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Roadmap for Real World Internet applications – Socioeconomic scenarios and design recommendations

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Abstract. This paper emphasises the socioeconomic background required to design the Future Internet in order that its services will be accepted by its users and that the economic value latent in the technology is realised. It contains an innovative outlook on sensing aspects of the Future Internet and describes a scenario-based design approach that is feasible to roadmap the dynamic deployment of Real World Internet applications. A multi-faceted socioeconomic assessment leads to recommendations for the technology deployment and key features of the Future Internet that will globally integrate technologies like Wireless Sensor and Actuator Networks and Networked Embedded Devices.

Keywords: Real World Internet, Future Internet, Scenario-based Design, Socioeconomics, Business Models, Requirements

1. Introduction

In the context of the current endeavour to create a global architecture as well as application services for the Future Internet, the SENSEI project [1] will be considered as a case to demonstrate how a scenario-based approach and socioeconomic assessment can contribute to the design of the Future Internet (FI). SENSEI (Integrating the Physical with the Digital World of the Network of the Future) is an Integrated Project in the EU's Seventh Framework Programme, in the ICT (Information and Communication Technologies) call: The Network of the Future.

The SENSEI project is designing an architecture that aims at being a key enabler of the real world dimension of the Future Internet [2]. SENSEI's vision is to realise ambient intelligence in a future network and service environment, and to integrate Wireless Sensor and Actuator Networks (WSAN) efficiently into the Future Internet. The system developed by the SENSEI project (of the same name, i.e. SENSEI) is expected to play an essential part in transforming the existing Internet, Mobile

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Networks and Service Infrastructures into a future network capable of dealing with the challenging demands of a future networked society.

In this paper, the benefits of the technology characteristics in SENSEI's Future Internet framework are demonstrated through application scenarios. These scenarios are used as a roadmap for the system and architecture deployment. The application scenarios were not only used to picture a realistic vision of a Future Internet, but were also used to anticipate the evolution of the Real World Internet (RWI). The goal is to enable a Future Internet system that is designed for change, is accepted by all stakeholders involved, and creates value for the users.

To design such a system, a group of experts was gathered to analyse the socioeconomic dimensions of the Future Internet. The experts from different European universities and industrial companies in the ICT sector have backgrounds in computer sciences, engineering, business administration and management. Face-to-face workshops were organised and a wiki was set-up to produce application scenarios, to analyse the sociological perspective, and to assess the business characteristics. The results of this study are summarised in this paper.

In section 2 three application scenarios picture a roadmap for the deployment of Real World Internet services in the urban context. Section 3 explores to which extent this real world dimension of the Future Internet could be beneficial to the user and to society. Section 4 focuses on the business perspective of the dynamic deployment of the Future Internet and its applications. Based on the socioeconomic assessment of the roadmap, the concluding section 5 deduces the recommendations for the technology design and deployment.

2. Application scenarios for SENSEI applications roadmap

Eighteen application scenarios in eight application spaces were created by the SENSEI partners to analyse the "real world" dimension of the Future Internet [3]. The elaboration of the scenarios was continuously driven by the Future Internet vision and its key dimensions: Future Networks, Internet of Things, 3D Internet, Internet of Services and Internet of Contents [4]. The scenarios depict FI perspectives from short, to mid, to the long term. In the following case study, three scenarios are analysed to roadmap some RWI applications in the Smart City application space. The initial scenarios [3] – 1° *Smart Places*, 2° *Networked Inhabitants*, 3° *City Information Model* - present RWI applications through concrete usage situations and cover three deployment phases that describe a "*now*", "*new*", "*next"* time horizon.

2.1. Now - Smart Places

The first phase scenario describes the RWI applications that benefit to the stakeholders of a shopping mall. This is a realistic and "feasible" scenario in the short term since it involves a set of services provided to the users within a limited area. This scenario is incremental from a technological point of view since it exploits existing communication networks and trivial WSAN independent solutions (CCTV, anti-theft gates, temperature, bar code based stock control, etc.). In terms of context awareness, it is based on consumers' real-time geo-positioning, physical condition and dynamic user profile. From a business perspective, it involves the mall stakeholders federated by a neighbourhood of business interest. From societal perspective it provides services adapted to a user lifestyle that is very similar to the current lifestyle and relationships in western cities.

