From Innovative Niches to a Cooperative IoT Ecosystem

Creating Business Value for Federated and Interoperable IoT Platforms

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***Abstract*— This paper presents a novel approach for maximising IoT resources' value built on top of IoT platform federation considerations. The work presented is based on the premise of unifying the fragmented IoT environment that directly impacts on the market and matching heterogeneous user groups while supporting existing businesses. Moreover, it proposes, business value creation in a cooperative environment based on the principles of the sharing economy and the experience and lessons learnt from the symbIoTe project. symbIoTe is part of the IoT European Platform Initiative (IoT-EPI) and aims to enable IoT platform federation towards more cooperative IoT ecosystems.**

Index Terms*—*interoperability, federation, value creation, innovation, shareconomy, cooperation

I. INTRODUCTION

Nowadays, the world is living the era of integrated smart devices in many aspects of citizens' daily life and also in industry. One of the main key enabling technologies (KET) is the Internet of Things (IoT). IoT is behind this technological revolution, which fosters the digitization process within different industries and domains.

The digital transformation brings up many new opportunities transforming the IoT business landscape and creating business growth [1]. It creates new dynamics in the value chain bringing new stakeholders in the IoT domain or providing them with new roles. IoT is a rapidly evolving field with a big potential for improvement and space for innovation. It is also a widely diverse environment in terms of application domains and services, but also in technical terms such as communications languages, standards and protocols etc. that create a great level of complexity.

The IoT landscape of today may easily be dominated by vertical silos with a few large IoT players, leaving many businesses outside the value creation [2]. From an industry and economic point of view, this mandates the need for acceleration of the development of common standards and protocols towards building a common IoT landscape with more interoperable systems for capturing further innovation and business creation. The IoT domain requires adjustments in the ways that it creates value within existing and future IoT systems.

The next sections present an overview of the current value creation around IoT businesses and its limitations, and propose an innovative way of doing business around the main concepts of interoperability and federation. Furthermore, the paper introduces the case of symbIoTe project (symbiosis of smart objects across IoT environments) to explain further the concept. symbIoTe proposes a remedy for the fragmented IoT environment unifying views through an abstraction layer which allow the different actors involved in the IoT chain to interact in a transparent manner. The project proposes a new way of creating businesses that boosts collaborative and mutually-enriching business development, increasing co-creation opportunities in a sharing economy model.

II. LIMITATIONS OF IOT ECOSYSTEM

Businesses in IoT ecosystems, have shifted from linear models where, for example, telecom operators worked together to provide network services towards a networked information economy [3], and connectivity is only an enabler to pluralistic and non-linear value generation models.

Usually, in IoT-related industries the usage is centred on specific "spaces", such as homes, offices or stadiums, but the value generation and involved business models in these

"spaces" are highly diverse, often separated and potentially involving transactional business approaches.

In IoT ecosystems multiple value streams may overlap at certain IoT "spaces" or share the same physical infrastructure (e.g. at city scale), their cases may be highly disassociated in terms of used hardware, software, business models etc. and they do not interact nor collaborate. The lack of communication and interaction derives from a series of challenges and limitations that current systems face and that can impact negatively on the potential for further business growth. The challenges are not only of technological nature (protocols, communication languages etc.) but also shaped by the market drivers and dynamics.

At the same time, most IoT data produced is not currently used [4]. There is unexploited data from devices'/sensors' owners due to the narrow scope of its business or due to the lack of resources (physical or economical). Or in other cases, the data owners have different ideas on how to use data than those of other IoT stakeholders. But, what would happen if the data owner is able to sell or provide it to other IoT players?

