Blockchain and Artificial Intelligence – Managing a Secure and Sustainable Supply Chain

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Abstract. Supply chain management is often the most challenging part of any business that manufactures, sells goods, or provides services. Regardless of whether the operations are mostly physical or online, managing supply chains largely relies on being able to manage shared information securely, efficiently and effectively. Managing the information within the context of a closely-knit supply chain offers the benefits of extra resilience and ability to recover quickly from major disturbances. The authors propose here the development of a blockchain enabled and Intelligent Agent supported supply chain community that will provide a secure, intelligent, responsive and sustainable operational partnership. The technology used is simple, reasonably priced and the expected benefits considerable. The paper reports on work in progress on an enhanced prototype system.

Keywords: Blockchain, Supply chain, Intelligent Agents, Artificial Intelligence, Sustainable ecosystem.

1 Introduction

The global economy is highly dependent on China and more particularly supply chains across the world are dependent on Chinese input and drive. China's share of global trade in some industries exceeds 50%—in the global trade of telecommunications equipment, for example, China's share (by volume) was 59% in 2018. Because of Covid-19, it is likely that this period of globalization will not only come to a halt, but it will reverse. Some multinationals were forced under the conditions to relocate their supply chains away from China to other parts of Asia and even closer to their core operations, in Europe and the Americas. Such moves will lead to building quasi-independent regional supply chains, allowing global companies to provide a hedge against future shocks to their network [1].

Supply chains are difficult to set up and even more difficult to move, especially in the automotive sector. As more firms make a shift to such operation paradigm, the shift to regionalized supply chains will be the predominant outcome of this crisis. Optimizing transportation and storage for risk mitigation though is not an easy, safe and inexpensive venture and companies will need advanced technologies to support such significant

changes and mitigate the relevant risks. Smart ways of managing supply chains will need to be engaged to provide security of transactions and operations, and intelligent management that will support the creation of sustainable local and regional supply chains.
Blockchain driven and Artificial Intelligence managed supply chain could be the answer to securing the operations of a local / regional supply chain and providing the intelligence required to instill enhanced efficiency in operation. The above will yield sustainability into the supply chain, allowing it to counter the increased costs of shifting away from Asian markets and absorbing the higher wage costs of western economies [2, 3].
Blockchain offers a secure ledger for sharing documents. This is the founding stone of the development and operation of a digital community that supports a supply chain in any industry. Such digital communities are not a new concept as they date back from the dot.com era of the early years of the 21st century, called Valued Added Communities (VAC) [4, 5]. Partners in the digital community share information of transactions allowing other partners to complete complementary transactions as they collaborate in fulfilling a partner's requirements and at the same time meeting their own objectives. The level of detail shared between members of the VAC depends on the type of partner, but all participants in the supply chain receive notification of every transaction completed between members of the VAC offering transparency that supports sustainability.

2 Supply Chain in an Uncertain World

Disruption is an everyday part of life arising from a myriad of circumstances. Normal service can be restored relatively quickly in some cases depending on the impact, its duration and the effect it might have on society and the economy. Supply chain flow usually remains constant and continuous, with just the odd blip, now and again. This was the view up until the early part of 2020 and before the Covid-19 pandemic. This unique situation has placed a different kind on supply chains and has forced companies to rethink their strategies and their approach to sustainability of supply chains.

2.1 What is a Supply Chain?

In the realm of manufacturing, a supply chain is the process of the flow of goods from the upper echelons of value creation to the end customer consumption. It is a form of symbiotic connection in which customers and suppliers work together to achieve the best interests of each other, buying, converting, distributing and selling goods and services to create specific final products and to add value to their organizations.
Through the control of information flow, logistics and capital, intermediate products and final products are prepared from the procurement of raw materials and supplied to customers by distribution networks. All such systems contribute and are part of the supply chain. Failure of one system can affect the normal operation of the supply chain. Having alternatives available to pick up the disturbed work or services can lead to seamless operations and efficiency in performance [6].

All of the above depends on secure, transparent, and intelligent management of information. This is where Blockchain can contribute to support sustainable supply chains [7].

2.2 A Secure and Sustainable Digital Supply Chain

Political, economic, social, technological, environmental and legal factors have constant, profound, often unexpected, and dramatic impacts, both positive and negative, on supply chains and the wider domain interests they serve. Certainty is an elusive commodity. An agile, data-driven supply chain ecosystem will be better prepared to react and mitigate such impacts.

Sharing assets and capabilities across supply chains will increasingly provide the foundation to achieve the greater flexibility necessary to cope with an uncertain future. Collaboration within the supply chain ecosystem is vital.

