Blockchain-Based Transparent Disaster Relief Delivery Assurance

Mehmet Demir
Department of Computer Science
Ryerson University
Toronto, Canada
mehmet.demir@ryerson.ca

Ozgur Turetken, PhD
Ted Rogers School of Information Technology Management,
Ryerson University,
Toronto, Canada
turetken@ryerson.ca

Alexander Ferworn, PhD
Department of Computer Science
Ryerson University
Toronto, Canada
aferworn@ryerson.ca

***Abstract*— Blockchain technology presents benefits that change the way business partners interact. This new way of establishing democratic trust encourages business owners to think differently.**

Disaster relief and aid industries are built on the power of collaborating participants. A very high number of participants in different hierarchies, including donors, charities, disaster victims, insurance companies and government agencies interact under extraordinary circumstances of a disaster and hard times. Establishing a new way of trust brings forward a better disaster recovery.

In this paper, we propose a blockchain-based ecosystem. The blockchain-based disaster recovery not only would enhance the basic processes around disaster relief, but also promote the willingness of help by transparency and potential fraud prevention. This new blockchain system introduces an opportunity to be more resilient, to react rapidly, to communicate transparently, and to include new contributors such as IoT.

Keywords—Blockchain, computational public safety, humanitarian aid, disaster relief, IoT, artificial intelligence

I. Introduction: Call for Humanitarian Aid

Blockchain technology provides benefits that change the way business partners interact. This new way of establishing democratic trust helps business owners to think differently. The structure of participation can now shift from the centralized approach where one party has the authority and responsibility to a collective-effort-based community relying on technologically provided trust.

In what follows, we present a literature survey of issues in the disaster relief and aid industry as a problem definition. We briefly introduce the blockchain technology while highlighting the most impactful benefits followed by a survey of literature about blockchain technology in disaster relief. This survey includes the leading use cases and opportunities of the blockchain technology in this industry. Our main contribution is the design of a blockchain network as the proposed solution that addresses the issues and take advantage of the new features of the blockchain technology. Discussion and future directions related to our solution conclude this paper.

II. Problem Definition

Disasters happen frequently. In the last 40 years, the United States has had more than 250 weather disasters where the overall costs were at least $1 billion [1]. Disasters are not limited to weather and climate-related catastrophes. Poverty is a disaster [2], and wars are pulling the majority of people down to poverty [3].

A. Poverty, Hunger, and Refugees

World Vision [4] lists one of the main reason why people around the world do not have enough food to eat is because of lack-of-money. There are several causes for such poverty. Some of the common causes for not having enough money for obtaining food are diseases, natural disasters, lack of education, and economic opportunities of the environment.

There are an estimated 870 million people [4] in the world who are hungry. One in every eight people does not have enough food while the majority of the world is enjoying technological advancements, economic prosperity, and general comfort.

The Food and Agriculture Organization of the United Nations [5] estimated that 33 percent of the food produced in the world for human consumption gets lost or wasted. This loss means the food we have is enough to feed another 50 percent more of our kind. The same resources indicate that the cereal products wasted in industrial countries alone are more than the entire food production of sub-Saharan Africa. These cereal products alone could have fed approximately half of all hungry people on earth if not wasted.

The causes for this food loss vary. From production to consumption there are several stages of loss. In developed countries, cultural and lifestyle-related causes are plenty. Excessive production due to customer expectation of wide range of products to be available on the shelves, consumers denying products based on appearance quality in the expectation of cosmetic perfection and overall sense of disposing the material if not part of a perfect product view (cutting the crust of toast-bread) are some culture-based reasons of waste [6]. Our habits, lifestyle, and lack of public awareness lead to these significant food losses. It would not be easy to change these factors.

While one part of the world has access to more than they need, and other parts of the world do not have enough. There are several ways to readjust this. One of the methods would be acquiring, transporting, and distributing the food directly to the people in need. This supply chain that we also call food-aid has its problems. They are fueling conflicts by injecting valuable resources where governance is weak. In Afghanistan, Congo, Rwanda, and Somalia, the influx of aid is fueling conflicts [7]. Eighty percent of the food sent to Somalia is estimated to be

stolen [8]. Corruption of officials and middleman is an issue. Aid agencies paying bribes to warlords, rebels, or the army officials are common [7] [9]. We see that widespread fraud on food aid exists almost everywhere that aid is needed [10]. Bringing food to a region does not contribute to the local economy. It benefits the source region of food. It does not empower or train local people to produce more, either [11].