Another key impediment to market growth is that major IoT players, as expected, are taking over the market. Big companies have the ability to create their own ecosystems with interconnected resources and services, without allowing the entrance of other players and, in most cases, creating silos in the various vertical sectors. But there is still a large value captured by smaller niche players that can create highly customized and innovative solutions. For those smaller players, the implementation and realization of per-case individual and proprietary interconnection interfaces is a barrier to connect beyond their own niche to a wider ecosystem. In addition, any connection of a smaller player with a larger player will be dominated by the latter one, as the negotiation power (which translates to the dictation of the technical and business terms of interconnection) may be slanted. At the same time, smaller IoT players work isolated with low interaction between them and very dependent of the specific underlying platform and resources.

Overall, there is a very limited tendency of the IoT market to converge from numerous isolated islands setting to an interconnected scene, where individual players can grow beyond their own market and satisfy currently unserved needs. The lack of interoperability is nowadays more obvious in an increasingly digitalized world where customers are not only consuming technology but pushing for a more interconnected society, which can completely change the business culture.

III. Creating Value through Interoperability and Platform Federation

Looking into the IoT market, interoperability is a significant topic and it is a critical element for maximizing the value of the IoT ecosystems. Nearly 40% of the total value that can be unlocked requires different IoT systems to work together and can reach up to 60% in some settings [5]. A horizontal connection of IoT ecosystems through interoperability of devices and platforms can enhance the data usage, and its analysis, and bring together different actors essential for accelerating innovation across sectors and regions. Another important thing is that interoperability helps to launch services faster in the market by allowing smaller players to develop robust services using cost-effectively non-proprietary IoT resources.

Interoperability can go a step further under a more framed and secure way, but with the same facilitation, in the shape of platform federation. Traditionally, federation is applied to the interaction of two network or telecommunication providers in order to allow users to interact on two different systems. In recent years, federation has been applied to cloud computing, and is now considered the future of cloud. Federation models, based on interoperability, avoid vendor lock-in and provider integration issues, benefiting end users and democratizing the cloud market. This model increases the competitiveness of cloud providers, while creating new business opportunities. Platform federation enables closer collaboration between IoT platforms and direct resource exchange among them. The federation allows different platforms to search and access resources of other federated platforms as if they owned the resources. This kind of reciprocal agreements create more innovative business collaborations and novel products.

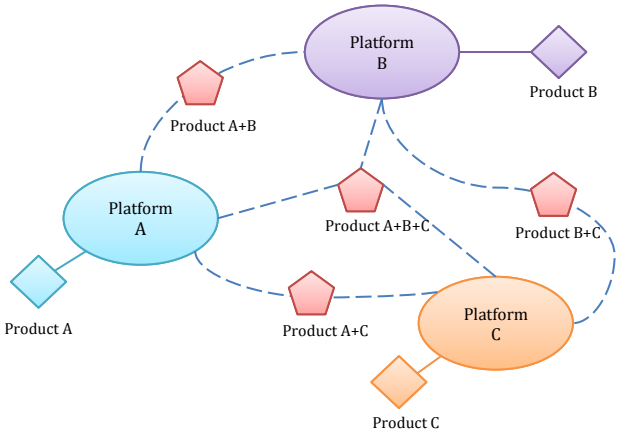

Fig. 1 New interconnections between IoT resources owners to create new services and products

The IoT platform owner is the key stakeholder for unlocking value and trigger new interactions. Platforms are characterized by multi-stakeholder interactions and bring together different elements, such as data, devices, applications and users. They generate value exchanges, creating opportunities to collaborate and transact at a global scale, as per the definition by the World Economic Forum [6]. The IoT platform providers are shaping the digital transformation of the industry and provide innovation through new solutions and new or adapted business models. The World Economic Forum suggest that the Platforms have two functional layers:

- "*Interactions*. Producers, consumers and platform orchestrators collaborate in the creation, consumption and compensation of units of value [6]. These value units can take the form of information, physical matter, labour or currencies of energy.
- *Infrastructure*. Underlying technology and architecture address concerns around APIs, interoperability, security, reliability and performance management. The

focus here is on the management of a complex set of open and interoperable technical elements at global scale and in a highly reliable and secure manner".

