Digitization and e-Verification of Medical Certificates in Alimosho General Hospital, Lagos, Nigeria.

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***Abstract* – Medical Certificates are legal documents issued by Hospitals to the patient. These certificates will be evidence to their employer, and insurance companies that they are fit to take on employment, and insurance claims of entitlement in Nigeria. Over the years, Alimosho General Hospital has been faced with the challenges of fake medical certificates issued by the hospital which has led to the death of the citizen, racketeering, and diminishing of the hospital's reputation.**

This paper presents a study that explores the importance of digitizing medical certificates and implementing e-verification systems in the healthcare sector by introducing unique QR codes on each certificate issued by the hospital for instant verification and authenticity of the document. It proposes this by converting hardcopy certificates, generating unique QR codes and establishing secure e-verification using a react-based application to design an interactive webpage that will store medical certificates in, a MySQL database. The certificates will then be used to generate unique QR codes and registered in a Hyperledger Fabric blockchain for e-verification. The paper recommends opportunities for implementing digital certificates and e-verification, along with the challenges encountered.

Index Terms – Medical Certificate, QR code, Blockchain, Hyperledger, Smart Contract.

I. INTRODUCTION

Medical certificate is a critical document when it comes to making a claim for leave from work and insurance. Moreover, if the certificate is issued manually; authenticity is a big concern. To validate manually issued medical certificates. This incurred additional time and money. In recent years, digitizing and verifying medical certificates have become critical in global healthcare [1], [2]. Digitization reduces errors and loss, while e-verification prevents fraud and ensures trust in the healthcare system. Robust infrastructure, data security regulations, and stakeholder engagement are crucial for success [3]. This approach could revolutionize healthcare in Nigeria and beyond, ensuring data integrity, accessibility, and security. Due to this advancement, ICT-driven projects in Nigeria aim to enhance healthcare efficiency and data security by digitizing medical certificates. This would aid the health sector to overcome the manual certificate validation process, reduce time, and cost and make the validation process more efficient [3]. Furthermore, digitizing medical certificates will contribute to consistent outcomes.

There are other tools/solutions such as Electronic Health Record (EHR) systems, digital signature solutions, blockchain technology, health information exchange (HIE) platforms, data security solutions, biometric authentication, collaboration and communication platforms, compliance management software, mobile health (mHealth) applications, training and education platforms, cloud-based solutions, and government support for policy development [4], [5]. Blockchain, a secure and distributed database, ensures data integrity through cryptographic hashing and a chain of interconnected blocks. Its tamper-proof nature aids in issuing and verifying medical certificates, reducing fraud, and empowering patients to manage their records [6].

This technology significantly enhances healthcare data management, offering decentralized storage, transparency, and robust security. Smart contracts streamline operations by defining terms and conditions, reducing intermediaries, and cutting administrative costs [7]. Its versatile applications in healthcare include improving mobile health apps, monitoring devices, and facilitating secure data sharing and storage [8]

This paper aim is to countermeasure manual medical certificate issuance and verification process by adopting digitization incorporating smart contracts on blockchain. While the objectives are to convert hardcopy certificates to digitized ones, generate unique QR codes using the QR code Monkey platform and establish secure e-verification by storing the digitized medical certificate using Hyperledger fabric. In comparison to existing solutions such as Electronic Health Record (EHR) systems, digital signature solutions, and health information exchange (HIE) platforms, blockchain technology emerges as a secure and distributed database offering tamper-proof data integrity through cryptographic hashing. Blockchain's unique attributes, including decentralized storage, transparency, and robust security, position it as a valuable tool for issuing and verifying medical certificates [9]. The introduction of smart contracts further streamlines operations by defining and enforcing terms and conditions, reducing reliance on intermediaries, and cutting administrative costs [10].

