Blockchain Healthcare Application

Current Collaborators: Michal Markevych, Anthony Franco

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Our Background

I am currently pursuing a Bachelor of Science in Computer and Cybersecurity Engineering, showcasing my commitment to academic and technological excellence. My summers have been strategically invested in multiple internships at Google, where I actively contributed to diverse teams and developed features across various product areas. These experiences have granted me firsthand insights into the inner workings of a large technology company, fostering a robust understanding of the industry from a software engineering perspective. The hands-on nature of my internships has equipped me with valuable skills, positioning me as a promising talent ready to excel in the dynamic technology sector. My academic commitment and practical experience exemplify a seamless integration of learning and application, making me well-prepared for impactful contributions in my future endeavors.

As a passionate and motivated individual with publications in the Cybersecurity and AI Space, I am excited to apply my computer and biomedical engineering problem solving skills into the Penetration Testing/Cybersecurity Analysis field. With a Masters in Cybersecurity and a passion for continuous learning, I have gained expertise in vulnerability assessments, penetration testing, IDS/IPS systems, data protection, and scripting.

In this project, I put my attention to using the Remix IDE to create an ethereum based smart contract for healthcare data coming from an IoT device. After a semester-long research working on this project, I have gained experience in working with smart contracts and am looking to apply smart contracts to other disciplines.

Abstract

In the realm of healthcare, the integration of blockchain technology has emerged as a pivotal solution for robust and trustworthy data management. Particularly critical in handling sensitive patient information, this innovative approach transcends theoretical concepts, shedding light on concrete implementations that extend beyond the confines of conceptual studies. As institutions recognize the paramount importance of secure data storage and seamless access to comprehensive patient records, blockchain technology stands out as a secure, transparent, and digital avenue to meet these evolving needs.

This comprehensive exploration delves into the current landscape of blockchain implementations in healthcare, navigating beyond mere theoretical frameworks and showcasing promising systems through systematic literature research. A key revelation lies in the increasing significance of secure data storage, prompting the development of hybrid solutions that marry conventional data storage with blockchain-based access management. Additionally, the automation of processes through smart contracts emerges as a recommended strategy.

Yet, amidst the strides made, certain ambiguities persist. The distinction between permissioned and permissionless blockchain frameworks, the integration of machine learning, and the legal intricacies of determining what data should reside in the blockchain warrant further investigation. This elucidates an ongoing need for research to solidify the application of blockchain in healthcare.

Against the backdrop of global health crises, such as the Covid-19 pandemic, healthcare practitioners grapple with the imperative to access, manage, integrate, and share health records securely. Traditional technologies falter in addressing these demands due to limitations in privacy, security, and full ecosystem interoperability. Here, blockchain technology emerges as a beacon of hope, offering solutions to healthcare data management challenges and enabling the automation of medical record mining for more accurate diagnoses.

Introduction

Embarking on the intersection of cutting-edge technology and healthcare, the Healthcare and the Blockchain project represents a groundbreaking initiative poised to redefine established norms. This endeavor unfolds within the context of the Special Problems course (ECE497) during the Fall 2023 semester, under the adept guidance of Professor Eral Oruklu. As aspiring Bachelor of Science candidates in Computer and Cybersecurity Engineering, we have passionately steered this transformative venture, illuminating the potential of blockchain technology in revolutionizing healthcare practices.

In the ever-evolving landscape of blockchain technology, our project stands as an innovative amalgamation of blockchain and modern healthcare, poised to transcend the boundaries of conventional solutions. Positioned at the forefront of technological advancements, our initiative holds promise in reshaping early paradigms and ushering in a new era of efficiency, security, and transparency in healthcare data management.

This introduction serves as a prelude to an in-depth exploration of the Healthcare and the Blockchain project, unraveling its intricacies, functionalities, and profound impact on the healthcare sector. Beyond the surface, we will navigate through the project's principles of operation, unraveling the architecture and software elements that underpin its functionality. Furthermore, we will candidly address the limitations inherent in the current implementation, charting a course for potential future enhancements. The journey culminates in reflections on the project's broader significance and its unique contributions to the dynamic field of healthcare technology.

In this comprehensive report, our aim is to provide a lucid understanding of the Healthcare and the Blockchain project—its objectives, its innovative role in healthcare, and the strides it makes towards shaping a technologically advanced and secure future for healthcare data management.

Related Work

In a previous iteration of this project, undertaken by Bryant Schultz and Shayaan Ahmed during the Spring 2023 semester (ECE 497 – Special Problems), the focus was on combining blockchain technology with medical devices. The objective was to revolutionize the storage, sharing, and security of sensitive medical data. The project aimed to provide patients with control over their medical information and enable secure sharing with healthcare professionals.

