A roadmap for interdisciplinary research on the Internet of Things: Economics and business

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1 Overview

This White Paper is one of the outputs of a joint TSB/RCUK Internet of Things (IoT) project to report on strategically important research topics and technologies and thereby help in shaping the priority areas of the RCUK and TSB programmes on the IoT for the coming years. The White Paper is the result of discussions at a workshop in Loughborough in July 2012.

The IoT is a world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these 'smart objects' over the internet, query and change their state and any information associated with them, taking into account security and privacy issues.[1]

Economics is the social science that analyses the production, distribution and consumption of goods or services.

Business is the provision of goods or services.

We use the term *ecosystem*[2] to refer to the totality of hardware, software and human, business and societal actors in the IoT.

The workshop considered the following key issues.

1.1 Economic and business values and drivers

Economic values and drivers pertain to the worth of goods or service as determined by the market, usually expressed in monetary terms. Business values and drivers include those not directly measurable in monetary terms, as determined by suppliers, customers and society. The relevant scope includes hardware, software and services (design, development, manufacture, deployment, ownership, operation), and data (collection, distribution, ownership).

There is a requirement for open business opportunities and a means of putting in place methods for making the players involved visible to the market and to other business communities. The deployment of means for facilitating an IoT business opportunity with concrete value proposition is required. There is a need to learn from other business fields, to find ways to correlate between business values when adding and costing new business, and to assure business continuity. A strictly economic approach to value may not be applicable to the IoT, but the monetisation of the value is a shared concern. Questions such as: 'How can a new business pay itself? How is a new business enabled to compete at local scales? How can one trace business operations in real time?' should also be raised.

1.2 Value chains

The value chain is based on the notion of value-added at each link in a chain of business processes. In the IoT it applies to Things and what you do with them; devices, networks, data and information;

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[1] Stephan Haller, SAP Research, Future Assembly, Prague, 13 May 2009.

[2] An ecosystem is a biological system composed of all the organisms found in a particular physical environment, interacting with it and with each other. Also in extended use: a complex system resembling this (Oxford English Dictionary). We use the term ecosystem in that extended sense, to refer to the totality of hardware, software and human, business and societal actors in the IoT. This is a superset of concepts like platform and framework (which are often poorly defined).

infrastructure and services. In complex evolving dynamic service systems where all stakeholders co-produce value the notion is expanded to that of a value constellation.

There is a need for tracing 'Things' from where information, knowledge and potential business values are generated in the ecosystem. The intrinsic values should be embedded in the Things. There are no existing common standards in quantifying and embedding such values in the Things, which is a major barrier for monitoring ecosystems. Open experimentations are therefore proposed, with a focus on value constellations rather than value chains. The disruption of value chains may occur in the constellation, where the value is potentially misunderstood. There is a need to bring knowledge and data together for quantifying values at whatever scale; the so-called 'data lens in the value chain'. Thus there is a requirement for putting in place open middleware with data lenses for creating, monitoring, evaluating and testing values in constellations.

1.3 Incentivisation; investment; policies and regulations

The IoT needs to be viable and sustainable. The incentivisation of stakeholders (data and information creators and owners, infrastructure and service providers, and consumers) and of communities to engage with the IoT was considered. Among the challenges are appropriate financial investment (public and private sector) and the (economic) policies and regulations that either need to be put in place or to be changed.

Most IoT users (or would-be users) want to access to information for free. Hence there is a need for investment in open demonstrators to prove value. There is a lack of understanding of monetisation in the IoT. Exchange and transaction models are needed for various stages and scales of IoT functions. As well as monetisation, these models should consider new financial policies and regulations which need to be put in place to support the emerging businesses of the IoT. The requirement for transparent business transactions in IoT ecosystems is of paramount importance in the formulation and development of such models.

1.4 Research challenges

The discussions during the workshop led to the identificaton of various short- and long-term research challenges in all of the above topics.

Building open platforms which demonstrate concrete value, even at a small constellation level within a given ecosystem, will be important for business communities in the UK. The most challenging and fundamental research will be on understanding, landscaping, monitoring and forecasting the dynamics of value constellations, while assuring their sustainability and evolving complexity. The requirement for addressing the issue of interoperability between businesses and communication standards within IoT ecosystems is key, while the need for quantifying business values in ecosystems is paramount.

2 Research priorities

2.1 Short-term research challenges

2.1.1 IoT Ecosystems

How it all fits together

There are challenges at all levels. Key technology challenges are relatively easy to identify, e.g. interoperability of hardware and software components systems, semantic interoperability (of data structures and meanings). Economic and business challenges have to do with monetary issues (cost, investment, revenue, profit) and operational issues (provision and use). For IoT ecosystems this leads to issues such as: who owns what and who is liable for what e.g. when data is re-purposed and combined in new ways; what happens when things go wrong – who does what, who is liable for what? The IoT in safety-critical systems is a particular concern.

Accessible open IoT platforms have the potential to bring business communities together with the aim of achieving sustainable economic growth on all scales. Challenges include enabling flows of data and information that are useful for each actor, demonstrating concrete flows of business value, and stimulating new players to join such ecosystems and enabling new business opportunities.

