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UNDERSTANDING THE ROLE OF IOT TECHNOLOGIES IN SUPPLY ECOSYSTEMS

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ABSTRACT

This paper introduces the concept of supply ecosystems for exploring the role of the Internet of Things (IoT) and its technologies in value added activities. The paper argues that the IoT has a role in helping to understand the information problems that firms face, and in identifying the way in which IoT technologies can help. To achieve this, the paper examines the vision and scope of the IoT and its perceived potential value to firms. Then, based on the available literature, the paper furthers the existing concept of supply ecosystems and argues that the potential value of the IoT to businesses can only be realized if a holistic, more ecological perspective, is used. The paper hence proposes that supply ecosystems can be used to understand the value of IoT in solving information problems.

Keywords: Internet of things, supply chain, ecosystems, information, decision making.

INTRODUCTION

Recent developments in the Internet of Things (IoT) have promised to help solve some profound problems in the production and consumption of goods and services [6]. According to a report from The McKinsey Institute, the IoT has the potential to add $6.2 trillion to the global economy by 2025 [23], and survey results by Accenture [1] predicted that the Industrial IoT could possibly add $14 trillion to the global economy by 2030. IoT technologies have been in use for many years in domains such as manufacturing, transport management, and energy conservation. Only recently though, have they been widely discussed in the media. While businesses and governments around the world are optimistic about the prospect of a more productive future brought by IoT technologies, there are questions that must be addressed in order to explore and exploit the opportunities offered by the IoT. In the context of supply chain management foundational questions would be *What does IoT mean to firms? How and in what ways should firms use these technologies in order to exploit the opportunities presented by the technologies?*

This paper addresses these questions by exploring the concept of supply ecosystems. It argues that they have a role in helping to understand the information problems that firms face, and in identifying the way in which IoT technologies can help. To achieve this, the paper examines the vision and scope of the IoT and its perceived potential value to firms. Then, based on the available literature, the paper furthers the existing concept of supply ecosystems and argues that the potential value of the IoT to businesses can only be realized if a holistic, more ecological perspective, is used.

This paper is organized as follows. The next section discusses the concept of the IoT and its perceived value. The subsequent section explores the idea of ecosystems and how they can be used to better understand competition and business activities. The discussion leads to a concept of supply ecosystems; this is then applied to examine information problems encountered in the conventional supply chain settings. Based on the previous discussion, the role of IoT and its value in supply ecosystems (in particular its contribution to solving information problems) is then discussed. The final section explores how the ideas proposed in this paper might help to define the future directions of the IoT in supply chain research.

INTERNET OF THINGS

The phrase 'Internet of Things' (IoT) was first used in 1999 during a presentation given to Proctor & Gamble by Kevin Ashton, who used it to describe the interactions that arise when everyday objects with embedded sensors or chips are incorporated into a network. Today, the term is widely used to describe a situation where "everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to accomplish some objective" [38, p.261]. The IoT describes a world in which objects, using a combination of hardware and software technologies, make themselves recognizable to each other, and can be connected via the Internet to any person and anything at any time and place [35]. Hardware technologies include devices (e.g., sensors, actuators, smartphones, and wearable technologies), and networks to connect them (e.g., 4G Long-Term Evolution, Wi-Fi, and Bluetooth); while software components include cloud computing, analytics programmes, and data visualization tools [7].

The IoT is argued by some to be more than a network of hardware and software. Shin [32, p.520] describes it as "a socio-technical ensemble" and stresses that its design and development should be based on human needs. Indeed, there is evidence to show that automation or electronic integration alone without business transformation is not sufficient to improve business operation through the IoT [16] and that contingency factors have profound influences on value creation from RFID supply chain projects [36]. As noted by Walport [37, p.19] "people will be an integral part of those systems". Cisco has expanded the idea of the Internet of Things to an Internet of Everything (IoE) by including people and process (Figure 1) and has argued that in order for the promise of the IoT to be realized, all elements in the network (i.e. people, process, data, and things) have to be appropriately developed.

