ripe.io: Reconnecting the Food Supply Chain

How Blockchain and the Internet of Things Can Help Us Understand Food

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March 20, 2016

Abstract

The food industry has fragmented over time as it struggles with data capture, sharing and cooperation, creating an opaque system with limited information and transparency. Pressure from regulation and consumers have created the conditions to change, but current solutions are costly and limited in scope. We present the case for using blockchain and applying the internet of things concept to the food system in order to provide an infrastructure in which data can be recorded, shared and validated while data privacy and security is maintained. The collection of this data enables virtual histories of shipments to be created, which can be used to increase efficiency, create new business practices and potentially restructure marketplaces. Overall the solution presents a novel and new method to understand food.

Keywords: blockchain, distributed ledger, technology, internet of things, sensors, food, agriculture, supply chain, data

1 Fragmented Food

The food system is an extremely complex supply chain, moving billions of pounds of food each year. Food passes through farmers, distributors, processors and retailers, often traveling thousands of miles prior to arriving in the hands of a consumer[1].[2] In the process, a shipment may be split, repacked or joined with another shipment, further increasing the complexity. Given the vast and nonlinear nature of the supply chain, the food system has become opaque, with limited traceability, information sharing, or even data collection. Five years ago the National Resource Defense Council highlighted the need for additional data as they published the much cited statistic indicating 40% loss in the food system.[3] Although 40% of food in the US is wasted, the inefficiencies are difficult to identify and therefore difficult to eliminate.

Today the food industry still suffers from many of the same challenges such as lack of data capture, concerns over data privacy, and difficulties managing inter-actor cooperation in the supply chain. Every actor has a unique set of relevant variables, leading to patchy data sets when comparing across actors. Data, when collected, is often siloed within one actor in order to protect competitive information. Additionally every actor utilizes a different technology platform making data transfer difficult even when needed. Further complicating the issue is the lack of traceability. Current traceability practice is typically one step forward and one step backward as per the Bioterrorism Act of 2002, making assembling a holistic picture of a product through its lifespan extremely challenging even for vertically integrated supply chains. A Department of Health and Human Services study found that only 5 out of 40 products could have all of their ingredients traced through the supply chain,[4] indicating the massive dearth of information.

However, new pressure from both regulatory measures and consumers are driving change. The Food Safety Modernization Act passed by President Obama in 2010 and the subsequent rules require increased recordkeeping and data collection along the supply chain, and recommend increased traceability measures.[5] At the same time consumers are increasingly demanding more information about their food, including provenance, ingredient transparency and environmental impact. These demands translate into economic value; organic, local and non-GMO movements have been experiencing rapid growth over the past few years[6],[7] and 82% of consumers believe ingredient transparency is important in making purchasing decisions.[8] Furthermore, an Accenture study indicated improved retailer-supplier cooperation could save businesses $265 billion,[9] demonstrating the economic benefits of increased data transfer. Sustainability is also a key driver; consumers are demanding more transparency to quantify the negative externalities associated with food production such as soil erosion, pesticide use, and water degradation. These pressures from every angle indicate the industry is in a key transition period for changing the way products are tracked.

2 Reconnecting The System

Although increasing traceability and data transfer results in direct economic benefits, implementation remains difficult. Current solutions to tracing and data capture are constrained in capacity and costly, limiting the possibility of adoption for an already low-margin industry. Many solutions are limited in scope, capturing data at a highly limited number of points along the supply chain and often tracking only a few specific variables. A solution to the traceability and data challenges currently faced by the industry must be able to record and track the wide range of data collected from a range of databases and software as an object moves down the supply chain . Additionally, the solution must be able to maintain data privacy and security while at the same time allowing data to be shared on a need-to-know basis. An optimal solution would go beyond the capture and recording of data to provide analysis and optimization to maximize freshness, minimize waste and environmental impact, and ensure a safer, more efficient supply chain.

