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# **Integrating the Business Networks and the Internet of Things Perspectives: A System of Systems (SoS) Approach for Industrial Markets**

## **Abstract**

In industrial business-to-business (B2B) markets, physical entities (such as products, machines, materials, or other objects) are increasingly connected among each other. This Industrial Internet of Things (IIoT) is quickly developing thanks to advances in fields such as information systems, factory digitalization, data sciences, robotics. Thus, industrial markets appear both as business networks - encompassing connections between individual or organizational actors – *and* networks of connected things. The purpose of this research is to provide an integrative perspective that encompasses both types of networks. It seeks to contribute to the literature on industrial B2B markets in two ways. First, it proposes the system of systems (SoS) theory - which emphasizes diversity and autonomy of systems - as an integrative perspective. Second, it argues that this integrated perspective contributes to a new view on how resources are produced, combined, and used, and, therefore, on business network models. We discuss the implications for one of the most established models, the IMP Group's A-R-A model.

**Keywords:** IIoT; B2B; A-R-A model; System of Systems (SoS); Smart farming

# **Integrating the Business Networks and Internet of Things Perspectives: A System of Systems (SoS) Approach for Industrial Markets<sup>1</sup>**

## **1. Introduction**

Networks constitute an important field of research in many disciplines. They are also an ever-evolving real-world phenomenon. For example, physical entities (such as products, machines, materials, or other objects) are increasingly connected among each other (Kopalle et al., 2020; Leminen et al., 2020; Suppatvech et al., 2019; Turunen et al., 2018). Such a constellation is often referred to as the Internet of Things (IoT) (Ardito et al., 2019; Ashton, 2009; Atzori et al., 2010). It constitutes an Industrial Internet of Things (IIoT) when these products, machines, materials, and other resources are industrial objects, or when they are used in a business to business (B2B) context (Falkenreck & Wagner, 2017; Jayashankar et al., 2018; Soltani, 2021). Such objects are typically tangible and inanimate, but they exchange large quantities of information: they communicate. The IIoT is quickly developing thanks to advances in fields such as information systems, factory digitalization, and data sciences. Establishing digital links between physical entities leads to the emergence of a system, that is, a set “of interacting units with relationships among them”, a definition coined by the ‘father’ of General Systems Theory, von Bertalanffy (1969) and reformulated by Miller (1973, p.68).

In other domains, scholars have studied networks composed of human actors, and/or composed of organizations formed by human actors (Holmlund & Törnroos, 1997; Koporcic & Tornroos, 2019; La Rocca et al., 2017; Ramaswamy & Ozcan, 2020). For example, research dedicated to

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<sup>1</sup> Throughout this work we will use the term 'business network' that has been used first by B2B scholars to refer to the networked nature of markets. We nevertheless acknowledge that the B2B literature is increasingly adopting the term 'business ecosystem' (adapted to business context from biology by Moore (1993)). Often these terms are used interchangeably. This is our position in this paper (see also Holmen et al., 2013; Moller, 2013). Sometimes differences are emphasized. For an in-depth review of the use of both concepts of ecosystems and networks in the B2B marketing literature see Aarikka-Stenroos & Ritala, 2017).

B2B markets has increasingly extended its initial focus on dyadic relationships between individuals or companies to study business networks that are composed of large numbers of human actors and organizational entities and, hence, encompass numerous economic exchange relationships (Aarikka-Stenroos & Ritala, 2017; Gadde et al., 2003; Wilkinson & Young, 2002). These business networks, too, are systems, because they also form “sets of interacting units with relationships among them” (von Bertalanffy, 1969; Miller, 1973, p. 68).

In the context of B2B markets, both the IIoT as a system of things (Aly et al., 2021; Beverungen et al., 2017; Kortuem et al., 2010; Langley et al., 2021; Suppatvech et al., 2019) and business networks as systems of actors (Sklyar et al., 2019) are essential vehicles of value creation (Chen et al., 2021; Kothandaraman & Wilson, 2001, Hakanen & Rajala, 2018). Both attract much research interest. While differences between the two concepts exist, both emphasize the notion of *connections* among entities, for example between two organizations in a business network where the connection is the necessary condition for a dyadic relationship to emerge. Accordingly, business networks have been described as sets “of two or more *interconnected* business relationships in which an organization is embedded” (Anderson et al., 1994, p. 2). The connections between physical objects through The World Wide Web in the IIoT create additional ties between firms (Ashton, 2009; Suppatvech et al., 2019; Leminen et al., 2020), for example between the factories of suppliers and customers whose machines exchange data, or between a maintenance service team and its customer organization. These electronic ties are not only a means of communication, but also of production and distribution among firms (Straub et al., 2004). Hence, they link organizational actors in a technological manner.

Despite certain similarities, the concepts behind the two literature streams, that is, the IIoT and the business networks literatures, describe connections and the related industrial value creation processes in quite different ways.

- In the business networks literature, the IMP group (Håkansson & Snehota, 1995), for example, has advanced a model that describes networks as being constituted of three elements: the actors involved, the resources used, and the activities that are performed (Actors – Resources – Activities / A-R-A model). In the A-R-A perspective, actors are essentially human, and technology essentially represents a resource.
- In an IIoT perspective, on the other hand, technologies are not necessarily resources. They represent diverse technological entities that may be seen as actors. Actors, as a consequence, are not necessarily human. Autonomic systems or machines may also be seen as actors (Andersson & Mattsson, 2015; Kot & Leszczyński, 2020; Sklyar et al., 2019). Connections do not exist exclusively between human actors and human actors, or between organizations and organizations (e.g., Straub et al., 2004; Chi et al., 2010). Rather, they may take the form of data and automatic communication between machines (e.g., EDI: electronic data interchange) or between human actors and machines where machines driven by artificial intelligence start to obtain remarkable levels of autonomy (Hoffman & Novak, 2018; Kot & Leszczyński, 2020; Sklyar et al., 2019).

Increasingly, value in B2B markets is created through such diverse connections and interactions, and more generally through a complex interplay of human actors and their organizations in business networks on the one hand, and intelligent objects in the IIoT on the other. The A-R-A model, which has proven to be useful for analysing B2B markets before the rise of the IIoT, does not completely account for such complex situations in its current form.

The purpose of this research is to provide an integrative perspective that encompasses different types of networks in B2B markets. It contributes to the literature on industrial B2B markets in two ways.

First, this research argues that the system of systems (SoS) theory - which emphasizes diversity and autonomy of systems - can offer such an integrative perspective (Bourne et al.; 2018; Choi,

2018; Maier, 1998; Mostafavi, 2011) as well as insights into how value is created in business networks when intelligent products and machines are involved. Traditionally, in the B2B literature, the IIoT has been studied with the objective of identifying new business model opportunities (Leminen et al., 2020; Suppatvech, et al., 2019; Ehret & Wirtz, 2017). Here, we propose to look at IIoT as a phenomenon that transforms / re-shapes business networks (Porter & Heppelmann, 2014; Püschel et al., 2016). Through a specific industry case, this research illustrates how the SoS perspective may contribute to depicting value creation in business networks when IIoT develops, i.e. when intelligent products and machines are involved.

Second, this research argues that the integrated perspective on (a) business networks and (b) the IIoT through the (c) SoS lens suggests that the A-R-A model described in the business networks literature may require adjustments to remain able to account for the increasing importance of IIoT actors, activities, and resources in business markets. Specifically, we argue that the line drawn in the A-R-A model between actors and resources becomes increasingly permeable because resources acquire agency through artificial intelligence and that these non-human actors may well use human or organizational actors as resources for specific activities. Since its formulation, the A-R-A model has been useful both for purposes of B2B teaching and research (Raskovic 2015; Lowe et al. 2012). However, when its object of study, that is, business networks, undergo major changes, such as caused by the digital transformation, the model must be questioned and, if necessary, adapted to ensure its explanatory power.

This research thus draws on the SoS perspective to identify the need for an evolution of the A-R-A model. It suggests that the relationship between actors and resources - as two main building blocks in the A-R-A model – deserves particular attention.

The paper is structured as follows. First we review how the issue of digital connections between actors and / or ‘things’ has been so far dealt with by the network approach. Second, we introduce the system of systems (SoS) perspective as a new conceptual lens that may allow us to integrate

the diversity of new connections that the IIoT creates in business markets. We illustrate the SoS perspective with an example from smart farming. Finally, we use the SoS lens and the smart farming illustration to discuss how IoT, by creating new types of connections with non-human actors, contributes to revealing new aspects of value creation. We then discuss the possible contributions that a SoS perspective of IIoT may make to the practice and study of business marketing, with a particular focus on the A-R-A model.

## **2. Literature review**

The network perspective assumes that the set of interconnected relationships in which an actor is embedded offers opportunities and constraints for its actions (Brass et al., 2004). While researchers consider ‘interconnectedness’ in business networks important for an organization, they have different views on its characteristics. On the one hand, the industrial network approach emphasizes the evolutionary and embedded features of business networks (Håkansson & Ford, 2002; Hakansson & Snehota, 1995). From this perspective, networks are considered borderless, self-organizing configurations which emerge from the interactions between the different actors therein. There is no single ‘hub firm’ in a network that can provide direction or control (Ritter et al., 2004). Actors in a network can only influence the network, rather than managing it. On the other hand, strategic management scholars maintain that networks are intentionally created to reach specific goals (Paquin & Howard-Grenville, 2013). A focal firm can manage and organize members in a network to reach the goals efficiently (Dhanaraj & Parkhe, 2006). The business network literature explains value creation in networks from both the perspective of ‘industrial networks’ and the ‘strategic management’ perspective.

### *2.1. Connections and value creation in business networks*

#### 2.1.1 Conceptual foundations

Value creation is a core concept for understanding industrial markets. Contemporary marketing literature considers that value creation takes place through interactions and resource integration between actors (Grönroos & Helle, 2010; Gummesson, 2008; Vargo & Lusch, 2008; Möller & Svahn, 2006). For example, the service dominant logic maintains that actors are connected by value propositions and value is created collaboratively through a process of resource integration among actors (Vargo & Lusch, 2008). Similarly, the interaction and network approach acknowledges that actors in a network create value by seeking, contributing and integrating resources through relationships (Hakansson & Snehota, 1995). Other researchers consider a value creation process as a value system in an intentionally created network where a single actor can have more control over the process (Möller & Svahn, 2006; Möller & Svahn, 2009). However, all these perspectives agree that value creation processes involve several actors who constitute a network in which resources are integrated through interactions. Therefore, when interactions and connections between actors change in a network, the value creation processes will also change. Hence, to understand value creation in business networks, it is important to analyse the connections and interactions between actors in these networks.

Researchers following an industrial network approach perspective adopt the Actor–Resource–Activity (A-R-A) model (Hakansson & Johanson, 1992; Hakansson & Snehota, 1995). According to the A-R-A model, actors interact through activities to combine resources to create value, which is the underlying mechanism in value creation within networks. The A-R-A model suggests that a business relationship consists of three layers: activity links, resource ties and actor bonds. Activity links connect organizations through technical, administrative, and commercial links as a relationship develops. In a network, these links form an activities pattern. Resource ties connect various resources in different organizations and can lead to innovation through the combination of these resources. Resource ties form a resource constellation in a network. Actors can be individuals or organizations, which are important for mobilizing

resources and access to information. Actor bonds form a web of actors connecting organizations in a network. An actor bond is perceived as a prerequisite for the activity and resource dimensions to occur. As a network evolves, interactions among actors will lead to changes in the pattern of activities, the constellations of resources and the web of actors. Thus, the A-R-A model captures the connections and dynamics of business networks in value creation. Note, however, that the A-R-A model does not specifically discuss the relationships that may exist between actors and resources, resources and activities, or activities and actors.

