**ICS 690-01 Blockchain technology**

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**Whitepaper**

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**Section A**

**Blockchain technology in Healthcare- Applications and Challenges**

1. **Abstract:**

Blockchain is a new technology that is being used to develop innovative solutions in a variety of fields, including healthcare. In the healthcare system, a Blockchain network is used to store and share patient data across hospitals, diagnostic laboratories, pharmacies, and clinicians. Medical institutions can use this technology to obtain insight and improve the analysis of medical records. As a result, it has the potential to increase the performance, security, and transparency of medical data sharing in the health-care system. It can help to alleviate concerns about data manipulation in healthcare by enabling a one-of-a-kind data storage pattern with the highest level of security. Blockchain technology and its significant benefits in healthcare are reviewed in this report. The paper gives a more in-depth look at the key features of the blockchain, as well the barriers to its adoption in the health sector. This review paper discusses few current Blockchain applications and challenges of adopting this technology.

1. **Blockchain technology overview:**

A blockchain is a decentralized, a digital ledger of transactions that is duplicated and distributed across the blockchain's complete network of computer systems. The blockchain's novelty is that it ensures a data record's accuracy and security while simultaneously building trust without the need for a trusted third party. A blockchain divides information into blocks, each of which contains a set of information. When a block is full, it is closed and linked to the preceding block, forming a data chain known as the blockchain.

Peer-to-peer technology is used to share this technology. There are no third-party obligations because transactions are handled directly between individuals.

A blockchain maintains digital ledgers with files, money tokens, smart contracts, media, health records, or codes in a safe manner due to hashing. This content is accessible to anyone with the right to access the ledger. So, a ledger that we keep on the network cloud is a chain of blocks (Blockchain). Every legitimate node in that network has access to the ledger and has an identical copy of it. Each node will view the same information that the others see on a block. The network will be more transparent because of this.

Because all network users can store and exchange information, and it keeps track of past and current state, it allows for trustworthy collaboration. As a result, the immutability and security of Blockchain have become well-known. On the blockchain, no data is saved in a single location. Instead, a network of computers copies and shares the Blockchain. To reflect new blocks, every computer connected to the internet updates its Blockchain.

1. **Types of blockchain:**

Every blockchain is made up of a network of nodes that are connected via a peer-to-peer (P2P) protocol. Every node in the network has a copy of the shared ledger, which is regularly updated. Each node can validate transactions, sending and receiving messages, and generating blocks. Some important types of blockchains are listed below.

* **Public blockchain**: It's a non-restrictive distributed ledger technology that doesn't require authorization. Anyone with an internet connection can sign up for a blockchain platform and join the network as an authorized node. A public blockchain node or user has access to current and historical records, can verify transactions, execute proof-of-work for incoming blocks, and mine. Cryptocurrency mining and exchange are the most basic uses of public blockchains. Public blockchains are mostly secure if users follow security rules and procedures. It is, however, only risky when the players fail to follow the security protocols. It mitigates the drawbacks of centralization, such as a lack of security and transparency. Rather of storing data in a single location, DLT disseminates data across a peer-to-peer network.
* **Private blockchain:** It is the restricted one that can only be used within a closed network. Private blockchains are often used within a corporation or organization where only a limited number of people are permitted to participate in a blockchain network. As a result, private blockchains are functionally equivalent to public blockchains, but their network is smaller and more restricted. Private blockchain networks are used in voting, supply chain management, digital identity, asset ownership, and other applications.
* **Consortium blockchain:** Itis a semi-decentralized kind in which a blockchain network is managed by multiple organizations. This contrasts with a private blockchain, which is controlled by a single organization. In this type of blockchain, more than one organization can operate as a node, exchanging information or mining. Banks, government agencies, and other institutions frequently use consortium blockchains.
* **Hybrid blockchain**: This combines the advantages of both private and public blockchains. It combines the benefits of both private and public blockchains, allowing for both private and public permission-based systems. Users may regulate who has access to which data is stored in the blockchain with a hybrid network. Only a portion of the blockchain's data or records can be made public, with the rest remaining secret on the private network. Users can simply join a private blockchain with numerous public blockchains because to the hybrid blockchain system's flexibility. Users can, however, publish it on the public blockchain to be confirmed. The hashing power of public blockchains is increased, and more nodes are involved in the verification process. This improves the blockchain network's security and transparency.

