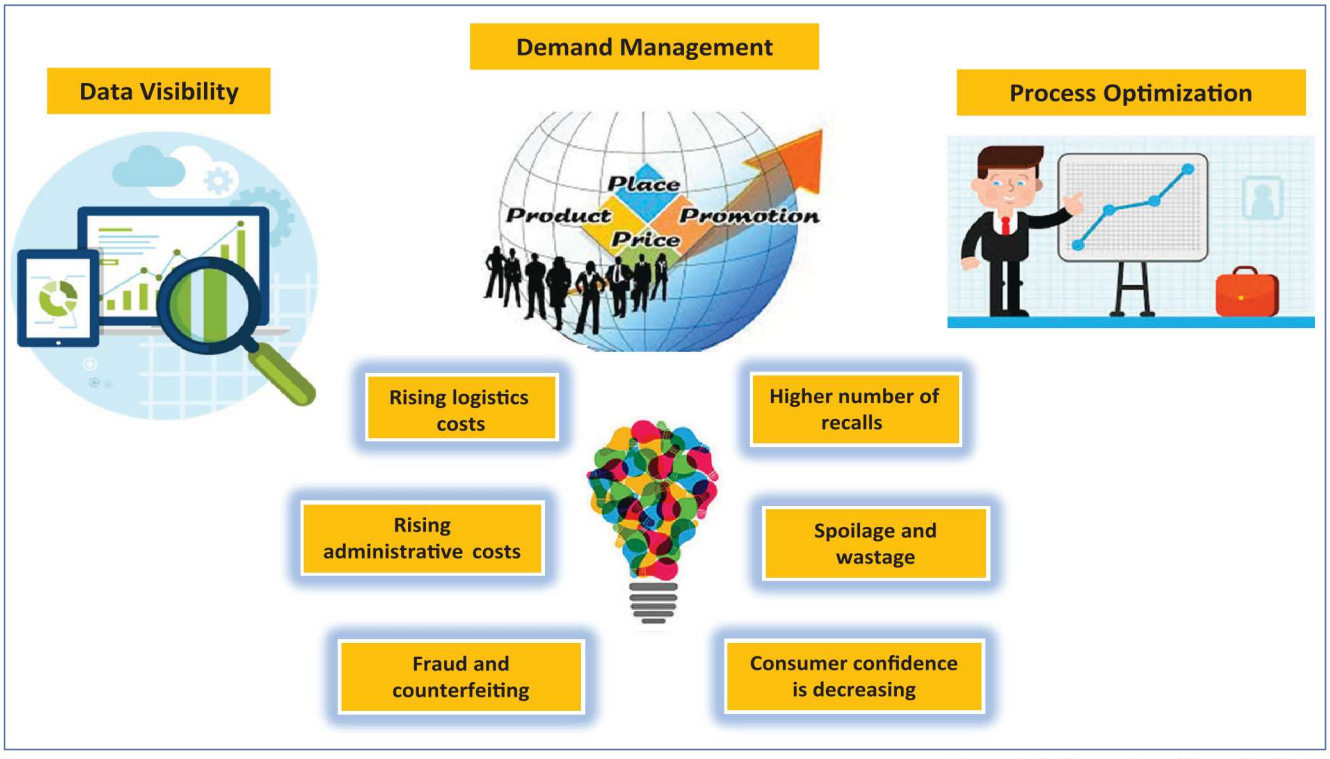

Current challenges in cold supply chains

How Blockchain and IoT Applications are Transforming the Cold Chain

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Introduction

The modern-day supply chain is a complex system with non-linear, multi-tier relationships and real-time digital processes essential for remaining competitive and profitable in the global marketplace. New distribution models, higher number of SKUs, shorter product lifecycles, increasing levels of customer service and volatility in demand planning have increased the complexity of supply chains. Supply chain operations are massive and impact 70% of the Global GDP. The sheer amount of transactional data and the number of parties involved bring challenges related to data harmonization and stakeholder integration. Today, the world loses billions of dollars due to fraud, counterfeiting and inefficiency of supply chains. In addition, there is a huge cost involved in compliance monitoring, auditing and maintenance. Thus, new supply chain models are based on micropayments, digital identity certificates and tamper-proof documentation.

Introducing Blockchain

Blockchain within the supply chain can provide stakeholders with a decentralized ledger that can store an entire history of transactions across a shared database, thus facilitating multi-party collaboration within the digital supply chain. Stakeholders can rely on one common information repository, which is always updated in real-time.

Blockchain is a type of Distributed Ledger Technology (DLT) that provides a singular mechanism to securely integrate, harmonize and synchronize data for all participants. The distributed ledger

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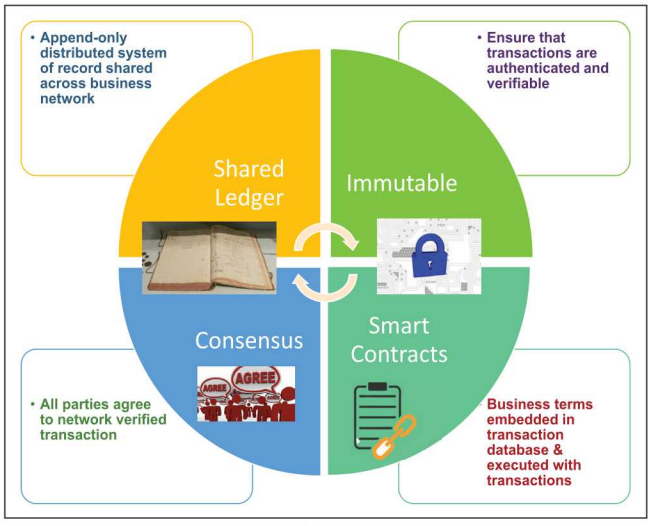

Figure 1: Key concepts of blockchain

provides grounds for increased automation across the supply chain, as well as concurrent optimization.

