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TABLE OF CONTENTS

1 Executive Summary

This document aims at providing an initial Internet Science perspective on possible roles of standardization in the development of the Internet in order to distil recommendations to standardization bodies. This exercise requires to first determine what could be standardized out of Internet science results and which current (and/or foreseeable) activities of these standardization bodies could be “influenced” by Internet science activities. In Deliverable D2.1.1, we focused on so-called technical standards (and refer to technical standardization) compared to social and economical standards which are also addressed in this version of the document (and following the review recommendations collected from the first intermediate release of this Deliverable); thus the scope of this document is the Internet science dimension.

This deliverable details the possible role of standardization with respect to Internet Science. The number of technical standardization bodies being plethoric (not counting alliances and other “open” initiatives) we focused our initial investigation in relationship to Internet Science to the big five (IETF, IEEE, ITU, ETSI and ANSI) and their satellites. This release also extends this set of bodies beyond communication technical standards such as ISO and BEUC but also non-technical international regulation bodies such as WIPO. We then propose a gap analysis between Internet science and (network related) standardization process. Combination to the well-recognized technology research to standardization gap yields a very complex problem to which no definitive solution or answer can be delivered at this point in time. It is important to underline that this document does not aim at identifying how these bodies perform with respect to their current work/charters.

Following the gap analysis and acknowledging Internet science is also a young discipline, we propose though several recommendations for standardization bodies in order to expectedly initiate constructive dialog and interest among the different parties involved:

1. Providing the playground for raising new emerging technologies such as brain-to-computer interface, new communication medium, e.g., bio-molecular/bio-chemical substrate) that could not be thought by the classical engineering design process but may lead to the inception of new foundational architectural concepts and for extending ecosystem to socio-economic actors and not only digital entities, etc. The example provided by the IEEE Task Force shall also guide us in determining when such initiative should be taken and conditions that should be met to minimize risk of progressively deflating participation.

2. Extending the reach of working charters to attract innovative ideas (on accepted problems); even if shorter term approaches driven by operational and economical

constraints would seem more appropriate at first glance, this approach would likely raise common interest topics between technologists and scientists.

3. Opening up standardisation effort in the privacy domain (recent development in this domain cf. RFC7258 provides interesting line of thought in that direction). Setting common principles in the user data protection, as the main pillars of regulations would enable first step in that direction (in particular, if the big data monster model generalizes and replaces the small but beautiful distributed model in place today).

2 Introduction

Deliverable D2.1.1 focused on so-called technical standards (and refers to technical standardization). Following the review of the document by the EC, this updated version of document extends to social and economical standards. The scope of this document covers thus all the Internet science dimensions. Sections 3.1, 3.2 and 4 are included from deliverable D2.2.1: they remain unchanged from that deliverable, but are repeated here to give context to the other, new contributions of deliverable D2.2.2. This document focuses on the architecture perspective, as it belongs to JRA2 effort. However, Section 3.3.3 reports boundary issues relating to other JRAs.

The importance of ICT standards is highlighted in the Digital Agenda for Europe [1] in delivering interoperability between devices, applications, data repositories, services and networks. It also stresses the fact that standards are to be used strategically as a means of stimulating innovation and promoting interoperability of innovative products. In this context, the EC has published in June 2011 a series of measures with the objective of supporting better standards for Europe, faster [2]. As a follow-up of the publication of the White Paper "Modernising ICT standardisation in the EU - The Way Forward" [3] and the related public consultation, one major requirement to strengthen the system of standard-setting in Europe is the recognition that global ICT standards will play a more prominent role in the EU, both from the standardisation strategy [4] and regulation standpoints. In particular, regarding EU funded research projects, [4] states: *Finally, standards can help to bridge the gap between research and marketable products or services. [...] A systematic approach to research, innovation and standardisation should be adopted at European and national level to improve the exploitation of research results, help best ideas to reach the market and achieve wide market uptake*.

In general, the term 'non-technical standards' is taken to refer to:

- Standards issued by umbrella bodies like ISO e.g. ISO 9000 (management quality, consumer satisfaction, regulatory requirements/compliance) or ISO 14000 (environmental management, assessment performance)
- Non-technical communications-focused concerns (such as the design and editorial standards for Web sites and other Internet communications)
- The activities, rulemaking and principles issued by non-technical international regulation bodies (e.g. WIPO) and governments and by (networks of) national regulatory authorities (NRAs)
- It may also refer to things that are not quite standards, like laws, regulations, codes of conduct, strategies, policies, etc.

Technical standards subset refer to norms regarding technical systems covering physical, chemical, biological, robotic, etc. systems and thus not limited to telecommunication systems. It is well recognized that technical standards are one important way to promote the translation of research results into emerging technologies [3] [5] [6] and are also, in certain circumstances, the necessary pre-conditions for their large development, deployment and adoption. However, some level of standardization awareness needs to be considered in the research life cycle but on the other standard bodies need to attract a critical mass of researchers to participate in the standardisation process in order to facilitate this process.

The critical question becomes thus to identify the possible role of standardization in the context of Internet science developments and results. In other terms, determine on the one hand what could be standardized out of Internet science results and which current (or foreseeable) activities of standardization bodies could be "influenced" by Internet science outcomes; requiring in turn to determine which of them show possible relationships to Internet science. For this purpose, Section 3 provides an overview of the possible role of technical standardization with respect to Internet science. As part of this section, Section specific issues related to JRA specific activities are also documented. The number of standardization bodies being plethoric (not counting alliances and other "open" initiatives) as a first step we limit in Section 4 our investigation of current standard activities in relationship to Internet science to the big five (IETF, IEEE, ITU, ETSI and ANSI) and their satellites. In Section 5 and 6, we further develop the role of standardization in several key domains such as Internet of Things (IoT). Section 7 analyses the gap between foreseeable Internet science-related activities and conditions to make them possible -with our current understanding of the standardization landscape. Finally, in Section 8, we propose three recommendations, recognizing they will certainly evolve as Internet science progressively matures.

3 Role of standardization with respect to Internet Science

The term “network science” refers to a scientific discipline, centred on discovery and understanding of network-related processes (the “why”) and objective proofs (the axiomatic and fundamental/universal laws, the “what”). This is in contrast with engineering-oriented research which involves a subjective dimension in the decision criteria and constraints driving network design choices. The latter is centred on the “how” by focusing on the realisation of new artefacts/systems or on more efficient technologies to replace existing ones together with their operation/control. Hence, in addition to the technology-oriented/engineering research to standardisation gap, we also have to recognize a gap between scientific outcomes and their possible/potential translation into emerging technologies. Internet science delimits a subset of these networks where entities are digital or socio-economical information processing agents. Hence in the remainder of this document we will refer to Internet science (instead of network science) as the major focus of this document is on architectural, technical and socio-economical standards.

JRA2 has been shaped under the premises that “design” should be derivable from scientific methodology (thus implicitly that such methodology exist). Observing this scientific methodology remains to be discovered it is worth noticing that applying a scientific method is not a sufficient condition for realizing a so-called “good” design. Indeed, such approach (or method) only answers the problem of building the design right -not the problem of building the right design; hence, this approach would only allow for verification of the design (whether its realisation meets its original specification) but not its validation (whether its execution meets requirements). On the other hand, absence of scientific method does not enable to qualify a priori the properties of a given design. Consequently, it would be much more useful to identify the tangible and objective limits of current network technologies design process(es) rather than arguing along unverifiable statements of existence of scientific design methodology (that is yet to be determined) and putting high expectations behind the hypothetic existence of such methodology in designing large-scale systems. In other terms, the question of “what” can be designed (and subsequently specified) has first to be determined before digressing on the realization methods and its properties. The same question applies when it comes to the standardization role with respect to Internet science in determining if their current design process would allow specifying these technologies (corroborating the need to identify their objective limits). In the following, a first classification is proposed including network-related architecture, procedures, as well as methods, tools and languages in order to provide an initial answer to the question of what influence or role could Internet science have in the standardization process and the identifiable gap between scientific outcomes and their possible translation into emerging technologies ? Implicitly, the underlying question points to the finality or utility of Internet science as a whole: will it remain explanatory by nature or seed novel concepts related to "networking"?

3.1 Architecture

Current approaches driving architectural research can be subdivided into two main categories:

- Driven by the ***theory of utility*** [9], which assumes longevity and adaptivity of the Internet thanks to its design principles (modularity principle, end-to-end principle, etc.). As long as the Internet runs (even if it could run better) it is worth maintaining the current architecture. The evolution of the Internet is driven at its "edges" with the expectation to perform capabilities the network alone is unable to provide in particular congestion control (e.g., Explicit Congestion Notification (ECN) and its variants), and traffic-engineering (e.g., multipath-TCP) or by means of overlays (IP multicast, mobile IP but also overlay routing and peer-to-peer fall into this category) which materializes the weak coupling principle. It is interesting to observe that independently of the investment and technology-oriented research outcomes, most of these advances have had relatively limited impact on the actual architecture of the Internet but also on its functionality and performance.
- Driven by the ***theory of change*** [10], which assumes that after several iterative cycles of adaptation of its architectural components, it becomes more effective to redefine their foundation. Following this approach, the design of the Internet is no longer adapted to address its objectives. The architecture resulting from reactive and incremental improvements to independently designed protocols is considered as a limiting factor of Internet growth and the deployment of new applications (at least those that do not directly benefit from capacity addition or communication system upgrades). However, in many cases, the result leads to the changing or replacement of components as main research objective instead of resolving these architectural challenges starting from root cause analysis and elaboration of new patterns by reconsidering its design principles. A variant of this approach assumes that the Internet can't evolve anymore because under current conditions its design is locked by inflexible systems running processes determined at design time to minimize the cost/performance ratio for a given set of pre-determined functionality. Among the prominent efforts falling in this category, we can mention open-flow, and virtualization but also the more recent software-defined/-driven networks (SDN).

As a consequence of the theory of utility, the evolution of the Internet is driven by i) incremental and reactive additions to its protocols or ii) when extensions to existing protocols are not possible anymore (without changing the fundamental properties of these protocols) by complementing them by overlaying protocols. With this evolution model, the influence of Internet science would be mainly targeted at the periphery and upper layers except of course if a major event occurs that would require more fundamental reconsideration of its architecture. Another would be the possibility to provide an answer to the critical question this evolution induces in terms of cost vs. functionality (one of the main Internet design principle).

More generally, whether Internet science could enable a "third architectural path" instead of the one implied by the theory of utility or the one implied by the theory of change remains an open question at this point in time. In other terms, the question whether new foundational architectural concepts and patterns can be derived out of the identification of common principles and laws characterizing the structure and regulating the behaviour of networks remains to be determined.

3.2 From Processes to Procedures

Network science aims at discovering/identifying, formalizing and analyzing common processes and properties among its constituent network-oriented disciplines (where the tern network comprises entities being either physical, chemical, biological, social or digital/ logical objects). Internet science delimits a subset of these networks where entities are digital or socio-economical information processing agents. Translating these processes when properly identified into computational procedures (i.e., algorithms which together with data structures constitute programs) is a non-trivial task. Indeed, this exercise requires the identification of a model (abstraction) of the process in terms of function, state and data: what computer science refers to as a “system architecture”. In the history of networking we have of course several examples that involved similar considerations such as the application of fluid dynamics to traffic and congestion control and navigation process to routing. Of course, and as these examples illustrate, the resulting system architecture does not need to be holistic and can be limited in terms of scope but it remains that transforming Internet science output into “specifications” (output of the standard process) will certainly raise the fundamental question of the “process resolution”. Whether new “systems” themselves could be derived out of the Internet science results remains an open question. For instance, the general idea of (epidemic) diffusion has been (re-)used to propose distributed routing processes in various domains and applications whereas the broader class of reaction-diffusion (generalizing basic epidemic models) have been investigated in the context of e.g. social networks and socio-physics. Designing out of them a global routing system (and underlying procedures) to provide information communication channels remains to be elaborated.

3.3 Standardisation from the perspective of social sciences

Standards are typically considered from the technological perspective. Most of the standards that bear this name concern technical aspects of hardware, software and operational procedures. This perspective is limited in three respects of particular relevance to Internet Science. First, an extensive literature demonstrates that the impacts of standardisation activities and the structure, conduct and performance of standards bodies cannot usefully be analysed and understood without taking socioeconomic perspectives into account; the objectives of standardisation are derived from the utility that results when human beings make use of technical systems in order to further their perceived interests, including the extent of compliance. Second, the processes by which changes in standards are linked to changes in technological and human systems are typically complex combinations of human and organisational communication and decision making. This means that both the theory of utility and theory of change aspects of standardisation are linked to societal processes and thus that the social science aspect of Internet Science is an essential component of standardisation. This is particularly relevant from the architectural perspective, both in terms of architecture as a set of overarching meta-rules or principles for design and in terms of architecture as an emergent pattern or aesthetic characteristic of system implementation, use and change. However, there is a third aspect of almost equal importance; some standards – or things that serve the same function as standards – are social or economic rather than technical. Just as technical standards can be formal or informal, social and economic standards can range from laws or regulations to societal norms and conventions. These aspects are specifically addressed by JRA4; they are mentioned in this section primarily for their architectural implications, specifically the need to ensure that Internet architectures are aligned with socioeconomic standards and *vice versa*.

