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The Role of Blockchain, IoT and AR in Future Healthcare: A Review

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Abstract

The healthcare industry is on the border of the technological revolution that unites tech, Internet of Things (IoT), Augmented Reality (AR), and Blockchain. Blockchain provides a transparent method for storing and exchanging records, which boosts data integrity and compatibility among systems. At the same time, IoT gadgets allow the real-time tracking of patient health indicators, aiding in prompt intervention and tailored treatment plans. Meanwhile, AR can elevate medical training sessions in surgical processes and patient involvement. Providers can streamline processes and cut expenses by blending these technological advancements and incorporating them into healthcare operations. The most exciting aspect is the potential to significantly enhance patient outcomes. Nevertheless, there are obstacles to overcome, like safeguarding data privacy, maintaining cybersecurity and navigating through requirements before these advancements can fully be harnessed to their maximum potential.

1. Introduction

This paper centres on the influence of combining Blockchain technology, Internet of Things, and Augmented Reality on patient care and hospital management. Understanding how these emerging technologies work is helpful, especially for industries that attempt to cut supply chain costs and streamline logistics. Hospitals will likely adopt these devices and tracking systems for efficiency and cost reductions. This document looks at the three technologies before analysing how these technologies affect healthcare systems (Kwon, H., et al., 2022).

Our modern society is sometimes characterised by the term “disruption” in reference to how digital technologies interconnect with many networks. Sectors related to the production or movement of goods are primarily targeted for disruption. The idea is to leverage brand-new technologies that further optimise and reduce costs in these operational and managerial spheres. These technologies also dovetail neatly with both patient care outcomes and patient experience. Both public and private healthcare providers thus may explore the potential breakthroughs these device tracking systems offer. As blockchain, IoT, and AR devices continue to penetrate sectors across the globe, senior management and staff can benefit from understanding what these devices are and why they matter. Identifying the potential effects of these

devices helps plan for change in how any company interacts with customers (Gadekallu, T. R., et al., 2022).

This article moves on to analyse these technologies in more depth. We start first with blockchain, as the other two technologies can only function as well with blockchain's ability to maintain a stable electronic repository (Chithaluru, P., et al., 2024).

1.1. The Convergence of IoT, Blockchain, and AR in Healthcare

The new generation of technologies, including Blockchain, the Internet of Things (IoT), and Augmented Reality (AR), are being adopted in modern society, promising to bring radical changes to industries in the future. Blockchain fundamentally enforces the idea of a decentralised system, aimed at achieving far greater levels of transparency than a centralised system, while maintaining high confidentiality. IoT, on the other hand, redefines the meaning of connectivity between individuals, devices, tools, and databases by promoting greater operational efficiency and improved functionality. The core of blockchain lies in a network where several computers of different types, all interconnected, share identical data, and each participant's computer retains its own copy of the combined work. Moreover, the confirmation and safeguarding of the data depend on the mutual agreement of all participants involved in a specific transaction (Javed et al., 2022).

AR enhances physical-world interactions by overlaying intangible textual or graphical information and virtual messages onto real-world scenes. In the past, blending the digital and physical worlds in a way that creates a new digital space seemed impossible. However, cutting-edge blockchain technology is now being used to facilitate this AR interaction (Farouk et al., 2020). Currently, the healthcare industry is in the process of adopting these technologies. In the near future, the combination of these three technologies could revolutionise healthcare by opening up new opportunities. This integration could provide a new avenue for the healthcare industry to improve medical treatment. In the IoT and blockchain ecosystem, several authorities have already adopted and tested mechanisms for medical record storage and management for research purposes (Mozumder et al., 2022). This helps minimise manual control of patient medical information, which is often scattered across different settings and centres. Additionally, a remote patient monitoring system has experimented with IoT devices and implemented blockchain tokens to manage patient actions. These examples illustrate how healthcare, IoT, and blockchain are interconnected. However, it is important to acknowledge the risks and challenges associated with these technologies, particularly concerning data security and privacy. AR has also gained recognition in the healthcare sector. Some telemedicine programmes now incorporate AR technology to support training and physical therapy, which is expected to become more functional in the future. As the demand for healthcare services increases, a new integrated system combining IoT, blockchain, and AR may emerge, offering new opportunities for future healthcare systems based on these technologies (Kim et al., 2020).

