BLOCKCHAIN BASED TRANSFORMATION IN GOVERNMENT: REVIEW OF CASE STUDIES

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ABSTRACT

Blockchains are immutable digital ledger systems implemented in a distributed way and usually without a central authority. Each transaction in the public ledger is verified by consensus of a majority of the participants in the system. Once entered, information can never be erased. The blockchain contains a certain and verifiable record of every single transaction ever made. It operates in a decentralized peer-to-peer network using cryptographic algorithms to verify, validate and distribute transactions across millions of nodes, enabling the secure, auditable, transmission of assets without intervention by a central authority.

The economic, political, humanitarian, and legal system started realizing the benefits of Bitcoin and blockchain technology and the fact that this is potentially an extremely powerful technology that could have the capacity to modify many aspects of society and its operations.

This document provides a short, high-level technical overview of the blockchain technology. It provides a review of application beyond crypto-currencies and financial applications through use cases in government and public services.

KEYWORDS: Blockchain, distributed systems, eGovernment, digital transformation.

I. INTRODUCTION

New technologies revolutionize business from every direction. Digital transformation is not a technological trend, but a pattern created by customer experience. Businesses are developing because customer expectations are developing. Digital revolutions over the past thirty years brought significant changes in all fields of economic activity, and the banking industry is no exception. The banking sector tends to keep in line with the modern technological trends, the trends of having easily accessible and secure Internet applications, the increased number of smart devices and changes in the consumer culture of the society. However, new technologies set the digital transformation course with the speed of customer experience [1]. In the last ten years a new technology, which has so far mostly affected the financial sector (since it was initially applied to digital cash) and is moving the course of how traditional banking is done, got into the focus in many organizations and governments. Numerous applications of blockchain technology are primarily oriented around the movement of cryptocurrencies from one account to another. However, blockchains have recently attracted the interest of stakeholders across different industries: from finance and healthcare to utilities, real estate, and the government sector [6][15][17]. The reason for this explosion of interest is that with a blockchain in place, applications that could previously run only through a trusted intermediary can now operate in a decentralized manner, without the need for a third party, and achieve the same functionality with the same amount of certainty. This was simply not possible before.

In this paper we look at the blockchain technology and we provide a detailed description of the main components, we explain the concept and the main principles, describe how blockchains and smart contracts work, explore some specific blockchain applications, look at the benefits, challenges and business opportunities in possible use of this fundamental technology across several industries and point out the potential to revolutionize our digital world with focus on public and governmental services.

II. BLOCKCHAIN COMPONENTS AND OPERATION

The blockchain is a distributed digital ledger of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one, after validation and making a consensual decision. As new blocks are added, older blocks become more difficult to change. New blocks are replicated across all the copies of the main book on the network, and all conflicts are resolved automatically using the established rules [3]. The blockchain is a distributed database that contains the transaction history of each asset (i.e., Bitcoin) in the chain and provides proof of who owns it at any given moment. This distributed general ledger is replicated to thousands of computer nodes around the world and is publicly available. Despite all its openness, it is also confidential and reliable. This is achieved through mathematical subtilty and computer power embedded in its "consensus mechanism" - the process in which the nodes agree on how to update the blockchain with each transaction of moving the value from one person to another. Users use public and private keys to digital sign and make transactions in the system in a secure way. Blockchain users can solve puzzles using cryptographic hashing methods hoping to be rewarded with a fixed amount of cryptocurrency [4][5].

Blockchain systems seem complex; however, they can be easily understood by examining each technology component individually. At a high level, blockchains utilize well-known computer science mechanisms (linked lists, distributed networking) as well as cryptographic primitives (hashing, digital signatures, public/private keys) mixed with financial concepts (such as ledgers) [2][3].

A **ledger** is a collection of transactions. Ledgers are often stored digitally in large databases owned and operated solely by centralized "trusted" third parties however we must trust the third party that the data is backed up, transactions are validated and complete, and the history is not altered. A ledger implemented using a blockchain can mitigate these issues through the use of a distributed consensus method. One of the aspects is that the blockchain ledger will be copied and distributed amongst every node within the system. When new transactions are submitted to a node, the rest of the network is alerted that a new transaction has arrived and at this point, this is a pending transaction. Eventually, one of the nodes will include this new transaction within a block and complete the system's required consensus method. This new block will be distributed across the network and all ledgers will be updated to include the new transaction. When new users join the system, they receive a full copy of the blockchain, making loss or destruction of the ledger difficult.

