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The Internet of Things (IoT)

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The Internet of Things

The Internet of Things (IoT) is a concept in the process of rapid realisation that has its roots in a range of technologies that offer various layers of functional capability including:

- Automatic identification and data capture (AIDC) technologies, including sensors and sensor networks
- Communications structures and networks
- Computers, data and information processing and storage structures
- The whole infrastructure that is the Internet, including applications layering characterised particularly by the world wide web, texting and emailing
- 'Cloud' computing infrastructure and services support, characterised by Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as Service (SaaS).

It is a concept geared to integration and scaling to accommodate global reach and as such makes particular use of the existing Internet and developments towards the future Internet. It is a concept that is receiving world-wide attention, with significant research funding through the European Commission for both IoT development and international collaboration. The UK is also supporting initiatives directed at development, innovation and enterprise regarding the IoT. The number of EC framework funded projects has resulted in the formation of a cluster group, the IoT European Research Cluster (IERC), to help link these IoT projects through activity chains. From this cluster there has emerged a definition for the IoT[1] which may help in gaining a feel for the essential elements. Thus the IoT may be seen as:

"A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."

A definitions such as this, which aims to encapsulate a far reaching concept in a relatively few words, generally requires further qualification to determine both structure and purpose of the concept concerned.

It becomes necessary to consider what imperatives can be identified that are unambiguous and clearly relate to the structure of the IoT and to its purpose in general terms. Stemming from these considerations should be statements of purpose and structure that can then be used in structuring an international framework for IoT that embraces the need for governance and 'soft law' legal underpinning on an international basis. Such a framework can be seen to be of importance in addressing international issues relating to the development of the IoT, including regulatory and standards issues as well as issues of socio-economic importance. It can also be of value in distinguishing an associated framework for applications and services and platforms for supporting new developments and concepts, such as those being proposed for other Internet-based initiatives such as Internet of People, Internet of Energy and so forth.

Two unequivocal imperatives present themselves as the basis for the Internet of Things (IoT):

1. Integration within the existing and future Internet and 'Cloud'-based developments
2. Interfacing and interaction with the physical world through object-connected technologies and electronically accessible identifiers

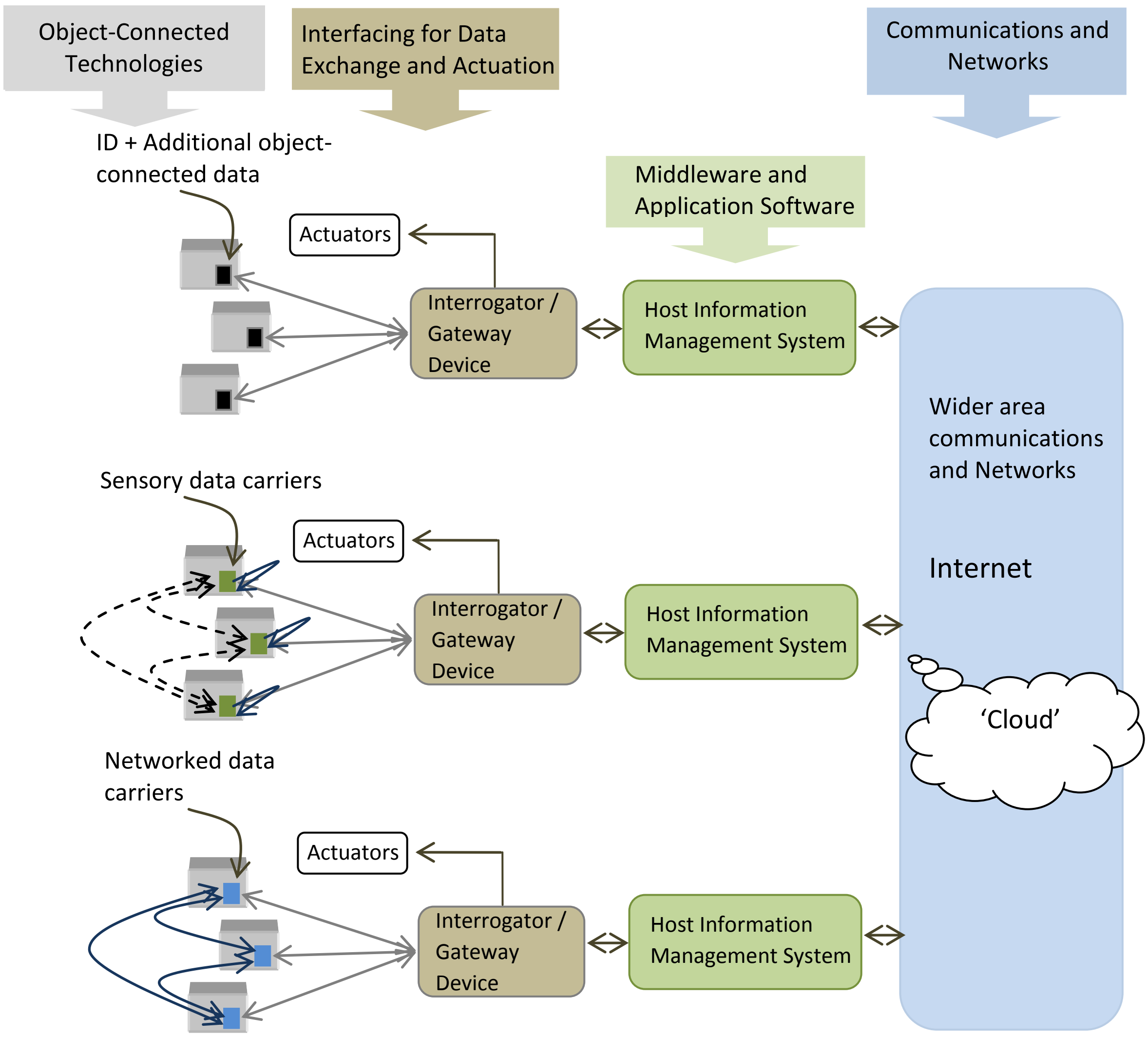
[1] Vermesan, O., et al., (2011) Internet of Things Strategic Research Agenda, in Internet of Things – Global Technological and Societal Trends, River Publishers, 2011.