2.2. New - Networked Inhabitants

The second phase scenario describes RWI benefits to city-dwellers in mobile lifestyle. This scenario is innovative from the technology perspective since it involves sensing various physical phenomena through heterogeneous communication networks and horizontal exploitation of WSAN (see section5.2). It relies on the improvement of the existing infrastructure: new sensor nodes and WSAN are added to enlarge the scope of the sensed phenomena with a continuous quality of sensed and processed information. From a business perspective, additional malls are connected together in order to offer a broader and ubiquitous scope of end-user services. From the societal perspective, it involves a new generation of applications that will impact deeply the users' behaviours, mobility, sense of sustainability and relationships.

2.3. Next - City Information Model

City Information Model is the most futuristic scenario from a technology perspective. It involves a global coverage and networking of the city by WSAN. Horizontalisation is optimised through using and reusing non dedicated WSAN for an exponential amount of applications. From a business perspective it facilitates dynamic supply and demand increase as well as just-in-time provision and the trend towards the experience economy [5] reduces stocks in stores and increases uptake of “you shop we drop” services. Micro transactions and demand for behavioural intelligence pulls data provision markets. New business actors such as the transport sector enter the network in order to provide a new generation of services to the citizens and to regulate the prices depending on energy savings and the carbon emissions related to clients’ purchases. From a societal point of view, it involves a holistic vision where new types of applications influence the society and new methods for supporting users' behaviours and values are created.

2.4. Scenarios road mapping

The three phases involve different levels of societal changes, business innovation and technical feasibility. They are not discreet but show a continuous timeline which depends on the context of the actual end use.

The first phase – Now - is *evolutionary* from a societal point of view and *incremental* from technological angle since it is the least integrated: the infrastructure of a mall is used for applications dedicated to the stakeholders of this place.

The second phase – New - is more *futuristic* from the socio economics point of view and *innovative* from the technology side since it implies the deployment of connections between different and separate areas in the city and it starts to integrate different entities in extension to the shopping mall, e.g. private residential WSAN infrastructures.

The third phase – Next - is the most *revolutionary* one from the society point of view because it involves holistic applications of RWI. It proposes a fully horizontal vision of RWI applications with integration of all types of WSAN infrastructures in the city for the provision of an unlimited scope of applications. This is a *disruptive* vision compared to the existing Internet technology.

3. Societal analysis of the RWI scenario roadmap

The Life Cycle description of Real World Internet applications enables to analyse some requirements that a RWI system has to challenge to provide benefits to the user and society [6] through FI applications in key domains such as environment, mobility, safety, professional and industrial activities, citizenship, and ethics.

3.1. The Future Internet experience

Real Word Internet will play an essential part in transforming the existing Internet, mobile networks and service infrastructures into a Network of the Future which is capable of dealing with the challenging demands of a future networked society [7]. It will change the user experience of Internet in the sense that the existing distinction between the physical and digital worlds will increasingly blur. Today's Internet will change from the distinct network, providing specific services accessible through dedicated terminals, to an Internet dissolved in the artefacts of the physical world accessible via heterogeneous networks enabling users to browse the world as they browse the Internet.

3.2. Environment

RWI applications must support the reduction of the human impact on the environment. The benefits are highlighted in the *New* and *Next* scenarios and are particularly tangible in city planning, transport schemes and built environment. Beyond the application spaces, a RWI system should be designed according to sustainable constraints:

- The RWI framework should support *horizontal* use and reuse of common WSAN infrastructures to develop a variety of applications. The RWI technology must reduce the necessity of end-to-end and vertical infrastructure dedicated to the delivery of a given application. It should not therefore require as many WSANs as applications.
- RWI system architecture should be *scalable* to enable its functions to *evolve* in order to meet the future requirements of technology changes and growth. It will not be necessary to replace the system to meet the increasing demand of context information and actuation.