This secure peer-to-peer network fosters trust in business transactions and is categorized into Permissionless and

Permissioned Blockchains, each serving distinct purposes in the healthcare domain [11]. This paper will explore and implement an e-verification system to validate medical certificates issued by Alimosho General Hospital in Nigeria. The rest of the paper is organized as follows.
Section II dwells on a literature review on digitization in healthcare. Furthermore, the methodology selected for this work is described in Section III. Moreover, Implementation and results are then discussed in Section IV. Lastly, Section V concludes the complete work in this paper.

II. Literature Review

Digitalization holds promise for addressing healthcare challenges in Nigeria, where a population of 206 million faces inequitable access to medical services. Implementing digital health solutions, such as telemedicine, can transcend geographical barriers and enhance healthcare delivery. Systematic health data collection supports evidence-based care and timely interventions. A supportive ecosystem, including institutional frameworks, infrastructure readiness, and forward-looking policies, is crucial for the success of digital healthcare. The Nigerian government's initiative, the NIGCOMHEALTH platform, aims to provide digital health services to 1.7 million citizens, particularly in remote areas. Market trends project a substantial growth rate of 14.96% in the Digital Health market from 2023 to 2027, reaching a market volume of US$1466.00m by 2027 [12]. This illustrates the transformative potential of technology-driven healthcare, fostering innovation and benefiting both startups and health professionals.

Blockchain technology is reshaping the healthcare sector by providing a secure and efficient way to store and share patient data among different entities including hospitals, labs, pharmaceutical companies, and medical professionals. The implementation of platforms such as Hyperledger Fabric, overseen by the Linux Foundation, ensures robust security and adaptability [13]. Emphasizing the significance of protecting patient privacy during data sharing for research or commercial purposes, the article addresses concerns regarding data confidentiality and consent. The decentralized and secure nature of Blockchain guarantees that only authorized institutions can access sensitive patient information, thus mitigating privacy risks [13]. Furthermore, the article highlights the potential of Blockchain to revolutionize various industries by offering enhanced data security and privacy, owing to its decentralized, immutable, and transparent nature.

Blockchain technology has also found application in the deployment of electronic health records (EHRs), with a focus on precise access controls and resolving scalability issues. Additionally, it has been utilized to safeguard medical information, regardless of cloud computing integration, contributing to the development of healthcare 4.0 technology [14]. The importance of Blockchain in enhancing EHR compatibility and interoperability has been underscored through a comprehensive examination of 18 Blockchain-driven solutions, which revealed both potential benefits and existing limitations [15]. Furthermore, the integration of Blockchain technology into cloud environments has been demonstrated to improve the secure exchange of EHR data, ensuring data integrity, confidentiality, authentication, availability, and streamlined user data access control.

A system leveraging Blockchain technology has been proposed to empower patients in managing and safeguarding their data, enabled by the Ethereum network and various programming languages and tools. The system securely stores patient data and executes decentralized operations through Blockchain smart contracts, ensuring high levels of security and privacy.

Smart contracts, or chain code in Hyperledger Fabric, are decentralized applications securing blockchain operations, functioning as the logic of a blockchain app [16]. Key considerations include concurrent execution, dynamic deployment, and treating app code as untrusted. The order-execute architecture common in blockchain platforms demands deterministic smart contracts and limits scalability. Several countries, including Estonia, Switzerland, and the United States, have embraced blockchain in various sectors, including healthcare. Nick Szabo introduced the concept of smart contracts in 1994, anticipating features like automation and security without intermediaries [17]. Solidity is the primary language for developing smart contracts, enabling their deployment and execution on the Ethereum blockchain [18]. They automate contract processes, minimize costs, and rely on secure blockchain technology, although legal recognition and security remain concerns.

III. Methodology

A. *Overview of Data Collection and Design*.

The primary objective of this research is to develop a digital system that enhances the verification of medical certificates using QR codes and Hyperledger Fabric blockchain technology. The study encompasses a comprehensive methodology that outlines the research design, framework, sampling methods, data collection, analysis procedures, and ethical considerations. It specifically emphasizes the use of qualitative analysis for online survey questionnaires obtained from clients and staff of Alimosho General Hospital to deduct the perceived usefulness (PU), perceived ease of use (PEOU), compatibility (CPT), relative advantages (RAD) and complexity (CPX) from the selected participant respond as represented in the Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT) to understand the adoption of digital innovations in healthcare. The research employs a random sampling technique, surveys both staff and patients and utilizes statistical software for analysis, aiming to assess the feasibility and acceptance of the proposed system in Alimosho General Hospital.

