Blockchain and IoT for Delivery Assurance on Supply Chain (BIDAS)

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Blockchain technology introduced immutable distributed ledgers to the technology landscape. With the current popularity and success of the blockchain technology, researchers are looking for further implementation opportunities for the tamper-free ledgers. The supply chain industry has been a beneficiary of blockchain technology with its rich set of participants. From financing all the way to tracking containers, there are opportunities in the supply chain industry to utilize distributed ledger technologies. Furthermore, Internet of Things (IoT) and wireless enabled devices add value by providing services based on their sensor capabilities. Our study is on the synergy of blockchain technology and IoT to provide quality data to supply chains. We believe that the next generation of IoT services would only be possible with the democratic autonomy of devices in an environment where privacy, trust, transparency, and security are provided. With blockchain and IoT, there is a potential in re-architecting supply chain systems. With the addition of IoT capabilities, there are opportunities to create better business models.

In this paper, we focus on delivery assurance in the supply chain industry, and we propose a novel blockchain-based transparent delivery framework for creating solutions that record and share data on the interaction of business participants. This framework helps create solutions that include handover and monitoring aspects of the delivery businesses and adds several benefits that come with the blockchain technology.

Keywords—Blockchain, Agent theory, IoT, Big Data, Delivery framework, Last mile, Trust, Supply chain, Computational public safety

I. INTRODUCTION

The supply chain industry has been focusing on blockchain research due to the structure of the industry where conducting business requires numerous contacts and handovers. This interest resulted in the existing literature to mainly focus on the handover of the goods with RFID tags scanned by the agents of the supply chain infrastructure. These events are typically recorded in the blockchain to be shared with all the partners. This sharing scheme is commonly designed to take advantage of the similarities between a shared database and a blockchain. Implementations typically use permissioned blockchains or a hybrid solution of permissioned blockchains with a public blockchain due to the privacy requirements of the businesses.

The scope of this paper is a subsection in the supply chain business context with a specific focus on what is called "the last mile." The last mile is the final task in the delivery process, at which point, delivery is marked as completed. Business processes assume the ownership of the deliverable is transferred to the client when goods are handed to the client or its representative or left at their property. Last-mile is often considered to be a costly section of the overall delivery process [1] as it is often the least efficient link in the supply chain, reaching up to be 28 percent of the total cost of the delivery [2].

Since improvement in delivery performance is a competitive advantage [3], several new approaches to deliveries are introduced or are being researched. Autonomous Unmanned Aerial Vehicles (UAV) [4] [5] and land vehicles [6] [7] are under development as emerging alternatives to conventional delivery methods. New methods also include robotic mobile store experience, which delivers many products to the customer and lets the customer choose which product to keep [8].

Delivery methods are not the only aspect of the industry that is under constant improvement. Delivery companies decorate deliverables with better tools and technologies to closely monitor the process. Besides conventional RFID tagged packages, smart packages with condition monitoring systems are emerging [9]. Condition monitoring systems [10] are collections of electronic sensors that monitor a variety of environmental conditions related to an asset and aid overall reliability of the delivery of this asset. Vibrations, acceleration, temperature, humidity, acoustics, and global positioning are some of the conditions that deliverables are subject to in the delivery process.

Traditional supply-chain industry has been utilizing RFID based IoT operations successfully in collecting sensor information under the governance of centralized authorities. Blockchain technology comes to the rescue when the centralized authority is not sufficient to cover all aspects of the business. When parties with conflicting interests collaborate in a business environment, they need to build trust for the smooth execution of the business transactions. It is typical that when the business goes as planned, there is no apparent need for intermediation; all parties conduct and continue their businesses within their tolerable margins. Yet, trust is critical in times of disagreement; when things do not go as expected, parties need proof, they need a reliable, untampered, and undeniable record of data related to the transaction in doubt. Blockchain technology provides this trust.

Besides its classic benefits, blockchain technology offers solutions to two main problems in the delivery industry. These

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are "Chain of custody throughout the handover of packages" and "Continuous monitoring".

Chain of custody is a problem when multiple parties conduct business indirectly through the interaction of their representatives, proxies or agents. These interactions, mainly the handover of packages between independent parties have a security and trust issue. Lack of chronological documentation or paper trail recording the sequence of custody and handovers with sufficient physical or electronic evidence, feeds the issue. This trust issue cost companies in the form of business loss or as expenses such as insurance fees due to difficulties in finding responsible entities for a harm that occurs at an unknown time.

As depicted in Fig. 1, delivery transactions start with an initiator. The initiator can be the sender of the packages or a last-mile delivery company who happens to be the first entity that has access to electronic systems that is equipped with IoT sensors that can prove the initiation of the delivery task. The package travels to the receiver who can also be called the receiver of the services as this entity is the receiver of the delivery service. So, the last entity that can be associated with the delivery is the receiver. In this conventional model of communication, while the package is on its way, information related to the business context of the delivery passes through several intermediaries towards the receiver (1 to 6) and through the same intermediaries back to the initiator (6-10). The meaning and time-value of the information depreciate as the information goes through an increasing number of nodes. Accurate information does not reach the stakeholders on time, and it often arrives indirectly. There are risks related to malicious censorship. Indirect stakeholders of the process receive information from multiple parties. It is then costly to filter and merge the information in order to find the truth to be used in business or conflict resolution.

