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Blockchaining for modern HDS

Andriy Luntovskyy | Bohdan Shubyn | Ilona Scherm

Die vorliegende Arbeit zielt darauf ab, die führende Rolle der Krypto-Technologie Blockchain bei der Entwicklung sogenannter moderner HDS (Highly-Distributed Systems – hochgradig verteilte Systeme) zu analysieren und untersuchen. Diese energieeffizienten und kryptografisch gesicherten Systeme basieren auf bestehenden festen, drahtlosen und mobilen Netzwerken und ermöglichen zeitgemäße QoS-Parameter (größere Datenrate, Erreichbarkeit, kleine Latenz).

Krypto-Technologien, insbesondere Blockchain, müssen die Vertraulichkeit, Authentifikation und Verbindlichkeit der zahlreichen Komponenten von komplexen internen Strukturen und Workflow-Schritten innerhalb von HDS, Smart-Contracting-Apps, Algorithmen für ML/AI, in Slicing-Elementen von 5G-Netzwerken etc., ermöglichen.

Schlagwörter—Blockchain, Highly-Distributed Systems, ML, AI, 5G Network Slicing, Smart Contracting.

The main aim of this work is analysis and research of the leading role of the crypto-technology Blockchain within the creation of so-called modern HDS (Highly-Distributed Systems), which are energy-efficient and cryptographically secured, based on the actual fixed, wireless and mobile networks as well as provide up-to-date QoS parameters (higher DR and availability, small latency).

The crypto-technologies and, in particular Blockchain, have to enable the confidentiality, authentication and compulsoriness for multiple components of the complex internal structures and workflow steps within the HDS, Smart Contracting apps, algorithms for ML/AI, in the slicing elements of 5G networks and more over.

Keywords—Blockchain, Highly-Distributed Systems, ML, AI, 5G Network Slicing, Smart Contracting.

I. Motivation: Highly-Distributed Systems

So-called HDS use modern combined fixed, wireless and mobile networks and possess a complex internal construction. They have to be secured(SAML – Security Assertion Markup Language, firewalls, IDS/IPS – Intrusion Detection /Prevention Systems) and provide extended QoS parameters (higher DR and availability, small latency).

The HDS deploy flexible structures, based on SOA and micro-services, as well as deploy efficient communication models (P2P, cloud-fog, M2M), which are able to solve the distribution conflicts in short time and support rapid access to the data analytics.

Such HDS are often developed under use of advanced SWT (Software Technology) process models like DevOps and Scrum and are driven via Blockchain-conform cryptographic structures, which provide compulsoriness of required workflow steps and predictable execution of the deployed modules, services, micro-services and of other components within the internal architecture of the above-mentioned HDS.

Since 2005 the P2P systems (Internet of Things, fog) in combination with convenient C-S communication model as well as server-less structures (SLMA, robotics) have gained on popularity. Then the Cloud-based solutions became a trend (2011) under predominant use of the load-balanced "thin clients" with functionality delegation to the clouds [1-3]. Under use of fog computing the IoT solutions are constructed. The workload is shifted on the edge [1,2] to the energy autarky and resource economizing small nodes. Finally, what does it mean "Highly-Distributed Systems"?

The term "Highly-Distributed Systems" (HDS) must be deployed for the new mobile, frequently "quasi-offline" or server-less apps (SLMA), which extend the convenient distributed systems. They understand the use of efficient and performant networks under clear co-operation goals, as well as no centralization in memory access or synchronization in the clocking. Additionally, they possess more redundancy and possibility for replications due to use of flexible P2P structures, use of cloud and fog services. A very important role the energy autarky plays. Highly-Distributed Systems have more strata and layers in their architecture (better modularity and management with efficient conflict resolving) as well as are better secured especially for privacy and anonymity. For the development of such systems, the agile SWT methods and process models must be used [1-4].

