TOWARDS A FRAMEWORK FOR FUTURE DRIVEN SUPPLY CHAIN NETWORKS USING SOCIAL INTERNET OF THINGS

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ABSTRACT

Two decades ago, the convergence of computing, embedded sensors and network technology ushered in the Internet of Things (IoT) as a means of delivering intelligent services. The 'things' in question - smart objects large and small - are collectively weaving themselves into the fabric of society, underpinning scores of smart city programs worldwide (including the Thailand 4.0 initiative). IoT is reaping massive benefits for industry too, especially in supply chain management (SCM) which provides our focus here.

More recently, Social Internet of Things (SIoT) signalled the fusion of IoT with social structure phenomena, enabling formation of trust-based communities among the afore-said objects - herein supply chain agents - similar to that of established social networks. Whilst SCM spearheaded use of IoT, we envisage SIoT enabled supply chains capable of dealing with both long standing issues (e.g. lead-time logistics and the bullwhip effect), but also a raft of contemporary challenges (e.g. devolved company operations and, stiffer quality compliance demands) which we assert, pare down, to matters of information management and trust in that information. These supply communities are based on smart objects that mimic behaviour of humans (and organizations) within a social network context. Thus they exist within their own social networks, playing autonomously by rules exerted by humans to protect their privacy and control interactions within other objects.

Here we apply an existing theoretical framework and smart object architectures to our notion of supply chain communities, characterized by appeal to a worked example highlighting how a SIoT-oriented supply network can mitigate the problems stated. This is a work in progress; a review paper with identified problems and a hypothesized solution now being validated; results of ongoing simulation are being analyzed for future publication.

Keywords: 1) Supply Chain Management 2) Social Internet of Things 3) SIoT Supply Chain

1. Introduction

Social media, block chain and Internet of Things; just some of the technologies that are disrupting markets, competition and companies, unleashing a digital tsunami that long ago rendered trusty benchmarks like Moore's law irrelevant. It is extraordinary to contemplate how communication has evolved since launch of the inaugural Explorer browser in 1995. Yet changes in how we communicate, connect and discover have major implications for business and people; quite simply they are *the* defining economic issue of our age. Consultant Brian Solis (2011) coined the phrase "digital Darwinism" to capture the essence of its impact.

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This is certainly true in the supply chain field which still primarily functions around distributed models, aged relics of the personal computer era. Conceptually, the idea of supply chains and their management thereof has existed for well over a century. Focal brands like Apple, Nike and Starbucks apportion success to having their supplier networks on a string. While most companies long since migrated operations from EDI to the Internet, the internet itself continues to evolve and therefore so too must supply chain practitioners. Investigating the potential of emerging technologies is a necessary part of that evolution which this paper is seeking to further.

In 2010, a new term entered the internet lexicon; the Internet of Things (IoT). IoT connects products, machines, and people; just as the original Internet connected computers. While the term is credited to Kevin Ashton circa 1999, its founding principles go back to the 1970s. However, the next increment in evolution of the internet is already here; inspired by social networks (SN), Social IoT (SIoT) proposes to share resources of smart, internet-enabled objects by assuming characteristics inherent in SNs so as to mimic human engagement. This paper explores potential application of SIoT to supply chain management.

Section 2 will review related literature; Section 3 presents an existing SIoT framework we are now applying to various supply chain problems; Section 4 'characterizes' this application via a provisional worked example and a set of metrics for evaluating our ongoing simulation and testing; Section 5 discusses our conclusions and current research agenda.

2. Literature Review

While our introduction emphasized technology over context, one cannot address specifics without discussing the conditions under which it exists. Therefore we first review literature on supply chain management prior to that on (S)IoT.

2.1 Supply Chain and Supply Chain Management

Dating back more than a century supply chains (SC) are considered by many as the backbone of a nation's economy. Global research company Gartner produce an annual list of companies that "best exemplify the demand-driven ideal of today's supply chain management (SCM)". Apple, Proctor and Gamble and Amazon so excel that they have held top five positions for at least seven of the last ten years. However, when SCs implode, the fallout is potentially massive; from music festival ticketing fiascos (Hughes et al., 2016), to chicken-less KFCs (Owens, 2018); from Boeing's forage for fasters (Kotha and Srikanth, 2013), to the Olympics that nearly didn't happen (Sousa et al., 2016).

2.1.1 Definitions of Supply Chain and Supply Chain Management

Many supply chain definitions have been proposed and yet consensus remains elusive. La Londe and Masters (1994), Lambert et al. (1998) and Lummus and Vokurka (1999) for example all portray agent based perspective SCs (suppliers, manufactures, retailers, etc.) through which materials flow (no mention incidentally of fiscal or information flows). Cox et al. (1997) and Quinn (1997) meanwhile adopt a process view spanning flows, aligned to activities, from the supplier's supplier to the customer's customer; what differentiates Quinn (ibid.) is an explicit recognition of information flow, although money flow remains implicit.

