

# **Blockchain Technology for Efficient Management of Supply Chain**

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## **Abstract**

Increasing global demands in the supply chain in this fast-paced world entails more transparent and efficient supply chain management, which can be encountered with the use of blockchain technology combined with the Internet of Things (IoT). This study explains the effects of blockchain technology combined with IoT in terms of transparency, risk reduction, flexibility, speed from the customer's demand to the customer's deliverable. Supply chain objectives are achieved using various mechanisms of blockchain technology by which the customer can track the real nature of the products getting delivered to them, which surges the value and trust of the organization. The blockchain is a decentralized, digitized, public ledger of all cryptocurrency transactions. By implementing blockchain, the traceability and capacity to share information about production processes will be made easier and trustworthy. Traceability takes center stage in organizations supply chain; furthermore, it is a tool in fighting product counterfeiting and protecting brands. Implementing blockchain can revolutionize the way a supply chain works. This paper examines the case-studies on early implementation of block technology with IoT with special importance on the degree of deployment of blockchain technology for validation, transparency, and traceability purpose at various industries; such as e-commerce, food, and warehousing.

## **Keywords**

Blockchain, Traceability, Supply chain, Internet of Things, Transparency, Validation, E-commerce

## **1. Introduction**

### **1.1 Traceability and its effect on Supply chain**

Traceability can be defined as (Shields, 2014) the ability to trace the history, location, and distribution of products, parts, and materials by means of the documented record identification. Traceability can be explained in many ways, but they all refer to a process by which a product moves from its original raw material extraction and production phase to the final customer. A system is required to maintain records and follow the pathway as raw materials, parts, and products come from suppliers and are processed and ultimately distributed as end products to ensure traceability in the supply chain. Traceability not only provides information on the components of products, parts, and materials, but it also information on transformations throughout the value chain. As discussed by (Opara, 2003) traceability contributes to the demonstration of the transparency of the supply chain through the use of verifiable records and labeling. Traceability increases the financial worth of the overall quality management system by acting as a linkage for identifying, verifying and isolating sources of disagreement to agreed standards and customer expectations. Traceability has grown its importance as the global supply chain is evolving into a tangled web as companies are expanding to meet the increasing demand of the population (Fisher, 2015). Because of this tangled web of the global supply chain, it has become very difficult to trace the origins and history of the product in the supply chain. When it comes to food safety, the likelihood of safety problems is rare but they do occur; here public health, life and the livelihood of the companies are at stake.

One good example to showcase the importance of traceability in the supply chain would be the 2006 spinach outbreak that occurred in North America. In September 2006 there was a foodborne illness caused by E. coli bacteria found in uncooked spinach. E. coli is some potentially deadly bacteria which causes dehydration and diarrhea. This outbreak affected 26 states causing illness to 200 people including three deaths and 31 kidney failures. Washing the spinach was not a solution because the bacteria was not only outside the spinach but also inside that is absorbed through the roots. So, the U.S. food administration called a ban on eating fresh spinach or any product which contains fresh spinach (Calvin, 2007). This caused a huge breakdown in the spinach supply chain as they could not trace the origins and history of the spinach which was infected by the E. coli bacteria. It took the U.S. food administration two months to trace the source of the infected spinach which was one farm in San Benito, California. If there was better traceability in spinach supply chain it would not have taken two months for the food administration to locate the source of the infected spinach, also there would not have been a need to ban spinach all over the U.S.

## **1.2 Blockchain Technology**

The concept of blockchain technology emerged after the innovation of Bitcoin in 2008 by Satoshi Nakamoto (Nakamoto, 2008). Bitcoin is an electronic cash that allows online transactions from one party to another without any involvement of any third party such as banks. The transactions take place through a network generally called a blockchain network. Basically, a blockchain network provides a storage space for data, which are secured, immutable and decentralized (Xu et al., 2016). This means that the database can only be entered or updated but cannot be edited once it gets into the blockchain system. The data is only updated in the system if there is a consensus between the whole responsible network.