3.3.1 Definitions of architectural standards from the social science perspective

a) Standards in relation to architecture in general

The general characterisation is linked to theories derived from other domains - biology, buildings and other structures and public spaces such as cities. As discussed in the first ‘Thinking architecturally’ workshop, it is useful to see architectural principles as a set of constraints on design, experimentation and practice. They (standards) may themselves be designed, refined on the basis of experience or the emergent consequence of vernacular expression (e.g. ‘rough consensus and running code’). The rough consensus method (as used in Netmundial) does serve to initiate a conversation, but is loose enough to reach a result (particularly in such multi-stakeholder environments) because it does not dot every 'i' but leaves some aspects to be negotiated later (among smaller groups if particularly relevant to their interaction or in the future if not enough is known to finalise the standard, but where the presence of a 'rough consensus' standard may reassure the parties that investment will not be stranded by a wholly incompatible standard. It is also especially suited to governance standards, which have to be compatible with a wide and changing variety of processes and institutions among the stakeholders. In the spirit if the 'layered protocol' argument, it might be scalable only to the efficient level of standardization (layer or module) but not beyond, which could provide a cheap and decentralised way of finding out what those levels or modules are. In more general terms, standards for Complex Adaptive Systems (CAS) are more 'architectures' than 'designs.' On the other hand, it might be hard to monitor or enforce compliance with such an ephemeral or virtual standard. Standards may also be expressed in different ways (as above) ranging from formal models to specified rules for design and implementation to a series of instances (in which case the codification of the architecture amounts to pattern recognition). Within this framework, two major types of variation leading to Internet evolution are foreseen; variations within the standard, which lead to refinement (Kuhnian innovation within a paradigm) and disruptive innovations that break (or appear to break) the standard. The linkage to evolution comes through the response of designers, users and other stakeholders. Standardised innovation may not be noticed, so the reaction is likely to be gradual and localised; non-standard innovation stands out, and gets noticed – it may even rewire the network of attention. This applies specifically to networked communities; standards that are the exclusive province of closed and homogeneous clusters (e.g. systems engineers) influence users and society more than they are influenced by them, and are rarely noticed outside the domain. Disruptive changes – especially those arising outside the standards community – do get noticed; they may produce new standards, but may also change participation in standards activities.

b) Internet and computer standards

This kind of standard is sometimes viewed as a critical infrastructure system. Standards that provide foundations for interoperation of independent applications and autonomous systems are especially important; errors or vulnerabilities arising from mistaken, unexpected, unprincipled or (generally) innovative use of such standards might not be noticed until interactions among fully deployed systems reveal "killer" design faults. This means that standards – even narrowly technical ones – should be accompanied by clear and simple guidance for adopters, and based in critical reasoning about a) how adopters might use them (in what context, with what variations) and how they may interact (with systems following other types of standard or with a realistic range of non-standard or unstandardized elements. In specific relation to the Internet, this means thinking beyond the individual system and its intended users and uses. It may also mean giving clear indications of the limits of the standard – some aspects only work in specific types of system, which means that higher-level (macro) standards are needed as well. The complication is that the meso- and macroscopic level systems to which they refer are neither designed no controlled, though they may be regulated or governed by loose adherence to general principles (like end-to-end). But at a concrete level, the micro-guidance may be expressed in tools, documents or theorems[1].

c) Economic standards

These are of three kinds, mirroring the designed, refined or emergent distinction:

- The *designed standards* are the 'rules of the game' expressed in legal structures within which markets take place (laws and regulations in civil law domains, conventions for contract law (Rome (I/II), Vienna conventions etc.).
- *Refined standards* include market rules in common law regimes.
- *Emergent standards* cover the norms of economic behaviour (including self-regulatory codes). Another critical bit of emergent economic standardisation is commoditisation – commodities are by definition standardised; even 'new' artefacts like mass customisation are standardised at a slightly higher level (rules for making commodities, or 'layer' standards – see below).

In addition, we have the following types of standards:

- *Societal standards* include ethical norms and aesthetic standards (elegance, beauty, etc.).
- *Layer standards* – often, aspects of systems are standardised, with homogeneity (apparently) confined within. For example, messages are not standard but packets (and associated management) are; individuals are not standardised, but their data profiles are; observations and sensor reports may not be standardised, but 'big data' are. The interaction between the standardised and the particular is of crucial importance. For instance, in relation to re-use of personal data, the use of those data to target the specific data subjects is highly particular and the interests affected are the subject of fundamental rights; the use of data for anonymous profiling and general market analysis is standardised and the interests are general and transferrable (in other words, an economic right).

[1] See Sullivan, K. J., Socha, J., & Marchukov, M. (1997, May). Using formal methods to reason about architectural standards. In Proceedings of the 19th international conference on Software engineering (pp. 503-513). ACM.

Standards and standardisation issues of different types have important interactions: technical, economic and/or societal issues may be handled – and raised - by any combination of technical, economic and/or societal standards – there is no presumption of a 1-1 correspondence.

d) Energy-related standards

Cf. JRA8 (please refer to page 30).

e) Economic considerations applying to standards more generally

There are also economic considerations to apply to standards more generally. These reflect two traditions: standards as a communal or collective form of intellectual property right, and standards as a form of self- or co-regulation. The issues analysed include the way adherence to standards is linked to reputation, market access and market power, the struggle for control of standards (open or closed, public or proprietary), etc. Some of this is 'narrowly economic' in the sense that the resulting standardisation game is played between profit-motivated entities (firms) for money; other versions are broadly economic in the sense that parties view standards not as critical infrastructure per se but as a public good, and may have shared or non-comparable motivations. Both the narrow and broad games can be played between firms, technologies, countries, ministries, etc.

To develop a classification framework that reflects this game-theoretic perspective, we need to identify the players, the processes in which they are involved and the types of standards that result. Regarding standards as a potential constraint on subsequent activities, we can relate them to other constraints such as laws or contracts by considering the way they are formed and enforced and the resulting impact of key stakeholders. The architectural aspect derives in large part from the 'rules for making rules' governing the societies involved and the breadth of the standards. The completion of this work requires further interactions among the JRAs (as detailed below); for now we propose the following groups of players and standards types.

Players – these can be divided into conventional broad categories (governments, businesses, citizens or their clusters) or divided into more specific groups defined by the following considerations.

- Who participates in forming (calling for, proposing, commenting, approving, promulgating) standards?
- Who is bound by standards – and how (what accountability, certification, liability)?
- Who is affected – and what do they know about standards and patterns of compliance or adherence?

Standards – these can likewise be divided in many ways, according to whether they are:

- Formal or informal – this applies to the processes of standards formation (e.g. a formal RFC, regulatory or legislative process vs. an informal 'evolution of conventions' societal dynamic) and to the standards themselves (in particular, the extent to which they are defined in terms of conduct or outcomes and the degree to which they are specified in 'black-letter' or 'constructively ambiguous' terms.

- Ex ante or ex post – in other words, whether standards compliance is verified and enforced before or after the instance or activity. Standards defined in outcome or functional terms tend to be ex post (when outcomes and functional performance can be assessed); they are flexible and invite innovation, but may come 'too late' and provide little guidance to third parties who may rely on specific details.

- Open, networked or closed – again, this applied both to standardisation processes (e.g. who has standing to propose, specify, comment on or approve standards) or to the standards themselves (e.g. the description of open standards is available to the public and anyone can implement and use the standard, while closed standards are not described to the public in sufficient detail to permit open implementation)[2]. The literature deals extensively with the technical and economic aspects of closed and open standards; however, studies of self-and co-regulation[3] (of which standardisation may be regarded as a subset)

3.3.2 The Internet Science aspects of architectural standards

It should be obvious that architectural thinking, not least where standardisation is concerned, can make serious contributions to the design and implementation of policy directed at or affected by the Internet. But the specific contribution of science to standardisation and Internet Science to Internet architectural standards may not be so obvious. This section considers the potential contributions of the 'hard' and 'social' science aspects of Internet Science to standardisation processes, the challenges facing Internet Scientists in optimising their contributions and the steps needed (in relation to the overall EINS road map) to overcome them.

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[2] Closed standards, like other forms of proprietary intellectual property right, allow standards 'owners' to sell or license the standards and/or compliant services or products. This creates incentives for standards and the creation of closed 'compliance clusters' within which other issues (e.g. security, reliability) may be handled by negotiation or self-regulation, but at the same time limits uptake and acceptance and can create competing or even conflicting closed or open standards.

[3] See e.g. Cave, J., Simmons, S., & Marsden, C. (2008). "Options for and Effectiveness of Internet Self-and Co-Regulation Phase 3 (Final) Report". Report for European Commission. Available at SSRN: http://ssrn.com/abstract=1274571.

a) Contributions of Internet Science to standardisation

It is useful to distinguish (as in Section 3.2) between 'scientific results' and 'technological innovations'. For technologies that are derived from scientific breakthroughs in mature areas (i.e. within the boundaries of a Kuhnian paradigm) it is common for the distance between scientific output and technological input to increase; of course, during phase changes (when causality may reverse) this no longer holds. The implication is that scientists are best involved in the early stages of a cycle of technological refinement of existing basic knowledge; but they may be needed during the late phases of disruptive technology application in order to identify paradigm-shifting outcomes and factor this into new scientific models and enquiries.

'Hard science' can advise on

- Concrete findings and results
- Models and propositions; and
- Practical judgements: what is feasible; likely effects of specific restrictions; what needs further study or monitoring

To complement this, 'social science' can advise standards bodies and standardisation process stakeholders as to:

- The nature of standards processes - how stakeholder interests, perceptions and powers of action influence participation and standards (concretely, to what extent can they be trusted to produce sound and effective standards);
- The likely impacts[4] of particular standards – who will comply and to what extent, what can be observed and inferred from the resulting behaviour and interactions, what spillover pressures will arise for other domains (law markets) and measures of performance (income, innovation, service quality, competitive performance, application effects (like health, financial market efficiency); and
- The networked structure of standardisation processes - who participates and how individual entities divide their efforts between playing the standards game and others (markets, R&D, lobbying).

[4] Note that some of these impacts on which the social aspects of Internet Science can shed light may be considered matters of 'hard science' – e.g. whether a given standardisation process or framing will lead to loose or tight technical standards. Others fall directly into the social science domain – more or less information, welfare, individual discretion and empowerment, profit for specific stakeholders, etc.

b) Challenges facing Internet Science contributions to standardisation

The standing of scientists in general – and Internet Scientists in particular – in standardisation processes does not always allow the contributions identified above to be made effectively. Specifically, in order to play this role, Internet Science will need to be:

- 'ready for prime time' – in other words, are its phenomenology, methods and results sufficiently distinctive, rigorous and relevant to earn recognition from the rest of the applied science community (especially the disciplines contributing to Internet Science)?

- Will Internet-related standards bodies and processes listen to what Internet Scientists have to say?

One specific domain where Internet Science has a vital role to play concerns interoperability (a system property) and trust (a human analogue). Standards provide a common framework for systems that might interact. The power of this depends in large part on being able to rely on what is received from other parts of the system and on being able to farm out activities to other parts of the system. The key added ingredient coming from the complex Internet is that these 'other parts' may be 'other levels' – the problem of emergence.

Closely linked to this, but perhaps more fundamental, is the *complexity* aspect. The Internet provides a dual example of complexity, being both:

- A complex adaptive system, which has the goal of adapting its structure and behaviour to address an objective set in advance – ion other words, a system whose boundaries and objectives form essential parts of its architecture; and

- An adaptive complex system, in which all aspects of the system including its boundaries and objectives, change endogenously and in response to the environment.

When studying the behaviour of specific Internet players or giving policy advice, we may take their 'hard-wired' objectives as axiomatic – at least as a starting point. But declared objectives, effective agendas and net influence may be different things, especially in imperfectly-observed systems with extensive feedback where individuals may behave 'as if' they were pursuing quite different objectives from those they declare, or even those they intend. Inferring the objectives empirically is a point of intersection between CAS and ACS, in two senses.

In a normative sense, social sciences can identify the sets of objectives which can best be adopted by the multiple stakeholders whose decisions and behaviour create the Internet.

Conversely, in a positive sense studying the 'revealed preferences' (the organising principles) of past behaviour can identify which of the myriad of possible objectives are actually influential at key points and how this aligns with power and the specific triggering events.

In view of the evolutionary flexibility suggested by the ACS perspective, turning loose malleable or plastic technologies is preferable to hard-wiring specific standards or behaviours that may not turn out to be useful in practice – especially if their effects or the existence of superior alternatives cannot be observed easily and in time to adapt. Thus detailed standards should probably not be promulgated blindly or without learning (in an Internet Science way) from the past.