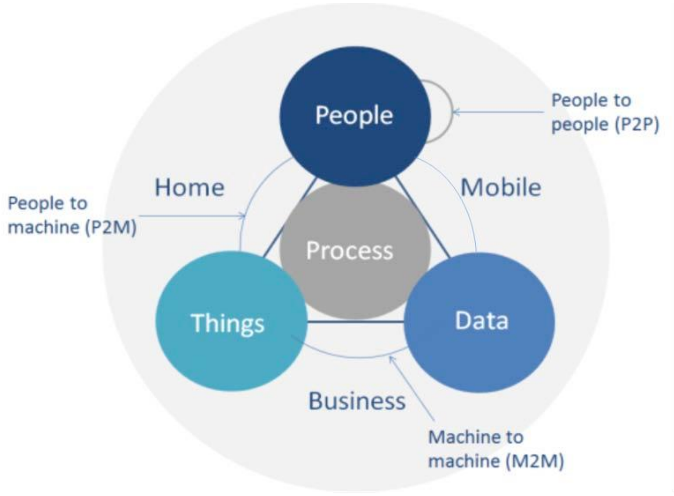

Figure 1. Cisco's summary of "The What, Where, and How of the Internet of Everything"
Source: [5]

The current perceived value of the IoT can examined at two levels: operational and strategic. At an operational level, IoT sensor data can be used to regulate flows of materials, products, and information on the shop floor with minimum human intervention. Sensor data can also be used to automate replenishment by sending to the supply chain system a signal that triggers a delivery. At strategic levels, IoT technologies can capture data through different devices and applications that connect within and across different sectors. In this sense the real value of the IoT comes from using such data to inform decision making in ways that make it more responsive and immediate than is currently possible. As was noted in The Economist [4, p.21] "the most exciting possibilities, perhaps, will emerge from the insight provided by the amount of new data being generated, captured and analyzed and the value that is generated from such information". In addition, the volume and velocity of data can lead to innovations that change business models. Radio-frequency identification (RFID) tags are increasingly being used to help firms achieve a circular business model by tracking the whereabouts and usage of the materials [30]. This helps to reduce costs and increase margins, and most importantly affords opportunities to reintegrate products back into the economic system at the end of their current use [20].

So far there is no universal definition for the IoT and there is no agreement on its true value to those who adopt it, e.g. individuals organisations, and governments. This paper views the IoT as a socio-technical ensemble including people, process, data, and things that possesses the following characteristics:

- It is a network not only of things but of people interacting through processes with things or with other people.
- The value of IoT technologies can only be realized when they are connected to other devices.
- Connected devices can make themselves recognizable to others so that they can communicate with others and with their environment via the Internet.
- The IoT senses, captures and exchanges enormous volumes of near real-time data that is potentially valuable to firms with the right analytical tools.
- An IoT technology can capture data through different devices and applications that connect within and across different sectors. In other words, it is a boundary object that can spin across organizational boundaries to coordinate actions.
- The more that people, things, and processes connect in the IoT, the more valuable it becomes; and so too does the data it captures and generates.

BUSINESS ECOSYSTEMS

James Moore was one of the first people to promote the idea of business ecosystems [25]. He drew on some key concepts from ecology and argued that firms should not to be viewed as discrete entities, but as parts of a business ecosystem comprising competitors and collaborators and infrastructure. Moore [26, p.33] describes a business ecosystem as "an intentional community of economic actors whose individual activities share in some large measure the fate of the whole community". A business ecosystem can be regarded as a network of interdependent organisations whose services and products complement each others.

Building on Moore's work Iansiti and Levien [11] described a business ecosystem as "a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival" (p.8). They emphasized the holism of an ecosystem and argued that its health significantly affects its members' performance and that the fate of a firm is intertwined with of other elements and of its business ecosystem.

The parallels between business ecosystems and biological ecosystems make it possible to draw on concepts from the latter to describe the former [12, 18]. Iansiti and Levien, for example, drew on the ecological concepts of keystone species and co-evolution to describe the dynamics of the system and the complexity of relationships (e.g. competitive yet interdependent and collaborative) within a business network [11]. Two of these parallels are considered in the following subsections: keystone species and co-evolution, which briefly discuss these key concepts from ecology to describe business dynamics and inter-firm relationships. The section on limiting factors discusses a further idea from ecology that has particular relevance to supply chain management.

Keystone

Keystone species are disproportionately influential species in an ecosystem as they regulate ecosystem health. In the context of business ecosystems the term has been used to describe a dominant firm around which ancillary firms co-evolve [11]. Keystone organisations are critical to the maintenance of relationships within business ecosystems. They play a role in helping to "enhance stability, predictability, and other measures of system health by regulating connections and creating stable and predictable platforms on which other network members can rely" [11, p.9]. Iansiti and Levien [11] used the software sector as an example and postulated that keystone organisations are the driving forces behind software ecosystems, and provide stability in an otherwise unstable environment. Studies that use the keystone concept also argued that keystone organisations are likely to dominate the development or control the diffusion of innovations [9, 13]. As a consequence of their position in an ecosystem, keystone organisations (e.g. Walmart and Microsoft) can determine the characteristics of the ecosystem, establishing standards and providing platforms: services, tools, or technologies that members of the ecosystem can use to define their role [12, 15].