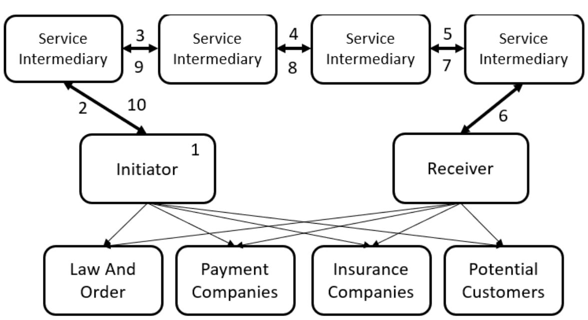

Fig. 1. Information flow from delivery initiation to completion

The continuous monitoring problem originates from the traditional data centric IoT application model built with the intention to monitor systems in detail. Advances in the IoT technology made the collection of data possible, but the systems architecture to process the collected data did not advance equally. A broad set of devices collects large volumes of data that needs to be processed and preserved with its original quality. Most delivery vehicles today carry GPS sensors and other telemetry capturing sensors providing high resolution data [11]. Conventional IoT support systems process this data by centralized analytics applications that have a high processing power. Recent advances introduced parallelism to the processing logic. Parallelism such as big data increased the capacity and throughput, however this parallelism took a derivative of the data by stripping its detailed attributes that have the most value related to trust. The lack of trust in the individual devices and security issues have decreased the range of functions that these devices can execute. Blockchain technology is a gateway to more capable IoT systems. Otherwise untrusting parties can cooperate by quality record collection, processing and keeping [12].

There are several similar ideas on the Internet and literature indicating that blockchain technology will revolutionize the delivery industry [13] [14] [15] [16] [17]. These articles also emphasize that a cryptocurrency [18] [19] for delivery business would be successful. However, current work [20] does not provide a framework for solving delivery problems on a structured platform. Instead the focus is on the benefits of the technology and opportunities that it presents [21] [22].

In what follows, we present a literature survey of blockchain applications in the IoT field. This survey highlights the importance of trust and the leading use cases of the blockchain technology in IoT. Following that, we present our framework to solve the above-mentioned delivery industry issues by modeling the delivery blockchain that consists of data from stakeholders, system actors, and IoT sensors. Our framework considers the participants, data models, and interactions. We also present a use case to discuss the framework. We present the details of the design and the benefits of such a solution that follows this framework. We conclude this paper with the critical lessons learned and future directions of our research.

II. Blockchain Technology Review

A distributed ledger is a system with rules around keeping and sharing data between participants of a network while synchronizing, validating, and keeping the integrity of the information. This shared set of data can be stored and modified in the system. There are live examples of distributed ledgers for discovery services [23], virtual server management services [24], and financial services [25] [26].

Blockchain technology is a type of a distributed ledger that fulfills the reliability promise by chaining the blocks of transactions based on their hash values. By placing the hash of each block into the content of the next block, the system connects the blocks and forms a chain. Even if malevolent parties complete this expensive operation, distributed ledger implementations require consensus to accept the new blocks. Changes in the old blocks would be detected through the comparison with the local copies of the distributed ledger and rejected by other nodes in the network.

Bitcoin, as the first mainstream implementation of the blockchain technology, demonstrated to the world that cryptographic techniques combined with high volumes of participation could create a ledger environment where all parties witness and validate all records. This pattern of record-keeping inspired several solutions in digital exchanges where goods and payments are transferred electronically.

The blockchain concept is not new anymore and using blockchains is seen as a disruptor for all industries [5] around the world. Blockchain technology acts as a trusted agent between otherwise untrusting parties. With these characteristics, blockchain applications are widely used to integrate businesses and individuals.

Blockchain implementations can vary on participation. Public blockchains enable anonymous participation of members and transparent sharing of all information. This level of participation and transparency is not suitable for all applications. Permissioned blockchains limit the participation and block creation authorities to the designated parties. There are several hybrid blockchains for handling other varieties.

Blockchain providers have met the demand in terms of requirements and flexibility. Especially since the blockchain technology is a comprehensive technology that empowers small players around the globe and gives them an opportunity to participate, global interest in the application of the technology has soared.

III. The Synergy Between IoT and Blockchain Technology

Internet of Things (IoT) is the network and ecosystem of devices that collect and share data. IoT networks typically are formed by numerous interconnected devices that are the service provider-consumer interfaces between humans, technology, and organizations [27]. With the perception capabilities of sensor networks, the IoT universe has an excellent detection capability. The environment data such as location, motion, temperature, and acceleration that are collected by sensor units is an invaluable means by which the digital world understands the physical world. Near Field Communication (NFC) devices, Radio Frequency Identifier (RFID) devices, wireless sensors, and mobile phones are standard tools of today's capable IoT ecosystems. IoT networks have the potential to automate a significant number of manual tasks and improve human life [28].

This network of billions of devices demands more of everything. Network bandwidths are increasing to enable a higher volume of communication. Wireless technologies and networking are increasing their coverage to include more participants. IoT infrastructure components are connecting devices to collect a massive amount of high-quality data and to provide further intelligent services. There are several architectures proposed for IoT in order to solve its communication issues. Some of the standard layers include a sensing layer for sensors, networking for connecting the sensors, and a service layer for providing interfaces for clients to integrate into a network of sensors [29]. Most application integration is centralized at the middleware layers [30] and exposed to tampering by malicious entities.