More generally, complex systems interact with standards in several ways:

- Standards change the evolution of such systems by constraining the response of parts to the whole or vice versa; and
- The 'native' behaviour of complex systems drives towards standardisation in terms of:
    - Motifs
    - Modularisation
    - Self-similarity/scale-free structures
    - 'synch' and even
    - Self-organised criticality and related 'phase change' behaviour.

There are a host of examples of aspects of the Internet displaying the kinds of standards-related behaviours that social scientific aspects of Internet Science can predict or anticipate, including:

- The Internet of Things (see Section **Error! Reference source not found.** below)
- Big Data – especially in relation to algorithms and security, but also in setting limits to what can be done based on analytics; and
- Cloud computing.

3.3.3 Boundary issues relating to other JRAs

JRA1 – Complexity aspects (emergence, synch, self-organisation, scale-free-ness, motifs, modularisation)

The Internet can be considered as the most widely deployed combination of a communication and distributed information storage and processing system. The big promises put behind the current information processing systems and communication technologies (IT) despite their increasing architectural and computational complexity, including so-called social digital networks, are however facing three major challenges: i) unable to originate novel information pattern on their own (thus at best capable to sustain evolution but not progress) because information processing and transformation perform with the pre-requisite of known/pre-determined finality (objective function) often dictated by the system-itself; such systems are thus unable to transform/exploit the information they receive as input and/or generate into new patterns whose characteristics couldn't be inferred from their individual properties or from individual objectives independently; as an example unable to predict advent of anti-social networks; in a certain sense, the system doesn't produce more than what it receives (the ratio I_{out}/I_{in} which measures "emergence" of new information patterns and structures is < 1). ii) relying on centralization of information stored out its context (thus loosing part of its semantic and in turn its value) in order to derive offline learning models: assuming that the amount of information continues to grow exponentially exhaustive pattern search for similarity will unavoidably mobilize more and more resources (storage capacity) -independently of the computational complexity in time/space of the processing algorithm (to paraphrase the input size remains n independently of the processing performance even if logarithmic in the input size)- but more importantly will be unable to take benefit of increasing heterogeneity of patterns resulting from the growing number of new domains for which these systems are progressively deployed; iii) trend toward "cloudification" exacerbates computational complexity; indeed as as fine-grained information needs to be centralized before being processed offline (independently of its expected utility), processing output is at best informative as coarse-grained and post-training requests have no effect on processing, i.e., the same query always produces the same result, moreover, the value out of the exchange process disconnected from its processing; thus, limited to a bare "transport" of information. Of course, being part of the trend one may question whether these observations are not due because these systems are still in a very early phase of expansion; recent epidemiologic spreading studies show however that after a steep adoption by susceptible, the system may also steeply recover (within 2 to 5years) in absence of renewal process.

Structuring standardization-related recommendations remains unarticulated so far mostly because bodies like IETF are exclusively centred on protocols instead of functional distribution and processing information (including its structure and semantic) that would be required in order to address these fundamental challenges. The first one is a main challenge in incorporating collective and artificial intelligence and derivatives (incl. machine learning) and is certainly of foundational interest for generic-purpose adaptive systems that would be designed to run in a wide variety of dynamic environments without requiring expert training phases, i.e., autonomously. The second stems from a decentralization of the information processing and instead of moving rough data to a central point thus centralizing information, move toward the dynamic control of decentralized learning functions and learning output (to achieve scaling and increase utility). The third point relies on the former to move toward an organic collective processing of information; the ultimate target being knowledge achievements (determine who knows what).

JRA3 - Standards for metadata descriptions of resources for the Internet Science Evidence base; such resources include datasets, analytic tools and e-Infrastructures

There is no single standard for publishing resources online. Several ones are being used and even proprietary description formats are common, e.g., <snap.stanford.edu/data>, <konect.uni-koblenz.de/downloads/#full_datasets>. In domains such as bioinformatics, medical reports, etc., there are more widely accepted ontologies, which are used as schemas. There are a lot of links in the LOD cloud, but for a particular application context, one needs to realize the mappings one needs and this is challenging. Below, first few important standardization efforts for metadata description of online resources are described and then we describe the proposed schema for describing online datasets, tools and infrastructures in EINS.

- *Dublin Core*: The Dublin Core Metadata Element Set is a vocabulary of fifteen properties for use in resource description. The fifteen element "Dublin Core" described in this standard is part of a larger set of metadata vocabularies and technical specifications maintained by the Dublin Core Metadata Initiative (DCMI). The full set of vocabularies, DCMI Metadata Terms [DCMI-TERMS], also includes sets of resource classes (including the DCMI Type Vocabulary [DCMI-TYPE]), vocabulary encoding schemes, and syntax encoding schemes. The terms in DCMI vocabularies are intended to be used in combination with terms from other, compatible vocabularies in the context of application profiles and on the basis of the DCMI Abstract Model [DCAM]. This document, an excerpt from the more comprehensive document "DCMI Metadata Terms" [DCTERMS] provides an abbreviated reference version of the fifteen element descriptions that have been formally endorsed in the following standards:

    - ISO Standard 15836:2009 of February 2009 [ISO15836]
    - ANSI/NISO Standard Z39.85-2012 of February 2013 [NISOZ3985]
    - IETF RFC 5013 of August 2007 [RFC5013]

  A number of Metadata Workshop conferees represent organizations that have ongoing activities or are starting activities that will be influenced by the results of the workshop. These include:

- The OCLC Spectrum Project
- The OCLC Internet Resources Cataloging Project
- Library of Congress

- *AGLS Metadata Standard*: set of descriptive properties to improve visibility and availability of online resources. AGLS is published as Australian Standard AS 5044-2010. The 2010 revision supersedes AS 5044-2002 AGLS Metadata Element Set and is renamed the AGLS Metadata Standard. This revised version takes into account changes introduced by the Dublin Core Metadata Initiative (DCMI) in January 2008. It also makes technical changes to support linked data and Semantic Web projects, recognising that the internet is no longer just a medium for publishing human-readable documents. This AGLS Metadata Standard provides a set of metadata properties and associated usage guidelines to improve the visibility, manageability and interoperability of online information and services.

  We first describe a vocabulary of properties for use in resource description. The full set of Vocabularies also includes sets of resource classes, Vocabulary Encoding Schemes and Syntax Encoding Schemes. The terms in AGLS vocabularies may be used in combination with terms from other, compatible vocabularies in the context of application profiles and on the basis of the DCMI Abstract Model. Since January 2008, DCMI includes formal domains and ranges in the definitions of its properties. So as not to affect AGLS implementations created in compliance with earlier versions of this Standard, domains and ranges have not been specified for the fifteen properties of the dc: namespace (http://purl.org/dc/elements/1.1/) or the four properties in the agls: namespace (http://www.agls.gov.au/agls/1.2/). New properties with names identical to those of the Dublin Core Metadata Element Set Version 1.1 have been created in the dcterms: namespace (http://purl.org/dc/terms/) and new properties with names identical to those of the AGLS Metadata Element Set Version 1.2 have been created in the aglsterms: namespace (http://www.agls.gov.au/agls/terms/). These new properties have been defined as having sub-property relations to the corresponding properties of the original element sets and assigned domains and ranges.

  Implementers may use the original 19 properties either in their legacy dc: or agls: variant, or in the current dcterms: or aglsterms: variant depending on application requirements. Over time, it is strongly recommended that implementers use the semantically more precise dcterms: and aglsterms: properties, as they more fully follow emerging notions of best practice for machine-processible metadata.

- *VoID*: RDF Schema vocabulary for expressing metadata about RDF datasets. It provides four categories of metadata:

    1. General metadata, that gives information such as the title, description, license of the dataset. It helps potential users to have a rough understanding whether the dataset is appropriate for their purposes.

    2. Access metadata, that describes methods to access the RDF dataset. It gives the URL of the SPARQL endpoint of the RDF dataset, or the location of the RDF dump (file) of the dataset.

    3. Structural metadata, that provides high-level information of the structure and statistics of a dataset and can be used for querying the dataset.

    4. Linking metadata, describes the linkages and relationships between datasets.

  However, VoID is only for describing RDF datasets, and thus not suitable for describing generic Internet resources.

- *DCAT*: RDF vocabulary designed to facilitate interoperability between data catalogs published on the Web. Three main classes of DCAT are:

    - dcat:Catalog, represents the catalog

    - dcat:Dataset represents a dataset in a catalog

    - dcat:Distribution represents an accessible form of a dataset. e.g. downloadable file or a queriable interface.

  DCAT is usually used with FOAF (to describe persons that are related to the datasets) and SKOS (to describe related concepts). It can also be used with VoID to provide statistics, if the given datasets serve RDF.

- *SKOS*: provides a model for expressing the basic structure and content of concept schemes such as thesauri, classification schemes, subject heading lists, taxonomies, folksonomies, and other similar types of controlled vocabulary. Usually SKOS is used along other vocabularies in a similar way as Dublin Core.

- *Schema.org*: an emerging approach supported by the dominant search providers is to use Microdata (http://schema.org) markup and vocabularies to describe Internet Science datasets available online. Many sites are generated from structured data, which is often stored in databases. When this data is formatted into HTML, it becomes very difficult to recover the original structured data. Many

applications, especially search engines, can benefit greatly from direct access to this structured data. Schema.org is a collection of schemas that webmasters can use to markup HTML pages in ways recognized by major search providers, and that can also be used for structured data interoperability (e.g. in JSON). Search engines including Bing, Google, Yahoo! and Yandex rely on this markup to improve the display of search results, making it easier for people to find the right Web pages. On-page markup enables search engines to understand the information on web pages and provide richer search results in order to make it easier for users to find relevant information on the web. Markup can also enable new tools and applications that make use of the structure.
When a taxonomy for the description of the various properties of online resources is missing, then one can use DBpedia (http://en.wikipedia.org/wiki/Wikipedia:Quick_cat_index) and other widely adopted taxonomies (e.g. ACM taxonomy).

- *Microdata Description*: Microdata is a simple semantic markup scheme that's an alternative to RDFa. It has been developed by WHATWG and supported by major search companies (Google, MSFT, Yahoo) for indexing. Like RDFa, it uses HTML tag attributes to host metadata. The microdata effort has two parts: markup and a set of vocabularies. The vocabularies are controlled and hosted at schema.org. The markup is similar to RDFa in that it provides a way to identify subjects, types, properties and objects. The sanctioned vocabularies are found at schema.org and include a small number of very useful ones: people, movies, etc. The Microdata markup consists of three basic tags: itemscope, itemtype, itemprop. An itemscope attribute identifies a content subtree that is the subject about which we want to say something. The itemtype attribute specifies the subject's type. An itemprop attribute gives a property of that type.

JRA4 – Standards as collective IPR and as complements to regulations and laws; interaction is extent to which architecture can substitute for a constitution.

The JRA4 perspective includes the mechanisms for identifying, assessing and devising effective solutions to problems associated with specific activities that potentially damage others (governance processes); the laws and regulations themselves (governance outcomes) and the resulting activities of individuals in response to the selection and incentive structures flowing from these. Standardisation processes, outcomes and activities form subsets of these. The analysis of standards and standardisation is thus a central focus of JRA4. To see how standards relate to other forms of governance, it is necessary to consider specific domains or governance problems and the scope of different activities. Without re-capping the entire area of overlap, the following aspects are of particular relevance.

First, standardisation activities involve the creation, implementation and enforcement of a specific set of rules defining acceptable and unacceptable structures, behaviour, technologies, etc. In this respect, they overlap with other forms of control. However, laws and regulations in the strict sense are generally produced by government bodies, which have specific powers and competences enshrined in the constitutional and legal fabric of nations and other entities; participation in this process (except via the indirect methods of political influence) is neither voluntary nor free of constraints. This element of compulsion ensures a high level of scrutiny and evaluation of the initial problem (the justification for action), the form of the rules, the impacts across a broad range of stakeholders and (perhaps most importantly) the feasibility and consistency of any proposed rule with existing rules and processes. This 'weight' makes legal processes an attractive platform for the participation of many stakeholders – they pay attention to the platform and its rules, seek to bring their concerns to its deliberations, and do so under (relatively) clear understandings regarding the jurisdiction (remit and influence) of any particular forum[5]. In contrast, many standardisation bodies and actions have a much looser structure of permitted associations, procedures, available tools and enforcement mechanisms, with a high degree of openness and a strongly voluntary character. This makes them self- or co-regulatory in character, with attendant advantages of flexibility and credibility, but disadvantages of capture, creep and potential conflict or overlap that exceed those of formal rulemaking.

