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A BLOCKCHAIN BASED SYSTEM FOR HEALTHCARE DIGITAL TWIN

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Abstract— Digital Twin (DT) is an emerging technology that replicates any physical phenomenon from a physical space to a digital space in congruence with the physical state. However, devising a Healthcare DT model for patient care is seen as a challenging task as the lack of adequate data collection structure. There are also security and privacy concerns as healthcare data is very sensitive and can be used in malicious ways. Because of these current research gaps, the proper way of acquiring the structured data and managing them in a secure way is very important. In this article, we present a mathematical data model to accumulate the patient relevant data in a structured and predefined way with proper delineation. Additionally, the provided data model is described in harmony with real life contexts. Then, we have used the patient centric mathematical data model to formally dene the semantic and scope of our proposed Healthcare Digital Twin (HDT) system based on Blockchain. Accordingly, the proposed system is described with all the key components as well as with detailed protocol flows and an analysis of its different aspects. Finally, the feasibility of the proposed model with a critical comparison with other relevant research works have been provided.

I. INTRODUCTION

According to the latest statistics from the World Health Organization, about 930 million people worldwide are at risk of falling into poverty due to out-of-pocket health spending of 10% or more of their household budget [1]. Currently, there is a surge in improving the healthcare situation and a myriad of developments are ongoing in the healthcare sector with respect to Artificial Intelligence [2]_[4], Big data [5], [6], and in other spectrum. Though, it is not something that can be assuaged outright, whereas the real problem is not in the slow advancement of the technology, rather the mishaps in real life, e.g., adverse events, late diagnosis, etc [7]. DT can bring an immediate alteration in the healthcare sector from its root by incorporating analysis, predictive measurements, decision making paradigm, and data collection [8].

There are some notable developments in the healthcare sector incorporating DT. Martinez-Velazquez *et al.* [9] have developed a cardio twin based on the heart that can mitigate the risk of any Ischemic heart disease. Barbiero *et al.* [10] have proposed a general framework to provide a panoramicview over current and future physiological conditions. However, the recent developments in DT for the healthcare sector, have some drawbacks from the perspective of data sharing, storage, and access control [11]. Also, without any proper framework, collecting a large amount of data haphazardly will cause a disarray which will perpetuate when involving other data transformation techniques [12]. For these reasons, it is a prominent task to decide in which way DT will perceive which healthcare data from which dimensions [13]. To solve these problems, we propose a structured mathematical data model to collect the patients' data in a systematic and prede _ned way so that a cluster of acute information about a physical patient and its surrounding environments can be accumulated while they are at the hospital. With the proposed data model the patient can be individually identified as well as the patient portfolio can be concocted with the clinical data.

It is often reported that people show a lack of concern regarding the security of the health data which leads to integrity and confidentiality breaches [14]. Around 881 breach reports have been recorded within the last 24 months and are under investigation by the U.S. Department of Health &

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Human Services [15]. Therefore, to effectively solve this problem, a system is needed that can store and keep data securely with proper structure. Moreover, around 60% of the counties in the world have the capacity to review the progress and performance of the healthcare systems and around 59% can use data to drive policies and planning for the health sectors [16]. To cover these wide distributed nationwide healthcare sectors, having the mentioned potentials, a distributed network can be implemented by enforcing a distributed storage facility without any central governing authority [17]. For this reasons, the block chain technology can be integrated with DT to accumulate this insurmountable health data in a structured and distributed way with adequate security properties. In a block chain based DT system for healthcare, block chain renders the services of collecting intricate and diverse data immutably with proper access and sharing mechanism, on the other hand, DT provides proper data analysis, aggregation, prognosis, and representation services which are conducive to build a proper healthcare DT. To mitigate these issues, in this article, we present a concrete mathematical model for patients' clinical data and then propose a block chain based Healthcare Digital Twin system based on the presented data model.

II. OBJECTIVES

The patient centric mathematical data model to formally define the semantic and scope of our proposed Healthcare Digital Twin (HDT) system based on Block chain. Accordingly, the proposed system is described with all the key components as well as with detailed protocol flows and an analysis of its different aspects. Finally, the feasibility of the proposed model with a critical comparison with other relevant research works have been provided.