IBM predicts winners of the IoT technologies will be those who can decentralize peer-to-peer systems and can lower costs. The winning choice would be privacy and long-term sustainability instead of full control of data [31].

Several other challenges in the IoT world can be solved with the collaboration of parties. A good example is how a peer can provide a solution to a device to upgrade its firmware after the manufacturer disconnects the necessary service [32]. Discovery services about the correct firmware file and the conditions to receive such service can be made available with smart contracts which are a feature of blockchain technology.

Decision-making mechanisms based on peer-to-peer networking is essential for IoT. Central trust figures or authorities are not available for every network, and they can be a bottleneck to the overall network where they exist. A community of peers in the form of a peer-to-peer network fulfills this requirement where all decisions are made collectively, and unilateral choices are prevented [27]. Since devices on the Internet will have to act independently, and have to carry their operations individually, peer to peer solutions are essential for IoT adoption.

Condition monitoring systems have a fundamental role in active IoT space [10]. These systems formed as a collection of electronic sensors monitor environmental conditions related to an asset. Even though the global positioning of an asset is the most important information for the supply chain processes, depending on the nature of the deliverable, the data collected about the environmental conditions of the deliverable can be substantial through the delivery process. Fragile or perishable assets can be monitored for vibrations, acceleration, temperature, humidity, and even acoustics. Sensing of unpredictable conditions and automatic recording of this information on a blockchain will be an added benefit of IoT towards better delivery systems [33].

IoT architectures benefit from decentralization since there are high numbers of nodes in these systems and scalability often requires independent operation of devices while producing collective value. Devices in the IoT systems interact with each other and this large-scale interaction can benefit from the injection of trust created with the introduction of a blockchain. Considering the delivery businesses are introducing autonomous vehicles and other non human agents to their business model [34], it is important that blockchain technology certifies that the gathered sensor data is original and not tampered. This promise of the blockchain technology would make IoT networks a trusted agent in business transactions. When a business event or a monitoring event occurs, IoT sensors detect the event; blockchain technology lets the entities share and use this information. This ability to access the original information brings trust to the interaction, and otherwise untrusting parties can do business together.

Each IoT device may not be a full blockchain node [35]. Each node may not have the processing capacity or data storage capacity to be involved fully. However, they can be sending messages to the blockchain network through their network connection. They can also receive the summary of the related communication with the help of smart home centers.

IV. Blockchain and IoT for Delivery Assurance on Supply Chain (BIDAS) Framework

Supply chain industry has numerous opportunities with the emerging blockchain revolution. In this research, we study a growing segment of the supply chain space named the parcel delivery industry [36]. Our novel contribution to the supply chain industry is the definition of a framework that guides the structure of the blockchain implementations in delivery operations of the supply chain industry.

Parcel delivery is especially a good business area to focus as an increasing percentage of customers are ready to pay more for improved delivery service [34]. This business area is also the most open to new technologies. McKinsey is expecting 80 percent of all deliveries to be completed by autonomous vehicles, including drones [34] in the next ten years.

We targeted delivery operations since we believe this business area can be improved. From the cost perspective, the technology is, and will be, reducing costs compared to the cost of labor for the same amount of work. Scalability and availability of autonomous resources are, and will be, higher. Autonomous options are ready to change the industry entirely as they can deliver 24/7; without a holiday, a weekend break, labor law restrictions or a strike to slow things down.

In order to solve the information flow problems and aid other supporting business processes, we propose a blockchain and IoT delivery assurance on supply chain framework (BIDAS). Our framework targets delivery problems identified earlier in the paper. When a delivery ecosystem is being built, we recommend using our framework as a guideline to define, describe and implement the blockchain solution. Following the steps depicted in Fig. 2, delivery operations can benefit from the blockchain revolution.

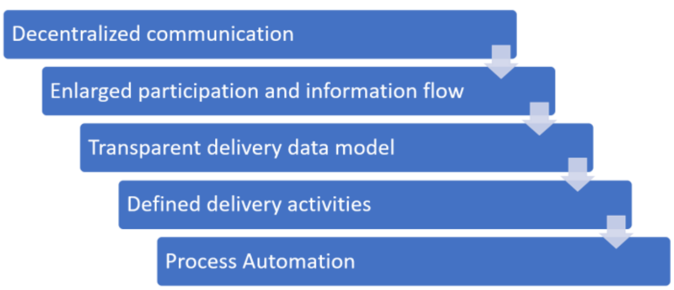

Fig. 2. BIDAS framework recommended steps for delivery assurance

A decentralized model of business

BIDAS advocates replacing centralized information flow with the decentralized architecture of blockchain systems as depicted in Fig. 3. BIDAS fully involves all the service intermediaries hired in the process as well as the passive beneficiary stakeholders. All stakeholders become blockchain network participants. They benefit from transparency and support the system by their active involvement. BIDAS is not only a blockchain framework. Decentralization alone is very beneficial to existing business models.