Contributions of Previous Students

- Bryant Schultz:
  - Developed the communication code for BlockChainDB.
  - Contributed to the report sections on functional validation and verification, results, and conclusions.
  - Involved in overall research and design aspects of the project.

- Shayaan Ahmed:
  - Wrote sensor code to simulate fake sensors.
  - Contributed to the report sections on introduction, background, and architectural exploration.
  - Involved in overall research and design aspects of the project.

Project Overview

- The project explored challenges in building a secure blockchain system for medical data, considering factors like data security, user-friendliness, scalability, interoperability, and compliance with medical data regulations.
- Utilized BigchainDB as the blockchain platform due to its decentralized nature, security features, and scalability, allowing for the creation of a simulation of a healthcare blockchain platform.

Functional Validation and Verification

- Implemented a pair of keys (public and private) for each patient to secure and retrieve data.
- Simulated medical sensor information, including heart rate, temperature, and glucose levels.
- Validated data transmission to the blockchain by comparing hashed values locally and on the chain.

Results

- Utilized BigchainDB's asset-centric approach for creating, transferring, and updating assets, focusing on fixed data and metadata.
- Emphasized simplicity, security, and patient access to their own data.
- Achieved a balance between security, encryption, and user access.

Conclusion and Future Work:

- Successfully demonstrated the integration of arbitrary sensor data into the blockchain for healthcare applications.
- Set a foundation for future work, suggesting potential expansions like incorporating actual sensor data, integrating with existing medical devices, deploying a local blockchain network, and creating user interfaces for doctors and patients.

Notes for Future Work

- Highlighted the change in ownership of BigChainDB to PlanetMint in 2019, with a recommendation to refer to their public GitHub repository for updated information.

This related work serves as a valuable reference for the current project, providing insights into the challenges faced, design decisions made, and the overall success achieved in combining blockchain technology with healthcare applications. The exploration of different blockchain platforms and the

emphasis on security and simplicity can inform and guide the ongoing development of the Healthcare and the Blockchain project during the Fall 2023 semester.

Principle of Operations

The project unfolds as a revolutionary health tool, aiming to redefine the security and accessibility of health records through innovative means. At its core, the project employs a sophisticated operational framework, leveraging the power of smart contracts and the aggregation of sensor data. This strategic approach facilitates the seamless uploading and updating of users' health data through the decentralized blockchain architecture.

The operational sequence initiates with the user's mobile application, serving as the catalyst for retrieving health data captured by the device's health app, often embedded in a smartwatch or a health-related device. Once acquired, the application proceeds to update this information on the blockchain by triggering a transaction through a pre-deployed smart contract embedded within the blockchain network.

A concise depiction of the project's operational flow is encapsulated in Figure 1, elucidating the interconnected process from the capture of sensor data to the pivotal step of updating information on the blockchain.

