NEW TECHNOLOGIES APPLICABLE TO DOCUMENT AND RECORDS MANAGEMENT: Blockchain

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Digital documents can nowadays be created in two ways – they can be digitized from existing paper records or be born digitally. Digitization, in the broadest sense, is the transformation of an analog signal into a corresponding digital form. In a more narrow sense, it represents the transformation of different materials into digital format, turning them into binary code saved in a computer file. Digitization splits the notion of preservation into two parts – the preservation of the content or information recorded in a document and preservation of the physical object, i.e. the medium that carries the information. The information content is digitized and saved separately from the physical object (Stančić, Digitization of documents, 2000). It is important to note that every digitally preserved record should have its characteristics of authenticity, reliability, integrity and usability intact (ISO 15489-1:2016 Information and documentation – Records management – Part 1: Concepts and principles, 2016). The trustworthiness of a record refers to its accuracy, reliability and authenticity (InterPARES Trust Terminology Database). Archiving and preservation represent a unique challenge due to the long-term nature of these activities. The problem of long-term preservation and maintenance of digital information can be interpreted as preserving records so that the technology they are based on does not become obsolete. Digital objects require constant and continuous maintenance and depend on a complex ecosystem of hardware, software, standards and legal regulations which are constantly changing, being amended or replaced. When compared to analog records, digital ones face greater risk of decaying, primarily because of the fast pace of information technology development. Preserving digital records is much more than the preservation of a computer file – the goal is to enable access to the content while at the same time ensuring that its important characteristics are maintained.

1.1. Digital signatures and digital seals

The result of e-business and digital communication is the creation of an ever-increasing number of digital documents and records which might also contain digital signatures or have digital seals attached to them. Therefore, it is necessary to analyze the challenges of the long-term preservation of such digital records.

While technically the same, the difference between digital signatures and digital seals is that a digital signature can be only associated with a natural person and the signing key must be under the sole control of the signatory, while a digital seal can be associated only with a legal entity and the signing key must be under the sole control of the process assigning a seal to ensure integrity and origin (What is an electronic seal?) (eIDAS, 2014).

In order to be preserved for the long term, digitally signed records must also have the basic characteristics of authenticity, reliability, integrity and usability, which require a more complex approach to preservation compared to digital records that are not digitally signed or stamped. Just as there is a difference between the short-term and long-term preservation of digital records, there is also a difference between the preservation of digital records which are digitally signed or sealed and those which are not. Digitally signed or sealed records contain one more level of complexity in the form of a digital signature or seal, making their preservation more complicated.

Even though digitally signed records can be preserved for a longer period, they may lose their legal validity if this record cannot be validated or if it loses its property of non-repudiation. If an error occurs in the process of digital signature validation, the trustworthiness of the digital record becomes deprecated. This issue arises because a digital signature, and more precisely the certificate it is based on, has a limited lifetime and the validation of this signature requires a connection to the certificate authority (CA) which relies on the Public Key Infrastructure (PKI). If any of the elements of this system malfunction, digital signature validation will fail. This is especially important when preserving records that contain advanced digital signatures (Herceg, Brzica, & Stančić, 2015).

1.2. Digital timestamps

In the context of digital signatures, the digital timestamp plays an important role. It represents a digitally signed certificate of a timestamp issuer which confirms the existence of the data, documents or records to which the timestamp relates, at the time stated on the timestamp. The digital timestamp provides reliable proof that the data, document or record was created earlier or just before the time indicated in the digital timestamp. Any subsequent changes to data, documents, records or timestamp are not allowed and can be easily detected. Therefore, the digital timestamp confirms: 1) that the data, document or record at hand existed in that form at the time indicated in the timestamp, 2) that the data, document or record was not changed after the time indicated in the timestamp, 3) that the digital signature verification can be reliably performed even after the revocation or expiration of the certificate (in that case it can be verified that the data, document or record has not been changed, but the validity of the signature's certificate cannot be verified), and 4) that the data, document or record was sent or received at the time indicated in the timestamp. The Timestamping Authority (TSA) digitally signs the hash value of the data, document or record along with the time value (coming from a trusted source, e.g. it can be linked to Coordinated Universal Time), thus issuing a digital timestamp which is subsequently combined with the data, document or record and the signatory's private key to create the digital signature indicating the time of signing.