Co-Evolution

An ecosystem is characterised by competition and cooperation [19]. Just as organisms compete for limited resources (e.g. food, water, and energy), firms also compete for limited resources (e.g., customer demand) [31]. Moore ([25] and Lewin and Regine [18] noted that collaboration between firms or even between competitors is relevant to the stability and healthiness of a business ecosystem. Lewin and Regine [18] challenged the usual focus on competition and survival of the fittest and argued that the idea of head-to-head competition is of limited value in an increasingly networked economy. They advocated a shift in focus from one in which relationships between firms are emphasized to one in which relationships between ecosystems are considered.

Co-evolution is a common feature of ecosystems [22]. It is the process by which entities change together so that each creates a context for others [25]. In a biological ecosystem, each organism evolves in response to the evolution of others; but such processes are also a normal part of industry: manufacturers and ancillary industries change together over time [18]. In business, co-evolution can be seen as "reciprocal cycles of adaptation among one or more elements of an economic system" [26, p. 32]. As a result of co-evolution "Firms do not stand by themselves... For an industry with special input and skill needs, growth and effectiveness is strongly conditioned by how rapidly and effectively a support structure grows up" [28]. A firm's ability to adapt to the environment and align its business objectives and strategies well with those of a key player (i.e. a keystone organisation) and other parts of a business ecosystem is thus critical in determining whether it can operate effectively within and outside the ecosystem [27].

Limiting Factors

In the above discussion on co-evolution it was observed that both organisms and firms compete for limited resources. The strategies that evolve for optimising access to and use of such resources help to determine the nature of an ecosystem and the interactions within it, and it could be argued that ecosystems are defined by the relationship of their component parts to limiting factors.

Processes of life require essential resources; and for them to continue, each resource must be available at a level above a biologically determined minimum. Blackman [2] observed that the resource closest to the minimum is the one most likely to limit growth and development. In a food chain, an organism, itself may be a limiting factor, with organisms at the top of a food chain relying on those lower down in much the same way as customers rely on materials in a supply chain.

One obvious limiting factor in natural ecosystems is energy. Madden [21] describes energy as "the currency of life" because, in biology, it is the most fundamental limiting factor. All living things have evolved systems that help to address three basic questions relating to energy [21]:

- Where can the energy needed to stay alive be found?
- How can it be stored?
- How can use of energy be reduced?

If the idea of defining ecosystems by limiting factors is extended beyond a specifically biological context, an ecosystem could be regarded as consisting of

- at least one limiting factor (eg, time, money, fuel, equipment etc),
- a physical environment,
- inter-relating users of the limiting factor(s).

This being the case, the above questions relating to energy could be applied to other limiting factors, with the inter-relating users co-evolving interactions based on relationships to the limiting factors and solutions to the problems of how to get them, how to keep them and how to use them. All of these are relevant to the consideration of supply ecosystems.

SUPPLY ECOSYSTEMS

There has been a significant change in market dynamics since the late 1990s: a shift from supply push to demand pull [8]. One consequence of this shift is that any company attempting to succeed on its own has proved to be limited in terms of creating values for a customer-centric market [15]. As a result, some have argued that the supply chain model should give way to a supply ecosystem model which permits firms to work together to create new values [8, 14, 15, 19].

Supply ecosystems have been defined as sets of "interdependent and coordinated organizations that share some common adaptive challenges and that collectively shape the creation and nurturing of a sourcing base that contributes to competitive advantage and superior performance" [14, p.166]. They can be regarded as extended supply networks consisting of "vast loosely coupled networks of organisations and fraught with a variety of problems ranging from deep information and incentive asymmetries to the imperfect quality of information" [12]. Where traditional supply chain models focus on dyadic buyer-supplier relationships, a supply ecosystem model emphasizes multilateral collaborative relationships among loosely interconnected firms.

Understanding of ecosystems varies according to spatial scale [39]; similarly the scope of a supply ecosystem can be broad and focused on an entire sector or economy, or narrow and focused on particular value added activities (e.g. logistics, inventory management). The scope of a supply ecosystem can also be specific to a firm focusing on its relationships with other firms and the environment. Supply ecosystem analysis can include those firms that fall outside the traditional supply chain analysis but directly contribute to the value creation process [12].

