Cross-Blockchain Databases for Governments: The Technology for Public Registries and Smart Laws

Oleksii Konashevych¹

¹ Erasmus Mundus Joint International Doctoral Fellow in Law, Science and Technology, European Union

*Correspondence:*
Corresponding Author
oleksii.konashevych2@unibo.it

**Keywords:** Blockchain, governance, public services, trusted third party, cross-blockchain name-value storage, smart law

**Abstract**

There is an ongoing competition among blockchain technologies and the existence of one ultimate blockchain is impossible for many reasons. On the other hand, such variety can create difficulties in adoption, especially for the governments and corporations. The proposed technology ensures a blockchain agnostic approach and aimed to create a unified ecosystem of multiple networks. The cross-blockchain protocol can be used to develop services where end-users decide for themselves their most preferred blockchain. The invention solves problems of duplication of tokens in the result of hardforks, issues with scalability, digital identity and even the “problem” of immutability (enforceability). A cross-blockchain DB means a consistent non-conflicting key-value database across a bunch of defined blockchains. It is not a new blockchain, but a protocol for developing databases on existing blockchains. The protocol is also a basis for a “smart law” which is a framework for public registries and their governance.

**1 Introduction**

This is the original research that introduces a robust approach to developing public services based on the blockchain, different from multiple attempts by various governments to use distributed ledger technologies designed in a centralized fashion (“permissioned DLT,” and “private DLT”). The proposed protocol and methods aim to decentralize governance with a cross-blockchain infrastructure. There are no academic research and development in this space yet, though the idea of using blockchain for state-level governance and public registries is an open discussion in academia and blockchain industry. A conceptualization in this field so far was limited to mere ideas of disrupting governance (regulations, bureaucracy, middlemen, etc.) superficial in their essence, unable to address issues of how to design the system where law and technology will not collide, exposing existing problems: enforceability in an immutable ledger of the blockchain technology, scalability, sustainable governance, and many more are discussed below.
There are many examples from the past of ICT when the market benefited for standardization. For instance, to eliminate the creation of multiple incompatible I/O\(^1\) solutions by different producers of storages, Common Access Method committee introduced to ANSI\(^2\) an interface and protocol standards (IDE/ATA) (Official IDE/ATA Standards and Feature Sets, 2001). The common interface prevented the industry from pulling the blanket over itself, but to create a single common approach for processing data. If it was not the case, users would encounter different interfaces, which would require exclusive I/O solutions for different hard drives. With the standards, market became unified and more competitive. Standard I/O of data simplified work of developers of operating systems and software; but at the same time producers could still design their exclusive solutions and know-how for storage devices.

Data insertion in the blockchain is the most fundamental feature of the blockchain beyond cryptocurrencies. Once published with the transaction, any arbitrary message remains immutable\(^3\), irrevocable and public in the ledger. Different methods of data insertion gave rise to almost all useful applications of the blockchain technology: tokens, smart contracts, dApps, DAOs, etc. (Sward et al., 2018).

There are various approaches to publishing data. In the first-generation networks like Bitcoin, data is published using special scripts and methods [1], taking into account that the blockchain was not explicitly designed for these purposes (see (Nakamoto, 2008)). To manage inserted data and build some useful applications (tokens, voting, etc.) from it, it requires developing an overlaid system. For example, ‘Colored Coins’ (Colored-Coins/Colored-Coins-Protocol-Specification: Colu Colored Coins Protocol)) were based on Bitcoin, but worked as a separate technology aimed to mark and trace some coins by publishing some instructions in the blockchain. Other projects made handworks and replicated the original blockchain to develop useful applications as a native part of a core wallet (Namecoin (Namecoin), Emercoin (Emercoin), NEM (NEM – Distributed Ledger Technology (Blockchain)), NXT (Nxt - The Blockchain Application Platform), etc.).

New generation of blockchains – the distributed ledger technologies – are mostly designed for general purposes, not only for a cryptocurrency. Native mechanisms for data insertion were laid down as a basis of DTLs. For example, in Ethereum (Ethereum Wiki, 2017) an executable program code of a “smart contract”\(^4\) is inserted into the blockchain; moreover, any arbitrary user data itself is inserted and managed through smart contracts. Therefore, if a user wants to develop a database, first they create a smart contract and insert it into the blockchain and then will insert data using this smart contract.

The ability to publish data, maintain registries and manage them seems to be almost the major issue when using blockchains for public tasks, especially in the context of using state-owned registries.

---

\(^1\) Input/Output

\(^2\) ANSI-American National Standards Institute

\(^3\) In PoS, this type of hardfork is called “roll-back”. The user that has enough stakes in PoS (normally, 50%+1) may re-write blocks from any moment of the history. It is considered a malicious action, of course, if the roll-back is not designed purposely as a feature of the system.

\(^4\) Please do not be confused with the term “smart contract”, because it was proposed by N. Szabo (1997) [18] much earlier than Ethereum emerged. The Ethereum’s smart contract can be just a program not necessarily Szabo’s contract.

This is a provisional file, not the final typeset article
The coin itself does not carry any information other than its face value, its rightful owner and from where it has arrived at this address. Even the elementary creation of a colored coin in Bitcoin required a logical add-in, which used different methods of transaction processing and publication of data. More complex systems, for example, Turing-complete systems publish both variables and executable program code on the blockchain. Thus, it is difficult to underestimate the value of data insertion into the blockchain.

As a result of the analysis of the existing methods of data operation, this paper proposes an approach to create interfaces with common standards for data insertion, extracting and processing it in the form of creating an end-to-end database.

Situation with blockchains is similar to issues of the past. There are many blockchains and at the level of their protocols, there are different methods of processing data, but there are no common standards for the interaction of blockchains with other systems.

This research utilizes the experience of implementing and operating Name Value Storage technology since 2013/14 in Namecoin (Loibl, 2014) and Emercoin (Emercoin NVS - Emercoin Community Documentation). These interfaces and principles appeared suitable to develop a common cross-blockchain standard with some improvements proposed in this research.

A Cross-Blockchain Name Value Storage (CBNVS) is a method of building databases across more than one blockchain. Such databases make possible the development of different applications based on blockchain. Each blockchain at the level of their protocols performs transactions (with scripts, smart contracts, or any other know-how at the protocol level), but the CBNVS allows retrieving the resulting data.

The main issue addressed by this research was the creation of a database with unique keys across multiple blockchains. The uniqueness of keys is the fundamental requirement of consistent non-conflicting entries in the database. Blockchain is a censorless system and cannot limit the publication of any duplicate or chunk data. The proposed solution allows building an index database with unique keys from the data which is inserted in the blockchain in a standard form provided by NVS protocol.

The table will contain key-value entries where keys (called “names”) are unique across the chosen bunch of blockchains. The entries themselves will have properties of tokens, that is, controlled and managed records in the wallet of its owner.

CBNVS addresses issues of scalability, hardforks, price volatility and even the “problem” of immutability, which discourages governments from implementing a public blockchain for e-governance, at the same time providing all the benefits of the transparent and secure technology.

For example, CBNVS can be used for public property registries since its output function can be designed to overcome the problem of immutability: all records are still in the blockchain, but irrelevant entries are patched and filtered based on mechanisms of social consensus (governance). Before reading the sections that follow, if you are not familiar with the technology of Name-Value Storage, it is advised to refer to Annex first.

2 Public blockchains issues

2.1 Permissioned DLTs
Typically, the consensus of such systems is based on Proof-of-Stake protocol or other protocols that allow one user, or a group of users, to control the system to some extent.

Having enough stakes at the control, it is possible to design different schemas with privileged (‘master’) nodes that are authorized for creation of blocks, writing transactions and some other specific rights providing that other participants of the network will not have them. Such systems can also be closed; therefore, users will need authorization to read the information from blocks, whereas some protocol provides completely anonymous interaction (see, for example, DLT Quorum by JP Morgan (Blockchain and Distributed Ledger | J.P. Morgan)). Compared to existing centralized closed government systems, such DLTs may have some advantages; however, conceptually they are the same. They are centralized and censored, and moreover, are not necessarily immutable for those who control it.