1.3. Long-term preservation of digitally signed records

Long-term preservation of digital records that are digitally signed or have a digital seal attached to them is a challenge for the archival profession. Such digital records are not easy to preserve, not only because of the constant technological advances, but also because the certificates they rely on have a limited duration. For example, the Financial Agency (FINA), a Certificate Authority (CA) in Croatia, issues certificates valid for two years, while the Agency for Commercial Activities' (hrv. Agencija za komercijalnu djelatnost, AKD) certificates are valid for five years (used in e-identity cards). The root certificates of the issuer generally have a longer validity period, e.g. ten years. After the certificate expires, it will no longer be possible to check the validity of the digital signature, but it will still be possible to check the integrity of the record itself. Currently there are several approaches to long-term preservation of digital records that have digital signatures or seals attached to them.

According to PREMIS (Data Dictionary for Preservation Metadata: PREMIS version 3.0, 2015), preservation repositories use digital signatures in three main ways:

1. *For submission to the repository* – an agent (author or submitter) might sign an object to assert that they truly are the author or submitter.

2. *For dissemination from the repository* – the repository may sign an object to assert that it truly is the source of the dissemination.

3. *For archival storage* – a repository may want to archive signed objects so that it will be possible to confirm the origin and integrity of the data.

Only in the third case, where digital signatures are used by the repository as a tool to confirm the authenticity of its stored digital objects over time, must the signature itself and the information needed to validate the signature be preserved.

According to Blanchette (Blanchette, 2006), from the point of view of archives there are three possible options:

1. *Preserve the digital signatures*: This solution requires the deployment of considerable means to preserve the necessary mechanisms for validating the signatures, and does not address the need to simultaneously preserve the intelligibility of documents.

2. *Eliminate the signatures*: This option requires the least adaptation by archival institutions, but impoverishes the description of the document, as it eliminates the signature as one technical element used to ensure the authenticity of the documents.

3. *Record the trace of the signatures as metadata*: This solution requires little technical means, and records both the existence of the signature and the result of its verification. However, digital signatures lose their special status as the primary form of evidence from which to infer the authenticity of the document. Moreover, this approach requires the existence of a trusted third party to preserve and authenticate the metadata.

Certain authors argue that the only option is the first one, i.e. to develop a Trusted Archival Service (TAS) which could guarantee that the signature on a record can still be validated years later (Dumortier & Van den Eynde).

However, results of the previous InterPARES projects recommend the third option, i.e. to organize a digital archive so as to check the validity of the digital signatures at the ingest phase, add the validity information to the records' metadata, and preserve the records without addressing the digital signature's validity further. Thus, the issue of trust is shifted from the (digitally signed) record to the archive preserving digital records and the associated (validity) metadata. This follows the more traditional model of archival preservation, which stands in contrast to the underlying premise of blockchain and distributed ledgers technology as not reliant upon a trusted third party or preservation intermediary (Nakamoto, 2008).

The research results of the current InterPARES Trust project show that there is a fourth option based on the principles of blockchain and distributed ledger technologies, i.e. to register the validity of the digital signature in the blockchain. This approach will be explained below.

2. Blockchain

In order to fully understand how the blockchain and distributed ledger technologies can be used in the context of document and records management, the underlying principles will be explained.

A blockchain is a distributed database of (transaction) records storing hash values of data, information, transactions, documents or records and it is associated with the concept of distributed ledger technology (DLT). The name is composed of two terms – "block", which refers to the complete set of contents, and "chain", which refers to the interconnection of the blocks. This chain grows linearly, and the encryption of a new block, in the context of cryptocurrencies, is called mining. Blockchain is implemented through a peer-to-peer network in which each connected computer (node) stores data on all transactions (a blockchain does not store data, only their hash values).