Sustainability is the ability for a business to operate successfully without compromising the ability of future generations to meet their own needs. To be sustainable, supply chains must become more flexible and responsive whilst incorporating increased resilience and traceability. Once again, technology and innovation will be the enablers with engineers at the heart of the ecosystem, delivering supply chain success [6, 7]. Blockchain can contribute to enhanced traceability and Artificial Intelligence algorithms can provide the technological edge to make supply chains, flexible, responsive and efficient, while maintaining the transparency of transactions that support all members.

2.3 Value Added Communities

The quest for flexible and sustainable supply chains based on transparency and sharing of information is not new to the business world.

In the past successful businesses evolved into colossal organizations that incorporated a large number of business functions. These shared little information or direct interaction and were managed centrally through a complex web of activities that contributed little towards customer satisfaction or to the organization's core objectives. The standalone mega organization is too dysfunctional for the modern business world. E-businesses were the first to realize this at the dawn of the 21st century. They had made information the key driver of all activities; retaining only the core functions of their business and focusing only on those activities that contribute directly to the attainment of competitive advantage. In this way, e-businesses have become more flexible and responsive to customer requirements, creating additional value for their customers and achieving a larger customer base.

Notwithstanding some spectacular failures at the turn of the 12st century, the dot-com era has enhanced the experience in this area and has shown that the ability to create "added value" is the key factor of success in the modern competitive environment. To reap fully the benefits of Internet technologies and extract value for both the business and the customer, e-businesses realized that they needed to further exploit the wealth

of information they gather by sharing it across businesses that can be seen as complementary within the supply chain. This led to the formation of mutually collaborative online communities known as “value-added communities”.

Value-added communities (VACs) are groups of businesses that function at the various points of the supply chain and are connected electronically to enable optimal response to customer demand. At the same time, this electronic network should offer maximum return for the “community” as a whole. This is done through the establishment of a series of communicating computer systems that support the key activities of each of the participating businesses. Customer demand is used as the empowering input for all the above systems. Through the electronic business facility of the trading organization (brand-owning company), information is processed, filtered and forwarded through the relevant networks to other computer systems such as MRP, MRPII, ERP, that each may support the function of one of the members of the “community”. Thus, planning and coordination of activities within the “community”, can be performed according to evolving market trends and continuously revised on a real time basis [4].

E-business development though and especially the above concept of VACs involves a considerable level of uncertainty and risk. Developing a VAC involves integrating a number of different business functions, belonging to different organizations, which may be linked to diverse and conflicting objectives, or differing levels of commitment to the evolution and functioning of the VAC [8].

In the early days of value added communities, communication was based on slow internet connections, email systems and simple text messaging, with information shared on a peer-to-peer network like architecture as shown in figure 1 below.

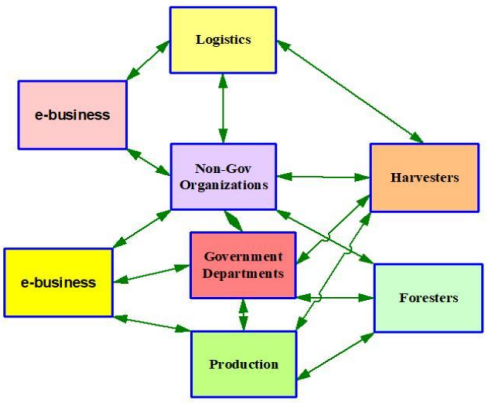

Fig. 1. Value Added Community structure [5]

Covid-19 is beginning to reshape trade fundamentally by accelerating the trend towards shortening supply chain reaction times. Intelligent agents operating on behalf of various members of a blockhain supported VAC can utilize the shared information in negotiating the completion of transactions. The security and privacy offered by blockchain technologies supports the transparency of such transactions and the sharing with the partner members [9].