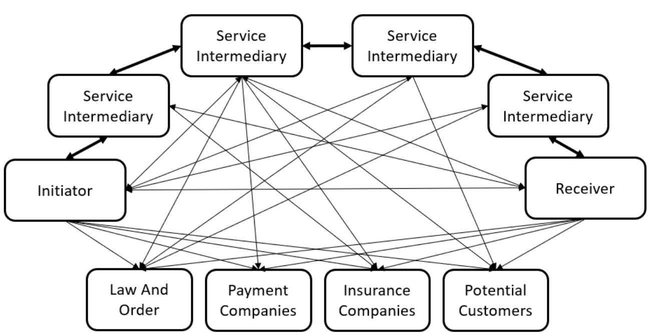

Fig. 3. Information flow with BIDAS

Participants and information flow

Agency theory identifies uniform information flow as an important aspect of successful business interactions [37]. Asymmetric information prevents best possible outcome to be achieved and results in losses named 'agency loss' [38]. Principals and agents in conflict of interest are common in supply chain industry [39]. Despite being expensive with conventional methods, monitoring had been part of solution towards closing the gap of information [40]. BIDAS applies the agency theory and aids the solution of information asymmetry with reliable monitoring using the permanent records of the blockchain.

In BIDAS, principal is the actor that assumes ownership and responsibility of the delivery. Ownership and responsibility are assumed with providing a commitment or when the goods enter its custody. A person or a non-person entity can be principal. A principal assumes the responsibility of the handover actions as part of delivery business directly or through its agents. BIDAS especially focuses on the IoT based delivery businesses. Therefore, agents in BIDAS can be a wide variety of sensors. Beside sensors, infrastructure that hosts the sensors can also be agents.

BIDAS models the interactions as depicted in Fig. 5. Delivery models start from a role named initiator. An initiator is usually the creator of the delivery task. Typical examples are an online bookstore or a delivery company receiving a package in one of their stores. From this point on, the delivery operations are a series of handovers where one party hands the package to the next until the package is delivered to its final destination. BIDAS addresses the first problem in the delivery business that we listed above with the label "Handover of packages". The main concern in the handover of packages is the chain of custody. Chronological documentation of electronic evidence is a must for delivery businesses [41]. Blockchain does this evidence collection in a democratic network and on an immutable ledger. The second role in the systems is for the system intermediaries, which are actors in the delivery business that transport the packages towards the destination. BIDAS models the communication flow between the initiator and service intermediaries.

TABLE I. LIST OF ROLES IN PACKAGE DELIVERY HANDOVER

Party Type	Initiator	Service Intermediary	Receiver
Principal	Initiator	Service Intermediary	Receiver
Actor/Agent	Initiator Actor/Agent	Service Intermediary Actor/Agent	Receiver Actor/Agent
Sensor	Initiator Sensor	Service Intermediary Sensor	Receiver's Sensor
Sensor Host	Initiator Sensor Host	Service Intermediary Sensor Host	Receiver's Sensor Host

BIDAS also assumes there can be several layers of intermediaries where some portion of the transportation or delivery business is outsourced to other service intermediaries. The last type of actor in the BIDAS interaction model is the receiver. This role can be assigned to a customer that orders a book or food or any other material for delivery. This actor is the last node in the system. When the goods are delivered to the customer, or in other words, the last interaction between the last server intermediary and the receiver happens, the delivery process is marked as completed. The package delivery handover roles template is listed in TABLE I.

For each delivery service stakeholder, there are multiple types of parties. These parties represent different types of actors that are involved in handover interactions. Each delivery service stakeholder has principals and their agents. Beside the principal and agent of agency theory, IoT adds sensor devices that detect and respond to conditions and changes in an environment [42]. In the delivery scenario, sensors can be RFID devices, GPS, thermometers, barcode scanners, microphones and video cameras. Sensor host is an actor that is a structure, device or vehicle such as a building door, vehicles, robots, UAVs, cashier station or warehouse. These four types of actors in the same delivery service stakeholder has relationships as in Fig. 4.

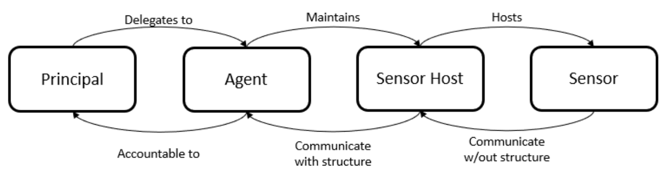

Fig. 4. Principal-Agent-Sensor Host-Sensor model of BIDAS

Even though BIDAS provides guidelines to model the communication on the blockchain architecture, handover problems can be solved by modeling business interactions that are depicted in Fig. 5.

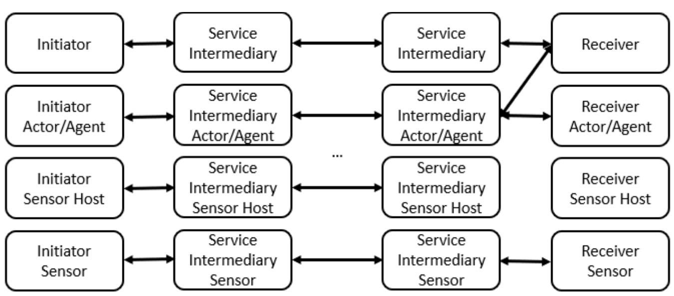

Fig. 5. The BIDAS business interactions model

Data model

A blockchain-based process is like any other process in terms of modeling the data. Blockchains can be modeled similar to databases where structured or unstructured data are stored. Due to the extended amount of communication, blockchains tend to have a minimum amount of data. Single-purpose blockchains such as cryptocurrencies prefer structured data as the validation of the transactions require all information encapsulated in a transaction to be well understood. For business transaction blockchain implementations, unstructured data is acceptable and expected as the business information tends to vary and evolve.

