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EnviroInfo 2020

Environmental Informatics
New perspectives in Environmental Information Systems: Transport, Sensors, Recycling

Adjunct Proceedings of the 34th EnviroInfo conference

Nicosia, Cyprus, September 23-24, 2020

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Andreas Kamilaris · Volker Wohlgemuth · Kostas Karatzas
Ioannis Athanasiadis

Editors

Environmental Informatics

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Preface

This book presents short papers and work in progress papers of the 34th edition of the long-standing and established international and interdisciplinary conference series on environmental information and communication technologies (Envirolnfo 2020).

The conference was held from 23 –24 September 2020 virtually. It was organized by the Research Centre on Interactive Media, Smart Systems and Emerging Technologies (RISE), Nicosia, Cyprus under the patronage of the Technical Committee on Environmental Informatics of the Gesellschaft für Informatik e.V. (German Informatics Society – GI). RISE is a research centre of excellence in Cyprus, aiming to empower knowledge and technology transfer in the region of South-East Mediterranean. It is a joint venture between the three public universities of Cyprus (University of Cyprus, Cyprus University of Technology and Open University of Cyprus), the Municipality of Nicosia, and two renowned international partners, the Max Planck Institute for Informatics, Germany, and, the University College London, United Kingdom.

Combining and shaping national and international activities in the field of applied informatics and environmental informatics, the EnviroInfo conference series aims at presenting and discussing the latest state-of-the-art development on information and communication technology (ICT) and environmental related fields. A special focus of the conference was on digital twins and, in particular, the emerging research concept of digital twins for sustainability, where natural systems are twinned with digital replicas, to improve our understanding of complex socio-environmental systems through advanced intelligence. Sustainable digital twins of smart environments are also a flagship project of RISE.

This paper collection covers a broad range of scientific aspects including advances in core environmental informatics-related technologies, such as earth observation, environmental monitoring and modelling, big data and machine learning, robotics, smart agriculture and food solutions, renewable energy-based solutions, optimization of infrastructures, sustainable industrial/production processes, and citizen science, as well as applications of ICT solutions intended to support societal transformation processes toward the more sustainable management of resource use, transportation and energy supplies.

We would like to thank all contributors for their submissions. Special thanks also go to the members of the programme and organizing committees, for reviewing all submissions. In particular, we like to thank our local organizers at RISE who responded fast and generated a digital twin of the physical conference and hosted it online. We also deeply appreciate the help and support of the Environmental Informatics community that backed up our efforts to cope with the COVID-19 pandemic and to have a stimulating and productive online event. Last, but not least, a warm thank you to our sponsors that supported the conference.

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Nicosia, December 2020

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Blockchain-based Electronic Record Books for Transparency to Prevent Marine Pollution

Hauke Precht[1], David Saive[2], Simon Czapski[3], Jorge Marx Gómez[4]

1. Introduction

Although, international shipping is subject to many international regulations and numerous port states' measurements towards environmentally friendly shipping, illegal oil and waste dumping is still present. Pollution caused by oil spills is still one of the major marine pollutions from vessels [1]. While the coast guards' activities to combat these unlawful actions are increasing [2], the shipowners' creativity to find ways of illegal dumping increases as well. One phrase commonly used to describe a particularly sophisticated method of illegal oil dumping are so-called "magic pipes" [3]. These are pipes linked to the machinery of a ship to bypass the ship's pollution control systems to illegally discharge oil and oily waters directly to the sea [3]. This is not an uncommon way of circumventing international regulation. For example, in June 2019 a Portuguese shipping company plead guilty to use such a magic pipe [4], and in July 2017 a Greek shipping company was found guilty of the same offence [5]. Such illegal dumping of waste is a significant threat to the environment. One of the biggest cruise shipping companies in the world has been fined 20 million Dollar due to illegal dumping of plastic in The Bahamas [6]. All cases had one thing in common: falsification of the record-keeping, i.e. of oil and other waste record books. As the person responsible for the record keeping, either the captain or the vessel's machinery officer [7], enters every relevant event by hand, they decide if and how a certain pollution-related event is entered into the respective record books. This enables easy counterfeit and fraud considering pollution related record books. Therefore, international regulation towards greener shipping cannot succeed as they lack clear evidence. If falsification of such record books could be prevented, regulations could be applied more strictly.

