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The Applicability of Blockchain Technology in the Mobility and Logistics Domain

Wout Hofman and Christopher Brewster

Abstract Blockchain technology in the last 3–4 years has attracted a great deal of attention due to its potential for the disruption various sectors of the economy including the financial sector, and more recently the mobility and logistics domain. The technology, which was developed as the foundation for the cryptocurrency Bitcoin, has developed much further with creation of Ethereum and the concept of "smart contracts." This chapter discusses the position of blockchain technology in a hyperconnected environment, and analyses a prototypical logistics scenario where the technology could be used. We describe the characteristics of blockchain technology and provide examples of how it is being applied for mobility and logistics. The chapter concludes by considering particular opportunities for mobility and logistics based on the current characteristics of the technology, and also identified a number of challenges faced by the technology.

Keywords Blockchain technology · Mobility · Logistics

1 Introduction

Hyperconnection or universal connectivity is mentioned as one of the most important aspects of the Physical Internet (Montreuil et al. 2013) that can be applicable to both passenger and freight transport. It encompasses 'super-fast connectivity, always on, the move, roaming seamless from network to network, where we go—anywhere, anytime, with any device' (Biggs et al. 2012). Examples of the implementation of hyperconnection can be found in city logistics (Crainic and Montreuil 2016). A hyperconnected world not only comprises individuals with embedded sensors in their smart devices, but includes all types of devices (e.g. vessels, trucks, containers,

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and trains). These devices can be considered as assets used for value delivery, either on an on-demand basis for one or more customers or according to timetables, thereby offering "Mobility and Logistics As A Service" (MAAS and LAAS). Different sensors and supporting communication technology would be used for the identification and tracking of assets, but also as a basis to predict behaviour of these assets like an Estimated Time of Arrival (ETA) at a next destination (e.g. station, port, terminal). Several research papers have identified supply chains and logistics as the main areas for implementing the closely related concept of the "Internet of Things" (Atzori et al. 2010; Gubbi et al. 2013). These developments will probably lead to intelligent objects (Whitmore et al. 2015) or what is otherwise known as ubiquitous computing (Weiser 1991). Cars using the NVIDIA chipset can be treated as hyperconnected computing platforms, thus implementing ubiquitous computing. Already Automatic Identification System (AIS) with Global Positioning System (GPS) is being used for vessels and barges, trucks have on-board tracking units collecting data through CAN bus acting as sensors, and cars and trains have identification mechanisms. The introduction of LoRa technology (www.lora-alliance.org) and 5G (Boccardi et al. 2014) for communication extends the battery life of sensors and thus their utility for machine-to-machine interaction. The combination of ubiquitous computing and long battery life makes possible the decentralisation of decision making to, for instance, transport means (i.e. autonomous vehicles, trains, vessels, and barges) and cargo, where individual boxes can find their way through a logistics network like individuals.

Hyperconnection is mostly described in terms of businesses collaborating in chains (Schonberger et al. 2009) as in the Hyperconnected City Logistics (Crainic and Montreuil 2016) and this is supported by hardware and communication technology providing computational capabilities and level one interoperability (Wang et al. 2009). In the existing literature, neither the information that any two stakeholders have to share, nor their interaction choreography has been explicitly described. Data integration is required to achieve state awareness (McFarlane et al. 2016), also known as situational awareness (Endsley 1995). Conceptual interoperability (Wang et al. 2009), which has not been implemented by supply and logistics stakeholders so far (The Digital Transport and Logistics Forum (DTLF) 2017), is a necessary requirement to support MAAS and LAAS.

It is in this context that we consider Blockchain Technology (BCT) which has received an immense amount of attention and investment in the last 2–3 years. This chapter explores the capabilities of BCT as a means to contribute to situational awareness and decision support by autonomous agents. First of all, the state of the art of blockchain technology is presented, secondly a logistics scenario utilizing a blockchain is described as a basis to identify challenges. Finally, the chapter will explore future potential capabilities of blockchain technology in the area of mobility and logistics.

2 An Overview of Blockchain Technology

BCT uses a combination of technologies that have a considerable history in computer science and in commercial applications. These component technologies include public/private key cryptography (Rivest et al. 1978), cryptographic hash functions (Preneel 1994), database technologies especially distributed databases, consensus algorithms (Vukolic 2015) and decentralised processing. The fundamental purpose is to achieve database consistency and integrity in a context of a distributed decentralised database, where the database nodes are either controlled ("permissioned") or uncontrolled ("unpermissioned"), the prime example of the latter being Bitcoin.

BCT arose out of technology developed in the creation of Bitcoin (Nakamoto 2008). Bitcoin, as conceived by Satoshi Nakamoto, was an attempt to create a "cryptocurrency" outside the control of government, a currency that would operate purely on the Internet (Grinberg 2011). Bitcoin was built on a number of key elements:

- A distributed file called a "blockchain" spread over all computers participating in the system.
- Proof of work—in order to write on the "blockchain" each node needed to complete a complex mathematical procedure (a process which eventually came to be called "mining") in order to have the "right" to write on the blockchain.
- Digital signatures—in order to know which person (using an identity expressed as a number) performed an operation each operation is signed using public-private keys.
- Chained hashes—this technology is widely used in version control and allows each documented to be "hashed" into a digital "summary". A sequence of such hashes are used to construct the blocks in the blockchain.
- Byzantine consensus—the Bitcoin protocol claims to have solved the problem of "byzantine consensus" which prevents "double spend" of Bitcoins.

This enables the creation of a distributed database (a "ledger") which can be used to record transactions of Bitcoins from one person (represented by their public key) to another. This database is immutable and ensures the impossibility of conflicting transactions.