The strategic management perspective maintains that a network can be orchestrated by a hub firm (Agrawal & Cockburn, 2003; Burt, 2000; Dhanaraj & Parkhe, 2006; Möller & Rajala, 2007). Network orchestration is a deliberate planning process for assembling and managing organizations in order to reach a common goal (Paquin & Howard-Grenville, 2013; Perks et al., 2017). A strategic network is created intentionally for value creation (Möller and Rajala, 2007). A hub firm in a strategic network orchestrates different organizations with agreed roles in value creation processes (ibid.). The hub firm can configure business relationships in a network through networking activities or mechanisms (ibid.).

Both views are relevant to understanding connections in business networks. Firms will confront both network management situations when a firm is in a controlling position or when different network members can have strong influence over each other (Ritter et al., 2004; Möller & Rajala, 2007). Both network management situations exist.

### 2.1.2 Network connections in a digital context

Since advances in digital technologies have transformed connections in network management (Papert and Pflaum, 2017; Pflaum & Gölzer, 2018), recent research has adopted network perspectives mentioned above to study the impact of digitalization on the interconnectedness of business networks. From the industrial network approach and adopting the A-R-A model,

Makkonen and Vuori (2014) find that IT enables a supplier to contribute to the context or the content of a buyer's value creation process. Through the same theoretical lens, Pagani and Pardo (2017) find that IT-based solutions facilitate the development of new links and new combinations of resources between firms in networks, offering insights into how value is co-created in the digital era. Thus, digital technologies create additional opportunities to develop new relationships or new resource combinations in a network in value creation.

For the network orchestration perspective, the research has largely analysed the impact of digitalization through the emergence of digital platforms (Gawer, 2014; Sawhney, 1998). Digital platforms are technology-enabled structures in which "networked operations could take place" (Eloranta & Turunen, 2016). It has recently been suggested that platforms have become tools for hub firms to orchestrate their networks (Eloranta & Turunen, 2016; Perks et al., 2017; Wei et al., 2019). Also, using the term 'keystone players', other authors (Iansiti & Levien, 2004; Zahra & Nambisan, 2012) emphasize how certain companies - thanks to an "explicit innovation architecture/ platform" - become value dominators (Zahra & Nambisan, 2012, p. 221). This stream of research observes that relationships in a network become more and more loosely coupled due to the modularization of offerings and digitalization of business processes. The decoupled network structure facilitates more frequent resource combination and relationship reconfiguration in value creation. For example, Eloranta and Turunen (2016) propose that digital platforms can help network orchestrators to efficiently form new links, recombine resources and form new capabilities in complex networks. Perks et al. (2017) further propose that a value platform, which includes a technical architecture and a set of organizational norms, rules, and activities, can support network-centric emergence and reconfiguration over time. Wei et al (2019) further focus on the design of a platform, especially platform openness, and investigate how this feature can allow a hub firm to reconfigure its network and resources frequently.

Therefore, whether seen from the industrial network approach or from the network orchestration perspective, digitalization allows relationships in a network to be loosely coupled. In fact, digitalization, by codifying part of the knowledge transferred in relationships, allows for ‘less tight’ (loose) coupled relationships (Valtakoski, 2017; Wei, 2019) which can be efficiently reconfigured, since it allows reduced distribution, transaction, and search costs (Kohtamäki et al., 2019; Pagani, 2013).

## *2.2. The Industrial Internet of Things (IIoT)*

As one of the most recent digital technologies, the Internet of Things (IoT) has further transformed business networks and makes relationships within them more loosely coupled. In a business-to-business (B2B) context, the Industrial Internet of Things (IIoT) is based on communication between machines offering B2B services (Falkenreck & Wagner, 2017 & 2021; Hakanen & Rajala, 2018; Leminen et al., 2018). Machines are equipped with digital logic, sensors, and networking capabilities so that they can sense, associate, communicate and carry out autonomous actions (Leminen et al., 2020). Porter and Heppelmann (2014) argue that ‘relevant entities’ to be considered are now shifting from “discrete products, to product systems consisting of closely related products, to systems of systems that link an array of product systems together” (Porter & Heppelmann, 2014, p. 12). IIoT providers should consider whether they apply an open or a closed system in IIoT (ibid.). Those which apply a closed system approach offer customers the entire smart, connected product system by themselves, while those apply an open system approach allow the customers to connect the platform with components offered by other companies. However, a closed system “is often impractical for systems of systems” (Porter & Heppelmann, 2014, p. 18), since these closed approaches become more difficult as technology becomes diverse, and customers want more choices (ibid.). Therefore, from the systems of systems perspective, an open approach is more applicable and practical in

IoT. In such an open system, the relationships become more loosely coupled, as smart machines are provided by other companies and can be connected or disconnected with the platform. Since these ‘smart’ machines also have different layers including devices, networks, services, and contents (Yoo et al., 2010), the interconnections among these machines form modular product systems, where machines can be reconfigured at different levels of a loosely coupled network (e.g., Porter & Heppelmann, 2014). The IIoT thus represents a “networked interconnection” of objects (Xia et al., 2012, p.1,101).

From the systems of systems perspective, an IIoT system is an open system (Porter & Heppelmann, 2014), which means it allows outside players to participate and create new applications. In such an open system, the ‘networked interconnection’ of objects in IIoT also depends on ‘cross-side network effects’ to become successful. This concept of cross-side network effects originates from the platform literature, which means that more participants on one side attracts more participants on the other side(s) and vice versa (Katz & Shapiro, 1994; Rochet & Tirole, 2006; Gawer & Cusumano, 2014). The value to the participants on one side depends on the number of participants that join the network on another side (Gawer & Cusumano, 2014; Van Alstyne et al., 2016). More participants on one side will attract more participants on another side. Consequently, participants can get more value from the platform since they can have more opportunities to identify suitable exchange partners, and vice versa. Cross-side network effects are also important in IIoT networks. As the number of machine suppliers increases in one category, this will attract more machine suppliers in other categories to join the network as they anticipate more opportunities to connect their machines with other machines. As a result, the increasing number of machines in different categories also attracts more users to join the network since they can have more opportunities to recombine the machines. As such, cross-side network effects help form an emergent and dynamic network in IIoT.

IIoT, however, not only encompasses communication between devices (machine to machine) but also communication between human actors and machines (Fleisch et al.; 2009; Li & Li, 2017). For example, the literature on cyber-physical systems (CPS) - which focuses on the integration of computation and physical processes (Lee, 2008) - also largely discusses ‘humans-in-the-loop’, that is, the integration of human actors in automated CPS processes leading to situations of interconnectedness between human actors and CPS (Cranor, 2008; Herterich et al., 2015). A human-in-the-loop CPS typically consists of a loop involving a human, an embedded system (the cyber component), and the physical environment. Humans’ roles in the loop can be manifold. For example, they can perform security-critical functions (e.g., monitoring or taking decisions), or trigger automated processes that are launched through brain sensors, or augment the neurophysiological capabilities of a functionally locked-in individual (Schirner et al., 2013). Cranor (2008) distinguishes three dimensions of interactions between humans and cyber-physical systems, that is, communication, capabilities, and behaviour of humans in relation to CPS. The IIoT helps support CPS and link several CPS as well as humans or organizations among them, thus establishing a complex configuration of interconnectedness (Emmanouilidis, 2019; Nunes, Zhang, & Silva, 2015).

Against this background, the IIoT can be defined as an intelligent infrastructure aided with computer networks linking objects, information, and people (Ardito et al., 2018; Li & Li, 2017; Suppatvech et al., 2019). At the same time, some researchers observe that “it is only recently that the importance of people as an integral component of the overall IIoT infrastructure has started to be fully recognized” (Petrov et al., 2018, p.1) and others stress that “the human operator represents one of the most vulnerable in the IIoT system, one who can easily be overlooked” (Nuamah & Seong, 2017, p.5). Among the human-in-the-loop issues that the scholars identify in systems of systems and in particular IIoT systems, there are tasks such as information visualization and concepts such as cognition and trust. At the same time, while

early contributions to the literature saw the human elements as potential sources of failure (e.g., Cranor, 2008) or as a weak sub-system that would be augmented through CPS (Schirner et al., 2013), technology is evolving toward social computing, intention- and mission-aware services, location- and context-aware services, and people-oriented IIoT platforms (Petrov et al., 2018) where the role of humans is seen in a more equal light.

### *2.3. A System-of-Systems approach*

#### 2.3.1. Towards an integrative perspective on human and technological networks

While the two types of networks described earlier, that is, business networks and the IIoT, have received much attention in different streams of literature, they are often discussed separately; business networks receive much attention, for example, in marketing, supply chain management, and purchasing, whereas the IIoT and related phenomena is often discussed by authors in the fields of IT, information systems, supply chain management, production, and data science. In this article, we aim to propose a view that allows an integrated perspective on these forms of networks as they become increasingly intertwined.

For this purpose, we suggest drawing on the system-of-systems (SoS) concept. several authors have already argued that “IoT presents several characteristics of SoS” (Alkhabbas, Spalazzese & Davidsson, 2016; Aziz, Musharaf & Sayyed, 2021; Lukkien, 2016). They, for instance argue: ‘SoS and IoT have many common properties’ (Aziz et al., 2021, p. 231).; or: ‘IoT systems follow SoS paradigms and face similar challenges’ (Lukkien, 2016, p. 56). Thus, ‘It is clear that IoT and SoS share some major characteristics’ and that ‘the Internet of Things can be regarded as a System of IoT-based systems’ (Alkhabbas et al., 2016, p. 35).

SoS are broadly defined as “assemblages of components that are themselves significantly complex, enough so that they may be regarded as systems and that are assembled into a larger system” (Maier, 1998, p.269). Essentially, a SoS is a system consisting of different subsystems

(or components) which maintain some independence before and after being part of a SoS (Boardman & Sauser, 2006). We acknowledge that other perspectives might be fruitfully applied as well. For example, the literature on viable systems – encompassing the viable systems model (VSM) and the viable systems approach (VSA) – is also concerned with the interplay between different subsystems including organizations, individuals, and technology (Barile et al., 2012; Beer, 1984; Cardoso-Castro, 2019; Saviano & Caputo, 2017). Certain researchers see the VSM specifically as a model for studying the complexity of organizations relying heavily on information systems (e.g., Richter & Basten, 2014; Mugurusi & de Boer, 2014) or broader, but still well delimited groups of firms, such as in an ‘industry’ (e.g., Devine, 2005).

This stream of literature builds on the key concepts of Beer’s VSM in order to develop a coherent framework for investigating the way viable systems survive in their environments by interacting with other systems entities (Barile et al., 2013; Saviano & Caputo, 2013); that is, the ways a system perceives, interprets, and reacts to environmental changes in order to become even more effective (Barile et al., 2011; Barile et al., 2013; Saviano et al., 2014).