Another reason why the choice of one DLT by the government leads to centralization is based on the fact that if any government decides to choose a DLT, and it is not open and public as the blockchain is, the government itself is responsible for developing an infrastructure (nodes).

On the contrary, open blockchain systems do not have central authorities that build the network. The infrastructure is self-organized incentivized by cryptocurrency with free competition. Any user is free to add their own computational resources for public needs and therefore, compete for having rewards for finding blocks and this reward is not distributed by someone centrally, but automatically obtained as per the protocol.

Therefore, permissioned systems are rarely considered a significant evolutionary step in government systems. Blockchain is a new word in governance, but this technology has some principal features that can restrain its implementation at the state level and this research conceptualizes ideas to address them.

The proposal in this research concept utilizes the immutability of the blockchain with the help of “smart law.” It reduces centralization when possible and makes it accountable when centralization is inevitable.

The principle of decentralization is the basis of this research; therefore, we neither argue nor compare blockchain to centralized solutions. Centralized databases have already been in use for quite a long time by governments, therefore we already know their advantages and disadvantages.

2.2 Hardforks

Hardfork is the major concern for systems with open competition because there are no authorities that impose and enforce one exclusive status quo. The system can split into two or more branches or “forks” after which each branch becomes independent.

In the result of the split, tokens are duplicated. For example, if the system is used to manage rights on movable or immovable property (often mentioned as “asset-backed tokens”), in the result of a hardfork, the user will still have one plot of land but two title records in parallel systems, which they can be managed independently, thereby creating legal collisions. For example, in one system, the user sells the plot, but in the other, the user still owns it.

2.3 Immutability
Being an advantage of the blockchain, it can cause a lot of untoward use cases. For example, the loss of private keys will make a cryptocurrency, a token or a smart contract uncontrolled with negligible possibilities to ever restore it. Even if the blockchain can prevent many ownership disputes, the imperfect nature of people’s relationships will always cause issues with ownership and the need to settle when they arise. The blockchain itself in its pure design does not leave practical possibilities enforcing any legitimate judicial decisions or any rightful actions by authorities. Thus, it is considered that the only possibility to do this at the protocol level is the centralization of power. Hence, in this way, permissioned DLTs are justified as the only one possible solution, making the blockchain helpless.

2.4 **Anonymity (pseudonymity)**

The authorization and authentication for a transaction is provided only with the relevant private key which belongs to the asymmetric pair. The public key of the pair is taken to generate the address of the transaction and the address (to which coins are recorded) is the only public record in the system that identifies the user. Some research showed that addresses can be deanonymized by different digital fingerprints (IPs, behaviour patterns, etc.) (Ober et al., 2013), (Androulaki et al., 2013). The pure blockchain protocol is not suitable for keeping records on property and securities from the perspective of governments and users themselves. Blockchain anonymity veils money laundering, financing terrorism, and other unlawful activity.

Beyond that, at the practical level, the censorless nature of the blockchain creates confusion in identifying records. Anyone may perform any transaction and publish any data in the blockchain. If the government must authorize a land title deed, how do you define if any transaction on the blockchain belongs to the town’s clerk if they are all pseudonymous? Without overlaid solutions for digital identities and trust services, it is almost impossible to create any scalable model for governance.

2.5 **Personal data**

In blockchain, any published data is exposed, and removal is not an option. In permissioned DLT, the personal data is stored by the government in closed DBs. Actually, nothing specifically changes in terms of the typical government service. The government keeps a closed database, these include clerks who are authorized from the government record transactions and people who apply to the public body to perform a transaction (typically, a property register, cadastre, cars, boats, aircraft, shares, companies register, etc.). A cryptographic hash, published as immutable evidence, in permissioned DLT. The same can be done in public blockchain which does not address the issue – the main database is still centralized unless it is properly designed as it is proposed in this research.

2.6 **Scalability**

One exclusively chosen blockchain for governance will necessarily create issues. Again because of the open and free nature, the blockchain protocol does not restrain publishing junk data in the blockchain. The potential bandwidth of Bitcoin per year, for example, is roughly 220 million transactions (Roio, 2013). For instance, 300 public registries in Ukraine generate as much as Bitcoin’s bandwidth (Data.gov.ua) which leaves no space for other cryptocurrency transfers. Overload with the transactions creates the problem of high transaction fees and price volatility. Although Bitcoin is not the best in terms of bandwidth, it is still the most attractive in terms of security (Cost of a 51% Attack for Different Cryptocurrencies | Crypto51). This is not a workable solution on a scale even for one country with a 40-mln population, randomly chosen as an example.
2.7 Price volatility

Due to speculations, the price can dramatically fluctuate; therefore, creating a bad user experience for those who need cryptocurrency to pay fees for publishing and managing data, running smart contracts, etc. Together with the mentioned scalability issues, it makes it infeasible for the government to use or even to announce their intention to use any specific blockchain. It will inevitably incentivize agiotage on the market, exacerbating the problem of scalability even more.

Eventually, as might be thought, the permissioned DLT is much better than the blockchain, as it addresses all these issues due to its centralized nature, purposed to control and restrict unwanted practices and manually fix troubles.

This creates two basic misconceptions: centralized DLT is presented as an improved version of the blockchain, able to address known limits. As we can see, it does, but this is not a blockchain (not decentralized, not censorless, etc.). And the second is that one DLT is opposed to one blockchain.

It is proposed to create the solidarity of reliable blockchains working in a bunch. The government should not choose one blockchain, but instead are to provide an infrastructure solution based on common technical standards to support free competition of blockchain technologies. A market-driven approach is aimed to address the problem of scalability. People, not governments, decide which blockchain to use.

3 Building a ‘nameindex’ across blockchains

3.1 General idea

The idea of a cross-blockchain database is that users will publish their NVS records in any preferred blockchain of the bunch. See Fig. 1. Then the program will collect and maintain users’ key-value entries across defined blockchains in one spare database. Any service deployed on CBNVS will deal with entries without imposing users which blockchain to use. A cross-blockchain database can be used by developers to build end-user applications (tokens, smart contracts, etc.).

NVS is a database of ‘key-value’ records where keys (known as “names” in NVS) collected across the blockchains and ‘values’ related to their keys. For example, the Name “Alex” and the Value “+61414739692” when storing a record of a telephone book. The exclusiveness of the name in the database is provided by its timestamp. Blockchain is a “timestamp machine”, which provides certainty in the chronology of facts (transactions). The concept of blockchain timestamping is a matter of academic interest presented in several publications (Buldas and Saarepera, 2004), (Gao and Nobuhara, 2017), (Gipp et al., 2015), (Breitinger and Gipp) and (Crespo and Luis García Cuende, 2016). Thus, the ‘name’ which is published first in a bunch of CBNVS blockchains, appears in the spare public database, any other entries with the same names are filtered, therefore, name squatting is impossible.

NVS provides the name’s owner for a set of possibilities to manage it (change and update the Value and transfer the Name record). NVS is a ‘raw’ material for any sorts of monetary and non-monetary tokens, overlaid electronic currencies, smart contracts and decentralized applications.

NVS creates a file “nameindex”. In the original protocol it was designed using Berkeley DB. Because NVS is an open standard, being implemented in the wallet, it builds independently the same “nameindex” for every wallet of any user in the network. But for a cross-blockchain interaction, we
interpolate this concept and build a database not on one blockchain, but through a bunch of defined blockchains.

![Cross-blockchain 'key-value' database diagram](image)

**Fig. 1.** Cross-blockchain ‘key-value’ database

When the user installs a node, NVS hooks “key-value” entries from downloading blocks checking if they are compliant with the NVS standard. The found records are added to ‘nameindex’ database. When the user enquires “Name”, NVS retrieves the information from nameindex. NVS has three commands for managing records (name_new, update and delete) which are triggered through the blockchain transactions.

NVS ensures exclusive user’s right to manage their record through the native blockchain mechanism of cryptocurrency owning. Each record is attached to the coin and therefore related to the address. Thus, the user controls their NVS record with the private key.