The goal of ripe.io is to reconnect the supply chain by telling the story of a product by promoting transparency along the entirety of the supply chain and assembling the histories of products as they move. We propose a new end-to-end solution applying a software stack consisting of a blockchain, on top of which a hardware solution can plug in and upload its data along the way, creating an internet of food using sensors. Blockchain, sensors and the internet of things concept complement each other, filling in each others' weaknesses to provide a robust solution set.

2.1 Blockchain and Food

Blockchain is an innovative technology protocol conventionally known to be invented in 2009 by an anonymous scientist or group of scientists using the pseudonym of Satoshi Nakamoto to support the Bitcoin network.[10] A blockchain is a distributed ledger technology in which all participants have a copy of the ledger to witness and verify transactions by themselves. Data is recorded as bundles, called 'blocks,' which are linked together by referencing the previous block, forming a 'chain.' Although current blockchain usage is limited to applications supporting bitcoin and cross-border payments, activity in the space is booming with over $1.4 billion dollars invested in blockchain companies in 2016, and over 90% of North American and European banks actively exploring implementation of blockchain technology over the next 2 years.[11] Furthermore, organizations both large and small are exploring blockchain and ledger technologies to coordinate information and secure transactions across multiple industries such as insurance, health care, music, real estate, and more recently, supply chains. Useful applications of blockchain technology include:

- Record-keeping with guaranteed historical accuracy and transparency
- Contract automation based on member-approved rules and conditions
- Trade facilitation among community members without a middle-man

Underpinning blockchains are ledgers in a classical sense in that the ledgers allow participants in a blockchain the ability to record transactions, events and activities that are associated with each entity. The blockchain serves as the fundamental infrastructure for individual data sets to plug into, allowing for data sharing from disparate actors and technologies. Individual actors can use blockchain technology as a common, trusted repository of communication, data management and validated actions, where each participant can post and authenticate information about an activity that requires validation, such as authenticating one's identity in order to authorize a buy-sell transaction. This validation is achieved by a consensus algorithm of trust of all parties that see the data. Security of the transaction is achieved by a series of digital, cryptographic public and private "keys" that lock and unlock records for the purpose of controlling data flow and validating authenticity. Ontology systems can also be implemented, further tying together the system by creating a language of food. This unification allows the blockchain to follow food products in a unique way from seed to table by recording information about a physical product as it evolves over time. For example, the original data posted to the blockchain (Grower ABX seeded tomato field 12Z on March 14) serves as a block record. As food moves along the supply chain, various types of data can be posted to the blockchain as entries in the ledger, e.g. tomatoes were harvested and packed on June 7. A second entry might record that the temperature on the truck was at 55 degrees for 274 miles. These individual entries can then be associated, enriching the data associated with the shipment and essentially creating a virtual copy of the physical item. This virtual copy is the sum of the entries associated with the unique item, ultimately becoming the history of the food product through its lifecycle. With this information, businesses can improve traceability, analyze environmental conditions through harvest and transport, and gather auditable documentation on the history of a product. Additionally, retailers can track a shipment's current location and condition; food processors can better monitor storage conditions; etc. If consumers were allowed access to the data, they could have visibility into data such as the grower and their farming practices, food miles traveled, ripeness indicators or previews of taste.

The blockchain can support multiple types of data: real-time data points (e.g. ambient temperature according to a sensor), manually entered information (e.g. genomic information about the seed), third party data via traditional APIs or integration, or proprietary encrypted information (e.g. food preparation process). In the cases where large amount of information need to be stored, the blockchain contains a file signature and a pointer to an external source of information (e.g. IPFS directory, USFDA records, etc). This information is categorized initially in an Assertions, Evidence and Certifications model. Anyone on the blockchain can post and sign an assertion, which can be associated to an identifier for a bundle of produce. Assertions can be made without any evidence, but assertions for which there is evidence should command more market power. Some evidence can be captured automatically, using sensors and IoT technology. This type of evidence will be identified and signed by the parties that handled the data capture. Other evidence will be captured manually: a farmer's profile could contain the USDA ID that confirms compliance with organic farming practices. A certification is a third party validation of an assertion, verifying its authenticity. For example, the USDA could certify that a farm is indeed organic.

