# Adopting a Blockchain-Based Algorithmic Model for Electronic Healthcare Records (EHR) in Nigeria

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**Abstract** This work seeks to explore solutions to the challenges posed in sharing/integrating/transferring EHR data across heterogeneous healthcare institutions in developing nations, particularly in Nigeria. This blockchain-based algorithm model for EHR interoperability seeks to address EHR interoperability challenges such as semantics across heterogenous healthcare institutions, the proper infrastructure and consensus structure for the sharing of EHR across healthcare institutions, privacy and security of patients' records, etc. Hence, this algorithm model, when adopted, is adjusted and contextualized to fit developing nations by addressing the underlining fundamental challenges. EHR interoperability would become a reality across the heterogeneous healthcare institutions in these nations. Future works on EHR will focus on the aggregate blockchain model. Also, the Artificial Intelligence (AI) model inculcating blockchain technology would be an attractive option to dive into future works on EHR.

**Keywords** Electronic Healthcare Records (EHR) · Electronic Medical Records (EMR) · Healthcare Information Systems (HIS) · Interoperability · EHR challenges · Blockchain · EHR semantics · Security · Privacy

## 1 Introduction

Information Technology (IT) or Information and Communication Technology (ICT) is the driving force behind innovation and processes in twenty-first-century society. Computer algorithms that transform manual processes and procedures into automated

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processes in organizations are constantly on the increase. Daily, engines, robots, etc., in industries and organizations are designed, developed, and deployed using the computer algorithm model as their driving force. The term information systems refer to all the processes and procedures involving computing components like hardware, software, telecommunication, people, and procedures.

In the healthcare sector, computers are used intensely to drive care in the industry. Terminologies, such as Electronic Health Records (EHR) system, Healthcare Information Systems (HIS), Electronic Medical Records (EMR), among others, have gradually become the computer terminologies used in the implementation of computerization in the healthcare sector [1, 2]. Developed economies are at the forefront of this computerization of the healthcare sector, albeit the developing economies such as Nigeria are not precluded in this phenomenon, even though not to a greater extent than their developed counterpart. The implementation of EHR is no longer an issue, as it has become a common phenomenon even among developing economies, as the impacts and gains seem plausible [3]. However, when it comes to information or data exchange among two or more healthcare institutions, exchanging or sharing their EHR among themselves to facilitate or enhance individual care becomes a challenge. This is as a result of some impeding factors such as the right model or algorithm to use for EHR interoperability that could properly handle delicate, ethical, and legal issues such as security and privacy of patients' records, semantics among others which pose as major challenges to EHR interoperability even the world over. Other issues such as the right kind of network infrastructure, standards, and the right consensus model that would drive this interoperability process are still daunting tasks. A centralized system, a client–server system, cloud-based system, and bulk transmission infrastructure frameworks have all been proposed as solutions to this issue [4]; these frameworks of interoperability infrastructures have their downsides which borders on the issues of trust, operational control over records or information, and the right model to handle diverse semantics that is employed by different healthcare institutions and their practicing personnel [5, 6].

This study seeks to explore extant works in the areas of EHR and interoperability in healthcare institutions in developing economies of the world, focusing on Nigeria, using the framework proposed by Peterson et al. [6] to contextualize and underpin the work. Peterson et al. [6] work on interoperability using the blockchain algorithm model seems to overcome most of the challenges faced in EHR interoperability, such as trust, security, privacy, semantics, and other sundry challenges in network interoperability of EHR.