Nevertheless, international regulation strongly relies on the record-keeping of the ship's emissions. All ships are subject to the "International Convention for the Prevention of Marine Pollution from Ships" (MARPOL) [8]. MARPOL itself is subdivided into a main part and six annexes in which emissions and pollutions are described: oil (Annex I) [9], noxious liquid substances (Annex II) [10], other harmful substances (Annex III) [11], sewage (Annex IV) [12], garbage (Annex V) [13] and Sulphur (Annex VI) [14]. All annexes impose the duty of record-keeping on the shipowners, e.g. regulation 17 and 36 in Annex I for the Oil Record Book Part I [15] and Part II [16]. Part I covers machinery operations while Part II is for cargo/ballast operations. This creates a complete record of all activities concerning oil and oily waters.

MARPOL offers strict guidelines for the form of such record books, e.g. in Appendix III to Annex 1 [17]. To the current day, paper-based record books are still used, although the MARPOL itself allows the

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usage of electronic record books: In 2019 numerous resolutions have been adopted to implement the "Guidelines for the use of electronic record books under MARPOL" [18]. They aim to "facilitate port state control inspections" and "to reduce administrative burdens and contribute to onboard environmental initiatives, e.g. reduction of paper use." [18], since the maintaining of the traditional handwritten oil record book, for example, can be "a real headache" [19], next to the already described issues concerning counterfeit of data. The flag states approve the usage of certain technology for electronic record books [20]. All record books serve to control the correct handling with the named oil, waste or garbage. The entries contained are used as evidence for public inspections as well as in court proceedings [21].

In Germany, electronic record books are governed by the "Bundesamt für Schifffahrt und Hydrographie" (engl. "Federal Maritime and Hydrography"; abbr. BSH). The BSH approves such technology for electronic record books, that does comply with ISO 21745. The before described regulations and guidelines allow the usage of electronic record books in a technology-neutral way. This paper aims to answer the question, if a digitization of a ship's record book benefits from using blockchain as a tamper proof technology. As different countries may use different standards to approve such technology, the focus of this paper is for Germany, i.e. the solution must comply with ISO 21745. The following paper is structured as follows: First, an overview of related work is given. Next, it is evaluated if blockchain is suitable for digitizing record books followed by a proposed solution combining blockchain and IoT sensors. The paper concludes by summarizing the key finding and provides an outlook of next steps and future research.

2. Related Work

Koss already described in 1996, the importance of optimizing waste management within the maritime sector [22]. A general investigation of using distributed ledger technology (DLT) within the shipping industry was carried out in [23], identifying that the usage of DLT for digitizing paper contracts with potential for the scientific use of data, improve shipping operations and processes while making operations safer and environmentally friendly [23]. Similar research is shown in [24] describing existing projects in the maritime sector leveraging blockchain technology, for example, a new verified gross mass of packed containers. Further, the authors describe the possibility of using blockchain for bill of ladings [24] which is also proposed by Wunderlich and Saive [25]. In general, the maritime industry requires external motivation to adopt new technology, for example the possibility to save costs or new legal requirements [24].

Since the ship's logbooks serve to keep track of all types of oil and waste disposal, general approaches to the use of blockchain in waste management must also be considered. Several papers have been identified showing scenarios in which the usage of blockchain technology can be beneficial for waste management. Ongena et al. provides a analysis of the general applicability of blockchain in waste. They identified key problem areas in waste management such as fraud and manipulation, wrong or loss of information, manual processes, lack of knowledge about technology and lack of control [26]. A more specific investigation of blockchain in waste management was carried out by Laouar et al. as they propose to use blockchain for tracking movements and collection of solid waste [27]. The goal of their smart-contract-based system is to enhance the transparency of waste management information [27]. Like the problem areas in waste management in general, identified by [26], Laouar et al. identified seven problems within the current waste chain and stating cheating, manipulation, loss or wrong information as well as lack of control which were also identified in [27] as key problem areas. Gupta and Punam also propose a smart-contract-based waste management system, focusing on e-waste and regulation constraints in India [28]. A similar approach is presented in [29], where a deposit system, based on blockchain is presented, also focusing on Waste Electrical & Electronic Equipment (WEE). Another waste management system is proposed in [30] motivated by smart cities. Further, they use Unified Modeling Language (UML) and Temporal Logic of Actions (TLA+) to proof correctness preciseness and completeness of the proposed modelling [30]. Hakak et al. add another point focusing specifically on wastewater management. They propose to tackle current shortcomings of tampering or modifying sensor data, currently stored in databases, by leveraging blockchain technology [31]. An approach for cross-border waste tracking is shown in [32]. The authors describe a system based on blockchain for tracking cross-border movements and preventing illegal dumping while maintaining data protection standards [32].

