Opportunity to Leverage Information-as-an-Asset in the IoT – The road ahead

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***Abstract*—In traditional product companies, creating value meant identifying enduring customer needs and manufacturing well-engineered solutions. Two hundred and fifty years after the start of the Industrial Revolution, this pattern of activity plays out every day, especially in a connected world where products are no longer one-and-done. Making money is not anymore limited to physical product sales and other revenue streams become possible after the initial product sale, which are service-based information and knowledge in today's IoT (including subscriptions and apps, new analytics for cognitive capabilities…). While information and knowledge are the "new oil" of the IoT era, it nonetheless remains challenging to perceive and extract the real value of those assets, as information is not as tangible and concrete as physical assets. In this respect, this paper introduces the major "laws of information" and discusses how these laws can be leveraged to their full extend thanks to the IoT possibilities. Further, the paper discusses the key challenges that remain to be addressed in today's IoT to concretize such laws. Finally, a set of real-life business use cases identified by the Open Platform 3.0™ Forum are presented from the information law perspectives.**

***Index Terms*—Internet of Things; Standards; The Open Platform 3.0; Value creation; Business Services;**

I. Introduction

The digital revolution has been initiated by Internet and mobility technologies, which have definitely changed the way we interact with information. Over the past few years, a flourishing number of concepts and architectural shifts appeared such as the Internet of Things (IoT), Big Data and Cloud Computing. These concepts lay the foundations of the 'Web 3.0' also known as the Semantic Web (connecting Knowledge), and the 'Web 4.0' also known as the Meta Web (connecting Intelligence) [1]. Such evolution brings boundless societal and economic opportunities, for reducing costs for cities, increasing the service for the citizens in a number of areas (public health, transport, smart living, industry…), and fostering a sustainable economic growth. Although it is difficult to predict the real revenue as the exact overall contribution of IoT is not easily determinable, neither predictable, recent surveys conducted on the early IoT adopters are showing positive and encouraging signs. For example, Harvard Business Review Analytic Services [2] surveyed – in September 2014 – 269 early adopters from around the globe: 62% say IoT somewhat increased or significantly increased their customer responsiveness; 58% say it increased collaboration within the business; 44% say it increased revenue from services and products; and 54% credit it with increasing market insight and believe it increased employee productivity.

These convergent forces – united by the growing consumerization of technology and the resulting evolution in user behaviour – offer the potential to create new business models and system designs. However, they also pose architectural issues and structural considerations that must be addressed for businesses to benefit. Among the major obstacles:

1) *Vertical silos hamper organisations' efforts to act globally:* while an endless stream of new smart and connected things hits the market every day, it mostly feeds 'vertical silos' that are closed to the rest of the IoT, thus creating "islands" of information and knowledge. This is illustrated in Fig. 1 through the black/solid arrows. This situation inevitably creates a market separation per application domain, hindering technical innovation and investments in the IoT business;
2) *People may be reluctant to step into the IoT arena:* the reasons of this reluctance are multifold: *i)* difficulties in perceiving the real added value that the IoT may bring in all sectors of society; *ii)* major ICT players hand over customer data and are not willing to let the customer have a full end-to-end control, thus resulting in user frustration; *iii)* the non-maturity of the IoT makes it very challenging to develop a clear approach to foster innovation, trust and ownership of data in the IoT while at the same time respecting security and privacy in complex environments;
3) *Difficulty to leverage information-as-an-asset:* while information and knowledge are the "new oil" of the IoT era, it remains very challenging to perceive and extract the real value of those assets, as information and knowledge are not as tangible and concrete as physical assets.

Depending on the angle with which we look at each issue, issue 3 can be seen as a challenge but also as a final goal of the IoT – *information-as-an-asset* – that is directly impacted

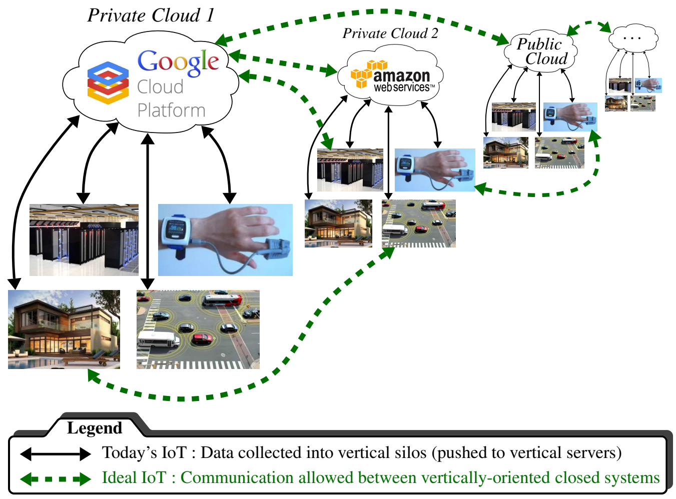

Fig. 1. Overview of the Today's IoT – Silo challenge

by issues 1 and 2: the vertical silo model and the people reluctance prevents actual and potential IoT players from fully exploiting the IoT paradigm whose "value creation" is heavily dependent on information management and transformation. Seen from this angle, this paper mainly discusses the issue 3 to better seize the importance of addressing issues 1 and 2 – *"The road ahead"*.