In order to better understand the blockchain and distributed ledger technologies, one needs to understand the underlying technologies and concepts. Therefore, hash algorithms, Merkle tree, distributed consensus, and finally, blockchain will be explained next.

2.1. Hash algorithms

Hash, or message digest, is a *one-way* function that quickly calculates a unique fixed-length string out of any data, information, document or record of any size. The one-way characteristic means that it is not possible to recreate the original document by knowing its hash. It is extremely difficult and nearly impossible to create "collisions", i.e. to have two or more meaningful records with the same hash value. That is why the resulting hash value is also referred to as a *digital fingerprint*. Figure 1 shows an example of an online hash generator using hash functions MD5 and SHA. If someone receives the. docx file with the summary of this paper and its corresponding hash value (s)he can generate the hash of the received file and compare it with the received hash value. If the two are the same, the file has not been changed, i.e. its integrity has not been compromised.

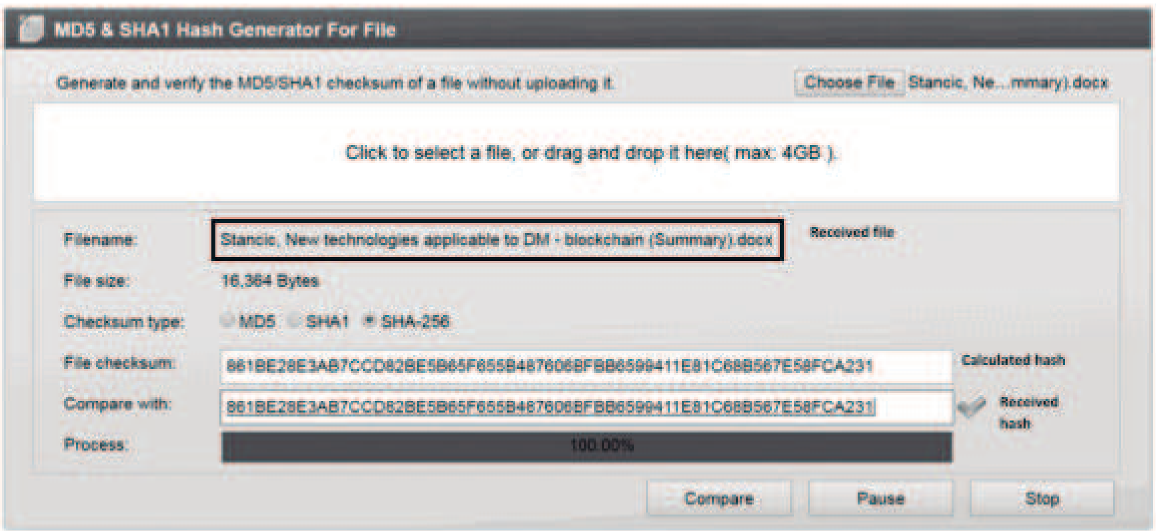

Figura 1. Comparació dels valors *hash* amb el generador de valors *hash* Online MD5, http://onlinemd5.com/

2.2. MERKLE TREE

Hash values may be grouped together to form one hash. This will be illustrated by the following example (Figure 2). A company creates a number of documents per hour. A hash value is calculated for each document. At every hour, all hash values from all documents are grouped and hashed together to get just one "hourly" hash. At the end of the eight-hour working day, for example Monday, all eight "hourly" hash values are hashed together to get one hash value for Monday. This hash is called root hash or top hash. This approach was first introduced in 1980 by Ralph C. Merkle (Merkle, 1980). Since the structure resembles a tree (upside-down), it was named the Merkle tree.