A keystone organisation is the anchor of a supply ecosystem. Its requirements promote the evolution of platforms – services, tools, or technologies – for ancillary companies to use; and companies linked to the platform usually align their own objectives and activities not only to the keystone organisation's but also to those of other companies in the ecosystem.

The relationship between the keystone organisation and its ancillaries is shaped by information. Wal'Mart's procurement system provides its suppliers with real time information on customer demand and preference; Apple's devices (e.g. iPhone, iPad, and iPod) allow software companies to create programmes for a defined market; and Toyota's just-in-time procurement system provides real time information to suppliers regarding the inventory level at Toyota enabling them to plan their own production. Where a supply ecosystem has evolved around a keystone organisation, that organisation holds the power to shape the fate of other organisations within the ecosystem. This is especially true where resources can be substituted or where new firms are seeking a niche within the system.

Information is used to coordinate and control value added activities. Efficient information flows improve decision making and help to reduce waste and to increase efficiency; but information is a limiting factor that has profound effects on the health of a firm and the nature of a supply ecosystem. Thus, firms need to determine what information is needed, how to obtain it, and how to use it [15].

Traditionally, attempts to optimize the use of limiting factors in a supply chain relied on predictive models that took an overview of the value added process. Milgrom and Roberts [24] for example, argued that modern manufacturing involves closely coordinated changes in the overall business processes, rather than small adjustments. Biology by contrast, relies on small, timely adjustments that occur when components of the system respond to changes that they sense in their environment. Making timely adjustments to respond to the environment is difficult in traditional supply chains because accurate real time information is not always available. Figure 2 illustrates information and material flows in a conventional supply chain. Information is only communicated between adjacent links in the chain. Such linear information flows restrict real time information causing adjustments to be based on limited information. This results in lags in decision making, affecting timing of delivery and maintenance of stock level. The resulting amplification of errors, or bullwhip effect, can thus be characterised as informational problem caused by conventional predictive supply chain models [10]. A typical example would occur when a retailer receives a large order from a single customer and increases the next order to its supplier. The supplier (one level along in the supply chain) interprets the adjustment as indicating a growth in the market and orders more from its distributor. Similar conclusions by that and other distributors would lead to excesses in inventories along the supply chain.

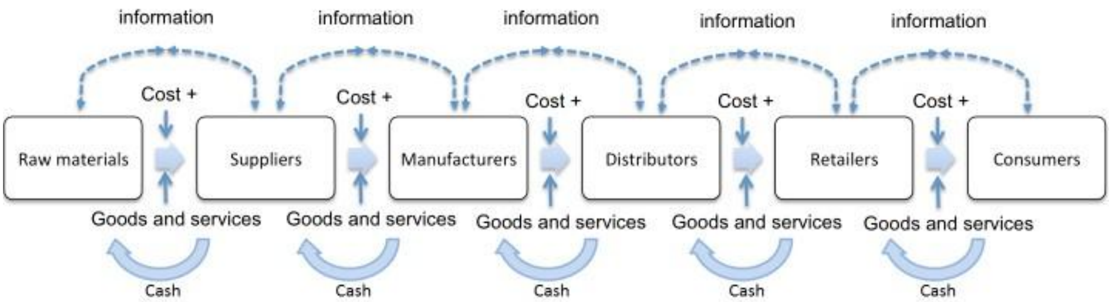

Figure 2. Optimised supply chain management

INTERNET OF THINGS AND SUPPLY ECOSYSTEMS

To alleviate informational problems in supply chains, inter-organisational systems (IOS) have been adopted for operational improvement and information sharing [17]. Electronic data interchange (EDI) and enterprise resources planning (ERP) are typically used to facilitate connectivity and integration of data and information between trading partners. This improves order processing and reduces lead times for manufacturing and logistics [10]. However, since most IOS are based on linear supply chain logic they tend to focus on facilitating data and information exchanges between two trading partners. IOS designed for supply ecosystems would need to focus on multilateral relationships. These are non-linear and happen simultaneously, so such an IOS would need to facilitate communication of data and information between multiple firms. In addition, it would also need to recognise that firms can, when optimizing the use of limiting factors, be both competitors and collaborators.

The interaction between the people, process, data, and things that make up the IoT can make a significant contribution to non-linear informational problems of this kind. As Kim et al. [15, p.154] point out "a healthy information flow is an indication of a healthy ecosystem". The smart technologies of the IoT are able to automatically capture, store, and disseminate data in near real-time, giving them the potential to maintain a healthy information flow that can facilitate and coordinate supply chain activities.