The platform federation establishes itself within both functional layers. In the interaction layer the federation provides new connections among platforms under a platform orchestration and creates bonds for new market solutions in Business-to-Customer (B2C) and Business-to-Business (B2B) solutions. In the infrastructure layer, the federation provides a secure reliable place for exchanging resources under common APIs facilitating and minimizing coding efforts in multi-stakeholders' interactions.

The foreseen value creation for IoT stakeholders in platforms' federations come from the following possibilities:

- **Sell** IoT resources (used or unused) to third parties developing new revenue streams.
- **Buy or exchange** IoT resources to create new services and products or enhance existing ones.
- **Scale-up** existing solutions to new geographical markets or new IoT domains with new resources received.

Considering these new possibilities inevitably the potential to create, innovate and save money accelerates between the federated platforms. Traditionally, the concept of sharing economy, or shareconomy, applies to peer-to-peer (P2P) interactions through online transactions. In the last few years, with the rise of the Information Technologies (IT), this model has evolved to marketplaces in order to exchange goods and services. Some examples of business models based on this are Uber or AirBnB, who are in fact able to provide offerings at a lower price than traditional business, like car rental or hotel rooms. Platform federation through an interoperability framework is key for evolving shareconomy introducing in the field non-tangible goods, such as data, combined with physical resources, such as sensors or devices, to be exploited by third parties in the form of new services or enhancing existing ones.

Value in shareconomy for IoT works in two levels: Co-creation and Coopetition.

- **Co-creation.** Value is generated through the interaction between stakeholders where both share resources and services to be mutually benefited through a synergetic relationship.
- **Coopetition.** Value is generated through the interaction between stakeholders where both share resources and services to be mutually benefited but will compete in the end for their market share.

These two ways of creating value are of crucial importance for organizations, especially SMEs and startups, which may not have the potential to remain competitive in the continuously evolving IoT market. Cooperation through a shareconomy scheme can provide them with the opportunity to reach a higher value if compared with their current situation and, at the same time, develop new revenue streams from services that were not initially considered and save money in resources.

Challenges in cooperative IoT ecosystems

These collaborations can actually be complex to achieve. Small players want to acquire resources in the most cost-effective way and receive a benefit that can clearly justify the cost of the investment. At the same time, each company and start-up tries to keep their unique selling points and maintain their competitive advantage. This suggests that sharing, exchanging or even selling resources is a delicate matter that the owners will not easily agree upon. An important point is that data owners do not want to lose control of their resources and when handled externally by third parties it can raise uncertainties. In addition, much data comes directly from the end users collected by mobile phones for example which creates an extra complexity for privacy and confidentiality. Finally, the resources offered should be reliable and come at a desired quality, amount and time. The partnerships have to be well defined, create trusted relationships and be able to satisfy the expectations in order to avoid the risk of investment.

IV. THE SYMBIOTE PROJECT CASE

The European Union (EU) acknowledges the importance of research, innovation and deployment of IoT and IoT interoperability. Under the Horizon 2020, the EU research and innovation programme, the EU invested almost €200 million in IoT projects promoting the idea of open and easy accessible IoT platforms and connected smart objects. Part of it was the IoT European Platform Initiative (IoT-EPI) and seven research and innovation IoT projects: Inter-IoT, BIG IoT, AGILE, symbIoTe, TagItSmart!, VICINITY, bIoTope. This paper examines the case of symbIoTe project.

symbIoTe project (https://www.symbiote-h2020.eu/) develops an interoperability framework that brings together vertically isolated platforms and provides solutions that can increase co-creation opportunities. symbIoTe provides flexible interoperability mechanisms that can be implemented by its incremental deployment in four levels, however, this analysis focuses on the first two. In the first level, symbIoTe allows unified IoT resource discovery and access. symbIoTe acts as an intermediary, providing a "search engine" for IoT resources, and offers a unified way to expose and register IoT physical resources (sensors, actuators etc.) provided by registered IoT platforms. It further offers a unified way for third parties to search and discover those resources.