In this respect, section II first introduces the major "laws of information" that can be leveraged to their full extend thanks to the IoT possibilities. Section III gives insight into the overall IoT landscape and the underlying layer stack (existing standards, protocols, concept…). We therefore highlight how these different layers impact the "laws of information", and what key challenges remain to be addressed in the IoT to fully benefit from the identified "laws of information". Finally, section IV presents real-life business use cases identified by the Open Platform 3.0™ Forum, where the laws of information have a key potential for disruptive innovation and fast market up-take in IoT new market creation.

II. The Seven Laws of Information

"Value creation", which involves performing activities that increase the value of a company's offering and encourage customer willingness to pay, is the heart of any business model. In traditional product companies, creating value meant identifying enduring customer needs and manufacturing well-engineered solutions. Two hundred and fifty years after the start of the Industrial Revolution, this pattern of activity plays out every day. Indeed, in a connected world, products are no longer one-and-done and making money is not anymore limited to physical product sales; other revenue streams become possible after the initial product sale, including value-added services, subscriptions and apps, leading to new analytics and new services for more effective forecasting, process optimization, as well as customer service experiences (e.g., personalization and context gained through information gained over time). Central to these revenue streams is the 'value of information'. Moore and Walsh [3] introduced seven "laws of information", where the IoT brings the necessary resources to leverage these rules to their full extend [4]:

1) *Information is (Infinitely) shareable and can be shared with others without a loss of value:* The IoT eases the sharing of product related information and allows information distribution to all participating stakeholders. The information provided through the IoT can be monetised through paid access to the provided information, thus leading to a win-win situation;
2) *Value of information increases with Use, and it does not provide any value it is not used at all:* the IoT eases and consequently increases the distribution and usage of information. However, people have to be aware of the existence of information, and decision-makers have to be capable of interpreting and using information in a beneficial way. Again, if a 'pay-per-use' or 'pay-as-you-go' model for information access can be applied (e.g., to charge users per information request), this second law could be leveraged to its full extend;
3) *Information is Perishable and it Depreciates over time:* The IoT provides real-time information and thus provides high value information. However, one of the beneficial applications in the IoT is focused on product lifecycle information access [5]. Therefore, historical information about a product may keep or even increase its value over time;
4) *The value of information increases with accuracy:* Although "*100% accurate is rarely required in a business context*" [3], the IoT provides a fine grained view of the real world and therefore enables "high resolution management". Pricing models may also be based on service level agreements and reoccurring assessments of information accuracy compliance;
5) *The value of Information increases when combined with other information:* the IoT provides means to create ad hoc and loosely coupled information flows between any kinds of objects and systems. If these information flows are properly combined (e.g., fused), new knowledge can be generated (e.g., related to the user's or object's context), which opens up huge opportunities for context-driven, intelligent and pro-active support services of consumers' everyday work and life;
6) *More Information is not necessarily better:* While the value of information increases to a certain level if more information is supplied, it decreases when more information than can be processed is provided or when irrelevant for the end-user. Filtering, personalisation, and pre-processing can help to tailor the information to specific user requirements. A business opportunity exists to monetise customised/pre-processed information.
7) *Information is not Depletable:* Information instead is rather self-generating as summarising, combining or analysing information leads to more information. Again the multiple data sources that the IoT is composed of provide great business opportunities, e.g. to consider co-creation models where for example access to information is free, if this information is further enriched through data

analysis, may provide win-win business situations;

These seven laws of Information, combined with the possibilities of the IoT, show in what respect Information is a firm's most valuable asset. However, these laws cannot be leveraged to their full potential yet, as the IoT has not yet reached its full maturity, which is mainly due to the lack of a unified and structured platform to manage a huge heterogeneity, as will be discussed in the section III.

III. IoT landscape and its impact on the laws of Information

Section III-A gives insight into the main layers, standards and protocols that compose today's IoT. Then, section III-B highlights in which respect the current landscape impact the seven laws of information, along with key challenges that remain to be addressed in the IoT.

A. Today's IoT landscape

The IoT landscape is large and heterogeneous, from cloud-based systems to embedded software and M2M communication, where data-driven decision making capabilities are expected to move towards the edge nodes (embedded systems, sensors…) that begin to learn, adapt and act together in a predictive manner. It is nearly impossible to give a single and unified picture of the overall landscape of IoT standards due to its heterogeneity and complexity [6]. Nonetheless, in order to illustrate the main layers and solutions that shape this landscape, we have used an illustration from [1] that shows many of the most relevant existing solutions/standards for the IoT. A modified version of this illustration is given in Fig. 1, in which some readers will find similarities with the ISO stack (Link layer, Transport, Session…) but it is not intended to be mapped to the ISO stack. The different layers are:

