Real World Internet
Position Paper

Real World Internet - Overview

The Internet is evolving - in its use and in its technology. Born from the vision to create an open infrastructure to network computers across the world, the Internet has become a socio-economic backbone of our society, with countless private and business users as well as governments relying on it on a daily basis. The drivers for this evolution are a mix of emerging players with diverse and potentially changing interests, be it users, operators, manufacturers, service and content providers, together with advances in technology that have become available over the years.

Yet, the Internet was designed to provide a simple and transparent end-to-end transfer service across a heterogeneous wired network infrastructure, allowing the exchange of information between two or more communication endpoints. Its early applications were remote login and file transfer before the World Wide Web (WWW) emerged as the main driver for the Internet's current success. Today the Internet is dominated by a variety of different applications, mainly concerned with human centric information exchange, such as e-mail or the access of hypertext documents, audio and video files or real-time multi-media communications. Besides its applications, the infrastructure of the Internet is also evolving, extending its reach to mobile users and end-devices with the inclusion of next generation mobile networks. This evolution of the Internet has lead to a patchwork of fixes that are now telling the tale and are requiring a rethink of the fundamental pillars of the Internet Architecture.

In addition to the evolution of the more traditional uses and current trends of the Internet, the Internet is extending its reach to the real world through innovations collectively termed the Internet of Things (IoT). The IoT concept was initially based around enabling technologies such as Radio Frequency Identification (RFID) or wireless sensor and actuator networks (WSAN), but nowadays spawns a wide variety of devices with different computing and communication capabilities – generically termed networked embedded devices (NED). While originating from applications such as supply chain management and logistics, IoT now targets multiple domains including automation, energy, e-health etc. More recent ideas have driven the IoT towards an all encompassing vision to integrate the real world into the Internet – The Real World Internet (RWI). RWI and IoT are expected to collaborate with other emerging concepts such as the Internet of Services (IoS) and the building block of parallel efforts, such as the Internet of Energy (IoE) is expected to revolutionise the energy infrastructure by bringing together IoS and IoT/RWI. It is clear that the RWI, will heavily impact the way we interact both in the virtual and physical world, overall contributing to the effort of the Future Internet.

Vision of the Real World Internet

The ubiquity of mobile devices and proliferation of wireless networks will allow everyone permanent access to the Internet at all times and all places. The increased computational power of these devices has the potential to empower people to generate their own applications for innovative social and cognitive activities in any situation and anywhere. This wireless connection is not limited to user devices, almost any artefact from clothing to buildings can be connected and collaborate as a NED. Furthermore new sensor technologies and wireless sensor networks provide environmental intelligence and the capability to sense, reason and actuate. This leads to the exciting vision of the interconnection of artefacts embedded in our real environment, forming a society of "intelligent things" and "smart spaces".

Trillions of heterogeneous NEDs such as sensors and actuators located in open space or attached to existing objects, RFID enabled items, robots and Programmable Logic Controllers (PLC), generally many heterogeneous devices with communication and computational capabilities are integrated into the fabric of the Internet, providing an accurate reflection of the real world, delivering fine-grained information and enabling almost real time interaction between the virtual world and real world. Information about location, status and situation of objects and persons, information about the places as well as influencing and changing the places (through actuation), objects and persons based on the gathered information and defined rules and policies can now flow e.g. into enterprise systems (Figure 1) and decisions can be made in real-time.