As shown, there is progress in the use of block chain technology in the maritime sector and in waste management. However, to best of the authors knowledge, no scientific work is dealing with blockchain based digitization of a ships record book. Therefore, this paper aims to answer the general question, if the digitization of a ships record book based on blockchain is beneficial and if this meets requirements implied by ISO 21745 in order to improve data quality and to counter manipulation of record books to disguise illegal waste dumping on sea.

3. Towards a Blockchain and IoT based Record Book

Even though no scientific literature could have been identified, several solutions for digital record books exist within the maritime industry [33]. But only one solution, RINA Cube, advertised the possibility to use a blockchain-based oil record book [34]. However, no information on the used technology or actual usage could be acquired, as the authors did not receive answer upon contacting the company. That way, questions concerning privacy, reliability of data, regulatory compliance and general architecture remain unclear. Therefore, it is not possible to determine which flag state would approve this solution. Also, the presented solutions rely on manual entering of data, still opening the gate for counterfeit. This leads to the need of a general and transparent approach for digitizing the ship record book based on blockchain while solving problems resulting from entering data manually. Also, as mentioned, the general question if blockchain is generally suitable for digitizing a ship's record book needs to be answered as well. Further, it must be ensured that such solution is legally complaint, leading to the need to integrate law researchers early in the process, resulting in the need for interdisciplinarity.

As a first step, it is necessary to examine whether the usage of blockchain is beneficial when digitizing a ship's record book. To do so, it is first discussed, if the identified problem areas from general waste management (based on [26]), which can be optimized by blockchain, also apply to the maritime sector, specifically the ship's record book. If these problem areas can be transferred to this application case, it can be argued that a block chain is also advantageous, as it has already proven to be beneficial in view of the main problem areas of general waste management [26]. Therefore, each in [26] identified problem area, *fraud manipulation*, *wrong or loss of information*, *manual processes*, *lack of knowledge about technology* and *lack of control* is discussed in terms of ship record books.

Considering the first identified problem area, fraud manipulation, the authors state that entries can easily be counterfeit or afterwards modified [26]. As the ship's record book is paper-based, similar problems are present. It is stated in [26], that blockchain technology is not suitable to counter this issue, as the initial entry could be already wrong, even though the blockchain permits modification. To tackle this issue, Internet of Things (IoT) sensors could be applied. IoT describes the concept to allow several objects to collect and exchange data via network [35]. Such IoT sensors could be used to eliminate a possible source of error, i.e. the manual entering of data, by producing the corresponding data and storing it in the blockchain. A similar concept of combining IoT sensors and blockchain is already well known in supply chain traceability, as shown for example in [36, 37, 38]. In terms of general waste management tracking, Yeong et al. proposed an NFC-based waste management tracking system [39] whose concepts might apply to data gathering for ship record books. Closer related to electronic record books are the current attempts of connecting sensors in the bunker holds for automatic bunker (quality) tracing [40]. However, the usage of IoT sensors does not eradicate possible fraud manipulation completely. This is due to the nature of IoT architecture in which the sensors usually send data to (central) gateways for further processing, e.g. sending it to a blockchain. These (central) gateways could be attacked or be corrupted by the operator. Latter can be tackled in a way, that such gateways are not operated by ship owners but by a governmental or independent institution, leading to a counter-measurement on an organizational level. As the problem of data integrity is a problem for IoT or cyber-physical systems (CPS) in general, dedicate research areas emerged. A promising approach is to add a digital watermark to the generated data of the sensor [51]. The sensor itself would add this watermark, so manipulating data send from those sensors will be detectable, leading to a reliable and hard to manipulate data source. Those approaches must be further evaluated and integrated into the proposed solution towards a secure system in general, which is out of scope for this paper.