The problem of double-spend is eliminated by the blockchain technology with the help of some cryptographic key (Pilkington, 2016). Each responsible people at the nodes of the blockchain network is provided with a private key and the public key is shared with all the other person. As soon as the future owner of cryptocurrency (digital tokens or digital representation of some other asset) shares his/her public key to the original owner, the transaction gets initiated. This transaction gets packaged with other awaiting transactions which in turn creates a “Block”. Now there is a possibility that many blocks are created at the same time by different nodes. To decide which block should be the next block in the blockchain a mathematical puzzle was introduced, which is also known as “proof of work” (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). After the position of the “block” is decided, it is further sent forward in the blockchain system’s network of participating computers which evaluates the transactions and determines the validity of the database through mathematical calculations. This stage is called the verification stage where evaluation is done based on agreed-upon rules when consensus has been achieved. The verified blocks are then time-stamped with a cryptographic hash, which also has a reference to the previous block’s hash. This forms an immutable “chain” of records. After all of these stages, the transaction is finished. Figure 1. Shows the basic flow diagram of simple blockchain network.



Figure 1. Flow diagram of the blockchain.

The main purpose of the blockchain, which evolved with bitcoin, was to provide a secure network in order to transfer the digital currency. But, now because of the benefits, like immutability of data, transparency, traceability and many more, blockchain technology has started to revolutionize commerce and industry. Blockchain technology is still believed to be in its novel stage of evolution and not much research has been done in this field. It will take several years for the potential users of this technology to completely rely on it and make full use of it. Marco Iansiti and Karim R. Lakhani (Iansiti & Lakhani, 2017) did a very good job in explaining the phases of technology adoption by giving an example of the phases involved in the adoption of Transmission control protocol/Internet Protocol, which were the foundation of the internet. After getting introduced in 1972, it took more than 30 years for TCP/IP to pass through all the adoption phases and reshape the economy.

The recent applications of blockchains can be seen in healthcare (Mettler, 2016), banking sectors (Guo & Liang, 2016) and supply chain (Abeyratne & Monfared, 2016). This paper will fully focus on the application of blockchain in the supply chain.

### 1.3 Blockchain for Traceability in Supply chain

In the current world of constant competition, it is essential for companies to know about the recent technological innovations and trends. Incorporating modern technologies in the supply chain can create better visibility, thereby helping companies to have better control over their business. There is a high need for the supply chain to be flexible, innovative and transparent in order to keep up with the technological trends and stay competitive in the market. There is no denying the fact that, the technology has the potential to simplify the supply chain and to help the business function more efficiently, but to identify and appropriately choose the correct technology is very important. We know that the main aim of any business or company is to enhance customer satisfaction and retention, which can only be achieved if their supply chain is efficient and stable). As any product has a life cycle (i.e. introduction stage, growth stage, maturity stage and the decline stage, similarly, technology also has a life cycle.

According to Ralph Schneider-Maul (Schneider-Maul, October 2017), it is Innovation Trigger : In this phase the technology gets introduced into the market with very high expectations, Peak of Inflated Expectation: Here the expectations reaches the maximum and starts to decrease as the first hype settles, Trough of Disillusionment: Further decline in the expectations with some negative consequences, Slope of Enlightenment: Rise in expectation again due to evolution of the trend, and Plateau of Productivity: The trend becomes mainstream and many companies starts using them. The author termed this as the Cap Gemini consulting's hype cycle for supply chain technologies. He also talked about the four trend categories i.e. new, fast-moving, mature and out, which is somewhat similar to the product lifecycle and gave an example of blockchain technology being in the mature trend, where the technology gets acknowledged in the market and can be considered mainstream.

According to McDermott, (Patrick, 2017), the three main issues in the supply chain are; process optimization, data visibility, and demand management. These issues can be solved by integrating blockchain in the supply chain. Implementing blockchain can solve the main problem of data visibility. There are two most important factors that build a strong bond in the supply chain, they are transparency and trust and blockchain can be used as an intermediary for building such bonds. Financial services companies started to show interest in this technology ever since IBM launched its blockchain hyper ledger (Brakeville & Perepa, 2016), which is a Linux based open source to create a blockchain for business –to- business and business- to- customer transactions.