BIDAS is not restrictive on the data model. Conventional delivery data entities such as Order, Order Item, Delivery Item and Receiver are to be used on the new blockchain-based data communication layer of BIDAS. There are already existing data standards and delivery data model samples [43] [44] [45] [46] [47]. The amount of data to be shared depends on the implementation. There are several privacy concerns about the maximum transparency a blockchain ecosystem can provide. For example, when the receiver information is openly communicated in the blockchain network, all members receive the details. Implementation of a delivery system must have an identity and consent system built-in in order to share the customer information only with the parties that the customer provides consent for.

All sensitive data will be represented in JSON-LD lightweight linked data standard [48]. It is easy to read and write. It uses Json structure. It has a general compliance with RESTful services, and unstructured databases.

Some entities we have defined in BIDAS include Receiver, Order, Order Item, Payment, Invoice, Deliverable, Delivery, Delivery Stage, Delivery Event, Delivery Schedule, Contact Event, Agents (Employees), Sensor Hosts, Sensors and Sensor Events. All Items have their identifiers. Beside the identifiers main attributes for each entity is listed in TABLE II.

TABLE II. LIST OF PRIMARY ENTITIES

Entity Name	Attributes
Receiver	Id, Status, Contact Details, Delivery Destination Details, Coordinates
Supplier	Id, Contact Details, Shipment Contact Details, Customer Service Contact Details,
Order	Id, Order Items, Receiver
Order Item	Id, Amount, Price, Tax
Payment	Id, Amount, Method, Details (Number, Expiration, security Code, Reference Number), Timestamp
Invoice	Id, Total Price, Tax
Deliverable	Id, Packaging Type, Dimensions, Weight, Order Items
Delivery	Id, ETA, Tracking ID, Deliverable
Delivery Stage	Delivery State and Status
Delivery Event	Receiver, Receiver Agent, Receiver Sensor Host, Receiver Sensor, Contact Event
Delivery Schedule	Delivery, Time Period, Date
Contact Event	Image, Signature
Agents (Employees)	Agent Id, Title, Salutation, Given Name, Family Name, Gender, Birth Date, Contact Details
Sensor Hosts	Id, Receiver, Sensors, Contact Details, Serial Number
Sensors	RFID, UID, Serial Number
Sensor Event	Sensor, Latitude, Longitude, Altitude, Latitude Direction, Longitude direction, Altitude direction, Temperature, Pressure, Acceleration, Noise

The Receiver entity describes the last entity that is involved in the series of handovers. This entity is typically the terminal entity where we consider the delivery to be completed. Depending on the business scenario, this entity can be a customer or a building or simply GPS coordinates or an autonomous actor. This information can include identifier, image, or any other data that can be used to prove the delivery. Whether the receiver information is kept in the blockchain in detail or represented with identifiers is the choice of the developer. In case the information is kept off the chain, a resource URL should be included to access the customer information in case it is to be used by a stakeholder. For a delivery notification to be sent, contact details must be available to some stakeholders.

Delivery destination information is the contact destination for delivery completion. An address or coordinates can mark the delivery spot. JSON-LD would make sure the address can also be stored remotely if it needs to be kept confidential.

Order is the representation of a complete list of deliverables to be delivered to a customer that is organized or purchased under a single business transaction. An order may have multiple deliveries in case the items in the order are to be delivered separately.

If the blockchain is to be used as a platform to integrate sales and payment systems as well, these records will also be on the blockchain. Payment amount, currency type, payment instruments, and status will be stored. The monetary integration can be improved with smart contracts for managing the commissions and fees in the process.

Deliverable information is a list of package/product/service information that is part of the same delivery. All the deliverables included in the delivery can be stored in the blockchain either in detail or as a URL representing the item. Standardized handling instructions must be available for each item for all handlers to comply. These instructions also should be in the form of URLs or codes since such information would be highly redundant.

Delivery schedule data contains the timing details of the delivery. Timeframe information can be kept on the blockchain to let stakeholders know when the delivery is intended to be.

Delivery agents used to be the delivery company employee, national postal services worker, or a subcontractor. With autonomous vehicles as an alternative channel to distribute parcels and other deliveries, the agent concept also has a wider variety. Crowdsourcing of the tasks also makes this role available to more [49]. The data representing the agent will be in the blockchain.

There are some general data considerations that every blockchain must address. Privacy requirements of the stakeholders and record-keeping options are part of our framework considerations. As already mentioned, several pieces of data can be kept off, but available to the blockchain in the form of URLs of identifiers. Record-keeping policies will be addressed with respect to the data storage policy. It is given that the data written to the blockchain is already disseminated to all stakeholders. If the data is kept off the chain, then the data governance will rely on the principal and storage of the data.

