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Integrating IoT with Virtual Healthcare: A theoretical framework for enhancing accessibility and efficiency in the U.S. healthcare sector

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Abstract

This paper presents an open source platform aimed at revolutionizing healthcare delivery in the United States by significantly reducing the cost of virtual healthcare software. The proposed platform addresses the pressing challenges of accessibility and efficiency in the U.S. healthcare sector through cloud native backend solutions and mobile apps driven by modular design and IoT-enabled devices. By leveraging IoT technology, virtual healthcare platforms can provide real-time monitoring, remote consultations, and personalized care, thereby improving patient outcomes and reducing healthcare costs. The platform emphasizes nationwide scalability, inclusivity, and a transition towards a proactive, patient-centric healthcare model. By leveraging the opensource community, modular design and a plugin architecture, it aims to enable feature extensibility beyond what is foreseeable today, promote interoperability, ensure data privacy and security, and promote technology adoption among healthcare providers and patients. The proposal presented in this paper lays the foundation for the implementation aimed at harnessing the full potential of IoT and virtual healthcare to enhance accessibility and efficiency in the U.S. healthcare sector, ultimately advancing the quality of care and well-being of the population.

Keywords: IOT; Healthcare; Open Source; Framework; USA; Patients; Review

1. Introduction

The U.S. healthcare sector is facing numerous challenges, including issues with accessibility, inefficiencies, and high costs, which necessitate the exploration of innovative solutions (Marques et al., 2019). Given the growing importance of technology in addressing healthcare challenges, there is an urgent need for novel approaches that leverage the potential of the Open source community, Internet of Things (IoT) and virtual healthcare to improve healthcare delivery (Pradhan et al., 2021). By providing an open source healthcare platform, we level the software playing field, promoting innovation, interoperability, integration and standardization. We also improve patient safety since the source code is easily scrutinized by anyone and bugs are easily identified (Gropper, 2011). Through the integration of IoT technology, it is feasible to address the current obstacles in the U.S. healthcare sector and enhance national healthcare outcomes (Marques et al., 2019).

The literature underscores several critical challenges that must be tackled for the successful implementation of IoT in healthcare. These challenges encompass problems related to accessibility, portability, interoperability, information security, privacy (Marques et al., 2019) and confidentiality. Additionally, issues such as the scarcity of cost-effective smart medical sensors, unstandardized IoT system architectures, heterogeneity of wearable devices, data multidimensionality, and the need for interoperability present significant barriers to the advancement of healthcare management systems (Junaid et al., 2022).

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In conclusion, the proposed platform that integrates IoT technology with virtual healthcare shows promise in revolutionizing healthcare delivery in the U.S. by addressing current challenges and enhancing healthcare outcomes. By drawing on insights from existing research on IoT applications in healthcare, it is possible to develop a comprehensive framework that overcomes the hurdles faced by the healthcare sector.

2. Proposed Approach

The approach proposed is an open source model with modular design and plugin architecture. A modular design is proposed to decompose the complex requirements needed for virtual healthcare into individual software modules dedicated to solving a specific sub-problem. This makes it easier to modify specific modules for new requirements without affecting the main system (Tseng et al., 2018). A plugin architecture shall be utilized to accommodate the ever changing IoT landscape and to accomodate the interoperability differences of current remote patient monitoring devices. In line with observations by Chiprianov et al. (2021), the plugin architecture will provide some stability to the system design while ensuring that the list of supported devices continues to be extensible. A high level view of the proposed design is shown in Fig 1