Blockchain technology can provide with a traceability system in order to track the products across a complex supply chain. By tracking the product, it means tracing their origin until the point it gets delivered to the customer. After these scandals, people have really become very concerned about the products that they buy from the stores and are demanding for a system in order to know about the originality of the product. In response to this many companies have started to test the blockchain technology in order to track the products. (The food institute, 2017) Walmart partnered with IBM to test the shipments with pallets of mangoes tagged with numeric identifiers. At each checkpoint, the status of the pallets was updated, right from the farmer to the store. Upon checking the shipment, it was possible to know about the day the mangoes were harvested, the location, the pests used in order to grow these mangoes and much more till the date the shipment arrived at the Walmart store. (Manilla Bulletin, 2018) Even Logistics companies like MAERSK with the support of IBM have started testing blockchain to track its shipments and coordinate with customs officials (Lu & Xu, 2017). OriginChain is a platform which employs a geographically distributed private blockchain at the traceability service provider company. The main aim is to create a trustworthy traceability platform that covers not only the organizations but also includes government-certified labs, big suppliers, and retailers having a long-term relationship with the company. There is much more such research and testing going on related to the application of blockchain in the supply chain where traceability is the prime focus. Figure 2. Below shows the basic flow diagram of a supply chain network and the need for traceability at each node i.e. either from supplier to the customer or from customer to the supplier. In the next section, we will highlight a few case studies and the importance of traceability in them.

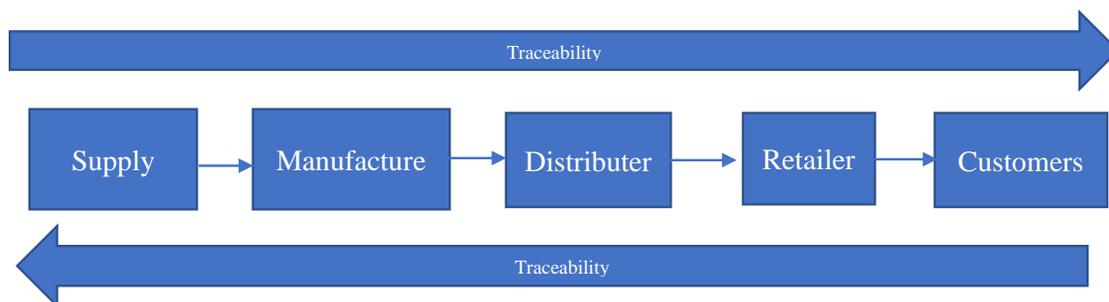


Figure 2. Traceability in Blockchain

Blockchain provides more people into supply chain network in a hassle free way with its intelligent business processes as result of its distributed trust and transparency, said Sanjay Almeida, senior vice president and chief product officer of Network Solutions for SAP (Scott, 2017). The combination of various tracking devices with blockchain technology will help in the high-level tracking of goods from the place where it originates to its delivery making the entire process legitimate and foolproof. One of the blockchain's major benefits towards management is that it provides a preferable better and possible solution for identifying with what and where the problem exactly lies (Alam, 2016).

Blockchain can be utilized in a supply chain to know whereabouts of the goods and also the quality of the assigned work completed, and thereby correcting or identifying the problem if any. Uncertainty hampers the smooth functioning supply chain. The transactions among a network of the supply chain which includes manufacturers, suppliers, distributors, providers, and clients must happen using a central third-party entity, instead of direct transactions with each other. This makes the transactions to be a lengthy procedure with a number of steps, which is the cause for the payments between a manufacturer and a supplier, distributor, or a vendor to take a number of days. The contracts and agreement which involves lawyers and bankers, with respect to industrial equipment's, consumer goods, food products, or digital offerings add to the extra cost and delay. Blockchain could be the solution to many of these issues, it can be used in any kind of exchange, agreements or tracking. Blockchain which is enhanced by electronic tracking technology can help speed up supply chains while adding greater intelligence along the way. The use of smart contracts over blockchain in supply chain reduces the additional cost and delay, resulting in a more efficient supply chain. The smart contracts are the contracts written in the digital form on top of blockchain technology. Dynamic demand chain produced by the smart contract is more efficient than the already existed rigid supply chain to maintain the online distributed ledger that keeps the online transactions on track (Mckendrick, 2017). The history of the products from the manufacturer to sell, along with transactions could be documented as the product passes from one node to another node in supply chain network. This makes the supply chain process more efficient and trustworthy by reducing time delays, added costs, and human error.

