Impact of Blockchain on Latin American healthcare systems

Impacto de Blockchain en los sistemas de salud latinoamericanos

Gabriel Silva-Atencio[1], Mauricio Umaña-Ramírez[2], Marian Valverde-Porras[3]

Fecha de recepción: 23 de mayo, 2022
Fecha de aprobación: 6 de septiembre, 2022

Silva-Atencio, G; Umaña-Ramírez, M. V;Valverde-Porras, M. Impact of Blockchain on Latin American healthcare systems. *Tecnología en Marcha*. Vol. 36, Nº 3. Julio-Setiembre, 2023. Pág. 78-86.

https://doi.org/10.18845/tm.v36i3.6223

1 Head of Chair in the Computer Engineering career. Latin American University of Science and Technology (ULACIT). Costa Rica. Email: gsilvaa468@ulacit.ed.cr
https://orcid.org/0000-0002-4881-181X

2 Industrial Engineer, Doctor in Business Competitiveness and Economic Development. Catholic University of El Salvador. El Salvador.
Email: mauricio.umana@catolica.edu.sv
https://orcid.org/0000-0002-0733-5183

3 Master's student and Associate Software Engineer. Latin American University of Science and Technology (ULACIT), SchoolMint. Costa Rica.
Email: mvalverdep037@ulacit.ed.cr
https://orcid.org/0000-0002-5338-8059

Keywords

Blockchain; Internet of medical things; electronic health record; healthcare system; digitization.

Abstract

Advances in information technology are digitizing health areas to improve medical services, diagnoses, and continuous monitoring. These technologies have improved distributed systems' security, reliability, and robustness. This digitization enhances the ease of calculating, storing, and accessing medical records, enabling better patient treatment experiences. However, it risks cyber-attacks, security, and privacy issues for data. In this article, we propose a reliable model based on Blockchain and the Internet of Medical Things, allowing the patient to provide consent to obtain and the option to share their medical records, getting more incredible speed when scheduling a consultation or receiving a treatment. In a Post COVID-19 era, this can take the steps for new strategic policies that offer people a more competitive system of social benefit in health and one of many avenues that help the prosperity of citizens in a world in crisis.

Palabras clave

Blockchain; Internet de las cosas médicas; historia clínica electrónica; sistema sanitario; digitalización.

Resumen

Los avances en las tecnologías de la información están digitalizando las áreas sanitarias para mejorar los servicios médicos, los diagnósticos y el seguimiento continuo. Estas tecnologías han mejorado la seguridad, fiabilidad y solidez de los sistemas distribuidos. Esta digitalización facilita el cálculo, el almacenamiento y el acceso a los historiales médicos, lo que permite mejorar la experiencia de tratamiento de los pacientes. Sin embargo, entraña riesgos de ciberataques y problemas de seguridad y privacidad de los datos. En este artículo, proponemos un modelo fiable basado en Blockchain y el Internet de las cosas médico, que permite al paciente dar su consentimiento para obtener y la opción de compartir su historial médico, consiguiendo una velocidad más increíble a la hora de programar una consulta o recibir un tratamiento. En una era Post COVID-19, esto puede dar los pasos para nuevas políticas estratégicas que ofrezcan a las personas un sistema más competitivo de prestación social en salud y una de las muchas vías que ayudan a la prosperidad de los ciudadanos en un mundo en crisis.

Introduction

Advances in technology and science have facilitated the solution of various problems and have given rise to new developments to deal with other challenges where the means to address them did not exist. In this context, the problem arises in which the Caja Costarricense del Seguro Social (CCSS) finds itself, which has an Expediente Digital Único en Salud (EDUS), where the medical records of each citizen are managed and where there is an excess of centralization, which makes the information very hermetic for said institution.

Currently, people expect instant and seamless access to their records when visiting any hospital in the country. Unfortunately, the EDUS system has fallen behind in meeting the expectations of its patients. Medical records are not easily accessible due to different standards and data formats, which means the medical ecosystem of each hospital is why it is not suitable for being instantaneous or for mobilization.