Christopher (1992) was more granular in differentiating between upstream (i.e., supply) and downstream (i.e., distribution) SC aspects, a theme also taken up by Mentzer, et al. (2001). The latter's understanding is particularly acute; not only are all flow types explicitly mentioned (as is the customer), but encompassed within are three degrees of supply chain complexity: a *direct supply chain* consisting of company, supplier and customer involved in upstream and/or downstream flows; an *extended supply chain* that includes suppliers of the immediate supplier and customers of the immediate customer, all involved in the upstream and/or downstream flows referred to; and an *ultimate supply chain* comprising all organizations involved in all upstream and downstream flows from the ultimate supplier to the ultimate customer.

In addition to defining the supply chain, several authors attempt to capture the essence of supply chain management. These can be classified into three categories: a management philosophy, implementation of a management philosophy, and a set of management processes. This betrays both confusion among academics attempting to succinctly convey its absolute semantics, and the intractable problems faced by practitioners attempting to establish a supply chain approach to management (Mentzer, et al., ibid).

As a *philosophy*, SCM assumes a systems approach viewing the supply chain as a single entity, rather than a set of fragmented parts, each performing its own function (Houlihan, 1988; Tyndall, et al. 1998). In other words, the philosophy of supply chain management extends the concept of partnerships into a multi-firm effort to manage total flow of goods from the supplier to the ultimate customer (Jones and Riley, 1985).

In contrast, when viewed as a *set of activities to implement a philosophy*, firms must establish management practices that permit them to act or behave consistently with the philosophy (Mentzer, et al., ibid.). As such, SCM is customarily seen through the lense of activities that constitute supply chain management, a synopsis of which from the literature includes: integrated behavior (Bowersox and Closs, 1996); mutual information sharing (Elram and Cooper, 1990); mutual risk/reward sharing and process integration (Cooper, et al. 1997); shared focus on customer service (Lassar and Zinn, 1995); and cooperation/building and sustaining long-term partner relationships (Tyndall, et al, ibid.).

Finally, as a set of *management processes* there are similarities in defining a process as a specific ordering of work activities across time and place, with a beginning, an end, clearly identified inputs and outputs, and a structure for action (cf. Cooper et al. ibid.; Davenport, 1993; Novack, et al. 1995). Monczka and Morgan (1997) concur, but go on to assert that supply chains, not firms, compete, a point well within the cross hairs of other altruistic interpretations (cf. Ha, et al., 2011; Xie et al., 2009; and Wu, 2013).

However, given that supply chains are a form of network, so network theory with its concept of strong and weak ties has potential to reveal interesting truths about SC behavior (Ketchen and Hult, 2006). Strong ties describe tightly coupled firms, whereas weak ties involve firms with more tenuous links; strong ties provide greater reliability, while weak ties enhance flexibility. Significantly, Granovetter (1983) argued that the relative strength of relational ties influenced how innovations flow through a social network. Specifically strong ties stifle innovation by fostering continuity, whereas weak ties foster innovation by stifling continuity.

Moreover, present day market dynamics suggest emphasis on creating a 'better', reciprocal SC community and on increasing sustainability and unselfish continuity of trading ties is becoming an anachronistic motivation as supply chain agents increasingly look to service their own needs and to increase value and convenience for themselves (Long, 2014; Egri and Váncza, 2013). One caveat is that the behavioral rules by which the autonomous SIoT objects previously referred to play is exerted by humans and as such, shaped by the values of those who prime (program) their behavior. Thus we define SCM as follows:

" Supply Chain Management is a term that refers to the management and management behavior (on a synergistic (strong tie)/antagonistic(weak tie) continuum) over the total bidirectional flow of commodities/services, information and remittance throughout an omni-channel order fulfilment network community, from upstream supplier(s) to the ultimate downstream consumer(s)".

2.1.2 A Brief History of SCM – Key Milestones

The genesis of supply chain management dates back, conservatively, to Frederick Winslow Taylor and his monograph 'Principles of Scientific Management' (Taylor, 1914). Taylor focused on improving labor-intensive, manual loading processes which rose to prominence during World War II. Central to 'Taylorism' is the notion of profit maximization by extracting optimum efficiency from machines and manipulating the workforce utilizing those machines in concert. However, counter claims argue such mechanisms reduce manual labor to commodity status, thereby alienating workers from management and so reducing output (cf. Mintzberg, 1989; Rhinehart, 2001).

During the immediate post-war period, pallets became the focus of logistics management. Indeed, they remain a staple for the storage and movement of supply chain goods to this day, largely due to their amenability to lifting and movement by jacking devices. However, it was the advent of personal computing in the 1980s that triggered radical transformations in SCM. From the humble spreadsheet, to Geographic Information Systems, from ERP/MRP systems, to complex scheduling algorithms, supply chain planning and execution took a quantum leap forward.

