long term. However, according to the International Energy Agency, energy efficiency is one of the largest influencing factors for improving the critical situation our environment and society is facing.

As referred in the Digital Agenda for Europe [EuCo10a], smart grids are seen as a major opportunity to merge power and ICT industries and technologies to bring huge changes in people's lives. ICT offers potential for a structural shift to less resource-intensive products and services, for energy savings in buildings and electricity networks, as well as for more efficient and less energy consuming intelligent transport systems.

Energy efficiency offers a powerful and cost-effective tool for building a sustainable energy future based on renewable energy sources. Furthermore, by focusing research on the development of

intelligent methods for optimising energy efficiency, the need for investment in new energy infrastructure can be reduced significantly, fuel costs can be cut, competitiveness is increased, and consumer's welfare is improved. However, in order to realise the full potential of energy efficiency, the current energy policies and technologies have to be further developed.

6.3 Challenges

Apart from the global environmental changes, the urbanization of society is another major factor that has to be considered in the context of energy. According to [UnNa10], the majority of people worldwide will be living in urban areas or cities by the year 2010, which is referred to as the "tipping point".

From this trend, it is clear that cities around the world will play a crucial role in the future energy system, displaying the large potential of cities for energy savings. The increasing energy demand in cities is without doubt a huge challenge that has to be faced. However, the overall building density of urban areas reflects itself as well as a chance for optimised energy efficiency. From these facts, it can be concluded that future cities will have to address major problems for guaranteeing continuous and efficient energy supply in the long term.

One particular application is to develop new surveillance and control strategies for both buildings and energy networks, allowing for the intelligent and adaptable management of the entire energy system, in the context of the stochastic distribution of energy supply and demand, especially taking the highly volatile nature of renewable energy sources into account. The underlying communication needs include sharing sensor information among consumers, producers, and the grid, with various requirements in terms of reliability, real-time behaviour, and bandwidth. Those strategies include power quality control, as well as interactive feedback to human users, and will increase the energy efficiency of the entire Smart City, requiring all participants (grids, buildings, and consumers) to be connected with appropriate means of communication. Therefore, it is important to build a consensus upon a communications architecture, its underlying communication technologies derived based on ICT requirements, data models that are able to cope with specific services' or applications' needs.

As a main recommendation, the cooperation between the ICT industry, other sectors, and public authorities, should be stimulated to accelerate development and wide-scale roll out of ICT-based solutions for smart grids and meters. The ICT sector should deliver modelling, analysis, monitoring, and visualisation tools to evaluate the energy performance and emissions of cities and regions.

Other challenges include: new communication and networking ICT technologies (improved immunity to environment electromagnetic noise, interferences and network performance; support of large unstructured mesh networks, including self-organisation, self-healing, and fast and reliable routing; open protocols for the development of new products and services, addressing authentication, security mechanisms, profiles, and certification); new affordable devices that gather environment data (e.g., weather sensors, small Doppler radars, and computer vision systems); new intelligent algorithms for smart ubiquitous environments; new light sources (i.e., next-generation-LED); new and fair regulations inside EU that enable the massive implementation of the Intelligent Street Lighting System idea provided by different vendors; new EU products for global markets that enable a steady economic growth; and advanced products and services based on IP created inside EU to foster innovations, and economic growth in the SME sector, based on an open innovation scheme inside the EU.

6.4 Technical Requirements

The requirements for the communications infrastructure in this area of energy efficiency and smart grids are: highly reliable, real-time communication for power quality control in the grid; protocol

specifications for smart grid components (several candidates exist), including day ahead planning, exchanging load schedules, schedule load shedding, and dynamic adaptation schemes; standardisation of smart meter communications; application level service definitions for distributed renewable energy sources and for accessing buildings and building automation systems from the grid, focusing on standardisation, aiming at interoperability, predictability and reliability; sensor (and actuator) networks for dynamic reconfiguration of open operated city grids to fully meshed topology, dependent on losses, local generation (buildings) and demand peaks; ICT infrastructure and reliability for adaptive protection based on multi agent systems; and reliable redundant communications.

6.5 Roadmaps

The area of energy efficiency and smart grids is being addressed by a few stakeholders, and some related areas have been put into a timeline. The building construction sector has identified some key areas for development in the next years, [REEB10], which include smart meters and Wireless Sensor Networks, Figure 9, while energy efficiency auxiliary technologies are expected to continue to be developed [EPOS09], Figure 10.