The VSM refers to systems that comprise five sub-systems (operational units, coordination, collective subsystems, relationships with the environment, normative management) which are required to co-exist and function jointly for the system to perform, whether the system is one company or a group of companies in a market (Schwaninger, 2006). Hence, the VSM perspective is very concrete and relies on clearly specified components and characteristics of coordination, whereas the SoS perspective is more open and does not specify general perspectives that are always present in a SoS or in a system. Moreover, the VSM includes a discussion of ‘the environment’ and how it can lead the system to failure. For our purposes, we prefer to build on the SoS perspective because it is less specific in its assumptions and

conceptualizations, which allows for a broader and more flexible perspective on real world phenomena that do not correspond to the notions of ‘organization’ or ‘market’. Moreover, the VSM/VSA perspective use the notion of ‘environment’ in a manner that seems to draw a line between an organization (or a market) and the outside. The SoS doesn’t draw such a distinction that may require a decision as to whether an object of analysis is inside or outside of the focal entity one is studying. Hence, while we acknowledge the usefulness of the VSM/VSA perspectives, the remainder of our research is based on the SoS perspective.

### 2.3.2. The SoS perspective on business networks and the IIoT

The SoS concept has been used in different sectors including manufacturing, defence, energy, and air traffic control (Cadavid et al., 2020; Karcianas & Livada, 2020). What makes the SoS concept particularly interesting for our purposes is the attention paid to *interactions* between the different subsystems and the consequences of these interactions (Abdoli et al., 2019). Interactions being the basis of value creation, considering digitized business networks as SoS has the potential to reveal new forms of value creation because SoS emphasizes certain specificities of these interactions. Interactions in a SoS are shaped by specific properties of the SoS.

Boardman and Sauser (2006) identify five differentiating characteristics of a SoS: autonomy, belonging, connectivity, diversity, and emergence. Indeed, constituent systems need to remain *autonomous* to achieve the general goals of the SoS. Since they are autonomous and have their own purposes, they can also choose to which SoS they *belong* to fulfil their goals and the general goals of a SoS. Since constituent systems can make autonomous decisions about which SoS to be part of, this can lead to numerous possibilities of *connections* which are not predesigned by the system designers. With different functionalities from different constituent systems, the SoS can have *diverse* capabilities and functionalities. These capabilities are not

static but continuously *emergent* due to other factors: constituent systems' autonomy, their choice to belong, resultant numerous connections, and their diverse functionalities. In comparison, a system (in its more classical definition) has predefined functions and consists of components with limited autonomy and independence. Therefore, these characteristics differentiate a SoS from a 'classical' system.

Viewing an IIoT business network as a SoS can lead us to think about the potential challenges in network management and the approaches to managing these challenges. Indeed, the five main characteristics of a SoS lead to specific network management challenges in terms of objectives, control, and uncertainty (Choi, 2018). For instance, since different constituent systems have their own objectives, it is only possible to reach an optimized (i.e., good enough) general goal. In addition, a SoS does not have a centralized control, which makes it harder to reach a general goal. The large scope of a SoS also exposes itself to many external uncertainties. Its dynamic structure prompts to think carefully about which system to include into a SoS.

Regarding the management of these challenges, research has mainly focused on the design principles of the architecture, which includes stable intermediate forms, policy triage, and leverage at the interfaces, thus ensuring collaboration (Maier, 1998). Following this perspective, some studies applying SoS thinking in the IIoT context emphasize the design of technical architecture (e.g., Nikolopoulos et al., 2019). Other studies maintain that both technical architecture and coordination among stakeholders are important (e.g., Wolfert et al., 2017). However, the literature has not yet provided a convincing understanding of the new types of interactions (for instance between machines) allowed by an IIoT nor how the characteristics of an IIoT - when seen as SoS - impact the value creation process (as a matter of resource combination).

#### 2.4. Summary

In an industrial SoS, interactions take place at different levels (Leminen et al., 2020; Yoo et al., 2010): between machines, between organizations, between humans, and between humans and machines. The network management situations are continuously changing. We argue that neither the industrial network approach nor the network orchestration view can sufficiently explain the dynamics of industrial SoS since they do not allow us to capture the specificity of new actors implied (machines) and new types of phenomena generated (autonomy / connectivity / diversity / emergence). Therefore, there is a pressing need for a new theoretical lens to understand these network dynamics triggered by IIoT technologies. It follows that SoS thinking is proposed as a more sufficient theoretical lens to understand the IIoT phenomenon, since it emphasizes the features of constituent systems and the networks' dynamic connectivity. Note that, in this article, we focus on the role of SoS in a specific context, that is, in industrial markets. We do not aim to study SoS in all possible fields of application, but in the environment of exchanges between professional actors in business-to-business transactions between companies and the individuals representing these companies. Therefore, we refer to industrial SoS. By doing so, we wish to signal clearly that the empirical setting in which our case illustration is set, as well as the conclusions we draw, are formulated for exchanges in industrial markets. This means that we do not see industrial SoS as a concept that is distinct from the general SoS concept, but rather as a specific environment in which SoS today play an important role and that deserves specific attention, because, for example, the emergence of industrial SoS may require a new perspective on established models.

### **3. Illustration: The John Deere Smart Farming System**

Though our paper is a conceptual one (Jaakkola, 2020), we propose an illustration to further substantiate the key role that SoS could play in giving an account of an IIoT. We describe one case illustration, based on secondary data.

Our data includes product descriptions, customer cases, videos, white papers, catalogues, popular press, financial newspapers, blogs, and online forums. This secondary data collection was conducted in such manner as to capture the main building blocks of what an IoT represents in a context. While we admit that this data may be incomplete, we must keep in mind that it does not pretend to the status of a qualitative case study, but rather aims to illustrate certain aspects of our conceptualization of IIoT as a SoS. For Siggelkow (2007) “a concrete example” may help to imagine “how the conceptual argument might actually be applied to one or more empirical settings” (Siggelkow, 2007, p.22).

The use of secondary data has already been discussed by different authors (Calantone, & Vickery, 2009; Ellram & Tate, 2016; Rabinovich & Cheon, 2011). Johnston (2017) emphasizes its utility in research areas, ‘such as information and technology that are constantly changing, utilizing existing data allows projects to be completed and findings to be produced much faster,’ (Johnston, 2017, p. 624). In the marketing and management field, various authors have already used secondary data. Finch and Geiger (2011) rely on “secondary and archival” data as well as “newspaper and journal articles” to illustrate their work on ‘market objects’ (Finch & Geiger, p. 902). Nambisan and Sahwney (2011), illustrate their work on orchestration processes with different examples of “innovation projects led by companies such as IBM, Boeing, Microsoft, Henkel, and Salesforce.com” (Nambisan and Sahwney, 2011, p.40). Gupta et al. (2009) use several case illustrations for their work on knowledge-based core competencies. And the recent work by Hartman et al. (2018) takes the early sales strategy of Salesforce.com as an example to illustrate their ‘new theory of selling’.

To illustrate the relevance of a SoS view of IIoT, the John Deere Smart Farming System is taken as an illustration. By using a company case as an illustration, we remain consistent with the position of Eisenhardt and Graebner (2007), who state that “cases are selected because they

are particularly suitable for illuminating and extending relationships and logic among constructs” (Eisenhardt & Graebner, 2007, p.27).

John Deere promotes a smart farming system (IIoT applied to farming) under the label ‘Precision Ag Technology’. We use the acronym JDSFS throughout this article to refer to the John Deere Smart Farming System.

Smart farming has often been used as a context for exploring the impacts of digital technologies and the IIoT phenomenon in particular (for a recent review of IIoT solutions for smart farming, see for instance Navarro et al., 2020). In the B2B marketing field, Jayashankar et al. (2018) and Jayashankar et al. (2020) have recently explored smart farming as a “unique combination” of physical resources (land, machinery, and raw materials) and “skills, knowledge and competencies” (Jayashankar et al., 2018, p.811). However, in these works the authors focus on the shift from agricultural goods to ‘operant resources’ and thus pay less attention to how things, once become ‘smart things’, were creating new connections with other things, or human actors, and were potentially creating new types of value creation.

John Deere agricultural equipment includes tractors, combine harvesters, cotton harvesters, planters/seeders, silage machines, sprayers, and so on. John Deere uses technology to connect machines and people. Technology allows the company to go beyond providing automated guidance of vehicles. Data is collected quickly and easily for analysis and decision making by farmers or for sharing with other partners. According to Leminen et al. (2020), John Deere has developed and taken in use a completely new radical business model architecture and new systemic and connected M2M-enabled business model modules. It has created a new multi-layered platform architecture where actors from several other industry sectors can bring and develop their own services for the buyers, enabling JohnDeere and its partners to innovate new

smart and connected business model modules that make the best use on the novel business model architecture (Leminen et al., 2020, p.306).

As Porter and Heppelman (2014) put it, John Deere provides an integrated farm management system through data. Data collected, for instance, by a sensor from a planter or a sprayer will feed a data server located in the cab, and every five seconds, the data will be pushed to the cloud. Data is then centralized on an online portal (the Operations Center) where it can be used, processed, and shared. Conversely, it is possible to send planting instructions to a planter directly, and the machine will change its seed planting accordingly. In such cases the planting can be considered highly automated<sup>2</sup>. Yet, though the vehicle's autonomy is already present in farming through automated guidance (more than 70% of farms over 1,000 acres use it), the immediate focus for many of agriculture's major manufacturers is not full autonomy. Andrew Rekow (manager of autonomous solutions at John Deere) states: "As long as the sprayer is spraying, and as long as our wheel speed is correct, we know we're applying, we're doing the job correctly", but he adds, "With a job like tillage, where you have to look behind you and make sure the job is getting done right, that's going to take a little more to automate the task"<sup>3</sup>. Whilst full autonomy is not the goal, John Deere is, however, continually improving sensors on its vehicles. At the 2019 Agritechnica machinery show in Hanover, Germany, the company presented a sensor package including three sets of cameras providing 3-D images, and LIDAR (light detection and ranging), which emits infrared pulses and detects the reflection to see ahead. For Andrew Rekow, this package, along with the AutoTrac system and artificial intelligence, "can create a picture of a tractor and the world around it and drive that machine to finish a task"

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<sup>2</sup> John Deere and the Birth of Modern Precision Agriculture <https://precisionagriculture.re/john-deere-and-the-birth-of-modern-precision-agriculture/>

<sup>3</sup> The future of autonomous tractors is clouded, but John Deere has a few ideas. <https://www.dtnpf.com/agriculture/web/ag/news/article/2020/01/07/future-autonomous-tractors-clouded>

In the following table, we use the JDSFS to illustrate the different building blocks of an IIoT system. These building blocks are common to different existing descriptions of IIoT provided by different scholars (Cila et al., 2017; Langley et al., 2021; Nguyen & Simkin, 2017; Woodside & Sood, 2017). An IIoT is made of the following: *things* (they are ordinary things that could be used with no computing or information processing capacities; see Keskin & Tan Erciyes, 2019); *hardware* (they enable the ‘things’ to use the internet for communication and are integrated circuits, SIM cards, sensors, and so on, which “allow everyday objects to collect data and transmit it to the platform”, Keskin & Tan Erciyes, 2019, p.1,619); a *platform* (that “collects the data from the ‘things’, uses logic and intelligence to make a decision, and communicates it back to the ‘things’ using the hardware and internet”, Keskin & Tan Erciyes, 2019, p.1,619); and the *internet*.