2. Modern Issues in Healthcare

It is essential to note that healthcare is among one of the most dynamic in the global economy. As the client base expands, the industry faces several challenges: increasing expenses, low productivity, and restricted access to care. Among the most significant difficulties, healthcare faces are siloed systems, which increase the likelihood of security breaches and transaction errors. Addressing the challenges of sharing healthcare data is crucial for several reasons, including improving security as patients transition between care facilities and enhancing research by providing access to "granular data"- detailed, specific information—on a broader scale. This inefficiency is so widespread in healthcare that it has become a

major area of research. Additionally, it is one of the new directions being pursued by developed countries to encourage life sciences companies to focus on caring for emerging patient populations (Razu et al., 2021).

A primary driver of change is the growing momentum for patient-driven, consumer-centric care. As a result, healthcare systems and providers are in urgent need of data transparency reforms. For example, when a patient arrives at an emergency room, staff often have to contact other medical facilities to retrieve their records. This process can lead to delays and risks for patients, as approximately one in three records may be outdated or inaccurate. An estimated 80 percent of clinicians agree that sharing health information is essential for reducing costs and improving the quality of care. Given the constant push for reform, organisations must implement contingency plans to protect shared information and ensure its security. By doing so, organisations that prioritise transparency and the secure sharing of patient data will be at the forefront of pioneering patient care, demonstrating their commitment to safeguarding patient information (Liu et al., 2023).

2.1. Security of Data and its Exchange

Privacy of data is a paramount factor more so today since information of patients is has trended towards being in electronic form. The contemporary technology platforms are vulnerable to phishing, ransomware, where one offers to sell personal data or the other locks off the health-care systems, and denies access to patient's data. Over 300 cybersecurity breaches in 2018 resulted in the compromise of 13 million individual files—records that today's data-driven IoT world is making increasingly more vulnerable as the number of connected devices and systems exponentially grows. Compromised health information is not only costly, but it is also psychologically traumatic for the patient and can result in a patient's lack of trust in healthcare systems or even death (Seh, A. H., Al-Amri, et al., 2022).

The avenues that need to integrate with several healthcare systems make interoperability a problem- one that affects efficient data sharing. A classic example was observed in the new EHR system used by the U.S. Veterans Affairs and the DOH's EHR system, which could not interconnect, and this is due to EHR systems used by some of the most important healthcare providers. Sharing a patient's medical data can transform the treatment of bones and may even save a life due to medication complications, allergies, or incompatible treatments. Inefficient data sharing alone has been considered a dangerous healthcare practice and has been known to result in decentralised medical data being a factor in over 86% of medication errors. Thousands of patients die each year from medical errors that would be significantly reduced just by accessing patient medical records internationally (Alhejaili, M. O. M., 2024).

There are expectations placed on blockchain technology to provide solutions to these challenges and allow healthcare practitioners to act on reliable information to optimise patient care. Electronic healthcare records and other healthcare data that revolve around the use of blockchain could tie fragmented healthcare systems and provide a wholesome view of a patient's record and experience. This integration would allow stakeholders to instantly access a patient's medical history, fostering large-scale collaboration, more efficient treatments, and deeper patient insights. Blockchain also prioritizes the privacy of medical information and is inherently compatible with regulatory frameworks such as General Data Protection Regulation (GDPR) and Health Insurance Portability and Accountability Act (HIPAA), ensuring that patient data is protected while improving accessibility (Soltanisehat, 2020).

3. Applications of Blockchain in Healthcare

Through the application of blockchain technology, there is a high possibility of dealing with some

questions connected with the control, security, and privacy of electronic health record (EHR) data. This is done by making an invulnerable record secured with cryptography and consensus. The use of blockchain offers three primary applications in healthcare:

1. Data security
2. Secure microtransactions
3. Enhanced EHR interoperability through the decentralised nature of the information stored on the blockchain.

Enhanced data interoperability can unlock a range of new services—both medical and non-medical—benefiting both providers and patients. Providers can have greater confidence in patient records, while research indicates that patients, doctors, and other stakeholders are willing to share patient data as long as it is anonymised. Implementing tamper-proof ledgers is also recommended for facilitating collaborations among healthcare providers in complex care management and related data management sectors (Ahmad, L., et al., 2020).

Practical case studies of blockchain in healthcare include its use for secure in-home pill dispensing and linking the pharmaceutical supply chain. There are also ongoing research projects, such as a pilot programme between major healthcare providers and a medical centre, which will use blockchain to automatically verify the credentials of their employees across organisations. While research is still in progress, there are no fully integrated blockchain systems within international health networks. However, several health systems have adopted aspects of the technology (Ray, P. P., et al., 2020).