On the other hand, health systems provide better care, a supply chain, safety, and health, among other essential aspects for an institution in charge of social welfare. That said, vulnerabilities can be detected in the efficiency of a supply chain, from contacting the supplier at the cost of manufacturing the medicine to the final delivery to the user. Therefore, this research identifies how the delivery of these medicines could be improved, as well as optimizing doctor-patient appointments.

Among the advances in science and technology towards the problem raised is Blockchains, a tool that would help us meet the identified needs, transmitting health information across the farthest geographic and institutional boundaries to provide a suitable and secure management mechanism.

The main advantages of Blockchain are decentralization, security, transparency, and immutability of data. These allow information to be verified and value exchanged without relying on a third-party authority. Based on these benefits, one of the areas that this Blockchain technology will most impact is medical since electronic health records and records will be in a secure layer, difficult to be hacked [1].

The disruptive potential we want to show the Blockchain reader is its technology, which eliminates the need for an entity to manage, store, and finance a database.

On the other hand, in search of support for the decentralization and structure, both physical and digital, of the medical records of the fund, it is essential to mention the concept of the Internet of Medical Things (IoMT) in infrastructure areas and intercom. This is one of the most recent paradigms in the health field, which would help ensure patients' quality of life, carrying out medical processes efficiently and agilely.

This needs to be answered, given that the Costa Rican technological infrastructure is still being determined in the face of emerging technologies. The limitations presented by the current technology base in the health system for a possible application of Blockchain are studied.

This study aims to provide the benefits obtained by implementing Blockchains in the EDUS system, manage the integrity and privacy of the data and ensure the limitations when implementing IoMT in Costa Rican hospitals.

Literature review

Blockchain is a peer-to-peer (P2P) network that sits on the Internet. In 1991 the first publication on this technology was made with its proposal to create a digital registry. Still, it was not until 2008 that Bitcoin was born, a cryptocurrency that uses Blockchain technology to make electronic payments without the need for supervision by financial institutions [2].

Peer-to-peer is a network where each device shares its resources with every other device on the web. All the machines are directly connected to these networks and do not need a server device since their connection is direct. This type of network is a fundamental piece of Blockchain technology.

Blockchain technology is a secure record of historical transactions, collected in blocks, chained chronologically, and distributed across different servers, creating a trusted provenance [3]. A distributed database also maintains a continuously growing list of ordered records called the "blocks" [4].

Many believe Bitcoin and Blockchain are the same, but this is untrue. Around 2014, those who realized that Blockchain could be used for more than cryptocurrencies began to invest and explore how it could disrupt many operations. The Blockchain is an open, decentralized

ledger that permanently records transactions between two parties without needing third-party authentication. This creates a highly efficient process where transaction costs are predicted to reduce Field drastically[5].

It has always been common for companies and institutions to keep their information in books. The institutions that own these books control access to this information and, as such, can act as intermediaries when other interested agents need to consult and have access to the data [6]. The intermediary role can be presented because the information is private or needs to be validated by the institution.

When the information is in the hands of an institution, it becomes a "central authority," an intermediary that has full access to the information and intervenes in all transactions. As Porxas and Conejero clarify, [6], we should not equate this "central authority" with a public authority, a credit institution, or a regulated entity. It is simply the term used in the works on this technology to identify the owner of the information in the traditional system based on trust, also called the "centralized" system.

The concept of Blockchain completely changes how information is stored and handled. Through an open-source internet protocol that allows for "decentralized" storage of data, the need for an intermediary or central authority to control storage and access to information is eliminated.

Blockchain technology, such as Distributed Ledger Technology (DLT), allows the creation of networks to share record books of electronic transactions, very similar to accounting books; or, in other words, shared digital databases [6]. The main differentiator is that the information is "distributed" among all the network members; therefore, no entity or institution owns the data.

Blockchains are a network or chain of computers (nodes) where each node has a complete copy of the information. In this way, each time the data stored on the network changes, a "block" is created.

Before any block can be added to the Blockchain network, it must go through a validation process where, using some computer algorithm, all nodes in the network must authorize the change in information. Validation processes differ for each Blockchain system, using either the Proof-of-Work or Proof-of-Stake method.

