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Review on Advantages of Blockchain Technology in Healthcare

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Abstract: *Blockchain is a trustworthy solution for population health data management as well. With the standard approach, information about every patient is distributed over multiple systems that are not interoperable- This makes aggregating health data for a particular population cluster challenging. Blockchain technology has been emerged in the last decade and has gained a lot of interests from several sectors such as finance, government, energy, health, etc. This paper gives a broad ranging survey of the application of blockchain in healthcare domain. In fact, the ongoing research in this area is evolving rapidly. Therefore, we have identified several use cases in the state of art applying the blockchain technology, for instance for sharing electronic medical records, for remote patient monitoring, for drug supply chain, etc. Blockchain technology moves in the direction of persistent revolution and change. It is a chain of blocks that covers information and maintains trust between individuals no matter how far they are. In the last couple of years, the upsurge in blockchain technology has obliged scholars and specialists to scrutinize new ways to apply blockchain technology with a wide range of domains. The dramatic increase in blockchain technology has provided many new application opportunities, including healthcare applications.*

Keywords: Blockchain Technology; healthcare; Advantages; Electronic Medical records; Remote Patient Monitoring; pharmaceutical supply chain;

I. INTRODUCTION

In the last decade, blockchain is emerging as one of the most promising technology that captures attentions of several academic researches and industry. This concept was originally introduced by Satoshi Nakamoto in a white paper in 2008. It is defined as a decentralized, distributed, immutable ledger which is used to securely record transactions across many computers in a peer-to-peer network, without the need of third party.

The first generation of blockchain, Blockchain 1.0, is underlying on Bitcoin which is the first implementation of blockchain based on cryptocurrency applications[1]. The next generation, called Block chain 2.0, is emerged with the concept of smart contract that it is considered as a piece of code defined, executed and recorded in the distributed ledger. The third generation of blockchain technology, Blockchain 3.0, deals essentially with non-financial applications such as government, energy, health, etc. In fact, severalorganisations have adopted this technology and applied it for several use cases in the healthcare domain. The most interesting features in blockchain that are beneficial to healthcare applications is decentralization, privacy and security since blockchain technology may ensure for example a secure access to medical data for patients and various stakeholders (insurance companies, hospitals, doctors, etc.).

Based on the conducted literature review, we believe that no review paper so far conducted a comprehensive classification for blockchain technology in healthcare applications. To address this shortcoming, we aim, in this paper, to provide the reader with technical background in diverse blockchain-based healthcare applications, focusing on latest development as well as achievements in this area. This paper provides a broad technical study of recent blockchain technologies deployed in healthcare, and analyses their strengths and weaknesses.

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II. LITERATURE REVIEW

This section provides an overview of fundamental concepts related to the blockchain technology and several applications of this technology in the area of healthcare. Comparison of existing review papers has also been tabulated and discussed in this section.

A. Blockchain

Blockchain, a distributed ledger, is a chain of time-stamped blocks containing a specific number of validated transactions. Blocks are linked cryptographically using the hash value of the previous block. Each transaction generated by a user or node is digitally signed using a private key and broadcasted to the etwork. A validation/mining node takes up that transaction and encloses it into a block then block is broadcasted to the network [14]. Each node of the network checks the validation of the block by implementing the consensus protocol. The validated block is appended to the chain then updated ledger is replicated throughout the permissioned nodes of the network. Consensus protocol replaces the trusted third party or the central authority. Fig. 1 illustrates the difference between centralized and distributed ledger [1] [15] [16] [17]. The ledger provides security, auditability and anonymity-based transparency.