Introducing the Internet of Things

The Internet of Things (IoT) technology involves collecting data from physical objects, aggregating and synthesizing this data and presenting clear diagnostics that will help users in decision-making.

Combining IoT with Blockchain allows participants in a supply chain to proactively optimize components of their processes like inventory management to support an efficient and agile product path. In other words, stakeholders in a supply chain can react quickly to event information and automate their responses. This leads to more preparedness for unexpected events and minimizes disruptions in the supply chain.

Using predictive analytics on information such as Point of Sale data can dramatically improve demand visibility, while reducing the negative consequences of poor forecasting such as the Bullwhip Effect (a distribution channel phenomenon that refers to increasing swings in inventory in response to shifts in customer demand). The benefits include improved inventory management, accurate determination of re-order points and better on-shelf availability.

The consensus, immutability, and finality provided by blockchain technology allow for a decentralized ecosystem where no single party can control or alter the data, and no two parties can collude to commit fraud. This ability for completely trusted peer-to-peer interaction facilitates direct relationships between participants in a supply chain and can help to minimize involvement of third party intermediaries.

The long-term benefit of blockchain is to help reinforce trust between parties, because it generates a digital paper trail where every transaction is locked, giving visibility of who the parties are and what is transacted. As the technology allows users to look at all transactions simultaneously and in real-time, large organizations such as Walmart are considering blockchain as a viable long-term solution.

What is Blockchain All About?

A blockchain is a decentralized shared digital transaction ledger of cryptographically secured time-stamped records, which relies on the consensus of a global peer network to operate. The blockchain consists of a timeline chain of 'blocks', where each block is a transaction record and linked to another via time-stamps and other attributes. As each block is created, a cryptographic hash is created, which is encrypted with everything that was in the previous blockchain before the hash. It becomes impossible to go in and change an earlier block because it will make everything on top of it invalid. Blockchain uses heavy-duty encryption to ensure virtual security so that each time-stamped record is immutable and cannot be hacked or modified. For this reason, blockchains are resistant to data modification since the alteration of one block requires consensus across the recorded chain or ledger. If the transaction is validated, the block is added to the blockchain, which itself will be located on multiple computers, so there are distributed, identical copies of the ledger. As the transactions are not stored in a single location, it is almost impossible for external parties to tamper with any central data. The distributed nature of the ledger as well as the blockchain hashing mechanism reduces the potential for cyber-attacks with no single point of failure.

Although there are private blockchains, the system is generally public and does not reside on a central database. Instead, it runs on computers by individuals around the world; hence it is decentralized and distributed. Participants in a blockchain collectively keep the ledger up to date in a way that it can be amended only according to strict rules and by general agreement.

With blockchain, the entire supply chain becomes transparent. All kinds of data including times, locations, names of parties, shipment conditions, etc. can be stored. Blockchain technology enables physical items to have a digital record that includes unique attributes of the physical item. This is an important feature that allows for the ability to verify the authenticity of goods in transit.

Smart Contracts

Manufacturers typically deal with many contracts with suppliers, distributors and buyers. Both paper and digital contracts are potentially open to alteration and fraud. Smart contracts could help overcome this hurdle. Smart contracts should not be confused with legal contracts: they are basically self-executing programs, enabling smart assets to be controlled digitally. They are made up of computer code that can monitor, execute and enforce agreements. Smart contracts placed on blockchain can be verified, recorded and monitored for compliance by the entire network of computers connected to a blockchain. Smart contracts can speed up transactions and reduce costs, creating far more agile value chains that enable closer cooperation and trust between manufacturers and their partners.

Smart contracts can automate invoice settlement and help in areas like customer service where it has been difficult to track device contracts. Now smart service contracts can be attached to devices and easily tracked. Manufacturers can more easily let customers know when products need servicing, and trace suppliers of faulty parts more efficiently and recall products swiftly, containing the problem and saving costs.

Salient Features of Blockchain

- A data set is defined and entered as a transaction
- When a portion of the data set changes, a new transaction is created, linking the new entry to the past entry
- Transactions are randomly assembled into blocks
- Transactions can be replicated in multiple blocks
- Each block is encrypted and has a unique hash code, which makes it near impossible to hack
- Smart contracts can be triggered when data conditions are met

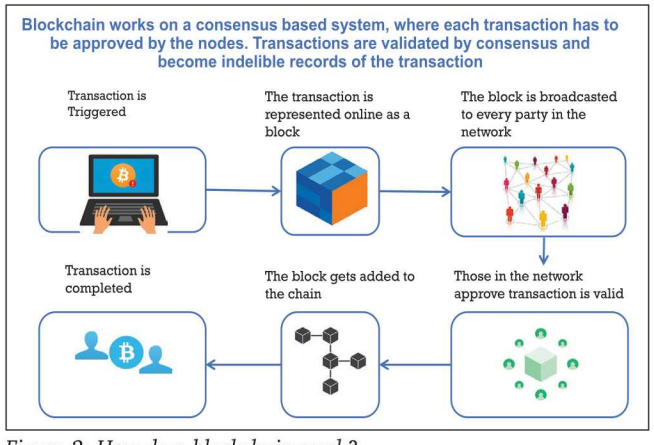

Figure 2: How does blockchain work?