Standards also differ from laws in that they are rarely if ever mandatory. That is, stakeholders can choose whether or not to adhere to them on the basis of the resulting reputational, interoperability, perceived quality and other consequences. There is also a difference between actual and declared adherence; certification of standards compliance is a characteristic of firms and other entities used by customers, regulators, business contacts and others to make broader inferences about the nature of the firm. From this perspective, a standards-based approach may produce rules of different stringency, levels of compliance and transparency than an equivalent law-making or regulatory approach[6].

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[5] In other words, standards are rarely uniquely authorised, but must contend with others in ways that laws and regulations do not.

[6] Note that these are not the same; laws are made by legislative processes, and regulations interpreted and enforced by regulators. Although many regulatory processes are quasi-judicial, this does not make them laws. Moreover, many regulators have considerable discretion to create new rules by fiat or precedent independently of legislatures in pursuit

An example is provided by IPR. Most forms of IPR convey exclusive ownership (in some sense); standards may be regarded as ‘belonging’ to those who adhere to them, and thus constitute both a collective form of IPR and one where membership of the collective is (except for proprietary standards) voluntary; in exchange for participating in this right (and reaping its benefits) those adopting a standard also buy into an extended mutual governance process.

But neither standards nor laws are always adhered to; neither is even the best of them future-proof. In both domains, there is an implicit structure for motivating departures from the current norm and testing whether these departures constitute and improvement to an extent that justifies change. For laws and regulations, this typically involves legal cases and judicial decisions; standards tend to operate more like guidelines, in which overt departure from the standard automatically brings a higher level of scrutiny and may trigger a migration of users and other parties, producing a de facto change. This does not mean that the prior standard is dropped – again in distinction to formal processes, most of the Internet-related standards in existence have not been implemented and may never be implemented. Unlike, say, exclusive IPR (e.g. ‘sleeping patents’) these adopted standards and unenforced laws to not inhibit future innovation. So in this sense, standards may be more flexible and innovation friendly, at least in some contexts.

The architectural aspects are thus threefold: accepted standardisation procedures (e.g. the by-laws of standardisation bodies and procedures like RFC (request for comments) constitute and architecture for standardisation that serves a role analogous to a constitution in a government process; a rule for making rules. Secondly, the (patchwork) body of existing proposed and rejected standards provides a ‘vernacular’ architecture for the governance space, especially on the Internet where the jurisdictional certainty and deliberate and formalised processes of change associated with formal laws and regulations are difficult to sustain. Finally, by creating a voluntary and largely open platform for the engagement and continual contestation of interested parties based on an ongoing flow of real-world data and experimentation, standardisation provides an architecture for the formation of networked communities of interest involved in Internet governance, but also in the governance of societal and economic behaviour (from content to commerce) extended onto the Internet.

JRA5 – Privacy standards, PBD; interaction is again the extent to which privacy raises specific architectural challenges and the privacy implications of architectural standards and design choices.

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of their (statutory) duties, and often accompany these by analytic or consultative practices that differ from those involved in law-making (to say noting of standardisation).

In the field of privacy and data protection various standards have been adopted. They are related to the different contexts in which information is processed and to the nature of personal data. Nevertheless, the approach adopted by the JRA5 has not been focused on the existing technical standards, but on the more general strategy adopted by the EU lawmakers in regulating data processing. From this perspective, in the EU proposal for a new legal framework for data protection a central role is played by risk-assessment and by the adoption of privacy-oriented architectures. These two elements represent the basis and the constitutive features of the future framework of standards in the area of data protection.

The data protection impact assessment evaluates ex ante the future impact that a given service or product could have on personal information. An important element of this assessment is the continuity of the evaluation, which follows products and services during their entire life-cycle, redefining the assessment when new features or modifications are introduced. This prior and permanent analysis reduces the need for lawmakers to follow technological developments and it fosters preventive solutions consistent with the principles of data protection. From this perspective, given the case by case approach of the assessment, standardization processes concern the procedures of assessment rather than the requirements that are necessary to reduce the potential negative impact of data processing, which vary in different contexts. Nevertheless, an adequate strategy to limit risks in data processing is based on the results of the prior assessment and uses them to adopt specific solutions embedded into the architecture of processes or products (data protection by design).

In the light of the above, processes or products can be clustered in some macro-categories (e.g. devices that use biometric information, processes of video-surveillance, etc.) and similar solutions can be adopted in the various situations related to the same category. In this sense, standardization may concern not only the evaluation process (i.e. data protection impact assessment), but also the remedies "by design" that can be implemented.

Finally, and more in general with regard to standardization in data protection, it should be noted that the adoption of privacy-oriented technologies or processes is more suitable than ordinary “behavioural” rules to address the transnational dimension and continuous evolution that characterise the ICT environment.

Data protection is usually based on rules that permit or prohibit some activities (“behavioural” rules), using a model focused on prescription, ex post evaluation and sanction. This model is efficient in contexts where individual activities are traceable, the identities of authors of unlawful activities can be discovered and laws are enforced in an easy and not expensive (or time-consuming) way. Nevertheless, these conditions are not always present in the on-line environment. For this reason, it could be useful to design processes and technological instruments in a privacy-oriented way, in order to create a “structural” barrier to their possible unlawful use.

Moreover, as above mentioned, the implementation of technical solutions of data protection is less conditioned by the local legal framework than the implementation of “behavioural” solutions and it could be realized uniformly in different legal systems.

In conclusion, a few considerations should be expressed about the effect that the complexity of data processing, the power of modern analytics and the “transformative” use of personal information have on the potential adoption of standards in the area of data processing.

Regarding the new digital context (Big Data, Internet of Things, quantified self), the traditional approach adopted by the European data protection regulations seems to be partially inadequate.

In the field of consumer data protection, the main pillars of regulations are represented by the purpose specification principle, the use limitation principle and the “notice and consent” model. Nevertheless, massive data collection and powerful analytics increasingly limit the awareness of consumers, their capability to evaluate the various consequences of their choices and to give a free and informed consent.

These elements lead us to reconsider the traditional model of data protection with regard to the future digital age. It is necessary to define standards and procedures in order to adopt rigorous impact assessments of data processing, which do not focus only on data security, but also consider the social impact of data processing and the ethical use of data.

For this reason, future standards should have a wider field of action and involve different expertise, both in the definition of the standards and in their application to specific contexts and cases.

JRA6 – The interpretation of standards as community norms and the formation of clusters around specific (networks of) standards.

Standards adoption constitutes a coordination game, in the sense that interactions between entities are better for each if their standards are compatible and in the sense that Internet stakeholders are not indifferent among the standards. It may be that some standards would, if universally adopted, be preferred by a subset of the players (e.g. by shifting costs, liabilities, controls or benefits). Other standards may be universally preferred. If we model this using the ‘evolution of conventions’ approach pioneered by Kandori, Mailath and Rob (1993) we can see which standards are stable, albeit in a limited way (one standard with alternative forms; one choice per player, fixed network of interactions; and myopic standard selection). From this we learn that: payoff-dominant standards (best for everyone) are not necessarily stable, but generalised risk-dominant (easier to get into and harder to escape from) ones are; that stability depends on the likelihood of mistakes of different kinds; that the path towards a stable standard runs through unstable ones; that dense local connectivity speeds convergence; and that optimal standards can be stabilised by policies that favour experimentation away from the current standard. This model shows the influence of social groups, but does not address their formation. A complementary line of analysis, associated with e.g. Jackson and Wolinsky (1996) examines the strategic formation of network links (there are related literatures on coalition formation, but they are at present harder to transpose to this context). It shows that the topology (and structural motifs) of voluntary network associations are strongly influenced by the payoffs to the individual players (taking into account what they know about other parts of the network, including their partners' other connections); that efficient and stable networks may be disjoint and that specific sharing of information may stabilise efficiency. To extend this analysis, it is necessary to bring the network formation and conventions models into temporal contact (let them operate in the same time frame); include multiple interacting standards; tie link formation directly to standards adoption (and vice versa); and add non-technical layers of standardisation and interaction. This is an architectural matter to the extent that available standards, information about and certification of compliance, rules for changing or adopting standards and constraints on the making and breaking of links form an institutional infrastructure to strategic standardisation processes.

A second point of contact concerns the societal function of on-line communities. This reflects the way in which standards adoption creates a 'ready-made neighbourhood' of other users of the same standards. This voluntary association may not result in direct pairwise interactions, but may create affordances (like Granovettor's weak ties) and also a kind of 'generalised relationship' with entities whose overall characteristics form a cluster, but who are not directly known. This changes expectations about trusting them and linking with them. It also changes incentives for compliance, monitoring and enforcement, innovation and collaboration and thus the dynamic efficiency of such groups and their potential contributions (positive of negative) to other societal problems. (Examples abound in the Internet Governance sphere, gaming community, etc.).

JRA7 – Standards influence on network systems dependability (system's availability, reliability, and its maintainability)

Internet standards provide building blocks for Internet-based critical infrastructures. Security standards like TLS provide security to fight off attackers. Routing protocols define how Internet technologies are able to react to failures and other challenges.

Here, reaction times from standards were often not considered fast enough for resilient networks and services. This lead to additional standards providing improved mechanisms. Nonetheless, a lot is left to best practises and their documentation, which happens at IETF and other system-specific standards bodies as well as by organisations like ENISA or the Bundesamt für Sicherheit in der Informationstechnik (BSI, German Federal Office for Security in ICT). A reason is that standards usually describe a protocol and its details, yet dependability and secure and resilient operation and management of a network infrastructure are much larger questions. Another issue is that standards do not contain and react to the newest developments and current challenges. Resilient content distribution for high-profile services has also become a business for companies like Akamai. Notable practices for dependability are for instance anycast techniques. One practise is based on DNS. Another on IP anycast where the routing tables lead the same IP address to different machines in different locations. This allows to limit challenges to certain geographic regions and computers from challenged regions will after some reaction time gradually shift to the service provided in other regions. To conclude, standards provide building blocks for the well-established parts of the used technologies. Best practises provide more general guidelines. The dependable operation of a network is a larger and partially multi-disciplinary endeavour.

JRA8 – Energy- and sustainability-related standards.

There are already standards for electrical equipment (hardware) and for power grids, but they don't necessarily meet the reliability, security, etc. needs of the Internet; hence these standards may need to be adjusted.

Recent 'Smart network' technologies have highlighted the need for hybrid architectural standards for Internet-enhanced power network operation and for electric-network-enhanced communications network enhancement (e.g. use of electric networks to carry broadband). Some of this involves standardisation in the classic sense of governing the client-server power relations of traditional networks (which include generation-distribution-end user consumption hierarchies and the intermediating functions of national and local grids). This is analogous to the classic 'content provision' architecture of early Internet instances. But neither model persists; in the power domain, local (co)generation and the need to minimise I2R losses means that a hard-and-fast partition into generators, distributors and users is not possible or useful; the different characteristics of usage, generation and demand management models mean that a degree of openness in these standards is required. Similarly for the 'prosumption' and P2P aspects of the Internet and new use cases requiring much more active backhaul management, greater traffic symmetry and (correlated) variation and different requirements for latency, jitter, speed, security, etc. So both legacy standards (Internet and power) need to change.

This is particularly true where sustainability and resilience are concerned; energy uses (and waste) arise from the operation of the system and from monitoring and reporting levels of utilisation. They are also affected by individual decisions based on this information (e.g. congestion- or load-based pricing, and the need to provide look-ahead price and service information. At the same time, data on usage patterns and their responsiveness to signals and constraints in the short (intra-day; level or timing of use), medium (subscription and contracting) and long (equipment purchase) time-frames are vital to collect, store and analyse; this requires standards both for the network-level aggregation of such data and for individual or local data exchanges.

The types of standard to use in these areas may be somewhat different from classical standards. They may combine both ceiling and floor aspects. For example, energy use and efficiency floors are set in the Ecodesign Directive and its Delegated Regulations for specific types of equipment; these are complemented by the labelling/disclosure requirements of the Energy Labelling Directive. The idea is to reduce variance and improve information to empower consumers and encourage producers, in order to produce continuous improvement

The broader issue is the value of combining legally-enforced standards with 'reputation-based' standards to take into account the heterogeneity of individual behaviour, the value of sensitising individuals and helping the evolution of consensus attitudes (and their translation into action) and the recognition that appropriate standards need to evolve as technology and use evolves, but that the current standards will create the incentives for innovation and invention of new technologies, use patterns and business models.

4 Current activities at standard bodies in relationship to Internet Science

This section outlines current activities that show some level of "relationship" to Internet science. Beside IRTF and IETF which sits under the same organization, i.e., the Internet Architecture Board (IAB) itself under the Internet Society (ISOC) -see Fig.1, all other bodies cited in the following are separate organization. Their relationships are topical and driven by liaison processes.