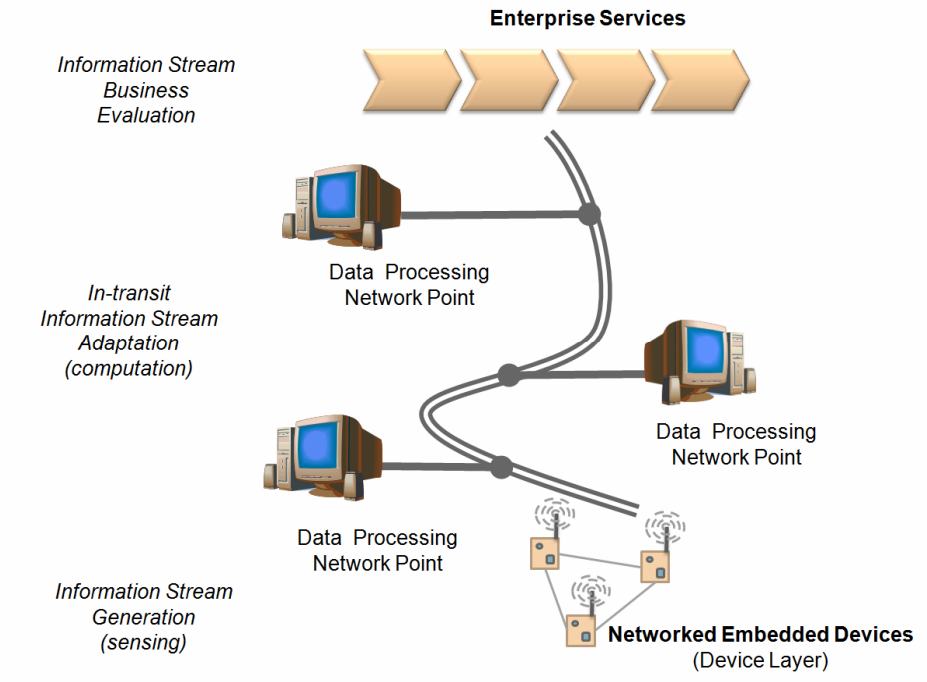

Figure 1 - Coupling of RWI with Enterprise Systems

NEDs such as sensor and actuator networks, RFID readers have become more powerful with respect to computing power, memory, and communication; therefore they are starting to be built with the goal to offer their functionality as one or more services for consumption by other devices or services. Due to these advances we are slowly witnessing a paradigm shift where devices can offer more advanced access to their functionality and even host and execute business intelligence, therefore effectively providing the building blocks of a service-oriented architecture. As such, event based information can be acquired, processed on-device and in-network. This capability provides new ground for approaches that can be more dynamic and highly sophisticated, and that can take advantage of the available context. Cross-layer collaboration is expected to be a key issue in such a highly dynamic and heterogeneous infrastructure such as the RWI (Figure 2).

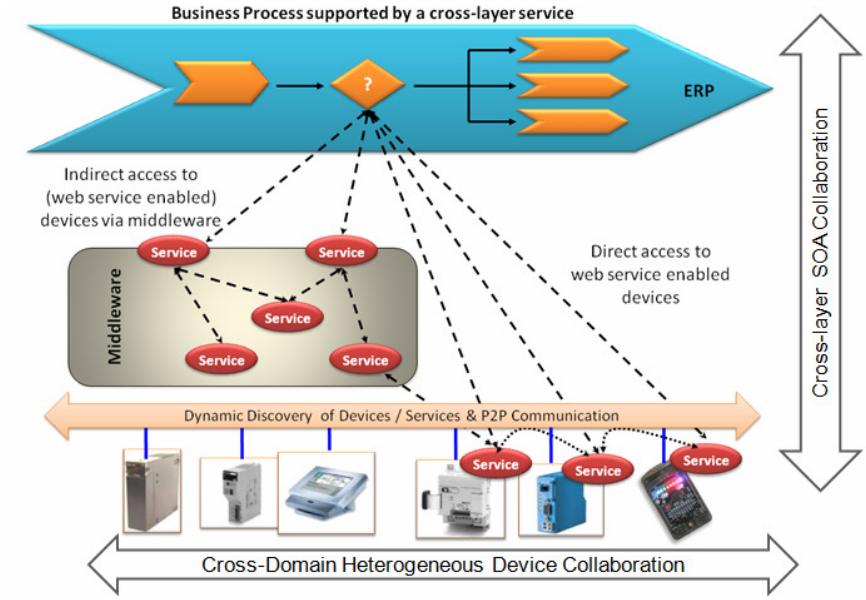

Figure 2 - Cross-layer SOA based collaboration in the Real World Internet

This results in an unprecedented level of detailed information that can be composed and used by many different applications such as:

- Ambient assisted living and health care – providing support for the elderly and impaired, giving them a new found improvement of their lifestyle and independence; allowing for more patients to be cared for in their own homes.
- Supply chain monitoring and logistics – counterfeit, intelligent maintenance, customer care and efficiency throughout the lifecycle of products, including more efficient recycling.
- Efficiency for transport, energy and facility management – alleviating congestion, providing more intelligent public transport that is responsive to needs, not timetables; managing office and home lighting, heating and air-conditioning depending on levels of use and occupancy.
- Improved Augmented Reality simulations – simultaneous visualization of virtual and real environments.

- Social and leisure applications – updating social networking based profiles (such as Facebook, HI5, MySpace, etc.) automatically; monitoring user's fitness levels during any activity and providing timely feedback to influence and adapt the exercise routine appropriately.
- Manufacturers can create extended products, using RFID for uniquely identification, sensors and actuators to create value in physical goods by adding a service component to them.

Vision: Social Devices

The vision of a coherent and heterogeneous society of Internet-connected objects, from anytime, any place connectivity for anyone, to connectivity for anything, must explore the possibility of embedding social capabilities in objects and devices. In this vision, physical objects should have identities and a virtual personality. These "social devices" when faced by a local problem, can "talk" with other artifacts that can provide their experience about that situation, or offer additional information that may help to come up with a solution to the problem.