Each transaction that is submitted to the network passes through several steps to be included and published in a block of the blockchain:

1) For each input transaction A, an output hash value #A is created using a cryptographic function.

A **transaction** is a record of a transfer of assets (digital currency, units of inventory, etc.) between involved parties. As a comparison, this is analog to a record in a current account each time when money was deposited or withdrawn.

Hashing is a method of calculating a relatively unique fixed-size output for an input of nearly any size (e.g., a file, some text, or an image). Even the smallest change of input will result in a completely different output digest. Hash algorithms are designed to be one-way: it is computationally infeasible to find any input that maps to any pre-specified output. If a particular output is desired, many inputs must be tried by passing them through the hash function until an input is found that gives the desired result. Moreover, hash algorithms are designed to be collision resistant: it is computationally infeasible to find two or more inputs that produce the same output. A commonly used hashing algorithm in many blockchain technologies is the Secure Hash Algorithm (SHA) with an output size of 256 bits (SHA-256).

2) Transactions are grouped in sets and each block in a blockchain contains multiple transactions.
3) Hash values are further combined in a system called Merkle tree.

A **Merkle tree** is a data structure where the data is hashed and combined until there is a singular root hash that represents the entire structure. The root is an efficient mechanism used to sum up the transactions in a block and verify the presence of a transaction within a block. This structure ensures that the data sent in a distributed network is valid since any alteration to the underlying data would be detected and can be discarded.

4) The result of all the hashing then goes into the block's header, and it is combined with the hash of the previous block's header and a timestamp. This combination becomes a part of the cryptographic puzzle. The solution for the puzzle is to find a nonce value.

Nonce value is a number manipulated by the mining node to solve the hash puzzle and with this, it gives them the right to publish the block. After creation, each block is hashed thereby creating a digest that represents the block. The change of even a single bit in the block would completely change the hash value. The block's hash digest is used to help protect the block from change since all nodes will have a copy of the block's hash and can then check to make sure that the block has not been changed.

An additional feature of blockchain systems is that they can run so-called **smart contracts** [12] which is an auto-executable code that fires off once certain conditions are met. A smart contract is computer protocol or collection of code and data which runs automatically under defined criteria when deployed on the blockchain. The contract executes the appropriate method with the user provided data to perform a service. The code, being on the blockchain, is immutable and therefore can be used (among other purposes) as a trusted third party for financial transactions that are more complex than simply sending funds between accounts. A smart contract can perform calculations, store information, and automatically send funds to other accounts. It doesn't necessarily even have to perform a financial function.

When a user connects a blockchain system, the user agrees to the initial state of the system. This initial state of the system is recorded in the only pre-configured block, the genesis block. Every blockchain has a published genesis block, and every new block is added to the blockchain after it, based on an agreed-upon consensus method. Each block must be valid and therefore can be validated independently by each user in the blockchain network. By combining these two points: the initial state of the system and the ability to verify every block, the users can agree on the current state of the blockchain.

Users interact with the blockchain via a pair of a private/public key. They are addressable on the network via their public key, and they use their private key to sign their own transactions. The public key may be made public without reducing the security of the process, but the private key must remain secret so that the data is cryptographically protected. Even though the two keys are mathematically related to each other, the private key cannot efficiently be determined based on knowledge of the public key. The use of asymmetric cryptography brings authentication, integrity, and nonrepudiation into the network.

Mining is the process when the transactions that have been collected and validated by the network using the process above during an agreed-upon time interval are ordered and packaged into a timestamped candidate block. The distributed transactions then wait in a queue, or transaction pool, until they are added to the blockchain by a mining node. Mining nodes are the subset of network nodes that maintain the blockchain by publishing new blocks. A transaction is added to the blockchain when a mining node publishes a block. To add a new block to the blockchain, all participating nodes must come to a common agreement (consensus). One such consensus model is **Poof of Work Consensus Model (PoW),** which is designed for the case where there is little to no trust amongst users of the system. In this model, a user gets the right to publish the next block by solving a computationally intensive puzzle. An important aspect of this model is that the past work put into a puzzle does not influence one's likelihood of solving future puzzles. There is no shortcut to this process; mining nodes must complete the work which requires that they expend computation effort, time, and resources to find the correct nonce value for the target.