III. LITERATURE SURVEY

1) A Comprehensive Survey of the Internet of Things (IoT) and AI-Based Smart Healthcare

Smart health care is an important aspect of connected living. Health care is one of the basic pillars of human need, and smart health care is projected to produce several billion dollars in revenue in the near future. There are several components of smart health care, including the Internet of Things (IoT), the Internet of Medical Things (IoMT), medical sensors, artificial intelligence (AI), edge computing, cloud computing, and next-generation wireless communication technology. Many papers in the literature deal with smart health care or health care in general. Here, we present a comprehensive survey of IoT- and IoMT-based edge-intelligent smart health care, mainly focusing on journal articles published between 2014 and 2020. We survey this literature by answering several research areas on IoT and IoMT, AI, edge and cloud computing, security, and medical signals fusion. We also address current research challenges and offer some future research directions.

2) A Novel Cloud System for Mobile Health Big Data Management

The era of big data continues to progress, and many new practices and applications are being advanced. One such application is big data in healthcare. In this application, big data, which includes patient information and measurements, must be transmitted and managed in smart and secure ways. In this study, we propose a novel big data cloud system, s2Cloud, standing for Smart and Secure Cloud. s2Cloud can enable health care systems to improve patient monitoring and help doctors gain crucial insights into their patients' health. This system provides an interactive website that allows doctors to effectively manage patients and patient records. Furthermore, both real-time and historical functions for big data management are supported. These functions provide visualizations of patient measurements and also allow for historic data retrieval so further analysis can be conducted. The security is achieved by protecting access and transmission of data via sign up and log in portals. Overall, the proposed s2Cloud system can effectively manage healthcare big data applications. This study will also help to advance other big data applications such as smart home and smart world big data practices.

3) ModelChain: Decentralized Privacy-Preserving Healthcare Predictive Modeling Framework on Private Blockchain Networks

Cross-institutional healthcare predictive modeling can accelerate research and facilitate quality improvement initiatives, and thus is important for national healthcare delivery priorities. For example, a model that predicts risk of re-admission for a particular set of patients will be more generalizable if developed with data from multiple institutions. While privacy-protecting methods to build predictive models exist, most are based on a centralized architecture, which presents security and robustness vulnerabilities such as single-point-of-failure (and single-point-of-breach) and accidental or malicious modification of records. In this article, we describe a new framework, ModelChain, to adapt Blockchain technology for privacy-preserving machine learning. Each participating site contributes to model parameter estimation without revealing any patient health information (i.e., only model data, no observation-level data, are exchanged across institutions). We integrate privacy-preserving online machine learning with a private Blockchain network, apply transaction metadata to disseminate partial models, and design a new proof-of-information algorithm to determine the order of the online learning process. We also discuss the benefits and potential issues of applying Blockchain technology to solve the privacy-preserving healthcare predictive modeling task and to increase interoperability between institutions, to support the Nationwide Interoperability Roadmap and national healthcare delivery priorities such as Patient-Centered Outcomes Research (PCOR).

4) A New Concept of Digital Twin Supporting Optimization and Resilience of Factories of the Future

In the context of Industry 4.0, a growing use is being made of simulation-based decision-support tools commonly named Digital Twins. Digital Twins are replicas of the physical manufacturing assets, providing means for the monitoring and control of individual assets. Although extensive research on Digital Twins and their applications has been carried out, the majority of existing approaches are asset specific. Little consideration is made of human factors and interdependencies between different production assets are commonly ignored. In this paper, we address those limitations and propose innovations for cognitive modeling and co-simulation which may unleash novel uses of Digital Twins in Factories of the Future. We introduce a holistic Digital Twin approach, in which the factory is not represented by a set of separated Digital Twins but by a comprehensive modeling and simulation capacity embracing the full manufacturing process including external network dependencies. Furthermore, we introduce novel approaches for integrating models of human behavior and capacities for security testing with Digital Twins and show how the holistic Digital Twin can enable new services for the optimization and resilience of Factories of the Future. To illustrate this approach, we introduce a specific use-case implemented in field of Aerospace System Manufacturing.