Proof-of-Work (PoW) and Proof-of-Stake (PoS) are consensus mechanisms, which means how the network validates the transaction and allows it to be added to the network.

In other words, the PoW method is a cryptographic algorithm network nodes use to validate a transaction. The nodes use their computational resources to solve the cryptographic algorithm, and when 51% of the nodes in the network solve the algorithm, the transaction is authorized. Also, the first node that manages to solve the cryptographic algorithm receives a reward, which differs for each Blockchain network. The PoS method is also a cryptographic algorithm, but unlike the previous one, it does not contemplate the existence of rewards for the node that validates the transaction.

The exercise of validating the transactions, the creation of the blocks, and their subsequent incorporation into the distributed registry are carried out by the so-called validator nodes [6]. When most nodes approve the transaction, the blockchain adds the block.

Each block has a unique time-stamped cryptographic hash or a condensed and converted version of a more extensive set of data (such as the characters in a password) into a set of smaller hashes, linking it to the previous block in the chain, e.g. Therefore, it is impossible to reorder the block retroactively. Information about partnerships cannot be retroactively altered because they are stored on multiple nodes across a distributed network; even if one node is

damaged, the others will have the correct version of the ledger. The data change does not delete the previous entry but instead creates a new block showing the changes; the last version of the data can always be seen by simply going back to the previous block [7].

With its decentralized and trustless nature, Blockchain technology can create new opportunities and benefit businesses through increased transparency, enhanced security, and a more accessible traceability [8]. Therefore, Blockchains are not limited to cryptocurrencies. There are many benefits that this technology can offer to different sectors.

One of the most essential attributes of Blockchain is that its database is open to the public. This forces the institutions involved to be more honest when doing business. In financial systems and businesses, this adds unprecedented accountability, making every sector accountable for acting with integrity toward the growth of the company, its community, and its customers [8].

In the same line as above, due to the decentralized nature of Blockchains, the intermediary can be eliminated and thus speed up information transactions. As Koksal describes, compared to traditional financial services, Blockchain facilitates faster transactions by allowing P2P cross-border transfers with a digital currency [8].

That is why each block is encrypted with complex algorithms; once the information is part of the network, it is almost impossible to decode. Similarly, blocks cannot be modified or deleted once added because they are immutable. Blockchains' immutable and uncorrupted nature makes them impossible proof of falsified information and hackers. Its decentralized nature also gives it the unique quality of being "trustless," meaning parties do not need trust to transact Field securely[8]. Each block in the chain has a timestamp and an association with its previous block. This makes it easy to see the transaction's origin and destination. Blockchain's security can show that the information it stores will be difficult to extract because the blocks are unalterable, and if a block is altered, it breaks its connection with the chain.

As Koksal asserts, this can help improve security and prevent fraud in exchange-related businesses, but also help verify the authenticity of the assets traded. In industries such as medicine, it can be used to trace the supply chain from manufacturer to distributor or, in the art industry, to provide irrefutable proof of ownership [8].

EDUS is the official application of the Costa Rican Social Security Fund, which allows citizens to access relevant information in their records through intelligent devices [9].

The benefits provided by EDUS are described below: It allows the user to consult the right to medical care, update their data without leaving home, consult the details about their prescribed medications, see the details of the next appointment, and schedule it on their smartphone. In the same way, the user can clarify doubts about diagnoses, and details of registered allergies, find out how many people are in his subsequent surgery, and keep track of it. In addition, you can easily switch users and access any of your associated dependents [9].

This allows you to carry out the ascription process at the health establishment that corresponds to you if you are direct insured. You can also access appointment data (previous and pending), request or cancel appointments between you and your family members at affiliated medical institutions, and finally, check the status of your insurance for medical health services and validate their insurance condition for access to medical services.

In case of having received medical attention in the establishments that have implemented the Unique Digital Health File, the insured can see the information related to the medications that have been prescribed, as well as the surgical route. Likewise, the user can view their medical information, such as appointments or scheduled surgeries and test results, among other information linked to the system, such as Disability, Old Age, and Death regimen.