Activities and automation

Delivery systems modeled with BIDAS not only use the entities to store the information on the blockchain networks like a distributed database but also record the business activities. Activities that are a natural part of package delivery are listed in TABLE III. Identifying and utilizing these activities is important since in the blockchain solution these activities map to smart contracts. This gives all stakeholders the ability to create contracts to automate their business processes.

The first type of interaction is the registration of entities other than delivery. Receivers, Receivers' receiving agents, providers, payment companies, delivery agents, and the delivery company can be registered to the system. This can be an upfront activity for larger entities such as providers and payment services, or it can be an on-demand activity for customers and their agents. We will not go into the details of these relatively straightforward activities.

The second type of activity is the operational entity creation, such as the creation of order, delivery request, and payment request. These are business activities that trigger further operations in our blockchain. The delivery event, delivery acceptance, and payment automation are the next category of activities that can be modeled.

TABLE III. LIST OF ACTIVITIES IN PACKAGE DELIVERY

Activity Name	**Description**
Registration	For each actor, a registration is needed to be for identification in the system
Create Order	Initiator creates an entity for delivery, order, set the status to order received
Delivery Status Change	Participants update the status of delivery such as shipped.
Observation Recorded	Sensors or sensor hosts records device readings and observations
Handover	Participants indicate that the package has changed hands
Return Delivery Item	Receiver or initiator changes the destination back to the return destination for the order
Cancel Delivery	Receiver or initiator changes the destination to the cancel destination for the order
Complete Delivery	Service provider of the last mile marks the delivery as complete.
Received Delivery	Receiver marks the delivery as received
Opinions Recorded	Parties record their opinions related to the delivery

The final group of activities is on the sensor events. These activities are solely on the monitoring of the deliverable based on sensor information. Monitoring information received from the condition monitoring systems will be recorded in the form of events. A sensor data model will be developed for these events. Each event will be modeled with a data type. Common attributes such as timestamps and duration will be included with the data. With the help of smart contracts, activities such as a thermometer reading in a package can trigger operations if programmed as such.

The delivery completion event will be included in the blockchain. The customer or customer's agent will accept the deliverable and mark the delivery successful. Alternative scenarios such as failure are also to be modeled. Opinions of the parties (word of mouth) are stored in the blockchain as well. There is a great benefit for the customers with reliable information besides the order and delivery information stored in a tamper-free environment.

V. USE CASE: E-COMMERCE DELIVERY

Our proposed solution to the challenges of the last mile is to follow the BIDAS framework and create a blockchain for all participants to record, verify, and share information related to delivery events. In this section, we demonstrate this with an e-commerce use case where a user orders goods from the Internet and an e-commerce company ships them to the customer's home.

This is a good use case as delivering the products purchased from e-commerce vendors to the door is quite standard in the parcel delivery use cases. As part of e-commerce transactions, customers purchase goods through e-commerce company web sites and receive the goods through the delivery channels. The industry also has 68% preference on interconnected systems that enables retailers, shippers, and customers to be closely connected [50]. Therefore, we believe modeling this interaction on a blockchain where all stakeholders have fast and direct access to the information is appropriate.

Decentralized model for the business

Blockchain networks mainly differ by the roles of participation and governance of the chain. Public blockchains govern the system with democratic principles that value the majority. As a result of this choice, they are highly dependent on cryptocurrencies to incentivize usage, maintenance, and ethical behavior. Permissioned blockchains solve behavior-related problems by assigning roles to participants. Since consensus mechanisms and other chain lifecycle decisions are made only by identified, and permissioned members, several risks related to a hostile takeover are prevented. Our solution encourages the public to become a member of, and use the blockchain. It is expected that read-only members at least benefit from the opinions in the system related to products and experiences.

Participants and information flow

Following the BIDAS framework, we identified the participants and related information flow in the proposed blockchain network is as depicted in Fig. 6. Participants include customers, e-commerce companies, parcel companies, delivery drivers, home IoT devices, smart home centers, and insurance companies.

All participants benefit from this system. First, the distributed system removes the single point of failure for individual operations. Any actor in the system is not connected to the monolithic legacy system they usually use. A delivery person does not need the delivery company systems to be up. Payment details are available even without the payment company being online. Other potential customers can see the opinions about the seller and goods, governing authorities can access the transaction details in case of conflict, insurance companies can resolve the losses, delivery companies can monitor individual deliveries, and overall, transparency encourages increased quality of service.

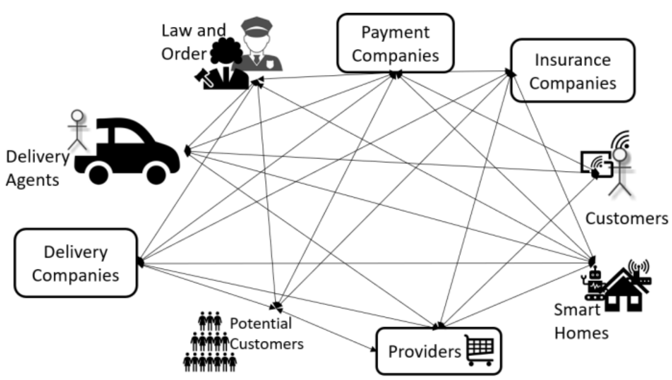

Fig. 6. Participants of the blockchain-based solution

In our proposed solution, IoT devices have a vital role in representing the home and occupants of the home. The delivery is only considered flawless when the device accepts the packages and signs for their receipt.