The research's significance lies in its potential to enhance healthcare verification processes, emphasizing the importance of digitization and blockchain technology in healthcare. By aligning with TAM's principles of perceived usefulness and

ease of use, and adhering to ethical standards, the study aims to contribute valuable insights that can improve healthcare delivery through the adoption of digital verification systems.

B. *Architecture Diagram and Discussion*

For the effective implementation of any information technology, gaining user acceptance of that technology holds paramount significance. The need to embrace information technology more can lead to its inadequacy or sluggish adoption within healthcare. The deficiency in technology acceptance profoundly impacts critical goals, such as managing and storing patients' data. The acceptance of technology serves as an indicator of a favourable psychological disposition towards adopting pioneering technological solutions [19]. This Study is builds on a literature review emphasizing the importance of digitization and the acceptance of emerging technologies, especially blockchain, in healthcare. It examines into technology adoption, digital transformation, and healthcare management principles. The aim is to integrate theories such as the Technology Acceptance Model (TAM) and the Innovation Diffusion Theory, focusing on adopting digital innovations in healthcare organizations. The proposed research model follows the TAM belief-attitude-intention-behaviour framework based of survey respond form the client and staff of the hospital. The hypotheses (H) are:

H1: User Behavioural intention (BI) positively affects actual proposed system use.
H2: Attitude toward usage (A) positively influences BI for proposed system use.
H3: Perceived usefulness (PU) positively impacts BI for proposed system adoption.
H4: PU positively influences attitude (A) towards proposed system use.
H5: Users' ease of use perception (PEOU) positively influenced their attitude (A) towards using proposed system.
Early studies linked users' prior experiences with compatible technologies to their adoption of new ones, impacting their belief in ease of use. Compatibility significantly affected Perceived Usefulness (PU) and behavioural intention. Various studies consistently supported compatibility's influence on PU, PEOU, and intention to use [20], leading to hypotheses:
H6: Compatibility positively affected PU of proposed system.
H7: Compatibility had a positive effect on PEOU of proposed system.
Perceived relative advantages positively influenced users' intention to use [20]. Limited research exists on relationships among relative advantages, PU, and PEOU. One study suggested a link between higher perceived relative advantages and greater perceived usefulness. Consequently, the hypotheses were formulated as:
H8: Relative advantages positively impacted PU of the proposed system.
H9: Relative advantages had a positive effect on PEOU of proposed system.
Early research indicated that complexity negatively affected the intention to use technology. Moreover, complexity showed a negative association with PU[20], leading to the following hypotheses:
H10: Complexity had a negative impact on PU of the proposed system.
H11: Complexity negatively affected PEOU of proposed system.

In conclusion, the proposed IDT-TAM integrated model consists of hypotheses H1 - H11.As shown in Figure 1 below.

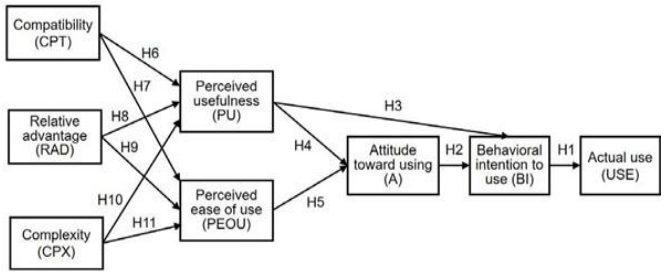

Figure 1 Image source: Integrating innovation diffusion theory and the technology acceptance model: The adoption of blockchain technology from business managers' perspective (Lou & Li, 2017).