1. **Key Features and characteristics of Blockchain:**

* **Immutability:** Immutability refers to a blockchain ledger's ability to remain unchanged and untampered, making data manipulation impossible. Data can never be updated or modified once it is saved in a specific block, ensuring greater data security. The immutability of blockchain, which is achieved through cryptographic hashing, has the potential to reshape and transform the auditing process into one that is rapid, reliable, and cost-effective. It can also help to build confidence and verify the accuracy of health data used and transferred by organizations.
* **Decentralized:** Instead of a central authority, data is managed via a decentralized network. As a result, the entire network is based on the peer-to-peer or user-to-user model. Many businesses, including banks and governments, have begun to use blockchain to keep track of their information. This not only improves data transparency but also makes data traceability easier.
* **Enhanced Security:** The use of private and public keys to encrypt data ensures that it is totally secure. The information on the blockchain is cryptographically hashed. The network information hides the data's true nature. Public keys are generated at random as a long string and distributed to the whole network. The private key, on the other hand, is used as a password to access users' data.
* **Distributed ledgers**: Throughout the network's nodes, all stored data is shared many times. Anyone on the network can easily verify and view the data that has been provided. This also assures data security and synchronization with other files because the network's ledger is maintained by all other users on the system. The processing power was distributed across the computers to attain a better outcome. Most importantly, because there is no central location, the data cannot be manipulated or attacked.
* **Access control:** Data owners can grant, change, or withdraw permissions to access data via blockchain transactions. Importantly, data owners can handle different types of data differently and apply varying degrees of access security to them. Depending on the perspective of some start-ups, confidential medical data may be kept secret or shared to only a few entities, while less sensitive data may be donated or even sold. As a result, the blockchain may be used to enforce meta-consent in a practical way.
* **Consensus:** Blockchain relies on consensus algorithms to function. Every blockchain includes a consensus mechanism to help the network make decisions and to ensure decentralization. The nodes can achieve an agreement quickly and efficiently. When millions of nodes are validating a transaction, a system needs consensus to function properly.
* Anonymity, Transparency, faster settlement is some of the key characteristics of blockchain.

1. **Blockchain technology in healthcare and working:**

Graphical user interface

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The increasing digitization of the healthcare industry has resulted in large amounts of sensitive data being processed digitally. Healthcare data analysts and researchers around the world are struggling with multi-dimensional healthcare data generated from a variety of sources, including IoT devices that create a vast volume of medical data. Similarly, healthcare data providers are wary of disclosing sensitive medical information. The most essential healthcare big data stakeholders are currently patients, payers, suppliers, and analyzers. All of these parties must collaborate and communicate efficiently. Furthermore, because medical health data is dispersed throughout numerous health institutions, dealing it in a secure manner has become increasingly difficult. Many current healthcare systems that rely on centralization look to be at risk of failure and information infiltration as a result of an increase in cyber security attacks. Blockchain's decentralized storage, transparency, immutability, authentication, data access flexibility, interconnection, and encryption are built-in features that make it suitable for healthcare big data management. Today's demand is for high-quality health-care facilities that are supported by innovative technology. Furthermore, the health-care environment is shifting toward a patient-centered strategy that emphasizes two primary aspects that are accessible services and proper healthcare resources. People can participate in health research studies using Blockchain technology. Furthermore, improved research and sharing data on public well-being would improve treatment for various populations. When properly implemented, this technology improves security, data interchange, interoperability, integrity, and real-time updating and access. Data security is also a major concern, particularly in the domains of personalized medicine and wearable technology. Patients and medical demand a secure and simple method of collecting, sending, and consulting data through networks; as a result, Blockchain technology is being used to address these challenges.