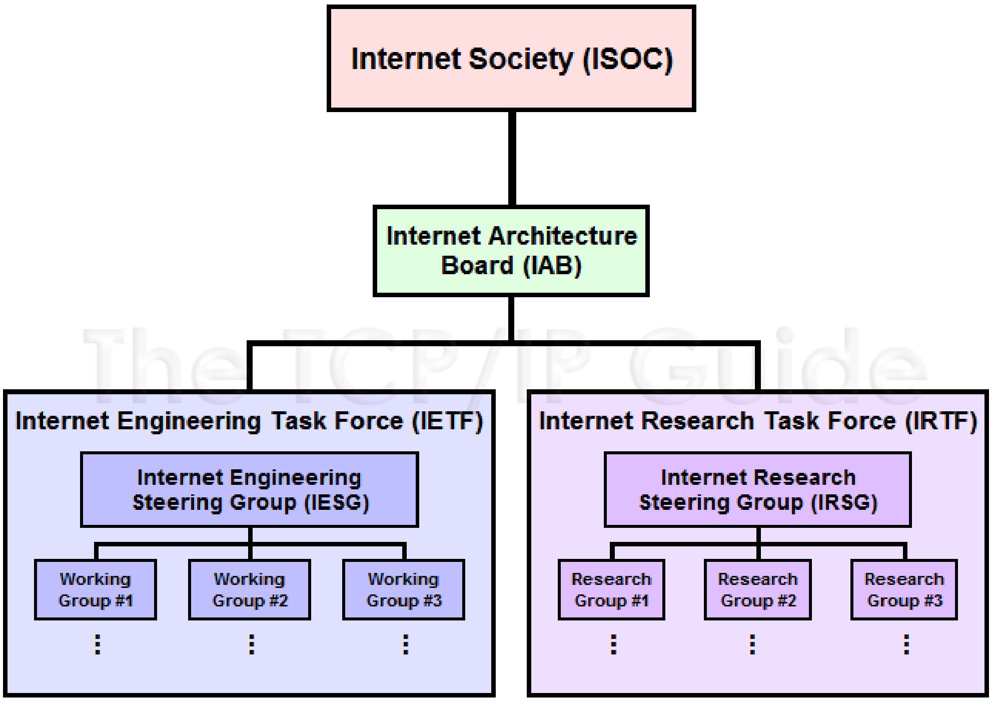

Fig.1 ISOC Structure (ref: the TCP/IP Guide, available online)

4.1 Internet Research Task Force (IRTF)

The Internet Research Task Force (IRTF) mission is to promote research of importance to the evolution of the future Internet by creating focused, long-term and small Research Groups working on topics related to Internet protocols, applications, architecture and technology.

The IRTF Research Groups (RG) are expected to have the stable long-term (with respect to the lifetime of the RG) membership needed to promote the development of research collaboration and teamwork in exploring research issues. Participation to the IRTF RG activities is by individual contributors, rather than by representatives of organizations. In addition, as the IRTF from time to time holds topical workshops focusing on research areas of importance to the evolution of the Internet, or more general workshops to, for example, discuss research priorities from an Internet perspective, the outcomes and results of this project could be the seed for such event.

Among the active IRTF research groups let's cite the following:

- The *Network Complexity Research Group (NCRG)* aimed at defining and analysing the complexity of IP-based networks (http://irtf.org/ncrg). The research group attempts to capture network complexity by borrowing from biology to statistical physics models. This research group is now closed due to relatively limited activity (representative of the situation where protocol engineers still believe complexity of standards can be accommodated by network engineering common practices, e.g., addition of resources).
- The *Routing Research Group (RRG)* aims at exploring routing and addressing problems that are important to the development of the Internet (http://irtf.org/rrg). This research group is now closed due to relatively limited activity
- The *Software-Defined Networking Research Group (SDNRG)* investigates SDN with the goal of identifying the approaches that can be defined, deployed and used in the near term as well identifying future research challenges. In particular, key areas of interest include solution scalability, abstractions, and programming languages and paradigms particularly useful in the context of SDN (http://irtf.org/sdnrg).
- The *Information-Centric Network Research Group (ICNRG)* is to couple ongoing ICN research with solutions that are relevant for evolving the Internet at large. It will produce a document that provides guidelines for experimental activities in the area of ICN so that different, alternative solutions can be compared consistently, and information sharing accomplished for experimental deployments (http://irtf.org/icnrg). The important aspect to highlight with the advent of the ICNRG is the acceptance that in terms of architecture and related protocol design, information is as important as functionality.
- The *Network Management Research Group (NMRG)* provides a forum for researchers to explore new technologies for the management of the Internet. In particular, the NMRG will work on solutions for problems that are not yet considered well understood enough for engineering work within the IETF. The initial focus of the NMRG will be on higher-layer management services that interface with the current Internet management framework. This includes communication services between management systems, which may belong to different management domains, as well as customer-oriented management services. The NMRG is expected to identify and document requirements, to survey possible approaches, to provide specifications for proposed solutions, and to prove concepts with prototype implementations that can be tested in large-

scale real-world environments. Measurement plays a key role in Internet science by enabling confrontation of theoretic results to observation and vice-versa modelling phenomena from observation data.

4.2 Internet Engineering Task Force (IETF)

The Internet Engineering Task Force (IETF) is a large open international community of network designers, developers and researchers concerned with the evolution of Internet architecture, protocols and its daily operations. The IETF defines the protocols for IP networking. The technical work of the IETF is taken up in its working groups, which are organised by topic into several areas (e.g., routing, transport, security, etc.). Much of the work is handled via mailing lists. The IETF holds meetings three times per year.

The IETF has more than 100 active working groups across six areas: the Application area (APP), the Internet area (INT), the Real-time Applications and Infrastructure Area (RAI), the Routing area (RTG), the Security area (SEC), and the Transport area (TSV). An exhaustive description of each of working group is beyond the scope of this document.

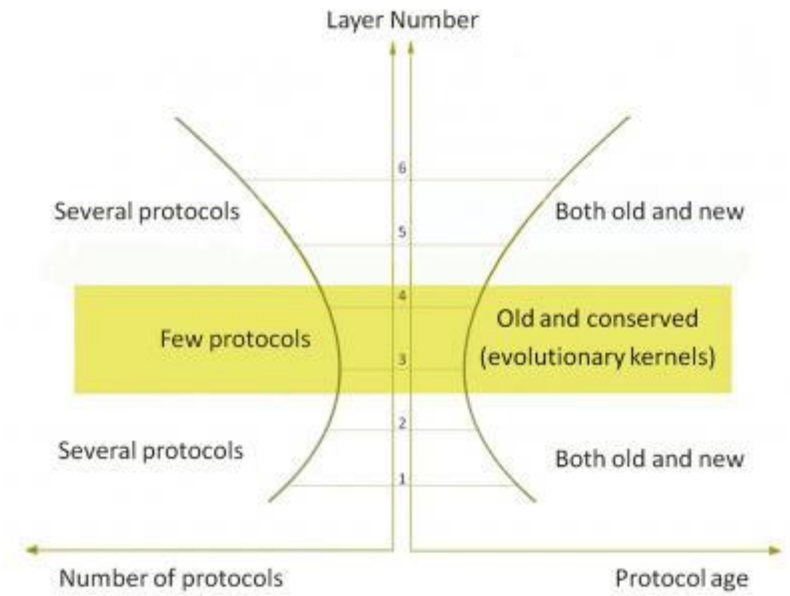

Fig.2: Hour-glass model and Internet protocol age vs number.

The IETF and its working groups are primarily focused on standardising protocols (by definition: procedures and messages/format) assuming weak coupling with operating systems to facilitate interoperability while fostering (up to certain extent) generic protocol design to ensure longevity. This extent is mainly defined by memory and computational capacity that were scarce resources in the early days of the Internet and communication stacks tailored for computers networks (the social/human dimension is mainly absent from design considerations). In contrast to other bodies, the IETF follows a “neutrality” and fairness principle in specifying its protocols along the hour glass model structure (see

Fig.2,) [7]. Moreover, most of recent protocol developments are mainly "problem-driven" leading progressively to an architecture mainly driven by its protocols.

4.3 Internet Society (ISOC)

The ISOC is a professional membership society that provides leadership in addressing issues that confront the future of the Internet, and is the organisational home for groups responsible for Internet infrastructure standards, including the Internet Engineering Task Force and the Internet Architecture Board (IAB). The ISOC serves the needs of the growing global Internet community. Since 1992, the ISOC has served as the international organisation for global coordination and cooperation on the Internet, promoting and maintaining a broad spectrum of activities focused on the Internet's development, availability, and associated technologies. The ISOC also acts as a facilitator and coordinator of Internet-related initiatives around the world.

From commerce to education to social issues, the ISOC goal is to enhance the availability and utility of the Internet on the widest possible scale. The Society's individual and organisation members are bound by a common stake in maintaining the viability and global scaling of the Internet. They comprise the companies, government agencies, and foundations that have created the Internet and its technologies as well as innovative new entrepreneurial organizations contributing to maintain that dynamic. As such, the ISOC is not a standardisation body but a useful relay at both local/country and global/international or continental level.

Fig.3 (from the internetsociety.org) provides the timeline evolution of Internet related bodies (ISOC, IAB, IRTF, IETF) along with the Internet growth:

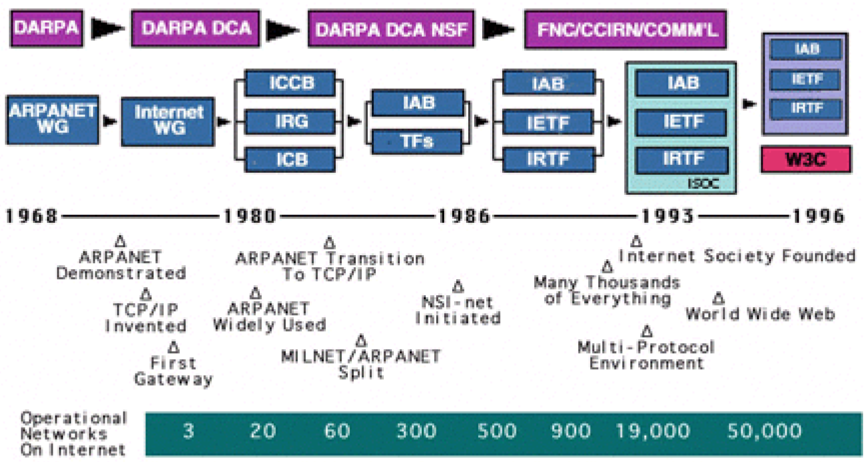

Fig.3: Evolution of the Internet and related bodies (ISOC, IAB, IRTF, IETF)

Note that the IAB has conducted on December 4-5, 2013 a Workshop dedicated to Internet Technology Adoption and Transition (ITAT) < http://www.iab.org/activities/workshops/itat/> at Cambridge, UK. At the time of writing the report of this workshop is not yet available but main conclusions are: 1) the IETF needs to re-engage with researchers more (the IRTF is a pathway for such activities), 2) more specifically, IETF is going to initiate an experiment asking graduate students in departments who study communications, to help with IETF document reviewing (to reduce the bottleneck, and increase awareness of the process, and act as additional training opportunities in those departments).

4.4 Institute of Electrical and Electronics Engineers (IEEE)

In 2012, the IEEE setup a Task Force on Network Science (TFNS) chaired by Jack Cole and led by an Executive Committee including university and military academy members. The planned/current activities of TFNS include:

- Educational Activities
  - Encouraging Students in Science, Technology, Engineering, Mathematics
  - Developing, Recognizing Network Science Curricula, Professional Certification
  - Giving Tutorials in Cognition, Social Network Analysis, Neuroscience, Bio-Inspired Technology
- Publications - Conference proceedings
  - Newsletter - Transactions
  - Standards
  - Guide to Network Science
  - Professional certification
  - Broaden to related areas
- Wiki and online discussions
- IEEE online community (OC) at http://ns.oc.ieee.org/
- IEEE Network Science Technical Interest Profile (TIP) Code For Members To Indicate Their Interest
- IEEE Future Directions Committee Considering Networking Science Among Areas Such As SmartGrid and Cloud Computing

This activity includes an annual IEEE International Workshop on Network Science (NSW, URL: **http://ieee-nsw.org**); its second edition was organized on29 April - 1 May, 2013 held in West Point (NY), USA. The workshop scopes models of networks and their characteristics are essential in the study of numerous fields, and are themselves subject of research employing approaches from different disciplines. Despite disparate methods, commonalities arise in often non-obvious ways, making the exchange under a shared Network Science framework desirable. The IEEE NSW aims at bringing together researchers and professionals from academia, industry, and government interested or involved in Network Science for information and communication technologies (ICT). For this purpose, the workshop is organized into three tracks according to the primary domains: Information Delivery and Sharing, Networks and Infrastructure, Innovations in Social, Cognitive, and Biologically-Inspired Aspects of Complex Networks.