3.3. Mobility

RWI applications will support the users' mobility [8], in particular in the city lifestyle and transport organisation. These benefits will be perceptible at short term as exposed in the *Now* scenario but will be at their optimum level at medium term as pictured in the *New* scenario. Beyond application spaces, RWI design principles should integrate mobility in their intrinsic properties:

- The RWI system must ensure the *continuity* of the services that the user needs with an adequate quality despite the user's mobility.
- The RWI framework should *reduce complexity* to enable an easy access of user applications to the sensing and actuation services that are available everywhere. The RWI framework should provide mobile users with a good level of *security and privacy* protection.

3.4. Safety and security

RWI applications will improve the users' safety in various activities, in particular in the transport, built environment, crisis management and healthcare domains. These benefits will be perceptible in the short term as shown in the *Now* scenario but will be at their optimum level at medium term as pictured in the *New* scenario. Beyond the application spaces, a key design goal for RWI system should be *security* in order to guarantee the quality and reliability of the context information and actuation.

3.5. Citizenship

Integrating the physical with the digital world addresses the socio-economic medium and long term needs that arise through the increasing demand for incorporating ICT in many services for citizenship and quality of life. RWI applications are expected to increase the sense of the community by making perceptible the side effects of individuals' behaviour. In turn, it should improve the quality of services provided to the citizens. These benefits will be perceptible at short and medium terms as it is shown in the *Now* and *New* scenarios. The *Next* scenarios depict holistic applications of WSAN at the level of the entire society that involve deep changes in the citizens' practices (e.g. transport), in the society rules and business activities.

3.6. Professional and industrial

RWI will support professional and industrial activities. These benefits will be perceptible at short term as shown in the *Now* scenario. RWI system must support new business opportunities and new industrial partnerships by optimising the integration of sensed and controlled physical phenomena to the Internet:

- In particular, RWI must facilitate the *horizontal* reuse of sensing and actuation services for many applications marketed by diverse business stakeholders.
- RWI *scalability* must support the growth of business needs for sensing and actuation services.
- *Privacy and security* mechanisms must provide the adequate level of trust to support the information and actuation trades between the stakeholders.
- The *reduced complexity* of accessing sensing and actuation services for the applications they develop, use or trade must encourage the business actors and newcomers to develop new generation of services.
- The RWI framework should be *evolvable* to support system upgrades and technological changes required by business tussles [9] carried out by actors.

3.7. Privacy and Ethics

With the integration of a real world dimension to the Internet, privacy and related ethical issues will increase [10]. Even if RWI technology integrate the appropriate mechanisms, privacy and ethics can persist as critical issues and mistrust may slow the adoption [11] despite it enabling an open and secure market space for context-awareness and real world interaction. To address this challenge, mechanisms for accounting, security, privacy and trust that provide different levels of granularity are essential for RWI participating systems. Access to context and actuation services must be trustable and secure, while the privacy of individuals and corporations are not violated. RWI system must ensure that only authorised services are able to gain access to potentially sensitive private information and critical actuation.

4. Business challenges of Future Internet applications

The Life Cycle description of RWI applications is a way to depict the business challenges in deploying the Internet of the Future. The Smart City roadmap can be seen as a paradigm, which highlights two points. First, applications in Smart City domain are already available now. In this respect the stakeholders are already involved in laying the enabling foundation for the RWI vision. Second, a requirement of paramount importance is to integrate the stakeholders in this “runtime” [9] design process. From that point of view the scenarios also aim at considering how the stakeholders will make the system evolving and, in sum, will co-design the system.