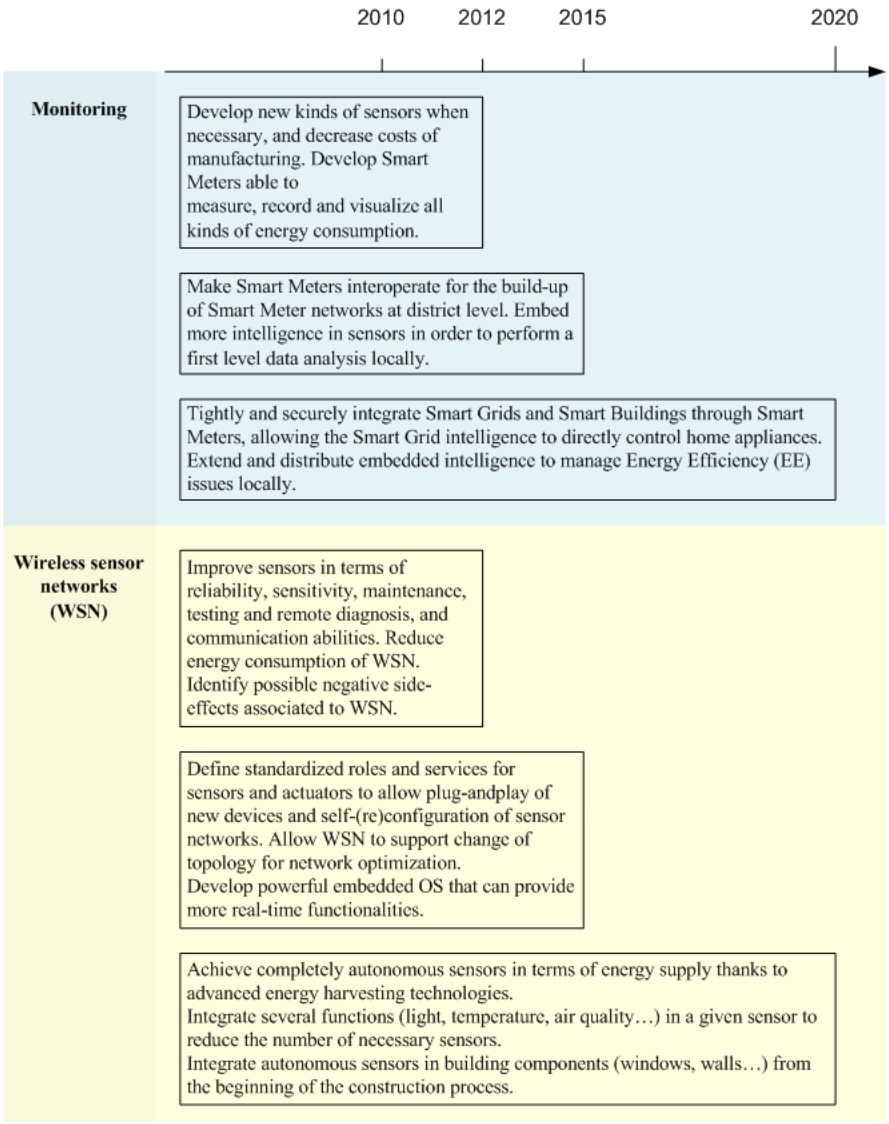

Figure 9 – Roadmap for monitoring and Wireless Sensor Networks in buildings (based on [REEB10]).

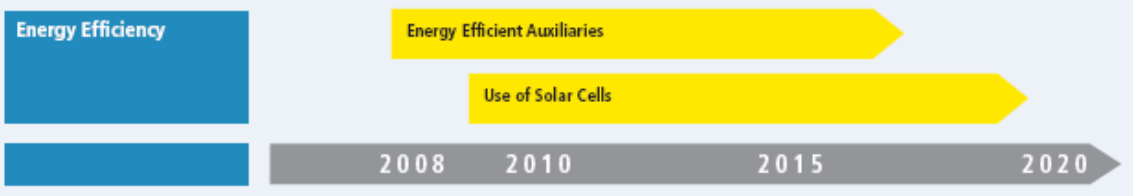

Figure 10 – Energy efficiency timeline (extracted from [EPOS09]).