Enter the mid-1990s; enter world of globalized manufacturing, with many companies from the West in particular seeking to bolster profits still further (or at least remain cost-effective) by moving operations to factories in developing countries, such as China, Brazil, Eastern Europe and parts of South East Asia. The 'built and consumed locally' model of supply chain management had by now given way to complex international networks. That is to say, Taylorist control has been superseded by technocratic control (Burris, 1999).

Although a modern day factor in almost every industry imaginable, the notion of SCM flourished initially in manufacturing (Vrijhoef and Koskela, 1999). Indeed manufacturing today competes less on product differentiation and product calibre, and more on inventory turns and time to market (Tanzer, 1999). This is sometimes attributed to the net effects of a 'surplus society' (Nordström and Ridderstråle, 2007), where similar companies, with similar employees of similar e …ducation, generate similar ideas yielding similar products of similar quality, sold at a similar price.

2.1.3 Supply Chain Information Management and Confidence Problems

Without being too reductionist, supply chain problems can be pared down to issues of information management and confidence in that information. Some problems are long standing, for example unpredictable lead time logistics and the bullwhip effect; others issues are relatively fresh, including devolved company operations and real-time stock visibility (See Table 1). Irrespective, many older problems have been exacerbated by, and many fresher problems arisen from, a common root cause; globalization (Choi et al., 2012).

Table 1: SC Problems

SC Problem	Description	References
Lead-time logistics	Time interval between placing and receiving an order.	Carbonara and Pellegrino, 2017; Bandaly, et al., 2016
JIT (Just-In-Time) policy on inventory to sales ratios	Inaccurate forecasts which lead to receiving excessive or insufficient goods or materials	Folinas, et al., 2017; Rajagopalan and Malhotra, 2001
The 'Bullwhip' effect	Occurs when demand variability is amplified upstream in the SC.	Haines, et al., 2017; Metters, 1997
Lack of integration	Devolving of company operations across multiple warehouses, stores, or offices in different ports, towns and cities threatens inventory awareness	Verdouw, et al., 2018; Wiengarten, et al., 2016
Quality and compliance	Quality and regulatory compliance are 'front burner' issues in food and beverage production, and in any regulated sector where failure can cause loss or injury to consumers	Liu, 2018; Tran, 2018; Gold, et al., 2016
Lack of stock level visibility	Inadequate stock level visibility/ lack of real time threshold alerts is a recurrent procurement problem	Somapa, et al., 2018; Szymczak, 2013; Enslow, 2006

The role information plays in supply chain management (especially decision making) is not lost on other authors (cf. Forrester, 1968; Chow, et al., 2008; Voss, 2003) and therefore worthy of attention in this paper. More magnetizing still is the prospect of SIoT driving machine-enabled decision making with minimum or no human intervention.

2.2 Internet of Things

Internet of Things is changing *everything*, weaving itself into the very fabric of society. The 'things' in question are objects: from large objects (cars); to small objects (wearables); and often bizarre objects (connected rectal thermometers anyone?). IoT has been actualized by advances in microcontrollers, microprocessors and other technologies along with infrastructures that connect them. This convergence of computing, embedded sensors and network technology ushered in a new era delivering intelligent goods and services sustained by voluminous data (Williams, 2014). We assert that IoT impacts on mankind at four nested levels contextualized vis-à-vis the supply chain as follows:

- For *individuals* at work, in warehouses, plants and factories, there are obvious benefits in terms of: *communication* (real-time instructions can be transmitted visually via smart glasses, or audibly using two-way headsets), *productivity* (where again pick-by-vision smart glasses enable hands free operator selection) and *safety* (where GPS/ beacon technology can prevent employees entering hazardous areas (Korman and Zulps, 2017).
- For *organizations*, IoT is concentrating minds; a seismic shift as against an incremental nudge and it demands a gamut spanning re-imagination of supply chain orthodoxies on value creation and value capture - everything from how materials are sourced, and how products/ services are designed, developed and sold, to leveraging customer experience for optimal growth. All of this accomplished through '*talking*': talking to customers, talking to employees and yes, 'talking' to the machines, plant and products (including living organisms such as plants and farm animals) that are becoming as much part of the modern supply chain as people and companies (Chong, 2013; deHaan, 2015).
- For *sectors* forced into to root and branch corporate rebooting by capricious consumption, tangled competition and new kid on the block offerings that pulverize value chains, traverse boundaries and dis-intermediate supply chains, a double whammy dilemma looms large; "which business are we in and who are our competitors?" (Porter and

Heppelmann, 2014; 2015). Whereas the internet is a supply chain enabler, IoT is its disruptor-in-chief, a shockwave to the established order of 'competitive forces' (Porter, 1979).