They underpin the purpose of the IoT and the framework criteria for distinguishing IoT Applications and Services. These imperatives form the basis for the CASAGRAS (Coordination and Support Action for Global RFID-related Activities and Standardisation) Inclusive model for the IoT.

A Brief Introduction to the CASAGRAS Inclusive Model

While models for the Internet of Things (IoT) have been suggested that are simply based upon radio frequency identification (RFID), and other radio-based edge technologies, a more inclusive model is necessary to accommodate and exploit the extreme potential for interfacing and interacting with the physical world. It is also important as a vehicle for accommodating the inevitable vagaries in networks and connectivity that are likely to arise in realising practical, scalable systems. While the inclusive model is more demanding in its outlook and realisation it is a vision that can be approached in a migratory, progressive, standards-supported manner. The framework presented by the CASAGRAS inclusive model distinguishes the various layers of structure and connectivity that can be seen to exist between the real world objects and its virtual counterpart, information management structures and networks, including the existing and evolving Internet. The essential elements of the model are presented below.

Schematic summary of the CASAGRAS Inclusive Model



Note: Sensor-RFID structures may distinguished that (1) allow communication simply with host readers and (2) between sensor devices (dotted lines).

The structure comprises:

- **Physical layers** – in which the physical objects or things are identified and rendered functional components of the IoT through the use of object-connected data carrier technologies, including RFID. The objects so identified may also be grouped or networked to fulfil particular application needs. Devices with additional functionality, in the form of sensory, location, global positioning and local communications capabilities, may be used to achieve network structures as well as single-device operation. Processing capability is seen as an important distinguishing feature in the devices constituting nodes within the IoT. With developments in processing power and reductions in cost and size an increasing percentage of object-based applications may be expected to exploit embedded or attached processing nodes. The range and flexibility of these devices and networks will clearly have an important bearing on the range of applications.