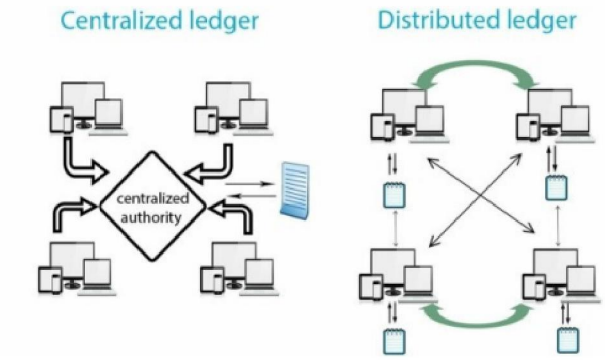

Fig. 1.Centralized vs. Distributed Ledger

1) Blockchain Evolution: Melanie Swan [15] categorizes the blockchain technology evolution into three phases: Blockchain 1.0, 2.0, and 3.0. Blockchain 1.0 is for the de centralization of money or known as “Internet of Money”. This first application established a peer to peer digital payment systems without reliance on a third party. This tier of technology implements Proof of work, the consensus protocol for validating a block to embed in the ledger [4]. A digital reward is givento the successful miner for mining the block, for his contribution to the ledger. The second generation is blockchain 2.0 which is the application of decentralization of smart property and smart contracts, came in 2014. It aims to transfer any unit of value using the concepts of smart contracts for automated administration and supervision. The smart contract is a script which triggers after meeting the conditions encoded within it [17] [13]. Ethereum and Eris blockchains come under this category. The third blockchain technology refers to blockchain 3.0 which targets the welfare of society and is particularly recommended to register and transfer public records in the areas of government, health, science, literacy, and art. Examples are healthcoin, learningcoin, gridcoin, etc. [15]. Blockchain 2.0 and 3.0 are also known as non-financial applications. Alternative consensus protocols and alternative crypto-currencies have also been introduced.

2) BlockchainOwnership:There are two basic types of blockchain i.e. Permissioned blockchains and Permissionless blockchains. Permissioned blockchain is a custom-built setup by a single authority or a consortium. The verification process can be done by a central authority or a set of trusted preselected parties (consortium). This private setup restricts data access to the group of users or a set of groups that controls the blockchain. A smaller number of participants provides efficiency and scalability [18] [12]. These blockchains ultimately have a central authority. This centralization of the setup can pave way for tampering as the 51% majority is required to get the consensus and it can be done easily in this controlled setup [5]. Eris, Ripple, and Hyperledger are examples [1]. Permis- sionless blockchains are fully decentralized to a large number of nodes and low in efficiency [1]. These blockchains require no prior authorization of participants for mining the transaction blocks. Anyone can contribute his/her computational power

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for network tasks and can get a monetary reward in return. This blockchain gives the public access to read and write transactions to the blockchain which is visible to everyone so also known as Public blockchains [18] [12]. Examples of permissionless blockchains include Bitcoin and Ethereum [4].

3)Features of blockchain technology:

Decentralization: The blockchain is a distributed digital ledger composed of a chain of blocks containing transactions. The decentralized database is shared and open to all parties throughout the nodes of the network [6], [19], [20], [12]. BLockchain-based networks provide fault-tolerant architecture as end-to-end replications remove the reliance on a single point of failure.

Consensus mechanism: Blockchain is a peer-to-peer distributed network without any intermediary. Each digitally signed block is sent to the mining pool where it is taken over by network nodes called miners and verified using the consensus algorithm [4]. The winner from the miners broadcast the block to all other nodes which confirm and validate the block with consensus and append the block in their ledger. The winner also gets a financial reward for its work [21]. Many alternative consensus protocols have also been proposed, such as proofof-stake, proof-of-burn, proof-of elapsed-time [6], [12], [17]. Data integrity is maintained by computing these consensus algorithms as a substitute to third trusted party.

Immutability: Blockchain is immutable and tamper-proof thus ultimately provides security [15]. The hash functionmakes the blockchain as a tamper-resistant ledger. A hash value is calculated by implementing some hashing algorithms (SHA-256, RSA, RIPEMD-160, etc.) on a block of transactions [20]. The hash value is further used to create a chain of blocks. In this way blockchain provides robustness. If someone intends to alter previous transactions, then it will require a change in the hash value which further needs the consensus of network and high computational power which is an unrealistic approach in this computational model. The hash value is also used to represent a user concealing real identity which is used for privacy purposes [17], [22].