7 Conclusions and Recommendations

The concept of Smart Cities gained importance in the last years, as a means of making ICT enabled services and applications available to the citizens, companies and authorities that are part of a city's system. It aims at increasing citizens' quality of life, and improving the efficiency and quality of the services provided by governing entities and businesses. This perspective requires an integrated vision of a city and of its infrastructures, in all its components: it has to incorporate a number of dimensions that are not related to technology, e.g., the social and political ones. A Smart City can be taken according to six characteristics: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living.

This White Paper identifies major topics of Smart Cities that will influence the ICT environment, as covered by Net!Works. Applications and requirements are grouped into 5 topics:

- Economic, Social & Privacy Implications
- Developing E-Government
- Health, Inclusion and Assisted Living
- Intelligent Transportation Systems
- Smart Grids, Energy Efficiency, and Environment

Each of the topics is put into perspective according to its potential, challenges, technical requirements, and roadmaps.

In order to achieve the goals of a Smart City, there is the need to increase efficiency and efficacy of government, developing environment-friendly applications, increasing mobility, providing better health services, stimulating economic prowess, etc. It is vital that a city clearly outlines these goals in policy making, defining a strategy founded in research to reach them, and which role the city should play.

All the domains discussed in this White Paper raise new challenges in security and privacy, and although security is not the main selling point for most applications, users implicitly expect systems to be secure and privacy-preserving. If users deem a system as insecure or threatening their privacy, it will not be able to establish itself successfully in the market. In order to achieve user consent, trust in, and acceptance of Smart Cities, integration of security and privacy-preserving mechanisms must be a key concern of future research. Overall research challenges can be classified into the following aspects: handling of the increasing complexity of distributed systems from the security perspective is required; identity and privacy management, where, e.g., pseudonymisation must be applied throughout the whole system, in order to separate the data collected about a user from the user's real identity; integration into systems of security technologies, e.g., advanced encryption and access control, and intelligent data aggregation techniques. A roadmap in this area foresees that the technological development should be accompanied by legal and communication aspects.

One of the critical elements that will be of ever increasing importance for the Smart Cities of the future is which role(s) the city will take up as an actor within an increasingly complex value network. New players enter the market, actors shift their business strategies, roles change, different types of platforms emerge and vie for market dominance, technological developments create new threats and opportunities, etc. This existing complexity increases exponentially, when considering the involvement of cities as actors in the value network, with all the agencies and domains they entail, and the large differences between cities themselves. Ubiquitous connectivity needs to be facilitated, supported by relevant services and applications (potentially in all the domains in this White Paper).

An element related to the trend of platformisation is cloud computing, which is increasingly helping the private sector to reduce cost, increase efficiency, and work smarter. From a business perspective, cloud computing is a key concept to enable a global ecosystem, where organisations are able to be more competitive. In the context of this ever-increasing complexity and platformisation, interoperability between systems will be exceedingly important. Standardisation is clearly an important task, affecting all levels of middleware implementation, assuring transparent and reliable interfaces to the

middleware, as well as interoperability between products and services across very different domains. Thus, interoperability and standardised ways of communication between systems is an important research subject, crosscutting all Smart City domains.

One particular challenge in the context of Smart Cities relates to open data business models. As services become pervasive and ubiquitous, the matter of opening up databases will become more important. Transparency towards the end user on how his/her information is being used, with clear opt-in options and secured environments, has to be the starting point when providing services that leverage personal data. The Public Sector Information re-use and utilisation of open data introduces a paradigm shift that will impact on many people working in public administration. Among many activities necessary for Public Sector Information provision and re-use, one can identify achieving most easy comparability and comprehensibility through furthering meta-data and data standardisation, and supporting the publishing of more fine granular data through mechanisms for automatic anonymisation or pseudonymisation of data sets.

The development of efficient and effective e-government is a prerequisite for the development of Smart Cities. The lack of horizontal and vertical integration across the various e-government and urban initiatives in EU states, and the relatively low level of interest shown by many national authorities, limit efforts for the systemic development and implementation of local e-government. The development of transnational authentication systems for citizens and businesses, the development of agreed frameworks for data privacy, and the sharing and collection of individual and business data, are key. Standardisation and interoperability are key requirements for the widespread adoption of technologies and services to provide e-government at the city level. Cities will need to be able to better integrate wireless networks, making provision seamless and transparent. Cities will increasingly move from being service providers to platform ones, providing an infrastructure that enables the development of a broad range of public and private applications and services. Standardised technologies and infrastructures that are necessary to provide personalised and location-based services need to be developed.