**Working:**

Diagram

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* The interaction between a patient and their doctors and specialists generates the data.
* This information includes medical history, present problems, and other physiological data. Using the primary data acquired in the first stage, an EHR is generated for each patient. Other medical data, such as that generated by nursing care, medical imaging, and prescription history, is also stored in the EHR.
* Individual patients who own sensitive EHR are given unique access controls that are only available to the property's owner. Parties who want access to such sensitive data must submit a request, which is then passed to the EHR owner, who will decide who has access.
* Along with the database, blockchain, and cloud storage, are at the heart of the entire operation. Databases and cloud storage store records in a distributed fashion, a blockchain ensures extreme privacy and customizable authentic user access.
* Healthcare providers such as ad hoc clinics, community care centers, and hospitals are end-users who seek access to a secure and reliable care delivery system that will be permitted by the owner. For example, no matter where you are treated around the world, your health record will be available on your phone and validated using a distributed ledger like blockchain, which healthcare providers will continue to contribute to over time.

1. **Benefits of blockchain in healthcare:**
   1. Patient Data management

Patient record management is one of the most popular blockchain applications in healthcare. Patients can see their medical history in a transparent and open way when health information is stored on the blockchain. When all patient’s information is kept in one place, it is easier for patients and physicians to access it. When patients transfer to a different medical facility, they frequently must repeat the medical tests they had completed previously. This problem can be solved by storing data on a decentralized peer-to-peer network that can only be accessed via smart contracts. As a result, it aids new physicians in learning about previous patient histories, helping them to gain a better understanding of the problem and address it effectively. This helps patients save their money.

* 1. Patient Consent Management

The lack of full data ownership by a patient is one issue that is widely mentioned. Medical records can theoretically be used or shared without a patient's explicit consent. This problem is addressed by blockchain, which collects patient data and stores it in an organization's database. The patient's data access is governed by smart contracts. A patient can share their medical records on their own terms in this way. Furthermore, a patient can share their health data and sensor readings with their doctor by adding particular rules to these smart contacts, making long-term treatment far more effective and individualized to obtain the greatest results. Patients will be able to see when their medical records are updated and give explicit approval to share them with healthcare providers or others. Patients can also choose to share their medical records with researchers and establish temporal limitations on how long third parties can have access to their medical records. Without the time and cost of an intermediary, medical insurers may obtain quick, verifiable confirmation of healthcare services directly from patients.

* 1. Research and Development

Patients cannot edit or delete specific medical information added to their profiles by doctors, but they can limit access by allowing full or partial accessibility to other partners in the healthcare ecosystem. Patients, for example, may choose to share their whole medical information with a specialist but just non-identifiable data with scientific research corporations or other larger healthcare institutions. Patients might be rewarded for following a certain treatment plan or contributing their data for clinical research using these contracts. In research and clinical trials, blockchain has the ability to improve healthcare prior to treatment. Biological and health data are currently being manipulated and faked, resulting in lower study quality. Collaborative research can draw more attention if stakeholders can ensure the quality of the data.

* 1. Drug Supply chain

Authenticating the origin of medical items to determine their validity is a major concern in the healthcare industry, as it is in many others. When the manufacturing process is completed, the medicine is moved from production stocks to wholesale distributors, and then to retail companies, where it is sold to customers. On supply chains, blockchain technology can be used to track drug production and distribution. Customers can have complete visibility and transparency of the things they are purchasing by tracing items from the manufacturing site to each stage of the supply chain utilizing a blockchain-based system. It's also becoming more important for medical equipment, which is rapidly expanding as more remote health monitoring is implemented, attracting unethical operators' interest. With blockchain characteristics namely transparency, immutability, and interoperability, drug supply chain management becomes safer and more accountable. As a result, pharmaceutical businesses can register their products on the blockchain and follow their progress from the point of origin to the point of sale. Thus, drug recalls are more straightforward, and counterfeiting is reduced. Any data or service provider in the healthcare supply chain can inspect the transaction.