Refugees are another class of people in need of help. The western world is familiar to see scenes from Africa, where refugees are migrating to neighbor countries due to drought and national disasters. People in this status are living in camps waiting for the food-aid due to insufficient economic condition in the host countries. There are other cases of refugees that are not bound to camps. With the erupting war, millions of Syrians are separated from their homes to become a refugee in Turkey and Jordan. They also could not carry their assets while running from fast approaching conflict. Several million of these refugees are residing in Turkish cities [12]. These people scatter to different cities in Turkey. Moreover, many tried or succeeded to continue their search for refuge in European Union states.

B. Cash and related trust issues

It is better to give cash to refugees so that they would purchase their needs in their dignity [13]. They may choose to purchase instead of being fed with common goods. As part of being a human, they may also have preferences. It is only logical to let them choose while the cost of help is similar. The Guardian also suggests one of the improvements in the aid by ending the waste and delay of transporting food through distances and giving cash instead [14]. The Atlantic also says cash is the most effective help [11].

So, when a $2 donation can feed several children, what is the reason for children dying in hunger? For the people who can help others with the means of financial help, the number one reason not to help is the lack of trust [15]. Lack of transparency in the means and results of financial aid, donors believe either their contribution is too small to make a change, or issues can not be solved at all [16].

Numbers can be unreliable when spending or consumption is not traceable. In a typical refugee crisis, the receiving state indicating a lump sum amount is less reliable than tracing the distribution of funds and spending electronically.

C. Supply chain issues related to disaster relief

Many people in the world lack food and shelter. Even though the numerical concentration is in third world countries, unexpected events such as disasters can bring even people of developed countries into a position of needing help. Hurricane Katrina (2005) killed 1833 people and left with a damage of $125 billion in the United States [17]. The need for disaster relief can be anywhere in the world.

The supply chain of disaster relief is also dependent on central sources and coordination. Depending on the conditions after the disaster, relief efforts are always open to discussion. The comparison of Hurricane Maria disaster relief provided to Puerto Rico to that provided to mainland states are still a matter of contention due to difference in response activities [18]. Lack of transparency is preventing a clear analysis of the events.

Intermediaries in the disaster relief also introduce a risk of corruption. The lack of transparency leaves the efforts and aid vulnerable to the middleman's decisions [19]. The trust issue caused by this middleman risk discourages contributors from using the donation media provided by centralized relief efforts organizations.

D. New vehicles of disaster relief

Disaster conditions often deteriorate the conditions for conventional vehicles. Floodwaters take time to drain. Mud and debris cover the roads. Fallen trees can be an obstacle for road vehicles. These conditions can remain even after the weather conditions are back to normal. These circumstances are ideal for adoption of a new vehicle of delivery. Drones or Unmanned Aerial Vehicles (UAVs) are already taking part in the humanitarian response efforts around the world [20]. With their abilities such as capturing images and videos, drones can assist the crews for disaster relief.

With the introduction of delivery drones such as Amazon Prime Air [21], there is new utility for drones in aid distribution. Emergency supplies delivery is a good task for a delivery drone. Considering delivery drones are preparing to deliver ordinary parcels, disaster time vital resources can be distributed with the help of these drones.

Crowdsourcing can be a powerful tool for mobilizing high volume of relief efforts [22]. However, using crowdsourcing without adequate auditing and transparency can cause fraud and result in loss of donors' trust. The monetary gain expected by the contributors as a result of their attendance may lead to misuse and misrepresentation.

III. How Can Blockchain Help Delivering Disaster Relief

Distributed ledger technology is the emerging new way of keeping records by distributing them to the participants of a network. Peer-to-peer networking is used to scale the reach of these networks so that participants can all maintain and witness the same set of transactions.

Blockchain is a type of distributed ledger where the integrity of the records is protected with the help of advanced cryptographic patterns. Transactions or simply data is bundled into blocks and supported with the metadata that helps to chain the block. Metadata of each block has a tree of hash values that maintain the integrity of the block and has the hash of the previous block to form the pointer that helps the chain impact.