Blockchain will work on enabling more intelligent business processes because of its distributed trust and transparency, which in turn will bring more people into connected supply-chain networks as e-commerce, food, and warehousing. Blockchain eliminates the middleman auditors, and by allowing all the nodes in the supply chain network. Every supplier can validate the product and track them by their own and the result balances on a near real-time basis (Koetsier, 2017). It builds trust among the suppliers as once the data (example-contracts, tracking data) are on the blockchain ledger, they are fool proof and cannot be tampered or destroyed.

Blockchain also provides great accuracy in details of the product by continuously monitoring the product quality also during shipment by analyzing data on the travel path and time period. The stakeholders linked with the supply chain can know exactly whether the product was in a wrong place or whether it remained in a location for too long by checking with the predefined condition and time period at that particular place. It is especially important for refrigerated goods, where the temperature at which goods are placed plays a major role.

## **2. Literature review**

The customer value depends majorly on the ability on the logistics service within the supply chain management of the company to deliver the product to the customer in a timely manner, high quality and in a cost-effective way (Flint, 2004). The performance of supply chain management is described as the performance with respect to quality, speed, dependability, cost, reliability, and flexibility (Rao & Holt, 2005). Apart from these objectives, the recent research in supply chain management has addressed the role of supply chain in sustainable products because of the rise in demand of the customer's eagerness to know the source of the products consumed by them from the retailers (Quak & De Koster, 2007). Global supply chains are complex and they face umpteen uncertainties. Another major aim of the supply chain management is to reduce the risk involved such as cheating, distorting information etc. in logistics. To rule out the risks involved and achieve the listed objectives, suppliers are to be evaluated (Manuj & Mentzer, 2008). Increased outsourcing and competition, the number of competitors have increased significantly. In the act of satisfying a contract the quality from the players, firms have introduced supplier evaluation programs using social criteria and environmental sustainability in which the suppliers are bound to explain how they tackle the issues related to social and environmental sustainability issues (Beske, Koplin, & Seuring, 2008).

In the era of continuous development across the world, the standard of living of the people has improved significantly, thereby changing the consuming habit of the consumer. The consumers have started giving attention towards food safety and quality. However, there have been a lot of food-related accidents or scandals that happened in past few years. Some of them are Chinese Milk scandal, 2008 (Huang, July 2014), where high levels of the industrial chemical were found in the powdered and ordinary milk resulting in a serious health-related problems and even death, the south

Wales E-coli Tragedy, 2005 (Honish et al., 2005), which was considered Wale’s largest E. coli outbreak which resulted in a tragic death of a five-year-old child and many more school children and adults were seriously ill during the outbreak. According to Matty (2011), 76 million Americans suffer from food poisoning each year. Many people are hospitalized every year for food-related illnesses and some even die. It has become very important for the customers to know about the origin of the food and the way it was manufactured. Could these scandals have been avoided? Probably, yes, if the blockchain would have been a part of the supply chain, but if not, at least it would have helped in tracking the cause of the issue in a much faster way than the usual way of tracking by going through all the suppliers one by one.

### 3. Case Studies

#### 3.1 Walmart

Walmart is specifically using the Blockchain technology for traceability in food products so that the consumer can track the origin, raw materials used and the process the product has undergone (IBM, 2018).

Walmart has identified the following benefits after integrating with IBM for food safety in the supply chain:

1. Reduction in fraud
2. Improved supply chain efficiency
3. Increased trust of the consumer
4. Lower inventory and courier costs

Table 1 shows some of the challenges faced by Walmart and how they used blockchain technology to improve traceability in their supply chain.