* 1. Security, Immutability and traceability

The qualities of the blockchain can considerably improve the security of health data. Each person has a public identifier or key as well as a private key that can only be used for specified time. In addition, the requirement to target each user individually to obtain important information would put a stop to hacking. With complete transparency, blockchain can protect and identify the trail of pharmaceutical supply.

Each patient's medical record is copied and kept on multiple nodes in the blockchain network, ensuring that these records are transparent and free of tampering. Blockchain technology ensures data integrity and aids in the resolution of the issue of incorrect data reporting. It also improves the accuracy of data analyses performed on clinical trial data by increasing transparency. Clinical supply chain tracing and checking, restoring trial data credibility, patient recruiting, and reducing total trial time are all concerns that blockchain can help with in clinical research.

* 1. Insurance and Billing

Patient billing inefficiencies affect the healthcare business, with overbilling accounting for an estimated 5-10% of total healthcare expenses. By automating the entire process with blockchain, claims adjudication, for example, can be considerably more accurate and easier on the patient. When it comes to healthcare, agreements tend to be more complicated to be legally defendable. Instead, they should concentrate on clearly and transparently explaining the price of healthcare services to patients. Having shared digital contracts between manufacturers, distributors, and healthcare institutions maintained on a blockchain ledger might considerably reduce disputes about payment claims for prescription drugs and other items, rather than each stakeholder having their own version of contracts. Smart contracts enabled by blockchain eliminates the possibility of a double interpretation.

1. **Challenges to incorporate blockchain technology in healthcare**
   1. **Scalability:**

Another restriction of the blockchain system is scalability, as the number of blocks grows, the system becomes slower and requires more computational power and energy to operate. This can be made considerably more difficult in an IoT setting, where data must flow in real time.

Private clinics, healthcare centers, rural hospitals, health research agencies, insurance providers, and individual patients are used by millions of individuals. It's highly unlikely that they'll all be able to maintain the same decentralized blockchain architecture. Additionally, blockchain technology necessitates requirements of experts and professionals to install or develop this technology. The scalability issue for healthcare big data must be overcome if blockchain is to become widespread.

* 1. **Data Storage:**

In healthcare and medical records, patients and wearable IoT devices generate a massive amount of data. Due to the technical and capacity limits of replicating the blockchain across every network participant, blockchain is not well-suited to storing large amounts of data (node). Large records, such as complete electronic medical records or genetic data records, would be inefficient and costly to store on the blockchain. Due to its ledger history, blockchain may have difficulty supporting large data sets such as MRI and CAT scan images in a single transaction. Huge files will have to be kept and tracked in backend repositories and encoded libraries.  Large storage space is required for data such as a patient's medical history, test reports, X-rays, the number of hospitalized patients, and mortality. Because of the increased database size, record searching, and information access become slower, which is inconvenient for applications where speed is critical.

* 1. **Lack of governance/ proper laws:**

Another challenge is lack of governance. Ensuring that blockchain technology works with privacy laws and regulations in various countries is not easy. The policies that regulate blockchain technology vary from one jurisdiction to the next. Furthermore, the lack of clarity on compliance is an obstacle to blockchain adoption in businesses. The legislation and regulations that govern blockchain technology are still in their infancy. Because these rules and regulations are expected to be mature, organizations should keep an eye on how the regulatory system evolves. Tokenization has become a tough topic due to a lack of legislative clarity on tokenized assets, as well as a reliable way to ensure interoperability. Data ownership, access rights, and the distributed storage mechanism of blockchain should all be properly described. Healthcare businesses should identify regulatory needs and provide suggestions to regulators in a clear and concise manner.