NVS mechanism consists of two functions: input and output. Input mechanism is aimed to create an NVS complaint transaction, meaning that it must contain all required fields of a new database entry. The name (key) itself must be unique in the database and it is accepted by the tool only under this condition. The output tool scans downloading blocks and creates a ‘nameindex’ file adding there hooked records, which are compliant with the provided standard.

All updates to records of the ‘nameindex’ database are performed through the blockchain transactions. It ensures that the user will not publish a name which already exists, and only the owner of the name may publish updates and transfer it.

A standard wallet with integrated NVS has UI and API which provides necessary assistance for the user to create a correct NVS transaction. Nevertheless, as far as public blockchain is an uncensored system, anyone may write manually the code of the ‘raw’ transaction which will not be necessarily
NVS compliant and send it directly to the mempool omitting NVS protocol, therefore, such entry will not appear as NVS record in the database. This is the major role of the output tool – to build a database as per the rules.

3.2 How and which blockchain is to include in the bunch?

CBNVS is based on a social consensus, the same as blockchain protocol at a higher level is a social consensus: the one who agrees with rules provided by the blockchain protocol, installs the node and run it.

In the architecture of a future CBNVS, the first step is to define which blockchains are scanned, how to add and exclude blockchains. Typically, the user will download and install the same software, assuming that in this way user’s consensus is expressed.

At the same time, any other CBNVS protocol may create a completely different database using the same or another list of blockchains with other rules and filters for the database.

It is also assumed that the provider of a “rightful” version of the national CBNVS may be a government and therefore, it can be centralized to some extent. Anyway, every user may decide to use multiple versions of CBNVSs, including those provided by the government and or any other community.

3.2.1 Initialization of a bunch

Originally, NVS is developed on a bitcoin-compatible blockchain used for publishing a standard OP_DROP command, which means that Bitcoin itself and its multiple altcoins that do not exclude this command from their protocols support the original NVS by default. It is assumed that non-bitcoin protocols can be used as far as they allow users publish standard NVS transactions thereby providing similar UX requirements. Particularly,

- Ensure that NVS records have unique keys across the blockchain or within the smart contract;
- Support algorithms for ownership, i.e. the one who published the name first, can exclusively own it during their specified period (“Lease Time”) after which the record is marked invalid and can be published again to any other address;
- The user can manage their record using the private key with the following commands: NAME_UPDATE that supports
  - change of Value and Lease Time;
  - transfer of the record to another address;
  - delete from the ‘nameindex’, after which anyone may publish the same name on their address;
- Support an interface (API) for hooking NVS records from the downloading blocks. Hooked NVS records that are sent to the cross-blockchain nameindex.
- Support chronology rule, i.e. only the first name is added to the database and managed there, all other identical names, published in the blockchain are ignored in the resulting nameindex.

To implement NVS in Ethereum, for example, one may design a smart contract to work as an NVS service. Another approach is providing a new standard to the whole Ethereum’s ecosystem.
The criterion for choosing a blockchain to a bundle is its reliability. Obviously, a PoW network with 3 nodes are less resistant to an attack then the network with 3 thousand of nodes. As of today, there is no golden standard of blockchain security, therefore, any decision must be empirically and expertly motivated.

The issue of network reliability is the subject of a separate study that is beyond the scope of this paper. However, for the purposes of this work, we show which approach should be taken to automatically and independently diagnose the reliability.

3.2.2 Exclusion of nodes and rescue of names

CBNVS must be able to smoothly exclude on the run any blockchain that become unreliable.

In the process of name indexing, a network is automatically excluded from the bunch of blockchains if its reliability drops down to an unacceptable level. The algorithms of exclusion and security criterion are defined during the initial set-up of CBNVS.

The system should not receive metrics that trigger the exclusion from a third-party source, except the blockchains themselves since we strive for decentralization as the fundamental criterion of reliability. However, in the following section certain centralized scenarios are also explained using permissioned DLT in the bunch and the use of digital signatures which certificates can be revoked using a traditional PKI scheme.

A decentralized system works as follows. Each CBNVS node collects data from blockchains for analysis. A blockchain network is indexed in the bunch while it meets the security threshold. Eventually, any running node will locally calculate these parameters and automatically exclude the network from indexing.

For PoW, this parameter can be difficulty/hash rate. For PoS such parameter is PoS difficulty, etc. Anyway, security level is never enough and there is plenty of room for further research and development.

When the CBNVS node detects a threat, it stops indexing from the relevant block. And the sustainability of the CBNVS is provided when all nodes will do the same independently. It is important to note that this exclusion happens not in the case of a hardfork and a rollback attack (hardfork with rewriting the history deeper than typical wait of confirmations), these issues are discussed in the section Chronology.

After the exclusion of a blockchain, all records till the block of exclusion remain valid in the database, however, they are not processed anymore even if the user tries to commit any transaction in the dropped blockchain. The user of the dropped blockchain can transfer the name from this blockchain to any other blockchain of the bunch.

The proposed concept of security leaves space for designing systems with different parameters. Here is one example. The bunch includes a few blockchains which have PoW and PoW+PoS consensus. The criteria for reliability for PoS and PoW are their dynamics of difficulty. If average difficulty decreases, say, twice, nodes drop such blockchain. The difficulty is calculated periodically for each blockchain of the bunch taking the longest period of difficult recalculation among blockchains in the bunch. For example, in Bitcoin, difficulty is recalculated every 2016 blocks (approximately 2 weeks) [14], in Ethereum, it is dynamically recalculated so that on average, one block is produced by the
entire network every 12 seconds (Mining - ethereum/wiki Wiki), therefore if the bunch consists of these two networks, the period is taken by Bitcoin.

### 3.2.3 Adding on the run

Once chosen and built, CBNVS may require adding blockchains in the future. The main issue here is choosing the exact block to index a new blockchain.

When a blockchain (which is running a while) is added in the bunch, rebuilding the nameindex from the very first block may lead to a logic conflict with ownership. If in added blockchain the same name already exists but was created earlier than the one in CBNVS, a new re-indexed version of CBNVS will reassign this record to the added blockchain. Thus, the previous owner of the record will lose their presence in the rebuild index.

A better approach is to index a new blockchain from the block when it is being added. Thus, reallocation of ownership is excluded.

### 3.2.4 How to transfer the name between blockchains

The name can be transferred from the dropped blockchain and between existing blockchains for better UX.

A user of a dropped blockchain may transfer the record to any blockchain left in the bunch. The user signs the [name + challenge] with their private key from the dropped network and then publishes this name in another blockchain. The system will see that someone is trying to capture the name which already exists in the database and analyzes if there is a signature added. It verifies the signature and if it belongs to the original owner of the name in the dropped blockchain, then the system updates the entry in the database. The same way names can be transferred between any blockchain in the bunch. The “challenge” is needed to excluded attempts of an authorized capture of the name. The owner of the name may sign the name for various reasons. Thus, the attacker may obtain it. To exclude this, the owner signs the name with the hash of the latest block.

Transferability of assets between blockchains is one of the most fundamental ideas here because it supports competition between blockchains which inevitably leads to better quality of technology and services.

### 3.2.5 Local NVS vs. CBNVS

Another issue of better design is the relation of a local and cross-blockchain NVS.

Any blockchain may have its own NVS even before it becomes a part of CBNVS. It is possible that names in one blockchain may be in conflict with other blockchains. Therefore, it is better for the design of the system that the local NVS running in parallel with CBNVS will prevent or at least notify users from publishing conflicting records.

### 3.2.6 Name squatting protection

The squatting protection was designed by Namecoin for their NVS system. When the user publishes a name, it becomes available publicly in the mempool before publishing in the blockchain. In PoW, where users can buy priority for the transaction by proposing miners a higher fee, the attacker right after has seen the name in the mempool and can try to push the same name first by proposing a higher fee.
For that reason, Namecoin designed two-step publishing protocol (Namecoin): (1) publish the name hash; then (2) publish the name itself.