If the user is a contributor, they have their pension estimate information, reported wages, and periods consolidated by employers. You can see your pension information, payments, and associated deductions if you are a pensioner. In both scenarios, you can see the operation details if you have a mortgage loan from the said regime. You can verify your rights to medical care even without carrying proof of ownership (employer order) or an insurance card [9].

One of the technologies that have come to change the paradigm of connectivity is the Internet of Things or also called by its name in English, IoT. This arises thanks to the number of devices (hardware and software) connected simultaneously and in real-time, sharing data through wireless features. Bernard Marr highlights the report published by Allied Market Research, where it is predicted that the market for IoT in the medical and health area will reach a net value of 136 billion US dollars by 2021 [10]. It is also essential to rescue the dimension introduced by Bernard Marr, establishing that, by 2025, 1.2 billion people will be very old, with the potential for this technology to take the health area to extremes that have not been explored by the world—human beings.

This definition provides a logical path to base the question of what IoMT is. It is highlighted that the IoMT is the medical area where IoT is applied in its purest form, and it is considered to be the set of medical and health devices connected to the Internet. From what can be concluded, it is a digital and physical infrastructure of health systems, where an entity in charge of health solves communication, efficiency, administration, and medical treatment needs.

IoMT supports the characteristic machine-to-machine (M2M) functionality. This is the ability of devices to exchange data and engage in sender-receiver communication. Such functionality favors the data transaction without needing a man in the middle (someone or some machine in the middle of the data transfer) that interferes with the communication. There is also the communication human-to-machine (H2M) and human-to-human (H2H), which are intrinsic characteristics of everyday computing that IoT and IoMT come to get better. It is important to emphasize that these functionalities: M2M, H2M, and H2H (characteristics of both IoT and, therefore, also of IoMT), manipulate data exponentially, which will require sizeable digital storage locations.

One thing to keep in mind when it comes to IoMT is the security aspect. For this reason, due to the intrinsic capacity of IoT (technology based on IoMT), an encryption mechanism is provided (being able to apply cryptography models to the data) with established protocols so that data transmission is in the most integrated way. And safe as possible.

It is highlighted that the communication of the IoMT is wireless, as described in previous paragraphs. However, going into technical terms and concepts, IoMT bases its connections on protocols such as Near Field Communication (NFC) and Radio Frequency Identification (RFID). These technologies enable devices to share data and, therefore, to have exponential information about their surroundings. Of course, the transmission speed will be affected by the speed of the internet that is being accessed and other factors.

Among the advantages of IoMT, the ability to obtain different data and information relevant to health in real-time, either from an individual patient or from pooled results, stands out.

Emphasizing the optimization and agility of work by health employees or registered institutions should be clear that this, being an infrastructure, will benefit the population and the different devices connected. This represents one of the IoT's intrinsic capabilities; better connectivity and data transfer are obtained. Another advantage that stands out is the ability to provide a more efficient and optimal health system for remote patients.

This technology, by having the appropriate and essential wireless capacity for this type of challenge, makes a paradigm capable of improving the quality of life of a patient without the need to be physically inside a medical institution.

Another advantage is the reduction of expenses for medical bills. It is a balance point since deductions cannot be eliminated, but a nominal cost is evaluated in the long term. This advantage does not fall only on the patient (or their family); it is also addressed to the medical institution in charge of looking after the user. In addition, it clarifies the safety and confidence of the appropriate medication for the patient, which must be in the hands of the patient or of those responsible for their health, such as their family.

A patient-team relationship is established that constantly monitors their health. In this way, the medical staff (doctors, nurses, and anesthesiologists, among others) obtain up-to-date information to carry out each case's tasks, minimizing the margin of error in the medical field.

This generates the possibility of creating the patient's files, more detailed about previous treatments or chronic diseases, as well as other known ones. In turn, it will provide a health architecture compatible with the information technology department that will group the connections and facilitate the transformation and dissemination of data between machines (M2M).

It should be noted that IoMT is one of the paradigms that can reap the most significant benefits in terms of mobile devices. Mobile technology, as its name suggests, is not static and, in many cases, is at the hand of a user, that is, in their pocket, wrist, or another part of the body. IoMT can even scan and receive data from these devices to have a technological environment that follows the patient or user step by step, which could even be described as a mobile technology environment.