Blockchain technology can create new opportunities for each industry through its features and capabilities. The literature recognizes the opportunity as a solution to a supply chain problem [23]. Even major software companies focusing on supply chain solutions acknowledged their interest in a blockchain-based solution to the issue [24]. Defense organizations and military [25] are seeing the blockchain environment as a communication medium for their logistics under extraordinary conditions such as disasters [26]. Blockchain technology can, at the least make the response process swifter [27].

There are some existing studies about using blockchain technology to keep and validate identity records for refugees

[28]. With minimum details, some ideas to use blockchain technology to aid refugees also exist [29] [30]. IBM provides one of the most elaborate reports about using blockchain technology in disaster relief [31] where experts advise extensive use of web/mobile technologies and IoT while leaving details of the blockchain at a high level.

A. Transparency

Blockchain technology enables building a higher level of trust for the interoperability of disaster relief organizations through information sharing [32]. Agents can record an aid delivery and share it with all its details such as GPS coordinates of the aid recipient in Africa, images of sites, and pictures of recipients.

Recording an extensive range of information in an immutable data store would also enable authorities to utilize artificial intelligence technologies for auditing. An AI-based system can recognize the duplicates, identify people, and mark suspicious/conflicting data during or after the operations.

Global auditing capability will improve trust in the aid ecosystem. An aid organization anywhere in the world can be audited by a higher authority in order to improve its position and brand.

Shared truth will help diminish the fraud that used to take advantage of the layers of bureaucracy. New transparency and immutability enable audits to be conducted anytime and on untampered data.

The digital environment of a blockchain also has advantages in extreme conditions of the disaster scenario. A refugee or a disaster victim is most likely to be stripped off their documentation. There may not be a proof for identity, but a collection of attributes such as facial features may represent the identity. Where anonymity is seen to be more of a fit at the recipient of the aid or the presenter/donor, blockchain systems can allow that with the use of hash values instead of real values.

Removing the intermediaries result in cutting operational costs that each involved party is spending on their operations. Removing the dependencies also improves the resilience of the services and increases high availability.

B. Cryptocurrency

Cryptocurrency integration can help monetary operations by creating a medium for donations and other monetary transactions. Using Ethereum or another programmable cryptocurrency can provide the ability to use smart contracts for payments. On the other hand, existing cryptocurrencies may not be a good medium for financial aid. Besides their current volatile state, there are adoption issues on spending with cryptocurrencies. Vendors may not accept it as easy as the local currencies. Local currency usage would be similar to electronic payments.

For the sake of isolating this project from the complexities of an existing cryptocurrency, we can assume at this stage that we will support multiple world currencies, or we will have our currency (DisasterAidCoin). Donations in our blockchain will be able to target a specific region in the world. This zone-limitation will prevent the funds from being accumulated and used for any other reason than the cause. Funds will be available for the services provided by the vendors in that region. This regional boundary can manage the refugee vouchers and coupons as well as the disaster relief donations.

Storing monetary transactions in our blockchain will also help with the requested traceability and transparency. The donors, if they prefer, can trace the destination of their donations. The blockchain system will store tracking data for every spending. Blockchain provides the ability to audit the spending on the blockchain transactions without the risk of corruption of the data.

C. Automation

Donations and aid usually have a specific target. Donation for a charity is for a specific cause. Donors assume and would like their donations to be spent for the cause they donated for. The same is true for the allowances given to the refugees. These allowances are for the immediate needs and to be spent in a time frame. Smart contracts can handle the automated tasks in a blockchain. If the system represents donations in the form of a smart contract, the smart contract methods can enable the additional characteristics that we need from the donation. Expiry of the funds may be a feature of the smart contract. An alternative solution to this is to embed this expiration login into the cryptocurrency. This way, the cryptocurrency would take care of the different states of the money, such as *active* when in use, *spent* when the funds are spent for the targeted cause, and *expired* when no longer available and returned when the expired money is refunded back to the donor.

D. Timely Reaction

Disaster conditions are different from regular operations. Disaster relief need to be delivered immediately without intermediaries and bureaucracy slowing it down. An example can be temporary evacuations of cities due to chemical accidents and hazardous conditions or fire. A modern country that has financial means to help its citizens does not need to take a long time to deliver the necessary coupons or allowances. There should not be an obstacle for the nations to take care of their own. Blockchain technology can help with the speed of distributing and allocating monetary resources. Payments can be instant, and accounting can wait until after the disaster conditions are relieved. Considering most disaster relief efforts highly depend on collected donations, reacting quickly with the help of technology can convince donors to donate more.