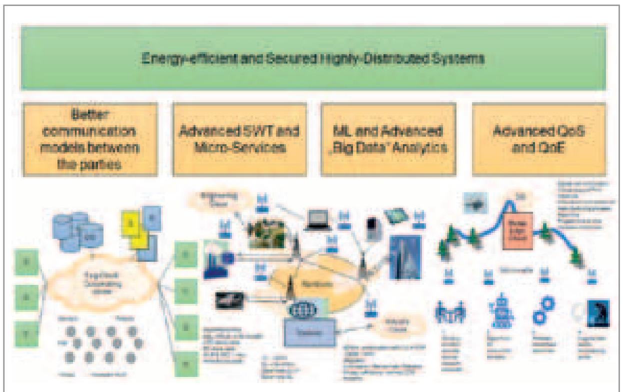

Fig. 1. To the motivation on HDS

The distinguishing features of HDS are as follows (Fig. 1):

1. Advanced communication models (C-S with Clouds, Fog, P2P, M2M)
2. Advanced methods for performance management and optimization as well as for QoE (Quality of Experience) increasing.
3. Advanced SWT (agile approaches like XP, DevOps, Kanban, Scrum and so-called Micro-Services [4]).
4. Advanced Data Analytics regarding to solving of "Big Data" shortcomings [1,2].

II. Blockchain as Decentralized payment System

A. Development of Payment Systems

Blockchain is a cryptographically distributed computer network application supporting a decentralized payment system and decentralized financial online transactions in the peer-to-peer (P2P) concept. However, the economic success of this crypto-technology will be evident in the next 10 up to 20 years.

Fig. 2(a, b) depicts the historical development of the payment instruments from archaic shells and early coins to e-cash and crypto-currencies, which can accelerate financial transactions and significantly reduce the cash mass. The important milestones of Blockchain technology are as follows [5-11]:

- 1991 – The basic principles from S. Haber and W. Scott: cryptographically secured chaining of individual blocks
- 2000 – Theory for cryptographic block-chaining of Stefan Konst as well as some implementation solutions
- 2008 – White Paper "Bitcoin: A Peer-to-Peer Electronic Cash System" for the conception of a distributed database system BTC created by so-called "Satoshi Nakamoto" (a pseudo of the known developing group as well as a lot of numerous speculations about the developer name, i.a. Elon Musk was mentioned, the founder, CEO and CTO of the companies like PayPal, SpaceX and Tesla)
- 2009 – Launch of the first publicly distributed worldwide Blockchain.

Additionally, an important question on the edge: who did actually invent and create Bitcoin? An assumption: The hypothetical Bitcoin author's pseudonym was combined by the names of the prominent companies:

Satoshi = Samsung + Toshiba | Nakamoto = Nakamichi + Motorola.

A graphical comparison of the decentralized chaining of the secured blocks with a centralized banking system can be seen in Fig. 2 (a,b). The deployment of Blockchain technology speaks mainly for a decentralized financial system. The advantages of such a solution are obvious (refer Fig.2b):

- Sustainability, general transparency and commitment
- Accelerated economic workflows and digitization processes (so-called IT in the digital age)
- Blockchain crypto-technology is also well suited to supporting current crypto-currencies (such as Bitcoin, Ethereum, Ripple, Litecoin, ZCash, Monero, Stellar etc.).

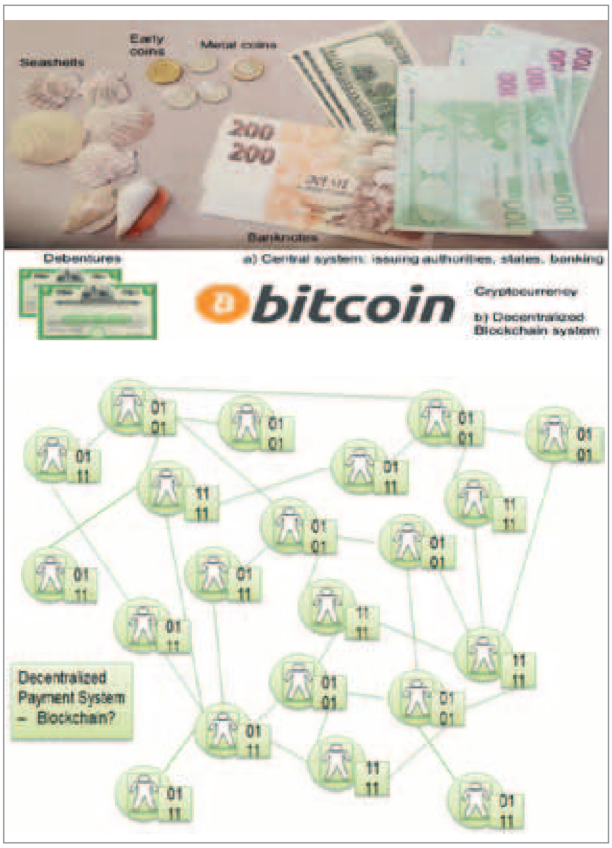

Fig. 2. Payment instruments in past and future: Decentralized chaining of blocks instead of a central bank system?