Traceability: Blockchain is a digital ledger consisting of continuously growing sequence of blocks. A block is comprised of a complete list of transaction records. In this chain of blocks, every block has a parent block. The first block in the chain is known as the genesis block. Hash code of genesis block is added to the header of the second block then hash code for the second block is computed over the hash of genesis block and transactions of the block jointly. Hash of the second block becomes the block header of the third block and so on. In this way, the blocks are linked with each other having a time stamp as well. This link can be chased back to the origin or genesis block [1], [20]. This feature of blockchain provides data provenance to keep chronical track of activities and may also help to investigate backward throughout the chain.

Smart Contract: A smart contract is a computerized computational logic or terms of the contract. It automatically triggers transactions between parties after fulfilling encoded logic. This implementation makes the blockchain flexible and programmable [1], [19] [13]. Smart contracts are programmed for management and administration purposes [6]. The smart contract can be implemented in supply chains, claim insurance [6] and clinical trials. Clinical trials usually encompass a sequence of dependent phases to get specific outcomes. Each phase can be encoded in a smart contract which will be triggered after the consensus of network nodes [23], [22]. So, smart contracts can enforce traceability and transparency with full control over associated processes.

Open Source: Blockchain projects are mostly open source. Developers can make contributions to it. Blockchain technology has the potential to accommodate the evolution to be brought by the future [8]. Transformation of financial blockchain to non-financial block-chains has already been announced in the big interest of the community. Ethereum and Counter-party have profound interest to build up more value-added services for the future architecture of blockchain technology [15].

Currency: The Bitcoin blockchain was first implemented in peer to peer digital payment system which also provides rewards in digital currency to the users for their contribution i.e. Proof of Work, to the network [6], [4]. Bitcoin was the first digital currency. In this evolution, many alt-crypto-currencies have been springing up. The major alternative currencies (altcurrencies) are monitored at http://coinmarketcap.com/. Over 1597 crypto-currencies have been developed in the digital cash system (Bitcoin, ethereum, ripple, litecoin, etc.). In different fields of life an economic

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layer can be embedded to give rewards in response to digital asset contribution and use e.g. learningcoin in education systems, journalcoin for the contribution of reviewers and editors, healthcoin to get national health services, etc.

B. Use of Blockchain in Healthcare

Healthcaresector always remains one of the most popular areas of research from the last few decades keep on finding innovative and more reliable ways to help the community and healthcare industry. Different stakeholders (practitioners, medical specialists, hospitals, therapists, patients, payers, etc.) need to organize, access and share health records without any modification in a secure and interoperable way. Data provenance is also essential to prove the authenticity of records. Blockchain technology is being implemented in different scenarios and has the potentials to address the key issues of the healthcare sector. However, it needs more research to be focused to deploy real-time applications of this technology. Following are some applications of this technology in the healthcare sector. MedRec platform provides decentralized record management, authorization and data sharing among healthcare stakeholders. Patients can save their data and can also grant and withdraw permissions to their records. This framework provides full confidentiality as the records are not stored on blockchain instead pointers to the data storage locations, logs and permissions are only stored in this blockchain [24], [4]. Gem in collaboration with Philips Blockchain Lab has been introduced Gem Health Network using Ethereum blockchain. This framework is established to address operational costs. This shared infrastructure provides interoperability among various providers accessing the same information to boost better patient care [8]. Guardtime healthcare platform creates a nonintermediated relationship between patient and provider in Estonia. Guardtime blockchain enabled transparent information sharing among the patient, provider, and payer which promises secure, reliable and auditable records [8]. Patient's health data is being required by research organizations. In this context, Healthbank has been providing a platform for patients to save and share their health data with research organizations which can be used for academic research and pharmaceuticals. This platform is also incentivizing patients with financial rewards for their contributions [8]. [25] designed Blockchain based Data Sharing (BBDS) access control system using permission blockchain. Owners of data can access their EMRs from a shared data pool. This secure and scalable system identifies, authenticates and authorizes users using cryptographic keys and digital signatures acquiring an edge over HDG (Healthcare Data Gateways) which is a smartphone application built over blockchain cloud [26]. Fast Healthcare Interoperability Resources: FHIRchain [27] was developed by the Health Level Seven International (HL7) organization for exchanging clinical data. FHIR increases efficiency and interoperability.