Various people realised that the underlying technology of Bitcoin may have far greater interest. The Bitcoin software provides an "unpermissioned" ledger for the recording of financial transactions but equally that ledger could be used to record non-financial transactions just like any ordinary database can. As the Ethereum White paper states "alternative applications of blockchain technology include using on-blockchain digital assets to represent custom currencies and financial instruments ("colored coins"), the ownership of an underlying physical device ("smart property"), non-fungible assets such as domain names ("Namecoin"), as well as more complex applications involving having digital assets being directly controlled by a piece of code implementing arbitrary rules ("smart contracts") or even blockchain-based "decentralized autonomous organizations" (DAOs) (Buterin 2013). This realisation, which the has been ascribed to multiple authors, has led to a flowering of efforts to use initially the Bitcoin Blockchain for various non-cryptocurrency purposes, and then the creation of alternative platforms or systems (such as Ethereum and Hyperledger cf. below). Together with the realisation that blockchain technology could have a variety of other applications, there arose a number of startups seeking to find opportunities to exploit this technology. The start-ups have grown in number in areas ranging from finance to insurance, from food and agriculture to also logistics.

The key principles of BCT can be outlined as follows:

- **Blocks in the blockchain**: Each block in a blockchain contains (a) an ordered set of records or transactions, and (b) a hash of the previous block in its header (starting from an initial block called the "genesis" block). This means its hash depends on the hash of its parent and so on in turn. This is key to blockchain security and guarantee of permanence since any change in the data of one block would affect all other blocks that follow. Such a change would require a new consensus process (typically involving "proof of work" although not necessarily). A chain of such blocks forms a blockchain.
- **A peer-to-peer network**: A blockchain depends a network of peers or "nodes" who usually provide the computing power to achieve consensus for example by "mining" if consensus is achieved by "proof of work".
- **A distributed immediately replicated file**: Each blockchain is replicated across all "nodes" or computers in the peer to peer network of that blockchain. The presence or absence of a particular node (e.g. being offline) does not affect the operation of the blockchain as a whole, and this ensures guaranteed "uptime".
- **Consensus algorithm**: In order for a new set of transactions to be written to a block, the block must be validated by a consensus algorithm. There are various such algorithms, the most common one being "proof of work" where a node must solve a cryptographic puzzle thus entitling it to validate the new block (and in blockchains based on cryptocurrencies to earn a "coin"). The major issue with "proof of work" is that it does not scale well in terms of the number of transactions. Other consensus algorithms include Byzantine fault-tolerant replication (Vukolic 2015) and "proof of stake" (currently being developed actively within the Ethereum project).
- **Cryptographic signatures**: All transactions in a blockchain are cryptographically signed with public key cryptography to prove identity, authenticity and enforce read/write access rights.
- **Permissioned versus unpermissioned blockchains or ledgers**: As discussed in Walport (Walport 2016) blockchains (or as some people call them "distributed ledgers") can be unpermissioned or permissioned. An unpermissioned blockchain has no single owner fulfilling the ideal that there is no central control. The best example is Bitcoin but the core Ethereum blockchain is also unpermissioned. A permissioned blockchain has a set of owners who control read/write/mining rights and thus operate the consensus algorithm. The Hyperledger Fabric works like this.
- **Smart contracts**: Taking the distributed database concept one step further, Buterin (Buterin 2013) proposed that a blockchain should be a virtual machine, a distributed computer that could run simple programs, so called "smart contracts". This

raises the prospect of writing autonomous pieces of software which run independently of human intervention so called “distributed autonomous organizations”.

Next, the blockchain technology stacks Ethereum, Hyperledger, and BigChainDB are presented. There is a variety of technology stacks, like Quorum, Ripple, and IOTA, that could also be discussed. There are thus a great many other BCT platforms or technology stacks, a survey requires an additional section. Ethereum and Hyperledger are however one of the first technology stacks and BigChainDB takes an alternative approach.

Ethereum (https://www.ethereum.org/): One of the most influential is the Ethereum Platform, an initiative of Vitalik Buterin (Buterin 2013) and Gavin Wood (Wood 2015), which was funded by approximately $20 M of bitcoin (Gerring 2016).The vision for Ethereum (Buterin 2013; Wood 2015) was to create a blockchain based distributed virtual machine which would allow “smart contracts” to run as “distributed autonomous” entities. This vision was a significant step in extending the vision as to what BCT was for and how it could be used. A “smart contract” for Ethereum was a small piece of code that would be run “on” the blockchain and crucially would function entirely independently without any possibility of censorship, downtime, fraud or third party interference. This enabled the vision of “distributed autonomous organizations” which would be entities entirely specified in the smart contract code which could run without human interference, and because the blockchain has guaranteed up-time without any possibility of stopping. The creation of the Ethereum Virtual machine as a Turing complete virtual machine was a core innovation, capable of running any program given enough resources (“gas”) to run. Ethereum uses a cryptocurrency “ETH” which is publicly traded on cryptocurrency exchanges, and an internal “metering unit” called “GAS”. Gas provides a means to provide transaction charges (including running smart contracts) and also allocate incentives for running the Ethereum VM. Ethereum currently uses a “proof of work” mechanism for consensus but as noted above has plans to switch to a “proof of stake” methodology.

Ethereum has had considerable mainstream success in being adopted by companies such as Microsoft and (initially) IBM to provide the underlying system for their own BCT offerings. A large proportion of blockchain start-ups and services are based on the Ethereum platform.

Hyperledger (https://www.hyperledger.org/): The Hyperledger project was founded by the Linux Foundation with the intention of developing cross-industry collaboration in the area of BCT and with a focus on supporting business transactions. This has meant a chief focus on permissioned blockchains. Many major technology companies and financial institutions were among founder members, although the most important and visible is IBM. Hyperledger is designed to be highly modular with the ability to plug in different alternative components for the same basic functionality. IBM has contributed “Hyperledger Fabric” which is the most used blockchain technology stack after Ethereum. Following the modular design, Hyperledger Fabric (https://www.hyperledger.org/projects/fabric) allows components, such as consensus and membership services, to be plug-and-play. It allows for “smart contracts” called "chaincode". The basic consensus mechanism is PBFT[SW1] [LG2] and there is no cryptocurrency because the design philosophy is for permissioned blockchain setups for specific business sectors. Apart from modularity and chaincode, key features of Hyperledger Fabric include:

- **Identity**: A membership identity service that manages user IDs and authenticates all participants on the network.
- **Privacy**: Private channels which are restricted messaging paths that can be used to provide transaction privacy and confidentiality for specific subsets of network members.
- **Efficiency**: Hyperledger Fabric uses a division of labour to assign different roles to different nodes claiming a consequent far greater efficiency of execution.