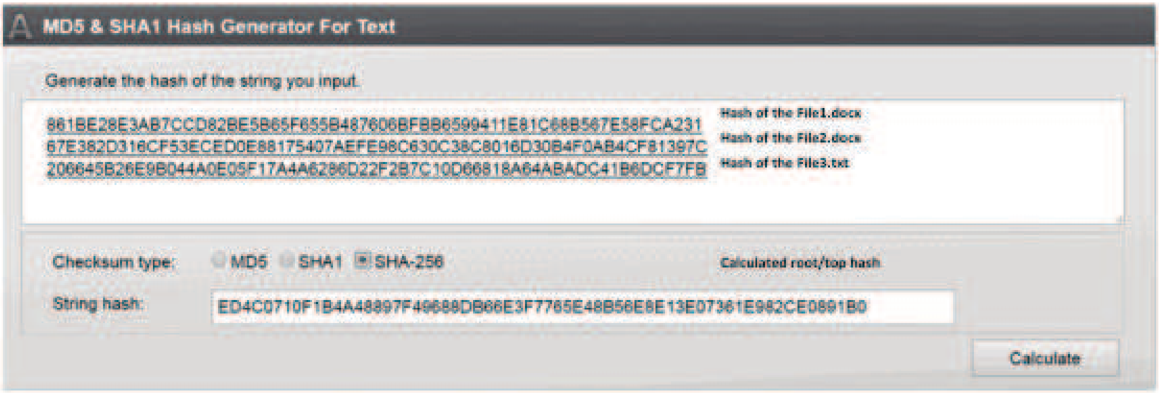

Figure 2. Creation of root/top hash

2.3. DISTRIBUTED CONSENSUS

Blockchain uses a distributed (peer-to-peer) network. The distributed network has no center(s) since all interconnected computers are treated equally. This type of network has no single point of control and therefore no single point of attack. Blockchain uses the principle of distributed consensus in which every participant (node) records every event in their ledger. Consensus is used in order to ensure that all ledgers are exact copies (i.e. are synchronized) and to determine the truth. The event (e.g. monetary transaction or registration of a document) is valid only if the qualified majority (50%+1 node) agrees.

Figure 2. Creation of root/top hash

2.4. CHAINING THE BLOCKS

The Merkle tree approach was used by Satoshi Nakamoto to create the virtual currency, or cryptocurrency, Bitcoin (Nakamoto, 2008). The rapid global spread of the popularity of Bitcoin and other cryptocurrencies has sparked wider interest and application of blockchain technology.

The blockchain creates a chain of linked blocks. This will be illustrated by extending the example explaining the Merkle tree and shown in Figure 2. The previously mentioned company can repeat the Monday hashing process for documents created every hour on Tuesday. This will result in two hash values – one for each day. Those two values could further be hashed together to create a new single top hash uniting single hashes from Monday and Tuesday. This single hash value could be further combined with the Wednesday hash value to create a new top hash, etc. Each new top hash is calculated from the day's hash and a previous top hash, thus linking the top hashes (Figure 3). Each new block is timestamped at the time of creation. This guarantees that the hashes, i.e. the data, documents or records, existed at the time of registration in the blockchain (Source: TRUSTER – Model for Preservation of Trustworthiness of the Digitally Signed, Timestamped and/or Sealed Digital Records, https://interparestrust.org/assets/public/dissemination/TRUSTERPreservationModel(EU31)-Finalreportv_1_3.pdf).