IV. Proposed Solution To Disaster Relief

Global Aid industry needs a global backbone to manage transactions transparently and reliably. We propose to develop a blockchain-based aid delivery assurance system (BADA) to store, coordinate and communicate disaster relief efforts immutably on a blockchain-based distributed ledger.

To design BADA, we will use the Blockchain and IoT for Delivery Assurance on Supply Chain (BIDAS) [33]. BIDAS is a delivery assurance framework to provide solutions to the two fundamental problems in the delivery industry, which are “Handover of packages” and “Continuous monitoring”. BIDAS offers a blockchain-based solution to track the handovers and guides the implementation with a pattern to design the solution.

BIDAS also enables all intermediary delivery agents and their IoT extensions, such as sensors to become a participant of the blockchain.

Our solution will follow the delivery assurance steps of BIDAS which are “Decentralized Communication”, “Enlarged Participation and Information Flow”, “Transparent Delivery Data Model”, “Defined Delivery Activities” and “Process Automation”.

A. Decentralized Communication

Like most other businesses with a high number of stakeholders, disaster relief ecosystems are conventionally consisting of central authorities managing the communication. Individuals donate funds and materials to specific organizations. Governments organize disaster relief and manage information traffic. They are the only trustable party in the ecosystem for all contributors. They may collect donations, or they may use their existing funds. They are an absolute authority about the final information about the events of disaster relief. They may share or censor information according to their organizational principles and direction. Aid agencies may collect donations and organize their own services. Service providers are either providers of material or relief efforts. Coordinated by the authorities, these teams join the relief efforts. Typically, all communication between individual teams is also managed by the authorities as depicted in Fig. 1.

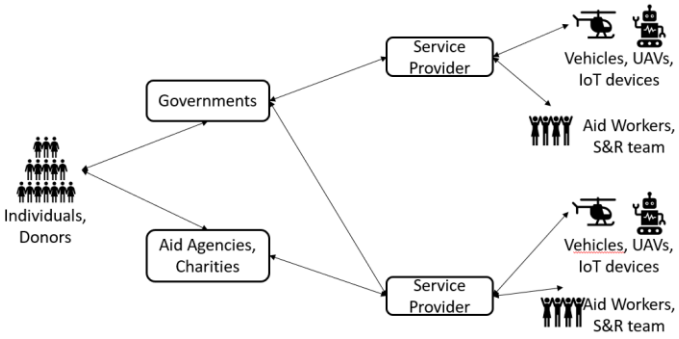

Fig. 1. Stakeholders of the disaster relief process and their conventional communication model

The first step of the BIDAS framework is to adopt a decentralized business model. Blockchain networks are distributed. Each node in the network is aware of other nodes in the network, and all nodes collectively form the blockchain. Each node in the network receives a copy of the ledger and can maintain its copy.

The main benefit of such a distributed architecture is the resilience of the network. If any of the nodes are malfunctioning, broken or inaccessible, the rest of the nodes can sustain the operations. Upon restart, each node synchronizes with the rest of the network and becomes up to date by obtaining the latest copy of the ledger. Each participant can decide on the importance of each piece of information without the need for central management. In disaster scenarios, central authorities are often unreachable or too busy to process requests. Central authorities usually are optimized around the ongoing business and not flexible enough to adapt to drastic changes in the conditions.

Peer to peer decentralized systems eliminates middlemen. Storing transactions in an automatically-shared and tamperproof database eliminate the need for many intermediaries. Legacy operations such as reconciliations are no longer needed as the blockchain networks handle this issue in real-time. Most importantly, the single point of failure is removed from the overall system. Any participant in the blockchain network can be down due to the disaster conditions. This absence does not impact the rest of the network.

Without the middleman, ecosystem would also retain the associated funds that were transferred to the middlemen for their services as commissions and handling fees. Some middlemen is significantly decreasing the magnitude of the help for their own benefits on the expense of most vulnerable people [7] [9]. Elimination of the middlemen is also important for fighting with corruption.