Delivery crews are also key participants in this ecosystem. Currently, delivery companies act as the sole authority on the data and operations from the warehouse to the door. All tracking activities and data belong to them. They also make mistakes, such as delivering the order to the wrong address. The sharing economy concept is catching up with the delivery business and provides opportunities to crowds to do Uber-style deliveries when they have available time. Our solution also removes the single authority status of the delivery company, but in return, asks for a very high level of transparency from delivery personnel and homes.

Adoption of this solution by various parties will be proportional to the benefits they receive from the system. There is much openness in this design that enables contributions from multiple vendors. Several payment companies can be involved, and several delivery options will be available. There will be more reliable opinion data in this system that are proven to be provided by people who have made purchases. Increasing the quality of the overall e-commerce space will finally benefit consumers with better service, increased quality, and lower costs. Privacy concerns on individuals' information is an ongoing discussion. The level of shared information can change depending on the implementation and time. Future online shoppers may not mind more details to be shared.

Businesses will find numerous opportunities with the blockchain to improve their data collection and precision. E-commerce companies are significant contributors who use the blockchain system to record sales. Blockchain will provide trust to the e-commerce companies as the lack of authority in the ordinary internet shopping will be replaced with the tamper-proof ledger of the blockchain. With the blockchain-based trust in place, starting a new e-commerce company will be more convenient. E-commerce companies can elevate their brand image by contributing to this project. Transparency will bring more trust to opinion collection as well. When the e-commerce company maintains the opinions, opinions lose their reliability due to the inherent conflict of interest. Customers trusting significant e-commerce companies can continue their trust. However, small companies lack the trust in the opinions provided to their website as there can be a conflict of interest between keeping original opinions and sales. The blockchain solution keeps the sales records and opinions together to eliminate the need to verify the opinion provider as a customer.

Blockchain technology created the fiercest competition for payment companies. The payment space has been the number one target for blockchain disruption. Cryptocurrencies introduced digital money without borders. Cryptocurrencies also prove the simplicity in sending money and having an undeniable log of the events. Our model brings a new approach to payments. If independent payment companies are preferred, they can be involved in the transactions. They can provide the execution of the payment with fiat currencies and register their transactions into the blockchain.

Insurance companies are hidden contributors to the processes. Most credit cards have shopping insurance. Delivery companies have delivery insurance. If an item is missing after its delivery, home insurances can get involved. There are benefits to their business due to the precision of data collected with the blockchain. Prevention of insurance fraud translates to increased revenues for the insurance companies. These companies will also benefit from removing manual and unreliable data collection. In case of incidents, the data in hand will be evidence-grade untampered data. Currently, insurance companies do not know the delivery timestamp. Their offers on insurance, such as damage in the first 30 days, are based on estimates. Precision in this field may benefit them. Most important of all, insurance companies will provide reliable service. The disappointments due to a difference in understanding between the parties in the transaction will be avoided with undeniable records in the blockchain.

Government agencies that are responsible for law and order can benefit from participating in the blockchain network. As more platforms use blockchain and more entities trust the distributed ledgers, courts will accept the information on the blockchain to be dependable. One more significant benefit of government involvement is for taxation purposes. Economic activities recorded on the blockchain platform can be used for tax and audit purposes. Lawyers can also be participants of this blockchain so that they can use the tamper-free information in case of a dispute.

Data model

BIDAS data model is a good fit for our use case. Therefore, we will include all the data definitions provided by BIDAS. Our data model includes Customer, Order, Order Item, Payment, Deliverable, Delivery, Delivery Stage, Delivery Event, Delivery Schedule, Contact Event, Agents (Employees), Sensor Hosts and Sensors. Details of these entities will be part of our implementation but not included here due to space constraints.

Activities and automation

There are several possible types of interactions in the eCommerce and delivery scenarios, as detailed in the BIDAS framework. Similar to the data model, interactions can be used extensively depending on the project. A delivery system that uses the blockchain for payment automation would have more interactions compared to a system only focusing on the delivery event.

We follow BIDAS framework and identify all the fundamental activities listed in TABLE III. In this specific use case, order creation, status changes, sensor readings, every handover activity, completion, acknowledgment and opinions will be recorded on the blockchain. Smart contracts will be created as needed for the business rules related to these events.

The typical interaction of a consumer is with a web site alone. A shopping cart interaction is followed by a checkout process commonly ending with payment with a conventional electronic payment tool such as a credit card. All information is given to the shopping site where this e-commerce company is the book of record and ultimate authority. In case of disputes, consumers contact the e-commerce company. There are legal boundaries, but in general, consumers need to obey the provider rules and decisions.

Our proposed new interaction sequence in Fig. 7 depicts the distributed version of online shopping. This interaction starts with the buyer contacting the provider and communicates the intention to purchase items. At this point, the buyer has their temporary or permanent identity provided to the system, and the provider has their permanent identity to be used system-wide. The provider records the start of the purchase process with the mark "acquisition initiated" recorded on the blockchain. The buyer, at this point, can contact the payment company and initiate the payment process. The payment company records this event to the blockchain. At this point, the purchase is completed. As we can see, the immediate benefit of the new model is the isolation of interactions and independence in choosing the payment processor. The payment information is not shared with the online vendor. This protects the payment information. The payment company and shopping web site are also independent.

