

# Position Paper on “In-Network Object Cloud” Architecture and Design Goals

Interconnecting Smart Objects with Internet Workshop 25<sup>th</sup> March 2011

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## **1. Integrating IoT with Internet**

### **1.1 Motivation**

The Internet of Things (IoT) has evolved from simple sensors into Internet-connected objects and Internet-connected smart objects, all of which will be a key component of the Future Internet. For maximum benefit and usefulness of these connected objects we need to enable generic integration of the functions of these inter-connected objects in the context of both user services and system management from the world of Internet. This integration must encompass a network and service infrastructure, having dynamic and global resources with self-\* capabilities together with a uniform interfaces. This position paper outlines a roadmap of architecture, design goals and supporting technologies.

Current smart object solutions and research activities fail to address some of the main issues required for the full realisation of IoT into a fully connected Internet environment: namely, identity, scalability, self-\* properties for small objects with limited connection and computation capabilities, security, and orchestration and management of billions of devices. Therefore, a significant effort is needed for enabling Internet-connected objects to become seamlessly integrated in the Internet, including operator networks and applications of important real-life stakeholders.

### **1.2 Internet Connected Objects**

The notion of an "Internet Connected Object" or an "Internet of Smart Objects" from the Internet of Things (IoT) is emerging globally as research theme in the area of federation. The paradigms of autonomic networking will enable the IoT industry stakeholders to achieve the desired levels of economic incentives, dynamicity, efficiency, and scalability, in order to manage both the current and future services, together with networks of object-based resources that are becoming more and more pervasive and sophisticated. This is why there is a need to gather all of the relevant competencies to progress this field into maturity by generating high levels of industrial impact, maintaining a business-driven approach, and utilising the high-value of previous work.

Smart Objects are emerging in very large numbers as new Internet connectivity points, as well as new resources for use by networks, services, and applications. As such, these Internet-connected objects are an integral part of the Internet and should be defined as a dynamic and global resources, rather than just simple sensor devices. To participate effectively, they require a network and service infrastructure with self-management capabilities, based on interoperable communications protocols, and enablers for rapid, cost-effective service and application deployment. One important integration element for these Internet Connected Objects is the introduction of a virtualization mechanism that offers a virtualized view of the interconnected objects to the applications, as well as views for supporting the virtualization of objects and their combination in virtual aggregations.

### **1.3 Internet**

The current Internet has been founded and developed in the last 40 years on a basic architectural premise, that is: a simple network service can be used as a universal means to interconnect both dumb and intelligent end systems. The simplicity of the current Internet has pushed complexity into the end-points, and has allowed impressive scale in terms of inter-connected devices. However, while the scale has not yet reached its limits, the growth of functionality and the growth in size have both slowed down and may soon reach both its architectural capability and capacity limits. Internet applications increasingly require a combination of capabilities from traditionally separate technology domains to deliver the flexibility and dependability demanded by users. Internet use is expected to grow massively over the next few years with an order of magnitude more Internet services, the interconnection of smart objects from the Internet of Things (IoT), and the integration of increasingly demanding enterprise and societal applications.

Although the current Internet has been extraordinarily successful, as a ubiquitous and universal means for communication and computation, there are still many unsolved problems and challenges some of which have basic aspects. Many aspects leading to these problems could not have been foreseen when the first parts of the Internet were built, but these do need to be addressed now. The very success of the Internet is now creating obstacles to the future innovation of both the networking technology that lies at the Internet's core and the services that use it.

We are faced with an Internet that is good at delivering packets, but shows a level of inflexibility at the network and service layers with a lack of built-in facilities to support any non-basic functionality.

## 1.4 Integration

This position paper attempts to identify a roadmap for the integration of the world of Internet of Things and the world of Internet and unite them into a single combined world. This transition combines the architectural elements from both IoT and Internet and the transition is depicted in **Error! Reference source not found.**

The resource-based objects will have identities, physical and virtual attributes, and use intelligent service interfaces to enable seamless integration into the information, context and knowledge planes of the Internet.

The service interfaces for such objects would facilitate: object interactions and interoperation over the Internet; the querying and changing of an object's state, information, and behaviour associated with it; event-based notification mechanisms and processing; applications and service deployment with seamless roaming across of the Internet, for mixed object and non-object resources