Blockchain is often described as a tamper-proof, or immutable, record that protects information from being modified, removed, or misclaimed by the wrong party. Trust relationships among the system actors will grow and evolve over time and will be facilitated by an explicit network known as a web-of-trust.[13] This web-of-trust will facilitate automation of information exchange and alerts between supply-chain participants. Blockchain technology requires multiple participants to dedicate resources in support of the blockchain; the ripe.io blockchain will be hosted and supported by the member organizations involved in a particular supply-chain.

One of the more powerful features of blockchain technology is what is known as a smart contract,[14] or an automated routine triggered by data and events on the blockchain. Smart contracts are fundamentally software algorithms that are governed by real world operating rules. Samples of smart contracts range from smart invoices where payments and or incentives are automated if contract terms are met, automated irrigation systems based on real time data, or automatic alert and rerouting of a truck in transit due to temperature issues in cargo. In effect, supply chain partners can create libraries of smart contracts to improve supply chain practices that are based on consensus data. Overall, participants in the blockchain benefit from lower cost, shared data management, automated risk monitoring, notification and mitigation activity, optimizations, financial settlement and cash flow improvements and compliance management.

2.2 Creating an Internet of Food

Blockchain as a software has had most of its success in the digital world. However, food is a physical object, and as a result there needs to be a method of data collection, upload and validation. In a labor intensive, high volume and low margin industry, the data collection must be cheap and ideally automatic. As a result, we apply the concept of the Internet of Things to the food chain in order to create an Internet of Food (IoF). In the IoF, sensors and other data gathering elements collect data which is sent to the blockchain, which then registers and documents the data collected.

The Internet of Things is the concept of connecting things to the internet using sensors, allowing for new information to be gathered, and new actions to be taken as a result of that information. Precision agriculture has long adopted the Internet of Things concept to measure and quantify parameters such as nitrogen content, water usage, and yield, allowing farmers to make better decisions and improve profitability. However, limited integration has developed beyond the field. As a result, we aim to extend the IoF to encompass the entirety of the chain, providing true farm to fork traceability.

At each life stage of the product, a sensor or sensor set collects data on a set of variables hypothesized or proven to be relevant to that actor. Different actors may have different needs and so will track different variables but any information collected can be tagged to the identity of the product. This data is uploaded automatically as to have no human interference, and can be referenced against expected values for validation to create trust. For example, a field sensor measuring temperature and relative humidity on the field will capture be able to capture with granularity the changes in the local environment, and upload this data to the blockchain, which can then be referenced against the local weather station to validate whether the measured temperature is within reason of the weather stations measurement. As different sensors gather and upload different data sets across the lifespan of a product, a history of conditions the product has experienced is created and documented in the blockchain. These datasets can then be analyzed and shared as needed to improve the entire ecosystem.

3 Benefits of the Internet of Food

The foundational infrastructure created by blockchain combined with sensor and other data collected along the supply chain has huge economic potential, as the technology set enables the decrease of inefficiencies, the unlocking of underutilized value, and the creation of new business models. Assembling a holistic picture of the life of a high volume product as it passes through multiple actors on an industrial scale is unprecedented; most attempts are academic studies focusing on a specific set of variables, or controlled in a vertically integrated supply chain. Participants in the chain are able to improve their processes first within their own operation, and second in their interactions and cooperation with other actors. The data sets collected can improve individual actor's operations by exposing inefficiencies and revealing insights that have not previously been recorded. For example, temperature and humidity monitoring in transportation could alert improper handling or packing, causing the formation of a hot spot in the truck, or the monitoring of moisture in a farm could help optimize water use. Additionally, the creation of holistic data sets allows longitudinal correlations between events and variables both upstream and downstream to better facilitate inter-actor cooperation. For example, new shelf life predictions can be conducted given a baseline of prior environmental conditions, allowing for more accurate estimation of lifespan and the creation of new best practices.

