

Research Challenges for Future Internet Usage Areas

*Editors: Michael Boniface, Mike Surridge and Colin Upstill
University of Southampton IT Innovation Centre*

This Position Paper addresses generic research challenges facing Future Internet Public Private Partnership (FI PPP) Usage Areas for which research centres provide key value. It is based on contributions from the following European research centres.



The Future Internet Public Private Partnership aims to facilitate the development and application of Future Internet technologies, boosting the competitiveness of European Industry, creating new economic opportunities for businesses, and empowering individuals and communities to innovate and benefit from their use.

(1) Use cases and scenarios for large-scale experimentation with the Future Internet platform

There is no universally accepted definition of the Future Internet, but stakeholders agree that it will be a socio-technical system comprising Internet-accessible information and services, coupled to the physical environment and human behaviour, and supporting smart applications of societal importance. The Future Internet will therefore become a critical infrastructure for the conduct of business and social interactions, disrupting established business models and value chains (gradually over time if not overnight) but also creating new opportunities. Efforts to create and deploy Future Internet applications must therefore also take account of socio-economic factors including the critical nature of the infrastructure created.

Future Internet applications are expected to be vertically integrated within sectors, multi-stakeholder (and cross-border), linking information and physical devices, providing facilities for improved understanding, management and operation of socio-economic activities spanning both the digital and physical worlds.

(2) Important innovative Internet functionality and technologies

A key attribute of Future Internet applications (and the underlying e-infrastructure) is that they should be 'smart', meaning that they are:

- intelligent and able to make choices based on a wide range of information that may be available on the Future Internet;
- flexible and able to dynamically adapt to the needs of (ever-changing) stakeholders by exploiting Future Internet capabilities for rapidly changing connectivity and configuration of facilities and services; and
- efficient and 'green' in their use of physical resources, though improved access to and exploitation of ICT resources.

Future Internet applications and infrastructures will typically be large-scale, technologically inhomogeneous systems that span organisational and administrative boundaries.

Applications will integrate information from numerous stakeholders including businesses, governments, and in many cases citizens. They may be coupled to the physical world through sensors and in some cases actuators, and may interact with physical processes and systems as well as digitised process and digital assets (content).

Applications will often interact in multipurpose ecosystems, providing services or other building blocks to each other. Finally, they must be easily used and managed, demanding a high level of user adaptation and self-management.

Applications will need to integrate a wide range of available and emerging technologies that have never before been combined in a coherent fashion: scalable sensor, content delivery and service networks; autonomic management of connectivity, devices and services; context awareness for user and other physical interactions; content awareness for data communication and processing; and on-the-fly composition of services and other resources.

Future Internet platforms are expected to be largely common across applications and sectors, comprising a collection of enabler technologies providing capabilities needed by applications.

(3) Functionalities expected of the Future Internet core technology platform

The Internet was originally devised to ensure reliable connectivity in a hostile military setting. However, its use and governance has evolved from that of 30 years ago, and continues to evolve:

- governance objectives have changed from supporting governments and academics to providing an environment in which businesses and citizens may compete as well as cooperate to extract value;
- connectivity (ISPs) is run as a commercial activity rather than by governments and academics, while new service models requiring guaranteed performance have emerged;
- trust between users has reduced dramatically;
- developers are no longer concerned mainly with systemic failure but with the need to develop and maintain emergent applications for potentially competing stakeholders; and
- societal and legal aspects of Internet use (e.g. equality, privacy) are increasingly important for businesses, governments and citizens.

In the Future Internet, these objectives have to be met in the context of technologically converging networks, services, content and devices, and closer coupling of the digital and physical worlds.

This will see an increased dependence on distributed information controlled by independent parties, governed by both markets and regulation, so the Internet becomes a critical infrastructure for information exchange, in which the consequences of failure have an impact in the real world. In this context, we have identified four areas where significant research challenges have to be met.