Compared Secondary Studies

Blockchain has been appeared a decade before in computing while it first came in the healthcare sector in 2014 with the advent of the non-financial version of the technology. Researchers are found enthusiastic to explore this unique technology to know the potentials and challenges. In this regard, six secondary studies were found that discuss the implementation of this technology is the healthcare sector.

TABLE I. COMPARED SECONDARY STUDIES

	Discussion Points					
References	**Features of BC**	**Benefits of BC in HC (All Stakeholders)**	**Challenges and Issues to BC Implementation**	**BC Applications in HC**	**Research Methodology**	**Cloud-based BC applications and platform in HC**
T.Kuo et.al. [6], K. Rabah [9], S. Angraal [28]	Partially Yes	No	Yes	Partially Yes	No	No
M. Mettler [8]	Partially Yes	No	No	Partially Yes	No	No
M. Benchoufi et. al. [23]	Partially Yes	No	No	Partially Yes	No	No
D. Randall et. al. [29]	Partially Yes	No	No	No	No	No
Y.Sobia et. al.	Yes	Yes	Yes	Yes	Yes	Yes

Table I presents five different aspects which have been reviewed by existing researchers and also compares to this study. The first aspect in Table I is "features of blockchain technology". All the secondary studies partially narrate the

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features of blockchain as compared to this research. The second aspect discussed by earlier studies is "benefits of the blockchain technology in healthcare". It is extracted that M. Mettler [8], K. Rabah [9], as well as this work, made an analysis of this aspect with respect to all the stakeholders of healthcare sector whereas other four review papers discussed few of the stakeholders. The third mentioned aspect, Challenges and Issues to BC Implementation, has been highlighted by T. Kuo et al. [6], K. Rabah [9], S. Angraal [28] and this work whereas M. Mettler [8], M. Benchoufi et al. [23] and D. Randall et al. [29] did not address this aspect of concern.

Rapid development of this technology is being observed in healthcare market however after comparing these reviews, it is found that few of primary studies have been included on the subject of the fourth aspect, BC Applications in HC, except D. Randall et al. [29]. Whereas this study classifies more primary studies to analyze Blockchain Applications in the healthcare sector. Furthermore, qualitative research methodology has been opted to extract results in existing research. Hence, we used a quantitative research approach making a distinction to nonstructured review process i.e. systematic literature review, to classify the primary studies to make a deeper enclosure of all the aspects compared in Table I.

III. PROBLEM STATEMENT

Healthcare is considered as one of the application areas of blockchain technology. But the technology adoption in the healthcare industry is relatively slow, and has been highlighted in the background paper on conceptual issues related to the health system, where the authors state that, "Pragmatic solutions already exist to address many of the greatest global health challenges, yet progress remains frustratingly slow because many health systems are constrained and cannot fully operationalize them.

Approach Followed

In this research paper I have followed the concept of qualitative approach to find the Advantages of use of blockchain in the healthcare industry. There are different research papers studied and analysed to answer the problem statement in this research paper

Key Concepts on Blockchain

In this section, we discuss the Advantages of blockchain technology to help understanding the rest of this paper.

Overview and Architecture of Blockchain

Essentially, blockchain is a peer-to-peer network that sits on top of the internet which was introduced in 2008 as part of a proposal for Bitcoin. The blockchain is a public ledger made up of a sequence of blocks, which holds a full history of transaction records that occurred within the network. A block is consisted essentially by a header and a body. The header of each block contains the hash of the previous block. Therefore, the blocks form a chain or a linked list where each block structure is based on the previous one.

Block headers also contain a *timestamp* indicating the time of when the block was published, *a nonce*, which is an arbitrary number that miners would change frequentlyto get a certain hash value to solve a mathematical puzzle and a *Merkle tree* that fundamentally decreases the exertion required to check transactions inside a block.

A Blockchain transaction can be defined as a small unit of task that is stored in public blocks. Each transaction is verified by consensus of a majority of the system participants. This way, tamperproof is ensured once transactions are packed into the blockchain. In regards to blockchain immutability, a same copy of the ledger is replicated, hosted and maintained by all participants.