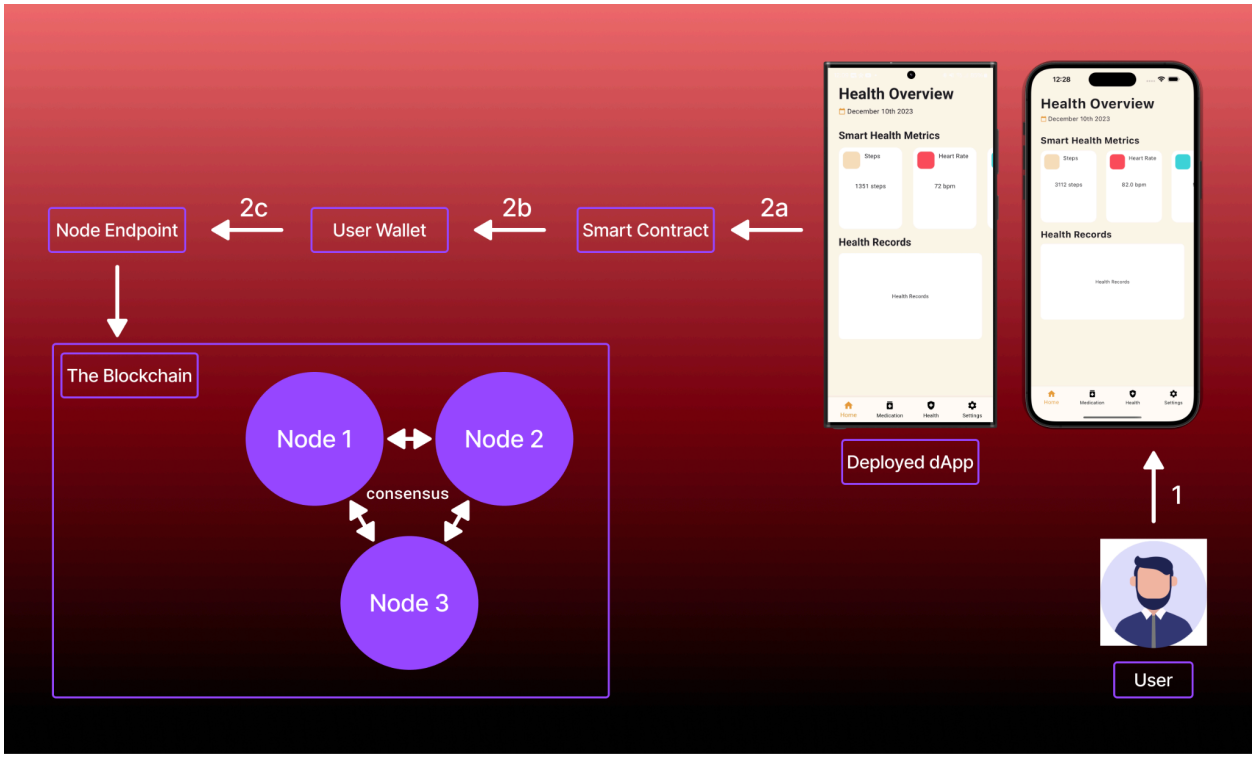


Figure 2: The Operational Flow of the Flutter Application with the Blockchain

In essence, the project's principle of operations revolves around an intricate interplay of user-engaged applications, sensor data capture, and the seamless integration of smart contracts. This dynamic orchestration not only fosters user-friendly interactions but also lays the foundation for a pioneering solution in the realm of secure and accessible health data management.

Software

The software architecture of the Healthcare and the Blockchain project is meticulously crafted to deliver a seamless, user-centric, and highly secure platform for managing health data. This endeavor harmoniously integrates cutting-edge technologies, excelling in executing pivotal tasks that span across mobile application development, blockchain functionality, and innovative code contributions.

Mobile Application

The cornerstone of user interaction within the project lies in its mobile application, a pivotal component designed to provide an intuitive and accessible interface for users to effortlessly engage with their health data. Noteworthy features of the mobile application encompass:

1. **Health Data Retrieval:** The application excels in retrieving health data from diverse sources, seamlessly integrating information from smartwatches and other health-related devices. This capability ensures a comprehensive and up-to-date representation of the user's health metrics.

2. **Secure Data Transfer:** With a paramount focus on data integrity and privacy, the mobile application initiates secure data transfers. This ensures that health information is transmitted to the blockchain with robust encryption, safeguarding sensitive data from unauthorized access.

3. **User-Friendly Interface:** Engineered with user convenience at its core, the application boasts an interface characterized by intuitiveness and ease of navigation. This user-centric design facilitates a smooth and engaging experience, promoting regular interaction with the health data management features.

Blockchain Functionality

At the heart of the project's software architecture lies a robust integration with blockchain technology, providing a secure foundation for health data management. Key facets of blockchain functionality integral to the project's success include:

1. **Smart Contracts:** The project leverages smart contracts to facilitate seamless transactions, enabling efficient updates to user information on the blockchain. These intelligent, self-executing contracts streamline the interaction between the mobile application and the blockchain, ensuring the accuracy and timeliness of health data updates.

2. **Decentralized Architecture:** Embracing the decentralized nature of blockchain, the project enhances security and resilience by eliminating single points of failure. This architecture ensures that health data is distributed across the network, reducing vulnerabilities and enhancing the reliability of the entire system.

3. **Data Immutability:** An indispensable aspect of the project's blockchain functionality is the assurance of data immutability. By design, health data records stored on the blockchain are immutable, providing an extra layer of reliability and authenticity. This feature ensures that once information is recorded, it remains unalterable, fostering trust in the stored health records.

Original Code Contribution

The development of the Healthcare and the Blockchain project involved a collaborative effort, with Anthony Franco and Michal Markevych contributing distinct and complementary elements to the original codebase.

Anthony Franco's Contributions:

1. Mobile Application Development:
    - Anthony took the lead in developing the mobile application component of the project.
    - He crafted the foundational elements of the application, focusing on creating an intuitive and user-friendly interface.
2. Integration with Smartwatches and Health Devices:
    - Recognizing the importance of comprehensive health data, Anthony implemented the functionality to seamlessly fetch health data from various sources, including smartwatches and health-related devices.
    - This integration ensured that the mobile application could aggregate diverse health metrics for a holistic user experience.
3. Secure Data Transfer Implementation:
    - Anthony played a crucial role in implementing the secure transfer of health information to the blockchain.
    - He ensured that data integrity and privacy were prioritized, incorporating robust encryption measures to safeguard sensitive health data during transmission.