- Emergent systems engineering and compliance: how to design Future Internet systems to meet requirements, given that they will be created and evolve dynamically 'on demand' with no overall designer?
- Operational risk management: how to ensure in real time that systems with no overall controller will operate in a safe and acceptable manner, including interactions with the physical world, and considering both autonomic and semi-autonomic adaptation processes?
- Turning information into value: how to make information accessible to applications that convert that information into value, and how to preserve this value over long timescales?
- Socio-economic and user acceptance: what platform capabilities are needed to ensure that users and society will accept the Future Internet and use it beneficially?

These capabilities and the associated research challenges are explored in more detail in our Position Paper "Research Challenges for the Core Platform for the Future Internet".

(4) Experimentation environment for large scale testing of the platform and new services and applications

Based on experience from previous research on disruptive technology (e.g. Grids), several challenges can be anticipated. The overall problem is to conduct innovative research to address the socio-economic, technical and application issues, while at the same time providing robust outputs to enable realistic open trials on a large enough scale, and maintaining the potential for commercial exploitation after the research phase.

Technical vs Socio-Economic drivers: History shows that disruptive technology can only have a successful impact through a balanced approach that also addresses socio-economic factors (e.g. the emergence of commercial cloud computing services, c.f. the failure of Grid computing to become ubiquitous). This is true even if huge budgets are used to attempt relatively modest levels of innovation (e.g. the UK's NHS IT Infrastructure project). The PPP will provide a substantial budget for R&D, but this is small compared with the innovation opportunities. It will be tempting to focus resources on technical challenges where research results are most tangible and easily exploited. This must be resisted.

Horizontal vs Vertical drivers: The PPP takes an 'application led' approach to defining and implementing the required technical innovations to create and exploit the Future Internet. This ensures a holistic approach to technical developments within each application sector, and maximises the chance of high-impact exploitation and commercial adoption. However, it will also encourage specialisation in each sector and make it harder to share solutions across the PPP, adding to the overall cost of infrastructure development, and precluding cross-domain business opportunities. A balance must be maintained between near-to-market vertical application drivers and medium-term cross-domain utility.

Research vs Development drivers: The PPP is not simply a vehicle for product development. It will have to go well beyond re-badging existing solutions to address research challenges to provide smart applications which are trustworthy, federated, scalable and converged at the technical, socio-economic and regulatory levels. Yet PPP results must also be robust if they are to be proven in large-scale testbeds and lead to short- and medium-term exploitation opportunities. It will be necessary to balance the need for research and innovation and the need for robust, demonstrable prototypes.

Exploitation vs Efficiency: The PPP aims to provide opportunities for Europe to exploit the Future Internet by providing and/or using innovative solutions, but to conduct the necessary research in an efficient way by sharing foreground across the PPP as a whole. However, exploitation may only be possible if the work builds on commercial background that cannot be freely shared, which may inhibit partners from implementing complete solutions needed for the Future Internet. The best solution is to ensure that a cross-domain solutions are standardised or vendor-neutral, allowing individual usage areas and testbeds to specialise without creating multiple instances of common capabilities.

Research Focus vs Durability: Focusing on vertically integrated Smart applications will help the PPP to manage some of the above challenges, by limiting the scope of the research and ensuring appropriate coherency and interaction between application sectors. However, the PPP should still contribute towards broader (e.g. the Future Internet in rural environments) and longer-term (e.g. virtual living) research challenges. The PPP should produce outputs to support these wider/deeper challenges, as well as starting points for commercial take-up.

(5) Potential roles

Many generic enablers and capabilities are available from EC and national research programmes (e.g. autonomic networks, cross-layer QoS management, dynamic security and dependability, federated information modelling and distribution, etc). These have been researched and developed in the context of one or more use cases and scenarios. By involving Research Centres to help address the applied research challenges discussed in this Paper, the FI PPP can build on their experience and capabilities, creating flexible platforms that deliver cost-effective testbeds, and enable socio-economically practical deployment of 'smart' applications on a Future Internet.