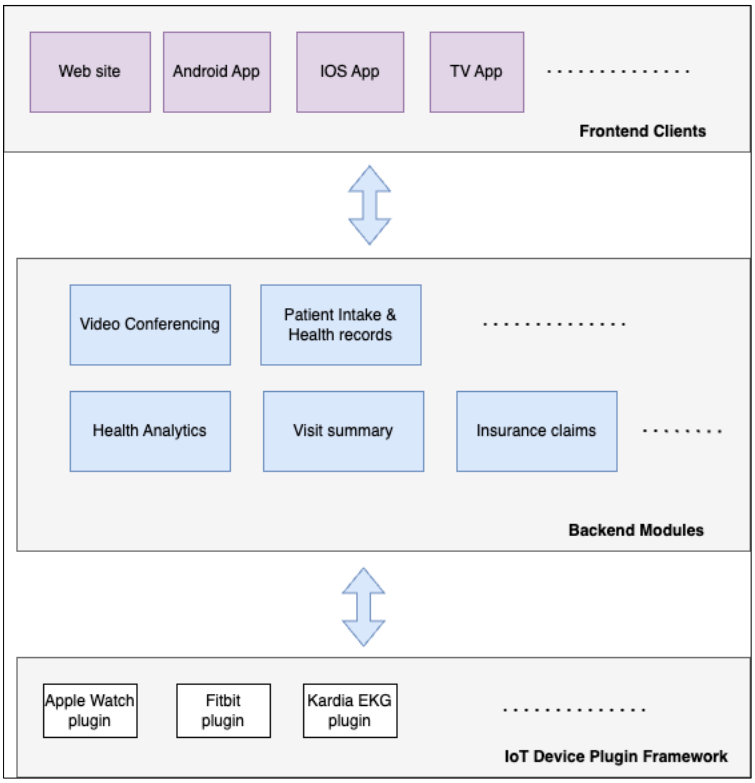

Figure 1 Proposed Model

A website and mobile apps shall be part of the platform's offering along with independent backend modules and IoT device plugins. Each component in the proposed solution can be evolved independently allowing for voluntary contributions from other researchers and experts in the open source community to provide functionality beyond what is possible today. The Linux Operating system makes a good open source case study in this regard. It's opensource model has sustained its continuous positive evolution (Godfrey and Qiang Tu, 2000). Similarly it is expected that the platform offerings will better than many commercial alternatives over time due to the open source community. The core components of the platform encompass data-driven backend solutions, advanced APIs, third-party integrations, and IoT device integration for real-time health monitoring. These components are essential for enabling seamless data flow, interoperability, and real-time monitoring within the healthcare system (Ayo-Farai et al., 2023; Babarinde et al., 2023). The platform also integrates security and privacy-preserving mechanisms, as highlighted in studies focusing on cybersecurity in IoT-based healthcare applications (Pirbhulal et al., 2022). Furthermore, the platform shall consider incorporating innovative approaches such as the use of digital twins for reinforcing cybersecurity in IoT-based healthcare, as proposed in recent research (Pirbhulal et al., 2022; Akindote et al., 2023).

The innovative aspect of the proposed framework lies in the fact that it will provide an enterprise grade virtual health care platform at no cost, significantly lowering the barrier to providing virtual health care. Secondly, it provides extensible integration of IoT with virtual healthcare, offering novel solutions to address the current challenges in the U.S. healthcare sector. By combining IoT technologies with virtual healthcare, the platform has the potential to revolutionize patient care by enabling remote monitoring, personalized treatment plans, and improved healthcare outcomes. Moreover, the platform is in line with the need for scalable integration of IoT and blockchain in healthcare systems, as highlighted in studies focusing on distributed security in IoT healthcare environments (Zaman et al., 2022; Okafor et al., 2023).

In conclusion, the platform proposed in this paper leverages the advancements in IoT technologies and virtual healthcare to address the challenges faced by the U.S. healthcare sector. By integrating key components such as advanced APIs, and IoT device integration, the framework offers a comprehensive approach to improving healthcare delivery and patient outcomes.

3. Implementation Strategy

Implementing the proposed platform requires careful planning and execution to ensure its positive platform evolution and successful integration into the U.S. healthcare sector. This section outlines a comprehensive strategy consisting of phased implementation, technology infrastructure development, developer advocacy and stakeholder engagement.

Implementing the proposed platform in the U.S. healthcare sector necessitates a meticulous approach encompassing phased implementation, technology infrastructure development, and stakeholder engagement (Balogun et al., 2024; Hassan et al., 2024). This approach allows for risk mitigation, scalability testing and impact as the platform is adopted nationwide. The plugin and modular design plays a key role as it allows individual modules to be developed, tested and shipped to production independently. This allows new features to be introduced without breaking existing functionality. This is also crucial to allowing the incremental support of new IoT devices without affected already supported devices.