* 1. **Adoption challenges:**

Blockchain is not a simple application or a platform that can be added to the IT stack. One of the most significant issues is incorporating blockchain with existing systems. In order to transmit to the blockchain system, healthcare companies must rethink their existing operations.  It is a big problem since it demands significant changes in present processes like careful planning, financial resources, and human experience to enable the smooth integration of blockchain technology into the healthcare sector. To use blockchain properly, entire processes must alter, workflows must evolve, tech stacks must be adapted to leverage the capability's true benefits, and ideas about how to run a business must move radically. Similarly, to ensure that blockchain-based solutions work properly, certain medical professionals will need to master the fundamentals of blockchain technology. This level of change is obviously difficult to implement across large businesses, especially in an industry where clinical and administrative use cases are both complex. Only few organizations that are ready to move beyond tests and adjust processes and tech stacks to capitalize on the potential of blockchain can overcome their apprehension to adopt it.

* 1. **Protocols/regulations:**

Every validator on the network must verify every transaction if the developing blockchain uses PoS as its consensus algorithm. As a result, depending on the data load, the network becomes noticeably slower which is bad during emergency cases. Furthermore, if access to their information is not previously approved by a doctor, during an emergency, the situation gets difficult. Due to the existing lack of proper methods, patients are often hesitant to participate or provide their consent to data sharing. To accomplish the efficiency of blockchain, protocols related to security, storage, validation, and access must avoid latency and meet throughput criteria.

* 1. **Security risks:**

In blockchain-based healthcare applications, interpretability is a major challenge that cannot be ignored. Sharing patient health data with researchers puts the patient's privacy at risk making reidentification possible. However, efforts to improve patient privacy in blockchain environments and build blockchain features for privacy are still in the early stages of development, and there is no guarantee that privacy will be preserved. A 51% assault is most likely to affect private permissioned blockchains. This occurs when an attacker compromises the central trustworthy node; because transaction validation is centralized, the attacker acquires the ability to control the network's processing power, leading a transaction to occur twice. This has significant consequences for data integrity and service availability, both of which are crucial in healthcare applications.

* 1. **Downside of Immutability:**

While blockchain's immutability is a plus for counterfeit records or pharmaceuticals, it eliminates the option of data manipulation when it's genuinely needed. For data alteration, all nodes must agree, or a new block must be created. In this case, data accuracy plays are very important because we need to make sure that the data to be stored in blockchain must be correct. When sections of a patient's health record are missing, the record's credibility and value are severely diminished.

* 1. **Infancy stage:**

Blockchain applications are still in their infancy, and more work in terms of technical discovery and research is required.

* 1. **Social Acceptance**

A cultural transformation is required in order for blockchain to be implemented in the healthcare industry. To provide the requisite processing power for both transaction blocks and cryptocurrency creation, blockchain technology needs the usage of a network of networked computers.

Incentive techniques should be used to encourage participants to contribute computing resources. Furthermore, healthcare organizations may require motivation to use blockchain technology and join the shared network.

1. **Current Applications**

Below are some applications that uses blockchain technology.

Graphical user interface, diagram, application, PowerPoint

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* Chronicled- MediLedger Network:

Helps Automating transactions between trading partners in Life Sciences Industry through the Mediledger network. In its MediLedger Network, Chronicled uses blockchain technology to connect trading partners and medical institutions closer together than ever before.

Source: <https://www.chronicled.com/>

* Patientory

Patientory is developing a blockchain-based health information exchange (HIE) to facilitate EMR interoperability and improve cybersecurity protocols. This application provides consumers with actionable health data insights, motivating them to take control of their health results.

Source: <https://patientory.com/>

* Healthverity

Curisium, acquired by Healthveirty in 2020 helps providers and payers to participate in novel contractual arrangements that are efficient and secure by building a technology that facilitates this process. Overall, Healthverity's acquisition has resulted in substantial customization and seamless automation of workflows, allowing for greater collaboration and cost savings for all parties involved.