Partly due to the backing of IBM, Hyperledger has received widespread support and is being used in many different projects, including its use by Walmart in the pork supply chain (del Castillo 2016) and in a major logistics project with Maersk (White 2018). Because of the identity management features and the ability to program chaincode so as to allow access to certain kinds of data to the smart contract participants, we chose to use this technology for the Proof of Concept as reported above.

BigChainDB: In contrast to Ethereum, Hyperledger or other blockchain systems, BigChainDB (https://www.bigchaindb.com/) does not build a full stack of Blockchain technologies, but rather offers an overlay onto existing database technologies to "blockchain-ify" them. "BigchainDB is designed to merge the best of database and blockchain worlds: scale and querying from the database side, and decentralization, immutability, and assets from the blockchain side" (McConaghy 2017). BigChainDB starts with an initial open source database (MongoDB) and then added blockchain characteristics including decentralized control, immutability, and creation and movement of digital assets (McConaghy et al. 2016). The main objective has been to overcome the widely recognised scaling problem that most blockchain projects suffer from. BigChainDB claims to be able to achieve over 1 M transactions per second with this approach. The project sees itself as providing a technological component in a more conventional technology stack. This means in part that BigChainDB explicitly excludes having a virtual machine or other mechanism for running "smart contracts". In their approach, such a functionality would be provided by Ethereum or some other similar technology. The BigChainDB stressed three characteristics as being important:

- Decentralized control i.e. where no single entity controls the network.
- Immutability i.e. where data once written cannot be changed or tampered with
- Transfer of digital assets, i.e. the ability to create an asset and transfer this without central control.

A BigChainDB instance consists of a number of nodes all of which contain parts (but not all) of the complete database. Decentralised control is achieved by this DNS-like federation of nodes which have voting rights in the validation of blocks. Voting operates on a layer above the actual database and in order to achieve speed each block of transactions is written before being validated by a quorum of nodes. Nodes vote to validate a transaction and at validation time "chainify" the block as each block provides a hash id of the previous block. Immutability is achieved through a combination of shard replication, disallowing reversions, database backups and cryptographic signing of all transactions (McConaghy et al. 2016).

3 Challenges for Logistics Inspired by a Business Scenario

Using a business scenario, we consider here the applicability and challenges of BCT and its added value for mobility and logistics. The example focuses on the sharing of the container status amongst autonomously operating enterprises during transshipment via a port. Both the physical and administrative status is considered. Firstly, the current situation is introduced and secondly its possible implementation using BCT.

3.1 The Current Situation

At arrival of a vessel in a port like the port of Rotterdam, various organizations are involved to ensure the container is transported to its final destination on time. Different modalities can be applied like rail, road, and inland waterways. However, transport of a container to its final destination depends on payment of sea transport charges (commercial release), physical availability of the container in the port (physical availability), and release of customs without any further inspection of its content (customs release). This status information is shared amongst the various organizations by messages according to a customer-service provider relation. Figure 1 shows an example of the value chain for transshipment of a container discharged from a vessel and transported by truck to a final destination. A shipping line operating the vessel has a contract with a stevedore for loading and discharging containers on the vessel. A shipping line informs a 'notify' of arrival of its containers in a port of discharge, e.g. a forwarder acting on behalf of a consignee responsible for commercial—and customs release in this example (the transport document lists at least one organization acting as 'notify').

Both a stevedore and a carrier have to receive the current status of a container to pick up the container and transport it to the final destination. However, they are not involved in the commercial and the customs release. The process is normally as follows:

- commercial release is generated by a bank to a forwarder and shipping line involved
- customs release is generated by customs to the forwarder
- a stevedore generates the discharge status to its customer (physical availability), a shipping line

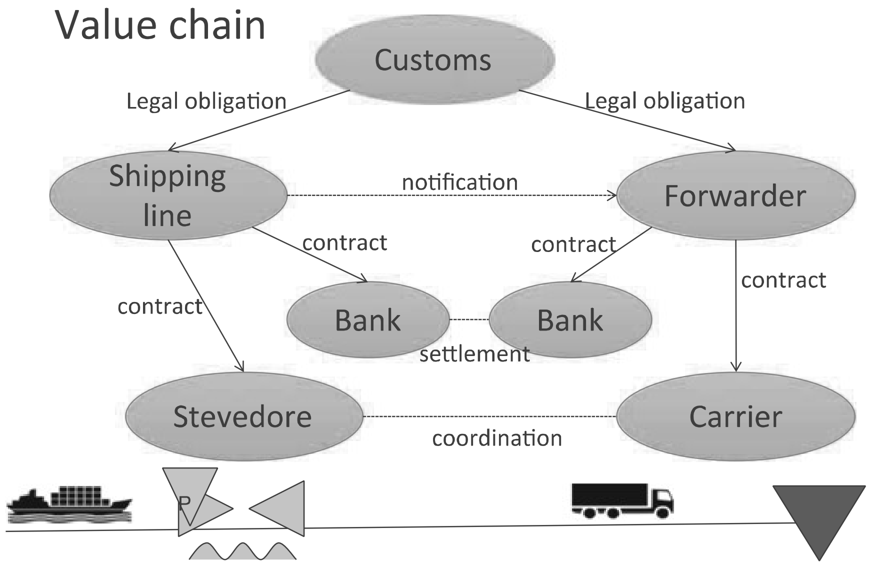

Fig. 1 Value chain for container transshipment in a port

- a shipping line makes commercial release available to a stevedore
- a forwarder send the commercial and customs release to a carrier
- a stevedore still has to receive the customs release and the carrier must know the discharge status to be able to pickup a container. A carrier also must be known by a stevedore to pick-up a particular container.