The development of Smart Cities requires a pragmatic approach to technological development and deployment that is based on open standards and interoperability, which is vendor neutral and focused on the needs of cities, citizens, and businesses. Technologies need to be deployable, and supported by sound business models. Smart networks and infrastructures need to be developed in order to exchange information from person to person, from people to machines, from machines to people, or from machines to machines. Smart Cities need to be able to integrate themselves into national, regional and international infrastructures. Although implementation aspects depend strongly on national, regional and local authorities, European wide recommendations and directives will definitely contribute to accelerate the deployment of Smart Cities in their e-government perspectives. Roadmaps have been established in Europe, in order to increase of trust in e-government.

Health, inclusion and assisted living will play an essential role in Smart Cities. Many existing and potential technologies under development for the maintenance and/or supervision of health and wellbeing offer a great promise, ranging from health monitoring services to “lifestyle monitoring”, encompassing platforms for elderly, support to independent living with social and medical assistance in the home, and helping people with chronic diseases, among others. Inclusion, being concerned with minimising all barriers to learning and participation, whoever experiences them and wherever they are located, has to consider the improvement of quality of life of users by ensuring seamless access to ICT-based services. Furthermore, the needs of people with physical impairments have also to be taken into account. Increased use of ICT among elderly people, the technologies used to be elderly friendly, and encourage elderly people to use the services, are also among the needs in this area; the major hurdle in this domain is the lack of familiarity of elderly people with such new services and technology. Current trends in personal health systems, enabled by the advances in ICT, biomedical engineering, healthcare technologies, and micro- and nano-technologies, can greatly contribute to these goals.

The demand for healthcare and assisted living services is rising, because ageing is changing disease composition. Furthermore, healthcare systems are likely to face substantial challenges in the future,

with public expenditure on healthcare likely to grow by 1.5% of GDP across the EU by 2060. In this context, the provision of healthcare services using immediate applicable innovative ICT is seen to be one of the elements helping the containment of healthcare delivery costs.

The challenges in health, inclusion and assisted living can be summarised into three different categories: Social, Market and Business, and Technical. The grand social challenges address access to public and private services, policy and ethics, and safety of people living independently. Market and business opportunities include a Go to Market plan, and economic and financial aspects. The technical challenges encompass geographical localisation and positioning, interoperability and maintenance of connectivity context, and pervasive borderless middleware platforms.

Requirements for ICT in health include biosensors and other new medical technologies (to reduce costs dramatically, and lead to do-it-yourself home care), high definition image and video wireless transmission (to enable remote diagnosis, also in mobile scenarios, e.g., ambulances), data security (encryption, authentication and authorisation), devices connectivity and interactivity, end-user interface problems, service discovery, scalability and survivability, interworking, community-to-community application messaging propagation, location information sharing, and application service migration. In Europe, an integrated perspective on healthcare solutions for the near- to long-term views has been presented, some of the enabling technologies being directly related to communications, bridging a direct gap in between the health area (within Smart Cities) and the technological development of communications (radio and network components) in the years to some.

Given that a vast majority of the European population lives in urban areas, their mobility needs result into a number of problems, such as traffic congestion, increased pollution levels and/or greenhouse gas emissions, or excessive travelling time and energy consumption. These problems can be largely alleviated by exploiting Intelligent Transportation Systems (ITS) and further adoption of vehicle-to-vehicle and vehicle-to-infrastructure communication networks, in Smart Cities. From the ICT viewpoint, applications should reduce the mobility needs for both individuals and goods, optimise trip planning and management, improve the vehicle manufacturing process, increase vehicles passenger and goods capacity, and enable more efficient transport networks.

A widespread adoption of ITS in urban areas has a tremendous impact on citizens' quality of life. On the one hand, traffic congestion can be reduced, and on the other, a number of energy-related and environmental problems can be alleviated as well. The information being managed by ITS applications could be relevant in other domains, which increases its potential.