Regardless of the type of blockchain, the business logic is encoded using smart contracts, a self-executing code on the blockchain framework that allow for straight-through processing. When embedded in the blockchain, smart contracts becomes permanently *tamper-proof*, as no one can change what's been programmed, *self-verifying* due to automated possibilities and *self-enforcing* when the rules are met at all stages.

Among the important features of Blockchain, decentralization by making the ledger accessible by all participants, immutability, so blockchain is nearly impossible to tamper and is censorship-resistant, availability by providing all

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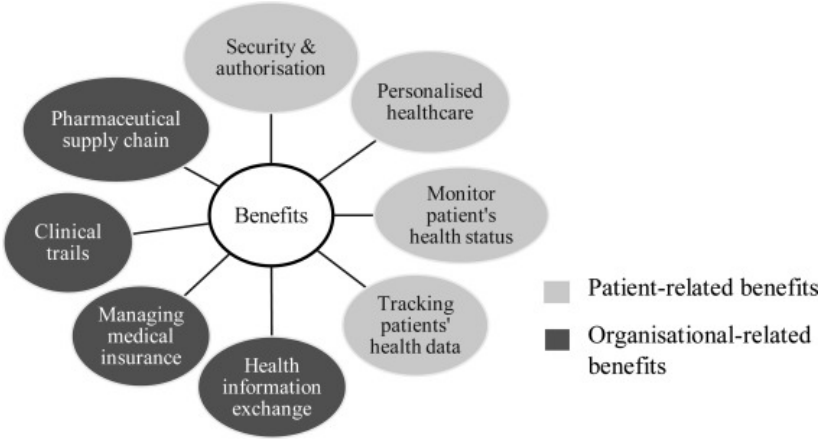
peers a copy of the blockchain to get access all timestamped transaction records, and anonymity, where each user can interact with the blockchain with a generated address, that does not reveal the real identity of the user.

Benefits Of Blockchainin Healthcare

1) Patient-centric electronic health records

Research published by Johns Hopkins University states that the third major reason for death in the US was medical errors resulting from badly coordinated care. Healthcare systems in every country are stumbling with the problem of data silos, indicating that patients and their healthcare providers have a vague idea of medical histories. One potential solution is creating a blockchain-based system for medical records connected to existing electronic medical record software that acts as an overarching, single view of a patient's record. It is paramount to emphasize the actual patient data that does not go on the Blockchain. Every new record appended to the Blockchain, whether a prescription, a medic's note, or a lab result, is decrypted into a unique hash function: a small string of letters and numbers. Every hash function is special and can only be decoded by the person who owns the data.



2) Supply Chain Transparency

A primary challenge across the healthcare sector is ensuring the origin of medical goods to guarantee authenticity. With the help of a blockchain-based system, we can track items from the manufacturing to every stage through the supply chain. This method enables customers to have complete visibility and transparency of the goods they buy.

Supply chain translucency is a top preference, particularly in developing markets where fake prescription medicines cause tens of thousands of deaths annually. It is increasingly necessary for medical appliances, which are increasing quickly with the adoption of more remote health monitoring, and therefore also attracting the interest of bad actors.

Pivotal uses of the Blockchain when paired with AI:

- Customer confidence: Customer confidence: The ability to track each package's end-to-end provenance, integrating with manufacturers, wholesale, shipping, etc.
- Supply chain optimization: Once all the data is in one place, companies apply AI to predict demand better and optimize supply accordingly.

3) Patient Data Management and Sharing

The Health and Human Services office received notifications of over 350 data breaches, resulting in the disclosure of 13,020,821 healthcare records.

HIPAA has strict restrictions on the privacy of patient records. Those records cannot be isolated as several parties other than the patient, and their physician may have to access their wellbeing. At the same time, handling patient data using a traditional approach can be a complex task since this data is dispersed over different healthcare databases.

Blockchain resolves these issues by delivering a unified platform for storing and managing all relevant data in one location while preserving security and access control. We can store pieces of patient data as blockchain blocks identifiable through the patient's unique ID. This method authorizes sharing health information (blocks) without revealing the ID if the patient wishes to remain anonymous

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Blockchain is a trustworthy solution for population health data management as well. With the standard approach, information about every patient is distributed over multiple systems that are not interoperable- This makes aggregating health data for a particular population cluster challenging. Blockchain thus becomes a secure medium for individuals to participate in population health studies and monetize the outcome of these studies.