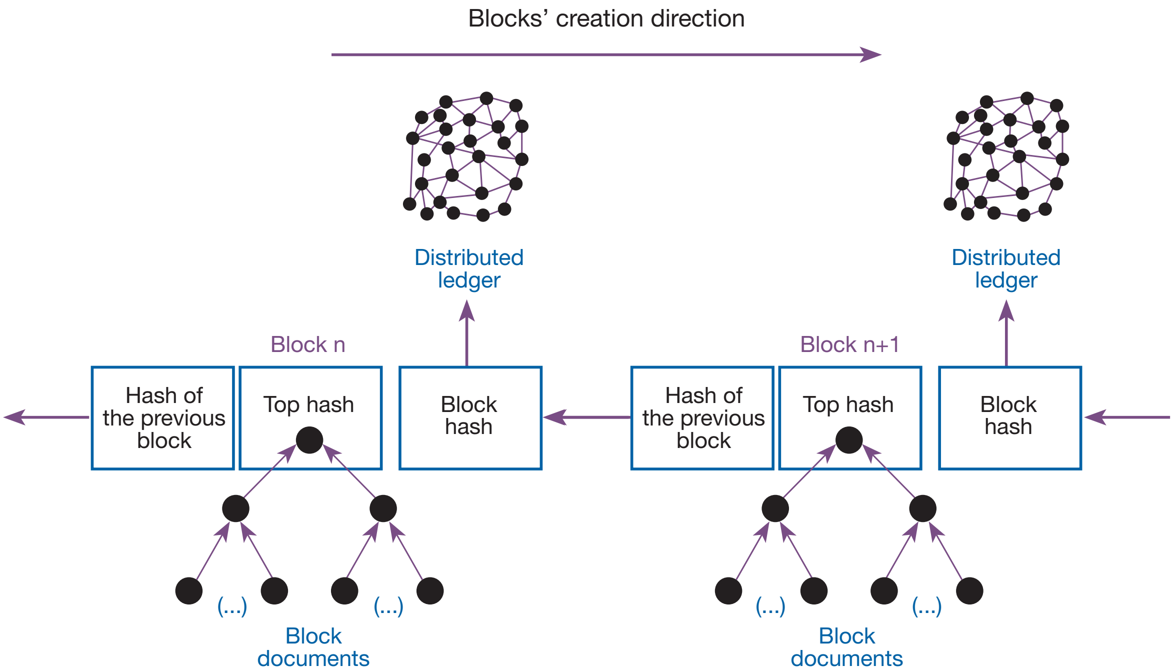

Figure 3. Blockchain creation

There are several strengths in the blockchain concept. First of all, only hashes are stored (registered) in the blockchain. The actual data, documents or records being hashed are stored in the institutional document or records management systems. Secondly, each additional block reinforces the preceding ones, since the blocks are chained together and each new block is dependent on the links of the previous blocks. Finally, modifying any block on the chain invalidates all subsequent blocks.

3. THE USE OF BLOCKCHAIN IN DOCUMENT AND RECORDS MANAGEMENT

Managing digital documents and records improves business productivity and organizational effectiveness. The most commonly used functions of document management are version tracking, tracing steps (where/when the document was/is) in the business process, verification of changes, document structure and contents as well as streamlined and trusted exchange of documents. Blockchain could be useful in several aspects of document management processes. For example, whenever a new document version is created, it could be registered on the blockchain. By doing that, and because each new block in the blockchain is timestamped, it becomes clear which document version was created when, and the changes made, document structure and contents could be traced back and verified if needed. Furthermore, in the course of business, documents are often sent to other parties. Registration on the blockchain could provide the necessary proof that a document was not tampered with, as previously shown in Figure 1.

On the other hand, documents are often digitally signed or sealed. Once they become records they should no longer be changed, and, in the course of records management and archiving, their authenticity, integrity, reliability and usability should remain intact, while some of them should also preserve the characteristics of non-repudiation, security and confidentiality. The problem, as indicated before, is that the certificates used in digital signatures expire in two to five years, leaving the record keepers and archivists with a situation in which the validity of digital signatures can no longer be confirmed. As part of the InterPARES Trust project, a TRUSTER VIP solution called TrustChain is being developed. The possibilities of using linking-based timestamping and blockchain technology for long-term preservation of digitally signed records are being investigated. TrustChain is a blockchain-based model that can be used to register information about the validity of the digital certificates from digital signatures on the blockchain at the time of ingest of the digitally signed or sealed records in the archive while the digital certificates are still valid. Later on, when the validity period of digital certificates expires, one can:

1. Confirm that the digital certificate was valid at the time of ingest,

2. Confirm that the record did not change (by recalculating hash and comparing it with the registered one and the one found in the digital signature),

3. Infer that when 1 and 2 are correct it is as if the digital certificate were still valid.

The TrustChain concept was published in the INFuture2017 conference paper "A model for long-term preservation of digital signature validity: TrustChain" (Bralić, Kuleš, & Stančić, 2017). However, the model is still in an early, conceptual phase and is going to be developed further.