In Emercoin, the cue is ordered chronologically, and fees even though are proposed they are burned instead, the miner/minter gets no fee from the user.

CBNVS must be designed in a way to accommodate both models. For blockchains where easy squatting is possible, there must be two steps.

When the squatter is a miner (minter), there is no simple solution. But if the system design does not allow cheating, squatting is just a free-market competition of who registers the name first. It is recommended to use two-step protocol in all cases, propose higher fees, and publish a new name simultaneously in all blockchains of the bunch. This reduces the chances for a squatter to capture the name. Once a new name is published, its capture in further transactions is impossible.

### 3.3 How to chronologize the index

This section discusses the problem of the inaccuracy of time in blockchains compared to each other and astronomical time, the possible consequences of hardforks, and roll-back attacks and variants of the system design to address these issues.

Let us define major issues to address in CBNVS architecture.

A. **Mistiming.** Timestamps in each blockchain are not necessarily accurate to astronomical time. It happens because a node which closes the block includes a timestamp based on its own knowledge of current time, which might be inaccurate. Normally, there are two protocol limits here: a block cannot be earlier than the last block and 2 hours ahead from median time of network peers.

B. **Orphan blocks.** The longest chain of blocks is accepted and shorter is dropped out. Nodes compete for finding new blocks and this kind of fork happens each time whenever any node presents the network a correct longer chain. If not addressed in the design of the system, it will create the problem of a forked CBNVS because nameindex normally is not re-indexing the whole ledger when new block arrives.

C. **Hardfork.** Let us separate retroactive “a rollback” hardfork in another category. The hardfork that is not a result of an attack, but a conscious and willing decision to change the blockchain protocol. The nodes that did not switch to a newer protocol will see compatible blocks with their version. The minority may create their own network. Two versions of the blockchain will have the same history of blocks till the block of the split. After that, users will have the same amount of cryptocurrency in both networks. CBNVS will not know about a parallel network. That is a solution itself though. Nevertheless, it is assumed that the community may wish to include a parallel blockchain. Is an automatic inclusion of a forked network for indexing possible? The solution must address the problem of logic collisions when two records in different blockchains represent the same asset.

D. **Retroactivity.** Even though some DLT systems may be designed to allow retroactivity as a legitimate feature, we assume that the immutability must be preserved as a major advantage. Therefore, we consider a roll-back as a form of attack which can cause a hardfork of CBNVS. The running CBNVS node will not notice that the history changed. The node does not re-index CBNVS from the beginning each time a new block appears. If the record belonged to address A in the original
blockchain, and in the result of retroactivity, it belongs to address B, the nameindex will still contain the record of the entry attached to the address A. At the same time, when a new node is installed or the old node starts re-indexing, it will create a new nameindex file with the name attached to address B. Therefore, new and re-indexed nodes will have a forked version of the database, while old nodes will have the original one.

3.3.1 Assumption of time inaccuracy

Inaccuracy may create some negative user experience. For instance, in one blockchain, the miner finalizes the block with a timestamp +02:12 minutes comparing astronomical time. In another blockchain, the block is closed -00:19 seconds from astronomical. If the same names are published there, they will be accepted only from the second blockchain, even though they are published at the same time. Technically, the second one will be earlier which is compliant with the protocol. See Fig. 2.

Fig. 2. Mistiming of name creation

Publication of the name at the same time can also be an issue. However, even if it happens, the node will compare the time of transactions in blocks and will select the one which is earlier among the blocks.

Time inaccuracy is a natural limit that cannot be resolved in a cross-blockchain index without either centralization or changing the protocol of each blockchain to provide for cross-blockchain time synchronization. Such changes in existing blockchains may become infeasible due to their decentralized nature.

Therefore, it is proposed that time inaccuracy will be the assumption users must accept. Free market competition will demand blockchain communities to provide for better services and UX. Normally, if a name is valuable for the user, the user may wish to send the same name simultaneously for the
registration in all blockchains of the bunch, thus competing with themselves. When one transaction arrives first in one of blockchains, the user may wish to transfer it to that blockchain which they believe fits best for their purposes.

### 3.3.2 Orphan blocks

NVS solves the problem of orphan blocks by pending a few blocks after the name was published. In general, this period is called “confirmations” and it is specific for different consensus, for example, in Bitcoin, 6-blocks period is a reasonable time to reduce the probability of the fork to be acceptable.

Therefore, in CBNVS, each blockchain will have its own pending time and CBNVS is tasked to add names to the cross-blockchain database after the quarantine.

### 3.3.3 Hardforks

Hardforks are different from just orphan blocks due to how they create two sustainable independent networks. One will be the majority and users will typically see this branch of the network. If the minority is organized enough, they may establish a new network. Till the block of the hardfork two networks have the same blockchain history. However, from the next block after the fork, all assets can be independently moved within the new blockchain, thereby, creating a kind of double spending.

To resolve this issue, let us define the scenarios of a hardfork.

1. The majority of nodes do not change the current protocol, only the minority buds off with a new protocol incompatible with the current. In this case, it is not necessary to do anything, the fork will exist for CBNBS as Elusive Joe; unless the community wishes to include it in the bunch.

2. Inclusion of a minor hardfork may happen in the following way. Beforehand the fork miners will put flags in blocks for the future fork, announcing to the community the number of a block from which the fork will happen. The CBNVS protocol detecting the defined threshold of flags (say 10% of nodes) will require the user to explicitly include this blockchain as a new one in the bunch.

3. To resolve the issue of duplicating names, CBNVS will apply the following rule. Until the user does not make any transaction in the bunch, doubled names do not constitute a problem itself, they can exist in parallel at any length of time. The user may decide to transfer the name or update it in any of the blockchains. The transaction which happens first among two blockchains will be accepted in CBNVS, and from that moment any other name transaction in the parallel blockchain will never be accepted by the protocol.

4. In the case when the majority is going to move to another protocol, the community will also use flags. When CBNVS detects that the majority is going to adapt an incompatible protocol, CBNVS will stop indexing the blockchain, and then ask the user for explicit consent for a new version of the blockchain in the bunch. This scenario can be combined with the accommodation of both blockchains described in (2) and (3).

In both cases with flags, CBNVS require a user’s consent, otherwise, CBNVS stops in the user’s machine, thereby preventing CBNBS forking itself.

### 3.3.4 Retroactivity

Retroactivity can cause the reallocation of ownership of NVS records in the blockchain locally, as well as capturing names from other blockchains on the bunch.
There are two specific issues to address:

(1) The node does not know on the run of a deep reorganization of blocks in the blockchain. Technically, this is still a legitimate behaviour. Here, applies the rule of the longest chain of blocks. When it is presented to the network, nodes automatically pick it up replacing the current chain. Because the CBNVS does not normally re-index database, changes in names ownership which happened due to this attack will not be reflected. That might be though as a solution itself; but

(2) When a new CBNVS bundle is installed on the node or the same bundle is re-indexed from the very beginning, the resulting nameindex will reflect changes that have happened due to the attack.

Therefore, in the result of retroactivity, the community will end up with two different versions of a cross-blockchain storage.

Before discussing the possible solutions, let us define the probability of this attack.

The fault tolerance of the bunch is defined by multiplication of probabilities of the attack of all blockchains of the bunch, because the failure of at least one blockchain in the group may lead to the failure of the whole bunch:

\[ P = (1 - (1 - p_1)(1 - p_2)(1 - p_n)) \]

The challenge is the practical part of this evaluation. The simple mathematical expectation of the attack for a bunch can be 0. Therefore, statistical methods may not be helpful.

Thus, we keep this in mind as a theory and for the implementation of any system based on this concept, it will be a good practice to remember that there are no perfect systems and all reasonable measures must be put into consideration.

More important is not the level of resistance to attacks, but the ability of the system to restore after the fault. Thus, let us define some measures that can be designed to address possible retroactivity issues.

In principle, four actions must be taken: (1) the node must detect an attack; (2) the node must detach the fault blockchain from the bunch; (3) a new or re-indexed node, must define that there was an attack and be able to build an uncorrupted nameindex; (4) the node must support the transferability of records from the fault blockchain to any of blockchains in the bunch.