Source; <https://healthverity.com/>

* Medicalchain

Medicalchain stores health records securely and maintains a single version of the accuracy using blockchain technology. Different organizations, including as doctors, hospitals, laboratories, pharmacies, and health insurance, can request permission to view a patient's record and record transactions on the distributed ledger to serve their purposes.

Source: <https://medicalchain.com/en/>

* Avaneer

To enable for secure data transmission between healthcare organizations, Avaneer Health uses blockchain and FHIR (Fast Healthcare Interoperability Resources) technology. The network makes use of blockchain technology to assure data privacy, security, and content-based use, as well as community-based participation on collaborative processes.

Source: <https://avaneerhealth.com/>

1. **Conclusion**

Using distributed ledger to implement blockchain in healthcare apps would provide the applications with good security mechanisms and easy access. However, in order to implement a successful blockchain, the industry requires more organizations to commit for transforming their general mentality to reflect these ideas.

Using a private or hybrid blockchain with well-defined consensus under governance, including storage optimizing techniques may improve the blockchain

The complete integration of Blockchain in healthcare is risky, due to major challenges as mentioned in this paper and it is also a very long way to go.

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**Section B**

**Cryptozombies: My learning review**

The Lessons I’ve completed and concepts I’ve learned:

Graphical user interface, application

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Lesson 1: Making the Zombie Factory

This lesson walks through creating a simple contract in solidity.

I’ve learned that, to specify which version of Solidity, use the command “**pragma solidity**”. Use “**contract** *contractName*” to create a contract. Solidity supports both fixed and dynamic arrays.

It introduces public/private functions and also to use “view” when there is no modifying the data. It also explains about “events” which communicates with front-end. By the end of this lesson, a solidity contract “*ZombieFactory*”. Created function that takes a name and generates a random zombie, which is then added to blockchain-based zombie database.

Lesson 2: Zombies Attack their victims

The chapter introduces mappings which is used for storing the data. We can use “**msg.sender**”, a global variable which refers to address of smart contract. Use “require” to make function throw an error when a condition is false. It explains concept of inheritance using “is” and how to use other files into a file using “**import**”. A newZombie’s DNA is calculated and the next chapter explains Functions can be internal or external, in addition to public and private. Internal is similar to private, but it is also available to contracts that inherit from the one that contains current function. Externals are identical to publics, but they can only be called from outside the contract, not from within it. You'll be shown how to get a cryptokitty(Zombie’s food) from their contract and combine it with your Zombie's DNA. This lesson made us to multiply zombie army by feeding.

Lesson 3: Advanced Solidity Concepts

This lesson is more about technical aspects of Ethereum developments. Ethereum contracts are immutable, it might be a good idea to split your project into numerous contracts, each of which could be modified later by referencing a new contract with updated code. It is standard practice to include ownership information in contracts.  Constructors are a type of function that has the same name as the contract and executes only once: when the contract is created. A “**modifier**” can be placed on the top of a function, usually to check for prerequisites before the function runs and arguments can be passed to these function modifiers. This lesson introduces concept of “gas” where users must pay when a function of DApp is executed. This lesson basically teaches us proper way of mapping zombies to owners.

Lesson 4: Zombie Battle System

“**payable**” functions can receive Ether. “msg.value” can be used to see how much ether was sent to the contract. “**transfer**” function can be used to send money to any Ethereum address. This lesson defines the rules of zombie attacks using attack function, incrementing winCount and lossCount values.

Lesson 5: ERC721 & Crypto Collectables

The first chapter explains about tokens: Within Ethereum, ERC20 tokens are ideal for representing alternative currencies but they are not interchangeable. Collectibles and other non-fungible assets are well represented by ERC721 tokens. Multiple token contracts are implemented. It also walks us through the transferring of token ownership.

Lesson 6: App Front ends & Web3.js

This lesson explains how to use Web3.js to connect with smart contract and create a basic front-end for the DApp.

\*\* I was able complete around 50% of lesson 5 and 25% of lesson 6

Thank you.