4. DISCUSSION

AImplementing blockchain in a document management process is not complicated. Enigio Time, one of the InterPARES Trust research partners who was also involved in the TrustChain model development, has developed a blockchain aggregator (Figure 4). The document management system (DMS) connects through an API to the blockchain aggregator, which in turn registers hashes on the blockchain. It also makes the registered hashes publicly available so that anyone can verify the integrity of the document. It should be mentioned once again that only hashes of the documents are registered and publicly available, while the documents themselves remain in the DMS. Blockchain is not storing the documents or records and that is why this concept is usable even in the case of business-sensitive or classified documents or records.

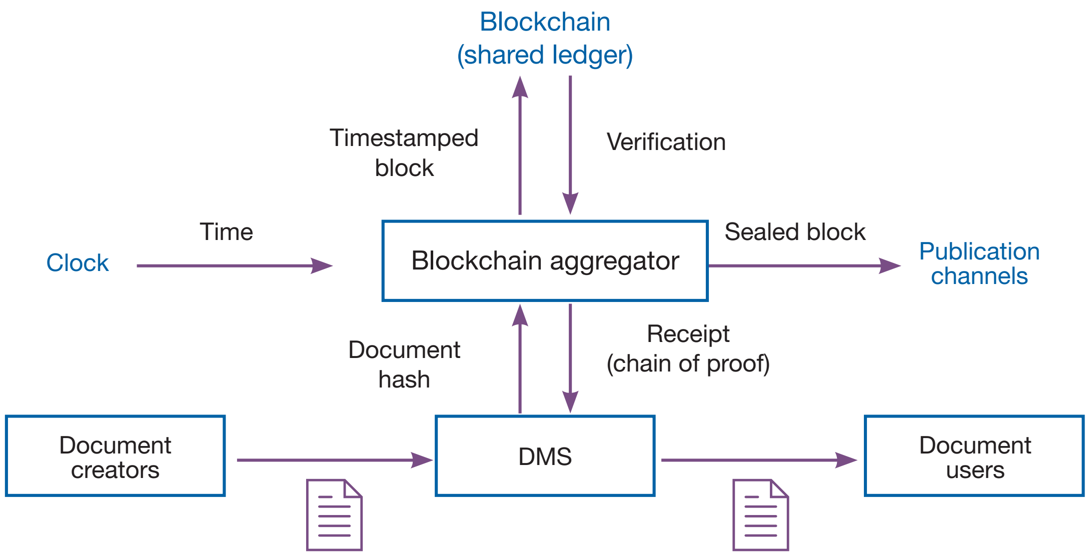

Figure 4. Connection of DMS to blockchain using blockchain aggregator

5. CONCLUSION

"Blockchain technology has attracted attention as the basis of cryptocurrencies such as Bitcoin, but its capabilities extend far beyond that, enabling existing technology applications to be vastly improved and new applications never previously practical to be deployed. Also known as distributed ledger technology, blockchain is expected to revolutionize industry and commerce and drive economic change on a global scale because it is immutable, transparent, and redefines trust, enabling secure, fast, trustworthy, and transparent solutions that can be public or private. It could empower people in developing countries with recognized identity, asset ownership, and financial inclusion" (Underwood, 2016). There are many blockchain applications that could transform society. Among them are blockchain-based financial services, smart property applications (e.g. registration of title to assets), smart contracts, applications in the healthcare or music sectors, notarization, tracking of provenance as well as e-government applications like public voting, identity management etc. Also, blockchain could find its use in establishing transparency of government and its communication with citizens.