This demonstrates that a lot of coordination is required between various organizations. Currently, Electronic Data Interchange (EDI) messaging is used to support this collaboration. It causes delays in physical handling due to errors (the wrong carrier received status information), lack of status information (a stevedore is not informed of the customs release), and delays in sharing the status (a stevedore currently submits a discharge list to a shipping line after the vessel has left the port). Delays in the physical processes leading to additional container storage at a terminal are currently caused by delays in information sharing and should be planned based on customer requirements. A (port) community system can address these issues by storing the container status, but it requires trust in the system and clearly specified Identification, Authentication, and Authorization (IAA) mechanisms (Johnson 2010).

3.2 *Implementing the Business Scenario with Blockchain Technology*

To illustrate the potential added value of the BCT in this domain, we have developed a proof-of-concept application implementing the aforementioned business scenario for sharing status information with Hyperledger Fabric. By sharing real time status data and permissions via a trusted blockchain environment, on-carriage processes

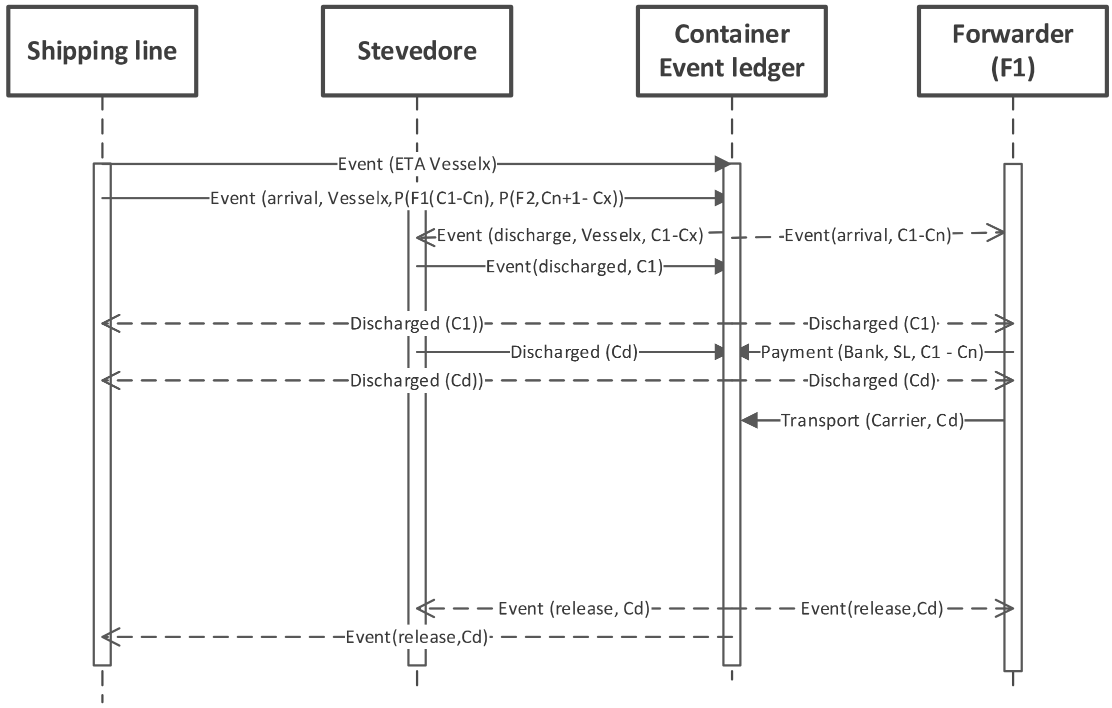

Fig. 2 Sequencing of operations for a container event ledger (selected roles)

can be planned differently, decreasing storage time at a terminal. Each arrow in the sequence diagram (Fig. 2) depicts an event with a function and permissions P of containers C to a role (forwarder = F). The functions of the event reflect milestones in the processes (Hofman 2017).

The first event in the example is the ETA of a vessel, followed by an arrival event. The dotted lines indicate that this information is available to customs and the stevedore, but forwarder F1 only has access to containers C1-Cn based on his permission P. A carrier has to request permission (P-req) on behalf of forwarder F1. By adding the transport order of the forwarder to the event ledger, the carrier could automatically receive the release event and the stevedore would be aware of the carrier picking up container Cd. Smart Contracts provide functionality to the participants, behaving according to rules agreed in a community and participation in a smart contract controls accessibility. Generation of events by trusted sensors (IoT, Internet of Things) could provide validation.

Each event in the sequence diagram of Fig. 2 represents an operation in the smart contract. For the sake of simplicity, we have chosen to develop one smart contract supporting the business scenario. The smart contract includes all relevant data[1] and operations (invoke and query) on these data. All stakeholders have to be registered and assigned roles within this smart-contract. When they are registered, they can query or invoke transactions associated to their roles. Invoke-transactions validate the data entered against the data structure of the smart contract, and the proper

[1] Hyperledger Fabric smart contracts are written in GO Language and each contains its own attribute-value data store.

role assigned to a particular stakeholder. For example, if a shipping line notifies a forwarder, the notifier has to have that role, and participate as a stakeholder in that specific smart contract on the blockchain. If a stakeholder notifying is not registered, an error occurs and the transaction is not added to the blockchain. If this stakeholder is registered as a carrier and not forwarder, the transaction is also not added.

For the proof-of-concept we developed a NodeJS web application that connects to the blockchain. This application exposes a traditional JSON API and has methods for enrolling users on the blockchain, deploying the smart-contract to the blockchain and interacting with our specific smart-contract. For demonstration purposes, we have developed a front-end application with the Angular framework.