(a) The running node will define retroactivity as a legitimate feature because here applies the rule of the longest chain, it is proposed to add heuristic analyzes at the level of CBNVS. It will keep the state of blockchain headers and compare them to detect changes that happen deeper than a normal reorganization of blocks (orphan forks). For instance, for Bitcoin, the norm will be to change up 6 blocks in depth. For each blockchain, this figure will vary. When CBNVS detects abnormal fork, it defines the depth of the fork by comparing two states of headers and marks the blockchain excluded from this block and continues normal indexing. When an attack is detected, it also recommended to back-up the name index. An automatic backup must happen when a new version with chain of blocks deeper then n-blocks appears in the node. In the result of this step, the running CBNBS node will preserve an original state of nameindex, and will detach the fault blockchain from indexing and will continue working.
(b) To detect corruption when installing a new node or re-indexing there can be used similar to RAID massive, see Fig 3. Existing methods for data storage among multiple drives are relevant to name-value storage. RAID has different methods. For example, in CBNVS with RAID 1 (Jones and Dawkins, 2009), the user will store the name in two or more blockchains. If one blockchain is attacked, when re-indexing the system, the node will detect the collision at some block by analysis of RAID collisions.

(c) The publication of a RAID record must contain the signatures of the [name+challenge] from the parallel blockchain. The pointer to the highest block will help to detect the exact height of the blockchain attack. From this moment CBNVS protocol will detach the blockchain from indexing allowing the possibility to rescue records from the fault blockchain by a transfer to rest in the bunch. Because the probability of a successful attack of two blockchains at the same time is significantly lower, RAID methods may create enough protection. The more redundancy is the lower chances of the fault of CBNVS.

![Fig. 3. RAID 1](image)

4 Why does the cross-blockchain protocol suit governments?

The cross-blockchain protocol allows omitting hardforks, solving the “problem” of immutability and reducing the influence of price volatility. CBNVS does not address issues of scalability (bandwidth and ledger bloat) of any blockchain but instead imposes a market-driven solution. With the proposed protocol, it is possible to improve old fashioned Public Key Infrastructure by building a decentralized ecosystem of trust services for digital identity and property.

4.1 Hardforks

The government plays the role of a keeper of a traditional property registry. In different countries, they may have different names and specialisations (cadastre, land title registry, real estate registry, etc.) but the purpose is the same: to provide certainty in property rights by tracking records of transactions. Also, similar works registries for movable properties (cars, boats, aircraft, etc.), shares, securities and corporate rights.

The use of any decentralized system, including the blockchain, was limited, because it may create issues with registry forking. The solution of having one blockchain and the government will point out which is legitimate, for example, Bitcoin or Bitcoin Cash, Ethereum or Ethereum Classic, is unlikely to be acceptable. Why would anyone use a decentralized system but end-up with the central authority? It also disables competition between blockchains, because it is the only favourable one.

CBNVS solves it by providing a free choice for users. The proposed protocol supports both blockchains after their fork. The same as Schrödinger's cat, the record has a dual nature until the user makes a decision. Having two records is not a legal collision; it becomes so when the user performs
two different transactions with the same record in different blockchains of the bundle. The protocol ensures that a user’s choice is irrevocable. Once it is done, they will not be able to perform a conflicting transaction in the second blockchain. Therefore, hardfork is not a problem anymore.

4.2 Immutability, trusted third parties and governance

Blockchain immutability is considered as one of the major advantages of the blockchain technology. The track of transaction records and inserted data are irrevocable. Since the blockchain was invented, the discussion of its use for state governance is opened, especially towards property registries.

In the previous subsection, we discussed the example when the name-value record represents someone’s property rights, for instance, a land title. CBNVS addresses the issue of credibility because the record itself worth nothing unless there is a certainty that it has legal connection with the real-world asset.

With CBNVS, it is possible to create an ecosystem of trust, where records refer to other records certifying them. For example, Alice publishes a land cadastral CBNVS record. Bob, a town’s clerk, creates his CBNVS record where he certifies that Alice’s record truly represents her land title (see Fig. 4)

![Scheme of trust services](image)

To buy Alice’s land, Charles needs to acquire her CBNVS record (a token). Because Charles trust Bob, his system will read Alice’s CBNVS and will find in this record the reference to Bob’s record and will read Bob’s statement which certifies Alice’s asset. Hence, Charles can trust Alice’s record and make a title deed even without meeting her in person. The parties may do an atomic swap: Alice will send him a title record and Charles will pay cryptocurrency in return.

In this way, any real-world facts can be certified: immovable and movable property, digital identity, fact of life (birth, death, missing, etc.), contracts, for instance, acknowledgement by a notary public (for civil law countries), facts of some events (force majeure, etc.). See Fig. 5.
Obviously, it is impossible to completely get rid of trusted third parties at least at this level of science and technology. Trust records address the problem of credibility. An intermediary is a “necessary evil,” especially in the world of growing digitalization and remote relationships. Without commercial intermediaries and governments, relations would have looked like scenes from gangster movies where the seller and the buyer need to meet personally and show each other the money and the product to make a deal. The progress required more effective economic forms. According to Potts et al (MacDonald et al., 2016), the current U.S. GPD consists of 33% of services produced by intermediaries.

In the proposed scheme, if Alice lost her private key, she cannot sell her property anymore. She may ask Bob to update his record specifying that Alice’s record is not valid anymore.

Similar to a conventional Public Key Infrastructure (PKI), CBNVS can be used to create certificates of digital identity. At the state level, there can be a root record, so to create a system of multilevel hierarchical trust records. For example, if Alice’s and Bob’s keys are compromised at the same time, Bob’s upper validator will mark his record invalid, and so on, going up to the root record if needed.

The scheme also accommodates two/multi factor authorization (2FA/MFA) and hardware devices for signing transactions. For 2FA/MFA, Alice will ask a trusted third party to send her a ‘challenge’ (secret phrase) using a closed trusted channel, which she will sign and include in the transaction as a proof, provided that the trust provider at the same time will publish the hash of the secret in his CBNVS. To protect private key from a theft, Alice will use a hardware wallet. For example, in the

---

5 This is one of many possible 2FA/MFA protocols as an example.
EU, such a level of protection is necessary to have a non-reputable\textsuperscript{6} Qualified Electronic Signature, as per eIDAS regulation (Trust Services and eID).

The government may hold a “root” of trust, the record which is used to sign certificates of trusted third parties. Such identity and trust services, even though require third parties, are not necessarily highly centralized. The scheme can accommodate a free market of services.

As opposite to single root record, there can be multiple root records and self-signed certificates of multiple third parties, where Alice as an end-user decides whom she trusts creating her own white list of credible entities, including government root, commercial providers, or even her own circle, similar to the concept of “web of trust” (Heinrich, 2005): Alice trusts Bob, but does not know Charles, Bob trusts Charles, therefore, Alice trusts Charles. See Fig. 6.

![Multiple TSP providers](image)

**Fig. 6.** Multiple TSP providers

The source of truth in the sequence of published name-value records where the latest record represents the latest state of affairs (valid, invalid, revoked, compromised, stolen, etc.). This is the first level of overcoming the immutability where the blockchain plays an important role because none record can be voluntarily altered or erased and all the history of transfers is preserved.

However, what if the root is compromised? To address this issue, NVS will use patches.

NVS output mechanism can be considered as a filter. In the discussion above, we proposed “timestamp” as the main rule for filtering records. NVS ignores repeating name records, adding to nameindex only first found unique names and then tracks updates to these records.

If we look to any jurisdiction as a kind of filter, the laws will be these filtering rules. What we normally call “legal” (as per the law) is not filtered in the system and shown in the database. In this way, legal norms and procedures can be digitized and applied to transactions.

\textsuperscript{6} A signature for which the signatory cannot deny that they are the originator of such a signature (as per eIDAS regulation in the EU).