3.1. Electronic Health Records

Blockchain's potential to revolutionise the medical sector cannot be overstated. One of blockchain's key applications is transforming Electronic Health Records (EHRs) at the intersection of blockchain and healthcare by focusing on the integrity of digitised records. While health information is highly sensitive and private for all parties involved, many countries still face a fragmented landscape of EHRs governed by varying rules and regulations. Blockchain enhances the security and integrity of these records by enabling patients to transfer their health data using a cryptographic key, which abstracts personal information. This allows for secure physician-to-physician transfer of health data without the need for third-party intermediaries, thereby streamlining healthcare processes and accelerating the delivery of care. Some regions have prioritised blockchain adoption, aiming to be among the first to use it for storing health data. Their goal is to transform medical records, making them more accessible and cost-effective for patients and healthcare providers (Chelladurai U., et al., 2022).

In some healthcare systems, surgery scheduling has been delayed by up to six weeks in one case and three weeks in another. Blockchain can address such issues by improving the speed of record entry and ensuring timely approval processes. Blockchain enables seamless record access and exchange, as healthcare professionals rely on standardised processes authorised by the blockchain network. The future of EHRs may shift from merely managing electronic records to maintaining stable, replicated health documents stored securely within blockchains. It is important to recognise that this shift in management involves more than executing a single transaction—it requires transaction verification for each new treatment or assessment using blockchain technology. While implementing blockchain to manage securely, new entries will necessitate updates to data protection laws; the anticipated changes may be feasible as predicted (Attaran, M., 2022).

4. The IoT in The Context of Healthcare Organizations And Performance

Internet of Things (IoT) entails the connection of physical objects like home devices, medical equipment, vehicles and any other object to the Internet to communicate with the service provider, manufacturer or other objects. The trends in the IoT field present significant long-term possibilities in the sphere of healthcare. Its incorporation in the sector has greater significance as it evolved to provide innovation in the health and well-being of the people. Often, IoT enables healthcare providers to gather several parameters related to a patient's health in real-time, experience improved patient care, faster recovery, shorter consultation time and even save lives. Innovative living applications include but are not limited to mental health, pregnancy, elder and child protection, weight control, and chronic diseases (Aceto, G., 2020).

Integration of IoT in Healthcare: First, let's discuss IoT in healthcare and the development of wearable technologies. More and more people use wearable devices in numerous fields to monitor their physical activity. These devices aggregate and wirelessly transmit data from temperature, blood pressure, pulse rate, and blood oxygen level. Wearable healthcare systems have emerged as a new medical device because of their ability to monitor patients remotely. Wearables may be worn like adornments or even attached to the human body as a component. Many wearable health monitoring devices have been developed to monitor sleep disorders and specific health conditions, especially in the elderly. Some wearable devices include smartwatches, hearing aids, fitness bands, and ECG monitors. In the case of patients with chronic diseases, including diabetes, hypertension, or heart diseases, wearables can sparingly contribute to clinical visits, hence decreasing the overall healthcare cost (Al Bassam, N., 2021).

4.1. Remote Patient Monitoring

Some of the most common IoT application areas include remote healthcare monitoring, as mentioned above. Telecare enables healthcare providers to track a patient's status from any location where the patient is receiving treatment. In addition to monitoring conditions related to heart rate, temperature, and other vital signs, physicians can receive real-time alerts and analyse health data quickly through remote monitoring systems. This allows for proactive treatment and timely interventions in life-threatening situations. Vital signs can be monitored through various devices, such as smartwatches, tablets, smartphones, or shared screens in a virtual health exam room. Even for patients without smartphones, smart home or in-home devices, as well as kiosks, can transmit vital data directly into Electronic Health Records (EHR), allowing clinicians to gain insights efficiently (Alshamrani, M., 2022).

Some of the most common IoT devices used for remote patient monitoring include home health devices or wearable mobile devices that track vital signs such as weight, temperature, and blood pressure. Other examples include fall-detection devices, call buttons, and telehealth devices equipped with monitoring systems and secure, high-speed internet connectivity. Home monitoring systems continuously capture physiological and health data in standardised, interoperable formats, which can be used in hospitals and long-term care facilities. Using cameras, remote patient monitoring devices can also track patient adherence, read biometric results, monitor sessions, confirm patient identity, and provide technical support (Kadhim, K. T., 2020).

These devices are particularly beneficial for monitoring patients with chronic conditions and supporting them in self-management, allowing them to live independently, adhere to prescribed care plans, and actively participate in community events. By leveraging telemedicine, remote patient monitoring technology enables clinicians to collect real-time data on side effects, symptoms, and the effectiveness of medications. Continuous monitoring helps prevent unnecessary hospital readmissions through virtual

visits. Alerts generated by real-time data can help prevent readmissions and allow patients to receive treatment at home. Health treatment protocols are defined through automated rules, while the analysis also incorporates subjective, patient-specific factors such as living conditions and social support (Yew, H. T., 2020).