- *Connectivity layer:* What kind of physical connectors are used (RJ45, USB, RS-232…);
- *Link Protocol:* How do those devices send the data (e.g., 802.14.5e has been designed from an IoT perspective). Although ZigBee covers a large portion of the entire stack, it has been placed here to avoid redundancy;
- *Transport:* TCP, UDP, IP are the most relevant standards on this layer. IPv6 and 6LoWPAN was supposed to be adopted by everyone on the last decade but the reality is quite different. Nonetheless, with the projection of having Billions devices connected in 2020, IPv6 will likely become a necessity in the future to respect the end-to-end principle;
- *Session/Communication:* This section is a key IoT layer with recent protocols that have been built to meet IoT requirements. Considering the paper's focus and compared with the initial picture, this layer has been divided into three sub layers, namely:
  - *Communication:* Established standards such as HTTP(S), FTP, SMTP are the main communication protocols for the IoT (especially HTTPS), however they are not suitable for implementation on low-power, low-memory and low processing power devices. The same for XMPP that is a well-established communication protocol in some domains due to its capabilities of creating and managing publish-subscribe systems. Several new standards have been published recently, which notably address IoT implementations for resource-constrained devices. The most relevant standards to date seem to be MQTT, CoAP and AMQP, which are all binary protocols running directly on TCP and/or UDP. These standards also include data synchronization capabilities that make them suitable for the Data Synchronization layer;
  - *Data Synchronization:* MQTT and AMQP use a publish-subscribe model for data synchronization, while CoAP rather uses the Observer model [7]. The Open Messaging Interface (O-MI), presented in [8], [9], differs from these standards because it uses text-based representations (XML, JSON…) instead of binary formats, it can use any of the 'Communication' and 'Transport' level standards as its underlying protocol, and it uses the Observer model for data synchronization. The main difference between O-MI and the other standards is indeed that O-MI targets generic IoT data synchronization between all information systems that are relevant for the IoT, not only the resource-constrained ones;
  - *Data Representation:* Most IoT data is exchanged using text-based formats such as HTML, XML, JSON, RDF, and even CSV, while binary representations are used mainly in local M2M communication with proprietary communication standards. However, XML and JSON only define the representation format, not the meaning of data. The Open Data Format (O-DF) standard, also introduced in detail in [8], specifies a simple and generic vocabulary for describing 'any' IoT object. O-DF is indeed intended to play the same role for the IoT as HTML does for the Web. However, O-DF can be extended with more specific vocabularies in a similar way as class inheritance in object-oriented programming. As such, O-DF is not intended to replace the existing hundreds or thousands of existing data representation standards and, in that sense O-DF is currently the only standard (to our knowledge) that has been designed for and that is suitable for generic IoT data representation;

- *Data/Context Processing:* IoT data must, in some cases, be processed under real-time conditions (see e.g. Storm), scalability constraints (see e.g. Kafka), using batch based-processing, and so on, but it also goes beyond the mere processing of data to aggregate, filter and retrieve 'context' information; This falls within the realm of Context Awareness [10]. One of the simplest forms of aggregation of context is to collect data related to a specific entity (e.g., a person) from different context sources. Aggregating and filtering data and context help both at the hardware level (e.g., to reduce the network communication cost by transmitting only important data) and software level (by only processing important data).

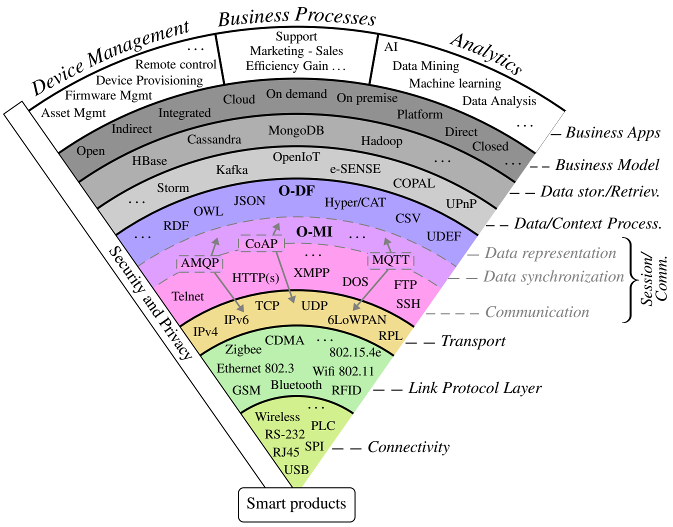

Fig. 2. IoT standards'/protocols' landscape: adapted from [1]

Well-known platforms for context aware computing are e-SENSE, COPAL, or still OpenIoT (see [11] for more information about context-awareness in the IoT);

- *Data/Context Storage and Retrieval:* Historical data is a key resource to better understand user behaviours, preferences, patterns, trends, needs, and so forth. Due to the scale of the IoT, storing all the context for the long term may not feasible. The realm of Big Data and NoSQL (Not only SQL) solutions starts here, where HBase, Hadoop and MongoDB dominate the field;
- *Business Model:* This layer is trying to capture the fact that business value and processes always rely on underlying business models, which can be 'Open' or 'Closed', 'Integrated' or 'Platform', 'Direct sales' or 'Indirect', 'Cloud based' or 'Private cloud';
- *Business Value:* This layer is split in three categories. 'Device Management' is about provisioning, registration, firmware management, remote access, but also product and asset structure. The second section, 'Business Processes', highlights the birth or transformation of Service for smart devices and marketing for product stakeholders throughout the product lifecycle, from beginning of life including design and production of the product, through middle of life including its use and maintenance, up to end of life including its recycling and disposal. It is a major challenge today for companies to get real control of their products throughout the product lifecycles [5]. Finally, the 'Analytics' piece shows how much technology could be applied to the set of information collected in the IoT, including machine learning algorithms, data mining, context reasoning techniques, and all the insights and visualization that can be derived from it.