- For *society* at large IoT is fuelling the spread of 'smart cities', conurbations targeting measurable improvements in the life quality of urbanites (Jin et al., 2014). Established in places like Dubai, smart cities are now taking seed here through an ambitious government initiative labeled Thailand 4.0. In a recent interview (Limsamarnphun, 2018), Michael Dell echoed a prevailing consensus on the societal dynamics at play here, (cf. Katz and Bradley, 2013; Abbasi and Nilsson, 2012; Rossi et al., 2013); namely availability of massive data harvested from IoT devices allied to shifting macro supply chain trends indicate our future urban smart cities will be catered to by decentralized production networks, be active in literally "millions of local markets", and (here's the crux), be predominantly autonomous and self-organizing.

While the number of internet connected devices is expected to exceed 50 billion by 2020, the IoT revolution is still in its early throes (Feller, 2018). Equally arresting is that IoT is the outcome of more than half a century of internet evolution (taking Licklider's (1962) "Galactic Network" concept as our baseline); so in the here-and-now it may seem to be its culmination. Not so. To borrow slightly from Martin Rees, the internet 50 years hence will be in every which way different from today, as humans are from bacteria. Continuing the biotic theme, recent comments about IoT from Intel's Jon Stine point to global business being in the midst of "accelerated Darwinian natural selection" where supply chain innovation will be a key factor in determining whether brands survive or thrive.

2.3 Social IoT and its Potential Application to the Supply Chain

In the midst of this long haul transformation, we focus here on a burgeoning offshoot of IoT now taking shape. Social IoT (SIoT) as a term first appeared in (Atzoni, et al.) 2011. Analogous to Social Networks (SN) for people, this fledgling paradigm introduces the concept of social relationships among objects where said objects autonomously mimic human behavior using social networking principles including 'friend' selection, interaction, and communication in finding desired services (Liu et al., 2017; Nitti et al, 2015; McPherson et al. 2001). With SIoT research still at an embryonic stage, practical applications are difficult to come by. However the idea of SIoT is growing rapidly as it has numerous potential uses (Atzori et al. 2012), one of which we consider here.

As stated previously, this paper explores application of SIoT to Supply Chain Management, *prima facie* a natural combination owing to their similarities. To underscore these similarities we again turn to Brian Solis (2011): *"Social Media is greater than the sum of its parts, but it is these parts that define the socialization of business. Today consumers interact with peers, brands and influencers in social networks at varying levels across more industries than you might possibly believe".*

Solis goes to the very heart of that which sustains both social networks and supply chains (recall our own definition from 2.1.1); in a word, **synergy**. Both are greater than the sum of their parts. Supply chain partner goals are (or perhaps were) aligned to help each other grow, meet customer demand and continuously optimize the cost of doing business. This synergy we argue closely bonds SIoT and SCM; and yet, it also has the capability to be antagonistic (rather than synergistic) in line with mutating supply chain trends (explained in 2.1.1). As such, and as this paper aims to demonstrate, SIoT can potentially address both long-standing supply chain issues as well the raft of 'fresher' challenges identified in Table 1.

3. Proposed SIoT Social Supply Chain Network Solution

Our proposed solution to the supply chain problems featured takes as its starting point the notion of objects assuming humanoid social networking behaviors, together with the major components necessary to realize that aspiration as described in Atzori et al. (2011). As such, objects establish social relationships with other objects autonomously based on appropriate policies (rules); the recurring phrase used is one of objects *mimicking* human behavior. This subsection describes the detail of that framework derived from Atzori et al. (2012), which proposed a possible architectural model for SIoT that we believe can be usefully applied to SCM. We now summarize the features and functionalities of smart objects (objects we envision assuming the role of supply chain agents) followed by the systems architecture for our Social SC network.

3.1 Objects Functionalities

Atzori et al. (2011) identified appropriate features and functionalities for the establishment and management of social relationships between objects in such a way that they are navigable when integrated into a social network context (see Figure 1).

Central to every object are the functions of ID management, object profiling, and owner control. Assigning an ID to an object universally identifies all possible categories of object. Object profiling meanwhile functions to determine static and dynamic information about objects, while owner control enables the identification of activities that can be performed by an object; e.g., information that can be shared with other objects or the type(s) of relationship to be established (with another object).