Since continuous communication, stakeholder consultations, and feedback mechanisms are essential for ongoing engagement (Zabell et al., 2021), a popular source code hosting solution such as Github will be used to enable active collaboration and open discussions on software bugs and enhancements (Seker et al., 2020). These collaboration is expected to ensure the continuous improvement and adoption of the platform. Healthcare conferences, open source conventions are also opportunities to promote adoption of the software. A UI based setup tool will be developed in each of the popular cloud provider marketplaces to reduce the cost of setting up the system. A DIY video tutorial will also be provided to guide the tech savvy user on how to set up the solution allowing for more cost savings. These are aimed at improving the platform's perceived ease of use, further encouraging adoption (Gefen and Straub, 2000). Health care providers will also have the option to purchase a support plan if they desire a managed service experience.

The success of this effort hinges on robust technological infrastructure (Mackey et al., 2019), ensuring broadband access in rural areas and equitable distribution of IoT devices (Mackey et al., 2019; Abrahams et al., 2023). Data security measures are paramount to safeguard patient information (Mackey et al., 2019). Patients also need to be informed about IoT-enabled solutions (Zabell et al., 2021). Policymakers are crucial for creating a supportive regulatory environment (Zabell et al., 2021; Ilugbusi et al., 2020).

In conclusion, the execution strategy outlined emphasizes phased implementation, robust technology infrastructure, and stakeholder engagement to drive successful adoption and integration into the U.S. healthcare sector. By following this approach, the theoretical framework can be effectively implemented, leading to improved healthcare delivery and outcomes.

4. Impact on National Outcomes

The integration of Internet of Things (IoT) technologies with virtual healthcare solutions has the potential to transform national healthcare outcomes in the United States (Uchechukwu et al., 2023; Fabian et al., 2023). By leveraging IoT-enabled virtual healthcare platforms, accessibility can be enhanced through remote access to medical consultations, monitoring, and follow-up care, thereby overcoming geographical barriers and improving healthcare access for underserved populations (Coulby et al., 2020). This approach can lead to timely interventions, preventive care, and reduced disparities in healthcare access, ultimately enhancing health outcomes for marginalized communities.

Furthermore, the proposed platform is positioned to enhance efficiency and cost-effectiveness within healthcare systems by utilizing IoT-enabled solutions and virtual care delivery (Dang et al., 2019; Onoyere and Adekanmbi, 2012). Through task automation, resource allocation optimization, and remote consultations, virtual healthcare platforms can streamline operations, reduce costs associated with in-person visits, and prevent costly complications through proactive health management (Dang et al., 2019; Adekanmbi and Wolf, 2024). This can result in long-term cost savings for both patients and healthcare providers.

Regarding patient outcomes, the integration of IoT with virtual healthcare solutions is anticipated to drive improvements through proactive health management and personalized care (Alrawashdeh et al., 2022). Continuous monitoring of vital signs, medication adherence, and lifestyle behaviors using IoT devices empowers patients to engage in preventive measures and take control of their health. Additionally, virtual healthcare platforms enable personalized treatment plans, remote consultations, and early detection of health issues, fostering patient engagement, adherence to treatment regimens, and self-management of chronic conditions (Alrawashdeh et al., 2022).

In conclusion, by harnessing the capabilities of IoT in conjunction with virtual healthcare solutions, the proposed framework has the potential to revolutionize healthcare accessibility, efficiency, cost-effectiveness, and patient outcomes in the United States. This integration addresses critical gaps in healthcare access, optimizes resource utilization, and empowers individuals to proactively manage their health, ultimately contributing to a more equitable, efficient, and patient-centric healthcare system.

5. Challenges and Solutions

Implementing the platform faces challenges such as regulatory hurdles, privacy and security concerns, and barriers to technology adoption. Regulatory hurdles encompass compliance with healthcare regulations like HIPAA and FDA approvals, requiring stakeholders to engage with regulatory authorities for tailored guidelines (Farahani et al., 2018). Privacy and security are critical due to the sensitive health data collected by IoT devices, necessitating robust measures like encryption and access controls (Alraja et al., 2019). Barriers to technology adoption by healthcare providers and patients include concerns about workflow disruption and privacy, which can be addressed through training programs and incentives (Lowry et al., 2017). To overcome these challenges, collaboration between policymakers, industry stakeholders, and healthcare providers is crucial in developing regulatory frameworks that balance innovation and patient safety (Farahani et al., 2018). Implementing privacy-by-design methods and continuous monitoring can enhance data security in IoT-enabled healthcare solutions (Alraja et al., 2019).