4) Drug traceability

Blockchain is a dependable solution to assure drug authenticity, as it enables tracking every drug to its very roots. We can use Blockchain to encapsulate data about the drug at every phase of its lifecycle. Every block containing drug data will have a hash linked to another block and a timestamp that we cannot alter.

The transactions in the Blockchain will be visible to all authorized parties, and the drug's movement from one party to another can be trackable in real-time. Medicine buyers will also ensure the authenticity of purchased products by scanning the QR code and looking up the data about the manufacturer and other relevant supply chain parties. Distributing a fake drug will be next to impossible in such a setup.

5) Cryptocurrency payments

There are blockchain use cases in healthcare-related to payment. For instance, Blockchain makes it possible to receive medical assistance and pay for them with cryptocurrency. One such example is Aveon Health, A technology-centred medical group. Aveon Health acknowledges the advantages of using Bitcoin virtual currency. Users can send and receive Bitcoins electronically using wallet software.

Blockchain in healthcare: use cases

Here are seven of the most prominent blockchain technology applications in healthcare:

- Transparent supply chain
- Faster medical credentialing
- Patient-centred EHRs
- Manageable medical trials
- Enhanced security
- Commitments enforced via smart contracts
- Genomic research

Blockchain increases healthcare supply chain transparency

Counterfeit drugs are a persistent problem. The World Health Organization (WHO) estimates that up to 1% of all medications available for purchase in the developed countries are not legitimate. This number increases in the developing countries to reach almost 10%. Proving this point, the Drug Enforcement Administration (DEA) captured over 9.5 million fake medications in the US in 2021. The agency reports this number is higher than it was in two previous years combined.

One of blockchain's use cases in healthcare is that it allows customers to track the products at every stage, including manufacturing, wholesale, and shipping to make sure the items are legitimate. This is crucial for both drugs and medical devices. Once a ledger is created for a drug, it records the point of origin, a laboratory for example. Since then, every manipulation on this drug is documented. Blockchain can incorporate rather extensive information, such as labor costs and how much waste was emitted during manufacturing and transportation.

Medi Ledger is an example of a blockchain protocol that healthcare organizations can use to verify information on prescription drugs' supply chain. This includes expiration dates, manufacturers, etc. Medi Ledger also allows different parties to exchange secure peer-to-peer messages. Many prominent healthcare providers, such as Bayer, Pfizer, and Cardinal Health use this network.

In another example, Paris-based Block pharma built a solution that scans medications' supply chain and verifies it across all points of shipment. The company's app allows patients to verify the legitimacy of their purchase. Block pharma is believed to intercept 15% of counterfeit drugs worldwide.

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Blockchain speeds up medical credentialing

Verifying credentials – training, skills, medical licenses, and education – is a tedious process that is typically performed via phone and email and can take up to four and even six months to complete. The Council for Affordable Quality Healthcare reports that payers spend almost $2 billion per year to maintain a comprehensive healthcare provider database. Blockchain technology can offer a faster and more reliable substitute that doesn't rely on direct human references.

IV. CONCLUSION

According to IBM, 70 % of healthcare leaders anticipate that the most significant effect of Blockchain within the health sector is the advancement of clinical trial management, providing a decentralized framework and regulatory compliance for sharing electronic health records (EHR).The healthcare sector is a problem-driven, data- and personnel-intensive domain. The ability to access, edit, and trust the data emerging from its activities is critical for the sector's operations.

If we divide the operations within the healthcare sector into triage, health problem-solving, clinical decision-making, realization, and assessment of knowledge-based care, achieving the desired health outcomes hinges on engaging a multidisciplinary group of health personnel that apply the most pertinent knowledge of technologies and skills when dealing with the patient. A blockchain-powered health information system has the potential to unlock the true value of interoperability. Blockchain-based systems can reduce or eliminate the friction and costs of current intermediaries.

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