Analyzing the second identified problem area, wrong or loss of information, it shows that this issue also occurs at ship record books, as entered data could be counterfeit or the whole book could be lost. That would be, in the worst case, if the ship sinks. As blockchain provides a decentral and distributed environment which stores the data, this technology is suitable to counter this identified problem [26].

The third problem area describes the manual process, as data needs to be manually gathered and entered in paper-based records, which is also done in ship record books. This cannot be solved by blockchain technology alone [26], but as stated above, the combination of IoT concepts and blockchain could automate the whole process of keeping records for ship record books which would save time for the crew.

Based on the conducted interviews in [26], a lack of knowledge and ability to work with technology within the waste management sector is shown. Similar can be observed in the maritime sector, which is slow to adopt new technology and requires external motivation, e.g. by new legal requirements or potential cost/time saving [26]. This is a problem, which cannot be solved by blockchain or technology in general but must be done step by step, supported by change management methods.

The last identified problem area by Ongena et al. describes the lack of control, describing the issue that governmental inspection at a waste division stations are time-consuming [26]. This can be simplified and solved by a blockchain-based solution serving as a trust factor, given that the organization can ensure that the data is entered correctly [26]. This also applies to inspections of ship record books. The use of IoT sensors can meet the requirement that the correct input of data must be guaranteed.

As shown, the general problem areas in waste management process also apply to ship record books. Thus, blockchain-technology should be applied. By combining IoT, i.e. sensor, and blockchain technology, problems considering data integrity can be solved. As the paper aims to show that a digital record book based on blockchain, now enhanced with IoT sensors, is usable in Germany, it is evaluated next if such solution is compliant with ISO 21745 as this is a condition to be met for acceptance by the BSH. This analysis is shown in Table 1. where the five fundamental functional requirements based on ISO 21745 are shortly described, and the proposed solution is discussed in terms of fulfilment.

ISO 21745 Requirement	Blockchain and IoT Solution
Data Storage: The data stored in an electronic record book must be identical with the paper-based record books. UTC as time format must be used, and all information must be in a clear legible font. Four types of data are supported: automatically-collected data, record book data, signed record book data and edit history data. [41] Further, it is described in that input values need to be protected, preventing manipulations and counterfeit along with an authorization system [41]. It is also required to provide monitoring of the system along with the possibility of status reports [41].	Using blockchain technology and sensor-generated data does not limit any of these requirements. Further, automatically-collected data is explicitly supported, thus enabling the usage of aforementioned IoT concepts. The requirement of an authorization-based system where users can be identified can be fulfilled by applications on top of the actual blockchain or by using private permissioned blockchains [42] with specific governance.
Record management: In the norm, it is stated, that automatically-collected data shall not be revisable and modifiable while record book data can only be modified by authorized persons. Further, changing actions need to be tracked and made visible. Note, that it is explicitly written, that records need to be protected against unauthorized deletion, destruction or amendment and the system has to take care of measurements against unauthorized or untraceable changes [41]. Further, the system shall store edit history data, like contents time, place and user who made the change. For automatically generated data, it is written that it shall not be revised and modifiable [41]. In terms of data synchronization, similar requirements apply, i.e. the content must remain unchanged.	Leveraging blockchain technology, entered data can be considered tamper-proof and non-modifiable [43, p. 125], fulfilling the stated requirement. Further, transaction data saves the required information of who has called the function, and what record entry has been made. Due to the decentralized and distributed nature of blockchain, it not possible to destroy or destruct the system, which fulfils another requirement in terms of record management. Similar holds true considering automatically generated data, which is part of the proposed combination of IoT sensors and blockchain for digitizing the ship record book. Also, the last stated requirements that the data remains unchanged when synchronizing is inherited by the nature of blockchain.
System output: This requirement describes that the output contents of the electronic record book	When using blockchain technology, the data is stored in blocks. An application layer is required to