By proactively addressing regulatory hurdles, privacy and security concerns, and barriers to technology adoption, stakeholders can successfully integrate IoT-enabled solutions into the healthcare ecosystem, improving accessibility, efficiency, and patient outcomes (Farahani et al., 2018; Alraja et al., 2019; Lowry et al., 2017). By addressing these common challenges in a single platform, we provide significant savings to clinics which is expected to translate to cheaper healthcare for the patient.

6. Future Outlook and Opportunities

The future outlook for IoT-enabled virtual healthcare is promising, with significant opportunities for advancements in technology and improvements in patient care. Advancements in IoT technology are expected to enhance virtual healthcare platforms by enabling more accurate monitoring, diagnosis, and treatment of medical conditions (Pradhan et al., 2021). The integration of IoT with artificial intelligence and data analytics presents opportunities for personalized treatment plans and streamlined healthcare delivery processes (Bradley, 2021). Telemedicine and remote patient monitoring are becoming integral components of healthcare delivery, offering opportunities to expand access to care and improve patient outcomes (Field & Grigsby, 2002).

IoT-enabled virtual healthcare platforms have the potential to facilitate personalized medicine and precision health initiatives by continuously monitoring individual health metrics and providing real-time insights into patient health status (Farahani et al., 2018). Additionally, these platforms offer opportunities for proactive population health management by aggregating and analyzing data from large patient populations to identify trends and implement targeted interventions (Gardasevic et al., 2020). As IoT-enabled virtual healthcare becomes more widespread, policymakers and regulators will need to address various policy and regulatory considerations such as data privacy, security, and reimbursement models for telehealth services (Khan et al., 2012). Clear guidelines and standards will be essential to ensure patient safety, data confidentiality, and quality of care in the virtual healthcare ecosystem. In conclusion, by embracing innovation and evidence-based practices, stakeholders can harness the transformative

potential of IoT to create a more accessible, efficient, and patient-centered healthcare system. The integration of IoT technologies with virtual healthcare is poised to reshape the future of healthcare delivery, offering opportunities for advancements in technology, improvements in patient care, and enhancements in healthcare delivery efficiency.

7. Conclusion and Future Directions:

In conclusion, the platform proposed presents a significant contribution to the U.S. healthcare sector. By leveraging IoT technologies and virtual healthcare solutions and making it open source, the platform has the potential to address key challenges such as accessibility, efficiency, and patient outcomes. The platform facilitates remote access to healthcare services, streamlines administrative processes, and enables proactive health management, ultimately leading to improved accessibility, operational efficiency, and patient outcomes. By emphasizing nationwide scalability and a patient-centric approach, the platform lays the groundwork for a more equitable, efficient, and resilient healthcare system in the United States.

While the platform represents a significant step forward in leveraging technology to transform healthcare delivery, there are several areas for future research and development. First, advancements in IoT technologies, such as wearable devices, sensors, and remote monitoring tools, offer opportunities to enhance the capabilities and functionalities of virtual healthcare platforms. Future research should focus on integrating emerging IoT technologies into the framework to further improve remote monitoring, diagnostic accuracy, and personalized care delivery.

Second, strategies for patient engagement and empowerment are critical for the success of virtual healthcare initiatives. Future research should explore innovative approaches to promoting patient participation, adherence to treatment plans, and self-management of chronic conditions through digital health interventions, education programs, and behavioral interventions. Finally, assessing the long-term impacts of the platform on healthcare policy, outcomes, and disparities is essential for informing evidence-based decision-making and driving continuous improvement in healthcare delivery. Future research should evaluate the scalability, sustainability, and equity implications of implementing the platform at the national level, examining its effects on healthcare access, quality, and cost-effectiveness across diverse populations and settings.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abrahams, T.O., Ewuga, S.K., Kaggwa, S., Uwaoma, P.U., Hassan, A.O. and Dawodu, S.O., 2023. Review of strategic alignment: Accounting and cybersecurity for data confidentiality and financial security.

[2] Adekanmbi, A.O. and Wolf, D., 2024. Solid Mineral Resources Extraction and Processing Using Innovative Technology in Nigeria. ATBU Journal of Science, Technology and Education, 12(1), pp.1-16.