Michal Markevych's Contributions:

1. Blockchain Smart Contract Development:
    - Michal focused on the integration of blockchain functionality into the project, particularly in the development of smart contracts.
    - He authored the smart contract code responsible for facilitating seamless transactions and enabling the efficient updating of user information on the blockchain.

2. Decentralized Architecture Implementation:
    - Recognizing the importance of a decentralized architecture for enhanced security, Michal implemented and optimized the decentralized nature of the blockchain.
    - This architectural decision contributed to increased security and resilience against potential single points of failure.

3. Data Immutability Assurance:
    - Michal took charge of ensuring the immutability of health data records on the blockchain.
    - He implemented features that guarantee the unalterability of recorded information, providing an additional layer of reliability and authenticity to the stored health records.

Collaborative Efforts:

1. Seamless Integration:
    - Anthony and Michal worked collaboratively to seamlessly integrate the mobile application with the blockchain functionality.
    - Their collaborative efforts ensured a cohesive user experience, where health data retrieval and secure transfer seamlessly interacted with the blockchain for storage and retrieval.

2. Problem Solving and Optimization:
    - Both contributors engaged in collaborative problem-solving sessions, addressing challenges that arose during the development process.
    - They collectively optimized the codebase to ensure efficiency, security, and compatibility with the project's overarching objectives.

In summary, Anthony Franco and Michal Markevych made distinctive and collaborative contributions to the original codebase. Anthony excelled in mobile application development and health data integration, while Michal focused on blockchain smart contract development, decentralized architecture, and ensuring data immutability. Their combined efforts laid the foundation for the innovative intersection of healthcare and blockchain technology in the Healthcare and the Blockchain project.

Flutter Code and Software Development

The architecture of our software, meticulously crafted for the Healthcare and the Blockchain project, stands as a testament to its commitment to providing a seamless and efficient tool for retrieving health data from diverse patients. By leveraging cutting-edge programming languages and libraries, our software excels in key tasks, notably fetching health data from mobile devices using Flutter Health & Fetching. Furthermore, it adeptly handles the reception and updating of user health information from the blockchain, creating a comprehensive and integrated health management solution.

The development of this software represents a true collaborative effort, with each team member contributing distinct expertise to various facets of the project. As an integral part of this collaborative endeavor, my contributions spanned multiple dimensions, showcasing a versatile skill set and a commitment to the project's success.

Mobile Application Development

My journey commenced with the development of the Flutter mobile application, laying the foundation for a user-friendly interface. Beginning with a bare-bones structure, I progressively integrated Flutter Health to empower the application to seamlessly fetch health data. This included retrieving vital metrics such as steps, heart rate, and blood oxygen, utilizing HealthKit on iOS and Health Connect/Google Fit on Android.

Blockchain Integration

Building upon the mobile application's success, my focus shifted to establishing a robust connection with the blockchain. I created a dedicated file that serves as the interface between the application, the blockchain, and the user's wallet. This file incorporates essential methods to facilitate the update of health data through the use of smart contracts. This strategic integration ensures that the health data seamlessly flows between the mobile application and the secure blockchain storage.

Key Files Overview

1. **nav_bar.dart:** Beyond its role in displaying the navigation bar, this file initializes prompts that seek user permission. These prompts are crucial for acquiring permissions to access health-related information, including Health Connect, Location, and Physical Activity.
2. **health_authorization.dart:** Functioning as a singleton, this file manages permission requests and orchestrates the retrieval of health data such as steps, heart rate, and blood oxygen. Its singleton nature ensures that the app handles permission requests seamlessly, avoiding potential exceptions by restricting the class to a single instance.
3. **home_info_health_cards.dart:** Upon initialization, this file fetches requisite health data and presents it on the user interface. Handling null scenarios with finesse, it employs a LinkedHashMap to store and display data using the HealthCard class.
4. **health_contract.dart:** Representing an ambitious Dart code, this file is the linchpin for establishing a connection to the blockchain. It encapsulates the contract address, web3 client, and credentials, offering methods for both updating specified health data and fetching the latest information.

In essence, this section of the project showcases the intricacies of our software development process, highlighting my contributions to the mobile application, blockchain integration, and the pivotal role played by key files within our repository. The collaborative synergy of these elements forms a cohesive and innovative solution at the intersection of healthcare and blockchain technology.