2.1.2 Value

How to create it, how to monetise it, how to measure it

Return on Investment is a key business measure. The challenges in the IoT include understanding the value propositions for different stakeholders. IoT users may demand infrastructures that operators cannot provide cost effectively within current business models and regulatory frameworks. Profit from the use of data may accrue far removed from the investment in collecting it. How do we measure the values of data and information as they flow through the value chains? This needs to be achieved in real time and in the context of potentially complex multi-level service agreements. What are the intrinsic and evolving values value(s) of Things? How much of the lifecycle, from conception through deployment and use to disposal or deletion, must a particular actor consider?

There is a need for formulating new data and information transaction models, and the appropriate tools for monitoring and measuring values and how they are changing, on local and global scales within value chains. Another challenge is models to deal with circumstances where things, data or services may not have or propagate intrinsic monetised values across the value chains. These circumstance pose issues for measuring new values in the ecosystem due to their unconventional and subjective nature.

2.1.3 Markets

Market enablers, economic blockers; business models, …

There is insufficient knowledge of the formal mechanisms that need to be deployed in the market to effectively unlock the potentials of new business activities across the value chains of the IoT. There is a need to research how business interoperability and convergence can be achieved under these market enablers. The commercial perspectives which can potentially be put in place under

these mechanisms must demonstrate economic sustainability, scalability and growth. Open facilities with means to kick-start (or support) new (or existing) IoT-based ecosystems are needed These facilities should develop inclusive partnerships with business communities in the value chain, and carry out some specific coordination actions for the identification of the market blockers, business models and requirements for business interoperability and convergence across prioritised domain-specific and cross-domain ecosystems.

2.2 Long-term research challenges

2.2.1 IoT ecosystem issues

Ownership, trust, governance

With ever-increasing size and complexity of IoT ecosystems, ongoing long-term research is needed on issues of data and information ownership, trust and governance. As business ecosystems grow, and in many cases become ever more dynamic, issues around ownership (particularly of derived data and information) will increase substantially in complexity. Trust in, and governance of, data and services will likewise become ever more problematic. For generalised trust metrics, there is a need to research how trust is objectively, semantically and numerically represented across ecosystems. New data and information markets and brokerage, novel data and information processing services, and decision support systems and services using them, will raise issues of governance that may simply be outside the scope of any existant policies, regulatory frameworks and even legislation. Other challenges include business drivers for market making; bottlenecks and barriers in value chains; the scaling of new business value chains; and cross-domain business interoperability issues.

2.2.2 Evolving value chains

Dynamically changing value chains and evolving value constellations

The structure and nature of value chains in the IoT will change as their associated business ecosystems evolve in dimensions and complexity. We use the term value constellations to refer to these large, complex and often dynamic aggregations. Models and simulations of evolving value chains need to be developed, tested and validated. Theories of the creation, aggregation, functioning and evolution of value chains and constellations should be derived, taking on board experimental observations and results. The validity and robusteness of these theories should be further investigated using multi-scale adaptive models, which simulate and forecast value chain dynamics with estimated uncertainties. A long-term goal is understanding trends about how these value chains form and evolve internally within and externally from ecosystems.

2.2.3 Cross-border issues

Regulation, legislation, compliance and standards

Specific challenges arise for IoT ecosystems that cross adminstrative or jurisdictional borders. Adherence to, and improvement of, specific standards for achieving business interoperability in the ecosystem need to be investigated. Furthermore, measures for the identification of bottlenecks and barriers which prevent good and sustained interoperability between businesses in the ecosystem need also be researched. These will be essential to provide a long-term view of how levels of interoperability between businesses in an ecosystem improve through time, or indeed

show some signs of decline. Early detection of declining inteorperability will be essential for timely mitigation measures to be deployed to assure sustainbaility of business activities within the ecosystem.

2.2.4 Complexity

Engagement with ecosystems

The numbers of Things and of IoT ecosystems is ever increasing in volume, heterogeneity and complexity. During the last decade, the increased usage of wireless communication technologies such as radio frequency identification (RFID), near field communication (NFC), ZigBee, Bluetooth and so on has greatly facilitated the creation of new business ecosystems. However, the resulting creation, generation, sharing, exchange and transaction of commercially relevant information in such ecosystems of Things is being challenged by issues including the requirement for a vast amount of ad hoc, robust, interoperable, secure and resilient intercommunication between Things and between different businesses in the ecosystem. These businesses may not necessarily use common standard communication technologies. However, they still require intercommunication in heterogeneous ecosystems to be conducted efficiently, reliably and with minimum but still manageable disruption. These challenges contribute to the current lack of engagement of various business communities with viable business ideas in these ecosystems. The use of a common methodology for monitoring, testing and validating the business ecosystem complexity is therefore required. The common methodology should also address how to model the dynamic adaptation of incentives for communities to remain engaged in the business ecosystem despite the growth of its complexity.

3 Concluding remarks

We cannot predict disruption; we need to facilitate disruption. We do not (just) need technology demonstrators, we need demonstrators that can be used to reduce cost or risk. Demonstrators should prove value, not just show capability.

We strongly recommend an action to build and support an interdisciplinary research community focused on the economic and business issues around the IoT. The starting point could be a joint TSB/RCUK Digital Economy Theme action, analogous to an EC Support Action, perhaps based on the EPSRC Network Grant model.

Workshop participants

This is a list of all participants in the economics and business group at the roadmapping workshop held in July 2012 in Loughborough. This report summarises the output of the economics and business group at the workshop, and does not necessarily represent the views of those listed here.

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