[3] Akindote, O.J., Adegbite, A.O., Dawodu, S.O., Omotosho, A., Anyanwu, A. and Maduka, C.P., 2023. Comparative review of big data analytics and GIS in healthcare decision-making.

[4] Alraja, M., Farooque, M., & Khashab, B. (2019). The effect of security, privacy, familiarity, and trust on users' attitudes toward the use of the iot-based healthcare: the mediation role of risk perception. Ieee Access, 7, 111341-111354. https://doi.org/10.1109/access.2019.2904006

[5] Alrawashdeh, M., Keikhosrokiani, P., Belaton, B., Alawida, M., & Zwiri, A. (2022). Iot adoption and application for smart healthcare: a systematic review. Sensors, 22(14), 5377. https://doi.org/10.3390/s22145377

[6] Ayo-Farai, O., Olaide, B.A., Maduka, C.P. and Okongwu, C.C., 2023. Engineering Innovations In Healthcare: A Review Of Developments In The USA. Engineering Science & Technology Journal, 4(6), pp.381-400.

[7] Babarinde, A.O., Ayo-Farai, O., Maduka, C.P., Okongwu, C.C., Ogundairo, O. and Sodamade, O., 2023. Review of AI applications in Healthcare: Comparative insights from the USA and Africa. International Medical Science Research Journal, 3(3), pp.92-107.

[8] Balogun, O.D., Ayo-Farai, O., Ogundairo, O., Maduka, C.P., Okongwu, C.C., Babarinde, A.O. and Sodamade, O.T., 2024. The Role Of Pharmacists In Personalised Medicine: A Review Of Integrating Pharmacogenomics Into Clinical Practice. International Medical Science Research Journal, 4(1), pp.19-36.

[9] Bradley, P. (2021). Population health management.. https://doi.org/10.1891/9780826144270

[10] Chiprianov, V., Kermarrec, Y. and Rouvrais, S. (2011). On the extensibility of plug-ins. [online] HAL Archives Ouvertes. Available at: https://hal.science/hal-00725543 [Accessed 26 Feb. 2024]

[11] Coulby, G., Clear, A., Jones, O., Young, F., Stuart, S., & Godfrey, A. (2020). Towards remote healthcare monitoring using accessible iot technology: state-of-the-art, insights and experimental design. Biomedical Engineering Online, 19(1). https://doi.org/10.1186/s12938-020-00825-9

[12] Dang, L., Piran, M., Han, D., Min, K., & Moon, H. (2019). A survey on internet of things and cloud computing for healthcare. Electronics, 8(7), 768. https://doi.org/10.3390/electronics8070768

[13] Fabian, A.A., Uchechukwu, E.S., Okoye, C.C. and Okeke, N.M., (2023). Corporate Outsourcing and Organizational Performance in Nigerian Investment Banks. Sch J Econ Bus Manag, 2023Apr, 10(3), pp.46-57.

[14] Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N., & Mankodiya, K. (2018). Towards fog-driven iot ehealth: promises and challenges of iot in medicine and healthcare. Future Generation Computer Systems, 78, 659-676. https://doi.org/10.1016/j.future.2017.04.036

[15] Field, M. and Grigsby, J. (2002). Telemedicine and remote patient monitoring. Jama, 288(4), 423. https://doi.org/10.1001/jama.288.4.423

[16] Gardasevic, G., Katzis, K., Bajic, D., & Berbakov, L. (2020). Emerging wireless sensor networks and internet of things technologies—foundations of smart healthcare. Sensors, 20(13), 3619. https://doi.org/10.3390/s20133619

[17] Gefen, D. and Straub, D. (2000). The Relative Importance of Perceived Ease of Use in IS Adoption: A Study of E-Commerce Adoption. Journal of the Association for Information Systems, 1(1), pp.1–30. doi:https://doi.org/10.17705/1jais.00008.

[18] Godfrey and Qiang Tu (2000). Evolution in open source software: a case study. Proceedings International Conference on Software Maintenance ICSM-94. doi:https://doi.org/10.1109/icsm.2000.883030.

[19] Hassan, A.O., Ewuga, S.K., Abdul, A.A., Abrahams, T.O., Oladeinde, M. and Dawodu, S.O., 2024. Cybersecurity In Banking: A Global Perspective With A Focus On Nigerian Practices. Computer Science & IT Research Journal, 5(1), pp.41-59.