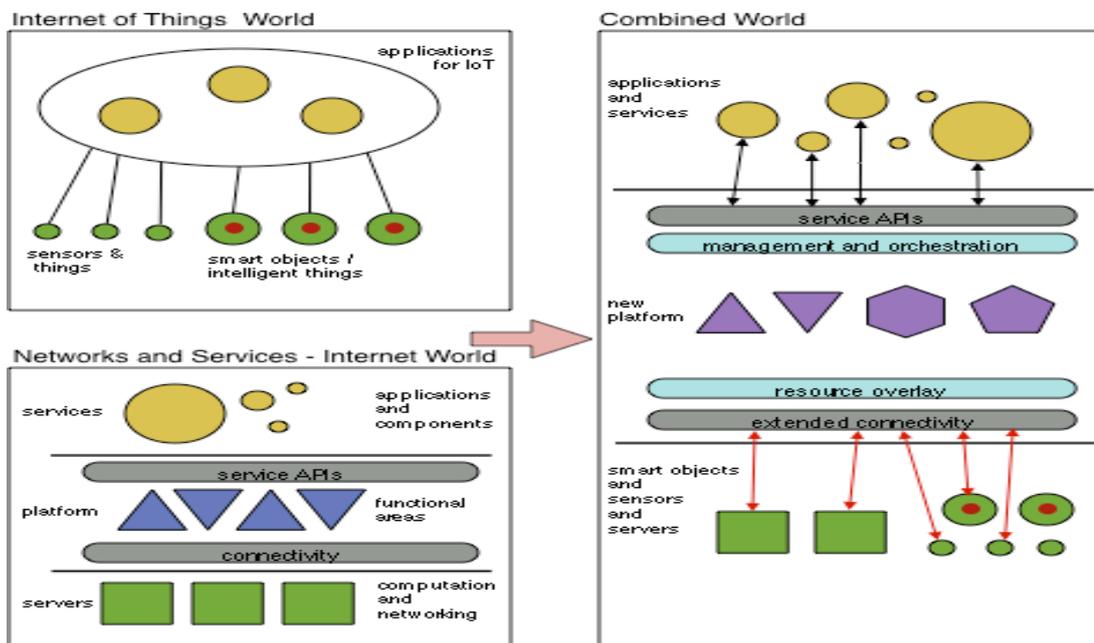


Figure 1 – IoT transition towards integration with Internet

Integrating the interconnected smart objects from the Internet of Things into the Internet would require solutions and capabilities, which are fundamentally missing from the current Internet infrastructure. These can be described as follows:

- **Technology aspects:** Energy-aware Infrastructures; Mobility of Services and devices; Inherent system management (self-\*); Adequate addressing and object naming schemes; Activation and on-demand provisioning of new functionality; Large scale and scalable deployment of both services and management; Advanced service platforms and facilities, which take advantage of flexible sharing of resources (e.g. connectivity, computation, storage and object based resources); Content-awareness facilities; Infrastructures and serviceware for interconnection of smart objects.
- **Applications and Social aspects:** Future Knowledge-based society; New applications and usage; Guaranteeing and facilities to support QoS and SLA.
- **Security, Trust and Privacy aspects:** Distributed Security, Enhanced Trust and Privacy
- **Economic aspects:** Cost considerations; economic viability of service offering including the need for appropriate incentives, diverse business models, legal, regulative and governance issues.

## 2. In-Network Object Cloud Architecture for the Internet Connected Objects

IoT comprises a digital overlay of information over a highly heterogeneous physical world of objects. In the near future, such objects are expected to outnumber the human population by at least one order of magnitude. The IoT is

expected to provide to Internet a resource fabric interfacing the physical world by means of a ubiquitously deployed substrate of embedded connected or networked devices. The resources provided are sensors, actuators, Radio Frequency Identification (RFID) tags / readers, Near Field Communication (NFC) enabled devices, Smart Objects – which are small computers with a sensor and/or actuator and a communication device, etc. These objects have the capability to process (monitor, record, and manage) events and context information concerning the real world and the entities contained within. Business services and end-user applications would use such events, context information, and interaction capabilities of the objects with respect to real world entities. This includes finding the relevant entities and then the resources that provide information about these entities or allow interactions with them.

Here we propose the development of a new architecture and infrastructure as an “In-Network Object Cloud” that enables the following functionality and characteristics:

- Virtualisation of all resources: Object resources, Service Computation resources, and Networking resources.
- Efficient linking of real world entities with relevant resources of the IoT.
- Information and Context model and services to objects and applications.
- Service and self-management enablers for applications and service provisioning on the platform.
- Federation capabilities enabling service roaming within multiple domains.
- Uniform service interfaces and business driven interfaces to enable generic integration of the interconnected object functions in the context of user services, taking special care of preserving their autonomous operation capability.
- Introduce security and privacy framework tailored to the needs of the IoT world.
- Introduction of economic mechanisms and services that enable the interaction among the stakeholders participating in the value chain, and the exchange of proper economic signals, so that the whole ecosystem is economically sustainable.

The main elements of the proposed architecture can be seen in figure 2.