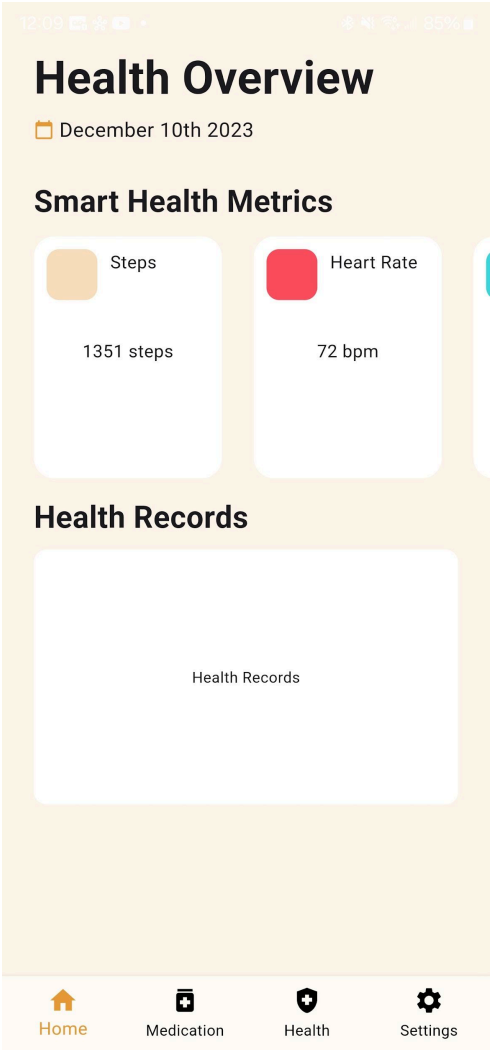


Figure 2: Flutter Application Successfully Running on Android Mobile Device

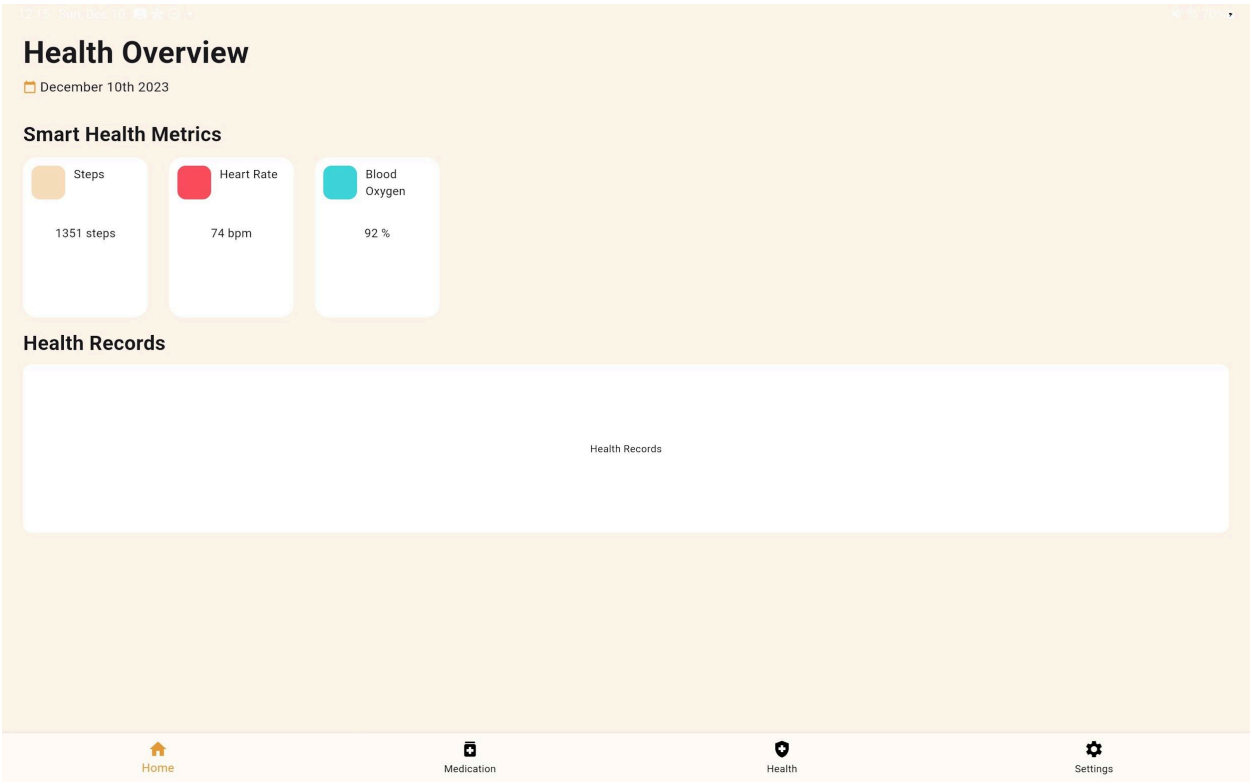


Figure 3: Flutter Application Successfully Running on Android Tablet Device

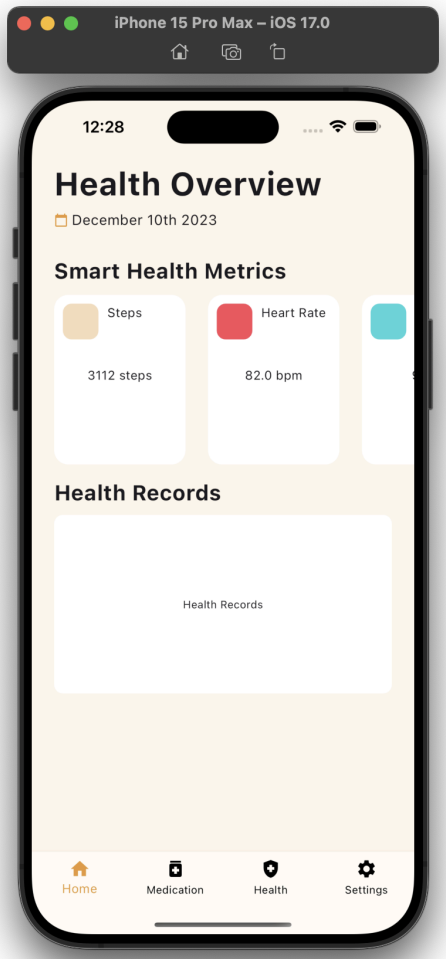


Figure 4: Flutter Application Successfully Running on IOS Mobile Device

Flutter Code Setup and WalkThrough

I will be walking through how to set up the Flutter code onto your local computer:

1. Install Flutter on Your Computer:
    a. Navigate to the official Flutter installation page: Install | Flutter.
    b. Follow the platform-specific instructions to install Flutter on your computer, ensuring a smooth setup process.
2. Install Android Studio (or Visual Studio Code):
    a. While both Android Studio and Visual Studio Code are viable options, the following instructions focus on Android Studio for its streamlined compatibility with Flutter: Set up an editor | Flutter.
3. Open the Project Folder:

a. Locate the folder containing your Flutter project on your local machine.
b. Open Android Studio (or your preferred code editor).
c. Use the 'Open' or 'Open Project' option to navigate to and open your Flutter project folder.

4. Run the Application on an Emulator or Device:
    a. Ensure that you have a virtual device (emulator) set up on Android Studio or connect a physical device to your computer.
    b. Select your target emulator or connected device to deploy and run the application.
    c. In Android Studio, locate the 'Run' button or use the terminal to execute the command for running the Flutter application.

Following these steps meticulously will have your Flutter code up and running on your local environment, ready for testing and further development.

Blockchain Code

In this project we made the design decision to not use a private blockchain but to attempt making the healthcare app on Ethereum's Public blockchain using the Remix IDE. Remix IDE is a smart contract development sandbox used to create and test out smart contracts. After getting to understand the environment and seeing what it was capable of we decided to use it for the remainder of the project. The first iteration of the project titled ECE497V1.sol is the first iteration of the smart contract which is described below.

ECE497V1.sol

- inputData Function: Takes in 2 input parameters heart rate (int) and glucose level (int)