This adds a further step to the concept of real world awareness to the Real World Internet. Their characteristics are:

- Devices uniquely identified.
- Devices natively designed for collaboration.
- Devices integrating local and global information in order to apply community knowledge to particular problems.
- Devices are able to interpret all the exchanged information at a semantic level.
- Devices as consumers and producers of content.
- Trusted devices with built in security.

The key factors for the success of the RWI are the following (Figure 3):

- The efficient internetworking of heterogeneous networked embedded devices with the Internet.
- Horizontal access via a unified interface to information generated by the RWI in a secure and trusted manner.
- Highly composable information to generate new and innovative services.
- Standardised way of describing information about the real world.
- Integration of security and privacy protections at the NED, infrastructure and service levels.
- The combination with other adjacent areas such as Audiovisual wireless networks, based on capturing devices and sensors (for example for enhanced security applications)
- The availability of holistic object discovery services that can combine object specifics with more dynamic information such as location, time, sensor information (e.g. IETF ESDS).
- Secure, reliable real time network infrastructure.
- Identity Management: There will be multiple identifiers for people, machines, objects and it is necessary to specify how identities will be assigned.
- Resilience in the sense of the ability to respond to failure or interruptions.

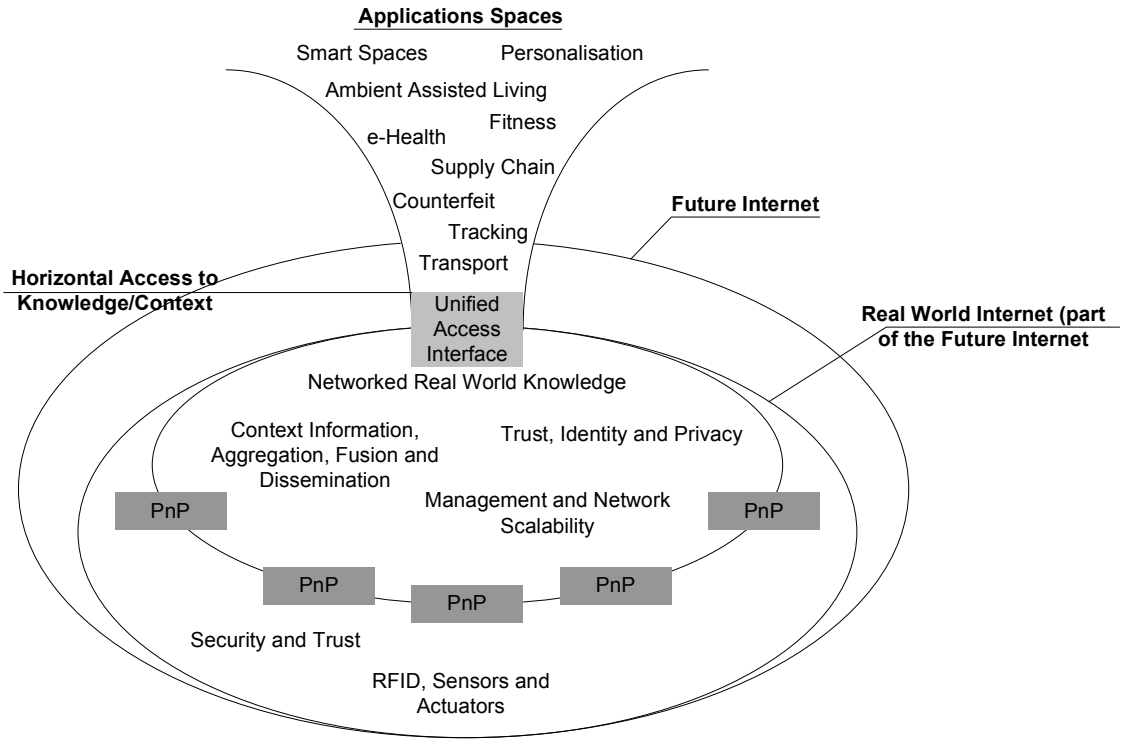

Figure 3 - Vision of the Real World Internet

Research Orientations

The architecture of the RWI will not be a standalone one. It is tightly coupled to the underlying communication infrastructure – the Internet (including mobile networks), and will have to evolve towards a common Future Internet architecture, providing building blocks for other initiatives such as the IoE and vice versa. Ultimately it will influence and help design the communication and service infrastructure that will become the Future Internet. The latter will be achieved by addressing the following RWI research orientations:

Firstly the **management, scalability and heterogeneity of devices and users** constitute a main challenge for the RWI. The RWI will be composed of trillions of sensors, RFID enabled objects and actuators, and together they will make up the majority of devices connected to the Internet. This is not just increasing the number of connected devices, but also the type of connected devices from mainly powerful computers to very low complexity devices. At the same time, the users of services provided over the Internet will change form mainly human users to machines – M2M will play a significant role. *So how can such a vast number of devices be managed and networked efficiently? Will current naming and addressing be efficient and sufficient? How does IP scale to low complexity (e.g. with the use of 6LoWPAN)? How can we integrate more data centric services on the Internet (in contrast to address centric mechanism)? In particular wireless sensor and actuator networks will be unreliable, dropping off and connecting*

fluently to the Internet – can we design efficient Plug and Play (PnP) mechanisms to manage these edge networks?