Using the data collected, we also illustrate the different types of connections that exist in an IIoT, whether between human actors (individuals & organisations) or between human actors and machines, or between machines.

**Table 1: The John Deere case: JDSFS as an IIoT**

<b>Data automatically captured by sensors and cameras (<i>hardware</i>) installed on vehicles or natural systems (<i>things</i>)</b>
<ul style="list-style-type: none"> <li>• At the 2020 CES in Las Vegas, John Deere presented the future R4038 self-propelled sprayer. The sprayer is informed by more than 400 sensors</li> <li>• Sensors equip row units (which put the seed in the ground). They measure the pressure being exerted on each seed as it’s planted. Based on the readings, managers can adjust the pressure and the spacing. That way the seeds are set at the optimal depth and distance apart for successful growth<sup>4</sup></li> <li>• Wheel sensors and ultra-sonic sensors are also used on sprayers to control boom height, more uniform spray coverage and put less wear and tear on the boom</li> <li>• Sensors are used for vehicle cab levelling, general motion sensing, load weigh calibration, and other tasks</li> <li>• Sensors can monitor temperature, humidity, wind speed and direction; they can also measure rain and leaf wetness</li> <li>• Sensors on slurry applicators allow precise application of liquid organic fertilizer based on target and limit rate. This eliminates over fertilization (causing laid crops) and under fertilization (causing low yields)</li> <li>• Sensors installed on SPFH (self-propelled forage harvesters) allow automated length of cut adjustment based on the dry matter content, enabling better silage packing and quality</li> <li>• Automatic calibration is provided with ActiveYield™, a sensor that ‘senses’ the weight of the grain in the tank as it fills and continually calibrates the yield system<sup>5</sup></li> <li>• Cameras are used for forage harvesters to control the rotation and flap position of the spout</li> <li>• Cameras mounted on combine harvesters can monitor video images of grains as they are taken up the combine’s elevator and into the tank</li> </ul>

<sup>4</sup> Tim Greene, “John Deere is plowing IoT into its farm equipment” <https://www.networkworld.com/article/3071340/john-deere-is-plowing-iot-into-its-farm-equipment.html>

<sup>5</sup> Precision Ag, <https://www.deere.com/en/technology-products/precision-ag-technology/?panel=harvest>

<ul style="list-style-type: none"> <li>Cameras monitor the detritus from the harvesting operation – stalks, leaves, and cobs – as they are ejected from the rear of the harvester to become fertilizer for the fields. These cameras check that no grains are being ejected – with the aim of ensuring zero wastage</li> <li>High-resolution cameras are used to see early-season maize or grain (at least 10 cm high)</li> <li>High-resolution cameras can work at night and allow vehicle wheels to be kept in the centre between rows to reduce yield-robbing crop damage</li> <li>Smart cameras powered by computer vision can distinguish between healthy and unhealthy crops as machinery passes through the field. This system allows targeted bursts of chemicals to be directed precisely where they are needed at individual plants – hence the 80 to 90% reduction in herbicide use touted above</li> </ul>				
<b>A platform</b>				
<ul style="list-style-type: none"> <li>The Operations Center is an open platform that enables producers to connect with software tools and partners like retailers, input providers, software companies, and equipment dealers</li> <li>It provides access to the field and machine information and allows, for instance, to send the right people to the right place to do the right job, and ensure they have the tools and fuel they need. The Operations Center can be considered the Air Traffic Control for farm operations. All data can be shared with trusted partners via the web from any computer or device</li> <li>The John Deere Operations Center<sup>6</sup> is an online farm management system that enables access to farm information anytime, anywhere. It is a cloud-based system. This centralized online portal allows one to access, view, archive, manage, and share all operation information</li> <li>The Center provides the interfaces for any third-party software or service provider to connect their software solution</li> <li>The Operation Center can receive a prescription from an agronomic and forward it to the respective machine in the field wirelessly</li> </ul>				
<b>New connections allowed by IoT technology</b>				
Connections between machines and dealers	<p><b>Dealers</b> can use JDLink to retrieve diagnostic trouble codes and maintenance data to identify problems or maintenance needs before the technician leaves the dealership.</p> <p><b>Dealers</b> can use JDLink to make sure the equipment is running at peak performance. JDLink™ gives the <b>dealers</b> (with the farm manager’s permission) the ability to view an operator’s screen remotely. Operator training, implement setup or trouble shooting a problem can then be accomplished without waiting on a service call while in the field.</p>			
Connections between machines and farm managers	<p>JDLink™<sup>7</sup> is a telematics system that <b>connects</b> all machines in the field with the <b>farm manager’s</b> office and mobile devices.</p> <p>JDLink™ allows <b>farm managers</b> to access machine data, to track actual machine location and location history, and manage maintenance plans and alerts, etc.</p> <p>Farm managers have access to machine information which allows, for instance, to send the right people to the right place to do the right job, and ensure they have the tools and fuel they need. JDLink™ gives the <b>farm manager</b> the ability to view an operator’s screen remotely.</p>			
Connections between different equipment manufacturers	<p>Data Connect<sup>8</sup> is the partnership with other agricultural equipment manufacturers to allow the sharing of machine and agronomic data on the John Deere Operations Center. For instance, DataConnect allows for a connection with the Claas Telematics and 365Farmnet<sup>9</sup> (a farm management system). DataConnect is also open to other manufacturers and it is hoped it will become an industry solution for data exchange in the same way ISOBUS has become a common standard for tractor-implement connectivity<sup>10</sup>. A growing number of third-party companies like Agricon, Pessl, Farmfacts and Airbus have already established interfaces for accessing their services via the Operations Center.</p>			
Connections between different human actors	<p>The Operations Center is an open platform that enables <b>producers</b> to connect with software tools and partners like <b>retailers, input providers, software companies, and equipment dealers</b>.</p>			
Connections between machines	<p>Multiple combines and grain carts can be coordinated in the same field. The Machine Sync<sup>11</sup> solution can create a network between a <b>fleet of tractors and combines</b>.</p> <p>The Machine Sync<sup>12</sup> solution can coordinate <b>tractors and combines</b>.</p>			
Connections between	‘Natural’ systems	Weather forecast systems	Expert systems	Satellite systems

<sup>6</sup> John Deere Operations Center <https://www.deere.com/en/technology-products/precision-ag-technology/data-management/operations-center/>

<sup>7</sup> JDLink™, <https://www.deere.com/en/technology-products/precision-ag-technology/data-management/jdlink/>

<sup>8</sup> John Deere, CLAAS, CNH Industrial and 365FarmNet form DataConnect. Interface is first direct, cloud-to-cloud machine data solution for North American ag industry, <https://www.deere.com/en/our-company/news-and-announcements/news-releases/2019/agriculture/2019nov05-dataconnect/>

<sup>9</sup> FarmNet, the software that ploughs, <https://www.365farmnet.com/en/>

<sup>10</sup> John Deere, CLAAS, CNH Industrial and 365FarmNet form DataConnect <https://www.deere.com>

<sup>11</sup> Machine Sync, <https://www.deere.com/en/technology-products/precision-ag-technology/guidance/machine-sync/>

<sup>12</sup> Machine Sync, <https://www.deere.com/en/technology-products/precision-ag-technology/guidance/machine-sync/>

machines, humans, and other systems	John Deere provides sensors to be directly installed in the fields. They can instantly see if the soil moisture levels are balanced and decide what measures need to be taken, for instance, starting an irrigation system. The crew can be advised and take adapted decisions. The John Deere Operations Center provides access to the field information and allows, for instance, the right people to be sent to the right place to do the right job.	The John Deere Mobile Weather service uses a third-party weather sensor that allows temperature, wind speed, wind direction, and relative humidity to be monitored to understand the weather conditions quickly and easily. Based on weather conditions, they decide whether to proceed with product application.	The Operation Center can receive a prescription from an agronomic and forward it to the respective machine in the field wirelessly.	During field preparation, farmers can use satellite guidance. Harvest can also be satellite guided. Data from row sensors used on several John Deere vehicles are combined with satellite position data from the StarFire Receiver. The future R4038 self-propelled sprayer has a geospatial connectivity.
<b>Machines working autonomously</b>				
<p>“There are different kinds of precision tractors some which will require a driver while others will not. However, both are highly automated machines which run by themselves using geographical positioning system technology and some other modems in the cabs. The driver on board would be engaged only a few times”</p> <ul style="list-style-type: none"> <li>• <b>Automatic</b> guidance of the vehicles is allowed by the combination of data from row sensors used on several John Deere vehicles combined with satellite position data from the StarFire Receiver</li> <li>• Machine Sync<sup>13</sup> <b>automates</b> unloading on-the-go between tractors and combines</li> <li>• AutoTrac™ Turn Automation<sup>3</sup> <b>automatically</b> guides the tractor through the optimum pass and carries out end-of-row functions at appropriate times during the sequence<sup>14</sup></li> <li>• <b>Automatic</b> calibrations are provided with ActiveYield™ that ‘senses’ the weight of the grain in the tank as it fills and continually calibrates the yield system</li> <li>• Trailers are <b>automatically</b> filled to maximum capacity</li> <li>• Spouts for forage harvester are <b>automatically</b> controlled in their rotation and flap position</li> </ul>				

#### 4. Case discussion

The John Deere case allows to illustrate how the IIoT - which is transforming farming in ‘smart farming’ - changes the connections between actors and consequently how some resources are newly combined. Hereafter we first discuss how different characteristics of the JDFSFS can be compared to the characteristics of a SoS. The SoS lens make us attentive to such aspects as autonomy, belonging, connectivity, diversity, and emergence. These five dimensions help us identify how connections are impacted in JDFSFS: new connections appear, other are modified. If connections are modified, potentially new resources combinations can occur, thus new possibilities for value-creation. This is what we illustrate in the third section of this part.

<sup>13</sup> Machine Syn, <https://www.deere.com/en/technology-products/precision-ag-technology/guidance/machine-sync/>

<sup>14</sup> John Deere, AutoTrac™ <https://www.deere.com/en/technology-products/precision-ag-technology/guidance/auto-trac/>

#### 4.1. JDSFS as a SoS (See Table 2)

In the JDSFS network, a smart device has its own functionalities and own goals. With its sensors and actuators, it can sense its environment and react to it based on its autonomous decisions (e.g., Porter and Heppelmann, 2014; Wolfert et al., 2017). For instance, a self-propelled forage harvester with high-resolution cameras can aim at the crop from the best position to execute a desired fill strategy. It can also be connected and communicate with different devices or systems through network infrastructures to fulfil the goals of these bigger systems (e.g., Porter and Heppelmann, 2014; Wolfert et al., 2017). The numerous connections are not predesigned but based on the effectiveness of being able to fulfil its own goals and the general goals of the bigger systems. For example, based on weather data and field data, a farmer can choose to connect different machines to optimize the planning process through the farming system (the Operations Center). This smart farming system is connected to internal or external smart devices or applications simultaneously, and connections may keep changing and take place within different layers, for example, network connections between two machines, or data exchange between two applications in the Operations Centre. The JDSFS therefore displays the characteristics of a SoS. In the table below, we show how different aspects of JDSFS can be compared to the five different characteristics of a SoS.