This is a provisional file, not the final typeset article
CBNVS can be designed with the initial set of specific rules, let us call it a “smart law”, to exclude some records or a group of records, and algorithms under which records can be re-assigned.

If the root record is compromised, the reset of trust is inevitable. For that purpose a patch to CBNVS will make the system to ignore compromised record and refer to a new root. The patch will be published in one of the proposed scenarios:

- Distributed (social consensus) – users will arbitrarily install the patch;
- Centralized – the patch is published as NVS record from the trusted address (or addresses), initially provided in the system, the patch automatically is recognized as authorized instructions and installed by the system;
- De-centralized – patch NVS is initially created in the system, with a blank Value, and controlled by a multisignature scheme. A user’s system accepts updates of the field Value where patches are published.

The combination of these methods may create better UX.

Also, many other cases are possible in a “smart law”. For instance, Alice passed by and Charles has the right to inherit her record. When Alice designed her “smart will,” she could not know which notary would fulfil her will, even if she specifies all licensed notaries in the country, by the time of her death, it might appear that the smart will cannot be executed by a notary because the list is invalid anymore, for example, because of the root reset, so none notary has access to trigger the inheritance.

In a traditional “paper” bureaucracy, Charles will apply to any notary to issue a record of inheritance that grants him Alice’s title right, the only thing that matters here is that, by the time of application he has to choose one of the existing authorized notaries.

Even if Alice designed her will to perform execution in an automatic way without any notary, this similar issue will still arise. Who will certify her death to trigger self-execution of the will?

Even if Alice assigns a redundant list of trusted third parties which has such authorization, they may still have legal issues that will lead to impossibility to run the will successfully without the violation of someone’s rights. For example, if Alice leaves everything to Bob, Charles may appear and claim that his rights are violated. If the parties do not come to a mutual agreement in the dispute, normally Charles has a right to bring it to a court. How and who will enforce justice in such a system? And finally, if Alice did not leave any will, therefore, someone must apply general norms of inheritance law.

Hence, the need for authorities, i.e. lists of authorized addresses (notaries, judges, clerks, etc.) and the procedures.

The blockchain can be used to improve and automate bureaucracy. Procedures can be designed in a more transparent and accountable way. Such automation can be done using, of course, closed centralized systems that are widely used by governments nowadays, the difference is that the blockchain provides a decentralized infrastructure. In centralized system, there will be someone who

---

7 Redundancy is not the best option. If too many people have access to her asset, it may decrease the security.
controls it being a single point of failure. In blockchain, even if some applications are designed in a
centralized fashion, it can be decentralized step-by-step in the future what is impossible in a
centralized system.

The system of governance has two elements: the “government” which is the list of addresses of
public bodies and “smart laws” which are algorithms that define how the government may act.

Government addresses according to their authorization may perform some actions in the CBNVS
filtering system. For example, the judicial system is in charge of issuing individual patches for
records in disputes. If Bob illegally seized Alice’s NVS record, the court will issue and disseminate a
patch in the system according to which this transaction is ignored, and therefore, “nameindex” will
show that Alice still owns this record, based on the previous valid transaction.

Patches are disseminated among CBNVS nodes through blockchain transactions; the authority
publishes specific NVS records, providing rules for nodes for reallocation of NVS records. Each
node in the network hooks such records, verifies if these records arrived from any authorized address
and apply to the current state of the cross-blockchain database. This allows addressing all possible
issues of the blockchain immutability: lost keys, deaths, hardfork doublings, contract breaches and
misappropriations.

This kind of scenario requires a certain level of centralization. Nevertheless, we can consider
CBNVS as a sort of public consensus, a social agreement, since each user voluntarily decides to use
this system on their own and also agree with this. If they trust the government, they can apply these
algorithms.

The proposed voluntary model may not be scalable; it will probably work in small communities. The
system may adopt more structured forms of scaled governance, through electronic voting on the
blockchain. Let us leave this issue for further research and development since the purpose of this
research is to introduce a cross-blockchain database; forms of governance should be developed
according to the political system where CBNVS is applied.

4.3 Price volatility and scalability

These two issues appeared in one discussion because a single solution is proposed. CBNVS is a
mechanism that supports free-market competition, and this is the key answer. Oftentimes, the issue of
bandwidth is considered as the problem of a standalone blockchain. One blockchain is compared to
one centralized system, for example Bitcoin (Ethereum, Tron, etc.) vs. Visa (MasterCard, American
Express, etc.). Readers may find figures that any of the named centralized systems can process up to
100 times more transactions per minute.

There are at least two typical fallacies found in discussions on scalability. First, centralized payment
systems can accept up 20,000 payments per minute, but they do not settle that amount of
transactions. It can take up to 3 days to handle that cue. This system is centralized and transactions
are reversible, any mistakes and balance deviation can be manually fixed (Payment, clearing and
settlement systems in the CPSS countries (“The Red Book”), Volume 1 - CPSS - August 2011,
2011). The blockchain instead provides immutable certainty in some reasonable time and does not
require intermediary, i.e. transactions are peer-to-peer. These systems provide for different UX and
hardly can be compared. Moreover, some third-party solutions can provide for instant transactions as
an added layer on a blockchain, for example, based on the technology of the Lighting Network
(Lightning Network).
The second inaccuracy is the comparison “one versus one”. The bandwidth of blockchain can and should be evaluated in a bunch.

A cryptocurrency is used in speculative purposes and in payments. Blockchain limits user experience in two things: (1) the speed of the transactions, from a few seconds to 10 minutes to wait for the finalization of a transaction, plus 1 hour for 6-block confirmations, and (2) the bandwidth, for example, Bitcoin has 1 Mb per block, and therefore, when too many transactions are coming in one moment, they are queued, which then extends the waiting period. Users may jump up into the queue since many blockchains support the priority of higher fees.

The real power of competition is that the user may choose another blockchain for payments and speculations. The buyer which sells products for only one cryptocurrency does gain the advantage on the market. Between two similar products of different sellers on the market, the seller who offers the product for multiple cryptocurrencies has more chances of being chosen. What is the principle difference for the seller to get 1 BTC for the product which she will immediately convert into 10,000 USD or 50 ETH which are convertible to the same amount of money? For speculations, investors will be choosing those cryptocurrencies that are more in use driving the price of these coins. Thus, all these market levers create an effective cryptoeconomics. Even the first dozen of the blockchain list on Coinmarketplace.com in total gives an incomparable bandwidth to any centralized technology.

Therefore, the answer to which blockchain the government should choose is none. Instead, the government should support a cross-blockchain protocol which enables a unified ecosystem of blockchain technologies, and each user decides which technology to choose.

4.4 Privacy issues: where to store personal data?

The use of public blockchains raises questions about privacy. It is impossible to fully convert the cadastral register into the open database if it contains personal data. Obviously, the blockchain cannot be used to publish any personal data in an open format.

The first approach is now generally accepted: the state stores personal data in closed centralized systems. This model can be used in the proposed protocol.

The second approach is to store data in an "inverted" manner. The government does not store any personal information at all, but only digital fingerprints (hash sums, encrypted data, salted hashes, etc.). The keeper of personal data is the owner of this data with their devices as carriers. For example, a smart card may contain all personal data, but that does not mean that its full copy should be stored somewhere on a state agency server.

The scientific community is actively developing such protocols. For example, the W3C offers the concept of Decentralized Identifiers (DID). It would be appropriate as an example to consider the project proposed by the developer M. Tiutin, who in 2018 at the EOS hackathon presented a model for storing personal data by a user with partial disclosure using the Merkle tree, where the leaves are hashes of personal data and the root (or multiple roots) is certified by an authorized person (state bodies, institutions, etc.) (Konashevych, 2019). Such a model may solve the problem of personal data disclosure.

_________________________

As of September 2019, https://coinmarketcap.com
The incorrect design of the system, say, of the same ID card leads to the fact that at the time of the request the entire amount of personal data may be disclosed to the interested person. But in many cases, both from a practical point of view and from the point of view of the law, not all personal data of a person is required, but only a part. In some cases, it is possible to use zero-knowledge protocols, when the data is not disclosed at all, but only cryptographic evidence of the correctness/existence of the fact is presented.