5. Augmented Reality in Medical Training

Augmented Reality (AR), on the other hand, is a form of Real Virtuality technology that overlays graphics, sound, haptics, smell, taste, or other sensory data onto the real world. This technology holds significant potential in medical training, offering promising opportunities to improve trainees' performance and patient recovery rates. There is little doubt about the challenges of training healthcare personnel in a vast field like medicine. AR addresses these challenges by integrating digital content into real-world environments. Learners of the present generation, or digital natives, are particularly adept at adapting to this approach, making it easier for them to grasp the knowledge presented (Barteit S. et al., 2021).

One area where AR has been applied in training is virtual surgery. This approach allows technicians to practice assembling myoelectric prosthetic devices and even low-cost traditional prosthetic hands in a risk-free environment. Additionally, advanced AR applications that include interactive anatomical models have been developed, helping medical students study human anatomy more effectively. This method can also benefit veterinary education, where integrating operating theatre tools and other physical materials may present fewer challenges. AR technology can enhance the retention of information among medical students. Placing equipment and personnel in the operating room is crucial for successful outcomes, and AR tools can be integrated into surgery as teaching aids. However, curricula must be revised to leverage AR in medical training fully. One of the main challenges to implementing AR in medical education is the need for more technical infrastructure (Moro, C., 2021).

There is also a need to educate instructors on using AR effectively and developing it as a teaching tool. AR is already used in nursing education to help create adaptable healthcare workers and digital citizens. Based on literature and case studies of AR in medical education, our institution could take advantage of AR's transformative potential to develop healthcare workers. AR-based medical learning has the potential to impact the healthcare industry significantly. Augmented reality can improve healthcare workers' education and could represent the future of healthcare training. By combining AR technology with virtual prototypes, new nurses could be better equipped to plan and manage patient care safely and effectively. Beyond its role in daily activities, AR embedded in e-learning is well-suited for application in the healthcare sector. Both theoretical and practical aspects of AR in healthcare training suggest numerous positive outcomes (Jeffries, P., 2020).

5.1. Simulation and Education

Simulation, with its significance and holistic value, is also a key aspect in the future integration of healthcare with blockchain, IoT, and AR technologies. Blockchain is a decentralised digital ledger technology that is increasingly being implemented to increase security and, specifically, to create high levels of integration and sustainability in the healthcare system. As healthcare teams turn more and more to health promotion and disease prevention and as we move towards a more patient-centred practice, the use of simulation in medical education grows. One emerging trend in evaluating residents is their participation in educational processes using high-fidelity mannequins, which can perform a limited range of procedures and interventions typically seen in the healthcare settings where applicants seek residency. This process occurs through computer programs that feature two-dimensional and three-dimensional

displays, simplifying learning and eliminating the need for cadavers. This form of learning is known as simulation-based education, highlighting the value and importance of educators in the healthcare system (Moawad, G. N., 2020).

Simulation can take various forms, including mentor-student role plays, collaborative role-playing with fellow students acting as co-workers, high-fidelity mannequin exercises, and peer-to-peer interactions in role-playing scenarios. Additionally, mixed reality role-playing is becoming increasingly common, where some students role-play virtually while others do so in person within the same classroom. In chiropractic education, simulated patients are extensively used in clinical training. The concept of AR education builds upon this, enhancing educational outcomes by integrating simulated patients into the learning process. For example, chiropractic education employs techniques that foster problem-solving and critical thinking, aligning with simulation-based learning principles (Radkowitsch, A., 2022).

6. Future Trends and Opportunities

Current and emerging economic and social issues are significantly impacting the healthcare sector. However, innovative technologies such as blockchain and the Internet of Things (IoT) are emerging as world-class opportunities. These technologies are key in creating value, transforming healthcare and enhancing patient treatment. From a clinician's perspective, blockchain, IoT services, and related devices offer optimal, highly convenient solutions. They connect to personal health management networks, supporting recovery and improving overall well-being through integrated physical and digital components. The combination of the Internet of Things, blockchain, and augmented reality enables a complete healthcare industry transformation (Agarwal, R., 2020).