B. Blockchain Architecture

Decentralized, cryptographically secured and unified blocks, their chains and transactions are grouped under a general, global public ledger (account), the structure of which is as follows (Fig. 3).

The Blockchain, as a networked Public Ledger, consists of participating nodes that represent an efficient P2P communication model. Typical features of the Blockchain are as follows [5,7,11]:

- Redundancy and synchronization
- Cryptographic hash procedures for integrity assurance and attack safety
- Decentralized management and control of the Blockchain
- Network subscribers are also referred to as Nodes (Full-Nodes, Miners, Validators) and run redundantly with mutual synchronization
- In addition, large block volumes can cause the "Big Data" problem. Fig. 3 depicts the structure for an exemplary block chain.
- The defining block chain (yellow color) consists of the longest sequence of secured blocks from the origin to the current block (blue).
- Alternative chains (pink color) became orphan as soon as they are shorter than another chain.

Within the Blockchain architecture between the following basic components can be distinguished: the simple Nodes, the Full-Nodes, and Miner / Validator [5-11]:

1. Nodes:

Each Blockchain participant (computer, smartphones, tablets, or even clusters) is qualified as Node, if he has installed the corresponding software, which runs based on the Bitcoin protocol or the program code of Bitcoin.

2. Full-Nodes:

A Node with full local copy of the Blockchain

Checking for so-called "consensus rules"

3. Miner/ Validator:

The individual participants or mining pool (high resource requirements regarding hardware and energy consumption)

Finalising of blocks (Miner – block generation, Validator – proving)

Externally they act each like a large participant, but in fact, many small blocks are generated for payment in fractions of the crypto-currency units.

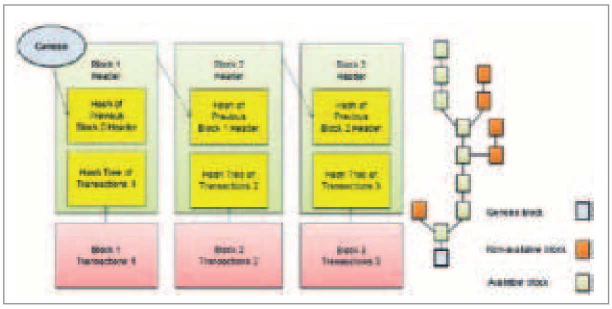

Fig. 3. Distributed Digital Public Ledger with Block chaining (Headers and Blocks within a Hash Tree)

However, the following problems occur during the Blockchain operation:

- Enormous energy consumption due to “mining” of crypto-currencies (processing of the hash blocks via its algorithmic complexity).
- Exponential memory growth (including capacity migration between USB media, smartphones, PC, storage media such as SAN / NAS, as well as cloud storages)
- Cryptographic data security is guaranteed, but privacy issues may arise. One-way out is as follows: no processing the complete Blockchain with all the transactions, but only use of excerpts of the Blockchain without a prehistory.

C. Mining of Cryptocurrency and Resource consumption by Blockchain

At least five factors are necessary and must be considered when calculating the profitability of the mining [5-11]:

- Hash-rate: how much hash values can be computed each second?
- Bitcoin „reward“ per Block: Bitcoin amount for each new computed block
- Mining difficulty: factor has always a new actual value!
- Electricity costs: in EUR per kWh
- Energy consumption: electrical power of Mining Rig in KW
- Pool fees: how much in % belongs to the joined pool
- Bitcoin price: exchange course for the crypto-currency BTC (or other units like XMR, ETH, ZEC, LTC)
- Investment (basis device costs): hardware investment for a Mining Rig.

There are different multipurpose and specialized devices for mining available, so-called Mining Rigs. The old good PCs or plain smartphones can be used too but under considering of the energy consumption problems. The following types of devices can be deployed to generate the hash values for mining process:

- CPU Mining: powerful processor is required
- GPU Mining: powerful graphics card is required
- ASIC Mining: Application-Specific Integrated Circuit (s. Table I) etc.

The practical experience has shown that in a lot of cases the Mining of the crypto-currencies like BTC, ETH, ZEC, XMR etc. leads unfortunately to “no reward” cases due to a large energy consumptions as well as essential CAPEX + OPEX.