IV. Implementation and Results

A. *Architectural Design*

To evaluate the efficiency of digitization and e-verification of medical certificate for the hospital. This study employs a class diagram (Figure 3) to show key entities in the project implementation, including:

- **Hospital:** Represents Alimosho General Hospital,
- **Staff:** Encompasses hospital personnel managing hospital operation.
- **IT Staff:** Comprises the hospital's IT department. responsible for digitizing certificates, generating unique QR codes, database management, integrating with hyperledger fabric blockchain, and validating certificate authenticity.
- **Patients:** Refers to hospital clients requesting medical certificates.
- **Verifiers:** Represents entities, such as employers and insurance companies, verifying the authenticity of presented medical certificates as shown in Figure 2 below.

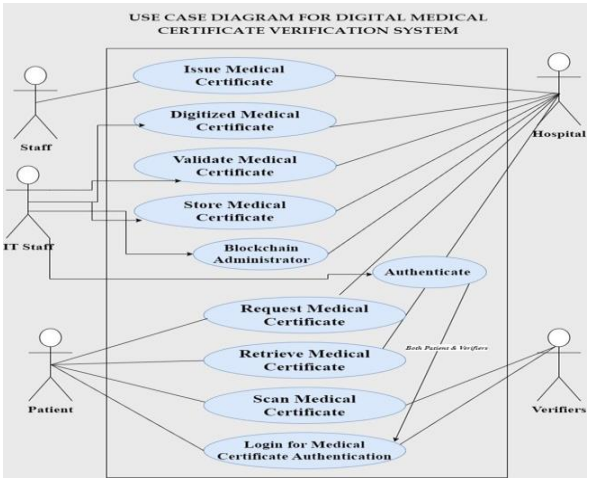

Figure 2 shows the use case diagram of the system.

An activity diagram is a UML flowchart depicting the sequential flow of operations. In our proposed system (Figure 4), it visualizes the steps for digitizing and e-verifying medical certificates. A patient requests a certificate, the hospital processes and digitizes it, stores in the database, generates a unique QR code, and registers it in Hyperledger Fabric blockchain using a smart contract or chaincode.

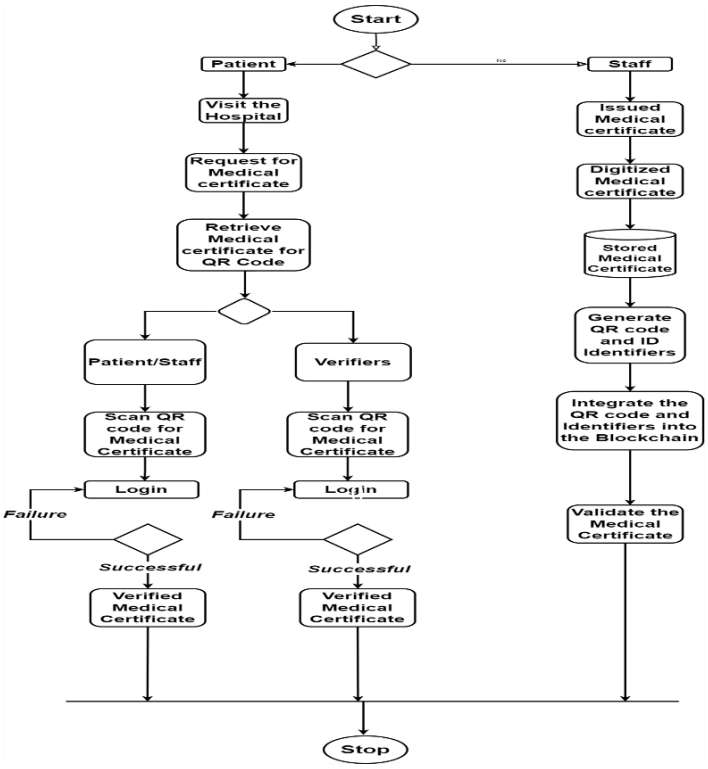

Figure 4: Showing Activity Diagram

B. *Requirements*

The table 1 shows the minimum hardware component requirement for running Hyperledger Fabric on Windows, though the exact requirements may vary depending on the network size, the number of transactions, and other specific use cases.