According to Pilkington, by 2040, the health area will have an ecosystem surrounded by multiple technological and medical factors that will make the interaction of an IoMT infrastructure possible. The ecosystem will have clinical devices, medical images, and information technologies focused on the health area and the pharmaceutical industry or drugs. All this will highly benefit specialists in detecting chronic diseases, mobile consumers, and primary health providers. Sports and fitness devices and wellness and health apps will come. Therefore, we will have the IoMT ecosystem that will provide health benefits through constant monitoring, which will result in longevity in the lives of your patient's [11].

Methodology

The methodology used in this article is qualitative research-action type, through which techniques are applied, such as the review of documents related to the topics to be discussed and internal group discussions among the author members of the article, to discuss and contribute ideas about the records and information found. The selection of these techniques occurs mainly because they allow the reinforcement of the findings of the most relevant factors during the experience period. This methodology also has the particularity of contemplating an initial review of readings, but it can be complemented as the article progresses.

The review process was carried out in detail, where articles that did not provide helpful information were excluded, and only those sources that were significant for the report were used, all based on the authors' judgment. The information search was limited to Spanish and English language sources. Additionally, as part of the information selection criteria, the articles examined the relationship between quality, user experience, and customer satisfaction individually and collectively. Action research aims to understand and seek solutions to specific problems of an organization, in this case, the Costa Rican Social Security Fund and its EDUS system. This

methodology is intended to arrive at a proposed solution to the problem of data decentralization in the EDUS medical record. This type of methodology, according to the results found, can denote the impact that it can create not only in a country or Latin America but worldwide if we remember that by 2021, humanity has not recovered from the COVID-19 pandemic, which has become an endemic evil for the entire world health system.

Results and discussion

If we can bring all the medical data together and make it securely accessible to the right staff, that could increase the quality and coordination of care. Also, patients will have more control and access to their information through verifiable consent. These are solid reasons that Blockchain technology is of great help in the health sector [12].

Patient data can be shared on a Blockchain in real time between groups of people and organizations authorized to read and manipulate it. Each event or process will have its history, becoming part of a permanent record within the chain that will remain unchanged when executed. In this chain, confidentiality can be guaranteed by agreeing on which transactions can be seen by the parties and by hiding the identity of that party if necessary. This way, Blockchains will move systems where a single owner keeps information, including medical records, prescription records, diagnostic tests, and more [12].

There are already consolidated solutions using Blockchain in the health sector; an example is MedChain. This solution brings the storage and distribution of medical information, allowing patients to control it. This platform has various functionalities, such as allowing the exchange of medical records while protecting the confidentiality of your data. The user can make medical consultations and diagnoses through the web and mobile applications. It allows managing the identity of users through smart cards—cryptographic databases index medical records.

MedChain is built on a decentralized network, connecting all healthcare providers, including hospitals, medical centers, clinics, and healthcare companies. The MedChain network contains two types of peer nodes: super peers and edge peers. A simple but reasonable pair selection approach is adopted. Super peers consist of servers from large healthcare providers, such as national hospitals, that are more capable of computing and storage, providing the primary infrastructure for sharing data. Edge nodes are the servers of small providers, such as community clinics, that only store actual patient data [13].

Even its payment method implements Blockchain technology, in which when paying for a data purchase service, the amount received is converted into a token and transferred to a smart contract. Accounts of patients whose data has been purchased will receive a portion of the tickets distributed proportionately among the patients, clinics, or other providers who have added the information to the database system. The platform gets the rest of the tokens, which are sent by smart contract to the address of the service provider [14].

As such, we see Blockchain solutions transforming the healthcare and financial ecosystem and increasing the quality of care by enabling innovative business models and development. The stored health information will change how you store clinical data and share it within your health centers, private institutions, and others. These aspects have made Blockchain technology so welcome in rapidly growing healthcare organizations.

Conclusions

By analyzing the case study and all the benefits that Blockchain technology can bring to an economy, a health innovation model could be created as an extensive registry with this technology that can even help predict medical services, demands in the supply chain for

suppliers, consumption habits, pension system, insurance system and this could be connected to the technology of this massive decentralized ledger, if this is administered by the state, as a health coverage policy in 100% of the citizens, it could be a success story, since the system and the budgeted approach would work for efficiency in the use of medicines, in the time of patient services, in M2M, H2M, and H2H interactions.