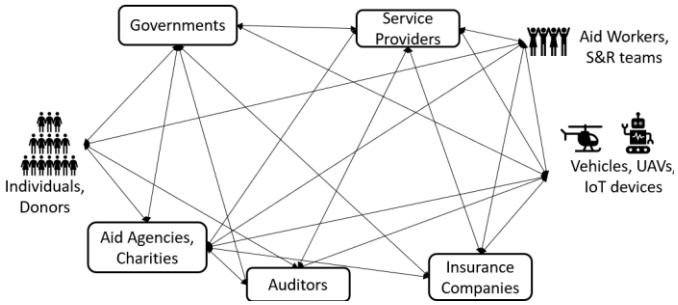

Fig. 2. Participants of the blockchain network and new information flow

B. Enlarged participation and information flow

The first step in designing a blockchain system is identifying the stakeholders. Modeling a business with blockchain technology does not change the set of stakeholders. In order to start the process of applying BIDAS, our first step is to identify the stakeholders and actors in the system. After this identification, we will

Most stakeholders with technical ability and processing power become participants of the blockchain ecosystem. They either use applications to issue transactions with the system, become a full node in the network by contributing to blockchain lifecycle, or only monitor the system to benefit from the new decentralized information flow, as depicted in Fig. 2.

From the functional perspective, individuals are donors and participate in the blockchain system by donating and managing their donation funds over the blockchain. They can also contribute to the overall health of the system by dedicating processing power as a node in the blockchain. How individuals would be represented is a sensitive topic due to the privacy preferences and laws. Blockchain systems enable contributors to choose between having clear identities, or staying anonymous.

Aid agencies and charities participate in the blockchain based aid ecosystem as they collect and manage donations. This platform increases the trustability of these agencies to gain the confidence of the donors. Moreover, according to the assumption that donors would donate more when they can trust their donations according to donation cause, these agencies can collect more donations with the success of this platform.

Participants under the group named service providers can be vendors provide services to refugees or disaster victims. Service providers participates in this blockchain mainly to record their activities and benefit from compensation.

Governments are a natural part of this ecosystem. Governments can coordinate and report their aid activities through this blockchain. Governments adopting this new aid system is necessary for adoption. Governments can also provide other services using this system. Distribution of regular aid such as welfare payments to poor people is an example of such use. Using this system will give authorities an advantage in tracking the location of the welfare recipients. Tax agencies can trace the charitable donation by tracking donations and can trace the income of service providers by tracking the spending.

Groundworkers such as S&R teams or refugee aid station workers can be a participant in the system with mobile devices with light operating systems or computers. They are service providers whose service is typically paid by government organizations.

Vehicles such as UAVs and other IoT devices can be a participant if they are playing a role in the delivery of the aid. These devices are typically part of the service provider networks.

Insurance companies are natural participants as they would like to monitor the relief effort related to their liabilities. Since their ability to know the cause of damages and minimize costs of relief improves their bottom line, these organizations benefit highly from a trustworthy system full of detailed information.

TABLE I. LIST OF ROLES IN RELIEF DELIVERY HANDOVER – 1/2

Party Type	Initiator	Service Intermediary	Service Intermediary	Service Intermediary
Owner	A Donor	A Charity	Trucking Company	Air transport company
Actor/ Agent		Charity Warehouse manager	Driver	Airport personnel
Sensor Host		Charity Warehouse system	Truck	Plane, airports
Sensor		Charity Warehouse exit sensors	Barcode Scanner, Truck GPS	Plane loading docks

TABLE II. LIST OF ROLES IN RELIEF DELIVERY HANDOVER 2/2

Party Type	Service Intermediary	Service Intermediary	Receiver
Owner	Crisis center	UAV company	Disaster Victim
Actor/ Agent	Crisis managers	UAV Operators	
Sensor Host	Crisis management center warehouse	UAV	
Sensor	Crisis center unloading docks	UAV Cameras, GPS	

Auditors and governance organizations such as the United Nations can provide value to this ecosystem by participating. They can audit the integrity of the system by validating the efforts and funds are adequate and expensed ethically.

Besides the list of participants, BIDAS provides guidance on the handover processes in the delivery. It is not always one participant that carries a relief material from the procurement all the way to the disaster victim. The interaction model in the aid delivery handovers is depicted in Fig. 3.