B. IoT landscape impacting the laws of information – The road ahead

Although all these layers are important to build a true IoT, the present paper pays particular attention to three of them:

- *the Session/Communication layer:* must enable devices to be discovered, broadcast their capabilities and interact with each other. A device must be able to say '*I have an On/Off status*', '*I have a temperature*', '*I can tell you where, when, and by whom I was designed and manufactured*', and any other product lifecycle aspect.
- *the Data/Context Processing layer:* Once knowledge is generated and properly shared among systems (thanks to Session/Communication layer), it can be applied towards more intelligent interactions, products and services (Web 4.0 vision). As previously stated, one promising branch of the Artificial Intelligence is "Context-Awareness" that offers huge innovation potential to leverage system decision-making and self-adaptation capabilities, as well as for the delivery of real-time context across different silos and domains, also known as Global Awareness;
- *the Data Storage and Retrieval layer:* Storing and accessing data all along the system/application lifecycle should be possible, while coping with the application needs/constraints. Providing cutting edge data storage is of the utmost importance in an era where Big Data spans from kilobyte to zetabyte.

When systems will be able to discover data across multiple application domains, platforms, to correlate the data using machine learning models (e.g., to find patterns or find similar people), to predict road traffic, product failures, energy consumption of a building, a district, *etc.*, then the IoT, the Web 3.0 and Web 4.0 could have a true meaning in the society. This would also make it possible to foster innovation and market co-creation by leveraging/concretizing the seven laws of information that have been introduced in section II. TABLE I summarizes how the layers of the overall IoT landscape – considering the three layers mentioned above – impact the seven laws of information. For instance, Law 2 (*Value of information increases with use*) is strongly impacted by the "Data synchronization" and "Data representation" layers (see TABLE I) since information must be easy to discover and understood by peer systems (thus information becomes increasingly used by such peer systems), where such discovery mechanisms are usually supported by Session/Communication protocols (see e.g. [12]).

Nonetheless, as previously mentioned, many challenges are still facing today's IoT, thus hampering the potential of the laws of Information in the IoT. Some of the key challenges are described hereinafter regarding each law of information, with respect to the key IoT landscape layers:

(Law 1 – Information is infinitely shareable) In today's IoT, there is no appropriate service billing mechanisms for micro-transactions such as 'pay-per-use' or 'pay-as-you-go' (e.g., to sell/buy a sensor data), which is a major obstacle to the establishment of win-win situations and, consequently, fails to engage people in the sharing process;

(Law 2 – Value of information increases with use) In today's IoT, the "sharable" information is not easy enough to discover and understand; more advanced mechanisms for data and service discovery (i.e., at the Session/Communication layer) are required in the IoT, e.g. by relying on novel geolocation,

TABLE I
IMPACT OF KEY IOT LANDSCAPE LAYERS ON THE SEVEN "LAWS OF INFORMATION"

		Key IoT landscape layers				
		Sess./Comm.				
		Communication	Data synchronization	Data representation	Data/Context Process.	Data storage/Retrieval
Law 1	Information is infinitely shareable	✔	✔	✔		✔
Law 2	Value of information increases with use		✔	✔		
Law 3	Information is Perishable and it depreciates over time		✔	✔	✔	✔
Law 4	The value of information increases with accuracy	✔	✔		✔	
Law 5	The value of Information increases when combined with other information		✔	✔	✔	
Law 6	More Information is not necessarily better	✔			✔	✔
Law 7	Information is not depletable				✔	

ontology-based approach and semantic web service discovery mechanisms [12]. Along with such new mechanisms, the development of appropriate IoT billing solutions is needed to motivate IoT players to share information in a proper and understandable way (by implementing efficient techniques for service and information publication-discovery) since it will be a new and direct source of income;

(Law 3 – Information is Perishable and it depreciates over time) Current IoT market solutions focus on real-time information, but a further attention should be given to "product/object lifecycle information" to keep track of the object throughout its lifecycle (from its design, manufacture, distribution, to its use, maintenance and recycling) [13], [8]. A product system's life cycle is characterised by the following three phases: *i)* Beginning of Life (BoL) including design and manufacturing, *ii)* Middle of Life (MoL) including use service and maintenance; and *iii)* End of Life (EoL) characterised by various scenarios such as reuse, disassembly and refurbishing, material reclamation without disassembly and, finally, disposal with or without incineration. Product life cycle management aims to manage product-related information efficiently during the whole product life cycle. Such an area thus provides a means to increase historical Object-related information value over time [14], nonetheless, more efficient methodologies and tools for the lifecycle management of IoT information as well as services and context knowledge are required.