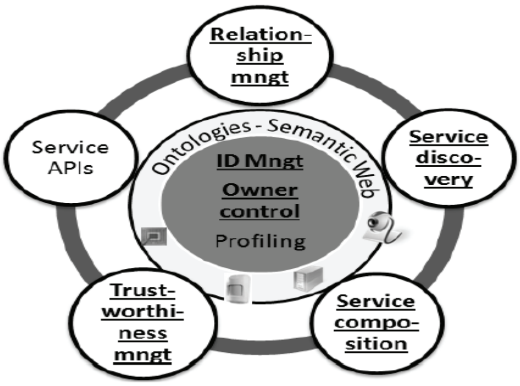

Figure 1: Features and Functionalities of Smart Agent(s)
(source: Atzori et al., 2011)

Atzori et al. (ibid) also identified further components deemed necessary in a smart object, including service discovery that enables objects to seek out other objects that can provide whatever services are required, when they are required (again the parallels with SCM chime with our view of fundamentally synergistic agents favoring strong ties, but with the capacity to become self-serving whenever needs dictate). Next up, the relationship management function allows objects to start, update and terminate relations with other objects, whereas service composition enables interactions between objects. This relates either to retrieving information about the 'real world', or finding services from other objects.

Trustworthiness is vital both in business and in social networking. The trustworthiness management component is therefore able to understand how information provided by other objects needs to be processed; reliability is based on behavior of other objects and strictly related to the relationship management feature. Nitti et al. (2014) defined two models of trustworthiness; with the first, every node computes dependability of its 'friends', and opinion of friends in common with potential service providers. Secondly, using a structure of distributed hash tables, information regarding each node is stored and distributed with the intention that any node can use similar information. Finally, the APIs service component is comparable to that required in social networking systems as an interface to any SIoT network. Using these functions, smart objects can form communities based on shared dyadic ties.

3.2 System Architecture

Atzori et al., 2011 also proposed a SIoT system architecture comprising: a *sensing* layer devoted to data acquisition and node collaborations in short local networks (i.e. between objects within a SC enterprise); a *network* layer aimed at transferring data across different networks (i.e. between SC enterprise objects); and an *application* layer used to deploy IoT apps together with middleware functionalities.

The architecture (Figure 2) is described both from server side and object side. The server side includes the network and application layers; the application layer itself contains sub layers including a database and metadata containing social member profiles, activities carried out by objects and descriptions about the data itself. Another database stores relevant ontologies of social activities as a semantic view; semantic search engines are used to extract this view.

The object side architecture may vary depending on the characteristics of an object. If an object is a dummy with the lowest functionality (e.g. it either has an RFID tag or sensing device) whose sole purpose is sending signals to other objects' gateway, then said gateway needs to be equipped with the whole set of layer functionalities.

However, if an object can detect the physical world data and transmit over an IP network, then network functionality will be assigned to that object (i.e. a gateway with an application layer is not required); the application layer in the server with gateway application layer functionality would be sufficient. Also, if an object is smart (e.g. a smart phone) it may implement functionality of all three layers with no gateway required.

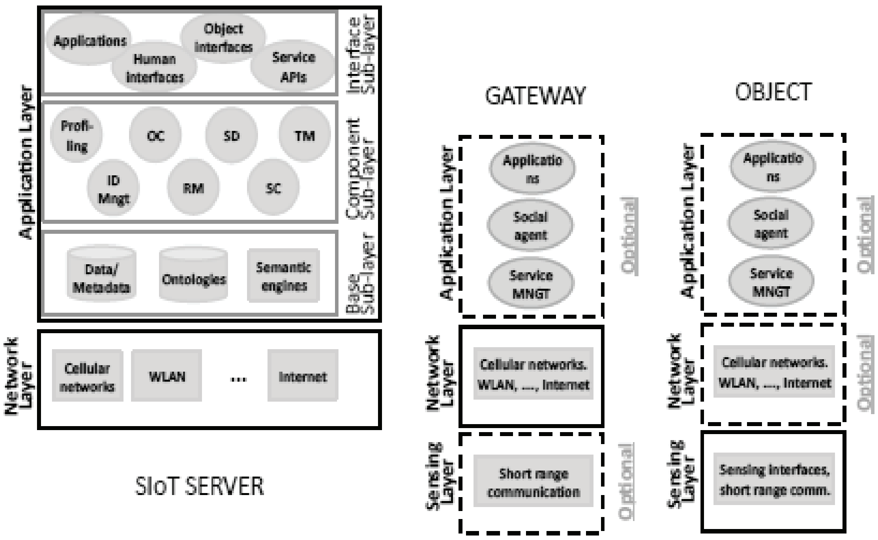

Figure 2: Layers of the Systems Architecture
(source:Atzori et al., 2012)

3.3. Social Supply Chain Network

In line with the above discussion we propose a social supply chain network that autonomously orchestrates SCs and allows them to interact directly within and across other SCs. Within the network, organizations can be considered agents composing an existing and/or new system built with SIoT capabilities. This includes a sensing layer; network layer; and application layer given that agents are smart and implement the functionality of all three layers. Agents will also have core components when socializing which include service composition, service discovery, relationship management, trustworthiness and service APIs. Therefore, in keeping with the theme of this paper, supply chain agents mimic people to provide fully automated information collection, analysis and use of monitoring and evaluation data. This allows SC agents to start new connections, discover new services, exploit the capabilities of each other, and exchange information. With these aforementioned capabilities and functionalities a supply chain agent (e.g., manufacturer) will contain several different objects aligned to departments 'inside' their business (e.g., sales, warehousing, production, etc.) that communicate with each other and also across the entire (supply) network to fulfill the efficiency and effectiveness of that operation.