The solution to the puzzle is the "proof" they have performed work. The puzzle is designed such that solving the puzzle is difficult but checking that a solution is valid is easy. This enables all other mining nodes to validate any proposed next blocks easily, and any proposed block that did not satisfy the puzzle would be rejected. A typical puzzle method is to require that the hash of the block be less than a particular value. Mining nodes then make many small changes to the block (the nonce) trying to find a block hash that meets the requirement. For each attempt, the mining node must compute the hash for the entire block header, which is a computationally intensive process. The required value may be modified over time to adjust the difficulty to influence how often blocks are being published. For example, Bitcoin, which uses the proof of work model, changes the puzzle difficulty every two weeks to affect the block publication rate to be around once every ten minutes.

Once a user has performed the work, they send their block with a valid nonce to the other nodes in the network. The neighbor nodes make sure this incoming transaction is valid before relaying it any further; invalid transactions are discarded. This means that when a user receives a completed block from another user, they are forced to include the new block because they know the other mining nodes will include it and start building off it. If they refuse to accept the new block, they will be building off a shorter chain of blocks, and by design, the longest valid chain is adopted. Note that a fork may still happen on the network when two competing nodes mine blocks almost simultaneously. Such forks are usually resolved automatically by the next block; the proof-of-work mechanism dictates that the nodes should adopt the fork that carries the greatest amount of work, and it is unlikely that the two competing forks will generate the next block simultaneously. Whichever fork grows longer first will be used to build on by the nodes as the correct one. This enables the network to reach consensus on the proper order of events again.

The recipient nodes verify that this work was done correctly, add the block to their copy of the blockchain, and resend the block to their peer nodes. Validity is ensured by checking that the providers of funds in each transaction (listed in the transaction's 'input' values) have each cryptographically signed the transaction. This verifies that the providers of funds for a transaction had access to the private key which could sign over the available funds. Verification of the nonce is easy since only a single hash needs to be done to check to see if it solves the puzzle. The other mining nodes will check the validity of all transactions in a published block and will not accept a block if it contains any invalid transactions. In this manner, the new block gets quickly distributed throughout the network of participating nodes.

However, a downside of the proof of work consensus model is its excessive use of energy in solving the puzzles, and this is not trivial. For example, currently the Bitcoin blockchain uses more electricity than the whole country of Ireland, and it is assumed that it will consume as much electricity as the whole country of Denmark by 2020 [11]. Software and hardware continually improve, with the result that puzzles can be solved more efficiently, but blockchain networks are growing, and the puzzle targets get harder as more mining nodes participate. Because of the increasing difficulty of the proof of work puzzles, it is becoming harder for any one computer to solve a puzzle. Therefore, mining nodes have organized themselves into "pools" or "collectives" whereby they collectively solve puzzles. This is because it is possible to distribute the work between two or more nodes across a pool to share the workload and rewards.

III. BLOCKCHAIN APPLICATIONS

Theoretically, anything of value can be stored on the distributed ledger: contracts, certifications, music, art, identities, policies, bills and votes, for example, governments are beginning to invest in blockchain for improved efficiencies and performance in regulatory compliance, contract and identity management and civic services.

Public and government services

Many governments and public administrations in the world's most advanced economies are now working on blockchains in general and have already embarked on extensive digital transformation [15].

"Public services" is a broad term covering a wide range of services provided by public authorities to their citizens – ranging from justice and law enforcement, healthcare, education to payment of welfare benefits. When such interaction takes place, it should run smoothly. Many public services can be automated and made easy to use. The interaction between the government and the users of a given service, should be through an easy-to-navigate and intuitive user interface and accessible through a single point of entry. The citizen could be identified once, and the information provided to the public administration could only be submitted once. This implies that the databases of all public authorities are interconnected, and data stored by one entity is available to the other. Technology allows fast and real-time delivery of public services. Digital public services where possible, need to be digitalized so that they can operate around the clock without human intervention [16][17]. Bellow, we underline some of the most advanced developments.