In the second level symbIoTe offers IoT platforms collaboration and cooperation by providing federation services within a symbIoTe-enabled ecosystem. It brings the functionality of "*Unified IoT Resources Discovery and Access"* in a closed environment of IoT platforms that want to collaborate directly with others without intermediaries and offers the IoT platform federation where platforms can interoperate under the conditions of signed agreements. This allows compliant platforms to share resources without the core services of symbIoTe. The second level requires the first one for its technical implementation. The flexibility that symbIoTe interoperability offers, opens up the opportunity for business growth and creates a dynamic ecosystem in which stakeholders can choose their specific collaboration modes.

As in any decentralised system, security needs to be addressed with utmost care. Within a federation environment, IoT platforms securely expose and exchange resources for their mutual benefit in a distributed fashion. In addition to this,

symbIoTe enables platform federation by also providing the means to define how such federated platforms will operate. symbIoTe defines how resources are exchanged and keeps account of the performed transactions, while takes into account security and trust to ensure that all involved actors are truthful and trustworthy with respect to the quantity and quality of offered resources.

symbIoTe provides a Quality of Service (QoS) control which set the rules that shared resources must comply with. The QoS mechanism also assists in the calculation of resource and platform trust score. Trust reflects the probability that an unknown party acts as planned and provides the requested action as promised. All interactions and exchanges are well documented, in the form of a signed agreement, and monitored in order to ensure transparency and further trust to the system [7]. This signed agreement is a Service Level Agreement (SLA) which describes the agreed conditions and requirements for all current and future platform to join the federation. A platform may belong to more than one federation at the same time and may choose to share some resources with either one or both, or share different resources with each one [7].

The core business idea of symbIoTe is to lower the barrier for interconnection of IoT platforms by focusing on purposeful and lightweight interfaces that are well documented and can be reused from one business interaction to another. This setting can especially unlock a rich ecosystem around the innovation potential of highly specialized and smaller players and offer them a space for co-developing value for their businesses. The interactions between platforms can be of monetary or non-monetary value (exchange of resources) and are based on bilateral agreements. These agreements are based on the principles of the sharing economy, where two or more actors collaborate to generate economic activities.

symbIoTe validates its concepts with five real-life use cases namely: Smart Residence, Smart Campus, Smart Stadium, Smart Mobility and Smart Yachting. The paper examines the case of the Smart Residence and the Smart Stadium using the methodology of the Value Network Analysis (VNA). VNA is a methodology to analyse and illustrate complex ecosystems [8]. VNA links specific interactions within the value creating network, it provides views of how financial and non-financial assets are converted into negotiable assets that impact positively the stakeholders involved [9].

Within the Smart Residence there is a sub-use case, the Healthy Indoor Air. On this use case, a private IoT platform for smart home is connected to symbIoTe in order to find partnerships and collect outdoor air quality data. The external platform connected through symbIoTe interacts with the smart home platform and provides air quality data in order to develop an additional service within the smart home aiming to achieve a better indoor air quality. If internal pollution is higher than external (or vice versa), various actions can follow such as opening of a window, an indoor air purificator can start to operate and a notification reaches the user aiming to provide the best possible conditions for the smart home owner. A key interoperability aspect here is the connection of IoT platforms of the smart city with an IoT platform of a smart home. Further connections for different services can also be developed in topics of energy use and mobility. The key interoperability aspect is the scalability of the use case which can be applied on the geographical location as smart homes require data from all the areas that clients have installations and they need to interact with their local IoT platforms that offer air quality data.