The SC we describe addresses all six IM challenges listed in Table 1 accordingly:

- *Lead time logistics*: SIoT capabilities and functionalities which enable objects to extract the semantic view and discover and interact with agents who can provide the services required come to the fore here. They allow calculation of precise lead times and agreeing of a preferred object with whom to maintain contact (subject to soft tie caveats). This leads objects to communicate and interact only with those who can satisfy their order preference(s) which in turn results in reduced latency between initiation and execution of the process, along with a commensurate reduction in waste.
- *Just in time policy*: the sensing and networks layers which are devoted to data acquisition and node collaborations in local (internal) networks and also across different networks (between enterprises) using the semantic engine capability are utilized here. Agents can detect and respond dynamically to real-time conditions; by analyzing data from engines and sensors monitoring the environment, e.g., temperature, humidity and traffic levels, transportation becomes more efficient, reliable and safe.
- *Bullwhip effects*: with SIoT capabilities and functionalities allowing agents to interact with each other comes the ability to retrieve information and extract the semantic supply chain view. This improves communication allowing agents to rigorously manage the flow of goods, services, finances and information (in quasi-real-time) across the supply chain; the net benefit is to sharpen agent synchronization in a way that is responsive to customer needs and hence has potential to lower total costs and thus mitigate the bullwhip phenomenon.
- *Lack of integration*: SIoT capabilities and functionalities allowing data acquisition and collaboration (inside and across enterprise boundaries) enables full integration of agents. This potentially opens the door to absolute tracking of purchase orders, and improved monitoring of stock levels e.g., an agent may autonomously trigger replenishment or production of commodities if warehouse store reaches a minimum threshold.
- *Quality compliance*: the contractual requirements established by national authorities relating to quality (and safety) are audited by a quality assurance agent (object). Using the SIoT capabilities described, a quality assurance agent sends contractual requirements to the suppliers and manufacturers and then subsequently checks whether information has been provided to fulfill such requirements.
- *Lack of visibility*: interaction between agents, data acquisition and node collaboration in local networks, combined with transferring data across different networks and extracting the semantic SC view allows retrieval of information about current 'real-world' problems.

Clearly vast amounts of data are generated, gathered and exchanged by each agent. However, valuable though it is, this value increases exponentially when shared and integrated with data from other agents and sources such as products, machinery and plant (Porter and Heppelmann, 2015). SIoT also yields process improvements by integrating functional units across supply chains to identify when and where, e.g., defects are being introduced. In addition, SIoT capabilities and functionalities improve trust in data exchanged, allowing agents to fully grasp how information from other objects has to be processed, thereby building reliability based on other agent's behavior for use by the relationship management service.

4. Characterization

In this section we present a step-by-step narrative (worked example) of our framework to concretize and explain its underlying detail. It should be stressed the approach we are proposing is best-suited to loosely-coupled supply chains that consist of relatively flexible and interchangeable relationships among suppliers, customers, and other agents. Since this remains a work in progress, ongoing simulations to prove concepts proposed herein are currently being analyzed for future publication. We do however state the metrics being used to evaluate these simulations.

4.1 Social IoT Supply Chain Network Narrative

Consider a hypothetical supply chain for baked goods that starts upstream with suppliers of raw ingredients (materials) and ends downstream with delivery of the product to the end consumer. As with any industry, baked goods supply chains are subject to numerous variations; so to circumvent all possible end to end perambulations, we borrow from Mack, 2018. Where possible however, conceivable variations are highlighted.

Raw ingredients are often supplied directly to baked goods manufacturers from **farmers** or possibly **agricultural cooperatives**. Flour, sugar, wheat and other commodities are generally interchangeable, so a manufacturer may buy from whichever supplier offers the lowest prices. However, other ingredients, such as flavorings or special types of flour, might not be widely available, meaning a manufacturer must seek out affordable suppliers.

At the **manufacturing** stage of a supply chain, a baked goods company converts the raw ingredients into a product, such as bread, cookies, cakes, patisseries and many other items. As previously indicated, the ensuing manufacturing processes will depend entirely on each given company's plans for the downstream stages. If for example the baked goods are to be shipped worldwide, preservatives must be added during the manufacturing process. Alternatively, if the goods will be packaged for home preparation, an entirely different production process will unfold.