The strategic policy of citizen health would seek an efficiency never observed in health care and the optimization of equipment, devices, and mechanisms. Intelligent systems and the correct adaptation of technological innovation, accompanied by the reduction of the digital divide, could make prevention and predictions for citizens who are not vaccinated against COVID-19 and exposed to a disease or chronic conditions, for example, in the system. State computer, citizens with chronic health problems or who have not received full-dose vaccination cannot attend events with crowds or circumstances that may endanger their health or that of other citizens.

By implementing Blockchain in the health sector, it will be possible to maintain control of patient data. The medical history can be granted to private doctors or consultants where patients consent to use their data. Something significant to note that is beneficial in using this technology is that these medical records cannot be modified or deleted since it provides data integrity and security to prevent medical fraud or falsification.

References

[1] F. Buitrago-Restrepo and I. Duque-Márquez, "La economía naranja: una oportunidad infinita," *Banco Interamericano de Desarrollo,* 2013. [Online]. Available: https://hdl.handle.net/11537/33528.

[2] M. Allende-López, "Cómo desarrollar confianza en entornos complejos para generar valor de impacto social," *Banco Interamericano de Desarrollo,* 2018. [Online]. Available: https://www.compostela21.com/videojs/elementos/noticias/bitcoin/Blockchain.pdf.

[3] R. Hernández-Sampieri, C. Fernández-Collado, and P. Baptista-Lucio, "Definición conceptual o constitutiva," *México: McGraw-Hill,* pp. 119-125, 2017.

[4] J. Howkins, *The creative economy: How people make money from ideas*. Penguin UK, 2002.

[5] R. Mendoza and P. Quiroz, "Tecnologías de la información y las comunicaciones más utilizadas por universitarios," vol. 4, ed. 3C TIC: 8, 2019.

[6] C. Brulg, "International Confederation of Societies of Authors and Composers (CISAC) Sun and storm," *Copyright Bulletin,* vol. 32, pp. 4-6, 1998.

[7] O. Economics and B. Council, "The economic impact of the creative industries in the Americas," 2014. [Online]. Available: https://policycommons.net/artifacts/307843/the-economic-impact-of-the-creative-industries-in-the-americas/1226671/.

[8] BCCR, "Sistema de Cuentas Nacionales de Costa Rica en el marco del Cambio de Año Base 2012," Banco Central de Costa Rica, https://activos.bccr.fi.cr/sitios/bccr/proyectocambioannyobase/DocProyectoCambioAnnyoBase/documentoscnadocpresentaciones/Metodologia-CAB-2012.pdf, 2020.

[9] J. M. Benavente and M. Grazzi, "Políticas públicas para la creatividad y la innovación: impulsando la economía naranja en América Latina y el Caribe," *Washington DC: Banco Interamericano de desarrollo–BID,* 2017.

[10] MCJ. "Banca para el Desarrollo y el MCJ establecen alianza para apoyar y fomentar emprendimientos artísticos y culturales " Ministerio de Cultura y Juventud. (accessed 2023).

[11] MCJ. "Presentación de Resultados: Cuenta Satélite de Cultura, Cuenta Satélite de Cultura." Ministerio de Cultura y Juventud. https://si.cultura.cr/cuenta-satelite-cultura (accessed 2023).

[12] A. Dovale and J. Morales, "Blockchain y el sector salud," *I+ S: Revista de la Sociedad Española de Informática y Salud,* no. 128, pp. 11-14, 2018.

[13] B. Shen, J. Guo, and Y. Yang, "MedChain: Efficient healthcare data sharing via blockchain," *Applied sciences,* vol. 9, no. 6, p. 1207, 2019.

[14] W. A. Espíritu-Aranda and C. F. Machuca-Nieva, "Modelo de Referencia para la Gestión de la Seguridad de Datos de Salud Soportado en una Plataforma Blockchain," 2021. [Online]. Available: https://repositorioacademico.upc.edu.pe/handle/10757/655799.