(Law 4 – The value of information increases with accuracy) People who take care of the quality of the information shared with peer' systems must be rewarded. 'Accuracy' is one dimension of data quality but many other dimensions could also be considered and rewarded (e.g., data reputation, relevancy, believability, understandability, completeness…). Businesses are increasingly using their enterprise data for their strategic decision-making activities. In fact, information (derived data) has become one of the most important tools for businesses to gain competitive advantage. Therefore, data quality and its assessment have become critical subjects in numerous sectors and business applications. Considerable research has been carried out on data and information quality in a wide range of sectors, nonetheless, in today's IoT, data quality is not monetised over its fair value, or not at all, since there is a lack of suitable billing mechanisms for the IoT (e.g., for micro-billing as described previously).

(Law 5 – The value of Information increases when combined with other information) The Vertical silo model is one of the major obstacles to enable novel combination of information and Context sources within and across silos, application domains. Context can be derived from anything that is significant in a given moment including the environment, an item within that environment, a user, or an observer. According to [11], an ontology-based context model is a pertinent solution to the problem of getting the right information to the right person in an evolving business environment. The Global Awareness paradigm, for instance, is a powerful paradigm to enable the discovery, acquisition, modelling, reasoning, distribution of 'real-time context' from across distinct silos and application domains, which opens up opportunities for disruptive innovation and services (e.g., to proactively support consumers in their everyday work and life).

(Law 6 – More Information is not necessarily better) Current practices in data storage, analysis and management will become unfeasible/unsuited to the IoT reality (also related to the problem of 'Big Data'). Further research is needed to cope with this issue to handle data storage by filtering and pre-processing more intelligently the data at source. Indeed, the main challenge is no longer to guarantee the existence of much needed information, but rather to find and provide the right information. In this regard, [15] argues that although Big Data solutions and cloud platforms can provide infrastructure and tools for handling, processing and analysing a huge amount of IoT data, there will always be a need for methods and solutions that can structure, annotate, share and make sense of the IoT data and facilitate transforming it to knowledge and intelligence in different application domains.

(Law 7 – Information is not depletable) Such a 'non-depletable' resource is of value if – and only if – innovation is constantly stimulated through the development of new services, otherwise it becomes rapidly obsolete in a connected world. In this regard, it is a new trend today to talk about "Ecosystem orchestration models" and related value creation opportunities from various stakeholders' point of view in the IoT [16], [17]. Ecosystems comprise a wide range of interacting and cooperating actors such as platform players, users, software developers, *etc.* In this regard, further research strategies and methodologies that are collaborative, engaging, participative and transformative are required. Also the research methods and traditions are siloed, and new multi-disciplinary approaches are needed for ecosystem based cross-industry R&D. Specifically we need transformative research methodologies for rapid prototyping and scaling up in large-scale pilots.

IV. Open Platform 3.0: Identification of New Business Opportunities

The Open Group has formed the Open Platform 3.0 Forum to help enterprises to use IT solutions by identifying a set of new platform capabilities, and architecting and standardizing a platform by which enterprises can reap their business benefits. Earlier this year, The Open Group published – in the Open Platform 3.0 White paper [18] – twenty-two use cases with cross-domain scenarios and applications as illustrated in Fig. 3. This platform shall foster information to flow between those domains (see red/solid lines) and, to this purpose, O-MI and O-DF are intended to be used (for interoperability purposes) in most of these use cases. Nonetheless, enhancing interoperability at the Communication/Session layer without considering how new value of services could be created at the upper layers (Business layers) is pointless. This is particularly true within the context of Open Platform 3.0 services that often involve a complex network of interdependent parties across multiple application domains (each party having its own concept of the value it expects from the service). Accordingly, we propose in this section to study and highlight what "law(s) of Information" can produce relevant added-value considering 18 Business Use Cases defined in The Open Platform 3.0. TABLE II provides a short description of the different business use cases, along with insights into the potential of each use case to increase one or more "laws of information", or to put it another way, the value of information asset in the context of enterprise business.

Considering the 1^{st} law of information (*Information is infinitely shareable*), it is important to note that depending on the objectives of the business use case, the openness of information is not always the main target of data collection in IoT. Some types of data are generated only for a closed use in a predefined context, without sharing with anonymous users. That is the reason why in some cases (e.g., healthcare environments) the first law of information is not marked as the information cannot be easily shared in an open and collaborative manner.

Considering the 2^{nd} law (*Value of information increases with use*), we claim that the key of success of any business use case in the IoT will vary depending on how information is largely used by both internal and external actors and systems. Indeed, sharing information in open innovation ecosystems will ensure quality and effectiveness for joint capability of collaboration, including collaborative processes for co-creation, co-specialisation, as well as social architecture fostering trust and sustainability of collaboration. We claim that the open source nature of The Open Platform 3.0 and standards such as O-MI and O-DF will be a primary vehicle for achieving important impacts including wide adoption, sustainability of IoT technologies, as well as penetration to the research and business communities.