In the context of document and records management, and taking into account all characteristics of the blockchain as well as its underlying technologies and concepts, it could be concluded that the blockchain can be used to:

- Confirm the integrity of a record,

- Confirm that a record existed or was created at a certain point in time (i.e. not after it was timestamped and registered in the blockchain),

- Confirm a sequence of records,

- Support/enhance non-repudiation of a record, and

- Improve the validation possibilities of digitally signed records during long-term preservation.

6. FUTURE WORK

Blockchain is in the process of fast-track standardization (started in April 2017) by the International Standardization Organization (ISO/TC 307) with the aim of supporting interoperability and data interchange among users, applications and systems. Also, CEN/CENELEC created a Focus Group on Blockchain and Distributed Ledger Technologies in order to identify specific European standardization needs in order to map these needs (including blockchain and DLT governance in the frame of General Data Protection Regulation – GDPR) with the current work items in ISO/TC 307 and to encourage further European participation in this ISO Technical Committee. The author has been appointed President of the Croatian ISO/TC 307 Mirror Technical Committee with the Croatian Standards Institute and will work on the standardization of blockchain terminology as a member of the ISO/TC 307 Terminology Workgroup.

Regarding the TrustChain model, future work will be focused on the full development of the model and on the creation of a working prototype.

7. ACKNOWLEDGEMENTS

The research presented here is part of a broader research study "Model for Preservation of Trustworthiness of Digitally Signed, Timestamped and/or Sealed Digital Records (TRUSTER Preservation Model)" which is part of the international multidisciplinary research project InterPARES Trust, http://www.interparestrust.org.

NOTES

1. *Croatian Encyclopedia* (Miroslav Krleža Institute of Lexicography, 2017)
2. The terms *electronic signature* and *digital signature* are often used interchangeably to mean the same thing. However, in this paper the term *electronic signature* will be used when referring to the signatures in which the identity of the signatory cannot be verified while the term *digital signature* will be used when referring to the signatures where the Certificate Authority (CA) confirms the identity of the signatory (except in the citations where the original terminology will be cited).
3. InterPARES Trust, http://interparestrust.org.
4. TRUSTER – Model for Preservation of Trustworthiness of the Digitally Signed, Timestamped and/or Sealed Digital Records https://interparestrust.org/assets/public/dissemination/TRUSTERPreservationModel(EU31)-Finalreportv_1_3.pdf
5. VIP – Validity Information Preservation
6. Enigio Time, https://www.enigio.com/
7. API – Application Programming Interface
8. ISO / TC 307, https://www.iso.org/committee/6266604.html
9. CEN and CENELEC's new Focus Group on Blockchain and Distributed Ledger Technologies (DLT), https://www.cencenelec.eu/news/articles/Pages/AR-2017-012.aspx

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RESUM

La cadena de blocs és una tecnologia relativament nova amb un gran potencial. Tot i que és més coneguda per ser la tecnologia subjacent a les monedes virtuals, pot tenir una gran influència sobre la gestió de documents. Els processos relacionats amb l'empresa i els organismes governamentals, com ara la signatura de contractes, els canvis en el cadastre o les votacions, poden millorar en l'entorn electrònic gràcies a l'ús de la tecnologia de la cadena de blocs. Podria augmentar la fiabilitat de l'intercanvi de documents, d'un nivell relativament insegur i poc fiable a un nivell nou, més segur i fiable. Una altra qüestió que cal tractar és la preservació a llarg termini de documents signats o segellats digitalment. Els certificats d'aquests documents solen vèncer al cap d'un període d'entre dos i cinc anys. Signar-los de nou o tornar a afegir-los un segell de temps pot resultar força complicat, però la cadena de blocs podria resoldre fàcilment aquest problema. Així doncs, l'autor investiga les qüestions identificades, informa de la recerca que s'ha dut a terme en aquestes línies en el marc del projecte internacional InterPARES Trust, explica els mecanismes que hi ha darrere els resultats que la recerca ha obtingut fins ara i suggereix accions que es poden emprendre per aplicar la tecnologia de la cadena de blocs a la gestió de documents.