Despite its initial traction, on 11 December 2013 the IEEE Computer Society dissolved the Task Force on Network Science, and with that all the associated web pages must be taken down, although the online community (44 members) and the mailing list may remain. This decision provides an example of evolution scenario: even if attractive at first glance, such type of initiative may rapidly fade out; if no federating concept (attracting several members/participants) shapes up fast enough to initiate a new cycle beyond individual contributions, the likelihood of decreasing interest may soon occur. In new domains (such as network science), standardization relies on contributions to produce cross-fertilized output, if contributions remain unexploited after a couple of iterations/meetings the number of contributions decreases rapidly.

4.5 European Telecommunications Standards Institute (ETSI)

The European Telecommunications Standards Institute (ETSI) produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.

Like most standards organizations, much of this work is carried out in committees and working groups composed of technical experts from the Institute's member companies and organizations. These committees are referred to as Technical Bodies (TB). Each TB establishes and maintains a work programme, consisting of Work Items (WIs). An ETSI WI is the description of a standardization task, and normally results in a single standard, report, or similar document. The TB approves each WI, which is then formally adopted by the whole membership (via a web-based procedure).

Industry Specification Groups (ISG) exist alongside the current Technical Organization supplementing the existing standards development process. An ISG is an activity organized around a set of ETSI WIs addressing a specific technology area. An ISG offers a very quick and easy alternative to the creation of industry forum, as it only requires a minimum of 4 ETSI Members and/or Applicant Members for foundation and adheres to the ETSI IPR Rules.

Let's cite the following ESTI TB and ISG recently created which aim at moving beyond current technology scope and limits (even if not departing from technology-oriented goals constraint by operational requirements):

- The ETSI Network Functions Virtualization (NFV) ISG aims at defining the requirements and architecture for the virtualisation of network functions and to address associated technical challenges. Network Functions Virtualisation (NFV) aims at evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage. It involves implementing network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need to install new equipment.

(http://portal.etsi.org/portal/server.pt/community/NFV/367).

- The ETSI ISG on Autonomic network engineering for the self-managing Future Internet (AFI) aims at designing a generic autonomic/self-managing network framework and architecture as reference model for engineering the Future Internet. (http://portal.etsi.org/afi).
- ETSI TC on Machine to Machine (M2M) Communications aims to provide an end-to-end view of Machine to Machine standardization, and will co-operate closely with ETSI's activities on Next Generation Networks, and also with the work of the 3GPP standards initiative for mobile communication technologies.
- ETSI TC Environmental Engineering (EE) is responsible for defining the environmental and infrastructural aspects for all telecommunication equipment and its environment, including equipment installed in subscriber premises. The committee is currently working on i) Technical Specification on the energy efficiency of wireless access network equipment; ii) assessment of the environmental impact of ICT including the positive impact by using ICT services and iii) Technical Report on the use of alternative energy sources in telecommunication installations.
- Quantum Key Distribution (QKD)

4.6 Methods, Tools and Languages

Methods and tools are certainly a domain where Internet science can feed standard bodies. For instance, the inception of the Internet science discipline has naturally and logically come together with a rejuvenation of the interest in the metrology discipline (at all levels from information to media) together with processing and analysis/mining of measurement data. At another level, new design methods inspired from those applied in other engineering/applied science domains (e.g., bio-engineering, bio-inspired mechanisms, etc.) might progressively come out that would enable establishing new design processes in protocol and network engineering.

On the other hand, the fundamental rules driving current "networking" protocols (as defined by their syntax and semantics) rely on the same principles and concepts agreed beforehand between the parties involved in the communication process; these protocols as currently designed are closer to biological systems communication where entities exchange a limited number of things in contrast to human language. Whether "networking" protocols would evolve or not toward providing similar properties than human language (in terms of productivity, recursivity, abstraction, and openness) remains also an open question.

4.7 International Telecommunication Union - Telecommunication Standardization Sector (ITU-T)

The Study Groups of ITU-T assemble experts from around the world to produce international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs). Standardization work is carried out by the technical Study Groups (SGs) in which representatives of the ITU-T membership develop Recommendations (standards) for the various fields of international telecommunications.

4.8 Network Science Collaborative Technology Alliance (NS CTA)

The Network Science Collaborative Technology Alliance (NS CTA) is a collaborative research alliance between the US Army Research Laboratory (ARL), other government researchers, and a Consortium of four research centres: an Academic Research Center (ARC) focused on social/cognitive networks (the SCNARC), an ARC focused on information networks (the INARC), an ARC focused on communications networks (the CNARC), and an Interdisciplinary Research Center (the IRC) focused on interdisciplinary research and technology transition. The Alliance unites research across organizations, technical disciplines, and research areas to address the critical technical challenges of the Army and Network-Centric Warfare (NCW). Its purpose is to perform foundational cross-cutting research on network science, resulting in greatly enhanced human performance for network-enabled warfare and in greatly enhanced speed and precision for complex military operations.

The Alliance is conducting interdisciplinary research in network science and transition the results of this research to benefit network-centric military operations. The NS CTA research program exploits intellectual synergies across network science by uniting parallel fundamental (6.1) and applied (6.2) research across the disciplines of social/cognitive, information, and communications network research. It drives the synergistic combination of these technical areas for network-centric warfare and network-enabling capabilities in support of all missions required of today's military forces, including humanitarian support, peacekeeping, and full combat operations in any kind of terrain, but especially in complex and urban terrain. It also supports and stimulates dual-use applications of this research and technology to benefit commercial use. As a critical element of this program, the Alliance is creating a sustainable world-class network science research facility, with critical mass in the NS CTA Facility in Cambridge (MA), as well as shared distributed experimental resources throughout the Alliance. The NS CTA also serves the Army's NCW needs through an Education Component, which acts to increase the pool of network science expertise in the Army and the nation, while bringing greater awareness of Army needs into the academic and industrial research community.

5 Role of standardisation with respect to other parts of the Internet context

As already discussed, standardisation plays important roles in governing the current state and evolution of the Internet, by facilitating interoperability, building trust within a broad range of stakeholders and participants and influencing the way the Internet and the socioeconomic institutions that operate on and around it respond to emergent challenges. At the same time, the advantages and disadvantages of particular standards to potential adopters depend on the relation between those standards and others in current use, the business models/activities of potential adopters and the degree to which those with whom they interact (or might interact) use the same or compatible standards. These costs and benefits drive both adoption and the way compliant activities are used to implement new business models, provide new services, exchange information and share activities. This leads to further rounds of standards creation, evaluation, adoption and to the addition or dropping of interactive links, business partnerships (and rivalries) and so on. Thus, the set of existing standards forms a network in its own right, which interacts strongly with both the Internet per se and with the networks of business and civil society institutions and transactions that make use of the Internet and the services offered over it.

In essence, Internet standards should be considered a layer of the multi-layered Internet. This complex network layer comprises (at a minimum):

- the set of standards linked by patterns of adoption and by the services based on the standards; and
- the network of standards bodies linked by the institutional and personal entities who participate in them (often in many-to-one or many-to-many patterns).

The characteristics of this complex network can be understood by considering:

- dynamics internal to the standards layer (esp. as discussed in chapter 3 of this document);
- linkages between the standards and technical layers of the Internet (discussed in operational terms in chapter 4 and the subject of a very large existing body of literature); and
- linkages between the standardisation and 'downstream' layers (markets and other contexts where the individuals and institutions affected by the adoption, implementation, violation and modification of standards operate.

In listing these vertical dimensions we have referred to dynamics and to linkages. These distinctions are important to understand how standards influence the architecture of the Internet itself and how the architecture of the Internet inn turn affects standardisation; this duality is pervasive, and is a direct consequence of the resonant relations among architecture, design and practice. These aspects are also essential in order to understand the role of standardisation in relation to innovation and progress in tackling societal Grand Challenges. Below, we briefly mention two salient aspects (dynamics and symmetry) and indicate how they are manifest in one specific domain connection – that between standardisations and markets.

As far as dynamics are concerned, much standards evolution is driven by changes in the underlying technologies, business models, applications, laws, etc. The evolution of standardisation bodies and activities is additionally influenced by institutional dynamic factors such as mission creep, capture, etc.[7]. Closely linked to this, however, are the linkages between today's and tomorrow's standards, driven by: a) the legacy set of standards and patterns of compliance; b) the existing set of rules and regulations that complement, extend or substitute for current standards; c) trend developments in the technical, economic and government spheres; and particularly the tension between current and expected future advantages and disadvantages of standardisation and standards. The existence of a standard or set of standards separates the context within which Internet stakeholders operate into an 'inside' (compliance) and an 'outside' (non-compliant and alternative).

This in turn divides the cooperative and the competitive modes of governance. Cooperation is divided between the contribution of members to existing standardisation processes and the cooperation of those seeking alternatives (or establishing independent (but possibly corresponding) standards bodies. Competition is divided between *intensive* competition (competition *within* a given market (or standard) and *extensive* competition (competition *for* a given market or standard, involving the creation of and struggle between contesting alternatives). The progress of innovation depends on the balance between these intensive (inside) and extensive (inside vs. outside) modes[8].

For example, data exchange and interaction standards exclude non-compliant systems *and* increase the opportunities available to those who adopt compatible standards[9]. At the same time, the exclusion of alternatives changes the incentives for innovation in a way that tends to favour both incremental changes within the existing set of standards and disruptive innovation that supplants the standard or triggers wholesale changes in many aspects.

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[7] See Cave, J., Simmons, S., & Marsden, C. (2008). Options for and Effectiveness of Internet Self-and Co-Regulation Phase 3 (Final) Report. Report for European Commis

[8] See e.g. Cave, J. (2009, September). Prisoners of our own Device–an evolutionary perspective on lock-in, technology clusters and telecom regulation. In Telecom Poliocy Research Conference (TPRC), Arlington, Va.

[9] See e.g. Cordes, J. (2011). An Overview of the Economics of Cybersecurity and Cybersecurity Policy. *2011 Developing Cyber Security Synergy*, 9.

The predictable net result is a form of *punctuated equilibrium* – periods of incremental and localised adaptation (change within existing clusters of standards) separated by brief periods of widespread and disruptive 'phase changes' (paradigm shifts). Given the importance of standards and the growing recognition of their economic and policy importance, these phase changes are likely to be spread to the economic and policy domains as well; as a result, they cannot be understood wholly in technological or standardisation terms, since some of the critical issues may be 'pre-empted' facilitated or even sabotaged by changes in laws or regulations, business models and so on. This makes the disruptive changes emergent phenomena; they cannot be anticipated, and may only be predictable on the basis of extensive collection and careful interpretation of a large volume of data covering all relevant domains. Put in its simplest terms, this means that the analysis of this aspect of Internet Science requires the full development of Internet Science as a whole – in other words, this demonstrates not only the essential linkage of Internet Science to e.g. economics, law and political science but the internal coherence or span of the nascent discipline itself.

As far as symmetry is concerned, standards are linked to markets and competitive economic forces in two directions. At the most basic level, the evaluation of the advantages and disadvantages of standards and the design and assessment of alternatives often turn on economic costs and benefits derived from markets. These markets are also shaped in large part by technology (what can be produced, how it performs, etc.) and by regulation.

In the market, standards compliance may influence market outcomes *directly* by influencing the usefulness, quality, performance and network externalities of competing goods and services. They may also serve as an *indirect* influence in which certified (or self-proclaimed) standards adherence serves as a kind of brand or carrier of reputation.

Regulatory decisions, in their turn, are based on the possibility of identifying violations and of crafting and implementing remedies. Changes in technology – including those associated with the uniform application of technology and the exchange of information made possible by standards – change these framework conditions for regulation. To provide a simple illustration; if the promulgation and adoption of suitable standards fro privacy-enhancing information exchange, storage and processing leads to 'good enough' compliance, then coercive privacy regulation (with all its 'one-size fits all' risks and burdens) may not be necessary and privacy can be pushed 'up the stack' into a technological privacy by design solution. On the other hand, if standards for monitoring information flows permit regulators to observe potential violations of privacy and to track them to their source then regulation may be made more effective, proportionate and transparent.

The flip side of this – a market *in* standards – comes about because standards, unlike laws, are not unique and do not have an automatic or canonical order of precedence or priority. Therefore, they may be seen as a form of regulatory competition in which the best (currently most useful) standards win. Of course, this is not automatically an efficient procedure, due to the 'lock-in' and 'tipping' effect of network externalities[10]. That such markets (or equivalent forms of selection-mediated standards evolution) emerge is undeniable. Whether they are optimal is open to debate – and to future investigation. This is a difficult issue to judge; even in the more restricted domain of exclusive property rights provided by e.g. patents and designs the questions of efficiency and effective governance remain contested. Analogous study of standardisation – particularly in the Internet context where the interaction of standards at different levels and the global connectivity of standards users combine with the very rich potential availability of cross-sectional and longitudinal data – is an important future challenge.

[10] Network externalities arise when adoption of a standard by one party makes it more attractive for others to adopt. The result is a tendency for single standards to predominate, even if they do not serve the needs of others equally well. From the efficiency perspective, such dominant regimes may not face enough competition to maximise total welfare or to change when circumstances change in an optimal way. Katz and Shapiro (1987) point to the possibility of both excess inertia (standards changing too slowly) and excess volatility (standards that change too fast) as a result of such externalities.