  The European Commission (2006) report, From RFID to the Internet of Things – Pervasive networked systems[2] identified the following network-supporting communication devices that parallel the object-connected technology depiction for the physical layer:

  1. Purely passive devices (RFID) that yield fixed data output when queried
  2. Devices with moderate processing power to format carrier messages, with the capability to vary content with respect to time and place
  3. Sensing devices that are capable of generating and communicating information about environment or item status when queried
  4. Devices with enhanced processing capability that facilitate decisions to communicate between devices without human intervention – introducing a degree of intelligence into networked systems

  These categories of technology clearly present implications with respect to the physical zone interfacing and networking requirements. They also have ramifications with respect to other parts of the data transfer and processing chain and data structuring needs. The ISO/IEC Standards developing communities have, and are continuing to develop international standards to meet these needs. The following illustrates the ISO/IEC developments with respect to various interfaces and functions, including sensors for RFID.

  Also important within the physical layers are the structures, such as electro and electro-mechanical devices (phones, displays, printers, access barriers and so forth), for achieving activation (depicted as actuators in the schematic) and other feedback functions; an integral part of many real-world applications.

- **Interrogator-Gateway Layer** – providing effectively the interfaces between the object-connected devices and between the interrogator and the information management systems. Fixed, broadband and mobility communication technologies that will yield the connectivity required for the IoT. Networking of interrogators and gateway devices may also be seen as an important infrastructural feature in this layer and an important contributory feature within the IoT. Interfacing with respect to actuation and control devices within real-world applications is a further important feature of this layer.

- **Information Management, Application and Enterprise Layer** – Interfacing with the interrogator-gateway layer the information management layer provides the functional platform for supporting applications and services. Networking and the facility to provide

[2] European Commission (2006) From RFID to the Internet of Things – Pervasive networked systems ISBN: 92-79-01941.

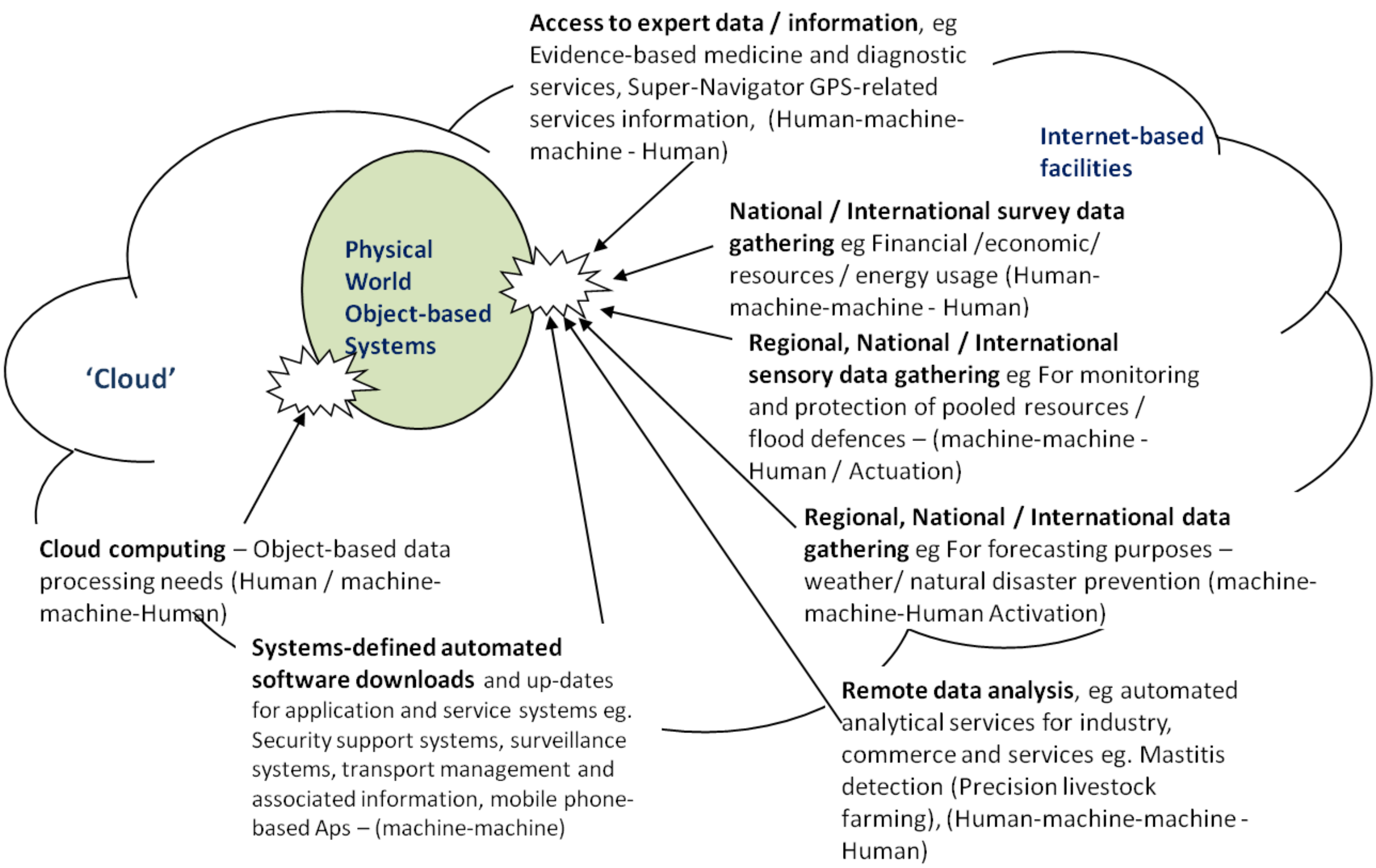
intelligent capability (in accordance with state-of-the-art developments) constitutes further important features in realising an IoT.