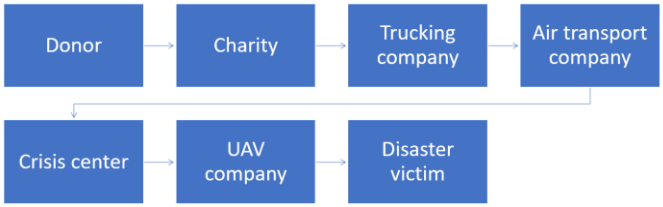

Fig. 3. The aid delivery interactions model according to BIDAS

BIDAS recommends recording these handovers in the blockchain. In order to do that, all handover activities are to be discovered as detailed in samples in TABLE I. and TABLE II. These roles and handover activities are not a restrictive list; however a successful implementation must start considering known use cases like these. All activities involved in the handover must be detailed as in TABLE VI.

C. *Data Model: Assets and attributes*

BIDAS framework recommends some fundamental entities such as Customer, Order, Order Item, Payment, Deliverable, Delivery, Delivery Stage, Delivery Event, Delivery Schedule, Contact Event, Agents (Employees), Sensor Hosts and Sensors. In the disaster relief scenario, some of these elements are named differently. For example, customers in a usual e-commerce-based delivery scenario are named as a victim in a disaster scenario. We make these changes and define our assets and attributes that will reside on the blockchain.

TABLE III. SENSOR READINGS

Sensor	Data
Charity Warehouse exit sensors	Material tracking information Truck entry and exit information
Barcode Scanner, Truck GPS	Truck load information (material tracking) Truck GPS coordinates
Plane loading docks	Plane load information (material tracking)
Crisis center unloading docks	Crisis center material receipt/tracking
UAV GPS	UAV location
UAV Cameras	UAV activity images (image before and after the drop)

BIDAS also guides to add all sensor readings and continuous monitoring data into the blockchain. We take this into consideration and add the data elements in TABLE III. to our data model.

TABLE IV. REGISTRIES AND ATTRIBUTES

Asset Name	Attributes
Donor (registry)	Public-key, Signature Optional: Name(s), Contact Information(s)
Charity / Aid Agency (registry)	Public-key, Signature Optional: Name(s), Contact Information(s)
Service provider (registry)	Public-key, Signature Optional: Name(s), Contact Information(s)
Service (registry)	Service Provider (Public-key), Name/Description, Price, Currency
Delivery Agent (registry)	Type, Service Provider (Public-key), Public-key, Signature

Registration activities are relatively simple. Our solution will have the lists of Donors, Charities, Service Providers, Services, and Delivery Agents. These entities in TABLE V. typically have their public key in the system to represent them in the consecutive transactions. They sign their registration to prove that they are registering themselves. Blockchain will include these records, similar to an identity management service. Enhanced security requirements may need these records to be validated by authorities.

TABLE V. TRANSACTIONS AND ATTRIBUTES

Asset Name	Attributes
Currency transfer	From (Public-key), From Signature, To (Public-key), Amount, Currency
Aid transaction	Donor (Public-key), Charity (Public-key), Amount, Currency, State (Donation, Expired), Optional: Location, Expiry-date, Original transaction
Delivery	GPS-Location, Time, Delivery Agent(Address), Service, Recipient (Signature) or Proof (Image, sound, ..), State (Ordered-InProgress-Completed) Optional: Aid Transactions

The most important transactions in the aid blockchain are the currency transfers, donations, and delivery of services as listed in TABLE V. Currency transfers follow a strategy similar to most cryptocurrencies. A transaction will represent the transfer of an amount from an account to another account. Aid transaction such as a donation is a micro currency transfer. However, the transaction record must include the business logic fields. For example, the expiry date and the donation status must exist. If a donation remains unused until the specified time, the transaction will revert by issuing another aid transaction with status expiration. Smart contracts can handle this task of expiration. Delivery is the most complicated transaction that will record the aid delivery. Whether it is a drone dropping a care package accompanied with an image from the drone's camera, or an aid worker distributing blankets to refugees with fingerprints, extensive list of details are recorded in this transaction to enable an audit. An aid delivery starts by the requestor creating a record on the blockchain. Then when an aid agency which we generally name as service provider accepts the delivery, the delivery is re-recorded with a new status: in progress. Multiple in-progress transactions will be on the ledger in case the business requires tracking. Finally, delivery can be marked as completed when the aid is delivered.