## 2 Review of Literature

### 2.1 Electronic Health Records (EHR)

Electronic Health Record (EHR) or Electronic Medical Records (EMR) are electronic documents that are unique and composed of patient data or information relating to their health history, medical prescriptions, demographics, laboratory results as well as tomographic reports, etc. [7]. EHR and EMR are at the forefront of Information and Communication Technologies (ICT) application solutions that have been advanced and employed primarily to supervise patients' healthcare records or information [8]. However, both EHR and EMR are considered to be the same and are frequently used interchangeably. There is a thin difference between the two. EMR usage is mainly restricted to or in a healthcare sector only during EHR traverse. It transcends healthcare sectors as patient's information or records could come from diverse sources aside from the healthcare organization, e.g., an EHR may receive or inculcate records into its database from sources like a government repository, etc. [9, 10]. Also, the EHR can provide real-time information centered around the patient, such as history diagnosis, test results, and allergies, that are employed in making proper clinical decisions regarding the patient. A prominent feature in EHR is that vendors and staff who are authorized access can modify patient records anytime and place. Both EMR and EHR systems are collectively called Healthcare Information System (HIS), which are very useful. They are employed in healthcare institutions to help improve healthcare professionals' proficiency in the discharge of their duties, thereby reducing time and costs and bringing about the encouragement of medical practices based on evidence [11].

Developing countries like Nigerian healthcare institutions are faced with a plethora of challenges in the effective implementation of EHR without recourse to compromising the security and privacy of patients' records. Nowadays, many secondary and tertiary healthcare institutions in Nigeria have implemented EHR, EMR, or HIS in their respective hospitals to help manage patient information in a digital format. These preclude compatibility integration as they are usually designed and developed by diverse firms or vendors and are implemented in different high-level languages and databases [12]. This process is unique and very effective when implemented in the same hospital or healthcare institution where this EHR is deployed.

### 2.2 Interoperability

According to the Electrical Electronics Engineers standard dictionary of computing, interoperability is defined as the ability of two or more components to exchange information and use the information exchanged. A more concise definition of interoperability by Peterson et al. [6] states "the extent to which the clinical intents could be conveyed across institutional healthcare boundaries." There are generally two main acceptable approaches to effective interoperability:

- Syntax: Syntax outlines the structural format on how the information should be traded. The syntax is oblivious of the contents that are being exchanged.
- Semantics: Semantics ensure that both networks engage in the data exchange of EHR and comprehend the information traded across both networks. This happens by incorporating the appropriate metadata; for example, in the taxonomy of medical science, classification means groups or lists of similar objects such as infections and laboratory tests. In contrast, ontology infers hierarchical relationships among concepts such as bacterial culture used to diagnose infections.

### *2.3 Challenges of EHR Interoperability*

1. Privacy and Security of Records: In many nations, the privacy and security of patient records is a legal and ethical matter [6]. Therefore, any healthcare institution that fails to protect and secure its patient's healthcare record, especially when exchanging them across other institutions' networks, may likely face litigations, a ban or withdrawal of services which may lead to a loss in revenue or shortage in finances as a result of low patronage by patients. Hence, this issue can be a significant challenge and a big setback in the wheels of progress in EHR interoperability. The phobia of compromising on it could sometimes outweigh the potential benefits that are concurrent with EHR exchange.
2. Lack of uniform and agreeable architectural framework across Networks: A lack of consensus architectural infrastructure among healthcare institutions and relevant stakeholders is another con that is bedeviling EHR interoperability across institutions' networks. Researchers and stakeholders in the healthcare sector have made several attempts to address this issue. Many have suggested a centralized data source, sending a large volume of data across institutions nodes, etc. These options often pose a unique problem. For example, a centralized approach is likely to increase security breaches, and control is usually shifted to a single centralized authority. The issue of complete trust by all parties' concerns may not be guaranteed. On the contrary, the humongous exchange of data would compel individual healthcare originations to lose control of their operational [6].
3. Heterogeneous and Complex Nature of Healthcare Data: Healthcare data is very complex and highly heterogeneous, thus making EHR interoperability a challenging task to surmount, as different healthcare organizations have diverse semantics and meanings for the same kind of data item. This work seems to proffer suggestions on the best approach of achieving EHR interoperability across different healthcare institutions by adopting the blockchain algorithm combed with FHIR, a standard exchange protocol set by level 7 health. And

we propose to adopt and contextualize it in the Nigerian Healthcare institutions system. This proposed approach seems to tackle the significant issues of structure and semantics bedeviling EHR interoperability [6].