One of the big promises of blockchain is to store and share data gathered from IoT devices. The Internet of Things (IoT) is a powerful technology that enables building a bridge between the digital and physical worlds. Putting sensors on equipment provides track and trace capabilities and enables players along the supply chain to monitor conditions while goods are in transit. Storing the sensor data on a blockchain provides a single view of the truth, and prevents data from being falsified. In essence, the digital file follows the physical object like a shadow and this becomes a mechanism to build trust.

What is the Internet of Things?

IoT is an ecosystem of connected physical objects that are accessible through the Internet. IoT digitizes the physical world. The technology involves collecting data from physical objects, aggregating the data, synthesizing the data and presenting clear diagnostics that will help users in decision-making.

The IoT infrastructure is dependent primarily on sensors that take extrinsic measurements of physical objects like temperature, speed, acceleration, sound, humidity etc. The most prevalent sensor is a Radio-Frequency Identification (RFID) tag that is attached to physical objects. The sensor transmits this information over a network. The network communicates data from the sensor. The network is made of hardware and software components and messaging protocols that enable the transmission of information from the network layer into the integration layer.

The integration layer aggregates the sensor data and integrates it with external sources. Further analysis is done by Augmented Intelligence (AI) technology that combines the raw sensor data and external data to provide actionable insights. The data gathered from these connected devices can be used for predictive and prescriptive analytics. The insights gathered by applications using the IoT data are used to bring about the desired changes in human or mechanical behavior.

Identification, connection, security, and the management of so many devices are the challenges to widespread IoT adoption. By 2019, 20% of all IoT deployments will have basic levels of blockchain services enabled. According to *Gartner*, by 2020, the installed base of connected or IoT devices (excluding PCs, tablets and smartphones) will reach 20 billion units, empowering a market worth of $3 trillion. The Internet of Things and sensors are now a major part of the world economy and will have multi-trillion impact by 2030.

Salient Features of IoT

- It automates the linkage between physical objects and digital transactions
- Data can be gathered at the source (using sensors)
- Provides a comprehensive view of the entire cold chain
- Enables prescriptive analytics for decision-making
- Ensures provenance, telling us when things happened and where

Combining blockchain and IoT enables peer-to-peer contractual behavior without requiring a third party to certify an IoT transaction, thereby providing a consistent answer to the challenges related to time stamping, records, privacy, trust and reliability. Thanks to IoT, all the data related to physical goods can be captured and linked across all stages of the global supply chain; and thanks to the immutability of the blockchain, this data can be shared effectively and securely by the different stakeholders in the global supply chain. Auditability and accountability are the key benefits of an IoT and blockchain alliance.

Real-time Cold Chain Monitoring with IoT

It is possible to reduce the operational cost of cold chains arising from spoilage and transportation, using real-time monitoring and IoT.

Reducing Costs of Spoilage

Improper handling of shipments can happen due to offloading and repacking temperature-sensitive goods outside temperature-controlled environments or loading packages into containers or vehicles that have not been pre-cooled.

Figure 3: Critical parameters can be monitored across a cold chain using IoT

Containers or warehouses sometimes develop hot spots – small areas or zones where the temperature may exceed acceptable norms. Real-time monitoring can help detect them, allowing vendors to act instantly and mitigate the damage. Instant flagging of issues such as temperature excursions, hardware and coolant malfunctions or deviations from handling protocols, enables measures to be taken to prevent damage in transit.

Temperature-sensitive cargo that exceeds the ideal temperature thresholds could be damaged irreparably or have a shorter shelf life. With real-time monitoring, one would be able to detect that, and compromised shipments can be re-routed to a repackaging center or an alternative market before the entire shipment becomes a sunk cost.

By assembling time, temperature and other data captured via mechanical and electronic sensors onto a decentralized ledger via a smart contract, it is possible to create an indisputable record of the status of perishable goods throughout the supply chain. The requirements for regulatory verification exist within a smart contract. The smart contract must include specific records and conditions such as the location, date and time for delivery of goods and specific temperatures recorded throughout the shipment journey.

The validated status of the goods upon delivery removes the need for exception management, compliance checking and in-person audits, thus reducing the costs associated with managing compliance of the cold chain. Retailers can show consumers the historical lineage of the product's path.

Reducing Transportation Costs

Active tracking thorough logs and real-time alerts about temperature breaches give shippers and Third Party Logistics (3PLs) enough of a heads-up to contain problems before the damage is irreparable. This not only reduces the cost of replacing spoilt goods, but also limits additional spends. Detecting temperature excursions in real-time means one can ship replacement goods before the spoilt shipment arrives, saving time while reducing spends on expedited shipments and improving customer experience.