Features of AntMiner S15	High-Performance Mode	Low-Energy Mode
Hash rate	28 TH/s	18TH/s
El. power	1596 W	900 W
Power Efficiency	57 J / TH	50 J / TH
NW connection	Ethernet	Ethernet
Weight and dimensions	7kg, 240 mm x 178 mm x 296 mm	

Table I. Features of a Mining Device (source: amazon.de)

III. Integration of Blockchain within the Applications

The use of Blockchain applications is depicted in Fig.4. The following topics can be mentioned:

- ML and AI [12,15]
- Digital Economy
- Crypto-currencies [5-10]
- 5G Network Slicing [13-18]
- Smart Contracting [8-11] and more else.

Up-to-date HDS [1-4] contain Web Services and Micro-Services as construction components andpossess, as a rule, multiple planes (SDN), several strata and slices (5G networks).

Every of the listed topics are concerning the HDS with built-in crypto-technologies and, in particular Blockchain, as well as must provide the confidentiality, authentication and compulsoriness as most important security aims for multiple components of the complex internal structures and workflow steps.

As the main disadvantage of the offered method, the performance reduction by real-time services as well as energy consumption can be mentioned as a critical position.

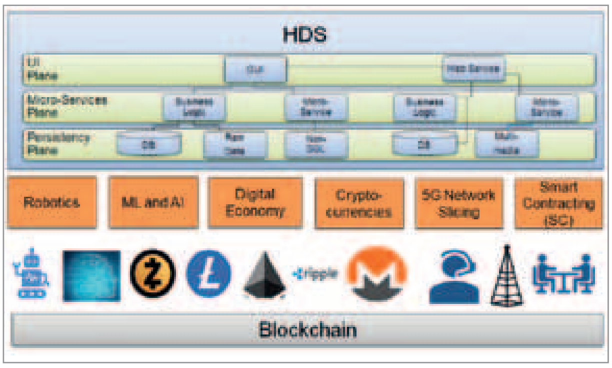

Fig. 4. Integration of Blockchain within the Applications and HDS

A. HDS and Smart Contracting

One of the mostly important Blockchain applications after the mining of the crypto-currencies are so-called Smart Contracts [8-11]. Historically, Smart Contracts (SC) does not require exceptionally Blockchain, but certain consensus algorithms (protocols), which are cryptographically conditioned via hashes, private and public keys and signatures.

A "smart" contract is a software-based agreement that allows and can contain a variety of contract terms. In the course of the usual contract processing (transactioning), certain linked actions can be executed automatically if there is a corresponding trigger. The contracts are offered and signed within and via the Blockchain or other Blockchain-like infrastructure.

The evident advantages of the discussed approach are as follows:

- Digitality and legal openness of the platform;
- Transparency, costs and time savings;
- Automation of the workflow step processing;
- Deployment at the HDS solutions for compulsoriness.

Smart Contracts within the HDS are driven via Blockchain-conform cryptographic structures, which provide compulsoriness of required workflow steps and predictable execution of the deployed modules, services, micro-services and of other components within the internal architecture of the above-mentioned HDS. The mostly appropriate environment for SC is a private Ethereum-Blockchain. However, Ethereum doesn't work completely conform to European Laws. An example of a Smart Contracting application for an e-Vallet for the ICE trains of DB.de [8-11,14] is given in Fig.5.

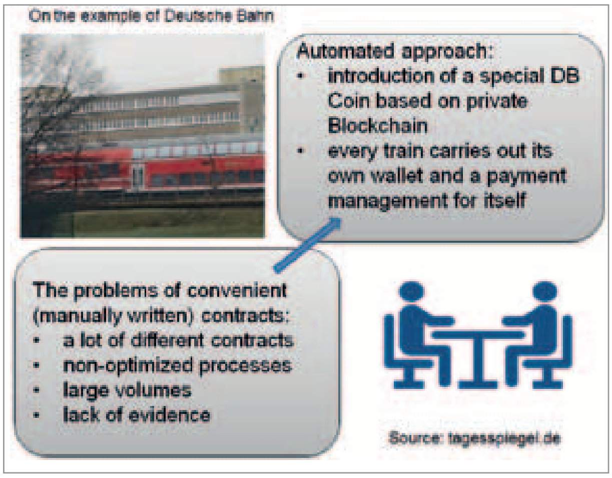

Fig. 5. Smart Contracting on the example of DB.de [8-11,14]

Furthermore, the Blockchain is used for Smart Contracting applications for the following world-wide leading companies deployed: Walmart, Maersk, Alibaba, CartaSense, Kuehne + Nagel (aimed to logistics, sea freight, stock exchanges, marking of containers) , Nestlé, Tyson Foods, Unilever (aimed to food delivery), Everledger (the registers for diamond certification) and so on. The first national economy Belorussia is nowadays, which has recognized SC completely.