Public services	**Benefits**	**Challenges**
Supply Chain	Traceability Transparency	Technical standardization Immature technology
Insurance and Healthcare	Increased productivity Interoperability	Scalability/performance Technical standardization
Energy Industry	Cost reduction Avoid double spending	Immature technology
Real Estate	Cost reduction Proof of ownership Fraud prevention	Selfish Mining Privacy Leakage
Voting	Immutability Avoid manipulation Security Transparency	Potential issues with data protection laws Loss of control
eGovernment	High integrity records in real or near-real time Single source of data Auditability Easy access Saving time Efficiency	Slowness of public sector in adopting new technologies Reluctance to change established processes Occasional need for transaction reversal (e.g., correcting errors)
Personal identity	Immutability Increased efficiency Accuracy Accessibility to services	Unclear regulatory framework Security concerns

Table 1: Blockchain applications, benefits and challenges

Supply Chain is one of the most appealing applications of blockchain technology. Recording the transfer of physical goods from a producer, to a shipping terminal, to a ship, to a cargo train, to a delivery truck and a store on a blockchain could play a crucial role in the trust and transparency with end customers. The blockchain could also be used to monitor supplier actions and to manage warehouse logistics efficiently by avoiding overstocking [5].

Insurance and Healthcare is another area where blockchain can make a difference. A patient's medical records are often scattered among hospitals, clinics, and labs. Very often we give the same information each time we visit a care provider and records of our health transactions reside in multiple systems which are usually not interconnected, sharing only the end (often manually produced) result of the process.

With blockchain, all administrative transactions from nurses, doctors, staff, medical providers, insurance companies, and pharmacies could all be written to a ledger. A health record placed on the blockchain could be read and updated from multiple locations or services and would contain a note of who made each addition to the record, and the patient can decide and choose whom to share the data with. At MIT, researchers are developing a system, called MedRec, that will integrate with current healthcare computer set-ups [10].

Energy Industry. Another application of the blockchain technology is the recording of autonomous, machine-to-machine transactions regarding electricity use. This would take advantage of digital platform opportunities and changing business models for tracing transactions on the smart grid. One notable use case in the energy industry for the blockchain is in recording certificates. There are different power plants generating energy and creating certificates that attest to the amount of energy produced for subsequent exchange. Currently, there are problems such as emission certificates being spent twice, as well as the need to address regulatory challenges and provide more uniform access for everybody in the market. A blockchain can efficiently track the issuance and spending of these energy certificates.

Another example of how blockchains are applicable in the energy industry is in the trading of excess renewable energy. Buildings can be wired with devices measuring energy usage and recording it to a blockchain, enabling owners to sell back energy to the grid without going via an energy provider or manage their microgrids that are independent of the established system [7]0.

Lo3Energy runs a project in Brooklyn, New York, where homeowners can buy and sell the energy they have generated with rooftop solar panels. The blockchain allows them to set their price – and to do so without a price-setting, commission-taking intermediary.

Real Estate. The government of Georgia is using blockchain to register land titles and validate property-related government transactions. A custom-designed blockchain system has been integrated into the digital records system of the National Agency of Public Registry (NAPR) and anchored to the Bitcoin blockchain through a distributed digital timestamping service. The digital timestamping service allows the government to verify and sign a document which contains essential information about the citizen and proof of ownership of property without exposing confidential information. The system will boost land title transparency, reduce the prevalence of fraud, and bring significant time and cost savings in the registration process.

In April 2016, The Bitfury Group announced that it signed an agreement with NAPR to pilot the first Blockchain land-titling registry in the Republic of Georgia. The Bitfury Group and NAPR successfully implemented a custom-designed Blockchain system that is now integrated into the digital records system of NAPR. Since the launch in February 2017, when Bitfury Group along with the government of the Republic of Georgia implemented the property registration on Blockchain had registered more than 100,000 documents. This project will continue to move forward and include smart-contract capabilities to improve and optimize business operations for NAPR, such as the sale of property, transfer of ownership and more [8][9].