- getHistory Function: Pulls the past input heart rate and glucose level along with a timestamp (in seconds from creation)
- *Drawbacks:*
    - Only simple set of data inputs
    - Each transaction is tied to user using wallet ⟶ no account creation/management

ECE497V2.sol

- registerUser: sets a password for the user
- updateMedicalRecords:
    - Heart rate
    - Glucose level
    - Temperature
    - password

- getMedicalData: gets medical data from the most recent patient
- Patients: after specifying a patient address outputs patient data
- *Pros:*
    - *Code now has more input*
    - *Code uses some sort of validation at the smart contract level*
    - *Can see past data history per patient*
    - *Ability of smart contract to interact with multiple users*
- *Drawbacks:*
    - Code could not keep a log of previously imputed health records
    - Contract experienced issues with user input after more than one address/user was input
    - Needed to find a way to link with mobile app
    - **User creation and credential checking uses too many resources and is too costly to run → Need to do user validation at the mobile app level to offload computing of password**

ECE497V3.sol

- transferOwnership: adds address to be used for data addition
- updateGlucoseLevel: update the glucose level
- getHealthData: pulls the most recent healthdata
- getRecordCount: outputs the amount of inputs that have been input
- Owner: shows the most current owner
- *Pros:*
    - *Code is capable and stable enough to be paired with the mobile app to complete transaction (good proof of concept that healthcare data can be stored in the blockchain)*
- *Drawbacks:*
    - *Still somewhat costly to publish smart contract (.139 eth ~ 300$)*
    - *We were not able to find a way to interface the mobile app to the remix smart contract*

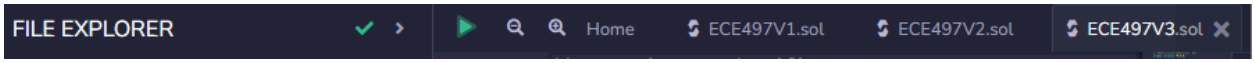
Code Summary: These versions of the code have led us to create the final version which just uses the blockchain as a ledger to store data. The change from running the credential management at the blockchain level to the application level has driven down the cost of healthcare data storage in the blockchain. Although the initial idea was to do the credential management at the blockchain level for security reasons, we think in order to make a valid product for the healthcare market we will have to do the data computation at the application level and only send encrypted data through the blockchain.