Considering the 3^{rd} law (*Information is perishable and it depreciates over time*), we identified business use cases where "product lifecycle management" scenarios (i.e where information collected from a product or smart object throughout its lifecycle) has a high potential to create value in the IoT. The

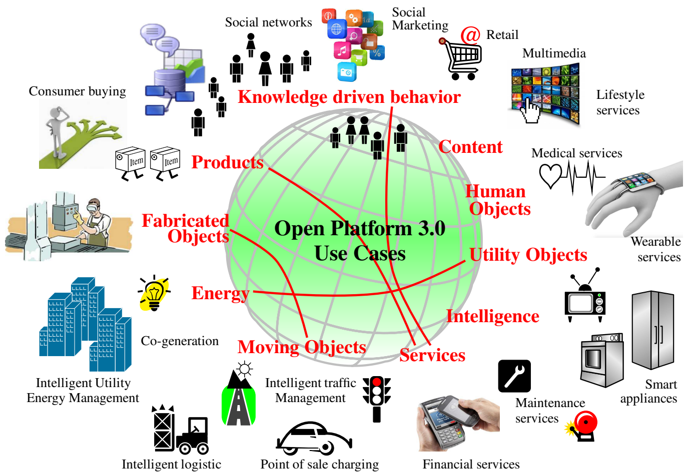

Fig. 3. Open Platform 3.0 Business Use Cases and Information flows across multiple domains

most telling examples are when dealing with "Supply Chain" scenarios (UC3, 15...) or still with complex products such as vehicles (see UC13), buildings and home appliances (UC14), and so on. For instance, in this use cases, vehicles designers or building constructors (in BoL) could be provided with real-time data about the conditions of use of their products/vehicles (i.e. information from MoL) and of retirement (i.e. information from EoL), which is key to improving improving future product designs and product generations or to provide innovative services such as predictive maintenance carried out remotely.

Considering the 4^{th} law (*The value of information increases with accuracy*), we identified business use cases where "accuracy" is of the utmost importance, or critical, from the use case's or data processing's perspective. For instance, data inaccuracy in the safe mobility scenario (UC16), e.g. inaccuracy related to the children's location is not as critical as Augmented Patient Care Sensor Feedback (UC7) since real-time patient-related information is of high 'criticity" (especially if actions are undertaken based on sensor feedback). Similarly for remote predictive maintenance scenarios (e.g., with smart electric vehicles or buildings) where actions are undertaken based on real-time sensor feedback (e.g., an operator may decide to shut down an equipment because sensors feedback raised a presumption that a failure will occur soon – accuracy is of the highest importance in that case).

Considering the 5^{th} law of information (*value of information increases when combined with other information*, producing decision support information generally requires validation, consolidation, and reasoning techniques for knowledge extraction from heterogeneous IoT information sources. In this respect, we emphasised in TABLE II the use cases where collaboration and co-creation of products and services (i.e., for easily combining disparate information sources and services) have a high potential, and where horizontal integration use cases could be identified, e.g., Electric Vehicles Ecosystem (UC13) takes place in a smart city environment where a huge amount of information sources (e.g., traffic information, user's agenda, car's features, charging station controller, predicted weather conditions...) can be inferred, combined to provide innovative IoT services ranging from simple data collection, processing, to context-driven, intelligent and self-adaptive support of ecosystem stakeholders? everyday work and life.

Considering the 6^{th} law (*More Information is not necessarily better*), we essentially identified business use cases where issues related to Big Data may occur and require new techniques, e.g. use cases dealing with energy aspects where huge amount of data generated by many buildings all across a city or region is collected and processed for real-time energy prediction and adaptation (see e.g. UC2) [19], or still use cases dealing smart retail distribution (UC15) where forecast processing based on big data analysis of roads and traffic is carried out.

Considering the 7^{th} law (*Information is not depletable*), we emphasized the business use cases that have a high potential for disrupting traditional business models, and particularly to comply with the vision of "IoT Ecosystem" that enables new forms of collaboration, engagement, participation and service co-creation and transformation. Given this, the emphaized use cases in TABLE II that enable open and standardised information exchange since "opens" and "standardisation" is the key for future efficient open innovation ecosystems.

V. Conclusion

Making money is not anymore limited to physical product sales. Other revenue streams become possible in today's IoT after the initial product sale, such as service-based information and knowledge (including subscriptions and apps, new analytics for cognitive capabilities. . .). While information and knowledge are the "new oil" of the IoT era, it nonetheless remains challenging to perceive and extract the real value of those assets, as information is not as tangible and concrete as physical assets.

In this paper, we agree with Moore and Walsh that claim that "*of all the corporate resources (people, finances, assets, information), information is probably the least well managed*", and that thanks to the emerging technologies of IoT, information becomes more profitable asset of modern enterprises. In this regard, we introduce in this paper the major "laws of information" defined by Moore and Walsh, and we discuss how these laws can be leveraged to their full extend thanks to the IoT possibilities, along with challenges that remain to be addressed with regard to each law. In this regard, the paper discusses how openness of the IoT environment and standardisation will be key for creating efficient open innovation ecosystems in the tomorrow's IoT. From our perspective, open IoT standards are of the utmost importance to address one of the most critical IoT obstacles: the "Vertical silos" that shape today's IoT and that constitute a serious impediment for co-creation of products and services in open innovation ecosystems.

Afterward, and in line with Open IoT standards initiatives, we provides a first insight into The Open Group Open Platform 3.0™ forum's Business Use Cases, where we emphasise what law(s) of information can produce relevant added-value(s) according to the use cases.

References

[1] O. Vermesan and P. Friess, *Internet of Things – From Research and Innovation to Market Deployment*. River Publishers, 2014.