Real-time tracking coupled with solutions like Robotic Process Automation and automated invoicing can help issue bills and collect dues faster. Automated electronic systems help bypass the usual lag involved with paperwork, allowing one to settle one's debts faster and save interest on working capital.

Issuing and managing invoices, organizing delivery schedules, responding to queries in-transit and checking up on progress require manual intervention and add to the overall complexity and cost of running a supply chain. Real-time tracking coupled with analytical dashboards and automated notifications could help reduce the manual intervention that older supply chain management systems demand.

Real-time paperwork that is available online could also help reduce delays due to complex or incompatible hardware. One can avoid delays to time-sensitive cold chain consignments, enabling the driver or logistics personnel to use their smartphone to download documentation for verification or compliance. Instant audits and verifications can reduce the cost of delays due to inspections. Maintaining the ideal temperature for cargo is not enough; it has to be proven as well. Real-time tracking data and secure online logs can help reduce the time taken to fulfill regulatory requirements, allowing the cold chain shipments to breeze through customs.

Reducing Operational Costs

While the cost of cold chain risk management may be high, the cost of cold chain failure is always extreme. Hence, cold chain managers overcompensate on things like packaging, mode of transport or choice of 3PL to offset inefficiencies in their risk management plans.

One of the biggest advantages of tracking logistics data is the ability to gauge performance over time, highlighting the best options when picking routes, modes of transport, packaging, 3PL as well as the likelihood of spoilage for that combination. Real-time monitoring adds a whole new dimension to these insights, allowing one to adjust everything on the fly while keeping costs low.

One can, for instance, choose the cheapest mode of transport and keep packaging to a bare minimum without worrying about the outcome since real-time tracking will allow you to define the outcome. Real-time data enables real-time responses. If your shipment gets delayed or your coolant runs low, you would know about it fast enough to dispatch a recovery or refit team to resolve the issue. Over time, the cost of such intervention is often lower than the cost of overcompensation, allowing one to run a leaner and more reliable cold chain.

Through package-level cold chain visibility, it is easier to single out compromised consignments, allowing one to recall only the spoilt products rather than the complete shipment.

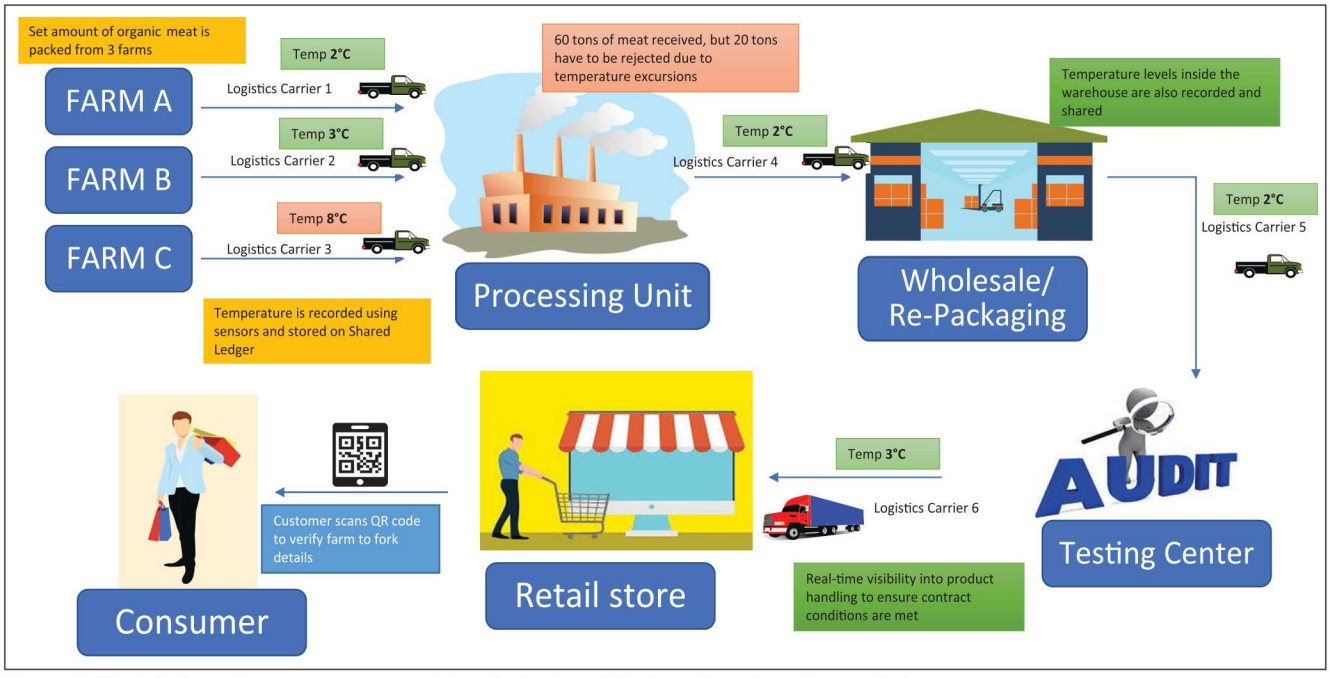

Figure 4: Blockchain and smart contracts enable a single view of food products from farm to fork

The ability to track cold chain shipments and prevent losses does not just add to the bottom line, it also reduces overheads that eat into it. By consistently delivering cold chain products within prescribed norms, one has more leverage to negotiate better insurance premiums.