An effective deployment of ITS in urban areas poses a number of technical, sociological, regulatory and economic challenges. At the technical level, it is often necessary to deploy large communication networks, which raises some concerns on the scalability of the solutions. Besides, the adoption of service platforms capable of dealing with heterogeneous devices collecting different types of data, each of them holding individual vendor requirements, constitutes a technical challenge as well. The availability of accurate location information is also challenging, therefore novel hybrid satellite/terrestrial positioning techniques need to be investigated. The main technical challenge in vehicle-to-vehicle and vehicle-to-infrastructure communications is the real-time exchange of data among vehicles and roadside infrastructure. The system has to be scalable in order to adapt to different business models and interact with other transportation providers, both public and private. Often, systems exhibit poor performance in large-scale deployments, so it is crucial to test technology on large-scale testbeds, and conduct extensive field trials before undertaking commercial deployments. Additional research is also needed on network optimisation methods, experimental characterisation and monitoring of data traffic, and definition of troubleshooting strategies from network edges. A further challenge, under the responsibility of public administrations, is to foster, publicise and convey the benefits that such technologies and applications will bring to citizens.

Although many technologies not related to ICT are foreseen in the development of the automotive sector, one can see that wireless communications and networks are key in this area. Roadmaps established in this area forecast that wireless communications will play a major role before 2020, that

the regulatory framework for emergency communications should be ready by 2016, and that the potential for exploring ITS for energy efficiency should have products on the market by 2015.

Smart energy grids are the backbone of the Smart City, and will be responsible for the intelligent management and operation of energy networks in cities, by utilising the potential for shift between thermal and electrical loads. A major requirement in Smart Cities is to leverage energy consumption between the different producers and consumers, which directly translates to reducing the pollution generated by today's cities and the emerging mega cities. The successful combination of smart processes (e.g., demand side/response management and real-time consumption management) and smart technologies (e.g., smart meters and intelligent home energy management devices) will enable energy efficiency and savings to be achieved in the residential and business market. In fact, intelligent systems and integrated communication infrastructure are highly demanded, which can assist in the management of the electricity distribution grids in an optimised, controlled, and secure manner.

The potential for smart grids is enormous. Smart grids are seen as a major opportunity to merge power and ICT industries and technologies to bring huge changes in people's lives. ICT offers potential for a structural shift to less resource-intensive products and services, for energy savings in buildings and electricity networks, as well as for more efficient and less energy consuming intelligent transport systems.

It is clear that cities around the world will play a crucial role in the future energy system, displaying the large potential of cities for energy savings. One particular application is to develop new surveillance and control strategies for both buildings and energy networks, allowing for the intelligent and adaptable management of the entire energy system, in the context of the stochastic distribution of energy supply and demand, especially taking the highly volatile nature of renewable energy sources into account. The underlying communication needs include sharing sensor information among consumers, producers, and the grid, with various requirements in terms of reliability, real-time behaviour, and bandwidth. It is important to build a consensus upon a communications architecture, its underlying communication technologies derived based on ICT requirements, data models that are able to cope with specific services' or applications' needs.

As a main recommendation, the cooperation between the ICT industry, other sectors, and public authorities, should be stimulated to accelerate development and wide-scale roll out of ICT-based solutions for smart grids and meters. The ICT sector should deliver modelling, analysis, monitoring, and visualisation tools to evaluate the energy performance and emissions of cities and regions. Other challenges include support of large unstructured mesh networks, including "self-techniques", and new intelligent algorithms for smart ubiquitous environments.

The requirements for the communications infrastructure in this area of energy efficiency and smart grids include highly reliable and real-time communications for power quality control in the grid, protocol specifications for smart grid components, infrastructure and reliability for adaptive protection based on multi agent systems, and reliable redundant communications.

The area of energy efficiency and smart grids is being addressed by a few stakeholders, and some related areas have been put into a timeline. The building construction sector has identified some key areas for development in the next years, which include smart meters and Wireless Sensor Networks, while energy efficiency auxiliary technologies are expected to continue to be developed.

In conclusion, one has addressed application areas within Smart Cities, i.e., e-Government, Health, Inclusion and Assisted Living, Intelligent Transportation Systems, and Smart Grids, Energy Efficiency, and Environment. Within these areas, examples have been shown, clearly linking the underlying technologies with end-users at a broader view (ranging from individual users to official authorities, and encompassing businesses). In order to achieve the goal of Smart Cities, one has to develop quite a number of technologies in the area of wireless and fixed communications networks, and many research challenges have been identified.

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