The criticizers speak about the wrong ethic side: SC leads often to reducing of the available jobs and distortion (corruption) of the one of the most ancient social institutes of contracting law over the world.

B. Chained Slicing in 5G Networks

5G-SDN is based on open interfaces and proven industry standards for hardware like Open Stack, which was used for LTE, WLAN, NFC, BT, ZigBee, 6LoWPAN too.

The next one is so-called "Network Slicing". The principle of Network Slicing is depicted in Fig. 6.

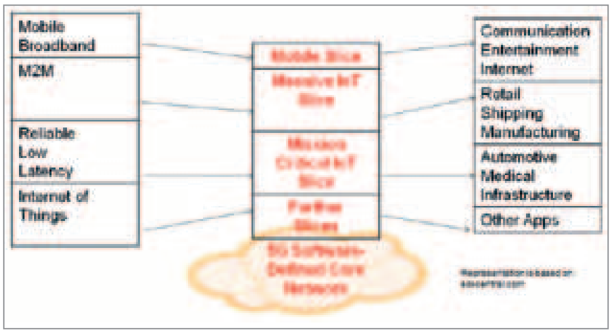

Fig. 6. 5G Network Slicing: example

The access and core networks control the creation, orchestration, deployment and operation of 5G and are divided to the so-called "slices" (or partitions). The "Network Slicing" concept means [15-19]:

- Shorter latency for mobile network access (under 1 ms) for real-time scenarios
- Quickly and efficiently creation and providing of differentiated access for different industry requirements (like L3 DiffServ)
- Better QoE management due to flexible deployment and modification of the necessary "slices"(partitions)
- Seamless and fast mobile broadband connections

Network Slicing is supported via the widely used SDN technology (Software-Defined Networking) and the next one NFV (Network Functions Virtualization). The individual-profiled 5G apps can be flexibly deployed under guaranteed QoE. For example, the rescue services can start these apps during a disaster status: traffic accident, avalanche shift or other critical event [15-19]. Different apps are supported via the available slices, which are involved taken into account the situation and QoS requirements.

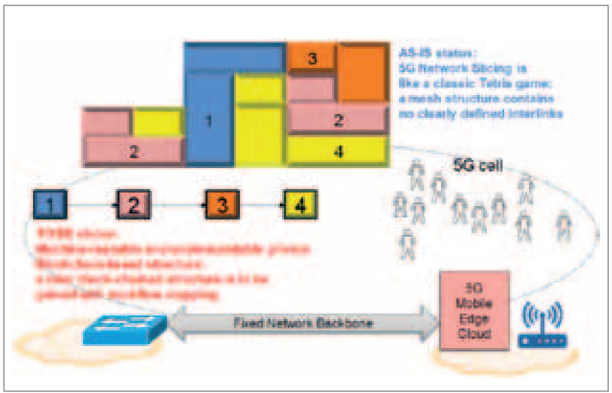

Fig. 7. Multivariate Tetris vs. a block-chained clearness

A possible solution is given in Fig.7. However, the Network Slicing must guarantee the secured transitions between the interlinked slices and modules within the slicing structures and provide their compulsoriness.

In the best way, the solution is possible based on Blockchain. In opposite to standard solutions, oriented to PKI and combined symmetric-asymmetric encryption (RSA) and digital signatures Blockchain provide its own security decentralized infrastructure, which distinguish from centralized PKI or bilateral Web-of-Trust, incorporated in convenient distributed apps [13].

The main goal is to transfer service data between 5G Network Slicing using a Blockchain that will introduce obligatorily and irreversibility by organizing linear chained structure. In the paper [9] this idea realized by using Key Distribution Center (KDC), which is co-operating with the Authentication Server Function (AUSF) and for a given network slice that serves n devices (or n distinctive use cases), KDC generates a key-pair (d, e) for the EL-Gamal cryptosystem: d and e are private and public keys. In our opinion, this method will not be effective enough.