6 Current activities of standards bodies in relation to specific issues: the example of IoT

The structure and conduct of standardisation processes and their associated institutions and stakeholders forms an important part of the dynamic architecture of the Internet. In this context, it is also useful to study the performance and impacts of standardisation in specific domains and in relation to specific standardisation bodies. These cannot be easily separated; the specific technical or other domain determines what is possible, desirable and inimical, while the constitution, constituency and track record of the standards bod(ies) involved determine how these threats will be dealt with and opportunities seized.

This is particularly important in the face of boundary changes, for instance when a new metaphor or way of visualising Internet activity brings together previously-separated domains and actors. In this Chapter, we consider as an example the Internet of Things; similar analysis could already be conducted for e.g. cloud computing,[11] algorithmic financial trading or Big Data analytics.

6.1 Standards as part of the governance structure of the IoT

Standards represent a form of collective intellectual property right. In relation to the IoT we distinguish three different functions.

Firstly, standards provide a basis for the open interoperability that lies at the heart of the IoT value proposition – standards that define technical and logical conditions governing connections and information transfer allow objects to communicate and interoperate.

Secondly, standards adoption creates explicit or implicit barriers to entry – non-compliant devices will not be able to 'work' with the rest of the IoT and will fail to provide the expected benefits to device owners, limit the functionality of system-level services, create additional vulnerabilities or system risks and exacerbate congestion and other network problems;

Thirdly, standardisation bodies create a platform for the *discussion* of crosscutting issues and *implementation* of coordinated activities including *innovation*[12] (in terms of new

[11] See e.g. Cave, J., Robinson, N., Kobzar, S., & Schindler, H. R. (2012). Regulating the Cloud: More, Less or Different Regulation and Competing Agendas. *Less or Different Regulation and Competing Agendas (March 30, 2012)*.

[12] The standards developed for the IoT necessarily cross existing sectoral boundaries. For example, electronic appliances and large-scale retail trade currently constitute separate industrial sectors, in terms of standards and business models, as well as in terms of the goods and services produced and the firms involved. However, without a set of common technical standards and interfaces (at both the device and semantic level) to facilitate their interoperation, loT-enabled devices like the smart fridge could not develop.

standards and in terms of new devices, services, etc. that employ the capabilities provided by the standards), *integrated service provision* and organization of *self- and co-regulation*.

IoT standards can be applied at different levels in the IoT. These include individual 'things' and their properties; binary interactions and linkages among things;[13] and systems, subsystems and assemblages.

Furthermore, standards can be classified in terms of the things they control, the items to which they pertain and the connections among them. For instance spectrum standards may control various aspects of IoT applications, including spectral bands used;[14]power; location; other aspects relating to interference; and 'handshaking (e.g. for agile/cognitive devices).

Within this broad scheme, IoT standards continue to be developed in a range of areas, listed below:

- data encoding;
- air interface;
- testing;
- security;
- privacy;
- application standards;
- power use and dissipation;
- For RFID:
- working conditions;
- label size;
- label position;
- data elements;
- format;
- frequency bands – these have implications for operational mode, storage, etc.

6.2 Adapting standards on IoT context

Looking ahead, standards developed for RFID, for instance, may need to become broader, more functional and/or less technology or function specific if they are successfully to be applied (i.e. taken up, used, open) to broader classes of objects (already visible for NFC). Standards may need to be promulgated above the level of things to encompass fixed or *ad hoc* assemblages, networks or ensembles of interacting and intercommunicating things. Standards optimised for existing interactions (primarily identification and simple

[13] These are not the same; a linkage is structural or latent, while an interaction (e.g. remote instruction, query, data exchange, etc.) is dynamic and active.

[14] These are obviously related, and may also be expressed in other mechanisms (such as licensing conditions or (tradeable) spectrum use rights

information-sharing) may need to evolve to support more complex interactions and system functions. By the same token, standards applying to the *IoT aspects of Internet-capable objects* may need to be reconciled to other functions of those objects (in cases where existing stand-alone devices and objects are brought into the IoT rather than designed to work inside it).

6.3 Relation between standards and other challenges

Standards applying to the IoT (or the IoT implications of other standards) affect other challenge areas. Among these are the following.

Competition: The competition and other broad policy aspects of standardisation processes (ranging from the standards themselves to the mechanisms for proposing, modifying, approving, promulgating, monitoring and enforcing them) will also need to change as the complexity of the objects and their interactions increases. In other words, the evolutionary dynamics of the Internet are influenced by standardisation and other reactions to perceived issues – and *vice versa*. To take a simple example, standards applicable to the technical/communication aspects of devices used to carry out financial transactions or to search for information used to support decisions *may* be able to exist alongside standards governing those functional aspects, but it may be that technical standards are the best way of handling functional issues, vice versa or even both.

Identification: standards can facilitate (as well as prevent) identification and enable e.g. mutual recognition schemes or federated identity.

Privacy: Standards control the way data are transmitted, recorded, processed, retrieved and shared. Standards relating to processing and the ability of remote systems to trigger software deepen the 'data control' aspects of security, and the interface (e.g. when activity records are hashed with identifiers).

Architecture: IoT standards may be used to give concrete form to architectural principles and to design specifications; they may in this sense be useful 'vectors' for spreading such principles. This stands in contrast to e.g. architecture and design of e.g. buildings, which tend to be more autonomous and isolated, competing with other designs or architectures primarily through downstream (uptake) selection.

Ethics: IoT standards may embed ethical considerations; what kinds of decisions 'things' can make and how they protect people via 'rules' (e.g. a version of Asimov's Laws) or hardwired functionality (e.g. privacy/security/information minimisation by design).

Governance: Standardisation is a form of governance; moreover standards can complement, substitute for or conflict with other forms of a) control and b) deliberative, reflective or reactive governance.

6.4 *Current state of play*

A wide range of standards bodies are actively engaged in producing standards for the IoT and in adapting existing standards to cope with IoT specifics. Table 1 provides an indicative listing.

Table 1: Sample of current IoT standards

Standard	Objective	Status	Org.	Comm. Range (m)	Data rate (kbps)	Unitary cost ($)
EPCglobal	Integration of RFID technology into the electronic product code (EPC) framework, which allows for sharing of information related to products	Advanced	GS1	~1	10^2	0.01
GRIFS	European Coordinated Action aimed at defining RFID standards supporting the transition from localized RFID applications to the Internet of Things	Ongoing	EC, CEN	~1	10^2	0.01
Various	Technical standards: frequencies, modulation schemes, anti-collision protocols	Ongoing	ISO	?	?	?
M2M	Definition of cost-effective solutions for machine-to-machine (M2M) communications, which should allow the related market to take off	Ongoing	ETSI	?	?	?
6LoWPAN	Integration of low-power IEEE 802.15.4 devices(sensor nodes) into Ipv6 networks	Ongoing	IETF	10–100	10^2	1
ROLL	Definition of routing protocols for heterogeneous low-power and lossy networks	Ongoing	IETF	?	?	?
NFC	Definition of a set of protocols for low range and bidirectional	Advanced		~10^2	<424	0.1

Standard	Objective	Status	Org.	Comm. Range (m)	Data rate (kbps)	Unitary cost ($)
	communications					
Wireless Hart	Definition of protocols for self-organizing, self-healing and mesh architectures over IEEE 802.15.4 devices	Advanced		10–100	10^2	~1
ZigBee	Enabling reliable, cost-effective, low-power, wirelessly networked, monitoring and control products	Advanced		10–100	10^2	~1
ISO/IEC 18000	Covers data encoding, air interface, testing, applicative standard in 5 frequency bands (below 135KHz, 13.56MHz, 2400-2483.5MHz, 860-960MHz, 433.92MHz).	Advanced				

In addition to this, IoT-specific standards, Internet standards and those that may arise in other domains will either expand or compress the niches within which the IoT may develop. Moreover, standards transposed to the IoT from other domains or arising within it may determine the balance of power and the effective functional, economic and societal performance of the IoT.

6.5 Challenges for the future

Taking this context into account, the current development of IoT standards raises a specific set of future challenges:

- Will these separate initiatives and the competition between alternative standards to which they give rise produce the *network of standards* needed for the most effective technical, economic and societal functioning of the IoT?

- How should IoT standards balance current performance against innovation, interoperability against independent competition and technological against functional specificity?
- What standardisation bodies and processes are needed in order to permit these standards to emerge –should these bodies be specific to the IoT? are combined or IoT standards bodies best?
- To what extent will existing standards bodies and the incentives operating on stakeholders distort standards development?[15]
- How can independent, open and ‘neutral’ standardisation be balanced against and integrated with other modes of governance?

[15] The distortion could lead to standards that are too light, too proprietary, difficult to comply with, easy to violate, disguised trade barriers, anticompetitive, harmful to innovation, harmful to public service delivery, biased against small enterprises, etc.

7 Gap analysis

Assuming the gap between scientific outcomes and their possible/potential translation into emerging technologies would be progressively addressed by involved parties, this section analyses the resulting gap between technology-oriented/engineering research and standardisation, considering that the latter remains one of the main condition for large development, deployment and adoption of new technologies. Standardization of protocols and interfaces has indeed played and is still playing a key role in the Internet development. In particular, the IETF has become the main Internet protocols factory while other standardization bodies like IEEE, ITU-T, are standardizing the infrastructure the underlying physical layers and W3C the technologies enablers creating the necessary open application to the Internet development.

The world's first operational packet switched network (ARPANET) came out of the initiative of the Advanced Research Projects Agency (ARPA, later DARPA) agency of the United States Department of Defense responsible for the development of new technologies for use by the military. The Advanced Research Projects Agency Network (ARPANET) was the first network to implement TCP/IP, and the ancestor of what was to become the global Internet. The network was initially funded by (D)ARPA within the U.S. Department of Defense (DoD) for use by its projects at universities and research laboratories in the US. The NS CTA seems to follow a similar track though its purpose is to perform foundational research on Internet science to enhance human performance for network-enabled warfare and in speed and precision for complex military operations.

In the early days of the Internet, its standards were driven by the research community (including computer communication and computer science). This materialized by the creation of the IETF (in 1986) that was an emanation from the research community. Indeed, the first IETF meeting was on January 16, 1986, consisting of 21 U.S.-government-funded researchers. Over time, as the Internet and its associated technologies progressively matured and were deployed at a larger scale, the Internet standardization gradually shifted to engineering and operational problems (the IETF is often qualified today as "problem-driven"). As a result, even though the research community is still relatively involved in the Internet standardization process, its influence is progressively eroding over time. As technologies continue to specialize and are integrated on vendor-specific platforms, the involvement of the research community is less rewarding. To circumvent this problem, open source code running on commodity platforms for experiments seems at first glance attractive; however, it rapidly leads to similar issues as the entry barrier naturally increases over time. Nevertheless, the involvement of the research community in standardization can bring a lot of added value (in particular when practical use cases are identified at this stage of the process) since it allows promoting novel ideas and concepts by confronting them to i) executability/developability, ii) deployability, and iii) operational environment and, if successful, will accelerate penetration of these ideas.

Major standardization bodies have adapted their processes to mitigate the fundamental problem of the eroding participation of researchers to the standardization process. The main consequence of this erosion is that moving beyond current technology objective limits by improving or replacing existing technologies becomes the wall garden of few technology experts leading over time to the progressive polarization between engineering community and research community and thus a loose-loose situation. To circumvent this problem, several initiatives have been initiated. For instance, ISOC created in the 90's the IRTF (the research arm of the IETF), the ITU-T defined the concept of Focus Group, the IEEE established IEEE-SA Industry Connections Program and Task Forces/Alliances, and the W3C, the so-called W3C Incubator Activity. In 2006, ETSI defined the concept of Industry Specification Group (ISG). All these entities share the same principles: they are open to academia and are based on a lightweight procedural structure compared to their "mother" standardization groups. However, open to academia and research doesn't necessarily imply elaboration of breakthroughs outside the shorter term technology-oriented targets of the "mother" standardization bodies.

One can also observe that, in the context of Internet science beside IEEE TFNS, few bodies offer a dedicated venue for exploiting its outcomes and when it is the case, their scope is rather narrow. Indeed, the social or more generally the human science dimension is often absent of main engineering concerns. This can be considered as a consequence of the technology "neutrality" which leads to avoid interference with elements classically considered outside of the sphere of direct technology influence/ interactions. Assuming this situation would evolve, it would also lead to consider additional dimensions in the design process with a critical question how to keep these technologies generic and thus interoperable despite socio-cultural differences among its actors. Observe these dimensions go well beyond classical considerations about context-awareness as these aspects do not limit to the spatial environment of the communicating computer and lead to fundamental reconsideration of the man-machine interface and its extension to e.g. brain-computer interface and intrinsic properties of the communication medium e.g., bio-chemical substrate. Moreover, the "scale" of networks under consideration remain driven by human-scale dimension, for instance, very few bodies focus on nano-scale networks or bio-centric networks even if these networks can also be programmed.