The **distribution** stage involves moving products from the manufacturing production facility to wherever the consumers are. Distribution can be simple, or it can involve many distinct channels. For example, a baked goods company might sell its wares directly to consumers through a factory outlet and its website, as well as to wholesalers. **Wholesalers** are merchants that buy products from manufacturers and use their expertise in shipping and distribution to re-sell the products to retail stores. Baked goods manufacturers might also sell their products directly to **retail stores**.

Delivery of the products to **consumers** marks the final stage in this (or any other) supply chain. Most consumers buy baked goods from a retail store, such as a supermarket or specialist bakery (again purchases may be online with home delivery). The retail store can promote such products in a variety of ways, such as choosing a visible position on its shelves or by offering samples to customers. Such promotions may or may not impact significantly on demand and therefore may or may not affect upstream supply chain activity.

4.1.1 Characterization Walkthrough

Using an app object on their smart phone, wearable or connected device, **consumer** agents access a social supply chain community to locate possible retailers able to accommodate their preferences and thereupon place an order. Features like service discovery, relationship management, trustworthiness, and service composition within the sensing, network and application layers enable him or her to identify their preferred agent (retail store) from which to purchase baked goods. Consumers may trade off store proximity against price of goods in reaching a decision; alternatively they may opt to purchase online with home delivery (and to pay with a mobile app such as Apple Pay or Google Pay) - which is the assumed case here. Using the service composition functionality, the store's retailing system interacts with smart shelves, bristling with a myriad of sensors capturing copious amounts of data, to locate the ordered items (thereby freeing up manpower to focus on other duties). The store shelves then interact with store staff - equipped with pick-by-vision glasses - by sending notifications about consumer orders which are then prepared for shipment. When assembled for dispatch, staffs communicate with the logistics agent (object) to inform them that a delivery is queued. By extracting real time information using the semantic view, the logistics agent-object detects whether that delivery can be made and if not requests reschedule.

In this case, the **retailer** buys baked goods either directly from a manufacturer's distribution centre or else from a wholesaler (who also buys their products from the manufacturer's distribution centre). Interacting with the store's smart shelves, the retail store analyses the semantic view to examine item stock levels. If necessary, the retail store agent object reaches out via the social SC community network to discover a manufacturer distribution centre or wholesaler that can provide the baked goods required (with the preferred preferences). Once located, the order is placed using SIoT functionalities like service discovery, relationship management, trustworthiness, and service composition via the sensing, network and application layers. Moreover, given that baked goods are perishable, so the retailer's shelves smartly communicate to staff signaling any inedible and/or expired products to be either thrown away or else relocated when approaching their expiry date.

When a **wholesaler** buys produce from the manufacturer's distribution centre, it does so in response to on hand stock insufficiencies identified by analyzing the sensor and engine data and also from customer needs. Moving products from the manufacturing production facility to wherever the consumers are, the machinery systems first prepare and package the baked goods; then, the **distribution** agent analyses the SC semantic view to retrieve information (new production and/or consumer orders) requiring dispatch. This involves using the service composition function for object interaction and the sensing layer with devoted data acquisition and node collaborations in local (internal) networks in addition to semantic engines that are used to extract information.

The **manufacturing** agent converts raw ingredients into baked goods, scheduling production around orders received and current stock on hand. If stock is insufficient, caused for example by a sudden unexpected order spike, a schedule agent updates the manufacturer agent which in turn may reprogram production machinery (e.g. dough mixers, cutters, oven-feed conveyors and of course ovens). Also, for smooth operation at the production side for instance, the sensing layer and semantic engine allows sensing and detection of real-time conditions, analysing such data to anticipate machinery failures and other delay problems before they happen; or to reschedule production and update other agents.

When the manufacturer's warehouse is in need of replenishment, it seeks out and then sends a purchase order for the raw ingredients required to a supplier – in this case **farms** or **agricultural cooperatives** who can satisfy their preferences. Or to be more precise, SIoT functionalities (service discovery, relationship management, trustworthiness, and service composition, together with the sensing, network and application layers) are used to canvas the SC community network to leverage the best deal since, as stated previously, the manufacturer can be selective with suppliers because many raw ingredients are interchangeable. The chosen supplier(s) then provide the required ingredients and undertake distribution. Responding to received orders from a manufacturer, the distribution agent analyses the required order to arrange dispatch, communicating with the transportation system to complete delivery.

4.2 Proposed Evaluation Measures

When evaluating supply chains one does so on the basis of performance metrics which can be qualitative or quantitative (Chan, 2003). A wealth of both types have been proposed including financial, operational and environmental measures (Zu et al., 2010), and asset management, information visibility and customer service measures (Closs and Mollenkopf, 2004) respectively.