## 3 Nigerian Healthcare Structure

The Nigeria healthcare sector is a collaboration of the government (both state and federal), the private sectors, and the religious organizations. The policies, technical operations, and running procedures are the responsibility of the federal government of Nigeria. Similarly, in their capacities and mandate, various state governments make policies and procedures to support the healthcare centers that are established and controlled by them. The local government healthcare centers, being the third tier and last on the rung of the healthcare ecosystem and its value chain in Nigeria, are regulated by the state government and financially supported by state and federal governments.

The issues raised as challenges to effective implementation of EHR and EHR data interoperability in Nigeria are as follows: inadequate ICT infrastructure and facilities, lack or inadequate power supply, lack of political will to change extant health customs and policies to reflect best global practices, incompatibility in many e-health system, breech of patient security and privacy, corruption and above all, lack of consensus ontologies, and standard in the healthcare system to handle semantics in areas that require standardization. Their study recommended measures that would correct or mitigate these challenges they identified as impediments to EHR implementation and data interoperability in Nigeria [13].

A framework that would break the impediments to effective EHR implementation and could lead to EHR data interoperability in Nigeria was proposed by Kruse et al. [14]. *Socialized Medicine* the name given to their framework was composed of a communication infrastructure, with a wired or wireless network, a mobile phone, and Internet connectivity. This Internet connectivity will enable doctors and patients to use their smart phone and other devices to communicate virtually and share information across heterogenous healthcare institutions platforms. Albeit for their framework to really be deployed and implemented in real time, the following components and infrastructure would be indispensable: A Web-based application software implementing a cloud computing infrastructure would be needed, a server-side scripting tool, and an integration of a real-time communication tool will also be required. The work proposed authorization and licensing for all category of users to ensure safety in the system. Three key gaps were identified from the review of the literature:

1. Differences in data semantics across healthcare institutions networks.
2. Guaranteed security and audit of patient records across the networks, and
3. Lack of control by patients over their records across the networks.

Although in the three gaps identified above, Pai et al. [15] and Bahga and Madisetti [16] seem to deal with some extent on semantics and security, leaving the issue of patient control on their data. They employed the cloud-based EHR approach alone to decipher security and semantics issues. This kind of architecture is not tested on the traditional client–server architecture to ascertain its workability regarding EHR interoperability in these nations under review. This study intends to close the gaps mentioned earlier by employing the blockchain-based algorithm approach proposed by Peterson et al. [6] to solve the current gaps of EHR interoperability in developing nations with particular reference to Nigeria's healthcare systems.

## 4 EHR Interoperability Blockchain Algorithm

A blockchain is a distributed transaction ledger, which is made up of blocks such that each block represents a set of transactions [17–19]. The properties of a blockchain data structure are interesting, and the chains of blocks that make up the blockchain are considered immutable. The immutability of a blockchain is achieved as a result of a verification number called a hash present in each of the blocks, which verifies each transaction's genuineness in the block. Also, a current hash block is dependent on a predecessor hash block. Hence with this scenario, it goes to say any transaction change occurring in a particular block hash will translate into changing the transaction history of the previous hash block as well. Thus, this setup makes the blockchain immutable [6, 18, 20, 21]. Blockchain technology precludes a distributed system, as it does not depend on a centralized trusted system for the verification and validation of information or data. It requires the use of another mechanism to reach a consensus before transmission can occur. The PWF makes sure that any node on the network that wishes to add to the network must carry out a complete computationally verifiable puzzle as a matter of requirement.