Blockchain code setup and walkthrough

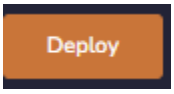
Procedure:

1. In the file folder called *"sourcecode"* you will find the 3 versions of our blockchain code written in solidify: ECE497V1, ECE497V2, ECE497V3
2. Navigate to https://remix.ethereum.org/

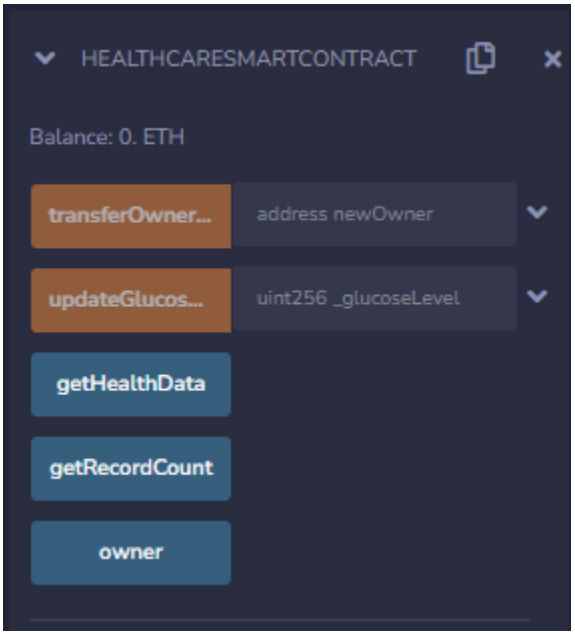
3. In the file explore tab on the left you should see a bunch of different files. In here you can right-click and select upload files. Upload the file you wish to use. You can then compile the code by pressing the green triangle on the top middle of the screen:



4. Navigate to the tab on the left called “Deploy and run transactions”
5. This is the remix ide sandbox where you can change gas limits, what contract you are running, what accounts you are using, and different ways to deploy your smart contract.
6. If you want to test out the smart contract:
    a. Select a “Remix VM” in the environment tab
    b. Keep all the other values as their defaults
    c. under “contract” select the contract you want to run. **Remember that to run a contract you much have completed step 3 and compiled the smart contract you want to run**
    d. You can then press deploy

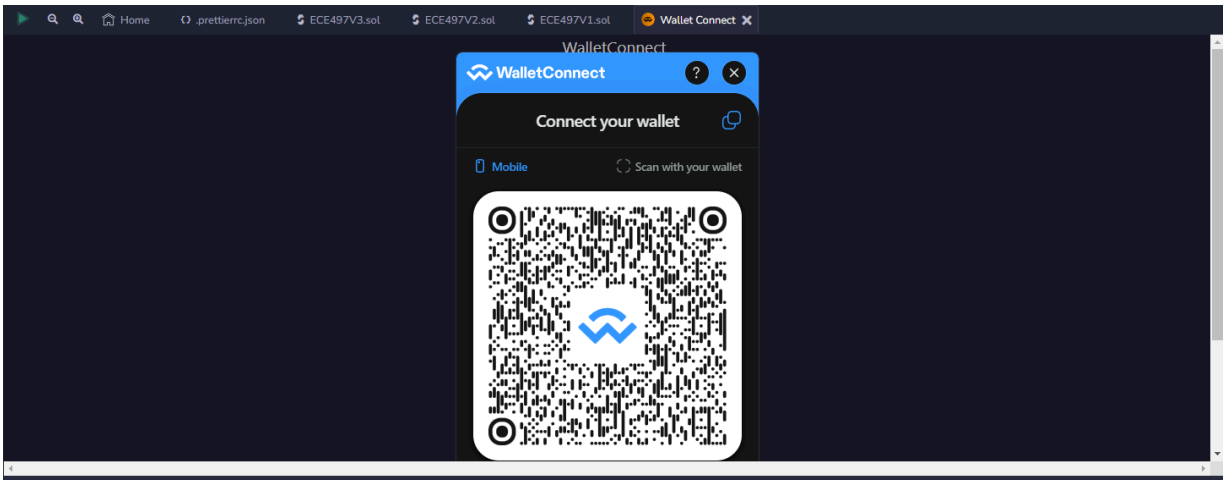


    e. Under “Deployed Contracts” listed below you will find the contract that you are running
    f. Press the little arrow to the left of the smart contract



    g. You should see a menu that looks like this. To run a function simply press the arrow next to the function if there is one there and put in your sample input then press transact.
    h. Functions that require input will be in orange while functions that don’t require any parameters (get functions) will be displayed in blue.
    i. Congratulations, you have run your first smart contract!

j. If you want to connect your smart contract to a wallet to run a transaction you can select “wallet connect” under the environment tab and then connect to your crypto wallet.