Voting. Ballot boxes and current online voting platforms are vulnerable to manipulation. A blockchain-based system could ensure security, transparency and mathematically accurate election results.

Sierra Leone is the first country to have its elections recorded on a blockchain. On March 7, 2018, the West African nation utilized the blockchain-powered platform provided by Agora to store and verify the votes cast during the country's presidential election. While it is the first country to incorporate distributed ledger technology into its democratic process, it is important to note that the ballot-casting process for the voter was the same as it was in previous elections. Following the verification of their relevant identification papers and the subsequent casting of their ballots, choosing one of the sixteen presidential candidates running, the voters had their results manually recorded into the Agora platform. Keeping strict accordance with the paper ballot, the ballots were added to the Agora-created permissioned blockchain. While everyone can view entries on permissioned blockchains, entries can only be validated by authorized persons.

Agora is a blockchain-based digital voting solution that governments and institutions can utilize to facilitate a free, fair, and accountable democratic process. The solution is developed by Swedish startup company for over two years and aims to provide a platform that enables immediate remote ballot casting that is tamper-proof while maintaining transparency and verifiability. The big picture for Agora is to deploy solutions to automate the entire electoral process with citizens voting electronically using biometric data and personalized cryptographic keys and the votes in turn validated by blockchain.

A lack of transparency is common for many elections around the world, but especially in some African countries where large sections of the electorate are often suspicions parties or ethnic communities that are manipulating the results in favor of one candidate or another. These suspicions remain even when there is little evidence of manipulation. A more transparent system could help restore trust. Blockchain-powered electronic voting will be cheaper for African countries by cutting out the printing cost of paper-based elections but perhaps, more importantly, vastly reduce electoral violence [13].

eGovernment. Estonia started building information society about two decades ago, and by now 99% of public services are available to citizens as e-services. Citizens can select e-solutions from among a range of public services at a time and place convenient to them. In most of the cases, there is no need to attend the agency providing the service physically. The Estonian government has been testing the blockchain technology since it first appeared in 2008. Since 2012, blockchain has been in operational use in Estonia's registries, such as national health, judicial, legislative, security and commercial code systems, with plans to extend its use to other spheres such as personalized medicine, and data embassies.

X-Road is the backbone of e-Estonia, a movement by the government of Estonia to facilitate citizen interactions with the state through the use of electronic solutions. X-Road is the platform that allows the nation's various e-services databases, both in the public and private sector, to link up and operate in harmony. Over 900 organizations use X-Road offering more than 2,000 services, using over 170 databases. The services provided include presenting a registration of residence electronically, inspecting one's personal data (address registration, exam results, health insurance, etc.) on the national databases, declaring taxes, checking the validity of one's driving license and registering vehicles.

Some of best e-solutions that have led Estonia becoming one of the world's most developed digital societies are:

Digital ID system. Technically, it is a mandatory national ID card with a chip that carries embedded files and using 2048-bit public key encryption, it can function as definitive proof of ID in an electronic environment. Functionally, the ID card provides digital access to all of Estonia's secure e-services, making daily tasks faster and much more comfortable. The ID-card is regularly used as legal travel ID for Estonian citizens traveling within the EU, national health insurance card, proof of identification when logging into bank accounts, digital signatures, i-Voting, checking medical records, submit tax claims, obtain a digital medical prescription, etc.

e-Residency. E-Residency is a transnational digital identity that anyone in the world can apply for to get access to a platform built on transparency, inclusion and legitimacy. E-residents then have access to the EU business environment and can use public e-services through their government-issued digital ID. e-Residents can establish and manage a trusted location-independent EU company online in one day from anywhere in the world, apply for a bank account and credit card, conduct secure e-banking, access international payment service providers (Paypal, Braintree, etc.), digitally sign and transmit documents, declare Estonian taxes online.

e-Residency has enormous potential to unlock global growth by democratizing access to entrepreneurship and e-commerce because it is building a new digital nation for citizens of the world where no one is held back from their entrepreneurial potential because of where they live or where they choose to travel.

e-Health solutions allow Estonia to offer more efficient preventative measures, increasing the awareness of patients and saving billions of euros. Each person in Estonia that has visited a doctor has his or her online e-Health record, containing their medical case notes, test results, digital prescriptions and X-rays, as well as full log-file tracking access to the data. Blockchain technology is used to assure the integrity of stored electronic medical records and system access logs in over 95% digitized data generated by hospitals and doctors. Therefore, doctors can access their patient's electronic files, no matter where they are and make better-informed treatment decisions 0.