Reducing Insurance Costs

Resolving cold chain supply problems requires fast exception management to protect consumers from problems such as bacterial outbreaks and spoiled vaccines. Maintaining cold chain safety requires constant regulatory compliance, verification and enforcement. These safety and remediation activities add to the supply chain insurance costs.

Product liability is the most complicated aspect of risk calculations for insurance purposes. The sheer volume of transactions in a supply chain makes the underwriting of supply chain risks more onerous. Blockchain technology brings about the transparency required to find out which link in the supply chain is culpable for poor quality or product wastage. This can help better claims tracking and validation of claims.

Blockchain and IoT Applications in Cold Chain for Food Products

According to the World Health Organization (WHO), 400,000 people around the world die every year from foodborne illnesses, with 1 in every 10 people falling ill every year from food contamination. For organizations that find themselves caught up in a food scandal, the consequences for their reputation, brand loyalty and bottom line can be dire and long lasting. According to a PwC study, the cost of a single adulteration verdict resulting from foodborne illness can be up to 15% of the company's annual revenue.

Whether they know it or not, many retailers have sold fraudulent food products. Current practices in the food industry are prone to human error, with a significant amount of compliance data currently being stored on paper or in a fragmented digital state, making it prone to error and vulnerable to fraud. Blockchain makes the supply chain more transparent, empowering the entire chain to be more responsive to any food safety disasters. The distributed ledger technology that blockchain offers, enables product traceability that can be used to quickly pinpoint a source of contamination and limit the number of people who get sick or die from foodborne illness every year. Attempts to tamper with a food item as it moves through the cold chain can be immediately identified and prevented before the contaminated food reaches a restaurant or retailer.

For food retailers, if a potentially hazardous food product somehow does make it to store shelves, it can be quickly and easily identified so that only the affected items are eliminated, alleviating the need for costly batch recalls. With blockchain technology, it is possible to track the entire product lineage. This feature is especially important, given the recent scandals associated with food adulteration and contamination. The technology provides valuable, permanent records and data sharing between disparate actors.

For food consumers, blockchain offers transparency that can help reassure them that the food they eat is just what the label says. For instance, consumers could scan a QR code on a package at a store and retrieve the complete history of their food, from farm to fork. This information is particularly useful, given that an increasing amount of food is imported, and country-of-origin

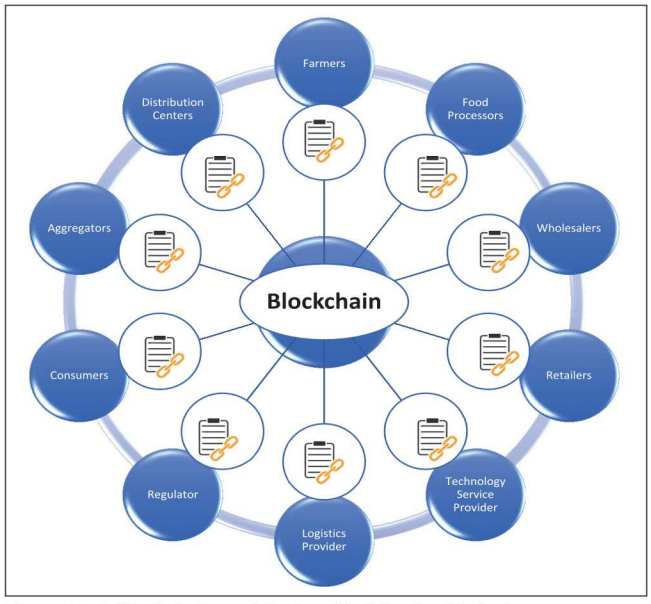

Figure 5: A blockchain and IoT-enabled food cold chain

labeling is difficult to decipher. For instance, meat claiming to be from the UK might actually have originated from another country and be processed in the UK. Blockchain provides a method of substantiating claims and building trust with quality-conscious consumers.

For food safety and counterfeit prevention to succeed, large-scale consensus, collaboration and governance across a huge number of stakeholders will be necessary. The paramount technical challenge facing blockchain and IoT convergence is the ability to scale to meet service and security requirements across a dynamic network of devices.

Blockchain and IoT Applications in Cold Chain for Pharma

The market for counterfeit drugs is rapidly becoming a global epidemic and counterfeit drugs are estimated to cost the pharma industry $200 billion a year. WHO estimates that 10 percent of medicines in low- and middle-income countries are counterfeit.