- **Wider communications and Internet Layer** – Providing the interface with other structures and networks including the Internet.

While interfaces are distinguished between each layer interfacing may also bypass layers, adding still further flexibility and options for object-connected applications and services. Net-born, as well as those requiring gateway supports, can thus be distinguished. Moreover, the developments in ubiquitous computing and networking, with integral communication capability, provide the key technological foundation for the Internet of Things infrastructure and its integration within the existing and evolving Internet.

While the Internet is taken has an imperative for IoT development, what emerges from the consideration of Internet together with the imperative for physical world interfacing and interaction, is a prospect for both Internet and Internet-independent (or IP-independent) IoT developments. It has also raised the prospect of what may be described as Latent IoT developments, developments that initially have no link with Internet of IP-independent network of network structures but could well be linked in some way at a future date. Many automatic identification and data capture (AIDC) applications fit into this category of structure, including Internet protocol (IP) and IP-independent supervisory control and data acquisition (SCADA) systems.

The schematic below is an attempt to represent the holistic tri-state structure proposed through CASAGRAS2 for the IoT.



In terms of the CASAGRAS inclusive model the CASAGRAS2 extension can be effectively viewed as layered structures that access and exploit either the Internet (IP-based) or IP-independent structures, or both. Both aspects of the model are generic in nature and present scope for the development of the IoT concept. Further delineation of layers and structures can be effected to achieve more detail of consideration, including functionality and application specific factors.

In considering further the delineation of layers it is possible, in a systematic manner, to distinguish the various areas of enabling technologies and associated standards, including prospective gaps in relation to standards and regulation. Still further delineation can take it to the levels of layering exemplified, but not constrained by the Open Systems Interconnection (OSI) standard, for all the enabling technologies, including the physical edge, object-connected technologies. Together with associated data and communication protocols this constitutes a framework for design and systems development. In this respect it is also important within such a framework to provide a guide to standards interpretation and use.

The design perspective extends to applications and services and the prospective structures for supporting such developments.

A yet further dimension to delineation relates to governance and the prospective needs to address both directly and indirectly details relating to the overarching framework. The nature and complexity of the IoT development point to still more delineation and roadmaps for both research and development.

Many of these aspects of delineation, including those relating to IoT architecture, technologies, and frameworks for governance and standards are to be found in the CASAGRAS2-IERC Cluster Book, The Internet of Things 2012 – New Horizons.

The book is downloadable from www.internet–of-things-research.eu

For agriculture, be it arable, livestock or integrated and urban developments, the IoT presents a substantial platform for exploitation through capability it presents for interfacing and interacting with the physical world and the coupled capabilities presented by the networking, global communications, information storage, processing and service support features of the Internet, Cloud and future Internet. Already, IoT precision farming applications and services are emerging and the NCPF will be both monitoring and engaging in these IoT opportunities and developments.

Prof Anthony Furness

Technical Coordinator, CASAGRAS2

The Centre will be following and engaging in IoT-based developments for agriculture.