The value network analysis (VNA) of the healthy indoor air case is represented on figure 2. It is a simple interaction between two platforms a private smart home platform and a public air quality data platform provided by a city authority. The two platforms connect via symbIoTe for creating a collaborative environment. The smart home platform provider pays symbIoTe a fee in order to get access to that data, while the air quality platform offers the data for free providing a service to its citizens and it might receive data back from homeowners if permitted, for demographic purposes for instance. This can be done under specific agreements that respect the user's privacy. There is also an IoT service provider in this network that creates an additional service upon this establishment and provides data quality services. The IoT service provider is generating a revenue from symbIoTe. While, symbIoTe is the fourth stakeholder which takes the role of facilitator of the exchanges and keeps the interoperability mechanisms up and running. This example demonstrates the symbiosis of IoT platforms and service providers and demonstrates the generation of multiple values in a multi-stakeholder interaction.

The second use case is the Smart Stadium. In this use case, stadiums and open areas where sport or music events can be held. The set up for this use case is one single small stadium. There are different platforms available in the stadium, like beacons and promowalls, which are not connected between

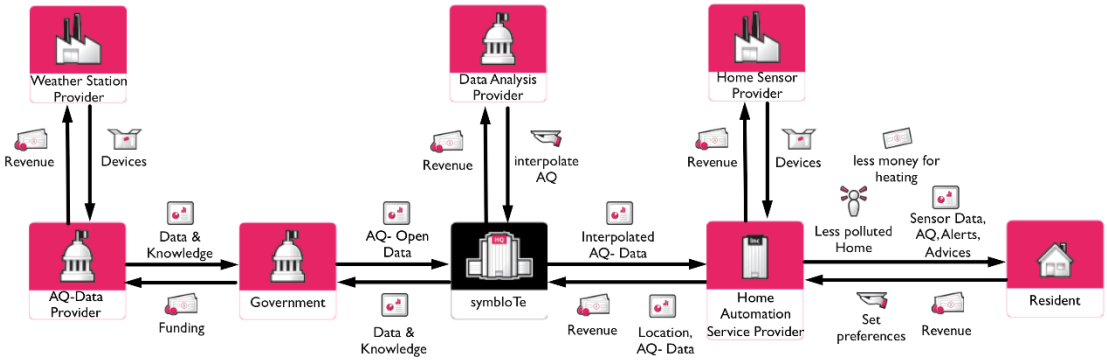

Fig. 2 Value Network Analysis of Healthy Indoor Air [10]

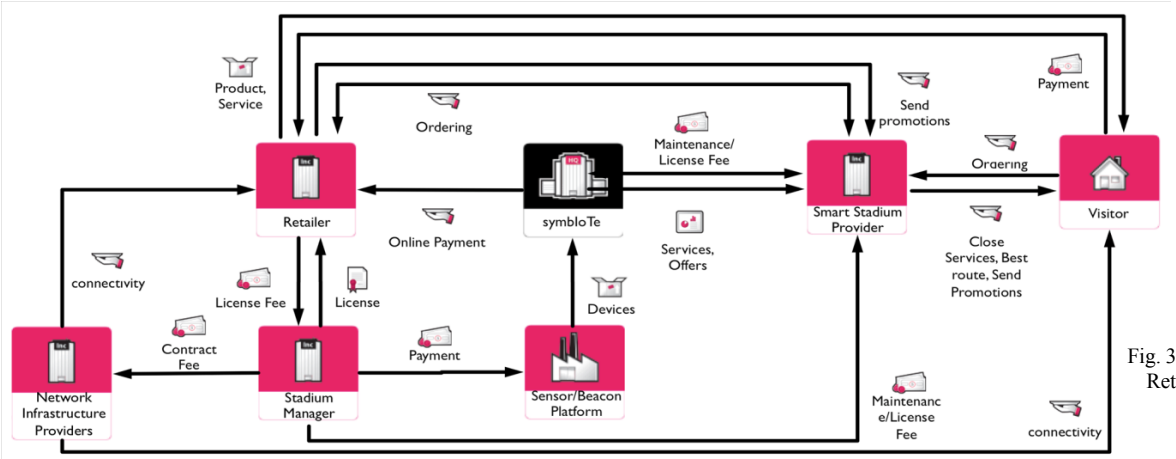

Fig. 3 Value Network Analysis of Retailers Application [10]

them. Thus, several opportunities for retailers are missed as they do not have the opportunity to access and interact with the attendees at the events.