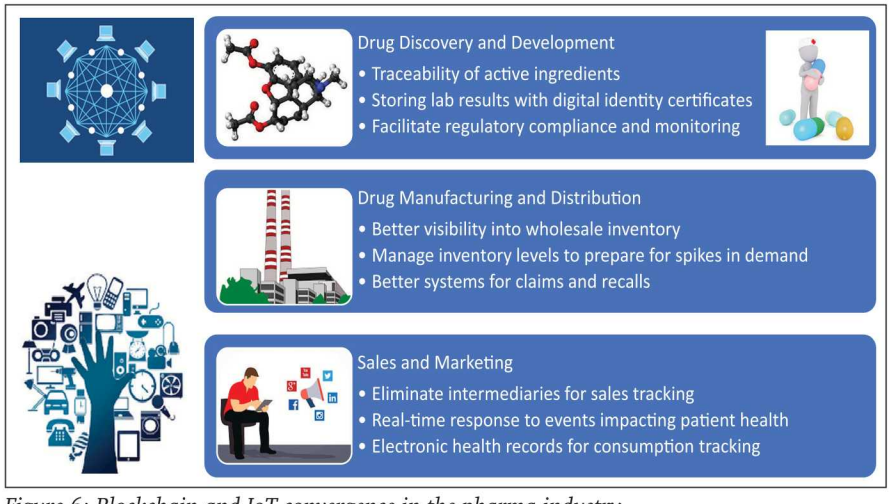

Figure 6: Blockchain and IoT convergence in the pharma industry

With increasing globalization, demand and complex supply chains, fraud and patient safety are increasingly becoming a top concern for regulators.

The US and EU have recently introduced legislations that require an electronic system that can trace and authenticate pharmaceutical products as they move through the distribution network. The Drug Supply Chain Security Act (DSCSA) in the US outlines steps to build an electronic, interoperable system to identify and trace certain prescription drugs as they are distributed in the United States. This will enhance the ability of Food and Drug Administration (FDA) to help protect consumers from exposure to drugs that may be counterfeit, stolen, contaminated or otherwise harmful. The system will also improve detection and removal of potentially dangerous drugs from the drug supply chain to protect US consumers. Similar legislation in the European Union, under the Falsified Medicines Directive, seeks to secure the supply chain through an electronic tracking system to prevent counterfeit and contaminated drugs from reaching patients and end consumers.

The key provisions of these legislations include Product Identification, Product Tracing, Product Verification, Detection and Response, Notification, Wholesaler Licensing and 3PL Provider Licensing.

For businesses that are subject to these regulatory requirements, blockchain offers a solution, providing serialization authentication and chain-of-custody tracking capabilities.

Blockchain makes smart contracts secure and accessible to stakeholders worldwide, effectively removing the middleman in payment and other transactions. It also eliminates a lot of rework.

Pharmaceutical companies now also monitor and control the origin of the ingredients in their drug products as well as environmental conditions such as temperature, moisture and time under which such drug products are synthesized and stored. IoT offers an efficient way for wholesalers and hospitals to optimize their inventory management and anticipate supply shortages. Blockchain technology offers a safe and efficient way to keep large amounts of data and transparently manage data access.

When certain drugs are shipped between warehouses, they need to be kept within specific temperature bounds to ensure they do not spoil. If a package goes outside those temperature limits, the drug can go bad and end up being delivered to hospitals and other providers, and then given to patients and customers. This is a huge issue for the pharmaceutical industry. The temperature logger is a hardware that stays with the product all the way from start to finish and tracks the temperatures. Once the shipment has been delivered, it displays its calibration

certificate digitally, ensuring it stayed within all temperature bounds throughout the duration of its travels.

Shipping hundreds of temperature loggers across dozens of products requires a significant amount of physical labor to turn off all the loggers and fetch the data. With new software platforms, it is possible to turn off the loggers remotely, which saves warehouse workers thousands of hours in manual labor. Today, hardware-based temperature loggers provide a simple alert when the product has gone outside the temperature bounds. However, many new start-ups in the IoT domain are working on providing 'recommended actions' for different classes of pharmaceutical products based on 'Time out of Temperature Range'.

It is not likely that major pharmaceutical companies will be keen to adopt blockchain technology right away, as it remains at an untested level and the complexity of coping with serialization is already an expensive headache. Thus, blockchain platforms would need inputs from multiple pharmaceutical companies, regulatory authorities and patient groups to really gain traction.

Blockchain and IoT Impact on Cold Chain Logistics

The logistics industry remains fragmented, riddled with data silos and archaic manual processes. Implementing blockchain in logistics could enable verifying, recording and coordinating transactions autonomously without the need for third parties.

For cold chain logistics service providers, the biggest challenge lies in ensuring that there are no 'temperature excursions', where temperature deviates from given instructions. It is a high-stakes need as a single lost shipment due to temperature-control failure can mean the loss of cargo worth millions. Sensors that monitor temperature, location, light exposure, humidity, barometric pressure and shock are now an accepted part of the supply chain. Live visibility of cargo using the reports generated through IoT devices is now being mandated by regulatory authorities.

One challenge for supply chain players is to comply with serialization by 2019. The move is part of a wider effort to ensure the security and traceability of medicines through the supply chain. Serialization will involve the addition of a unique code to be scanned at every significant point through the supply chain; it would increase the traceability of the product and improve the transparency of the whole process This will be enforced across the US and Europe in a bid to verify the legitimacy of a drug product down to the package level. It is hoped that the move will also do much to remove fake medicines from the supply chain, as well as easing the recall of products that have been deemed faulty. Blockchain technology has the potential to digitally validate any aspect of the pharmaceutical manufacturing and supply chain process that can be linked to a sensor without requiring on-the-ground inspection.