This is why creating an integrated infrastructure for managing healthcare data—across professional and individual systems—is essential. Such infrastructure helps address patient treatment, supports health service authorities, practitioners, and researchers, and contributes to achieving broader goals swiftly, efficiently, and cost-effectively. As a result, the overall quality of services is enhanced. Moreover, this approach fosters greater patient involvement, leading to more satisfying outcomes such as improved care efficiency and quality through active patient-care systems (Venigandla, K., 2022).

Personalised patient treatment is improving, incorporating complementary information that offers a better understanding of the recovery process, expected physical and mental changes, cost reduction in treatment, and actual treatment costs. Ongoing research and future trends in these technologies indicate a significant increase in adopting blockchain solutions in healthcare in the coming years. For example, blockchain can securely store and share patient records, ensuring high data confidentiality levels.

Regulations in healthcare are evolving, with a focus on digital care, opening up new possibilities for patient treatments. As new services or solutions are introduced, healthcare services are expected to integrate these technologies. These innovations will be precious for multidisciplinary medical teams. Detailed clinical assessments can provide the foundation for their application, while psychologists and neuroscientists can offer insights into psychological responses, including the autonomic nervous system (ANS) and its efficiency. Computer scientists will be instrumental in improving technical outcomes, ensuring that the results align with clinical research goals through machine learning and advanced data analysis tools. Finally, once therapies are implemented and tested, health economics can assess their cost-effectiveness, considering the quality-of-life years saved (Attaran, M., 2022).

6.1. Precision Medicine

As discussed, current trends present a significant opportunity to improve the existing healthcare scenario.

An analysis of various trends shows that applying the new trends helps precision medicine, to reap significant gains from blockchain, IoT, and augmented reality integration. Precision medicine is a novel disease management and prevention strategy that characterises genetic, environmental, and behavioural variations between individuals. Genetic and clinical information is employed in this model to design patient-tailored treatment plans, especially for cancer and cardiovascular diseases. The most significant use case of blockchain and IoT, along with augmented reality, is for developing personalised health devices (Tsimberidou A. M., 2020).

Illness is slowly being supplanted in health care with the notion of well-being. New ideas are being developed to move patients from hospital settings to home settings. IoT wearables make it possible for healthcare to keep assessing patients remotely. Consumer IoT devices already measure aspects like blood sugar, blood pressure, and the ECG. Integrating such devices with smartphones allows patients' health data to be immediately received, threats detected in advance, and responses given promptly. For instance, augmented reality can enhance the patients' appreciation of treatment pathways, test results or disease self-management since they can provide more of a window into the processes, helping them understand and gain more control over the situation (Subramanian, M., 2020).

More accurate health data can guide healthcare professionals in determining the best course of treatment. However, a significant challenge is that data collected from different devices is often stored in separate databases, some of which are owned by companies that sell wearable devices. To conduct comprehensive data analysis, this information must be consolidated, as the data from one device may influence the results of another. This situation raises ethical concerns regarding data ownership, consent, and potential misuse. Additionally, it introduces the risk of study bias if the data cannot be easily integrated from multiple sources.

Not only do we get all the detailed health data in one gadget, but these tools also offer an encrypted and secure place to investigate the problems and opportunities in topics related to lifestyle and medicine, including dementia, arthritis, cancer, cardiovascular diseases, diabetes, and obesity management. Augmented reality, virtual reality and personalised patient experience also strongly affect the healthcare industry's future.

Some applications are already in use, providing patients with a more immersive understanding of their treatment plans, test results, or disease management strategies. This could increase patient knowledge, alter behaviours and support better health outcomes. Additionally, it could enhance the quality of the doctor-patient relationship.

Sharing data across IoT platforms presents a significant opportunity to reduce healthcare costs while delivering a more personalised level of treatment. With patient data becoming interoperable across devices, and given the massive amounts of data that IoT devices can collect more precise data analytics will be achievable in the future. This could lead to long-term cost savings, not only by reducing the cost of software development but also by improving the quality of care and creating treatment plans specifically tailored to the individual (MacEachern, S. J. et al., 2020).

7. Conclusion

The merging of technology, with IoT and augmented reality has the power to revolutionize the healthcare industry in a way by enhancing how medical information is securely stored and shared transparently to ensure data accuracy and facilitate data exchange processes. IoT gadgets contribute to the real time monitoring of health indicators which helps in implementing timely interventions and personalized care

to enhance patient results. The excitement truly lies in the possibilities of reality as it advances training programs and surgical techniques while boosting engagement—a technology that fosters learning experiences culminating in improved treatment outcomes.

While these progressions show potential, for improvement in areas of healthcare delivery and outcomes, like data privacy and security remain concerns that need attention to move forward successfully in the future of healthcare.

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