On the other hand, these structures are not yet used at their full potential. In particular, when "pre-standardization" processes or associated organizations exist, they have often evolved in two directions, either by focusing on shorter-term engineering problems the "mother" standardization body is recognized for (and, in turn, being perceived as no longer fulfilling a research role) or by focusing on framework and high-level models developments of little practical use (in turn this observation brings us back to the "methodology" limits raised in Section 3 which shows limits in providing the answer to the functional realization).

It is anticipated that the outcomes of Internet science research could have the potential to increase the volume and novelty of so-called pre-standardization activities. It should also be noted that not all research results need to be initially incubated in pre-standardization. Depending on the standardization lifecycle and rationality, certain research results can go directly to the more classical standardization process without going through a preliminary pre-standardization phase.

In this context, the more general question becomes how research-focused standardization step can effectively feed the classical standardization process with a stream of novel ideas that will, if successful, lead to standardized architectures, protocols, etc. It has to be noted that the interactions and discussions in the context of (pre-)standardization can also feedback to the technology/engineering-oriented research process with valuable inputs to be further considered inside applied Internet science related activities organized within the EINS context, its satellite projects or other independent projects.

8 Conclusions and Recommendations to standard bodies

Following the gap analysis documented in Section 7 and acknowledging Internet science is a young discipline, recommendations toward standardization bodies are mostly focused at this point in time on:

1. Providing the playground for raising new emerging technologies such as brain-to-computer interface, new communication medium, e.g., bio-molecular/bio-chemical substrate) that could not be thought by the classical engineering design process but may lead to the inception of new foundational architectural concepts and for extending ecosystem to socio-economic actors and not only digital entities, etc. The example provided by the IEEE Task Force shall also guide us in determining when such initiative should be taken and conditions that should be met to minimize risk of progressively deflating participation.

2. Extending the reach of working charters/programs to attract innovative ideas (on accepted problems); even if shorter term approaches driven by operational and economical constraints would seem more appropriate at first glance, this approach would likely raise common interest topics between technologists and scientists.

3. Opening up standardisation effort in the privacy domain (recent development in this domain cf. RFC7258 provide interesting line of thought in that direction). Setting common principles in the user data protection, as the main pillars of regulations would enable first step in that direction (in particular, if the big data monster model generalizes and replaces the small but beautiful distributed model in place today).

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Annex I: IoT Standardization

Standards constitute an essential part of the governance architecture of all ICT-based systems.

The concrete content of standards determines the *functional and operational characteristics* of the things connected by the IoT and the protocols and other elements that constrain the linkages among them.

Standards are – to a greater or lesser extent – voluntary; the *adoption of standards* creates a network among IoT stakeholders in the sense that those adopting the same or compatible standards are linked more tightly than those who do not. These standards-based networks influence *how they can interoperate* (for standards that control interoperability). They also control linkages in other ways, for instance *market contact* to the extent that standards allow products and services from compliant suppliers to be used by compliant purchasers who may in turn combine these components to deliver their own systems. This can be studied by mapping the adoption of standards by IoT equipment developers and service providers and their interaction with related Internet and other standards.

Beyond mere functionality, standards allow IoT participants[1] to implement, certify[2] and credibly offer to their customers a range of *quality of service characteristics*[3]. Indicators can be found in QoS measures linked to existing standards and the terms of SLAs.

The decisions of stakeholders as to *which standards to adopt* drives the *ecosystem of standards and thus of functionalities*; technical[4], economic[5] and societal[6] incentives to adopt (or abandon) standards controls the prevalence and incidence of specific functionalities including interoperability, security, etc. This in turn influences *emergent* or *systemic* properties (e.g. resilience, robustness, trustedness/trustworthiness) of the IoT and the broader Internet of

[1] And, in some cases, suppliers.

[2] Certification may be supported indirectly by evidence of standards adherence, or directly if standards allow data collection and control that lets independent adjudicators validate and verify service quality levels. An opposite example is provided by *privacy* – privacy assurance can be certified by the results of privacy impact assessments, but in order to support regulatory intervention and market discipline, the conduct of such assessments must itself be standardised.

[3] This happens directly if adherence to a certain standard or network of compatible standards allows the system to delivery better service (however defined). It also arises indirectly if standards allow the better control of system behaviour and/or the collection of quality of service information.

[4] i.e. to deliver specific capabilities under defined circumstances, or to interoperate with specific existing or pending technologies.

[5] i.e. to exchange data, services, payments etc. with specific firms and customers by adopting identical or compatible standards.

[6] Societal incentives may reflect values such as openness and privacy, the need to deliver public services or a desire to make high-quality services available to all (or specific groups) on an affordable basis.

which it forms a part. This can be analysed by applying demographic analysis to the mapping of standards to adopters.

Finally, standards are the result of *standardisation activities*. Participation in standardisation is itself a governance activity. It is not distinct from architectural decision-making, innovation, competition or regulation; indeed, it often represents a particular way of carrying on those activities[7] and its role and consequences can be understood in relation to them. This can be studied by mapping participation in standardisation and by applying to the standards bodies (see e.g. the background discussion below) the methods developed for assessing the impacts of self- and co-regulatory arrangements (Cave, Marsden and Simmons 2009)

The above discussion applies primarily to single standards. Beyond this, *standards themselves constitute a network*; they are linked to each other directly (e.g. by incorporation or reference) and via the firms, technologies and products that use them. In this sense, the IoT also produces impacts via the *dynamics* of standards development and adoption are also worthy of study. The structure can be studied by applying content analysis and social network tools to the content of standards and to the patterns of adoption. The dynamics can be detected by seeing how the structure aligns with other structures (e.g. sectoral identity and firm size) and how it changes over time as the IoT develops.

It is important to note that this cannot be limited only to the providers of IoT 'things' themselves. The standards developed for the IoT necessarily cross existing sectoral boundaries. For example, electronic appliances and large-scale retail trade currently constitute separate industrial sectors, in terms of standards and business models, as well as in terms of the3 goods and services produced and the firms involved. However, without a set of common technical standards and interfaces (at both the device and semantic level) to facilitate their interoperation, loT-enabled devices like the smart fridge could not develop.

The current explosion of research and development activities arising throughout the economy demonstrates both the scope and the need for standardisation. As happens in other areas, appropriate or efficient standardisation must balance openness and consistency. This is not a simple matter of maximising interoperability. Standards influence such diverse elements as:

- The ease with which new devices and services can be added to an existing system;
- The extent to which such new entrants can compete for existing customers;

[7] Architecture and design (distinct though they are) often involve the re-use of standardised forms and methods; standards bodies both develop technological innovations and (through e.g. the request form comments (RFC) process) stimulate crowd-sourced innovation; development and enforcement of (proprietary) standards may control market entry and extensive (*for* the market)(competition; and standards use by public bodies as a condition for procurement or evidence of compliance constitutes a form of self- or co-regulation. [Ref Cave/Marsden/Simmons]

- The generativity by which standards adoption opens up new possibilities for innovation;
- The extent to which new standards can arise through fusion or federation of existing standards, fission into separate detailed specifications or dynamic 'standards networks;'
- The scientific and market 'contact' among different stakeholders, leading to improved or novel services and standards through a combination of competitive and cooperative engagement;
- The number and diversity of competitors for major contracts or for commoditised markets;
- The 'layering' of markets into common infrastructural layers that serve as a platform for more-differentiated 'superstructures[8]'

Table 1: Examples of IoT standardisation activities (a bit out of date)

Standard	Objective	Status	Org.	Comm. range (m)	Data rate (kbps)	Unitary cost ($)
EPCglobal	Integration of RFID technology into the electronic product code (EPC) framework, which allows for sharing of information related to products	Advanced	GS1	~1	10^2	0.01
GRIFS	European Coordinated Action aimed at defining RFID standards supporting the transition from localized RFID applications to the Internet of Things	Ongoing	EC, CEN	~1	10^2	0.01
Various	Technical standards: frequencies, modulation schemes, anti-collision protocols	Ongoing	ISO	?	?	?
M2M	Definition of cost-effective solutions for machine-to-machine (M2M) communications, which should allow the related market to take off	Ongoing	ETSI	?	?	?
6LoWPAN	Integration of low-power IEEE 802.15.4 devices(sensor nodes) into IPv6 networks	Ongoing	IETF	10–100	10^2	1

[8] Layering is viewed as one of the defining characteristics of the architecture of the Internet itself; even though the standard 7-layer architecture has been overtaken by developments, many architects see the ability to develop new technologies and functionalities 'within layers' as essential to balance scientific/engineering and market/evolutionary forces. [ref to materials presented at the EINS Thinking Architecturally workshop].

ROLL	Definition of routing protocols for heterogeneous low-power and lossy networks	Ongoing	IETF	?	?	?
NFC[9]	Definition of a set of protocols for low range and bidirectional communications	Advanced		~10^2	<424	0.1
Wireless Hart	Definition of protocols for self-organizing, self-healing and mesh architectures over IEEE 802.15.4 devices	Advanced		10–100	10^2	~1
ZigBee	Enabling reliable, cost-effective, low-power, wirelessly networked, monitoring and control products	Advanced		10–100	10^2	~1

Standards are also closely linked to other challenges addressed in EINS. One is *naming and addressing*. A key issue in loT relates to naming systems. Many loT applications will require (at least locally) unique identifiers across multiple locations; this in turn requires global coordination of the naming scheme(s). The most widely adopted solution in the RFID field is the Electronic Product Code (EPC). EPC identifiers are specified by an open, freely accessible standard issued by EPCglobal Inc. and based on work carried out in the last decade at the MIT Auto-ID Center. Starting from the EPC, information about a given object can be discovered through the Object Naming Service (ONS).

Standards are also crucial to *communications* among smart objects[10]. At the lower layers (physical devices (PHY) and media access controllers (MAC), the IEEE has a 802.15 Working Group on wireless personal area networks, which have contributed to e.g. the 802.15.4 specification at the heart of the ZigBee technology and has recently constituted an 802.15.7 Task Group to tackle optical wireless communications. Groups like the ETSI technical committee on Machine-to-Machine (M2M) communications are addressing the upper layers, though (to date) primarily from the perspective of telecommunications.

Of course, standards are needed much higher up the stack. To date, there has been relatively little convergence on standards relation to the data models, ontologies and data format (s) to be used in loT applications or on service-level interfaces and protocols. These elements are

[9] See e.g. SO 18092, 21481, 22536 and 23917; ECMA 340, 352, 356 and 365; ETSI TS 102 190. ECMA 340/352 and 150 18092/21481 describe the Near Field Communication Interface and Protocol (NFCIP-1 and -2). ECMA 356/362 and in ISO 22536/23917 describe test methods for interfaces and protocols. The Global System for Mobile Communications Association (GMSA) NFC working group (in operation since 2006) developed guidelines for NFC services supportable by cellular phones technologies, which are seen as enabling the diffusion of services based on embedded NFC devices (e.g., micro-payments).

[10] Miorandi et. al. 2012.

required in order to produce the semantic interoperability needed in order to assemble the critical mass and diversity necessary if IoT development is to take off[11].

The way forward with regard to standards, we propose the following problem statement: as the complexity of the Internet increases, its impacts (positive and negative are closely linked to standards. Existing and developing Internet standards, and those that may arise in respect of *Internets of Services, People, algorithms, etc.* and the *Webs of Services, People, algorithms, etc.* that evolve on these Internets, will either expand or compress the niches within which special or innovative types or aspects of the Internet may develop. Moreover, standards transposed from other domains or arising within it may determine the balance of power and the effective functional, economic and societal performance of the Internet. This observation leads to a specific set of questions:

1. What standards are needed for effective functioning on technical, economic and societal levels?
2. How should standards (in respect of specific characteristics[12]) balance current performance against innovation, interoperability against independent competition and technological against functional specificity?
3. What new or altered standardisation bodies and processes are needed in order to permit these standards to emerge?
4. To what extent will existing standards bodies and the incentives operating on stakeholders distort standards development[13]?
5. How can independent, open and 'neutral' standardisation be balanced against and integrated with other modes of governance?

[11] The W3C had a working group on "Semantic Sensor Networks" from 2009 to 2011; its final report is at: http://www.w3.orgi2005/Incubator/ssn/XGR-ssn-2011062. But there is little evidence of a shared approach among the various standards bodies.

[12] Defined in terms of layers or functions as in the Background section, but also in terms of higher-level characteristics like security, privacy, resilience, etc.

[13] The distortion could lead to standards that are too light, too proprietary, difficult to comply with, easy to violate, disguised trade barriers, anticompetitive, harmful to innovation, harmful to public service delivery, biased against small enterprises, etc.