[2] M. Bartolomeo, *Internet of Things: Science Fiction or Business Fact?*. A Harvard Business Review Analytic Services Report, 2014.

[3] D. L. Moore and P. Walsh, "Measuring the Value Of Information-An Asset Valuation Approach,' *European Conference on Information Systems*, pp. 789-799, 1999.

[4] D. Uckelmann, M. Harrison, F. Michahelles, *Architecting the Internet of Things*. Springer-Verlag Berlin Heidelberg, 2011.

[5] K. Främling, J. Holmström, J. Loukkola, J. Nyman, and A. Kaustell, "Sustainable PLM through intelligent products," *Engineering Applications of Artificial Intelligence*, vol. 26, no. 2, pp. 789–799, 2013.

[6] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Computer Networks*, vol. 54, no. 15, pp. 2787–2805, 2010.

[7] E. Gamma, R. Helm, R. Johnson, and J. Vlissides, "Design patterns: elements of reusable object-oriented software," *Reading: Addison Wesley Publishing Company*, 1995.

[8] K. Främling, S. Kubler, and A. Buda, "Universal Messaging Standards for the IoT from a Lifecycle Management Perspective," *IEEE Internet of Things Journal*, vol. 1, no. 4, pp. 319–327, 2014.

[9] S. Kubler, and K. Främling, "A standardized approach to deal with firewall and mobility policies in the IoT," *Pervasive and Mobile Computing*, In Press, 2014.

[10] J. Wu, I. Bisio, C. Gniady, E. Hossain, M. Valla, and H. Li, "Context-aware networking and communications: Part 1 [guest editorial]," *IEEE Communications Magazine*, vol. 52, no. 6, pp. 14–15.

[11] C. Perera, A. Zaslavsky, P. Christen, and D. Georgakopoulos, "Context aware computing for the internet of things: A survey," *IEEE Communications Surveys & Tutorials*, no. 99, pp. 1–41, 2013.

[12] European Research Cluster on the Internet-of-Things, *"AC02 – "naming, addressing, search, discovery"*. Tech. Rep., 2014.

[13] D. Kiritsis, "Closed-loop PLM for intelligent products in the era of the Internet of Things," *Computer-Aided Design*, vol. 43, no. 5, pp. 479–501, 2011.

[14] S. Kubler, W. Derigent, K. Främling, A. Thomas, and E. Rondeau, "Enhanced Product Lifecycle Information Management using Communicating Materials," *Computer-Aided Design*, vol. 59, no. 0, pp. 192–200, 2015.

[15] P. Barnaghi, W. Wang, C. Henson, and K. Taylor, "Semantics for the Internet of Things: early progress and back to the future," *International Journal on Semantic Web and Information Systems*, vol. 8, no. 1, pp. 1–21, 2012.

[16] The Institute of Electrical and Electronics Engineers, *IEEE-SA Internet of Things (IoT) Ecosystem Study*. IEEE Press Publications, 2014.

[17] H. Schaffers, N. Komninos, M. Pallot, M. Aguas, E. Almirall, T. Bakici, J. Barroca, D. Carter, M. Corriou and J. Fernadez, *Smart Cities as innovation Ecosystems Sustained by the Future Internet*. FIREBALL White Paper, 2012.

[18] M. . https://www2.opengroup.org/ogsys/catalog/W145, "The open group, the nexus of forces in action – business use-cases of open platform 3.0™."

[19] T. Hartmann, F. Fouquet, G. Nain, B. Morin, J. Klein, Y. Le Traon, Hartmann, "Reasoning at runtime using time-distorted contexts: A models@ run. time based approach," *Proceedings of the 26th International Conference on Software Engineering and Knowledge Engineering*, 2014.

TABLE II

OVERVIEW OF WHAT LAW(S) OF INFORMATION CAN PRODUCE RELEVANT ADDED-VALUES CONSIDERING 18 BUSINESS USE CASES DEFINED BY THE OPEN PLATFORM 3.0 FORUM