**Table 2: The JDSFS as a System of Systems (SoS)**

Aspects of JDSFS case to be compared to the 5 characteristics of a SoS		
<p>In the network of combines &amp; tractors that JDSFS creates, each vehicle has its own tasks and can work autonomously.</p> <p>The same goes for the different systems (natural, experts, satellite, weather forecasts, etc.). These systems have their own functioning and management.</p>	<p><b>Can be compared to</b></p>	<p><u>SoS characteristic #1: <i>Autonomy</i></u> (Bourne et al., 2018, p. 10)</p> <p><i>Autonomy</i> is the ability of the constituent parts of a SoS to “set and pursue its own goals without external control” (Bourne et al., 2018, p. 10). The constituent parts of a SoS “are managerially and operationally independent” (Bourne et al., 2018, p. 10).</p> <p>“The ability of the overall SoS to attain its purpose depends on the constituent parts maintaining their full functionality and the freedom to learn and adapt” (Bourne et al., 2018, p. 10).</p>

		-> <i>Subsystems in a SoS are autonomous, which means they can achieve tasks without the 'help' of the other subsystems. They can go on learning without the intervention of other systems.</i>
In the JDSFS, a tractor CAN combine with other tractors (but is not obliged to). When connected through JDSFS, combines & tractors can achieve another task, which is their speed coordination, and it is particularly helpful to upload on-the-go between tractors and combines in an efficient way. Claas, Agricon, Pessler, Farmfacts CHOOSE to join Data Connect <sup>15</sup> and establish interfaces for accessing their services via the Operations Center.	<b>Can be compared to</b>	<u>SoS characteristic #2: <i>belonging</i></u> (Bourne et al., 2018, p. 10)  "The constituent parts of a SoS are fully functional systems" (Bourne et al., 2018, p. 10). The constituent parts of a SoS can join different SoSs or they can operate on their own. Systems choose freely to associate themselves with a large SoS (Sausser, Boardman, and Verma, 2010).  -> <i>There is a relationship of "belonging" between the subsystems and the SoS which means that subsystems 'join' the SoS but can work without belonging to the SoS.</i>
A tractor can be connected to a self-propelled forage harvester to harvest crops. It can also be disconnected from this self-propelled forage harvester to be connected to another tractor for coordinated seed sowing.	<b>Can be compared to</b>	<u>SoS characteristic #3: <i>Connectivity</i></u> (Bourne et al., 2018)  <i>Connectivity</i> describes the relationships between the constituent parts of the SoS. These relationships cannot be designed in advance (Sausser, Boardman, and Verma, 2010): they are "dynamically formed (Baldwin, Boardman, and Sausser, 2013) and the connections between the parts of a SoS can be described as network-centric (Gorod et al., 2008) and loosely coupled" (Bourne et al., 2018, p. 10).  -> <i>The nature of the relationship between the subsystems and the SoS is one of "connectivity", which means that subsystems could connect (but also disconnect). One consequence is that the relationships in the SoS cannot be defined.</i>
In the JDSFS, a variety of humans, organizations and things can be connected or disconnected: farm managers, drivers, agricultural engineers, meteorologists, retailers, input suppliers, software companies, equipment dealers, tractors, combine harvesters, forage harvesters, soils, satellites, etc. Some are in the same field (two tractors) or hundreds of kilometres away (a tractor and a satellite). If one machine is failing (such as a soil sensor) it can easily be replaced by another machine. As such, the failure does not automatically block the whole smart farming system.	<b>Can be compared to</b>	<u>SoS characteristic #4: <i>Diversity</i></u> (Bourne et al., 2018, p. 11)  <i>Diversity</i> is about the "heterogeneity of constituent parts within a SoS" (Bourne et al., 2018, p. 11). It is a 'necessary condition for making the overall SoS resilient' (Bourne et al., 2018, p. 11).  -> <i>Subsystems are diverse. It is an important characteristic because it makes the SoS into a resilient system.</i>
In the JDSFS, due to the geographic distance between certain things and connected actors, identifying the factor causing a vehicle to be taken out of service can be very complicated. In the JDSFS, the openness of the platform allows new solutions and additional services, but the consequences in terms of	<b>Can be compared to</b>	<u>Characteristic #5: <i>Emergence</i></u> (Bourne et al., 2018)  <i>Emergence</i> , means that the SoS "produces properties and functions that cannot be traced back causally to its constituent parts" (Bourne et al., 2018, p. 11). "Such properties and functions are qualitatively novel, and their characteristics cannot be explained solely by the nature of the parts that generated them" (Bourne et al., 2018, p. 11).  -> <i>SoSs are "emerging" systems, meaning that their characteristics cannot be anticipated from the properties of the</i>

<sup>15</sup> John Deere, CLAAS, CNH Industrial and 365FarmNet form DataConnect. Interface is the first direct, cloud-to-cloud machine data solution for North American ag industry, <https://www.deere.com/en/our-company/news-and-announcements/news-releases/2019/agriculture/2019nov05-dataconnect/>

empowerment of different actors cannot be anticipated. 16	<i>different sub-systems. Their properties are always 'new' properties.</i>
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#### 4.2. With IIoT, connections are modified in the farming system

As machines in the IIoT have a different status (they are ‘smart’ machines, Pardo et al., 2020), new connections appear between machines and between machines and human actors.

In the JDSFS, *connections exist at all levels*. First, connections exist *between machines*. For example, at the device level, a smart tractor in John Deere has an operations system called AutoTrac™ Turn Automation<sup>1</sup> that automatically guides the tractor. At the network level, the JDLink™<sup>1</sup> is a telematics system that connects all machines in the field with the office and mobile devices. *Machines also connect with humans* in the JDSFS. At the service level, in the John Deere Operations Center<sup>2</sup>, an online farm management system, farmers can access, view, archive, manage, and share all operational information. At the content level, farmers can view the data gathered from the machines and weather sensors to plan and automate activities during the crop cycle. *Organizations also connect with organizations* in the JDSFS. For example, the John Deere Operations Center is also connected with other third-party sensors for capturing weather data or other third-party applications. Different applications can be developed and installed in the Operations Center to manage different tasks.

Not only are connections of different types in HDFS, but the machines and humans inside can *connect and disconnect*. Consequently, their position in the network (seen as the set of relationships an organization, machine or human has with other organizations, machines, and humans<sup>17</sup>) is changing. A machine can change its position due to network reconfiguration in the JDSFS. For example, a tractor can work with a self-propelled forage harvester to harvest

<sup>16</sup> For additional examples of perceived risks associated with a misuse of data collected in the agricultural sector, see Jayashankar et al. (2018), who identify “a risk of misuse of data for commodity market speculation and sale of data to third parties” (p.805)

<sup>17</sup> We refer here to a definition of position as it is commonly admitted in the markets-as-networks approach. See, for instance, Johanson & Mattsson (1992), Mattsson (1985), and Seyed-Mohamed & Bolte (1992). These scholars conceptualize an actor’s position. Here, we expand the concept to machines, and propose also to consider the position of machines within networks.

crops, but it can also work with another tractor to plant seeds. An actor (e.g., a farmer) can leverage IIoT technologies to strengthen a current network position or to change it to an undefined position in this network. Certain connections can be reinforced, resulting in the reinforcement of a position. For example, with JD Operations Center, a farmer can be connected to all the machines in the fields to perform farming tasks. In that case, the JD Operations Center strengthens a farm's network position since it supports resource reconfiguration and network orchestration processes.

In the JDSFS, *new connections* can also be created. For example, the JDSFS allows farmers to use its Operations Center to develop new connections at different levels with different machines developed by third-party companies, such as a weather station. In that case, the JDSFS connects farmers and their farms to a broader network. New connections can also be created between machines, for example, a John Deere tractor can autonomously carry out planting activities at appropriate times. It can also connect to other farming machines, such as harvesters. The interconnections among them will be changing and reconfigured based on a farmer's plan. Although these reconfigurations are constrained by John Deere's Operations Centre or the 'integrativeness' of third-party machines, they may be also constrained by the farmer's or the operator's capabilities.

Therefore, in the JDSFS, due to new connections between machines and machines and human actors, new and constantly changing types of interactions take place at different levels, between machines, between organizations or between human actors and machines. This dynamic connectivity that IIoT offers influences how actors can combine their resources for value creation.

#### *4.3. Changes in how resources can be combined*

As it creates or modifies connections between actors and machines, the IIoT in the farming system allows for new resource combinations, thus opening new value-creation opportunities. (see Table 2).

In the JDSFS, each one of the vehicles that are assembled for the general goal of ‘smart farming’ *can fulfil its own purpose*. For instance, ‘disconnected’ from a John Deere combine, a John Deere grain cart can still operate as a grain cart and so can the combine. Yet, connected, they build an ‘SoS’, allowing a ‘super goal’, in this case, speed coordination, to be achieved. Resources can then combine and recombine easily in so far as the operational independence of systems allow each of them to operate and fulfil their objectives on their own.

In the JDSFS, vehicles can be geographically dispersed in a field and yet be connected to each other. Dispersion is even more important when considering components such as weather forecast systems (potentially measuring a weather phenomenon occurring at the other side of the country but with a possible impact on the farm). The *diversity* and dispersion of resources that can be combined make for an almost infinite number of possibilities.

In addition, in the JDSFS, when the John Deere Operations Center uses a satellite for satellite guided harvest, neither of these two systems (the John Deere Operations Center or the satellite) control the system thus created. In fact, both systems (the farm and the satellite) are *independently managed*. The farm is managed by the farmer and the satellite is managed by a specific authority. This means that not only are the resources that are combined diverse and dispersed, but they sometimes belong to totally different worlds.

The JDSFS could also comprise of ‘just’ a tractor + a telematics system + a mobile or office device. Yet, it can evolve according to the different new components joining it. For instance, the farmer may add field-sensors (Field Connect™) to the system; or install a StarFire™ receiver and connect with the StarFire satellite network; or use DataConnect for connection with vehicles of another brand. This means that resource combinations can have *‘intermediary*

*stable stages*' (Maier, 1998) and at any of these stages (for instance, just a tractor and a telematics system *or* a more complex set of different vehicles, field sensors, weather forecast systems, etc.) the resource combination works and creates value.

Finally, in the JDSFS, the wealth of data being exchanged creates value for the farmer or the dealer or any other component of it. But, as in any platform, that wealth depends on how many components will be included and this cannot be fully anticipated. For instance, tomorrow, the JDSFS could include the managing systems of many different brands (e.g., Claas) which would benefit both the farmer (who could then manage different brands of vehicles) or a consulting partner (who has a more complete view of how the farm works). But *emergence* also opens the door to detrimental behaviours. For instance, recently, Sébastien Windsor, president of the French Chambers of Agriculture, pointed to a specific risk, stating:

When John Deere retrieves data from the use of its connected combine, he can analyse it to assess operating performance. Nothing prevents JD from reselling this information to traders who can anticipate purchases and sales according to the progress of the harvest. Ultimately, it is the farmer who undergoes the price variation.<sup>18</sup>

These means that what results from resource combination cannot be totally anticipated. It is to be considered *emergent*, i.e., 'expected or unexpected', and potentially 'beneficial or detrimental' (Hachem et al., 2020; Kopetz et al., 2015).