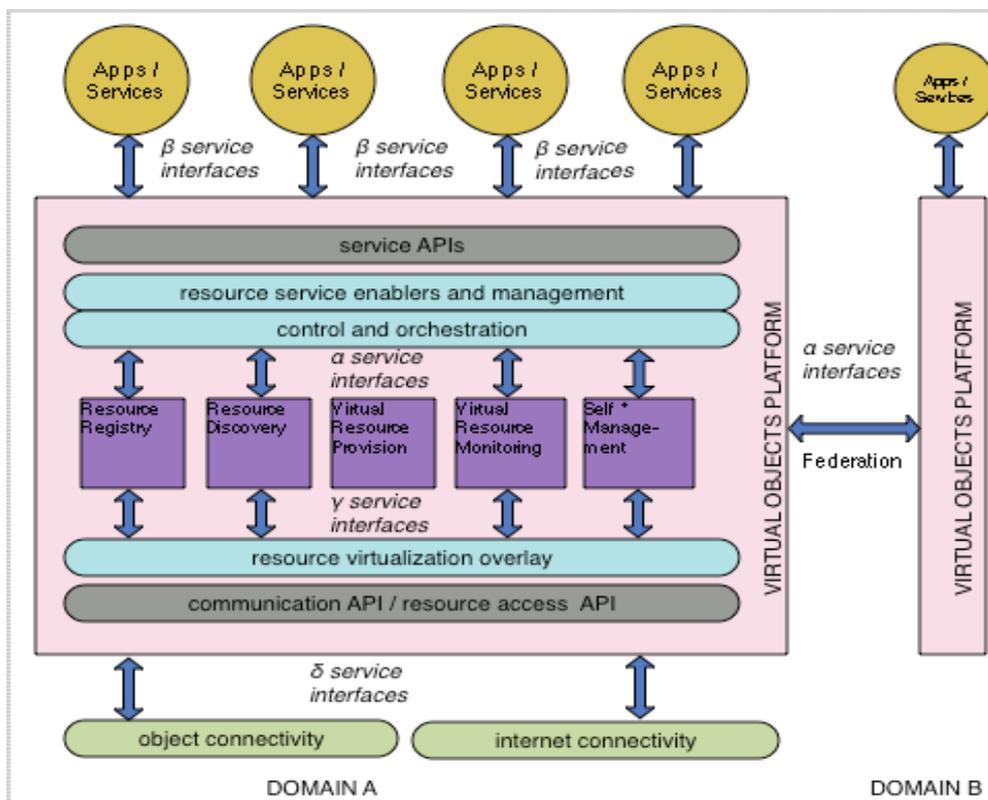


Figure 2 – In-Network Object Cloud Architecture

The provided functionality consists of the following aspects:

- Registry and Discovery of the relevant entities, e.g. based on identifier, location, type, provider, topic, or a combination of these.
- Lookup of resources that can provide information about the entities or allow interactions with them.
- Monitoring of objects and keeping the dynamic links between them up-to-date.
- Virtualisation of objects, networking and computational resources and linking virtual resources with real resources.
- Service enablers and self - functionality (self-management, self-monitoring, self-configuration, self-optimisation, self-healing, self-protection and self-adaptation).
- Orchestration capabilities for controlling and managing the composition and decomposition of multiple domains
- The  $\alpha$ -,  $\beta$ -,  $\gamma$ - and  $\delta$ - interfaces. The purposes of such interfaces are:
  - $\alpha$ -interfaces: to provide a rich set of APIs to enable highly customized applications and software as service entities.
  - $\beta$ -interfaces: to provide APIs to orchestrate and govern virtual systems and virtual resources that meet stated business goals having specific service requirements. They are responsible for orchestrating groups of virtual resources in response to changing user needs, business requirements, and environmental conditions.
  - $\gamma$ -interfaces: these mainly provide APIs that deal with virtual system setup and management issues. The APIs consist of methods for manipulating local network/service/storage/object resources abstracted as objects (i.e. as virtualized resources) or directly into the real resources (i.e. with no virtualisation). The abstraction isolates upper layers from hardware dependencies or other proprietary interfaces. The  $\gamma$ -interfaces isolate the diversity of setup and management requests from the actual control loop that executes them. They are responsible for determining what portion of a component (i.e. a set of virtual resources) is allocated to a given task. This means that all or part of a virtual resource can be used for each task, providing an optimised partitioning of physical resources according to business needs, priority, and other requirements. Composite virtual services can thus be constructed using all or part of the virtual resources provided by each physical resource.
  - $\delta$ -interfaces: these APIs provide access to lower level resources. It is a collection of protocols that enable the exchange of state and control information at a very low level between different types of resources and the external agents of the resources. These can aggregate resources into assured pools of virtual resources. The resource types considered are: transport resources, forwarding resources, computation resources, storage resources, and content resources.

### 3. Conclusions

This position paper outlines an architecture for an In-Network Object cloud that combines the world of both IoT and the Internet. We have presented the main functions and characteristics that such an architecture will require, together with an overview of the functional elements and interfaces that are needed.

By extending the scope of sensors and smart things into Internet service elements, we can utilize these devices far more effectively and with greater scope. As more of these devices appear on the Internet, it will be essential to have them participate as part of Internet applications.