3 A Distributed Ledger & Blockchain Technology

In the business context, a ledger, or general ledger, is defined as a central repository of the accounting information of an organization in which the summaries of all financial transactions during an accounting period are recorded.
In the common business environment, a digital ledger is stored in a central server, and distributed access is provided with, read and/or read/write privileges. To assure security, there is some sort of access control mechanism that authenticates users, enables secure access, and enforces access restrictions (for example, read-only).
In a system with ongoing transactions and a heavy volume of read and write access, the central server model can be inefficient.
An alternative is a secure distributed ledger, which consists of an expandable list of cryptographically signed, irrevocable records of transactions that is shared by a distributed network of computers.
Every participant has the same copy of the ledger. Each participant may propose a new transaction to be added to the ledger and when consensus that the transaction is valid is reached, it is added to the register.
Trust is central in a distributed ledger and it involves two concepts:
Security protocols and mechanisms, generally based on Public-Key Cryptography, ensure that the creator of each transaction is authenticated and validated.
Transaction creators prove they are entitled to make a transaction by satisfying the particular conditions associated with this application. Meeting these conditions involves the use of a secure digital signature [10].
Distributed Ledger Technology (DLT) is based on peer-to-peer (P2P) network technologies enabled by the Internet, but internet-based transfers require ensuring that an asset is only transferred by its true owner and ensuring that the asset cannot be transferred more than once, i.e. no double-spend. The asset in question could be anything of value. by Nakamoto in 2008 proposed a novel approach of transferring “funds” in the form of “Bitcoin” in a P2P manner. The underlying technology for Bitcoin outlined in Nakamoto’s paper was termed Blockchain, which refers to a particular way of organizing and storing information and transactions. Subsequently, other ways of organizing information and transactions for asset transfers in a P2P manner were devised – leading to the term DLT to refer to the broader category of technologies.
DLT facilitates the recording and sharing of data across multiple data stores (ledgers), which each have the exact same data records and are collectively maintained and controlled by a distributed network of computer servers, called nodes [11].
Blockchain is a particular type of DLT, uses cryptographic and algorithmic methods to create and verify a continuously growing, append-only data structure that takes the form of a chain of so-called ‘transaction blocks’ – the blockchain – which serves the function of a ledger.
One of the members (nodes) initiates a new addition to the database. A new “block” of data may contain several transaction records. Information about this new data block is then shared across the entire network, containing encrypted data so transaction details are not made public, and all network participants collectively determine the block’s validity according to a pre-defined algorithmic validation method termed as consensus

mechanism. Only after validation, all participants add the new block to their respective ledgers (figure 2). Through this mechanism each change to the ledger is replicated across the entire network and each network member has a full, identical copy of the entire ledger at any point in time. This approach can be used to record transactions on any asset, which can be represented in a digital form. The transaction could be a change in the attribute of the asset or a transfer of ownership.

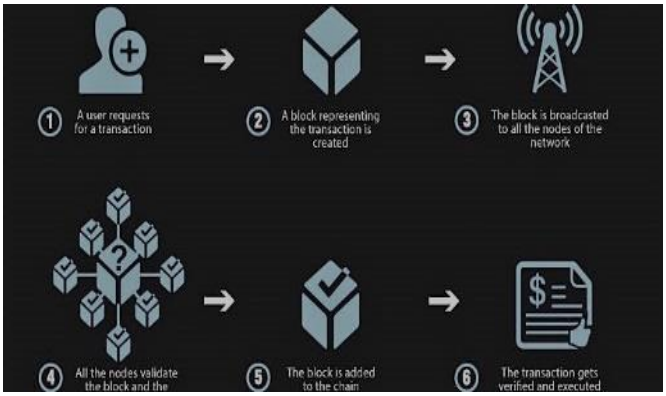

Fig. 2. Block Creation and Validation

Blockchain thus becomes a vehicle for trust, through the transparency of the public record and the validation of inputs from unconnected parties along the supply chain.
Distributed ledger supply chains are being developed and tested around the globe on different types of application domains. Directly linked to supply chains is the example of the IBM Food Trust blockchain, which went live as a commercial product in 2018. During the proof of concept phase, IBM worked with Walmart, who challenged them to trace mangos from farm to store.
Using Walmart's existing systems, this process took almost a week to run, while the blockchain-based system completed the task in 2.2 seconds [7].

4 An Intelligent Digital Supply Chain

In essence, blockchain is a data structure that makes it possible to create a digital ledger of transactions and share it among a distributed network of computers. After a block of data is recorded on the blockchain ledger, it is computationally infeasible to change or remove it.
When someone wants to add to the ledger, participants in the network, all of which have copies of the existing blockchain, run algorithms to validate the proposed transaction. If a majority of nodes agree that the transaction looks valid—that is, identifying information matches the history of a blockchain—then the new transaction will be approved and a new block added to the chain. The transaction is fulfilled or executed only when it has been approved for addition to the blockchain. Each block is connected to

the previous block via a hash (tamper-proof digital fingerprint). On the blockchain, users can observe transactions that have occurred, so they know which outputs are available for spending and which ones have been consumed. Each block in the blockchain represents, in effect, the claim by someone on the network that the transactions contained inside the block are the first ones to spend the inputs involved, and therefore any transaction in the future that attempts to spend the same inputs should be rejected as invalid [10].

Thus, a blockchain offers transparency and "democracy" in the handling of transactions submitted to it, developing and strengthening the bonds within the value added community it serves.

Based on such properties the authors have proposed the evolution of value added communities along the structure and concept of a blockchain. The objective is to create a closely-knit community of suppliers that serve the needs of a main manufacturer, organisation, or service provider.