In the VNA of figure 3, the visitor has already downloaded and installed the Smart Stadium app in their mobile device, sharing their location and registering their device. At some point the visitor decides to do a purchase, i.e. a souvenir or a snack, and opens the app to find the nearest shops where goods can be acquired. Once the shop is found, the visitor can order the desired product and the retailer receives the notification, so they are able to check if the product is available in stock or need to contact with other retailers in order to confirm the booking to the visitor. Once the process is finished, the visitor can attend at any time to buy the product. This purchase service is only available due to the possibility of interconnecting beacon platform and visitors' devices through symbIoTe. It provides real time interactions for improving services during the event.

Another example is the Promowall VNA depicted on figure 4, which involves the interaction with the promowalls installed in the stadium. In this example, as well as reserving the product, the user can also redeem coupons for discounts on certain products. Here besides the interaction of different devices, the interaction of stakeholders is also demonstrated. Without the abstraction layer offered by symbIoTe, where several platforms and resources can interoperate, an extremely complicated process would result as each stadium has its own provider, and the APIs exposed by devices vary from one location to another.

In order to understand further the potential of symbIoTe a series of living lab sessions were performed, where representatives of selected companies (mainly IoT platform owners) brainstormed their business model components and questioned each other's processes in view of new opportunities enabled by symbIoTe. The exercise was repeated, each time with similar groups of real-life users, as key stakeholders. The exercise was performed three times every semester with similar groups of stakeholders divided into a total of 12 teams of 3-4 people. From these sessions it was obvious that the interoperability framework proposed is an interesting concept for business development. The primary list of generic values or goals proposed by the symbIoTe team, such as "selling more goods", "accessing to more infrastructures", "improving existing services", or "optimizing prices"; were extended by actual stakeholders' values and goals in the context of their ongoing business processes looking into their real challenges and business development aspirations. The resulting overview of stakeholders' profiles, their existing business cases and real-life expectations was a good starting point for choosing the most promising symbIoTe components and/or packages but did not allow for a measurable comparison across components and use cases. These sessions validated the value creation for symbIoTe framework that enables interoperability.

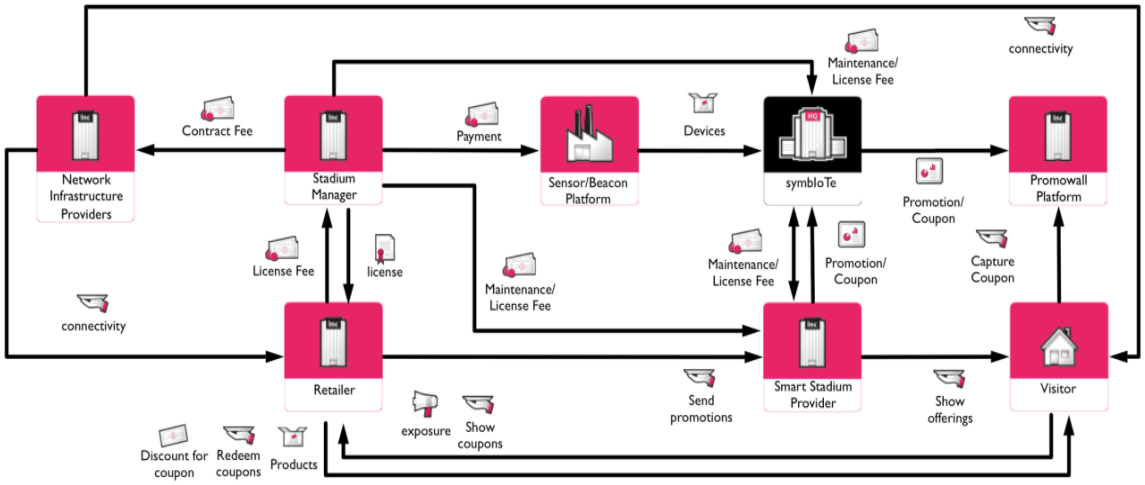

Fig. 4 Value Network Analysis of Promowall Application [10]