One of the key technologies of the IoT is Radio-frequency identification (RFID). Unlike the Universal Product Code with which firms can record the movement of goods by scanning them, RFID can track them without scanning, reducing time lags caused by gaps between scans. Furthermore, since modern RFID tags can be written to, data relating to the history of the goods, from production to purchase, can be recorded and accessed by authorized bodies [36]. While RFID has value in such backroom operations, other IoT objects have a role in other areas. Digital shelves for example, can be used in store to capture real time information about stock levels and i-Beacon can be used to capture consumer interaction with goods at the same time as pushing information to consumers.

Though IoT technologies can capture and distribute near-real time data, the issues of who can access the data and how much can be accessed, are a concern to many people. The existing IOS literature suggests that rights to access usually depend on the power relation between two trading companies [3, 33, 34]. In the case of supply ecosystems, keystone organizations may have a role in regulating information flows. This could be achieved through the provision IoT platforms (including services, tools, and technologies) that allow ancillary organisations timely access to the data needed for their decision making. The key function of the platform would be to make real time data available to members in order to alleviate informational problems. Figure 3 is a high level diagram which depicts an IoT platform for a supply ecosystem provided by a keystone organisation. The platform connects objects and feeds real time data about production events on the shop floor to an enterprise planning system within the keystone organisation that generates information for decision makers within and beyond the organisation. The platform also allows access to real time information about sales from retailers and possibly directly from consumers. Thus, a multilateral information flow can take place, instead of the rigid and linear flows that traditionally inform supply chain decisions.

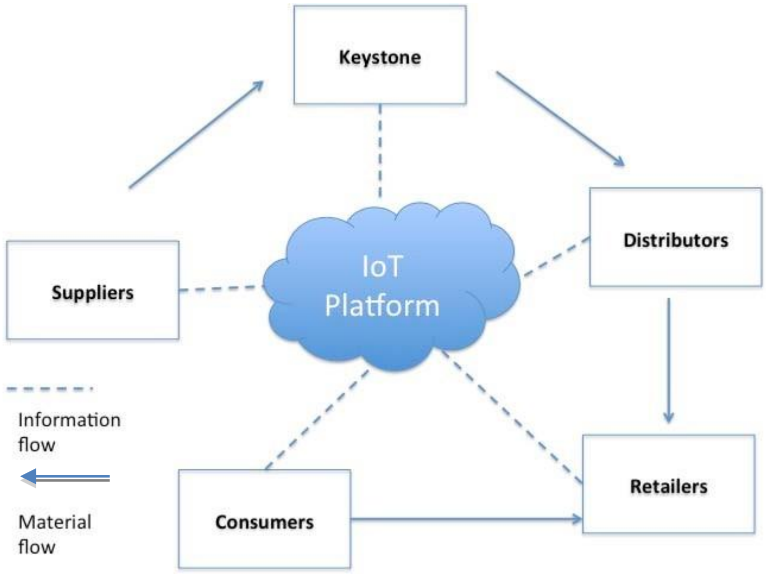

Figure 3. IoT platform for the supply ecosystems

CONCLUSION

The IoT and its technologies have the potential to play significant roles in supply ecosystems. As a network of objects, data, people, and process the IoT concept coincides with the idea of supply ecosystems which are networks of loosely interconnected entities whose performances affect one another's. In traditional inter-organisational systems, the focus is mainly on one-to-one relationships between two trading partners. By contrast, the IoT has the potential to connect information and to coordinate the activities of multiple parties, hence reducing informational problems caused by lack of, or delay in, bilateral communication.

There are however, challenges that may limit the potential of the IoT in the context of supply ecosystems. Firstly, issues affecting standardization and interoperability may hinder connectivity and communication, preventing the capture of some real time data. Secondly, negotiating who has access to what information remains problematic. Thirdly, the large volumes of data generated by the IoT pose a challenge for most organisations wishing to explore and exploit the data at hand. Fourthly, legal issue such as privacy and commercial confidentiality remain major concern for both organizations and consumer. Finally, the seamless integration between internal information systems and an IoT platform will be a challenge, not only for the keystone organization that provides the platform, but also for ancillary organisations, which may be parts of a number of different supply ecosystems at the same time.

The IoT may have a significant role in reducing the informational problems associated with supply ecosystems. However, in order to utilize IoT technologies, organisations will need to change the way in which they perceive information flows, relationships within a supply ecosystem, and the nature of competition.

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