Secondly, **networked knowledge and context**; the level of detailed information will increase beyond any previously imaginable levels. Raw data generated by the trillions of sensors is just the beginning – this information is composable. Processors and services can aggregate and fuse this information to provide higher level contextual information, forming complex control loops or delivering real-time streams of accurate real world information for post processing or statistical information. *What are the mechanisms that we need to filter and search this knowledge? What will be the traffic patterns that we have to deal with in addition to the commonly seen data traffic (email, web-browsing, IPTV) on the Internet and will the collective use of the Real World Internet impact these services? How can this data be modeled and represented? How can we compose new context information on the fly?*

Thirdly, **privacy, security and trust** will have to be adapted to both, the low complexity of the devices and the extremely sensitive information that will be made available through the realization of the Real World Internet. This will involve the development of highly efficient cryptographic algorithms and protocols that provide basic security properties such as confidentiality, integrity, and authenticity, as well as secure implementations for the various kinds of mostly resource constrained devices. Furthermore, in order to ensure personal safety, privacy, and freedom, we will need to accompany the development of the Real World Internet with adequate security and privacy protections, both at the infrastructural and application layers (as well as legal assumptions and basic human rights will have to be addressed). It is critical that security can be integrated in all device logical layers and the sensors or devices could deal and respond to the possible security attacks without affecting the normal working of the whole network system. Special emphasis should be given on the sensor wireless networks and RFID network security. *How to implement fast and secure cryptographic algorithms and protocols in devices highly limited in resources? How can we design usable and privacy friendly identity management tools that enable users to stay in control of their data? How can we provide anonymity, unobservability, unlinkability and pseudonymity properties? How can we anonymise data generated by individuals? How can we design transparency and feedback mechanisms that educate users and raise security and privacy awareness? How can we protect the infrastructure from adversaries carrying traffic analysis attacks on the communication system?*

Last but not the least; the **Real World Internet generated network traffic** will be different from the traffic models of existing traffic sources and will in many cases have specific quality of service (QoS) requirements for the underlying transport networks. This will be of particular importance once the number of RWI entities scale up. Modern networks are tuned and optimized for the existing traffic models especially in case of mobile networks (web surfing, SMS, voice, VoIP, etc.). To be able to serve the RWI traffic as efficiently as possible the underlying transport mechanisms will have to be modified and adapted for the new types of traffic and applications. *What is the RWI traffic model(s)? What are the RWI applications' quality of service requirements for the*

underlying transport networks? How to serve large number of RWI traffic sources? How to reduce the network resource utilization while preserving the quality of service?

Beyond these four topics, there are several additional challenges for the RWI e.g.:

- Standardisation! Standardise basic NED services
- Social and legal implications.
- Service understanding / automatic composition and modeling e.g. ontologies
- Mobility support, opportunistic networking, dynamic discovery & usage
- Governance of NED swarms / large scale distributed infrastructures
- Hard vs. soft real-time control
- Intelligent processing (in-network, on-edge, etc)
- Cross-layer collaboration (business systems / network services / devices)
- Self-sustainability (self-* features e.g. self-management, self-healing etc.)
- Business models – context based solutions (no one size fits all approach)
- Ease of use / application modeling / toolkits
- Infrastructure management (HW & SW set-up/maintenance etc)
- Devices Identification.
- Interoperability among systems and objects.
- Plug & Play devices.
- Size of RFID; sensors and actuators.
- Energy autonomy of devices.

Conclusions and Future plans

The RWI is an interdisciplinary domain which involves the characteristics of the IoT with the vision to integrate the real world into the Internet. Towards the realisation of this aim, specific objectives of this cross-domain topic should be fulfilled, as for example:

- Sketch proper real-world internet architecture(s).
- Lead the integration of NED into the Future Internet.
- Facilitate the dynamic creation of context and actuation services from more elementary sensing, actuation and processing resources and the horizontal reuse of these resources for a large number of applications
- Define the usage of Experimental Facilities and propose additional experimental facilities or features.
- Develop privacy and security technologies that meet the challenges of the future internet

Only time will tell how the RWI will grow to reflect our vision, but to make it a success, we need to be aware of the tussles of the different stakeholder and ensure that we design the fundamentals so that the RWI can grow organically within the space of the Future Internet.

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List of projects supporting the RWI

SENSEI	4WARD	AWISSENET
PROSENSE	PARADISO	RESERVOIR
C-CAST	ASPIRE	WISEBED
PrimeLife	ECRYPT II	M-Ciudad
VICTORY		