For example, to check the right to buy alcohol at the store, the law does not require the seller to know the name, personal number, etc. of the buyer, moreover, it is not even necessary to know their date of birth. From the point of view of designing an electronic system, it is a Boolean variable (*Older than 21? Yes/No*), where it is sufficient for the system to return 0 or 1 to satisfy the requirements of the law.

Thus, the storage architecture in the form of a Merkle tree will allow one of the leaves (each leaf is a separate part of personal data: name, surname, photo, date of birth, etc.) and the root that is signed by a trusted third party. So, the blockchain in this scheme plays the role of a public repository, where hashes, roots, and signatures are securely stored. And users present personal data from their local devices as evidence. See Fig 7.

![Diagram of a Decentralized Identifier (DID) on the blockchain](image-url)

**Fig. 7.** Scheme of a Decentralized Identifier (DID) on the blockchain

The largest companies and government agencies lose personal data from time to time. Storing data on centralized servers inevitably leads to leaks. For example, in September 2019, a database with the names, phone numbers and other information of about half a million Facebook accounts appeared on the Internet (A huge database of Facebook users’ phone numbers found online | TechCrunch, 2019). Assuming that the data of active users (Facebook’s grew its monthly average users in Q1 - Business Insider, 2019) is stolen (who needs to steal outdated accounts?), this means that the leak touched 17% accounts of the social network.
The model in which users store their data locally, without transferring it to centralized databases, has the advantage that it is much more difficult to hack half a million devices than one server with half a million accounts.

4.5 Use cases

The cross-blockchain protocol is very flexible technology. There can be designed one single cross-blockchain protocol for general purposes. But also, possible to create multiple customized databases for different applications: decentralized DNS system, property registry, Public Key Infrastructure, etc.

There also can be localized databases which are dedicated to a territory/community of its application.

The CBNVS for the government as a more centralized option may have in the bunch also permissioned DLTs or even provide for an API for closed government databases to develop a hybrid system. For example, a government agency may have its permissioned DLT for the registrar office. Clerks will issue certificates in this DLT to certify land titles which users arbitrary issue on any blockchain in the bunch. The user’s record will refer to clerk's record in the permissioned DLT.

5 Conclusions

The cross-blockchain protocol is a set of tools to build an indexed database across multiple blockchains. The technology makes possible to set up an initial bunch of blockchains and hook “key-value” entries from upcoming blocks. It is proposed a mechanism for adding new blockchains in the bunch where newly added blockchain is indexed from the current block. The protocol supports detaching a blockchain in case of an attack or decrease of reliability and such algorithms must be designed when a Cross-Blockchain Name-Value Storage is set up. Reliability and attacks are self-diagnosed by nodes independently based on heuristic analysis of hash rate, difficulty and abnormal orphan length. When threats are detected indexing of this blockchain is stopped and users may transfer the record to the rest in the bunch. Also, transferability of records among blockchains in the bunch works as a regular feature, which supports competition between technologies ensuring a free choice of a repository for end users.

The core of the system is name-value storage indexed through the bunch of blockchains. The uniqueness of keys (“names”) in the database is ruled by chronology. A name record which is published first among blockchains is added to the database. Subsequent entries with the same names are not passed.

Name-Value records are a raw material for building applications. They are assigned to addresses and controlled by users through the native mechanism of private keys. Users may change Name records inserting in the blockchain updated information and commands with transactions, i.e. change Value, Lease Time, Delete record from the database or transfer the record to another address.

The advantage of the protocol is that normally, it does not require changing blockchains, it is set up as an overlaid technology. The inserted data is recognized and hooked from blocks if it corresponds with the standard format. The platforms with extensive programming languages for smart contracts can be applied by developing the smart contract which introduces standard algorithms of the protocol. And the level of such blockchain the transactions can be performed within the developed smart contract and provide the resulting state of the token (“name”) and its attached information (“value”) to the cross-blockchain storage of the bunch.
The proposed technology addresses issues of the scalability, price volatility, hardforks and immutability, which discourage governments from the use of the blockchain, giving preferences to centralized frameworks, so-called “permissioned DLTs”.

The protocol can be used by governments to maintain public registries, for example, property (cadaster) databases. Users may own records which represent property rights (titles), providing references to trusted third parties which certified these rights. In the same way can be improved a traditional Public Key Infrastructure, where Certificate Authorities (Trust Service Providers) issue certificates to digital identities. The protocol can also accommodate more strict rules of IDs and electronic signatures for example as per eIDAS regulation in the EU, providing users to manage their private keys on secure devices (hardware wallets) and 2F/MF authentication protocols.

Such an ecosystem addresses issues of trust at the first level: each record has its trust provider which rectifies its validity. The access to the record is lost; the trust provider marks in their record that user’s record is invalid. To reset the provider’s record in case it is compromised and to reset the root record it is proposed to initiate a mechanism in CBNVS under which it is possible to issue patches.

The aim of the patch in a cross-blockchain protocol is to provide for the node a command which name record became invalid and which record is the right one. Such patches being published by authorised addresses are hooked by nodes in the network and applied to provide that every node has the same state of the database.

Such filters, authorised addresses, algorithms how they are introduced, run and updated constitute the “smart law” of a cross-blockchain database. The smart law can work in a democratic and decentralized way by electronic voting on the blockchain, which is a matter of the political system where it is introduced.

The protocol can be used to build a general database for any names, a customized nameindex for specific types of names and also can be localized, i.e. been in use by specific community, country, etc.

6 Annex

Name-Value Storage (NVS) is invented by Namecoin for decentralized Domain Name System (DNS) and then improved by Emercoin for publishing “key-value” entries in the database supported by API which simplify developing of applications. The data is published in the blockchain using OP_DROP command.

NVS service consists of two basic I/O elements:

(1) Publishing data. Tools for publishing data that are aimed to create transactions based on the standard. The moment the data is inserted into the blockchain, the wallet adds a record in “nameindex” file, which is a database table and

(2) Retrieving data. Tools for retrieving data from “nameindex” (Barkley DB).

The service works as follows. By using the command “NAME_NEW” and further mentioned parameters, the user creates a blockchain transaction. In the transaction, the user adds arbitrary data filing fields Name and Value. The transaction can be created using a standard user wallet interface or via API.
The service includes the following elements:

- **NAME** is the field to store 512 Bytes of the user’s data. When transaction is published the protocol verifies if the NAME is unique in NVS; NAME is a search key.
- **VALUE** is 20 Kilobytes limited field to store any user’s data connected with the relevant NAME.
- **LEASE_TIME** is the period when the NVS record is valid and maintained under the control of the user’s address; records are permanently stored in the database of the blockchain, even beyond lease time. When the period is over anyone can create the record with the same NAME.
- **PREFIX/SUFFIX** are service abbreviations added to before and after NAME, i.e. “prefix:name:suffix”. Abbreviations extend the usability of records of the same type: EmerDNS, EmerDPO, EmerSSH, EmerSSL, etc. [20]
- **NEW ADDRESS**, if blank, the system puts the user’s address by default. The user may specify any address, including one which does not belong to them, if they want to grant the NVS record to someone else.

The difference between the Namecoin (PoW) and Emercoin (PoW+PoS) of NVS protocol is that Namecoin, requires an initial transaction, when the user first publishes the hash of the name. Then the user creates the second command Name_FirstUpdate, they publish the name-value entry. This step is required to prevent squatting of names. Namecoin has a competitive rule for transactions, so user can “buy” a priority in the cue of transactions in the mempool by proposing a higher fee to miners. Therefore, names become available when appeared in the mempool. An attacker after see the name in the mempool may try to publish the transaction with the same name first by proposing a higher fee. There is no problem of name squatting in Emercoin because the cue of transactions is chronological.

In Emercoin, fees in cryptocurrency for the transaction is calculated depending on the volume of attached data, lease time, and difficulty level in the network, as per the formula, for details see Emercoin documentation (Emercoin NVS - Emercoin Community Documentation). The fee is “burnt,” i.e., becomes unrecoverable.