Whole chain traceability can also radically change food safety. Current one step forward and backward traceability would be replaced by the ability to track through the entire chain, with associated records of labels and documentation. Being able to access the entire product journey from a single platform would eliminate the difficulty of going through the supply chain step by step, vastly improving response times in the event of a food safety incident. Additionally when a large number of objects are tracked through the blockchain, the chain could identify cross-contamination events or exposure, as well as any other incidents such as a spoiled or damaged shipment, enabling preventative action to be taken on a select group of shipments instead of a whole lot. In the case of a recall, if the root cause was identified, specific shipments downstream of the incidents could also be retrieved in a pinpointed recall, saving a company millions compared to a blanket recall. If the data sets were to be shared with consumers, post-recall brand trust and loyalty could be repaired quickly as consumers could validate and verify the claims themselves.

Smart contracts can also simplify and allow the automation of multiple processes between participants on the blockchain. For example, a local restaurant owner could post a smart contract on the blockchain offering to buy a set quantity of produce over a set amount of time, as long as the produce meets a certain set of specified conditions. A farmer wanting to plan his crop could bid on that contract and promise to deliver the produce at a certain price. As the produce grows and ripens, each party can be notified if growing or handling conditions exceed boundaries set in the purchase smart contract. In the case when some value is deemed to be sufficiently out-of-bound as to violate the terms of the smart contract, the produce could be redirected to other purposes, while another farmer could fill the smart contract with surplus satisfactory produce.

Adopting a longitudinal view to data collection and history in the supply chain presents the potential to restructure marketplaces by introducing new methods of valuing products. Currently fresh fruits and vegetables are brokered with minimal attached information except in the case of high-end artisanal goods. Product differentiation is left to binary labels such as organic and non-GMO which command premiums in price. However the acquisition of additional accessible data allows for new features to be verified and marketed. For example, the geolocation record could be processed by an algorithm to calculate the number of food miles traveled by a product, or the distance between the production point and point of sale in order to prove the locality of a product. Additionally, binary labels such as conventional versus organic could be broken down into a spectrum of farming practices such as use of integrated pest management or no-till practices that could each garner consumer followings. These datasets and outcomes could be compiled into an index on which product is posted and sold. The index presents data in an agnostic format without taking a stance on desirability of certain aspects, and leaves it up to the user to generate a set of desired criteria to aid in purchasing and evaluation. These criteria can be compiled into a unique user scorecard, which can filter through postings and select products for desired traits. For example a restaurant may pride itself on serving local, sustainable food. The algorithm would then optimize the purchasing search for food produced within a certain radius of the restaurant, and prioritize for sustainability practices like limited pesticide use. In particular, taste is an unexplored category for segmenting produce and deriving additional value. By use of devices which can non-destructively measure the composition of a product and thereby derive a taste profile, purchasing could be tailored towards the detailed needs of a buyer. For example, with a given taste profile, a restaurant could choose to look for sweeter, less acidic tomatoes for a salad. Ultimately, this platform could create a new marketplace where purchasers buy the optimal product for their needs, while producers gain additional profit for their existing practices.

4 Conclusion

Pressure from every angle has created a perfect time for change within the food system. A low cost, secure and easy to implement solution is desperately needed to bridge the gaps in the supply chain and solve problems such as food waste, safety, quality and sustainability. ripe.io aims to reconnect the supply chain by promoting transparency and data capture along the chain through technology. Blockchain and the internet of food compliment each other to create a common collaboration platform in which data around food can be produced, tracked, validated and verified. The creation of unique histories of individual food items can solve for inefficiencies in the chain as well as create new value and business models in the system. Ultimately, the solution set offered has the potential of providing not just holistic farm-to-fork traceability, but also true understanding of our food.

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