3.3 Characteristics of Mobility and Logistics

As the business scenario illustrates, logistics has a number of characteristics which can also be applied in the mobility domain and appear to make the sector potentially a good target for the application of BCT. Characteristics include the following:

- **Heterogeneity and large number of (SME) actors**—there are many different kinds and types of organizations offering different business services from small family run enterprises with 1–2 trucks, to global operating IT driven enterprises and platforms with all types of assets (vessels, planes, trucks, cars, and containers) at their disposal, and those organizing logistics operations and handling all types of formalities. Furthermore there are various supervisory bodies (e.g. port authorities, customs and excise, police, infrastructure managers) who govern processes from various perspectives (safety, security, trafficking, etc.) at a national scale in collaboration with authorities of other countries.
- **Variability of demand**—there is limited predictability of customer demand both in terms of quantity and types of objects and individuals to be moved. It could be improved by sharing or detecting patterns in existing flows, which requires availability and access to data of these flows.
- **Time-sensitivity**—Rapidity of delivery is becoming a key differentiator for suppliers especially online retailers and hence the speed of the logistics component of the complex services provided becomes essential for high customer satisfaction. In E-commerce shipments, transport costs are independent of transport duration, but in all other flows of goods and passengers duration will come with a cost.
- **Lack of ICT integration**—in spite of the availability of sensor technology, current levels of IT integration are severely limited especially those types of integration which allow small-scale providers to be integrated with the large long distance providers.
- **Commercial/economic sensitivity**—for various reasons tied to the business models currently used, there is considerable lack of trust for electronically sharing data.
- **Liability**—sharing specific data might lead to liability in case of accidents, delays or incidents.

- **Commercial and regulatory pressures**—there are considerable pressures to reduce waste (empty transport) and to make the sector more efficient. Regulations forcing this are the major fear of Logistics Service Providers.
- **Local versus global information**—local, national goods movements need not always be available globally, e.g. waste transport or retail supply from national warehouses is local.

These are general characteristics of logistics that boil down to issues like (relative) low IT maturity and skills, lack of trust because business models are built upon lack of transparency, lack of uniformity in data semantics and process alignment, etc. Lack of trust prevents organizations in sharing (high quality) data. It requires an infrastructure for controlled data access and sharing that addresses these issues and provides easy to implement and easy to use applications to SMEs. Most often, centralized, competing IT systems, each with their governance model, are implemented to address all the aforementioned characteristics.

4 BCT for Mobility and Logistics

4.1 Examples in Mobility and Logistics

There are already many projects and BCT applications under development for the mobility and logistics domain. Most of them are still in the experimental phase. For instance, the Rotterdam Port Authority and the Municipality of Rotterdam have raised the Dutch BlockLab for logistics, experimenting with BCT for business scenarios. IBM and Maersk have raised a joint company to develop and implement the so-called Global Trade Digitization (GTD) blockchain providing visibility of container trips and share references to administrative documents (White 2018). Shipchain provides another competing visibility solution for shipments. Another application developed by Marine Transport International is to share the Verified Gross Mass of cargo loaded on a vessel, which is mandatory for sharing. Furthermore, there is a Blockchain in Transport Alliance whose members include various large platform providers like Uber4Freight and Descartes.

Similar developments can be observed in the mobility. For instance, the Blockchain Mobility Consortium (https://blockchain-mobility.org/) develops a distributed solution empowering vehicle owners in monetizing their assets and reducing insurance costs. DOVU is a similar example (https://dovu.io/). Also companies like Toyota are investing in BCT for mobility services for their (autonomous) cars. Other examples of applying BCT address issues like counterfeiting and theft. Examples include the Halal Chain raised to prevent counterfeiting by integrating production, inspection, insurance and logistics, and retail and consumers. Similar BCT applications are being developed for other products like coffee (Coffee 2017). There is also a generic solution focusing on for instance counterfeiting and stolen goods called BlockVerify (http://www.blockverify.io/).

4.2 Relevant Functionality and Opportunities

BCT can serve five basic functions relevant to mobility and logistics, namely:

- **Non-repudiation**. A BCT application can provide an immutable ledger providing proof that data was entered in the ledger at a certain time. It can be used in case of disputes between a customer and service provider or an enterprise and an authority. As such, data quality has to be optimal, the application needs to contain a complete log and audit trail. Non-repudiation can help address certain aspects of counterfeiting and theft which is of interest to consumers or authorities.
  Non-repudiation can be used to solve conflicts like related to service delivery, infrastructure utilization, etc. For instance, it can be used to proof a vehicle was driving at a particular road when a traffic ticket was issued. Another is the proof that goods have been delivered or have been handed over to the responsibility of a carrier.
- **Resilience and robustness**. A BCT application will run on several nodes that all contain the data or part of the data, depending on the type of technology used. There is, for instance, BCT that duplicates data to at most eight nodes of the network. These nodes can operate in different (cloud) environments, where the cloud operators would not have access to the data stored by the nodes. The network of nodes is resilient to failure of one node, such as a hardware failure or cyber-attack.
- **(Near) real-time data sharing**. Data entered in a BCT application is available to all participating users, based on the latency of the BCT utilized. Therefore, data is near real-time available to all users, depending on their access rights.
  There are several applications of this functionality. For instance, infrastructure managers have a real-time view of infrastructure utilization, release data of cargo is real-time available to a terminal and carrier (see the example), and customers of carriers or Logistics Service Providers are able to improve their planning and reduce express deliveries.
- **Billing and payment**. The log and audit trail can contain all details of using a particular service, e.g. for mobility and logistics. These could trigger billing and payment, for instance with one payment card (or and app on a smart device) that is used for MAAS. Of course, different service providers will have different pricing strategies linked to their service like first class travelling outside rush hours, which implies that a customer has to select a particular product and link it to its account.
  This type of function can be used for many purposes. Examples are in payment of services like energy consumption of a vehicle, energy production of an electric vehicle, infrastructure utilization, an delivery of goods according (standardized) payment conditions triggered by for instance Proof of Delivery. Especially in logistics, this functionality can also be applied for financing supply chains. Transparency of deliveries to a customer can be used to finance other activities, which can also be applied by vehicle manufacturers.
- **Decision support**. Entering status information like the position of a vehicle and its ETA at a location will improve decision making. In case a person knows a train will

be too late or not arrive at all due to an incident, that person may decide to choose another transport mode available. The same applies for the logistics example in the beginning of this section: if stakeholders have instantaneously access to status information, they can improve their decision, optimize planning, and reduce costs. There are various applications of this type feasible like predictive Maintenance, Repair, and Operation (MRO) of vehicles and infrastructure, (synchromodal) planning based on predictions of infrastructure availability and available transport capacity, optimization of behavior by selecting alternative routes (Montreuil et al. 2013), etc.