5) Experimentable Digital Twins—Streamlining Simulation-Based Systems Engineering for Industry 4.0

Digital twins represent real objects or subjects with their data, functions, and communication capabilities in the digital world. As nodes within the internet of things, they enable networking and thus the automation of complex value-added chains. The application of simulation techniques brings digital twins to life and makes them experimentable; digital twins become experimentable digital twins (EDTs). Initially, these EDTs communicate with each other purely in the virtual world. The resulting networks of interacting EDTs model different application scenarios and are simulated in virtual testbeds, providing new foundations for comprehensive simulation-based systems engineering. Its focus is on EDTs, which become more detailed with every single application. Thus, complete digital representations of the respective real assets and their behaviors are created successively. The networking of EDTs with real assets leads to hybrid application scenarios in which

EDTs are used in combination with real hardware, thus realizing complex control algorithms, innovative user interfaces, or mental models for intelligent systems.

IV. EXISTING SYSTEM

Peng *et al.* [53], in their article have presented a construction case on hospital DT in China, which had already been built. The authors have delineated how the hospital twin has been developed based on Continuous Lifecycle Integration method. A lot of sensors, for acquiring real time data of the hospital, have been planted during construction and the whole system can be controlled from a single point through DT. However, there is nothing mentioned about access control and encryption mechanisms for the collected data.

Liu *et al.* [54] have proposed a cloud based framework with healthcare DT. The reason behind the project is that there are elder people who hardly take medical services because of their indifference toward diseases. The authors have developed the system comprising of 4 parts: Physical object, Virtual object, Cloud healthcare service platform, and healthcare data. Although, some important aspects have been described, however, no algorithm has been mentioned for the predictive measures.

Shamanna *et al.* [55], introducing Precision Nutrition to DT. The paper is about Twin Precision Nutrition (TPN) which monitors a group of 64 years old type 2 diabetic patients to reduce HbA1c in blood. The platform collects data from body sensors and a mobile app (TPN) to track and analyze the body health signals in order to personalize the patients' treatment. Although the system is devising results based on real time data, the authors have not provided any mechanism by which they have conducted the analysis.

Barbiero *et al.* [56], in their article have proposed an architecture combining the qualities of a generative model with a graph-based representation of pathophysiological conditions.

In [57], Petrova *et al.* have proposed a DT platform for exploring the behavioral changes in patients with proven cognitive disorders with a focus on multiple sclerosis. One of the primary components of this platform is functionality for collecting data for the DT.

Disadvantages

- The system is not implemented public blockchain and only implemented private blockchain in which security is very less.
- The data is not accumulated while patient goes through disease
- assessment phase..

V. PROPOSED SYSTEM

1) A patient centric mathematical data model to represent the patient data in a defined and structured way.
2) The proper delineation of the clinical data with rea life contexts which will be perceived by DT while the patient is on the treatment phase.
3) A blockchain integrated Healthcare Digital Twin System architecture based on the proposed data model with proper threat modeling and requirement analysis.
4) A number of protocol flows utilizing the blockchain based system which showcases how the system can be utilized in different scenarios.
5) A detailed analysis of the proposed system covering its feasibility, advantages/disadvantages, comparisons with Health Insurance Portability and Accountability Act (*HIPAA*) [18] and the General Data Protection Regulation (*GDPR*) [19] as well as with other existing research works.
6) Finally, the limitations and the future scopes of the presented system.

Advantages

- The system is implemented DT which stands for the representation of the anatomy of a digital asset in a digital space which is the depiction of a physical phenomena from a physical space.
- In the proposed system, the system is implemented DIGITAL TWIN FOR DEVELOPING A PRODUCT and DIGITAL TWIN FOR AN INDIVIDUAL INSTANCE which are more secure and safe.