To enable applications like those explained for the Smart City domain the Internet will require an evolution in its applications and architecture. The evolution of the Internet goes along with the extension of its reach to mobile users and end-devices with the inclusion of next generation mobile networks. The drivers for this evolution are manifold: Advances in ICT foster the emergence of ever more players in the Internet value network. Different players as diverse as users, developers, manufacturers, operators, service and content providers, and legal bodies are involved in different RWI application spaces, all of them having different business rationales and potentially conflicting interests. Their different ambitions may lead to a permanent process of continuous refinement of the system. Users desire reliable, secure, exciting and easy-to-use services that are reasonably priced with the complexity of the underlying technologies hidden from view. Service providers aiming at making profit, try to exploit the latest ICTs to satisfy users’ needs. Sustainable economic success requires insights into both the technological development and the realization of economic value latent in ICT. ICT must create value for the customer therefore business models must prove their appropriateness as intermediaries between ICT and economic value. The deployment of an infrastructure capable for RWI services is the basis for applications that provide end-user oriented services. The ultimate goal is the creation of end-user oriented services which generate revenue.

Deployment of a vast range of RWI services implies the involvement or influence of many different stakeholders. Deployment of a particular SENSEI service may involve only one or a few. Some of the stakeholders might have direct benefit from the RWI services once they are up and running – others may not. Therefore, it is essential that the stakeholders require deploying RWI services which do not directly benefit from the RWI service get a recompense for their engagement.

Stakeholders can generally be seen as taking on different business roles. Several key stakeholders are of importance for the development, deployment and operations of RWI services and systems.

First, basic system enablers need to provide an underlying infrastructure. The System Manufacturer constructs and assembles a self sustained system, e.g. a computer or a sensor node. The component manufacturer makes components of systems and provides those to system manufacturers. Component Manufacturers includes sensor manufacturers or computing processor manufacturers.

Second, the process of developing and deploying RWI services and the required system infrastructure for use in service "runtime" involves another set of business roles. These can be directly involved in the process, or have an indirect influence by providing conditions for what services will be needed, or how the services and systems will be provided and operated. The Application Developer designs, constructs, develops and does initial testing of RWI services. The System Deployer deploys the system in the field where it will be functionally operable after it has been appropriately configured. It relies on e.g. non–functional system requirements. Stakeholder examples include a building construction firm doing electrical or appliance installations, or an operator which deploys a targeted infrastructure for RWI service provisioning. Authority bodies could, for example amend or repel laws, which can have an impact on services developing and deploying.

Third, after setting up the infrastructure and the development of services, several business roles are needed to operate and deliver RWI services. The Application Service Provider provides the end-user oriented services. Examples of end-user oriented services include the provision of context-aware information adapted to personal references, or building monitoring and control services. The Connectivity Provider makes connectivity available between different deployments in the system, for example wide area cellular connectivity for WSAN, or connectivity to hosting servers. The Sensor and Actuation Service Broker acts as a broker between users of services and providers of services. The Content Provider gathers, organizes, and presents information that is available from different sources excluding sensors and actuators. Content Providers might specialize on a certain topics, like weather forecast, monitoring and control information, tourist information, or map databases. The WSAN Service Provider delivers the services or information from one or several WSAN deployments.

An understanding of the roles and interests of different stakeholders is important to provide recommendations for the architectural design of the RWI. The architecture of the RWI must be design in a way that it realizes the economic value latent in technology. The concluding design recommendations will address this issue.

5. Concluding design recommendations

The scenario based assumptions of the RWI's impact on society support the business and technology roadmap assessment since it is aimed at understanding the possible arising demands for a system that globally integrates WSAN in the context of a Future Internet. Consequently, the architecture of a RWI application platform should be designed in a way that meets the demands of multiple players in the Future Internet: scalability, horizontalisation, privacy and security, heterogeneity, reduced complexity, simplicity, manageability, service differentiation, continuity, and evolvability [2].

5.1. Scalability

The architecture must be scalable to support efficient internetworking of an increasing number of highly distributed service end-points acting as producers and consumers of real world information and actuation. The key scalability requirement is to allow billions of sensors and actuators to be active simultaneously. It needs to support dense configurations of WSAN with many nodes active in each. This requires efficient usage of radio spectrum to allow for hundreds or thousands of nodes to be active in the same local area and to prevent conflicts with neighbouring WSAN on the same frequencies.