As the examples of applying the functionality show, there is a variety of options available to apply BCT I mobility and logistics. All options are on the various collaboration interfaces between stakeholders along three dimensions. These three dimensions are: (1) capacity utilization, (2) decision support in terms of planning and rerouting, and (3) payment, like indicated before. The following interfaces are foreseen:

- **Infrastructure user and—manager**: use of an infrastructure by any transport means, e.g. cars, trucks, barges, and trains. This functionality can also make use of data of all infrastructure users in a specific area at a given time interval. Storage of continuous data streams of IoT in a BCT application is not recommended, since the transaction rate of BCT is still too low.
- **Asset owner and—user**: use of an asset for its particular purpose like a car or truck. The user, i.e. the driver, can also be the asset owner. In this context, decision support relates to for instance MRO of the asset.
- **Customer and Logistics Service Provider (LSP)**: a providers offers capacity to customers for transport of freight and/or passengers, think for instance of public transport like train or metro and passenger transport by air.
- **Hubs and transport legs**: process synchronization of hubs like terminals, airports, and railway stations with respect to transport means that call upon these hubs and (potentially) have to pay for services provided by those hubs.
- **Governing and inspection authorities**: various authorities have specific tasks from a societal perspective as laid down in laws and regulations, e.g. (food) safety, security, and taxation. These authorities can use the data stored in private sector BCT applications to support their tasks, e.g. by risk assessment from a customs perspective or by monitoring passengers and freight movement from a security perspective assessing necessary licence information.

A blockchain application will automatically provide data integrity and—provenance. Data integrity is provided since data stored on a blockchain is immutable. Since each stakeholder enters its particular data to the blockchain, it will always be clear who the owner of a blockchain is (data provenance).

Non-repudiation and decision support are also relevant to authorities governing person-, goods-, and related money flows. Persons travelling internationally can store their details on a blockchain (or make them available using a blockchain) thus providing information to destination countries for risk assessment. The same is applicable to goods flows from a safety and security perspective and other risks assessed by for instance customs authorities. Tax authorities may be able to utilize blockchain data for VAT purposes. Finally, billing and payment could be used by auditors to automatically validate the administration of a company. These types of functionalities could dramatically reduce administrative costs for enterprises.

4.3 Issues and Challenges

There are still many challenges with respect to trust and economic sensitivity. Trust is (partly) addressed by permissioned blockchains, where there are procedures for joining a blockchain instance. The use of BCT as Identity Provider and Certification Authority could facilitate trust. The Sovrin Foundation (https://sovrin.org/) is such an example, but there others using Distributed Identity (DID) scheme developed by the World Wide Web Consortium (W3C).

Economic sensitivity implies that complete transparency is inappropriate current service providers and customers. Especially in logistics, lack of transparency is the basis for many business models of Logistics Service Providers (LSPs). Applying BCT would imply that significant amounts of data from all stakeholders would become transparently accessible, which is a large barrier. In a similar manner, this would apply to mobility. Thus, mechanisms have to be developed for controlled data access amongst stakeholders.

Governance is another significant issue in the use of BCT in mobility and logistics (van Deventer et al. 2017). The core issues are who has final decision making power in a networked system scenario, to change the system, to update or otherwise alter processes, and is this even allowed due to immutability of a blockchain. The procedures to install and operate a node have to be governed, especially in the context of operating nodes provided by a commercial provider like Amazon, IBM or Microsoft. To ensure proper operation of a BCT application, the code (e.g. Smart contracts or chaincode) has to be developed in a controlled manner by a team of developers. These developers should be independent of the business, because they control the functionality of the solution. Finally, the developers need to have establish transparent procedures to update the functionality according changing user requirements. These procedures should also include version management of the data structures stored on a blockchain application to adhere to immutability of blockchain data.

Most of the current BCT applications have very limited throughput and storage capacity, storing only small amounts of data, i.e. hashes which provide a link to actual data of an object like a car or container. This implies that a separate conventional database stores all data related to a particular object. This linked data is not stored on the blockchain. It would be worthwhile to explore whether or not this data can also be stored on the blockchain, thus providing non-repudiation similar to a cadastre for property.

Finally, another issue is data quality, which has three aspects. The basic functions that we mention depend on the willingness of users to enter data on a blockchain application, and this affects the completeness of the data on the blockchain. For logistics, the willingness to put data on the blockchain depends on transparency and the added value of a particular blockchain application to an organization. Correctness of data is the second aspect relevant to blockchain technology. All validation rules of data written to a blockchain are validated by a smart contract or chaincode. It makes these pieces of software code complex, combining process rules with data validation rules. There are also blockchain technologies like BigChainDB that are able to run a (JSON) validator as an extra module used before storing data in a blockchain. These mechanisms have to assure that whatever data is written to a blockchain is correct when retrieved. A final aspect of data quality is consistency of data. The data stored in a blockchain needs to reflect the physical world. The aspect of trust is relevant, but in logistics other mechanisms have been developed in the past to address this issue. For instance, there are at least three stakeholders involved in transport of cargo: a shipper, a carrier, and a consignee. If each of them enters data, the consistency can be validated.

5 Conclusions

This chapter has explored the potential of blockchain technology for mobility and logistics. We presented a business scenario for logistics and provided a brief overview of current developments in BCT including a number of examples where the technology is being used for mobility or logistics. As many authors have suggested, BCT could be significantly disruptive to mobility and logistics. Large car manufacturers like Toyota have already invested in this technology. This chapter also identifies potential applications for mobility and logistics, which can dramatically reduce administrative costs for enterprises, improve risk assessment by authorities like customs and food inspection authorities, and contribute to preventing counterfeiting and have proper VAT payment of services and products. BCT for mobility and logistics is still in its experimental phase. There are many different experiments, but there is not yet a large scale blockchain application operational to address the functionality identified before. We have also noted a number of limitations concerning governance, scalability and throughput which need to be overcome for the technology to demonstrate its full potential. Given current interest and widespread investment in the technology, we expect to see significant impact in medium term.