## **5. Discussion and implications for business markets**

In this section we discuss our findings relative to two aspects that allow us to answer our core question of how a 'system of things' *relates* to a 'system of actors'. The first aspect considers changes occurring in the connections between actors, and the second aspect considers changes occurring in the combinations of resources as the key to value creation.

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<sup>18</sup> Usine Nouvelle, n°3648, 2020, February 27. <https://www.usinenouvelle.com/editorial/sia-2020-le-digital-est-dans-le-pre.N933209>

### *5.1. Changes in connections*

The SoS theory has offered a new angle to understand network dynamics in the IIoT context, especially how new connections are created between machines, things, and human actors. Below, we discuss these new connections at different levels. While prior research on IT in a network context implies that IT can strengthen integration and coordination between firms (Chi et al., 2010; Straub et al., 2004), we propose that the impact of IT in an IIoT context goes beyond connections between firms.

- *IIoT changes the connections between machines.* The previous discussion has shone light on how IIoT, in the context of a farming system, has contributed to the creation of new connections between machines that have become smart machines (Pardo et al., 2020). Not only are these connections of a new type, due to the diversity and dispersion of machines that are connected, but they are also particularly dynamic insofar as each machine can connect and disconnect while always being operational. In addition, the SoS view has highlighted the emergent nature of these connections between machines and the fact that these connections can lead to unanticipated outcomes.
- *IIoT changes the connections between human actors and machines.* The dynamic connections of machines in an IIoT influence the connection between human and machines. The network of machines or devices can be easily reconfigured via the IIoT platform based on the different needs of the operator.
- *IIoT changes the connections between humans.* Through machines or devices, a user can have an influence on the activity of another operator. A human actor can send information

to a machine while it is operated by another human actor, so that the latter modifies the activity being carried out.

- *IIoT changes the connections between functional entities.* Interconnections between machines also influence the interconnections between functions within a company using an IoT system. In an IIoT context, information exchanges among machines become a foundation for cross-functional information exchange. For example, connections among machines enable instant information sharing instead of human-to-human communication. Data gathered from different machines (through sensors) and collected by a specific function is communicated to salespeople to help them refine their offerings.
- *IIoT changes connections between organisations.* Cross-side network effects attract different machine providers to join the network, which will create more and more connections at an inter-organizational level. Indeed, cross-side network effects help form an emergent and dynamic network in IIoT and create more and more new connections. For example, more machines and devices being connected to an IIoT network attract more technology providers to join the network, as those providers anticipate more opportunities to connect their devices and machines with other devices and machines, and consequently have access to more data to reconfigure the machines based on different usage situations. Therefore, the IIoT has an additional influence on the connections between organizations, other than the strengthening of integration and coordination that IT is generally supposed to provide (Chi et al., 2010; Straub et al., 2004).

## *5.2. Changing how value is co-created and claimed*

By changing the connections in the network, IIoT has an impact on how resources will be combined through these connections, and eventually value will be created between different actors of an IIoT system. We detail different aspects of the value creation process that are impacted when business networks integrate IIoT and thus become industrial SoSs.

- *IIoT has an impact on the availability and quality of the components of an offering.* In the previous section, we referred to IIoT in terms of operational and managerial independence, through the notions of autonomy and belonging. Such *independence* has consequences for B2B marketing thought and action. For a supplier, when designing an offering supported by an IIoT, there is no guarantee of the availability of certain components that the supplier doesn't control or own. More generally, Choi (2018) discusses the idea that a “globally optimal decision for the whole SoS” is impossible to achieve and that actors should be satisfied with “having a satisficing (i.e., “good enough”) optimization objective” (p.100). For instance, in the JDSFS case, the overall value created depends on the availability and quality of the data collected by a weather forecast system. But John Deere has no control over the quality of this system. With DataConnect, the global value of JDSFS also depends on other agricultural equipment manufacturers, but their availability cannot be guaranteed.
- *IIoT has an impact on the levels of risk and resilience associated with the value proposition.* In the previous section, using the SoS lens, we showed how *heterogeneous* and *dispersed* the components of an IIoT can be. Dispersion of components in an IIoT may have several positive or negative consequences, in particular in terms of risk. Any component is potentially an ‘entry door’ for different types of disruptions and geographical dispersion may lead to increased control costs to ensure security. At the same time, the dispersion may reduce the impact of adverse events when they occur locally and only affect a part of the IIoT. The undamaged subsystems may allow the IIoT to continue functioning.

- *IIoT has an impact on the capacity of marketers to formulate a value proposition.* Our findings point to the *emergent* nature of smart farming. Such a characteristic has several implications for B2B marketing. Firstly, it is impossible to perfectly define the value creation. As Cadavid et al. (2020) put it, the “dynamic nature of a SoS makes it difficult to anticipate its behaviour at design time” (p.1). We argue that other marketing contexts also display such traits. For instance, project marketing refers to a ‘creative offer’ as a sort of speculative proposal. Yet, an offering supported by IIoT technology never translates into a ‘definitive offer’, contrary to project marketing.
  
- *IIoT has an impact on the obligation for suppliers to collaborate.* In addition, when a company makes an offering supported by IIoT technology, and to allow its machines and devices to connect to a bigger IIoT system, different functions in different organizations need to coordinate to work together on technical and data connections among their machines and devices at the network and service levels (the different organizations having developed their own machines and devices independently, since machines are autonomous in performing their own tasks).
  
- *IIoT has an impact on how to manage new collaborations.* In the value creation literature, an important issue relates to how actors are ‘guided’ to combine their resources, and how the interaction where the resource combination occur is governed (see Akaka et al., 2014; Jayashankar et al., 2020; Pohlmann & Kaartemo, 2017; Vargo & Lusch, 2016). The cross-side network effects provoked by the IIoT that we discussed in the previous section do not always lead to positive outcomes. Technology providers with different standards joining the network of the IIoT may lead to quality uncertainties in the machines, as seen earlier. In

addition, fierce competition among them may also lead to saturation if the network fails to attract more users. Therefore, a company making an offering supported by IIoT technology needs to manage the connection issues in its network carefully. Interfaces between machines become an important aspect of resource combination. As indicated by Maier (1998), interfaces are important elements in a SoS. Leveraging interfaces is essential in designing and managing an IIoT due to the latter's emergent, dynamic, and diverse nature. Examples of questions that arise include; Since a customer can connect its machines to other third-party devices, should an IIoT firm develop open interfaces for third party devices? Who owns the intellectual property of these interfaces? Who can own and use the data? How can the data be used? In order to have two machines work together smoothly, at which level should the IIoT company and the third-party firms work together to develop the machines - at the device level, the network level or the service level? With which organization? Firms selling building blocks of an IIoT system need to be transparent about these coordination mechanisms. By doing so, it can strengthen customers' confidence in the emergent value propositions and weaken their risk perceptions in value propositions.

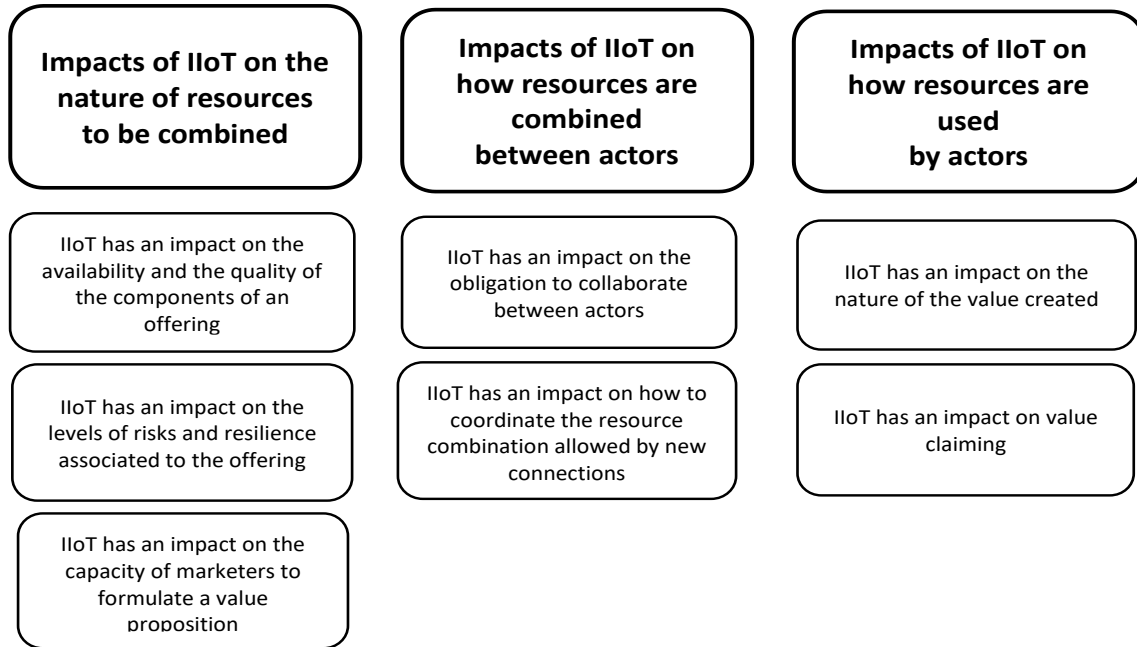
- *IIoT has an impact on the nature of the value created.* In our findings, we identify and illustrate the evolutionary nature of IIoT. Two interesting implications in terms of value creation exist. First, customers can 'enter' the offering at a first stage and that could be reassuring if they perceive a financial risk (they can start with only a few components but already have a fully operational system) or a usage risk (they believe they don't have the skills to use a large range of components, or don't need to for the moment). Yet, once satisfied with the 'intermediary stable state', suppliers of an offering integrating IIoT technology should have the opportunity to document an additional value for the customer if they accept additional components in the offering. Yet, the customer may also feel insecure

as an offering may appear to be a kind of ‘never-ending story’. Consequently, the customer may never feel that they have simply ‘made the right choice’. Second, the emergent nature of value creation is also reflected in the fact that value in an IIoT network can increase exponentially. In an IIoT network, machines can autonomously form subgroups to work together. According to Reed’s Law (Reed, 2001), a network is more valuable when actors in the network can easily form subgroups for cooperation, while the value scales exponentially with the connections in the network. Therefore, due to the autonomous nature of the machines in the IIoT, the value in an IIoT network will increase exponentially with the connections that exist inside it.

- *IIoT has an impact on how value is claimed.* Although, in our research, we mainly discuss value co-creation effects of the IIoT, we would like to highlight that the parallel process of value claiming is affected. We see two main effects: A modified basis for value claims and changes regarding the temporary characteristics of value claiming. Through the broadened base of available data, the IIoT allows changing value claims through pricing mechanisms which shift away from the sale of hardware and towards the service offering. While hardware pricing is often not linked to specific outcomes, but rather to a customer acquiring a capacity to perform certain activities, software-based services allow usage-based pricing concepts and performance-based pricing approaches. At the same time, the IIoT allows information to be transmitted much faster and, in principle, continuously. Hence, it enables permanent value-claiming activities as opposed to one-time or point-related pricing.