Paraules clau: gestió de documents, cadena de blocs, signatures digitals, preservació a llarg termini.

RESUMEN

La cadena de bloques —o blockchain en inglés— es una tecnología relativamente nueva con un gran potencial. Aunque es más conocida por ser la tecnología subyacente a las monedas virtuales, puede tener una gran influencia en la gestión de documentos. Los procesos relacionados con las empresas y los organismos gubernamentales, como la firma de contratos, los cambios en el catastro o las votaciones, pueden mejorar en el entorno electrónico gracias al uso de la tecnología de la cadena de bloques. Podría aumentar la fiabilidad del intercambio de documentos, de un nivel relativamente inseguro y poco fiable a un nivel nuevo, más seguro y fiable. Otra cuestión que debe tratarse es la preservación a largo plazo de documentos firmados o sellados digitalmente. Los certificados de estos documentos suelen vencer al cabo de un periodo de entre dos y cinco años. Firmarlos de nuevo o volver a añadirles un sello de tiempo puede resultar bastante complicado, pero la cadena de bloques podría resolver fácilmente este problema. Así pues, el autor investiga las cuestiones identificadas, informa sobre la investigación que se ha llevado a cabo en esta línea en el marco del proyecto internacional InterPARES Trust, explica los mecanismos que hay detrás de los resultados que la investigación ha obtenido hasta ahora y sugiere acciones que se pueden emprender para aplicar la tecnología de la cadena de bloques en la gestión de documentos.

Palabras clave: gestión de documentos, cadena de bloques, firmas digitales, preservación a largo plazo.

ABSTRACT

Blockchain is a relatively new technology with great potential. Although it is best known as the underlying technology of cryptocurrencies, it may have a profound influence on document and records management. Business and government-related processes, such as signing contracts, land registry changes, or voting, can be improved in the electronic environment by the use of blockchain technology. It could raise the reliability of exchanging documents and records from a relatively insecure and untrusted level to a new, more secure and trusted degree. Another issue to be discussed is the long-term preservation of digitally signed or digitally sealed documents. Their certificates usually expire in two to five years. Re-signing or re-timestamping them might prove to be rather complicated, while the use of blockchain could solve this problem easily. Thus, the author investigates the identified issues, reports on the research carried out along these lines at the international project InterPARES Trust, explains the mechanisms behind the research results achieved so far, and proposes actions that may be taken to implement blockchain technology in document and records management.

Keywords: document management, records management, blockchain, digital signatures, long-term preservation.

RESUMÉ

La technologie de chaînes de blocs (blockchain) est relativement récente, mais elle présente un fort potentiel. Mieux connue comme la technologie permettant l'usage des cybermonnaies, elle pourrait influencer profondément la gestion des documents et des archives. Dans le monde numérique, les processus indispensables aux entreprises et aux administrations, comme la signature de contrats, les modifications d'enregistrement d'actes ou le vote peuvent être améliorés grâce à la technologie des chaînes de blocs. Cette dernière pourrait augmenter la fiabilité des échanges de documents et d'archives d'un contexte relativement peu sûr et peu fiable à un nouvel environnement, plus sécurisé et digne de confiance. Il convient également d'aborder la question de la conservation à long terme des documents signés ou cachetés numériquement. Leurs certificats expirent généralement au terme de deux à cinq années. Le renouvellement des signatures ou des cachets correspondants risque d'être très difficile, alors que les technologies de chaînes de blocs pourraient aisément résoudre ce problème. L'auteur étudie donc les problèmes identifiés, synthétise les recherches menées dans ce domaine par le programme international de l'InterPARES Trust, explique les mécanismes ayant conduit aux résultats obtenus et suggère des mesures qui pourraient permettre d'appliquer des technologies de chaînes de blocs à la gestion des documents et archives.