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VI. MODULES

1) Hospital

In this module, the Admin has to login by using valid user name and password. After login successful he can do some operations such as Login, View Physicians, View Brad Details, View All Patient Records, Views All Medication Transactions, Generate Disease Hash Code, Views All Disease Records By Block chain, View Disease Results.

2)Physician

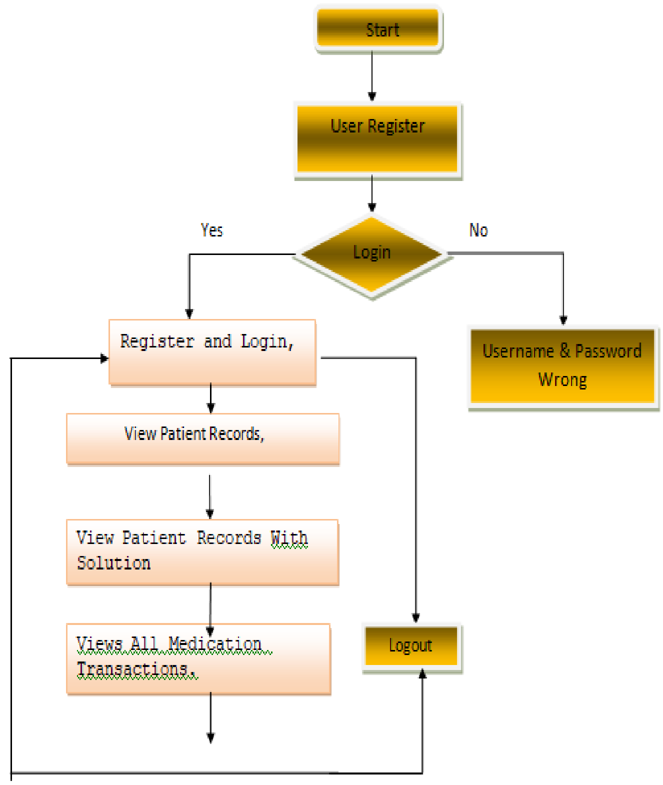
In this module, there are n numbers of users are present. User should register with group option before doing some operations. After registration successful he has to wait for admin to authorize him and after admin authorized him. He can login by using authorized user name and password. Login successful he will do some operations like Register and Login, View Patient Records, View Patient Records With Solution, Views All Medication Transactions.

3) Brad

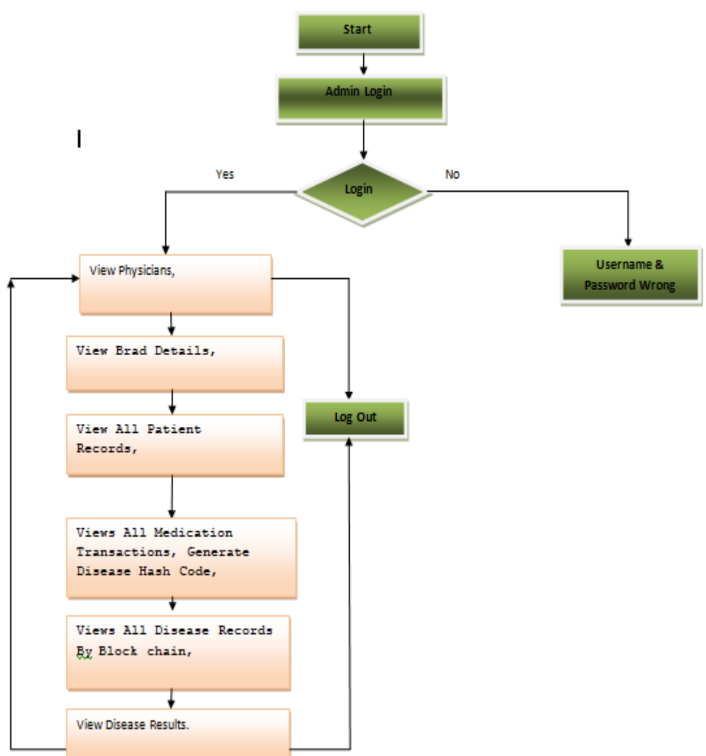
In this module, there are n numbers of users are present. Transport Company user should register with group option before doing some operations. After registration successful he has to wait for admin to authorize him and after admin authorized him. He can login by using authorized user name and password. Login successful he will do some operations like Register and Login, View Patient Records, View Patient Records With Solution, Views All Medication Transactions.