[20] Ilugbusi, S., Akindejoye, J.A., Ajala, R.B. and Ogundele, A., 2020. Financial liberalization and economic growth in Nigeria (1986-2018). International Journal of Innovative Science and Research Technology, 5(4), pp.1-9.

[21] Junaid, S., Imam, A., Balogun, A., Silva, L., Surakat, Y., Kumar, G., … & Mahamad, S. (2022). Recent advancements in emerging technologies for healthcare management systems: a survey. Healthcare, 10(10), 1940. https://doi.org/10.3390/healthcare10101940

[22] Khan, R., Khan, S., Zaheer, R., & Khan, S. (2012). Future internet: the internet of things architecture, possible applications and key challenges.. https://doi.org/10.1109/fit.2012.53

[23] Lowry, P., Dinev, T., & Willison, R. (2017). Why security and privacy research lies at the centre of the information systems (is) artefact: proposing a bold research agenda. European Journal of Information Systems, 26(6), 546-563. https://doi.org/10.1057/s41303-017-0066-x

[24] Mackey, T., Kuo, T., Gummadi, B., Clauson, K., Church, G., Grishin, D., … & Palombini, M. (2019). 'fit-for-purpose?' – challenges and opportunities for applications of blockchain technology in the future of healthcare. BMC Medicine, 17(1). https://doi.org/10.1186/s12916-019-1296-7

[25] Marques, G., Pitarma, R., Garcia, N., & Pombo, N. (2019). Internet of things architectures, technologies, applications, challenges, and future directions for enhanced living environments and healthcare systems: a review. Electronics, 8(10), 1081. https://doi.org/10.3390/electronics8101081

[26] Okafor, C.M., Kolade, A., Onunka, T., Daraojimba, C., Eyo-Udo, N.L., Onunka, O. and Omotosho, A., 2023. Mitigating cybersecurity risks in the US healthcare sector. International Journal of Research and Scientific Innovation (IJRSI), 10(9), pp.177-193.

[27] Onoyere, I.O and Adekanmbi A. O. O., 2012. Sustainable Energy Development In a Developing Economy: The Nigerian Experience. ATBU Journal of Science, Technology and Education, 1, pp 142 – 150.

[28] Pirbhulal, S., Abie, H., & Shukla, A. (2022). Towards a novel framework for reinforcing cybersecurity using digital twins in iot-based healthcare applications.. https://doi.org/10.1109/vtc2022-spring54318.2022.9860581

[29] Pradhan, B., Bharti, D., Chakravarty, S., Ray, S., Voinova, V., Бонарцев, А., … & Pal, K. (2021). Internet of things and robotics in transforming current-day healthcare services. Journal of Healthcare Engineering, 2021, 1-15. https://doi.org/10.1155/2021/9999504

[30] Seker, A., Diri, B., Arslan, H. and Amasyalı, M.F. (2020). Open Source Software Development Challenges. International Journal of Open Source Software and Processes, 11(4), pp.1–26. doi:https://doi.org/10.4018/ijossp.2020100101.

[31] Tseng, M.M., Wang, Y. and Jiao, R.J. (2018). Modular Design. CIRP Encyclopedia of Production Engineering, pp.1–10. doi:https://doi.org/10.1007/978-3-642-35950-7_6460-4

[32] Uchechukwu, E.S., Amechi, A.F., Okoye, C.C. and Okeke, N.M., 2023. Youth Unemployment and Security Challenges in Anambra State, Nigeria. Sch J Arts Humanit Soc Sci, 4, pp.81-91.

[33] Zabell, T., Long, K., Scott, D., Hope, J., McLoughlin, I., & Enticott, J. (2021). Engaging healthcare staff and stakeholders in healthcare simulation modeling to better translate research into health impact: a systematic review. Frontiers in Health Services, 1. https://doi.org/10.3389/frhs.2021.644831

[34] Zaman, S., Khandaker, M., Khan, R., Tariq, F., & Wong, K. (2022). Thinking out of the blocks: holochain for distributed security in iot healthcare. Ieee Access, 10, 37064-37081. https://doi.org/10.1109/access.2022.3163580