	Use Case Title	Law 1	Law 2	Law 3	Law 4	Law 5	Law 6	Law 7	Use case description
1	Retail Smart Store	✔	✔			✔		✔	A customer wants to browse through items in a store and potentially to purchase one or more items. He pauses from time to time to examine items. He receives value in the form of good advice leading to an optimal (price/quality) choice of product – or even to a decision not to buy. The system is aware (via sensors) of the items being examined and provides information to the customer about offers and other similar or related items (cross/up-selling) or about use/manufacture/ingredients of the item. The customer can consult reviews of the item by professionals or other customers (e.g., via social clusters) and analysis of recent purchase history for the item versus similar items.
2	Sustainable Shopping and Restaurant Street	✔	✔	✔	✔	✔	✔	✔	Enable efficient energy usage by stores, restaurants, transport, and municipal services. Local government, transport providers, energy providers, chamber of commerce develop shared solutions to optimize energy usage, improve quality and efficiency of public, private, and shared services.
3	Supply Chain Store Brand Integration	✔	✔	✔	✔	✔		✔	The ability to plan merchandise across multiple supply chain online markets, with paired store ordering, enhanced VMI, and enhanced shared transport planning and fleet usage.
4	Multi-Channel Customer Service	✔	✔			✔		✔	The ability to coordinate customer service response across different contract channels and devices, which includes customer service contact management, cross-device management for single customer account view, and customer preferences and behaviour analytics.
5	Social Gamification Orchestration	✔	✔			✔		✔	The ability to affect and reinforce customer and employee behavior across multiple platforms and devices by directing feedback and incentives.
6	Augmented Lifestyle Sensor Feedback		✔		✔		✔		Platform data aggregation and sensor visualization feedback
7	Augmented Patient Care Sensor Feedback		✔	✔	✔	✔			Personal Ambient Management (PAM) is a technique in which sensors are used to monitor and manage the behavior and movement of a patient. The sensors collect data on movement, sleep patterns, body function, and noise levels of communication. These can be analyzed to determine repetitive and anomalous behavior that can indicate self-harm or other conditions of the patient. Location and movement monitoring can create "geofencing" features that can detect that the patient has left a designated safe area, or the level of contact and interaction. Measures can be put in place from analysis of the data to improve patient care and quality of life as well as potential value for money and cost efficiencies in use of improved precision care interventions, and use of lower-cost automatic monitoring systems not requiring human support for all processes.
8	Open Government Data Interchange	✔	✔			✔		✔	Government data made available free to anyone to use. Data produced or commissioned by government or government controlled entities. Data that is open as defined in the Open Definition that is, it can be freely used, re-used, and redistributed by anyone. Ability to transfer and acquire products and services across multiple country borders. Provide secure, regulation-compliant information to citizens and businesses via open APIs.
9	Incident Management		✔			✔	✔		Using information from social channels and mobility to tackle incidents such as terrorist attacks, natural disasters, evacuation, and response. Possible steps for incident management include, among other things, natural disasters, terrorist attacks, *etc.*
10	Information Control		✔		✔	✔			Governments want to prevent unwanted rumor or fake-threat spread that can cause security issues. Some are switching off cell towers or putting a cap on SMS messaging to control this. They would want to have similar control on the social channels. Filtering and dealing with junk, abuse, and trolls on social channels.
11	E-Medical Data Access and Exchange		✔	✔					A person on vacation needs emergency medical care while in a foreign country. The medical care provider needs access to the medical history of the person needing medical care. One possible scenario: a person on vacation suffers a stroke while in a foreign country. The stroke prevents the person from speaking. The medical provider in the foreign country needs access to the person's medical history to determine the proper treatment. Some medical history is maintained by the person's primary care physician in the person's home country. Some medical history is located in a variety of other systems. Once medical treatment is completed, the medical history data needs to be updated by the medical provider. The medical provider will need to submit a claim to the patient's medical insurer.
12	Translational Research – Bench to Bedside	✔	✔		✔	✔		✔	Provide ability to quickly apply translational research at the bench-side to the patients on the bed as personalized care. One potential scenario: clinical researchers conduct disease (cancer) research, which is referred to as bench-side, while treating the patients on the bedside. Their study of molecular diagnostics involves studying the genomic and proteomic expression patterns to distinguish between the normal, pre-disease, and post-disease tissue or blood samples at the molecular level.
13	Electric Vehicles Ecosystem	✔	✔	✔	✔	✔	✔	✔	The Electric Vehicles (EV) use-case aims to extend conventional cars through the implementation of the EV ecosystem enabling interactions between different actors ranging from designers and manufacturers to drivers and services providers. An open web-based system provides real-time control of the smart car data stream, enabling personal, relevant, and timely services from different perspectives.
14	Smart Buildings and Home Appliances	✔	✔	✔	✔	✔	✔	✔	This use-case addresses the optimization of human machine interfaces of private households such as the TV control menus, in terms of customization, personalization, and product and service feedback. The key stakeholders are companies in the white goods and brown goods markets, software companies, and accessory (e.g., programmable remote controls) companies.
15	Smart Retail Distribution	✔	✔		✔	✔	✔	✔	Optimization of logistics of customer goods in urban areas, in particular in city centers. Both Security and Efficiency is targeted as scenarios. The efficiency one is: During transport, an RFID tag attached at the van is read on entry to a limited traffic zone, using short-range communication between the van and sensors located on fixed points at the city center. Forecasts based on big data analysis of roads and traffic provide a cloud-based service to the mobile of the driver for more efficient routing.
16	Safe Mobility	✔	✔			✔		✔	This concept applies to children traveling from home to school, but it is also extendable to elderly people or patients, and women traveling alone at night. For example, when a child leaves home, he or she wears an article of clothing with an embedded RFID tag. The event is read and recorded by the intelligent home infrastructure, and may be forwarded to the parents as a text message, email, or similar, if required, or only if the event deviates from the scheduled or "learned" expected behavior.
17	Investments and Asset Management		✔		✔				Key scenarios include qualitative and quantitative analysis, portfolio rebalancing, and managing risk. Many of the publicly traded companies and their leadership teams provide feeds (twitter feeds, blog posts, etc.), which many times provide indications about their performance and plans. Such inputs help investments personnel in making investments decisions.
18	Open Innovation, Crowd-Sourcing/-Funding		✔				✔		Use of external innovation sourcing for product and market development and the integration with crowd- sourcing and crowd-funding to facilitate bringing ideas to market.