References

Atzori L, Iera A, Morabito G (2010) The Internet of Things: a survey. Comput Netw 54:2787–2805

Biggs P, Johnson T, Lozanova Y, Sundberg N (2012) Emerging issues for a hyperconnected world. The global information technology report, pp 47–56

Boccardi F, Heath RW Jr, Lozano A, Marzetta TL, Popovski P (2014) Five disruptive technology directions for 5G. IEEE Commun Mag 52(2):74–80

Buterin V (2013) Ethereum white paper—a next-generation smart contract and decentralized application platform [Online]. Available: https://github.com/ethereum/wiki/wiki/White-Paper

Coffee M (2017) World's first blockchain coffee project—Moyee Coffee Ireland, Medium [Online]. Available: https://medium.com/@MoyeeCoffeeIRL/worlds-first-blockchain-coffee-project-cd04fff9e510. [Accessed 16 Feb 2018]

Crainic TG, Montreuil B (2016) Physical internet enabled hyperconnected city logistics. In: Transport research procedia—the 9th international conference on city logistics

del Castillo M (2016) Walmart blockchain pilot aims to make China's port market safer, Coindesk [Online]. Available: http://www.coindesk.com/walmart-blockchain-pilot-china-pork-market. [Accessed 21 June 2017]

Endsley M (1995) Toward a theory of situation awareness in dynamic systems. Hum Factors 1:32–64

Gerring T (2016) Cut and try: building a dream—Ethereum blog, Ethereum blog [Online]. Available: https://blog.ethereum.org/2016/02/09/cut-and-try-building-a-dream. [Accessed 11 May 2017]

Grinberg R (2011) Bitcoin: an innovative alternative digital currency. papers.ssrn.com, 9 Dec 2011 [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abastract_id=1817857. [Accessed 10 May 2017]

Gubbi J, Buyya R, Marusic S, Palaniswami M (2013) Internet of Things (IoT): a vision, architectural elements, and future directions. Future Gener Comput Syst 29(7):1645–1660

Hofman W (2017) Improving supply chain processes by subscription to milestones. In: 12th ITS European Congress, Strasbourg, France

Johnson B (2010) Information security basics. Information Secur Assoc J 8:28–34

McConaghy T (2017) BigChainDB 2017 roadmap, The BigChainDB Blog [Online]. Available: https://blog.bigchaindb.com/bigchaindb-2017-roadmap-d2e7123f9874. [Accessed 1 May 2017]

McConaghy T, Marques R, Muller A, De Jonghe D, McCullen G (2016) BigChainDB: a scaleable blockchain database [Online]. Available: https://www.bigchain.com/whitepaper

McFarlane D, Giannikas V, Lu W (2016) Intelligent logistics: involving the customer. Comput Ind 81:105–115

Montreuil B, Meller RD, Ballot E (2013) Physical internet foundations. In: Service orientation in holonic and multi agent manufacturing robots, Heidelberg, Springer-Verlag, pp 151–166

Nakamoto (2008) Bitcoin: a peer-to-peer electronic cash system [Online]. Available: https://bitcoin.org/bitcoin.pdf

Preneel B (1994) Cryptographic has functions. Eur Trans Telecomm 5(4):431–448

Rivest R, Shamir A, Adleman L (1978) A method for obtaining digital signatures and public-key cryptosystems. Commun ACM 21(2):120–126

Schonberger A, Wilms C, Wirtz G (2009) A requirements analysis of business-to-business integration. Fakultat Wirschaftsinformatik und angewandte Informatik Otto-Friedrich-Universitat, Bamberg

The Digital Transport and Logistics Forum (DTLF) (2017) An outline for a generic concept for an innovative approach to interoperability in supply and logistics chains. Brussels

van Deventer O, Brewster C, Everts M (2017) Governance and business models of blockchain technologies, TNO [Online]. Available: http://publications.tno.nl/publication/34625060/VN3AE9/deventer-2017-Whitepaper-Blockchain-images-spreads.pdf

Vukolic M (2015) The quest for scalable blockchain fabric: proof-of-work vs. BFT replication. In: Open problems in network security, Springer, pp 112–125

Walport M (2016) Distributed ledger technology: beyond blockchain [Online]. Available: https://www.gov.uk/government/publications/distributed-ledger-technology-blackett-review. [Accessed 2018]

Wang W, Tolk A, Wang W (2009) The levels of conceptual interoperability model: applying systems engineering principles to M&S. In: Spring simulation multiconference

Weiser M (1991) The computer for the 21st century. Sci Am 3:94–104

White M (2018) Digitizing global trade with maersk and IBM—blokchain unleashed, Jan 2018 [Online]. Available: https://www.ibm.com/blogs/blockchain/2018/01/digitizing-global-trade-maersk-ibm. [Accessed 16 Feb 2018]

Whitmore A, Agarwal A, Xu LD (2015) The Internet of Things—survey of topics and trends. Inf Syst Frontiers 17:261–274

Wood G (2015) Ethereum: a secure decentralised generalised transaction ledger—Homestead revision [Online]. Available: http://gavwood.com/paper.pdf

The Physical Internet from Shippers Perspective

Carolina Ciprés and M. Teresa de la Cruz

Abstract The Physical Internet will change the way that goods are handled, stored, packaged and transported across the supply chain. It mimics the Digital Internet, as freight in the Physical Internet would travel seamlessly as data is exchanged in Internet. Physical Internet has become a key element to achieve ALICE vision (Alliance for Logistics Innovation through Collaboration), representing shippers and logistics service providers. In order to achieve this vision, research challenges in five different areas should be tackled: sustainable, safe and secure supply chains; corridors, hubs and synchromodality; information systems for interconnected logistics; global supply network coordination and collaboration; and urban logistics. A survey launched by ALICE gathered the shippers' perspective on the realization of the Physical Internet, including as key factors the transition required (business and governance models, regulation) as well as the barriers/triggers for its implementation. Future steps will focus on gaining endorsement on this vision.

Keywords Physical internet · Supply chain · Transport · Logistics · Freight Mobility

1 Introduction

One of the first outcomes of Mobility4EU project[1] was to identify trends and drivers that will impact transport and mobility in Europe in 2030. Moreover, it has identified user demands that call for solutions. In the area of freight transport, a series of promising novel and innovative transport solutions were derived. The Physical

[1] http://www.mobility4eu.eu.