Personal identity. According to UNICEF, one in three children born in the world is not documented and according to the United Nations data shows that over 95 million people were forcibly displaced and became stateless persons or refugees in 2015. Many of these people either lost or never had an official identity profile. Additionally, the World Bank reports that 2 billion people do not have access to financial services, which impossible for them to have access to simple banking. Blockchain is being used to address these issues. Placing stateless people on the blockchain will provide accountability for people that are claimed by no functioning state. Blockchain documentation of the travels, identity, job skills, and associations of displaced people will create trust and comfort for governments and communities receiving refugees. Smart Contracts will set transparent criteria and ways for improving the condition and the status of refugees. Since refugees travel from place to place and receive immunization shots or complete integration protocols multiple times, blockchain could document this progress on the immutable ledger. A blockchain platform BanQu is developed, which aims to give people financial identities and helps displaced Somalis in the Dadaab refugee camp in Kenya to create economic identities. BanQu combines a person's selfies, biometrics and key physical characteristics to create an identity and upload them to the secure ledger along with other information, like relationship-based credit profiles made up of individuals attesting to successful business dealings with the person profiled. These blockchain-based identity systems will allow access to services such as hospitals, education and banking for stateless people around the world 0.

IV. Benefits and Challenges

A. Benefits

The main goal of the technology is to create a decentralized environment without the need of the third party to control the transactions and data. In parallel, it enables fast transaction platforms that are highly secure with low cost and with lower possibilities for errors and incidents. This will bring the possibility of reducing capital requirements, which will change the interaction of individuals and organizations, the collaboration between businesses and will increase the productivity of our economy. The potential benefits of blockchain are not only of economic nature, but they also carry a potential for solving problems for social, political, legal and health issues, which gives them the ability to reconfigure all aspects of society and its operations as we know them today.

B. Challenges

The blockchain industry is still in the early stages of development and besides the potential to deliver solutions for multiple issues, the adoption of the technology is facing limitations, risks and multiple challenges.

One of the most significant risks is how governmental regulation will unfold. Governmental agencies might introduce several laws with the aim to monitore and regulate the blockchain industry for compliance. These new lows will either sped up or slow-down the adoption process. Furthermore, several technical challenges and limitations have been identified, which need to be addressed in the future. Among these technical challenges are the maximum possible bandwidth, consumption of energy the processing time required to complete a transaction, as well as the high data volumes. Moreover, there are certain security threats that users are worried about. There are many issues to be resolved before individuals would feel comfortable storing their personal records in a decentralized manner. People are concerned about hackers, malicious users taking control of the blockchain, identity theft, money laundering and frauds. All in all, the technology is still evolving and maturing. As an increasing number of people and organizations are investigating it and start experimenting, more and more recommendations are formulated on how to solve current issues.

V. CONCLUSION

It is said that the blockchains – the global, distributed ledger running on millions of computers and available to everybody, where every kind of asset from money to music could be stored, moved, transacted, exchanged, and managed, without powerful intermediaries - will bring a revolution, because it will change the way we think and work and because its application is possible in many segments of our life. It seems that what Internet was in the 1990s, blockchain would be in the years to come.

Blockchain technology is one of the most powerful technologies of the future which could help in improving business, implementing fair trade, democratizing the global economy and supporting more open and honest societies. It is one of the first identifiable large-scale implementations of decentralization models, designed and executed at a logically new and more complex level of human activity. It opens the door for developing a free open and scalable digital economy from a centralized one, and there is no question that its impact will be significant.

Even if the blockchain industry is still in the early stages of development, we can already see its potential to digitalize many processes and speed our progress toward becoming a truly advanced society.

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