Table 1. Challenges faced by Walmart and how they tackled them

Challenges faced by Walmart	Tackled using Blockchain technology
Disparate record keeping which leads to scattered, incomplete and unreliable evidence of information	Using blockchain to store records, which then will be available to all sender, receiver, customer, regulators
Find the source of flawed parts and to trace the history and origin of the product	Blockchain records reflect a products geographic flow, its source, how it was treated, storage conditions, etc.
Natural disasters or unforeseen shortages/ hikes in demand can impact production	Blockchain optimized processes instantly trigger remediation action when foresees that there is any risk associated with the product

At the end of 2016, Wal-Mart trail tested an operation to track the products produced from Latin America to the US and also the products such as pork which is produced in Chinese farms and moved to Chinese stores. Walmart will be ready with a finished version of the projects “within a few years” as reported by Popper and Lohr (Lohr, 2017).

Wal-Mart has developed a blockchain that will manage supply-chain data for roughly 30 products in the present year after the retailer tested the technology for several months in its mango supply chain between the U.S. and Mexico. After a mango is picked, it makes many stops before reaching a store. Wal-Mart has developed a mobile application in which farmers, packing-house workers, and others along the way send details such as harvest dates, locations and images of their fruit to the retailer’s blockchain. This process is simple and more secure compared to the array of barcodes, scanners, paper forms and individual meetings and databases that Walmart use, said Frank Yiannas, (Yiannas, 2017). head of food safety. In a simulated recall under the blockchain system, Yiannas and his team traced the origin of a bag of sliced mangoes in less than three seconds. With Wal-Mart’s other systems, the same exercise took approximately seven days. The speed and accuracy could save sales, otherwise the entire mangoes would be lost as stores pull all mangoes off shelves while waiting for the results, he said. It could also prevent illness and death, he said. “We’re all after trust in the supply chain, especially in a crisis.”

In August 2008, the investigation regarding Wal-Mart Salmonella outbreak, the health officials from Indiana had detected a minimum of 84 individuals confirmed to be ill with Salmonella infections after consuming foods from Wal-Mart deli between May and August 2006. It took almost 3 weeks for Wal-Mart to track the source of the outbreak. This can be overcome by the use of blockchain technology as stated by Mr. Yiannas.

### 3.2 Project Provenance Ltd. (Tracking tuna on blockchain)

Using blockchain technology provenance is building a traceability system for materials and products which can store inherently auditable, unchangeable and open information that anyone can use to track the provenance of anything (Provenance, 2016). Provenance use blockchain technology along with mobile and smart tags to track physical products and verified attributes from origin to sale point. Provenance uses the peer to peer (blockchain) technology to track tuna fish caught in Maluku, Indonesia from landing to the factory and beyond and demonstrating how blockchain technology can enable supply chain transparency and traceability.

Building on the blockchain enables a global peer to peer network to form that is an open platform that can deliver neutrality, reliability, and security.

1. This network has allowed provenance to avoid double-spending of certificates and claims, which is otherwise impossible without a trusted third party
2. This peer to peer network acts as a base layer of truth which everyone can refer in a trusted way
3. This technology allows the unbreakable rules which are smart contracts which will be enforced by the protocol itself

The Figure 3 below shows the flow diagram of the blockchain network formed in supply chain and how the tuna fish is being tracked at each stage using a mobile, notepad and barcode from the producer to the consumer.