5.2. Horizontalisation

The horizontal reuse of sensing, actuation and processing services for a large number of applications must be facilitated. A key element in each step of the roadmap is the availability of a wide range of custom and personalised services coming from many vendors. Horizontalisation means that the infrastructure needs to be updated from whichever sensors and actuators are available. Similarly, the way WSAN are accessed from services needs to be independent of any infrastructure specifics. In addition, WSAN cannot be assumed to be homogeneous and single vendor: RWI application platform needs to provide horizontal functionality accessible to all of these services and that allows them to abstract from the vendor specifics of the infrastructure underneath, which can vary from location to location.

5.3. Privacy and Security

Privacy must be protected and adequate security must be offered for participating systems and the entities being observed and acted upon. The context model needs to adapt to the security context of those accessing it. It is also necessary to support resource protection at the network level. Moreover, it is required that communication between nodes in a WSAN cannot be interfered with.

5.4. Heterogeneity

The RWI application platform architecture must accommodate a variety of different (technology or administrative domains) WSANs at its edges. The applications need to accommodate a very heterogeneous environment with WSANs and devices from many vendors, a wide variety of networking technologies, including: WLAN, 2G, 3G, 4G mobile networks, and Body Area Networks. The context model needs to abstract from vendor specifics and provide a generalized, vendor independent way of accessing context while at the same time supporting vendor specific features as needed. The network & security infrastructure needs to interoperate across different networks. WSAN access points need to support nodes from different vendors

5.5. Reduced Complexity

Complexity of accessing sensing and actuation services for applications must be reduced. The network has to self-configure and make it easy for service implementers to find and interact with resources in the RWI platform. To enable the diverse service ecosystem that the applications need, RWI applications must hide specifics and provide a way to implement services that hides the complexity of the RWI infrastructure.

5.6. Simplicity

The architecture must reduce the barrier of participation for WSAN and thus facilitate deployment by ease of integration. Uniform ways to access context information should be supported. Adding resources to RWI application platform as well as accessing existing ones should be straightforward. Service creation in the RWI application platform ecosystem needs to be simple so as to stimulate maximum market adoption.

5.7. Manageability

The architecture must permit distributed management of its participating systems and their resources should the involved management authorities belong to different administrative domains. Due to the heterogeneity of the infrastructure as well as the large number of different stakeholders, management should be decentralized. A pluggable framework for sensor and actuator networking should be provided.

5.8. Service differentiation

Service differentiation should be supported to ensure predictable system behaviour in accordance with agreed service levels among participants despite changing system conditions. Context models need to take into account the vastly differing needs of services. Extensibility and management features are required to allow new differentiation services to be integrated. It should be possible to update sensor actuator nodes in the field when new differentiating services emerge. This means that depending on e.g. availability of certain sensors, networks or context information, different services are active or that services provide different levels of quality.

5.9. Continuity

It must ensure that requested services are provided with adequate quality, despite change of availability due to loss/disconnection or mobility of system entities. This means that it should be ensured that the network adjusts dynamically in case of disrupted services or networks. And finally the system should ensure that WSAN are robust against e.g. access point and node failures.

5.10. Evolvability

The RWI architecture must be evolvable to withstand technological change forced upon by tussles carried out by actors in the eco-system. This means that the management framework should support adding new networks and services. In the field equipment such as sensor/actuator nodes and access points are upgradable with new software.

These design objectives are structuring the technology developments of SENSEI system [12] which is aimed at being a key enabler of Real World Internet applications. However, such scenario-based road mapping and the derived assumptions have to be assessed and consolidated with regard to the real users and business stakeholders' expectations towards Future Internet. To do so, SENSEI project will submit its scenario portfolio to the users and business stakeholders by means of field inquiries. The analysis of their feedback will enable to consolidate and to adjust the initial requirements that are presented in this paper and will be reflected in the final design steps of SENSEI system.

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