In recent months, the shipping industry has fallen victim to industrial-scale cyber-attacks that have left large shipping lines, such as Maersk, paralysed and unable to serve clients. A blockchain-enabled supply chain is highly resilient to cyber-attacks, since a copy of the essential shipping data is stored on each node in a decentralised network, meaning that even if one node is compromised, the data is safe nevertheless.

IBM and Danish shipping giant Maersk have announced a joint venture to use blockchain in shipping supply chain. In a sector that handles around $4 trillion of goods per year, the firms said they expected savings of up to 15 percent of this amount, mostly by eliminating the bureaucracy and corruption risk in manual procedures. Maersk is also currently looking at how to use IoT monitoring to optimise in-transit cold treatment, which is a legal requirement in some countries that require certain fruit to be kept at a low temperature for a specific period of time, and certified as such, to eradicate fruit flies. As a part of its Remote Container Management Project, Maersk has equipped over 280,000 refrigerated containers with telematics devices, as well as outfitted over 400 vessels with GSM capability, to monitor reefer cargo and containers.

The blockchain, with the help of innovations in IoT, can be particularly useful for capacity monitoring. Cargo volume often defines the cost of shipping freight. By using IoT sensors in trucks and other shipping vehicles, shippers and transportation companies can detect the amount of space taken up in a shipment and determine the cost accordingly.

The blockchain could even be used to authenticate automatic payments from shippers to transportation companies based on the price of a given load, cutting out multiple middlemen and saving time and money for all parties involved.

When a small business wants to purchase a second-hand delivery vehicle, blockchain can help to authenticate information on the past performance of the vehicle and its maintenance history. Just as a blockchain can help validate the records of a second-hand vehicle, it can also help to validate the driver records of a new carrier.

Other Application Areas

Vehicle to Vehicle Communication Using IoT

Some companies are already implementing Vehicle-to-Vehicle (V2V) Communication, which essentially allows multiple freight vehicles to form a platoon and communicate, improving fuel efficiency and safety. Storing and validating the data created by the use of V2V Communication on the blockchain can help transportation companies across the world streamline their operations.

Digitization and Securing of Travel Document Workflows

Blockchain can greatly reduce bureaucracy and paperwork. Currently, an overwhelming amount of redundant paper-based documentation plagues importers, exporters, and in-

Figure 7: Blockchain can automate travel document workflows

termediaries in the global transportation process. There lies an incredible friction in global chain processes. Blockchain within the supply chain provides the ability for compliance, legal and customs documents to be digitally signed or notarized at different stages of transport – all located on a central blockchain. (Stakeholders may include transportation providers, governments, customs, brokers, importers, ocean carriers, ports, etc.).

It is widely reported that up to 10 percent of all freight invoices contain inaccurate data, which leads to disputes as well as many other process inefficiencies in the logistics industry. Instead of attempting to manage a lengthy paper trail, blockchain provides for an automated process of storing information in a tamper-evident digital format. This automation can be extended to services that currently require an intermediary such as insurance, brokerage, settlement services, transportation management, fleet management and freight forwarding. Blockchain could be used to track a product's lifecycle and ownership transfer from origin to store, even as it changes hands between the manufacturer, logistics service provider, wholesaler, retailer and consumer.

Challenges To Blockchain Adoption

Lack of Basic Information

Both IoT and blockchain are emerging technologies. Blockchain is particularly nascent in its implementation and virtually all enterprise activity in the blockchain space is in proof-of-concept (POC) or pilot phase. There are hardly any large-scale deployments using private or permissioned blockchain configurations.

> Managing the link between the physical world and the digital ecosystem is a major challenge. It is easy enough to use a sensor, but authentication and certification of this sensor is equally important. The level of granularity of information needs to be logical. Capturing millions of nodes of data and analyzing it is a resource-intensive process. The infrastructure required to store and process this data is also expensive. The economic viability of adopting this technology will have to be judged against the perceived benefits.

According to an SCM World Future of Supply Chain 2017 survey, 25% of senior executives surveyed found it disruptive and important; 61% found it interesting, but unclear about its usefulness.

Likewise, according to a recent Deloitte survey, 40% of senior executives of large companies know little to nothing about blockchain, yet many view the technology as a top priority. This data suggests that one of the first barriers to promoting widespread adoption of the technology in the food industry is basic education about how the industry can benefit from blockchain. A full understanding of what the technology can and cannot do is needed. It may not be suitable for a particular supply chain and may not always be a viable answer to driving business value. To avoid misunderstanding and misalignment, it is important not to look at blockchain in a tech vacuum.

Lack of an Established Ecosystem

The greatest obstacle is for the industry to identify what data they wish to collect, the format, and the level of analysis to be completed before they receive it. Advanced digital ledger technologies offer potential solutions but are still a few years away from practical use.

Resilience and Scalability

A decentralized consensus mechanism may offer myriad benefits such as information neutrality, authenticity and security, but today it comes at the price of scalability, especially in an IoT context. A big challenge is the ability to scale to be able to match service and security requirements across a network of devices. These requirements are not just precautions; they are the essential foundation to running IoT. These days, the scalability of IoT faces immense challenges. Traditional data storage structures are unsustainable, and it is also untenable for vast networks of nodes to process every transaction. There is also a limited bandwidth to support real-time transaction processing.