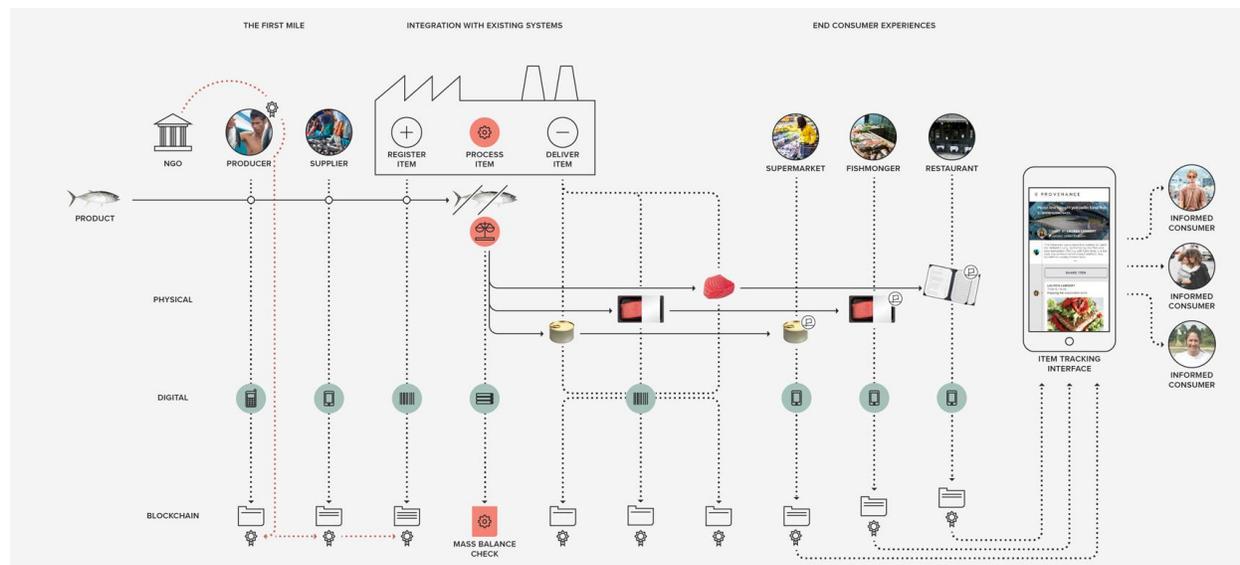


Figure 3. Flow diagram of Blockchain technology used by Provenance (Provenance, 2016)

### 3.3 British Airways

All the airports and airlines share data, but the exchanges are often between just a few departments at a time. This results in each department updating their own databases on its own schedule or timeline leading to separate copies from each department tending to drift out of sync, said Kevin O’Sullivan, a lead engineer at SITA.

British Airways tested blockchain technology last year on maintaining data on flights between the airports of London (Heathrow), Geneva (Cointrin) and Miami (Wilcox field). The main idea of opting blockchain was to rule out the conflicting information regarding flight from appearing at gates of the airport, on airport monitors across the airport, at their websites and in custom mobile applications.

The test result showed that the operations of the flights of all the three airports were nearly continuously to their blockchain, giving the entire operating departments a view of the same information at the same time. Maurice Jenkins, director of information systems and telecommunications of Miami International Airport, told that the result was one pure, true instance of data similar across all departments at any given time. He also said that by eliminating the information discrepancies between airlines; airport and passengers will be free of confusion at the gates and move people more smoothly.

British Airways, London (Heathrow) airport, and SITA are using blockchain for testing better ways of sharing information which is more accurate, reliable and fast. Blockchain will help the users for operational flight data to be synced which means that everybody can work on the same data set and make decisions accordingly based on it.

O'Sullivan stated that to date, using blockchain, numerous data sets from BA flights both in and out of Heathrow have been successfully merged. There is plenty of interest from other airports and airline spectator's eager to see if the result is as exciting as the promise. But it is too early before the aviation business truly unravels the full potential of blockchain in arresting the various issues related the mismatch of data (Simson, 2017).

### **3.4 Maersk**

Maersk, the largest container carrier in the world, accounts for 18% to 20% of the container market. Maersk high extent of shipping, handling one in seven containers globally, makes them a benchmark in successfully implementing the use of blockchain applications in international logistics (Gronholt-Pedersen, 2018). Maersk is using GPS location, temperature, and condition of the product using IoT to track its shipments (Jackson, 2017). The major problem faced by Maersk was the huge amount of paperwork involved for each and every container it ships.

Hundreds of shelves of paper records were found at Mombasa office, Kenya from the year 2014 (Lohr, 2017).

Frauds in the global supply chain system are a major problem for shipping industries. For example, the bill of the shipment on most occasion, is either tampered with a copy. Fake products are circulated by smugglers, causing a loss of billions of dollars every year.

IBM and Maersk worked together on a blockchain trial in 2016 (Hackett, 2018) conducting a pilot run, which tracked a container of flowers that sailed from Mombasa, Kenya to Rotterdam in the Netherlands, plus several follow-ups, much convinced Maersk of the blockchain system's potential. During the pilot run, the shipping cost was \$2000 and the cost of documentation was estimated around \$300, which accounted for 15% of the total cargo value (Groenfeldt, 2017).