Similar to the digital currency of Bitcoin, data blocks are added to the system at regular intervals of time. The proof of work is an interval determinant of time in the Bitcoin system. This work specifies a constant interval of time for creating a unit of block or a block period as recommended by Peterson et al. [6]. Accordingly, during this block period, the nodes go through four activity phases. The first phase is the transaction distribution phase; the time commences at $T\alpha$, after which transactions are passed over to the coordinating node or the miner node. This phase may continue until $T\sigma$ or until the miner node stops accepting a new transaction for the block. The coordinating node will then collect the entire new block and send it to the nodes for review in the block verification request phase, which is the second phase. This enables all nodes which contributed to the block in at least one transaction entry to show their approval by endorsing the block digitally. The block control is then passed to the miners in phase three's signed block return phase. The miners then add up the block to its local blockchain. Finally, distribution to the new blockchain is made in the fourth and final phase, called the new blockchain distribution phase. These phases are illustrated in Fig. 1.

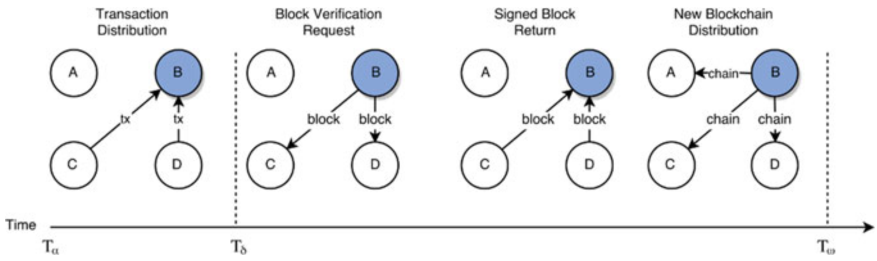


**Fig. 1** Shows the four phases of adding a block to the EHR blockchain

- Data Search and Access: As stated earlier, the actual patient's record is not in the block but the FHIR. With this model, searchability is possible and imperative. To perform a search, search privileges to query the block are assigned to appropriate external healthcare institutions, which carry out searches with the help of keywords resident in the secure index file of the transaction.
- Data Security: The blockchain model applied in this EHR work has its strength in the security, privacy, and anonymity of patients' transaction records. The blockchain encryption process described under the data search and access process is employed to secure this model. The network will also encrypt public information and direct all nodes shared key, while the source node should encrypt sensitive information. Finally, a security technique known as the privacy-preserving key (PPK) should be employed to enhance data search and access; thus, if an external network requests a set of record transaction from the blockchain that matches specific criteria, both the query and the transaction will remain encrypted and secure.
- Patient's Identification: The ability of EHR interoperability models to consistently identify patients across different healthcare institutions can be a daunting task. Studies have suggested some variation of the records in the central master plan index (MPI) file. In this model, similar to the blockchain Bitcoin model, data allocation to the model is done using addresses instead of the patient's name. At the same time, the key control to the addresses is assigned to the patient. The pro of this method is manifest in the fact that a single identifier consensus would not be required as a particular patient may have many different healthcare institutions' addresses. The procedure is a great significant departure from extant practices where healthcare institutions implement EHR own and assign patient's identifiers mechanism [6].

## 5 Conclusion

Interoperability of EHR has been a daunting challenge for developing economies and nations, with Nigeria not precluded in the list. The study revealed that the decentralized nature of the model makes it imperative and germane in handling the plethora of issues of EHR interoperability in the context of the review nations, as it addresses foundational and chronic problems of interoperability of EHR in these nations hitherto were barriers. In this paper, the authors presented topics such as semantics, privacy, search, patient identifier across different networks of healthcare institutions, and network consensus structure. Thus, we consider this model the most suitable and secure EHR interoperability model among the extant models on this subject; as the benefits of this model on both patients and healthcare institution speaks volumes. Future works on EHR will focus on the aggregate blockchain model. Also, the Artificial Intelligence (AI) model inculcating blockchain technology would be an attractive option to dive into EHR.

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