Lack of Digital Maturity

Blockchains require companies to connect and share data electronically. Networks of stakeholders that can connect and share information digitally will be essential for blockchain participants to fully identify risks and gaps. This is a far cry for many organizations, where the shift to digitalization is new. Determining how to link physical assets and at what point they will be tracked and converted into digital assets is essential, as it impacts relationships with stakeholders who may not want to share data back.

Managing Regulatory Constraints

The primary challenge for the broadest adoption of blockchain technology is regulation. The regulatory environment has not caught up with innovation. Enterprise-grade blockchain deployments will face numerous policy and legal questions. Chief among these hurdles is the lack of clear monetary regulations and policy associated with digital or cryptocurrencies. The IoT space is already foggy with legal uncertainties in data ownership, access, privacy and far beyond. Distributed Ledger Technology is not a replacement for governance; it merely introduces new ways to encode rules and process consensus.

Lack of Clear ROI

With regards to smaller businesses and retailers, they are still far from understanding why they should replace conventional tools for doing business and use blockchain, even if more people are aware of blockchain and its capabilities. The resistance to changing existing systems arises from significant switching costs and thus becomes a barrier to adoption.

Lack of Executive Buy-in

New technologies often suffer from a confusion of terminology and unrealistic expectations. A majority of consumers in developed countries find it sufficient to use non-blockchain technology for everyday lives. There is, therefore, no sense of urgency or need to adopt it. For major corporations, the cost of overhauling present-day systems for blockchain technology represents a monumental technological and logistical shift

Insufficient Skills

The ability to develop permission rules and data access across multiple 'chains' and integrating across multiple open

source platforms requires highly skilled resources and development teams. Since blockchain and IoT are relatively newer technologies, currently not many developers are fluent with them.

Very High Processing Power and Time

Blockchain nodes are expensive to process and consume a lot of energy. Since every blockchain is a ledger (and therefore a file or database) that exists in many copies, the computer resources and the energy required for the calculation, transmission and storage of the information increases as the blockchain grows in complexity and use. The energy footprint, therefore, needs to be a significant consideration in decisions on whether and how to roll out the technology.

> Processing time will be a critical challenge, as the time required to perform encryption algorithms for all the objects involved in a blockchain-based IoT ecosystem will be varying over a large range. IoT ecosystems are very diverse and comprised of devices that have very different computing capabilities, and not all of them will be capable of running the same encryption algorithms at the desired speed.

Storage is a Hurdle

Blockchain eliminates the need for a central server to store transactions and device IDs, but the ledger has to be stored on the nodes themselves, and the ledger will increase in size as time passes. This is beyond the capabilities of a wide range of smart devices such as sensors, which have very low storage capacity.

Security Concerns

Businesses must not only protect data, contracts, files, devices and networks, but also maintain privacy, authenticate identity, prevent theft and spoofing, and develop governance for autonomous device coordination and settlement. Adding IoT into the equation merely extends these decisions.

Data shared in a blockchain can be limited on a permissions basis and can also be limited to simply verifying that a product came from the person who it was supposed to come from. Hence, the main barrier is the issue of data confidentiality and ensuring that proprietary information is not shared or inadvertently disclosed as part of a distributed ledger visible to a large number of parties.

Need for Multiparty Collaboration

Multiparty integration with incumbent systems involves security and permissions testing across parties and designing and implementing shared operational and technical frameworks. Hence companies tend to take a sober approach and evaluate blockchain solutions against current solutions and the needs and risks associated with integration.

Promise vs. Uncertainty for Cold Chain Players

Blockchain is currently in a nascent stage with respect to adoption and implementation across various industries. The claims of cybersecurity and data security in the blockchain can only be judged after a few years of adoption.

The number of blockchain platforms is increasing rapidly and there are already many versions of blockchain, including Hyperledger Fabric, Ripple, Multichain and Ethereum. Most of them will work in situations that involve a few transactions. The pharmaceutical industry, however, ships thousands of units per day. Startups are entering the market, claiming to offer scalability. However most of the projects are currently at the pilot stage.

Another difficulty that pharmaceutical companies have is deciding whether to use a private or a public blockchain. Public clouds mean that the transactions could be viewed on the Internet. The most fundamental challenge, however, is the level of trust in the pharma supply chain, particularly between manufacturers and distributors, in terms of running a proof-of-concept. Once the scalability questions are addressed, distributors will have to decide whether they can play in multiple blockchains. Since regulations put the emphasis on manufacturers, small-to mid-sized distributors are at risk because they may not have the means to work in multiple blockchains. Hence technology adoption will be slow at the level of small manufacturers and distributors.

In Conclusion

Current supply chain operations do not work at the pace of business, but adopting blockchain and IoT within the supply chain could change that.

A well-run supply chain reduces transit time, enhances customer service and saves money. However, supply chain process improvements are rarely accomplished through sweeping changes. Incremental improvements to processes and a proactive approach to risk management are what usually work for most organizations.

Re-engineering the supply chain and embracing new technologies has the potential to manage supply chain risks, reduce costs and boost the value of an organization's service. But it would also be wise to keep in mind Bill Gates' famous remark, 'The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second rule is that automation applied to an inefficient operation will magnify the inefficiency.' We need to make a careful analysis of our supply chain operations before we decide on adopting any new technology.

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