must meet the requirements by the flag state [41], e.g. in this example, the requirements of Germany. Further, a file format shall be used, which prevents modification or editing, e.g. PDF [41].	provide functionality to the end users [43, p. 19], e.g. in this case a PDF export. This is similar to a classic software stack using relational databases. It can be stated that this requirement can be fulfilled when using blockchain, as it does not affect the storage of data in any way but only the presentation of the data.
Validation: The electronic record book shall provide and audit logging, stating what has been done and by whom and at what time [41]. Therefore, a user and authentication system is required along with role-based access control while also providing approval route [41]. Further, it is explicitly stated that the contents can be entered either automatically or manually.	The mentioned requirements in terms of validation can be linked to already described requirements in record management. Enhancements to the requirements concerning audit logs is the role-based access control. This is an aspect which needs to be considered when selecting the actual blockchain implementation. A private permissioned blockchain might provide a more sophisticated permission system than a public one, where such a system might be built around the actual blockchain. Nevertheless, it is no knockout criterion which prevents the usage of blockchain technology. Also, it is again stated, that records can be entered automatically, clearing once again the path for the usage of IoT.
System availability: This requirement states that it shall be possible to access and to create new records even if a storage medium fails, so at least two independent storage mediums are required [41].	As stated, the decentral and distributed nature of blockchain enables a high fault tolerance while keeping the system available. Therefore, the requirement of system availability can be achieved when using a blockchain approach.

Table 1. ISO 21745 compliance for blockchain combined with IoT.

Note that due to space limitations of the paper, only the key functional requirements of ISO 21745 were analyzed. The norm further describes factors like human-machine interface, the handling of system updates and test methods to verify the mentioned key functional requirements [41]. The comparison of requirements based on ISO 21745 and the proposed system consisting of blockchain and IoT sensors shows that it is in general applicable to use such a system while being compliant with the ISO norm. As next steps, a proof of concept-based prototype needs to be developed. It must be evaluated, what kind of IoT sensors could be used to track data automatically and how they could be integrated into the ship's infrastructure. Further, a blockchain (e.g. Ethereum, Hyperledger Fabric,…) needs to be selected, suitable for this specific use case. Questions concerning the scope of access (private vs public) and the used consensus algorithm need to be answered thoroughly. A possible approach for the selection process is described by Precht et al. [44]. In particular, the consensus algorithm should be carefully evaluated from a sustainability perspective, with respect to the high energy demand of proof-of-work algorithms. [45].

4. Conclusion and Outlook

As shown no research considering the applicability of blockchain for record books could have been identified, although progress has been made in the field of waste management in general. However, industry solutions exist. But only one of these solutions is blockchain-based. As no answer on the authors' inquiries were received, it remains unclear what technology is used and if this would be compliant to the ISO 21745 norm, which is required for a usage in Germany. Further, the general question if the process around the record books benefits form the usage of blockchain technology is not yet considered. In this context the paper presents the applicability of the identified problem areas from general waste management to the record book, namely *fraud manipulation*, *wrong or loss of information*, *manual processes*, *lack of knowledge about technology* and *lack of control*. It was also found that with regard to fraud manipulation, the use of blockchain technology alone is not sufficient as it does not prevent the entry of falsified data. To tackle this problem, a combination of blockchain and IoT sensors is proposed which automatically enters the respective data. As this paper is intended to show a possible applicability in Germany, the combination of blockchain and IoT sensors is evaluated for compliance with the requirements of ISO 21745 and it is shown that the proposed solution meets these requirements.

The distributed architecture of the blockchain and its resilience towards changes of the stored data requires a strict analysis of the usage of personal data [46]. Therefore, compliance with the requirements of ISO 21745 alone is not sufficient for the legally compliant use of block-chain based verification books. The General Data Protection Regulation (GDPR) [47] imposes various duties on the processor, i.e. offering ways for the rectification [48] or deletion of personal data [49]. If more than one company has access to the ledger, antitrust-regulations must be considered [50]. Besides, technical questions, such as which sensors should be used, how they should be installed on the ship and the general architecture, must be answered. This could be done by using a proof-of-concept approach. If all these challenges are met, blockchain-based electronic record books using IoT sensors can help improve data quality and thus help to enforce international regulations for more environmentally friendly shipping and transportation.

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