Since our blockchain system is custom, it does not have a limitation for the type of attributes. However, the size of data in a peer to peer network may have a performance impact. Therefore, a custom implementation may strategize externalizing files such as images or long strings. Most attributes described here are mandatory as they are assumed to be fundamental. Optional attributes typically are based on the business rules and requirements.

D. Activities and Automation

There are many activities in disaster relief use cases. Following the BIDAS framework, we defined the handover activities as detailed in TABLE VI.

TABLE VI. HANDOVER ACTIVITIES

Participant	Activity
Donor	A donor donates to the charity with the intention to help disaster victims
Charity	A charity procures material or prepares their existing material to be transported to the airport with trucks
Trucking company	A trucking company takes the material from charity and transport to the airport
Air transport company	An air transport company receives the materials from the trucking company and transport them to the destination airport to be delivered to the crisis center.
Crisis center	A crisis center received the material from air transport and prepared them to be distributed.
UAV company	UAV company receives the materials from the crisis center and delivers them to the victims.

There are other activities that BIDAS framework prescribes. These activities, such as Delivery status changes, the return of the packages, unsuccessful delivery, comments, and sentiments from stakeholders also can be part of the newly designed blockchain.

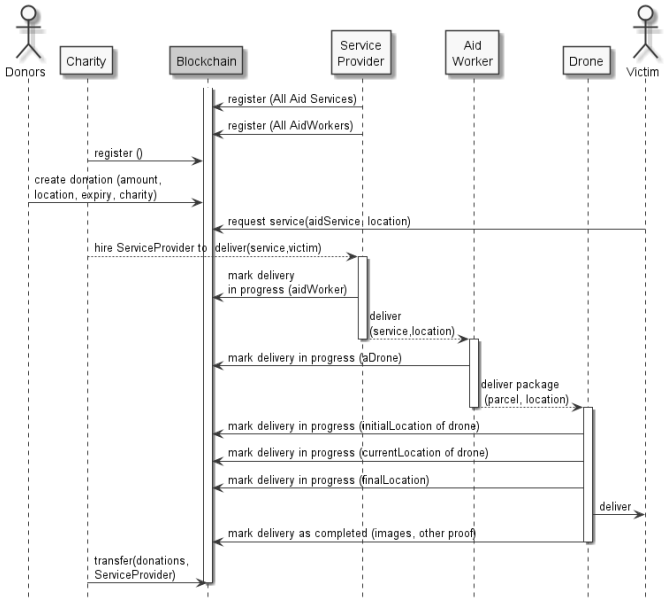

Fig. 4. The sequence of steps while delivering services with a drone

In this paper, we may not detail all use cases due to space considerations. We will focus on the use case for the interactions around drone-assisted delivering services in a disaster situation. This sample use case starts with a registration phase where all aid workers, service providers, and charities are registered. If there is a strong governing body, these registrations may be approved as well.

V. Limitations and Future Direction

In this paper, we introduced a novel use case where the conventional methods can be improved with decentralization. We listed the issues with the current model, detailed the advantages of the decentralized model, offered a solution using blockchain technology. We applied the BIDAS in order to start our implementation with guidance from a structured framework. We identified a good fit between the framework and our use case.

Like most blockchain implementations, the success of the blockchain ecosystem depends on its adoption. If the blockchain is implemented with the support and acceptance from the majority of significant stakeholders, it can be successful.

The governance of the blockchain system is usually an issue in implementations. Even Bitcoin blockchain has a team that develops the software and maintains the system. Bitcoin has an advantage of uniformity in the usage of the blockchain. In our design, since the blockchain usage may not be uniform in geography, country, and even purpose, a permissioned system is needed. NGOs, government agencies, and countries using this blockchain can contribute to the processing power.

There are many components to be developed for this ecosystem to work. Victims and aid workers need mobile applications to interface with the blockchain. Each mobile application must have the ability to keep a public key. Dependency on the cell phone system is a single point of failure. However, with no network in the disaster area, the system will have to drop to an offline processing state where the applications will delay the blockchain interactions until reconnecting to the network. Until this reconnection, mobile devices will have to store the details. Online services such as identification of victims or refugees using face recognition would be unavailable.

The next step in our research is to develop the blockchain system and validate functional requirements listed above as well as non-functional requirements such as response times, scalability, and capacity. We identified Hyperledger to be a suitable platform for the implementation of our blockchain use case.

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