In the figure below, we propose to reorganize these different impacts, drawing on the work of Gronroos and Voima (2013) in relation to different spheres of an *all-encompassing process* of value creation.

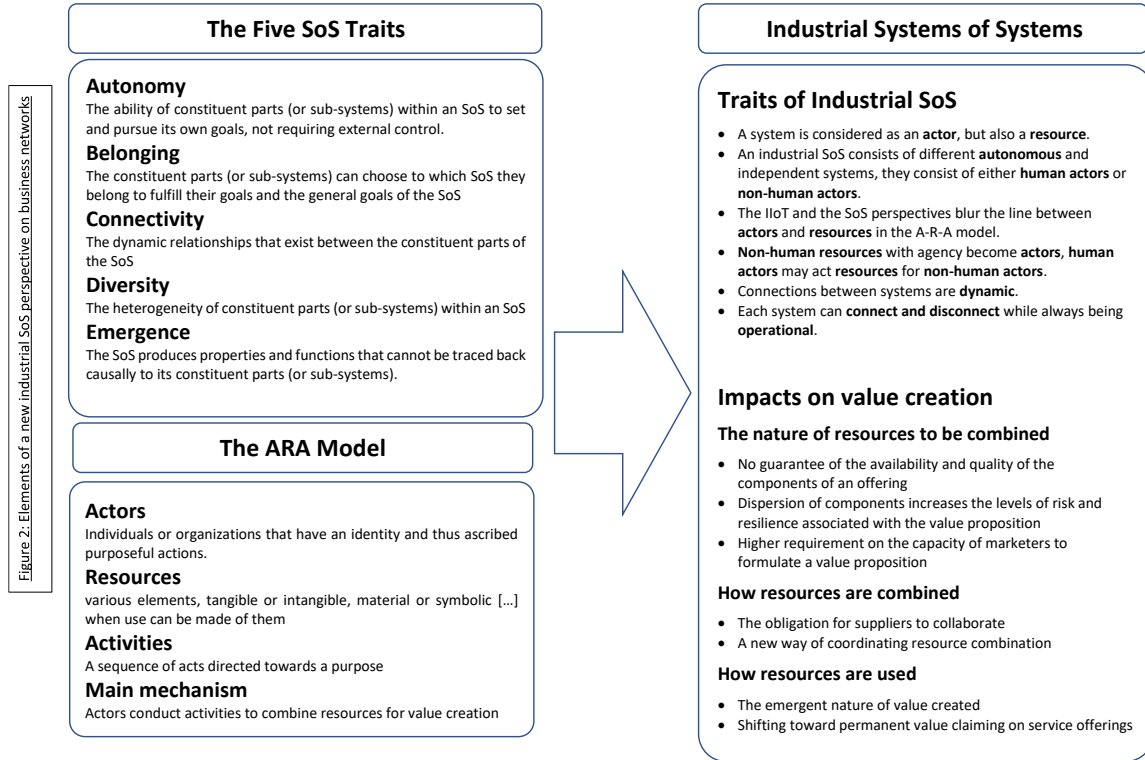
Figure 1: The impacts of the IIoT on value-creation related activities



### 5.3 Integrative framework

On this basis, we suggest the following integrative framework. Building both on the A-R-A model and the SoS perspective, we suggest that the five characteristics of the SoS are complementary with the A-R-A view of business networks. A combined view of the two leads to implications both for our perspective on B2B networks and the value creation process in such networks. Figure 2 shows how we see the relationship between the two established model perspectives (SoS and A-R-A) and how we focus the attention on the traits of these new business networks, that is, business networks that are impacted by the IIoT and the main implications on value creation.

Figure 2: An integrative framework



## 6. Implications

### 6.1. Theoretical implications

Our work has several implications for business market theory.

#### 6.1.1 Changes for value creation and value claiming

First, it allows us to build on and extend previous work that aimed to achieve a better understanding of how business networks are affected by digital technologies (e.g., Papert & Pflaum, 2017; Pagani & Pardo, 2017; Ritter & Pedersen, 2020; Syan & Sharma, 2018). The autonomy given to products and machines by technology redefines how business networks function. We propose that when business networks become industrial SoSs, both (a) the connections between things, human actors, and organizations and, (b) the nature of value

creation and value claiming are affected. We identify change in connections at four levels, four types of impacts on the value creation process, and two impacts on value claiming.

### *6.1.2 An evolution of the A-R-A model*

Second, our work questions the difference between ‘actors’ and ‘resources’ in certain approaches to network analysis in business markets, such as, for example, the IMP group’s A-R-A model, with its distinction between activities, resources, and actors as interdependent yet distinct layers that “add up to a business relationship” (Gebert-Persson et al., 2014, p. 11). While several authors have suggested directions for future research on the A-R-A model and highlighted the need for deeper discussions of its three components (e.g., Lowe et al. 2012; Raskovic 2015; Escher and Brzustewicz 2020), few of them (Andersson & Mattsson, 2015) have questioned the distinction between the definition of actors as human or organizational and resources as inanimate and lacking agency (Kot & Leszczyński, 2020; Sklyar et al., 2019).

Our work may allow a re-specification of the A-R-A model (see figure 3). Indeed, the A-R-A model draws clear lines between the conceptual categories. Resources are considered to encompass “various elements, tangible or intangible, material or symbolic [...] when use can be made of them” (Hakansson & Snehota, 1995, p.132). A broad range of ‘items’, raw materials, physical facilities, components, operating systems, finance, human knowledge and ability, and other elements can be considered resources (Cantù, Montagnini, & Sebastiani, 2010, p.224). From this perspective, machines and things in the IIoT would also be considered ‘resources’ without agency.

The actor category in the A-R-A model has been discussed and described in far less detail (Huemer, 2013). Actors are either ‘organizations’ or ‘individuals’. In the markets as networks approach, individuals are actors as “they can be ascribed motives and intentions and thus be claimed purposeful in their behaviour” (Hakansson & Snehota, 1995, p.192). Organizations also are seen as actors “because they are perceived to have an identity and thus ascribed

purposeful action” (Hakansson & Snehota, 1995, p.193). We argue that in past socio-technological stages of business markets, such a classification with a clear frontier between the actor and the resource categories was justified. However, when products and machines are transformed into smart products and exchange information between each other or between them and individual or organizational actors (as is the case, for example, in the IIoT), they are arguably characterized by agency, autonomy and authority (Hoffman & Novak, 2018; Luck & d’Inverno, 1995), and this aspect continues to evolve. While one may consider that they do not have motives and intentions, we propose that they pursue goals, follow rules, and make decisions based on these rules to reach their goals.

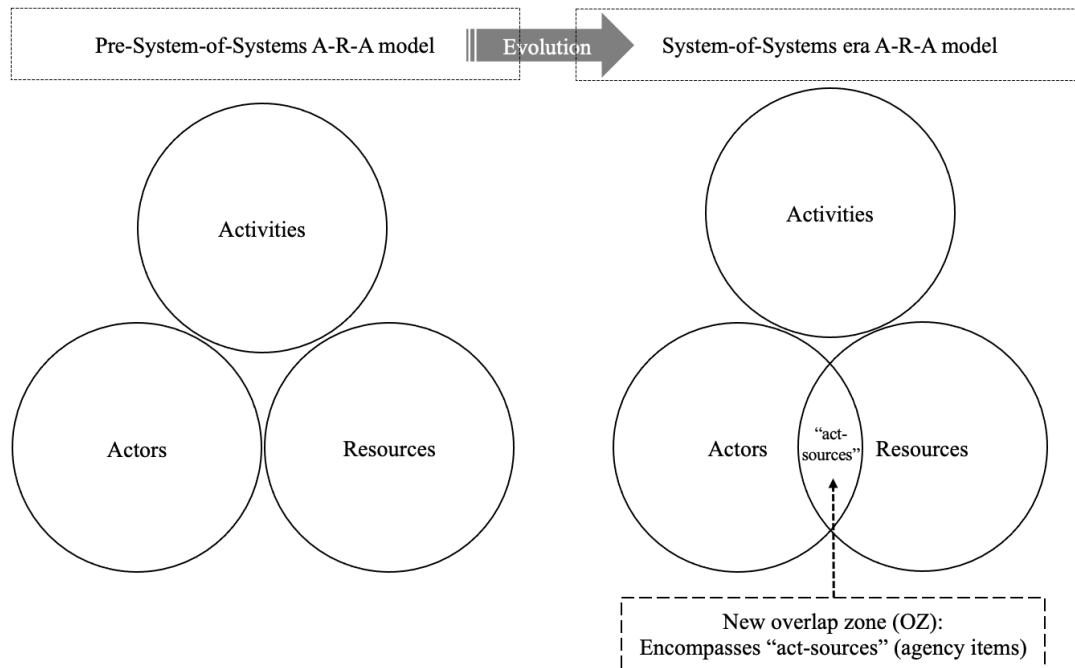
To illustrate our argument, consider a classical tractor that is used by the farm (or the farmer) for carrying out certain activities. It is a ‘non-smart’, passive resource (Pardo et al., 2020). When a tractor uses data coming from another tractor to adapt (without any human intervention) its speed and carry out speed coordination, is the first machine an actor and the second a resource? Are they both resources? When a tractor uses information sent by a human actor and, consequently, adapts its speed to comply with its rule of working, where is the resource? We propose that depending on their level of autonomy, smart products and machines may be considered both as resources and actors. We argue that therefore, in perspectives of business networks such as the one provided by the IMP group (Hakansson, 1982), in particular with the A-R-A model (Hakansson & Snehota, 1995), the hitherto strict conceptual distinction between actor and resource no longer holds. While the activity category, from our perspective, remains unchanged, the actor and the resource categories require an adjusted model perspective (see Figure 3). This representation reflects the fact that certain resources obtain agency when they are transformed into smart and interconnected elements in an industrial SoS. Hence, while they do not lose their material status of a resource and while they can, indeed, continue to function as a classical, agency-less resource, they typically adopt a new status. This status is represented

by the intersection (or overlapping zone) in the industrial SoS A-R-A model. At the same time, when intelligent IIoT machines – to reach their goals and following pre-specified rules – integrate individuals or organisations into activities that they orchestrate, they may add a resource status to the classical actors. Hence, they move into the overlap zone between resources and actors, too. Therefore, the A-R-A model undergoes two important changes:

- (1) The clear delimitations between the three constituent elements become blurred between two of the three elements (actors, resources).
- (2) The blurring of the formerly clear delimitation between actors and resources creates a fourth, non-distinct category - the overlap zone. Inside the overlap zone, we find network elements (individuals, organisations, resources) that are characterized by a double status; they function as both resource and actor (perhaps in the form of ‘agency items’, ‘act-sources’, or similarly labelled network elements).

Both actors and resources can fall into the overlap in a permanent manner or temporarily. This depends on the use that is made of the IIoT elements in the respective industrial SoS network. For example, in smart farming, when a tractor loses its connection with the network, it may turn into a resource again. Or an individual who does not receive digital instructions from the IIoT (e.g., because of a missing connection to the internet or a disabled graphical interface) turns to a simple actor outside the overlap zone. In any case, we argue that the industrial SoS perspective requires an adaptation of the traditional A-R-A model of business markets. This adaptation is required because the A-R-A model constitutes one of the most central models in the B2B literature for analysing business networks. As the digital transformation makes networks evolve, so should the models that have been designed to explain these networks.