Component	Requirement
Operating System	Windows 10 Pro or Enterprise (for Docker Desktop support)
Processor	Multi-core CPU (at least 2 cores recommended)
Memory (RAM)	Minimum 8 GB (16 GB recommended for larger setups)
Storage	Minimum 50 GB (SSD recommended for better I/O performance)
Scanner	For converting physical medical certificate to digital format
Barcode Printer	For Printing generated barcode on sticker paper.
Virtualization	Virtualization technology must be enabled in BIOS for Docker

Table 1: Hardware Requirements

This study requires specific software installations for a successful Hyperledger Fabric environment, including Docker, WSL2, Microsoft VS Code, and Git for Windows on Windows OS, and Git, cURL, and Docker on Linux OS as outlined in the Hyperledger Fabric Blockchain documentation (Prerequisites — Hyperledger-Fabricdocs Main Documentation, n.d.). Windows users need Windows 10 version 2004 or higher (Build 19041 and higher) or Windows 11 (craigloewen-msft, 2023) for Windows Subsystem Linux (WSL). Additional software, detailed in Table 2, was installed for different purposes in this study.

Software Components	Requirement
Operating System	Windows 10/11 Pro or Enterprise
Docker	Docker Desktop for Windows (with Linux containers)
Docker-Compose	Included with Docker Desktop for Windows
Node.js (Optional)	For Chaincode development in Node.js (LTS version recommended)
Go (Optional)	For Chaincode development in Go (version 1.14.x or later)
Git	For cloning repositories and samples
cURL	Useful for testing and making requests to components
Hyperledger Fabric Images	Docker images for peers, orderers, CA, etc. (Downloaded via Docker)
Hyperledger Fabric Binaries	Command-line tools like a peer, configtxgen, etc. (Usually downloaded from Fabric's GitHub releases)
XAMMP	Apache and MySQL to serve as databases for storing and retrieving digitized medical certificate
Text/Code Editor	Visual Studio Code (with Hyperledger Fabric extension is a popular choice)
Draw.io	This was used for creating the system design's UML diagrams.

Table 2: Software Requirements

Hospital medical certificates are digitized by the ICT department using high-resolution scanners. The digital copies are stored in the MySQL database via a user-friendly file management frontend. Each certificate is assigned a unique ID for verification, with patient and staff details entered. The scanned certificates are uploaded to the MySQL XAMPP database [21], generating a unique identifier and URL for QR code generation, integrated into the Hyperledger fabric smart contract. As shown in Figure 5 below.

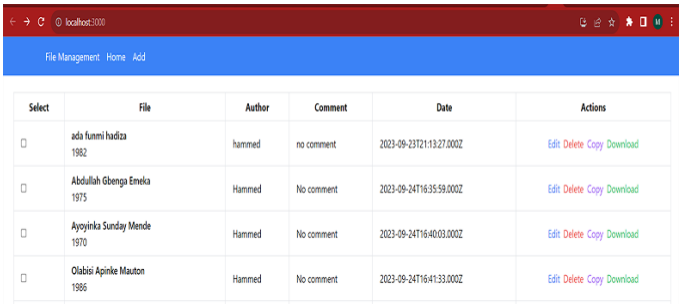

Figure 5: Showing the digitized medical certificates.

In subsequent phases QR code is generated by using the database URL from section 5.1 after clicking download in the front end. That will serve as an input to QR Code Monkey; to generate QR. This platform is chosen for its widespread use, offering unlimited scans and free commercial usage [22]., The resulting QR code will be printed on barcode paper using a barcode printer and affixed to the physical medical certificate.

Integrating QR codes into Hyperledger Fabric relies on smart contracts or chaincode, governing actions like verification and authentication. These contracts, written in chaincode, manage transaction execution and World-State evolution. The process involves running the Docker desktop app, developing smart contracts, and ensuring only authorized individuals can access, add, or alter medical certificate records on the blockchain. The QR codes and unique IDs of digitized certificates are recorded on the blockchain ledger for enhanced security and transparency. Verification involves scanning the QR code, prompting the verifier to enter the unique File name generated during certificate storage. The full smart contract code is provided in Figure 6 below.