Maersk and IBM followed up the pilot project with a company in Lyon, France named Schneider Electricals. A container filled with goods was tracked from the plant location and shipped to Rotterdam. Containers from Rotterdam were loaded onto a Maersk Line ship and shipped to the Port of Newark in the U.S and which then ended at the Schneider Electric facility. The number of countries involved in a shipment gives a brief idea about the time and paper work involved and the costs could end up to one-fifth of the total expense of physical transportation due to the spoiling of perishable goods on the event of lost or delayed documentation. This helps all the partners in global supply chain network to track freight as well as replace related paperwork with foolproof digital records.

### **3.5 UPS**

United Parcel Service (UPS), an American multinational package delivery company, evolved as one of the world's premier logistics company over the past century. The company delivered 5.1 billion packages and documents to nearly 9 million daily customers in more than 220 countries and territories in 2017 (UPS, 2017).

UPS has recently announced that it is a part of the Blockchain in Trucking Alliance (BiTA), a forum which is focused on developing block chain-like distributed ledgers for the freight industry (UPS, 2017). This move illustrates UPS dedication to blockchain technology solutions, and for solving obstacles while implementing in the package and logistics industry. There are many potential applications of distributed ledgers such as storing and sharing data associated with the tracking of individual shipments, payments, compliance audits with respect to shipments and insurance.

In block chain-like distributed ledgers, data is shared across a network of computers. Validated data once added to the online ledger, can be viewed by anyone with access to the ledger. This feature of block-chain technology combined with smart contracts makes them extremely valuable for sharing data in the supply chain network which includes freight shipments, including shippers, carriers, insurance providers, customs authorities, and institutions financing the shipments. This technology could also reduce a great deal of manual labor, involved in documenting, recording and sending much of this information and reduce back-end costs for freight shipping businesses.

## **4. Future Scope**

Food, raw materials and all current industry products as a measure of distance presently have a long distance and require a great importance. Traceability in supply chain research on the problem of increasing transportation and transporting products around the world is critically needed. This challenge goes along with the problem of food wastage. IBM collaborated with Capgemini at the Watson Internet of Things (IoT) center have successfully developed a prototype for Smart Container Management based on blockchain technology. The implementation of smart containers which has microcomputers (equipped with multiple microsensors which provides quality-related data like pressure, temperature, vibration, location etc.) helps in tracking the entire network and has the potential to transform the present supply chains into the highly integrated smart supply chain. By this upgrade, the supply streams can be

simulated virtually leading to the integration of physical processes and enables automation thereby increasing the efficiency of tracking through end to end the transportation of the supply chain resulting in agile cooperation network. In this process, if there are any negative effects on the products, a contractual penalty will be triggered automatically to all the members in the chain.

## **5. Conclusions**

The application of blockchain technology is not limited to cryptocurrencies (finance), supply chain activities are among the ones most likely that the blockchain technology is going to transform. The issues faced by the traditional supply chain management can be counted by the use of blockchain technology because of its speed, transparency, immutability and effective measurement of outcomes and performance. From the case studies, it is evident that the highest impact by the implementation of blockchain technology will be the food industry. The salmonella outbreak in Walmart is a good illustrative to explain the effect of blockchain in the food industry. Looking at the case studies and the scandals related to food and automotive industries, it is clear that, blockchain would have helped in avoiding or at least mitigating the impact, by making the supply chain more transparent and trustworthy. It also has a potential of making the entire chain to be more responsive. Blockchain technology in its initial stage is starting to change the way business is done and if it delivers on its promise of supply-chain transparency and traceability, it will be a great tool to help ensure that industries are doing the right thing. Traceability of goods moving across the supply chain is certainly one of the most important use cases for blockchain. Implementing Blockchain can dramatically reduce time delays, costs and mainly the human error. Apart from this, it can enhance transparency, can give greater scalability and provide better security. Blockchain can also help in achieving robust cybersecurity measure which in turn improves the trust and security at the same time, addressing concerns regarding global supply chain which consumes more time and resource to realize the full potential of the blockchain.

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