Using Blockchain we can win in terms of security and productivity even unless more complicated and resource consuming character of hash computing.

Let us to compare the both status and the advantages of the offered solution (refer Fig. 7):

- AS-IS status: 5G Network Slicing is like a classical Tetris game. There is a mesh structure with no clearly defined interlinks. The workflow is not mapped.
- TO-BE status: Machine-readable and understandable private Blockchain-based structure must be constructed instead of them. A linear chained structure must be gained. The compulsoriness of the steps and algorithm blocks is guaranteed as well as the further security aims: confidentiality and authentication.

C. Blockchained ML and AI

When talking about artificial intelligence (AI), we should also mention Machine Learning (ML) as an important basis. To begin with, we would like to represent what the difference between the convenient deterministic algorithms (cp. classical flowcharts, like SSADM or PAP by DIN 66001) and Machine Learning [12,15].

Fig. 8 shows that in classic algorithms we have Input Data and an algorithm that allows us to get results. In ML, we have Input and Output Data, which help us to get a neural network a learning algorithm and it will help in the future to make the neural network more powerful via training.

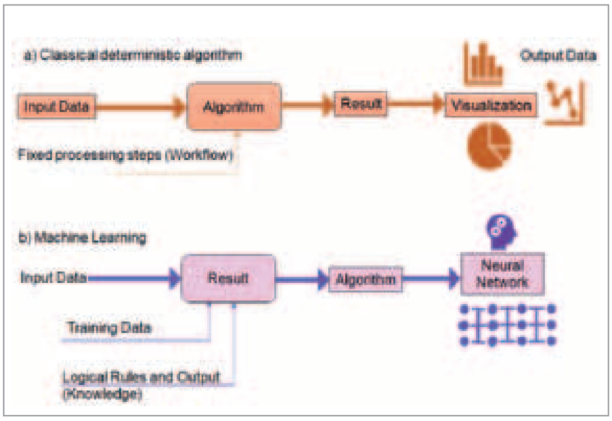

Fig. 8. Comparison of ML to deterministic algorithms

Nowadays, artificial intelligence is widely used in all spheres of life without stopping in its development. In some cases, such as 5G networks, we need to provide artificial intelligence at different levels of architecture with a clear sequence and compulsoriness of the algorithm steps (Fig. 9)

Fig. 9. ML with Blokchain transactions: a clear sequence and compulsoriness of the algorithm steps

In order to achieve this, we will use Blockchain, which provide the necessary hierarchy and sequence of actions. It will also allow to users of such a system to pay for clearly allocated resources without the need for overpayments. It increases the overall QoE in up-to-date HDS.

IV. Conclusions and outlook

1) The given paper represents a short overview on crypto-technology Blockchain and its deployment scenarios. The development challenges for the modern technology are investigated.
2) The technology promises "a new technological breakthrough" for widespread modern Highly-Distributed Systems, which detach convenient distributed applications.
3) HDS with Blockchain provide the confidentiality, authentication and compulsoriness as most important security aims for multiple components of the complex internal structures and workflow steps on the Blockchain basis.
4) In opposite to standard solutions, based on PKI and combined symmetric-asymmetric encryption (RSA) and digital signatures Blockchain provide its own security decentralized infrastructure, which distinguish from centralized PKI or bilateral Web-of-Trust incorporated in convenient distributed apps.
5) The HDS in telecommunication, industry, entertainment and education include ML/AI, Digital Economy, support multiple cryptocurrencies and 5G Network Slicing, Smart Contracting and more else apps, are oriented to Web Services and Micro-Services, which are placed on different planes, strata and slices.
6) The deployment scenarios on 5G networks include nowadays "digital twins" and slicing architecture. Blockchain with cryptography provide compulsoriness of the steps and algorithm blocks and guarantee the further security aims: confidentiality and authentication.
7) In mid-term, the standards for ML and AI will accompany the industries, digital economy and everyday life over the world and for each institution. The basic principles of use of ML/AI with Blockchain structures in behavioral models for 5G networks were represented.
8) The perspectives of so-called block-chained HDS solutions are discussed. As the main disadvantage of the offered method, the performance reduction by real-time services as well as energy consumption can be mentioned as a critical position.

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