The implementation successfully achieved the stipulated objectives of this paper by employing high-resolution scanners for the conversion of hardcopy medical certificates into digital format, stored the digitized medical certificate in MySQL database to generate a URL as shown in Figure 5. The system ensured secure e-verification through integration with Hyperledger Fabric blockchain, incorporating smart contracts to govern transactions and enhance authenticity. Overall, the implementation not only met the specified goals but also established a secure and well-structured framework for digitizing, verifying, and managing medical certificates.

```
C: > QR code > alimoshogh > JS alghcode.js > FileContract
'use strict';

const { Contract } = require('fabric-contract-api');

class FileContract extends Contract {

  async verifyFileName(ctx, id, fileName) {

    const fileData = await ctx.stub.getState(id);

    if (!fileData || fileData.length === 0) {
      throw new Error(`File with ID ${id} does not exist`);
    }

    const parsedData = JSON.parse(fileData.toString());
    const storedFileName = parsedData.fileName;

    if (storedFileName === fileName) {
      return true;
    } else {
      return false;
```

Figure 6 showing the system Smart Contract

Lastly, to demonstrate the result of the study, by using any device with QR code scanning feature to scan the presented digitized medical certificate, it will redirect the verifier to the page requesting for File name. If the entered file name is the same as the one printed on the medical certificate generated through the database as shown in Figure 8. The verification page will authenticate the certificate as shown in Figure 7.

Figure 7: Showing the verification Page.

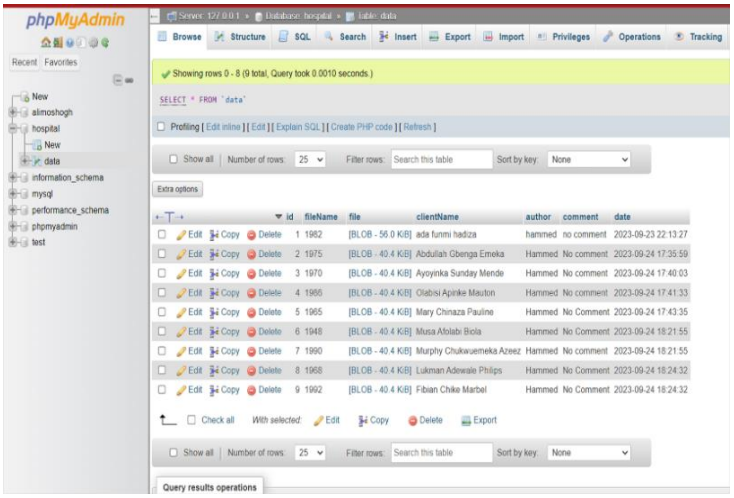

Figure 8: Showing the backend database.

V. Conclusion

The benefits of e-verification and digitalization in healthcare are far-reaching and transformative. Digital medical certificates, when compared to their paper counterparts, provides easy online access, verification and countermeasure manually generated medical certificates This rationalizes healthcare operations by reducing the physical space required for storage and enabling quick data retrieval, enhancing response time in critical situations. Moreover, they foster collaboration and continuity of care among healthcare providers. The standardization and accuracy offered by digitization make it easier to share medical information with various stakeholders. Integration of advanced technologies - Hyperledger blockchain, digital signatures, and QR codes aid in e-verification. Ensuring security, data integrity, reducing the risk of fraud. However, it is crucial to address cybersecurity challenges to safeguard patients' sensitive health data in this digital landscape. Implementing digitization and e-verification at Alimosho General Hospital in Lagos State provides efficiency, accuracy, security, and accessibility. This can significantly benefit the healthcare sector in the region. Nonetheless, it is important to acknowledge the study's limitations and the potential need for further research to refine and expand upon this digital approach to healthcare management.

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