V. CONCLUSIONS

Looking at the limitations of the existing way of doing business it is clear that the potential of IoT solutions can be much greater and interoperability will play a significant role in the coming years. This is already well-understood by many key IoT players and the increasing number of publications and articles on IoT interoperability. Also, IoT platform federation can actually be one way of creating interoperable systems, where resources are exchanged, remonetised or sold providing more efficient IoT setups in a secure manner.

A B2B shareconomy model for sharing data and resources that otherwise would go unused where mutual benefits through co-creation or coopetition can create additional value for companies and start-ups where openness can enrich the ecosystem and maximise innovation potential for whole IoT market. It is worth changing, not only the way we exchange resources and data, but also the way we do business.

symbIoTe project comes to enhance this understanding. Where we see stakeholders understand the value to their IoT resources and interoperability seems like a convincing option to expand their business scopes and create more robust or new products. On the other hand, openness and resources sharing are not always very welcomed concepts in an increasingly competitive market. Losing control over data usage can be worrying. This is why secure IoT platform federations under trusted agreements could be a more convincing scenario in interoperability. However, the early adopters and innovators will demonstrate the IoT potential and leadership in market uptake and indicate whether IoT platform federation will establish itself in the various IoT domains.

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REFERENCES

[1] Mark Turck: Internet of Things: Are We There Yet? (The 2016 IoT Landscape), March 28, 2016, http://mattturck.com/2016-iot-landscape/ (last visit March 12, 2018).

[2] J.R.M. Hand, “Evidence on the Winner-takes-all Business Model: The Profitability Returns-to-scale of Expenditures on Intangibles Made by U.S. Internet Firms, 1995-2001”, SSRN Electron. J., pp. 1995-2001, 2001.

[3] Y. Benkler. The Wealth of Networks – How Social Production Transform Markets and Freedom, Yale University Press, 2007, ISBN: 9780300125771.

[4] McKinsey & Company. The Internet of Things: Mapping the Value Beyond the Hype. June 2015. [Online]. Available: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/The-Internet-of-things-Mapping-the-value-beyond-the-hype.ashx (last visit Mar. 26, 2018).

[5] J. Manika, “McKinsey Global Institute”, Unlocking the potential of the Internet of Things, June 2015. [Online]. Available: http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitazing-the-physical-world. (last visit Feb. 22, 2018).

[6] World Economic Forum, “Digital Transformation Initiative: Unlocking B2B Platform Value,” March 2017, online: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-platform-report-final-3-26-17.pdf (last visit March 16, 2018).

[7] Deliverable 3.2

[8] Peppard, Joe, and Anna Rylander. "From value chain to value network: Insights for mobile operators." *European Management Journal* 24.2 (2006): 128-141.

[9] Allee, Verna. "Value Network Analysis and Value Conversion of Tangible and Intangible Assets." Journal of Intellectual Capital. Publisher: Emerald Insights, Year: 2008, Volume: 9, Issue: 1, Page: 5 - 24, Digital Object Identifier: doi:10.1108/14691930810845777 https://ocw.tudelft.nl/wp-content/uploads/Value_network_analysis_and_value.pdf. (last visit Apr. 30, 2018).

[10] Board of Innovation, the icons for the VNAs are taken from the the Bussiness Model Kit. https://www.boardofinnovation.com/tools/.(last visit Apr. 30, 2018).