Limitations

While the project exhibits innovative features, it is crucial to recognize certain limitations that may impact its overall effectiveness.

- High cost of publishing of smart contract (~300$)
- High gas fees per cryptographic function
- Code not being able to handle large amount of users (scalability issue)

Scalability

One notable constraint is scalability. As the user base grows, the current architecture may face challenges in efficiently handling a large volume of transactions and data. This limitation could affect the project's ability to scale seamlessly with increasing user numbers.

Blockchain Technology Reliance

The reliance on a specific blockchain technology, such as Ethereum, may introduce challenges related to scalability, transaction costs, and network congestion. The limitations inherent in the chosen blockchain platform could impact the project's overall performance, especially in times of high demand.

Integration Challenges

Integrating the project with existing healthcare systems or devices might pose challenges. Compatibility issues with diverse healthcare infrastructures and devices could hinder the seamless adoption of the proposed blockchain solution.

Cost Considerations

While blockchain offers enhanced security, the cost associated with transactions and deploying smart contracts on public blockchains, like Ethereum, may present financial challenges. The current cost model for publishing smart contracts might be a limiting factor, particularly for widespread adoption.

Addressing these limitations is crucial for refining the project and optimizing its performance in real-world scenarios.

Future Implementation

Envisioning the future of the project involves strategic improvements and expansions to overcome current limitations and embrace emerging technologies.

Scalability Solutions

Future implementations should focus on addressing scalability challenges. Exploring solutions such as sharding, layer 2 scaling solutions, or considering alternative blockchain platforms with improved scalability features could enhance the project's ability to handle a larger user base efficiently.

Integration with Emerging Technologies

Integration with emerging technologies, such as edge computing, could be explored. Leveraging edge computing for data processing before blockchain transactions may reduce latency and enhance the project's responsiveness, especially in scenarios where real-time data is crucial.

User Interface Refinement

Continuous refinement of the user interface (UI) and user experience (UX) is paramount. Incorporating user feedback and streamlining the interaction between the mobile application and the blockchain can enhance usability and encourage user adoption.

Collaborations and Partnerships

Collaborations with healthcare institutions and partnerships with wearable device manufacturers can enrich the project's ecosystem. Integration with established healthcare systems and devices can enhance the project's credibility and foster widespread adoption within the healthcare industry.

Enhanced Security Measures

Future implementations should consider further enhancing security measures, potentially exploring advanced encryption techniques. Striking a balance between data security, privacy, and efficient data transmission is crucial for the success of a healthcare-focused blockchain solution.

Cost Optimization

Addressing cost considerations is essential. Exploring ways to optimize transaction costs on the blockchain, potentially through the use of more cost-effective blockchain platforms or private blockchain solutions, can contribute to the project's financial sustainability.

By strategically addressing these areas in future iterations, the project can evolve into a more robust and adaptable solution for healthcare data management.

Conclusion

In conclusion, the Healthcare and the Blockchain project represents a significant stride towards revolutionizing health data management through the innovative fusion of blockchain technology and modern healthcare practices. The project's principles of operation, sophisticated software architecture, and commitment to original code contributions underscore its potential to address critical challenges in the healthcare sector.

While the project exhibits commendable features, it is not without its limitations. Recognizing constraints in scalability and potential technology dependencies, this underscores the importance of continuous refinement. Looking ahead, future implementations hold the promise of overcoming these limitations through scalable solutions, emerging technologies, and user-centric design enhancements.

As we reflect on the project's journey, its implications extend beyond the realms of academic exploration. The convergence of technology and healthcare within this initiative exemplifies the transformative power of interdisciplinary collaboration. The Healthcare and the Blockchain project not only envisions a future where health data is secure, accessible, and seamlessly managed but also sets the stage for ongoing innovation and improvements in the dynamic landscape of healthcare technology.

References

Beyond the links already provided within the document, these are websites used to develop the project:

- health | Flutter Package (pub.dev)
- Healthcare Dashboard (Community) – Figma
- SH asklepios UI Kit: AI Healthcare & Wellness App (Community) – Figma

Appendix

The repo is provided in the folder.