VII. DESIGN AND ALL DIAGRAMS

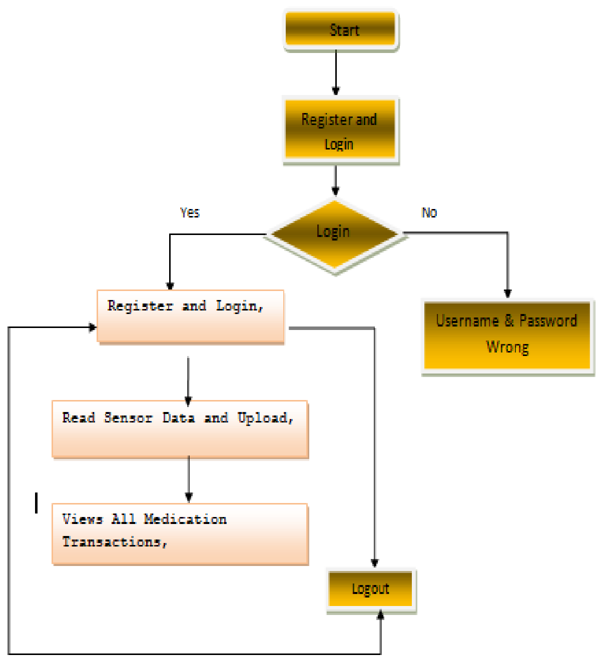
1) Flow Chart --- Physician



2) Flow Chart : Hospital



3) Flow Chart : Brad



VIII. FUTURE WORK

In this future works.

- The proposed system model can bring a new spectrum in the domain and in future we will develop and implement the proposed system and examine its pragmatic influence and performance.
- As HDT can be used for simulation, forecasting and estimation of future health conditions, it would be useful to develop a predictive system on top of the proposed architecture. In future, once the system has been developed, there will be scopes to explore how these aspects can be accommodated for the proposed HDT.
- In future, we will also investigate how to add additional features which could remove dissimilarities between HDT and HIPAA as well as between HDT and GDPRas mentioned in Section VIII-E.

IX. CONCLUSION

At present, many developments are going on in order to subside the uncertain health mishaps. Artificial Intelligence, Big data, and many more techniques are being used without any due consideration of how this vast and diverse data can be accumulated from the real world conveniently and store them securely. The digital twin technology can enable an effective way for collecting data and generating insight through analysis. But this data, being generated through numerous processes, needs to be systematically stored with proper security and handled by a compact system, which can also render all the requirements to create a digital twin in the healthcare sector. With these motivations in mind, our article presents a concrete mathematical model of Digital Twin for healthcare, proposes the Healthcare Digital Twin (*HDT*) system and provides the protocol flow for the system to coincide with the mathematical model.

The main contributions of this article are the following. The *HDT* is proposed with the incentive of remedying the segregated data collection process by incorporating a defined mathematical data model with which patient relevant data can be collected in a regulated way. The model has emphasized three core stages: Pre-Hospital Admit, Patient Disease Diagnose, and Surgical Operative Procedure, as these stages present the three most important stages for a patient. Next, the architecture of the system, being integrated with block chain, is constructed with the defined data model in consideration, so that users can use the data for other purposes without any conflicts. With proper protocol flows, there are some illustrations of how the system can be used for different use cases.

It is understandable that, even with the state-of-the-art technologies, a digital twin of a full patient body is still out of reach because of the extant nuances in the human body. There are a raft of opportunities to decrease this gap. We strongly believe that the proposed model and system in this article will be a step towards fulfilling this goal. In future, we will develop the proposed system and examine its applicability and performance.

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