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Internet can be found among those solutions, fulfilling user needs related to freight transport. Those needs are, among others, efficient transport flows & networks, real-time travel info & services, interoperable and seamless journeys, data security and/or privacy & transparency, protecting climate, environment and health, and empower new players & innovations.

Logistics and supply chain management is currently full of inefficiencies: even though the figures vary among countries, one in every three trucks carrying goods across Europe is travelling empty,[2] the average load factor is 50%,[3] manufacturing and storage facilities are underused resources and the use of multimodal transport systems still faces many challenges, not being a reality for freight yet. Inefficiencies not only have an economical cost, but also an environmental impact, increasing greenhouse gases emissions while governments aim at its reduction. Moreover, labour conditions of logistics workers can still be substantially improved.

The Physical Internet initiative tackles the above mentioned limitations, changing the way that goods are handled, stored, packaged and transported across the supply chain.[4]

This chapter will provide the vision of Physical Internet from the shippers' perspective. Section 2 will explain the basis of the Physical Internet concept; Sect. 3 will provide insights on each one of ALICE ETP roadmaps and how they help to fulfil the vision of The Physical Internet; Sect. 4 will detail the shippers' position on the Physical Internet based on the outcomes of a survey launched by ALICE; and Sect. 5 will state future steps towards gaining shippers' endorsement to the Physical Internet paradigm.

2 The Physical Internet Concept

This section provides an overview of the origin and basis of the Physical Internet.

The Physical Internet Concept was outlined in 2011 through the Physical Internet Manifesto,[5] and has been further developed since then, led by the Professors Benoit Montreuill and Eric Ballot. The idea behind this new paradigm is to mimic the way that the Digital Internet works. Thus, goods would travel through synchromodal hubs across an "open global logistics system", encapsulated in special designed containers to be modular, standard and smart-so called π containers (Fig. 1). Therefore, a Logistics web which is efficient, sustainable, adaptable and resilient would be deployed. Physical Internet should be inclusive, open and for the benefit of all stakeholders.

Handling and storage systems and facilities would be conceived to manipulate only π containers, being cheaper, easier, faster and more reliable than they currently are. The hubs are the nodes of the network where the containers are being stored or

[2] EC Press Releases, http://europa.eu/rapid/press-release_MEMO-88-81_en.htm?locale=en.

[3] Load factors for freight transport, European Environment Agency, 2010.

[4] See footnote 3.

[5] The Physical Internet Manifesto, www.physicalinternetinitiative.org.

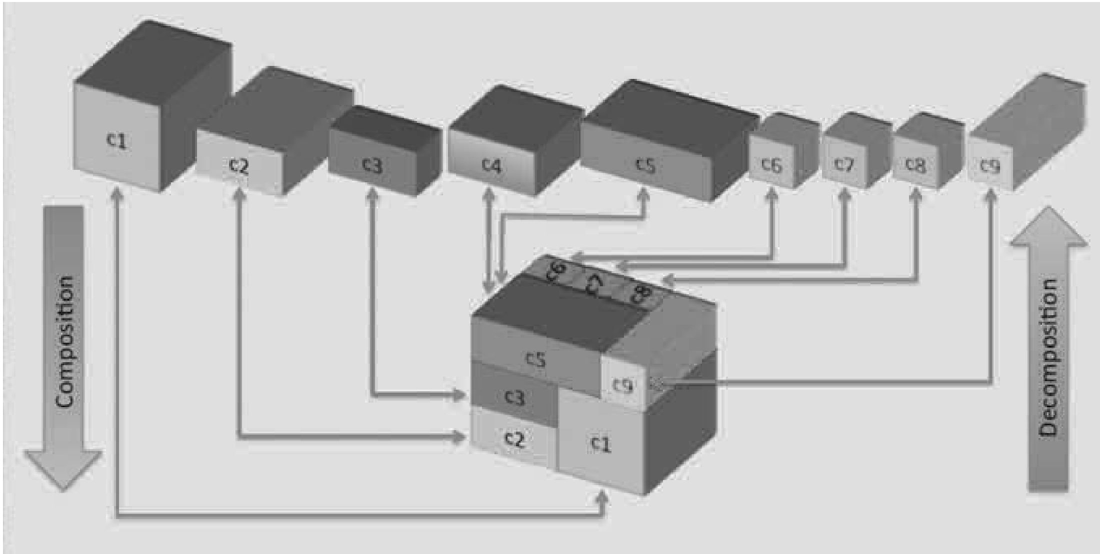

Fig. 1 Modularity of π containers (Montreuil et al. 2010)

dispatched according to the optimized flows, and are also where the interaction with the entities out of the Physical Internet takes place (Montreuil 2011).

In order to be realized, this new and advanced logistics system will need the support of information and communication technologies and other developments such as Internet of Things, big data analytics, 5G mobile networks, additive manufacturing, 3D-printing, and robotics.

Even though The Physical Internet Concept may seem very futuristic, the most innovative shippers and retailers are starting to test this model. New companies are blooming inspired in this concept, such as MonarchFx,[6] Carrycut[7] or CRC-Services.[8] MonarchFx is a brands and retailers alliance operating in the US and concentrated on e-commerce logistics. In a collaborative way, members use the alliance's shared routes and network when some of the specific orders cannot be fulfilled in the expected timeframe by their current network. The company has also a special focus on intelligent technology and automation. Carrycut is a digital marketplace for freight services, in the form of an app that brings together retailers, transporters and private users. Finally, CRC-Services (which stands for Collaborative Routing Centres) aims to increase the logistics performance for small and medium size deliveries creating an open network of regional hubs to connect logistics flows (multi-manufacturer and multi-retailer) achieving truck loading rates above 90%. In Europe, The European Commission envisions a series of measures in order to build a competitive transport system by 2050.[9] Some of the key goals include the optimization of the performance of multimodal logistics chains (more than the 50% of road freight over 300 km

[6]www.monarchfxalliance.com.

[7]https://www.carrycut.com.

[8]www.crc-services.com.

[9]Roadmap to a single European Transport Area-Towards a competitive and resource efficient transport system 2011.