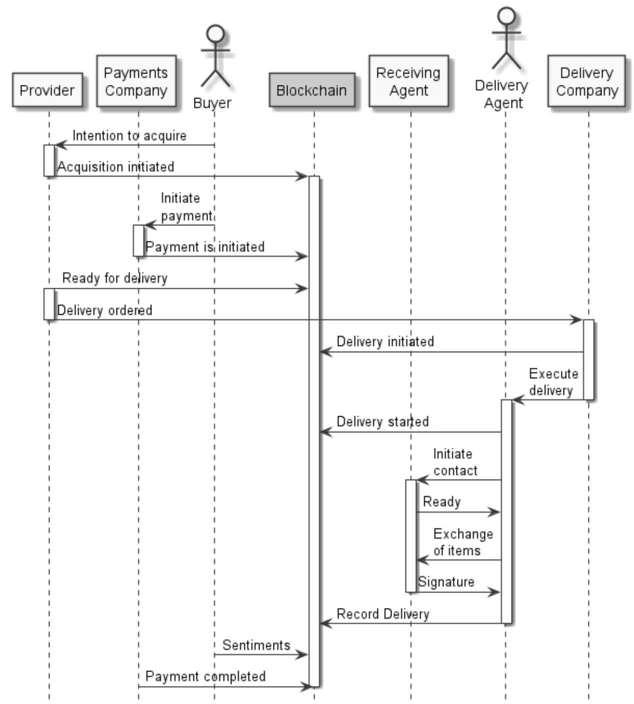

Fig. 7. The sequence of steps while purchasing goods

A typical delivery process starts with the provider recording the readiness of the delivery to the blockchain. This step is essential as the item is confirmed to be available, and new participants will be involved. The provider can choose the delivery company to take on this task. Alternatively, delivery companies can bid for the delivery opportunity, but for the sake of simplicity, we will assume that the provider selects the delivery company. The delivery company physically receives the items and marks the event on the blockchain as delivery is initiated. The delivery company contacts a delivery agent. The delivery agent is modeled to be separate from the delivery company as this model is open to outsourcing the task or sharing economy to take over some of these tasks.

The actual delivery starts with the agent marking the delivery on the blockchain as “started”. At this point, the delivery item is in transit. From this point on, the delivery agent can continuously record necessary sensor data. GPS location, temperature, acceleration, and several other pieces of relevant information can be stored and shared on the blockchain. These sensor data can be collected and used for improvements.

When the destination is reached, IoT devices will interact to mark the handover of the goods. There will be a contact initiation between the delivery agent and the home-based IoT device that represent the buyer. This can be a device connected to the home network, which communicates with NFC, and reads the RFID of the goods. At the very least, this device can communicate if this is the correct destination. This IoT utilization can prevent incorrect deliveries and lost packages.

Finally, the buyer will receive the goods, and they may close their part in the process by providing opinions about the experience. These opinions will be stored on the blockchain and will be shared with all participants. Since the blockchain is a reliable source for the originality of the records, even the newest and smallest companies may collect reliable opinion data. The payment can be processed at this point, and the business process instance can be marked as completed.

VI. Conclusion

In this paper, we summarized the issues of the delivery model. The information flow issues are listed and depicted in Fig. 1. We have presented a new application area for blockchain technology and a novel framework (BIDAS) to follow while applying this new methodology. In the delivery industry, blockchain technology can be the needed trust provider. From standard parcel delivery to complicated scenarios such as aid delivery, a system to record and maintain tamper-free information is useful. We listed details of these solutions where blockchain technology provides advantages to all participants. A transparent, accessible, and reliable environment benefits all participants.

BIDAS framework guides the implementation of delivery fulfillment using blockchain technology. We propose using blockchain technology to collect the details of the delivery lifecycle where several actors are collaborating. Our framework provides a structured approach towards a blockchain implementation by analyzing the participants, data model, and activities. Transparency of transactions and reliable opinion (word of mouth) data provide advantages to the public. Autonomous vehicles and delivery methods normally lack the human witnesses on their activities. Blockchain and IoT technologies can compensate for the lack of this witness.

Even though the application of the framework demonstrates the fitness of the framework towards providing a solution, our framework and its blockchain-based delivery model are not yet compared to the competition in terms of costs. The price sensitivity of the customers towards the delivery fees would be a challenge for this framework as the benefits of the blockchain may not justify the cost for every implementation [34]. If the price is the decision criterion, companies will focus on cheaper services and cost-cutting. This is a common challenge faced by all trust-based systems. Privacy and availability are also common challenges facing blockchain implementations. Strong privacy requirements may work against blockchain implementations while transparency and availability are sacrificed. Even if privacy is a determinant factor in the decision, our framework brings trustable monitoring even with limited information.

The next step for our research is the implementation of this BIDAS guided use case with a blockchain platform. Our initial research indicates that Hyperledger is a suitable platform for this implementation. We will take the next steps to define the details of the blockchain data model and implement selected scenarios for evaluating our implementation.

VII. References

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