When fields are completed and submitted by the user, the system calculates the fee and after the user’s confirmation sends it to the blockchain with the OP_DROP script.

The owner can update the record by publishing a new record with the same NAME with changed VALUE, LEASE_TIME (extend or reduce) and ADDRESS (transfer the record to a new address) using the command NAME_UPDATE. In this case, the system creates a new blockchain transaction as described above, but with new details. Therefore, nothing happens with the previous record. It always stays on the blockchain, but the NVS service is built in a way to show the latest NVS records, while the history of all records is still available.

There is also a command that terminates LEASE TIME of the NVS record, which is called “NAME_DELETE”. When this is used, it is not shown in the list of valid records anymore, and it is not controlled by the users’ address either.

NVS technology is used to develop applications that require permanent repositories. For example, decentralized SSL, SSH, DNS, etc. In DNS, the user publishes a record in the following format: Name = dns:domainname.coin, Value = NS record (A, CNAME, AAA, TXT and). The user may
include in Value a list of authorized subdomains ([Subdomain1|Subdomain2|…]). Therefore, squatting of subdomains is impossible. If any user publishes a subdomain that is not included in the list of the higher level domain records, the system just ignores this record. This is an example of how algorithms working as filters make it possible to have a decentralized governance of the system.

7 Acknowledgement

This paper is an outcome of the PhD research performed inside of the Joint International Doctoral (Ph.D.) Degree in Law, Science and Technology, coordinated by the University of Bologna, CIRSFID in cooperation with University of Turin, Universitat Autònoma de Barcelona, Tilburg University, Mykolas Romeris University, The University of Luxembourg. Thanks to supervisors of Oleksii Konashevych Professor Marta Poblet Balcell, RMIT University (Melbourne, Australia) and Professor Pompeu Casanovas Romeu, La Trobe University (Melbourne, Australia).

Thanks to Oleg Khovayko (CTO Emercoin, US) and Denis Dmitriev (CTO Emertech, Hongkong) who took active part in the discussion of the cross-blockchain protocol, provided their valuable advice. Oleg Khovayko shared his ideas of redundancy of cross-blockchain records, Denis Dmitriev suggested cross references for records and helped with the analysis of a fault probability of the cross-blockchain system.

8 References

A huge database of Facebook users’ phone numbers found online | TechCrunch (2019). TechCrunch. Available at: https://techcrunch.com/2019/09/04/facebook-phone-numbers-exposed/ [Accessed September 25, 2019].

Androulaki, E., Karame, G. O., Roeschlin, M., Scherer, T., and Capkun, S. (2013). Evaluating user privacy in Bitcoin. in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 596. doi:10.1007/978-3-642-39884-1_4.

Blockchain and Distributed Ledger | J.P. Morgan Available at: https://www.jpmorgan.com/global/blockchain [Accessed August 21, 2019].

Breitinger, C., and Gipp, B. VirtualPatent -Enabling the Traceability of Ideas Shared Online using Decentralized Trusted Timestamping. Available at: https://www.gipp.com/wp-content/papercite-data/pdf/breitinger2017.pdf [Accessed June 30, 2018].

Buldas, A., and Saarepera, M. (2004). On Provably Secure Time-Stamping Schemes. Adv. Cryptol. - ASIACRYPT 2004 3329, 500–514. doi:10.1007/978-3-540-30539-2_35.

Colored-Coins/Colored-Coins-Protocol-Specification: Colu Colored Coins Protocol Available at: https://github.com/Colored-Coins/Colored-Coins-Protocol-Specification/ [Accessed September 23, 2019].

Cost of a 51% Attack for Different Cryptocurrencies | Crypto51 Available at: https://www.crypto51.app/?fbclid=IwAR15KMMvqM6SydcPJ7c3XfZjMatogrp584ZfkswH8jDJ2xyAgFgulPeuC0I [Accessed September 16, 2019].

Crespo, S. D. P. A., and Luis García Cuende, I. (2016). Stampery Blockchain Timestamping
Data.gov.ua Available at: https://data.gov.ua/ [Accessed September 16, 2019].

Emercoin Available at: https://emercoin.com/ [Accessed November 10, 2017].

Emercoin NVS - Emercoin Community Documentation Available at: https://emercoin.com/en/documentation/blockchain-services/emernvs [Accessed June 28, 2018].

Ethereum Wiki (2017). Available at: https://github.com/ethereum/wiki/wiki/Glossary [Accessed July 4, 2017].

Facebook’s grew its monthly average users in Q1 - Business Insider (2019). Bus. Insid. Available at: https://www.businessinsider.com/facebook-grew-monthly-average-users-in-q1-2019-4/?r=AU&IR=T [Accessed September 25, 2019].

Gao, Y., and Nobuhara, H. (2017). A Decentralized Trusted Timestamping Based on Blockchains. IEEJ J. Ind. Appl. 6, 252–257. doi:10.1541/ieejjia.6.252.

Gipp, B., Meuschke, N., and Gernandt, A. (2015). Decentralized Trusted Timestamping using the Crypto Currency Bitcoin. in iConference 2015 Proceedings (iSchools). Available at: http://hdl.handle.net/2142/73770 [Accessed June 30, 2018].

Heinrich, C. (2005). “Pretty Good Privacy (PGP),” in Encyclopedia of Cryptography and Security (Springer US), 466–470. doi:10.1007/0-387-23483-7_310.

Jones, A., and Dawkins, B. (2009). Common RAID Disk Data Format Specification. 1–126. Available at: https://www.snia.org/sites/default/files/SNIA_DDF_Technical_Position_v2.0.pdf.

Konashevych, O. (2019). Will Blockchain Stop Personal Data Leaks? | Cointelegraph. Cointelegraph. Available at: https://cointelegraph.com/news/will-blockchain-stop-personal-data-leaks [Accessed September 17, 2019].

Lightning Network Available at: https://lightning.network/ [Accessed September 25, 2019].

Loibl, A. (2014). Namecoin. doi:10.2313/NET-2014-08-1_14.

MacDonald, T. J., Allen, D. W. E., and Potts, J. (2016). Blockchains and the boundaries of self-organized economies: Predictions for the future of banking. New Econ. Wind. doi:10.1007/978-3-319-42448-4_14.

Mining - ethereum/wiki Wiki Available at: https://github.com/ethereum/wiki/wiki/Mining [Accessed September 2, 2019].

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. 9. doi:10.1007/s10838-008-9062-0.

Namecoin Available at: https://namecoin.org/ [Accessed September 5, 2018].

NEM – Distributed Ledger Technology (Blockchain) Available at: https://nem.io/ [Accessed September 25, 2019].
Nxt - The Blockchain Application Platform Available at: https://nxt.org [Accessed January 26, 2017].

Ober, M., Katzenbeisser, S., and Hamacher, K. (2013). Structure and Anonymity of the Bitcoin Transaction Graph. *Futur. Internet* 5, 237–250. doi:10.3390/fi5020237.

Official IDE/ATA Standards and Feature Sets (2001). *PC Guid.* Available at: http://209.68.14.80/ref/hdd/it/ide/std.htm [Accessed September 25, 2019].

Payment, clearing and settlement systems in the CPSS countries (“The Red Book”), Volume 1 - CPSS - August 2011 (2011). Available at: https://www.bis.org/cpmi/publ/d97.pdf.

Roio, D. J. (2013). Bitcoin, the end of the Taboo on Money. *Dyne.org Digit. Press*, 1–17. Available at: https://files.dyne.org/readers/Bitcoin_end_of_taboo_on_money.pdf.

Sward, A., Vecna, I., and Stonedahl, F. (2018). Data Insertion in Bitcoin’s Blockchain. *Ledger* 3, 1–23. doi:10.5195/LEDGER.2018.101.

Trust Services and eID Available at: https://ec.europa.eu/digital-single-market/en/policies/trust-services-and-eidentification [Accessed January 19, 2018].