Figure 3: An adjusted industrial SoS perspective of the A-R-A model



### 6.1.3 The dynamic nature of value creation

The third implication that we draw from our research is the dynamic nature of value in the IIoT when seen through the theoretical lens of industrial SoS. In an IIoT context, machines are autonomous, and they are free to choose how to connect with other machines, individuals, or organizations. Since a machine is considered as both a resource and an actor, the dynamic connections between a machine and other machines, individuals or organizations can lead to a great number of resource combination possibilities, thereby making value more dynamic in this process. The IMP researchers suggest that actors play important roles in value creation in a network since they conduct activities together and co-create value by combining heterogeneous resources (Hakansson & Johanson, 1992; Hakansson & Snehota, 1995). Digital systems or digital tools are merely considered as digital resources, and connected actors combine these digital resources to create new activities (Pagani & Pardo, 2017). Through the SoS lens, we find that the autonomous nature of machines weakens human actors' involvement in resource combination and enables new connections to be formed more frequently, thereby making value created in this process more dynamic.

#### *6.1.4 Industrial Systems of Systems*

Overall, our findings propose a new mode for value creation in a network context, which we call the Industrial System of Systems (industrial SoS). In this mode, an industrial SoS consists of different autonomous and independent systems. A system can be a machine, an individual and an organization. A system here is considered as an actor but also a resource. Since these systems are actors, they can ‘choose’ to connect with other actors based on their own goals or the overall goal of an industrial SoS. This makes connections among systems in an industrial SoS very dynamic. Since these systems are also resources, the dynamic connections among them lead to a great number of resource combination possibilities, thereby creating emergent value for the actors involved in an industrial SoS. In the context of the IIoT, where network connectivity becomes more dynamic and where the boundary between actors and resources becomes blurred, the IIS mode offers further insights that go beyond the A-R-A model (Hakansson & Snehota, 1995), strategic nets (Möller & Rajala, 2007) and the value platform (Perks et al., 2017) to explain the value creation process in emergent dynamic networks.

#### *6.2. Managerial implications*

As the traditional production networks with multiple tiers (Straub et al., 2004) have evolved into new forms of business networks with new ‘levels’ (systems, and systems of systems), we are likely to see managers in B2B markets redefine business networks and how they manage within them. Our study offers the following managerial implications in the IIoT context.

##### *6.2.1 The emergent nature of value*

The first implication builds on the idea that value has an emergent nature. This emergent nature derives from the dynamic connectivity between machines. Since customers can reconfigure different machines in an IIoT solution and connect their machines with other third-party machines, they may not be able to predict predefined value in the selling process. This emergent

nature has posed some challenges and offered some benefits to managers selling IIoT solutions thus far. For example, managers need to specify terms and conditions in relation to these connections since customers may find it difficult to accept these emergent value propositions. They also need to specify the responsibilities among the IIoT solution provider, third-party companies, and customers. Managers must clearly explain the pricing mechanism in their value propositions so that customers can understand how they will pay for these emergent solutions and what risk they face.

On the other hand, the emergent nature of value also offers benefits. When customers can reconfigure different machines by themselves, their possibilities to co-create value together with IIoT solution providers improve. In this context, customers may also create new solutions that have value for them, but also possibly for other customers and the company that is at the origin of the value proposition. The latter may not have anticipated the new value proposition and needs to monitor the development of its systems and their role in the wider system of systems in which they operate. More generally, data gathered from their usages can help managers propose new customized offerings or product upgrades at the right time, which will strengthen customer relationships and possibly shape the markets in which they operate. Therefore, regarding the advantages and disadvantages of the emergent nature of value in IIoT, contexts, managers need to adapt their traditional practices of selling and relationship management from a perspective in which they are largely “in the driver seat” regarding their value proposition before, during, and after transactions with customer companies to a perspective of joint “captainships” with customer companies and other network actors.

### *6.2.2 Autonomy and independence of IIoT solution components*

The second managerial implication is that components of the offerings in IIoT solutions are autonomous and independent. Since machines operate independently, a breakdown of a machine will not lead to a breakdown of another machine, or even a total breakdown of a

solution. Managers need to emphasize this advantage in their value propositions. However, when they create solutions for customers, this may pose some challenges since the overall value may depend on the availability and the quality of third-party offerings. Therefore, in value creation processes, managers need to optimize the overall IIoT architecture design to minimize the risks triggered by third-party offerings. They also need to cooperate with different suppliers offering the same category of machines to implement backup solutions efficiently.

### *6.2.3 Dynamic connectivity in business networks*

The third managerial implication relates to the dynamic connectivity in business networks. The connections between machines in the IIoT exist at different levels, such as the network level, service level and content level. Different machines are connected through a telematics system at a network level, and data from these machines is centralized in an operations management system (a user interface) at a service level, in which different applications can be created to develop and manage new tasks. Managers can propose different value through reconfiguration of machines at these levels. Connections with other third-party machines also lead to potential resource combinations in value creation. However, since customers may be concerned about how different organizations cooperate in their IIoT solutions, they need to be more transparent about inter-organization coordination mechanisms in their value propositions.

### *6.2.4 Managing actors, resources, and “act-sources”*

Finally, the blurring of the lines between actors and resources raises questions for managers to answer. A central question is what relative importance they will allocate to human actors as compared to non-human actors with agency. The starting point may reside in the activities category of the A-R-A model and the comparison of different scenarios of actor combinations. We suggest that at least three scenarios exist. Firstly, in a human-lead scenario, human actors still maintain a lead over machine actors. This scenario is likely closest to traditional, pre-IIoT situations in which human actors determined how non-human resources, such as machines,

would work to create value. It differs from traditional actor-machine scenarios in that machines now do have agency and, hence, interact more actively with humans, for example by formulating questions, by suggesting advice, or by proactively supplying information. A second scenario encompasses situations in which machines take the lead, that is, they are assigned a leadership role that allows them to draw upon human actors and to assign them tasks. A third scenario could exist if human actors and non-human actors have equal decision rights and responsibilities. Such a scenario may provide the highest level of flexibility. At the same time, it raises questions regarding the solution of possible conflicts when machine actors and human actors disagree about next actions to take. Managers will need to examine carefully which scenario offers the best contribution to their company's value proposition and value creation processes.

This is closely related to as a second question, that is, understanding the opportunities and challenges of combining human and non-human actors in managers' own companies, but also within the networks in which they operate. Here, questions such as role definitions and coordination require answering. Finally, managers will need to define when and under what conditions such items that have been considered to constitute resources in the past should be given actor roles in which they take control as lead actors over human resources. Our discussion of the A-R-A model against the background of the IIoT and drawing on the SoS perspective raises more questions than answers. It calls both for future academic research and managerial discussions about this emerging yet highly relevant issue. In this context, we would also like to highlight that, from our vantage point, managers may manage inside a SoS, but they can't manage the SoS in which they operate. However, if this research stimulates both future academic studies and a new way for managers to look at their companies and networks, it may allow the A-R-A model to remain among the central frameworks in B2B thinking.

### *6.3 Future research*

Based on the implications above, this article presents some important starting points for future research. We encourage future research to focus on the possible avenues below.

First, we propose that due to their autonomy, smart products and machines may be considered both as resources and actors. From this perspective, future research could study how this new perception influences connections between resources, activities, and actors in the A-R-A model. According to the A-R-A model, the connections between the elements in the model are actor bonds, resource ties and activity links. However, if resources such as smart products in the industrial SoS obtain agency, how should we redefine actor bonds in this model? Are actor bonds still primarily about the connections between human actors or between organizations? Or can we extend this definition to include the connections between human actors and machines and between machines when these machines obtain agency? While B2B research has been studying relationship constructs for a long time, how will this new definition change the traditional relationship constructs such as trust, commitment, and power? Since more and more recent research has started to focus on human-(smart)technology relationships, such as human trust in artificial intelligence (Glikson and Woolley, 2020), relationship constructs in B2B relationships demand more investigations in this new context. In addition, as the perceived identity influences an actor's possibilities to act in an actor bond (Hakansson & Snehota, 1995), the perception and acceptance of both identities in these human-machine actor bonds may influence their interactions. Yet, what does identity mean in these human-machine actor bonds? Since machine and human actors have different types of interactions in these relationships (Makarius et al., 2020), more research needs to be conducted to clarify the roles and identities of machines and actors in these new types of actor bonds. Finally, we also encourage researchers to study how these human-machine or machine-to-machine actor bonds influence resource ties and activity links. For example, how does this new type of actor bond influence resource

heterogeneity in a network and facilitate resource combinations? Does it create new activity links in a network for value creation? As business relationships are multi-level in nature (Ashnai et al., 2016), how do these human-machine or machine-machine relationships influence inter-organizational relationships? Therefore, when resources such as smart products in the industrial SoS obtain agency and become actors, they may influence other layers of a relationship in the A-R-A model.

Second, since IoT technologies have been increasingly adopted in solution businesses (Paiola & Gebauer, 2020), we encourage future research to study how solution providers can manage these loosely coupled networks in the IIoT context. Since digital platforms can expand solution providers' research and facilitate solution-component reconfigurations, solution networks have become more and more loosely coupled (Eloranta & Turunen, 2016). While most of the components offered by the network actors in these solution networks are products and services without autonomy, reconfiguration of these components still depends on the focal actors, namely, the solution providers, to use the platform architecture as control points for network orchestration (Tilson et al., 2010; Pagani, 2013; Wei et al., 2019). However, in a solution integrated with IoT technologies, smart product components are more autonomous and can combine with other components to create frequent reconfigurations on their own. Customers also have opportunities to connect their solutions with components offered by external smart product suppliers. Thus, the IIoT and smart products further enable solution networks to become more loosely coupled and more decentralized. In such a network, a solution provider may play a weaker role in network management. The evolutionary nature of the value creation process indicated by our findings also poses more challenges in network management. Although cross-side network effects can enable a network to expand rapidly, the network expansion also leads to quality uncertainties. Fierce competition among machine suppliers may also lead to saturation, thereby reducing the value created in the network. Therefore, new

network management mechanisms need to be applied in these networks. Future research might thus focus on how new network management mechanisms can be applied in these networks. Since our findings indicate that the IoT influences a network at three different levels, we also propose that network management mechanisms can also be studied at three levels, that is, the strategic level, the operational level, and the technical level.

Finally, previous research has revealed the network behaviours of smart products (Pardo et al., 2020). Our article further indicates that the connectedness of smart products in an industrial SoS influences connections at three different levels, namely, individual/machine level, organization/function level and inter-organizational level. This finding suggests that the focus of smart product development should go beyond a product level to an organization/function level and an inter-organizational level, since the value of a smart product increasingly depends on how it exchanges data with other smart products, which in turn further influences information exchange between functions/organizations. When organizations develop these connected smart products, it is no longer just about product performance but also about company performance and network performance. This new point may trigger further research on co-innovation in a B2B context (Dawson et al., 2014). For example, how do two functions/organizations work together to develop connected smart products? How do these co-innovation projects influence the connections in a digital network or an industrial SoS? Therefore, we suggest that future research could focus on the development of smart products in a network context.

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