Table 2: Effectiveness and Efficiency Metrics

Dimensions	SC Problems	Metrics	Description	Reference
Effectiveness	Lead-time logistics	Order fulfillment lead-time	Average time between order entry and time of order delivery	Tsanos, et al., 2014
	JIT (Just-In-Time) policy on inventory to sales ratios	Perfect order fulfillment	Ratio of orders delivered: 1. Complete, 2. On date requested by the customer, 3. In perfect condition, 4. With the correct documentation over total number of orders	Tsanos, et al., 2014
	Bullwhip effect			Tsanos, et al., 2014
Efficiency	Lack of integration	Supply chain cycle efficiency	Ratio of time in which inventory is active in the supply chain over total time spent in the supply chain	Tsanos, et al., 2014
		Supply chain flexibility	Average time required for the supply chain to respond to unplanned 20% increase in demand without service or cost penalty	Tsanos, et al., 2014
	Quality and Compliance	Information Visibility	The quality of information usefulness compared to total information exchanged in terms of : 1. Freshness 2. Accuracy	Caridi, et al., 2010

Dimensions	SC Problems	Metrics	Description	Reference
	Lack of visibility	Information Visibility	The quantity and quality of information usefulness compared to total information exchanged in terms of: 1. Quantity; 2. Freshness; 3. Accuracy	Caridi, et al., 2010

A recurring theme is to classify supply chain measures along two dimensions, namely *effectiveness* and *efficiency* (cf. Mahadevan, 2017; Sillanpää, 2015; Gunasekaran et al., 2004; Tsanos et al., 2014; and Caridi et al., 2010). To evaluate the effectiveness and efficiency of our framework by simulation requires use of quantifed measures; from those listed previously we selected and combined the works of Tsanos et al. (ibid.) and Caridi et al. (ibid.) on the basis they most closesly align with our position that effective and efficient information management lies at the epicenter of supply chain performance (see Table 2).

5. Conclusions and Future Work

Dating back more than a century supply chains are considered by many to be the backbone of any nation's economy. So when they implode, the fallout is potentially massive; and as supply chains lengthen the potential for implosion increases commensurately. With global business in the midst of "Darwinian natural selection", supply chain innovation is a key factor in determining whether brands survive or thrive. First the internet and subsequently IoT 'lessened' the human interface and thereby drove down costs.

Recently a burgeoning offshoot of IoT began taking shape; Social IoT (SIoT) is analogous to Social Networks like Facebook or Twitter and even employs comparable mechanisms such as 'friend' selection. The difference however is that with SIoT smart connected objects rather than people form relationships. Given that supply chains are, in essence a form of network, so application of SIoT to SCM is an entirely logical proposition (yet to be tested). Moreover, like social networks, supply chains are awash with information and therefore deploying SIoT in an information management capacity to solve SC IM problems merely reinforces our hypothesis. In short, while the internet revolutionized SCM, the internet itself continues to evolve and therefore so too must the supply chain community. Investigating the potential of SIoT or indeed any emerging technologies is a necessary part of the evolutionary process that this paper has attempted to further.

SIoT currently enjoys little mass appeal, with virtually zero practical applications listed on Google scholar. However, a small number of papers have discussed this new paradigm conceptually. Having reasoned from an extensive literature survey documented here) and discussions with practitioners that all supply chain problems (at least those relating to effectiveness and efficiency), are *de facto* problems of information management and ought to be structured as such; the idea of using elements from social networking with the Internet of Things, thus enabling objects to mimic humans by autonomously establishing social relationships and discovering and selecting services/ information offered by distributed objects (and networks) with access to the physical world, maps structurally to the supply chain problems identified. The result is to render supply chains as interconnected networks, channels and node businesses that combine in the provision of products and services required by end customers. The smart objects' behavior intentionally balances strong and weak ties and hence reliability and flexibility. Our contribution is therefore to exploit this and to apply it in a way which we have argued has potential to solve several SCM problems.

It should be stressed the approach we are proposing is best-suited to loosely-coupled supply chains (or rather communities) that consist of relatively flexible and interchangeable relationships among suppliers, customers, and other agents. Interchangeable because the final product has a modular architecture (think cars or computers for example) , or as demonstrated in section 4, baked goods and other food/beverage produce.

This remains a work in progress and the baked goods example presented was simply intended to concretize what is still very much an abstract concept. Currently the authors are working towards publishing more rigorous proof of concept using discrete event simulation. Specifically we have coded the framework described in Section Three, along with the metrics introduced in Section Four in MATLAB/Simulink. Using multiple random permutations of the variables Table 2, we are now running simulations which are then checked against the appropriate metrics. This will tell us under what conditions (i.e. which parameter permutation) the framework provides optimal levels of effectiveness and efficiency to avoid the IM problems stated. Those findings are expected to be published by the end of 2018.

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