- The community could comprise a group of companies, from similar industries or not, that will utilise the regular services of the supply chain.
- The members of the supply chain will be companies offering complementary services and / or the same services with different levels of capacity and the ability to serve the main core of the community with greater flexibility and meeting their changing needs at short notice.
- Different suppliers can offer their capacity and availability details to satisfy the requirements of each job, in the form of a transaction.
- As each job or part of are assigned to a member of the community the details are shared with the rest across the Blockchain, so each other member is notified of what jobs or parts of remain unfulfilled and can make offers, as each transaction is received and approved by the members
- No financial details are shared for each agreement reached, thus confidentiality is not breached, but transparency as to which member is assigned a specific job is maintained.

4.1 A Block Chain Prototype

The images below shows the diagrammatic representation of an Intelligent Agent enhanced Blockchain that is currently under development at the University of the West of England. A cluster of Raspberry Pi computers (fig. 4) is utilised to build a prototype supply chain and subsequently a full value-added community as shown in figure 3. The first stage of implementation is complete at the time of writing with successful testing of all functionality.

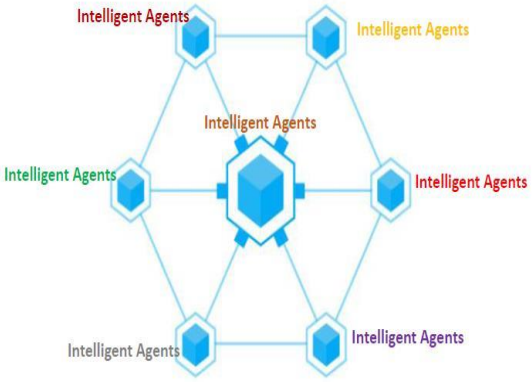

Fig. 3. Blockchain with Intelligent Agents

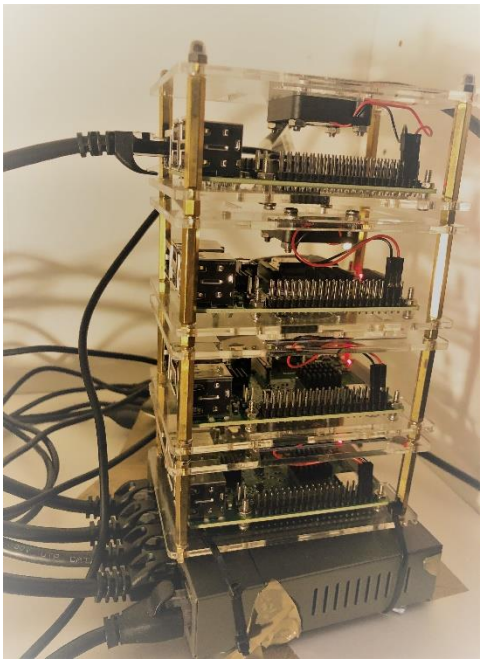

Fig. 4. Prototype Blockchain – cluster of Raspberry Pi computers

Intelligent Agents systems can be utilized at each company to negotiate the details of each agreement. Once an agreement is reached, the members of the community are notified through the Blockchain.

- Depending on the level of importance simple agreements can fully automated and negotiated and agreed by AI systems, or the AI negotiators requiring approval by a human decision maker.
- Regardless, the utilization of AI will minimize the complexity of decision making and it will speed up the negotiation with very high levels of accuracy, consistency and integrity.

The Blockchain will ensure that the information shared will stay secure and only within the community subscribed to it. Only the required level of details will be shared.

- The information available at any one time will current and it will allow AI systems on draw on it plan the sharing of jobs, negotiate with suppliers and process jobs in an orderly, timely, secure fashion at very fast speeds.
- This ability will allow companies to revise plans speedily and be able to respond to changing circumstances with high levels of flexibility.
- Supply chain will become an enabler to flexible operations at times of high volatility.

A diagrammatic representation of the resulting structure is shown in figure 3, with Intelligent agents supporting transaction analysis and response to each transactions submitted on the block chain be members of the value-added community.

4.2 The case of chain of custody – future work

Upon completion of the above value-added community as a working prototype of Intelligent Agent supported blockchain, the authors intend to complete a proof of concept project applied on a chain of custody system that monitors and audits the required quality standards in an industry focused on sustainable products in the print sector. The project will involve a full supply chain with manufacturers, suppliers, retailers, and the chain custodian. The aim of the project is to establish the potential of the enhanced value-added community concept to apply and enhance every type of supply chain, whether manufacturing or service oriented.

5 Conclusions

Supply chains need to become flexible, responsive, transparent, intelligent and secure. Major events like the current Covid-19 induced crisis can put any such systems at risk. The proposal put forward here is for a resilient system based on a value-added community that is supported by blockchain technology and artificial intelligence in the form of intelligent agents to support supply chains. The authors believe that the proposed system can provide the qualities that will allow a harmoniously functioning supply chain to be capable of responding quickly to any disturbance, and to be able to create a sustainable local / regional ecosystem of interrelated companies.

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