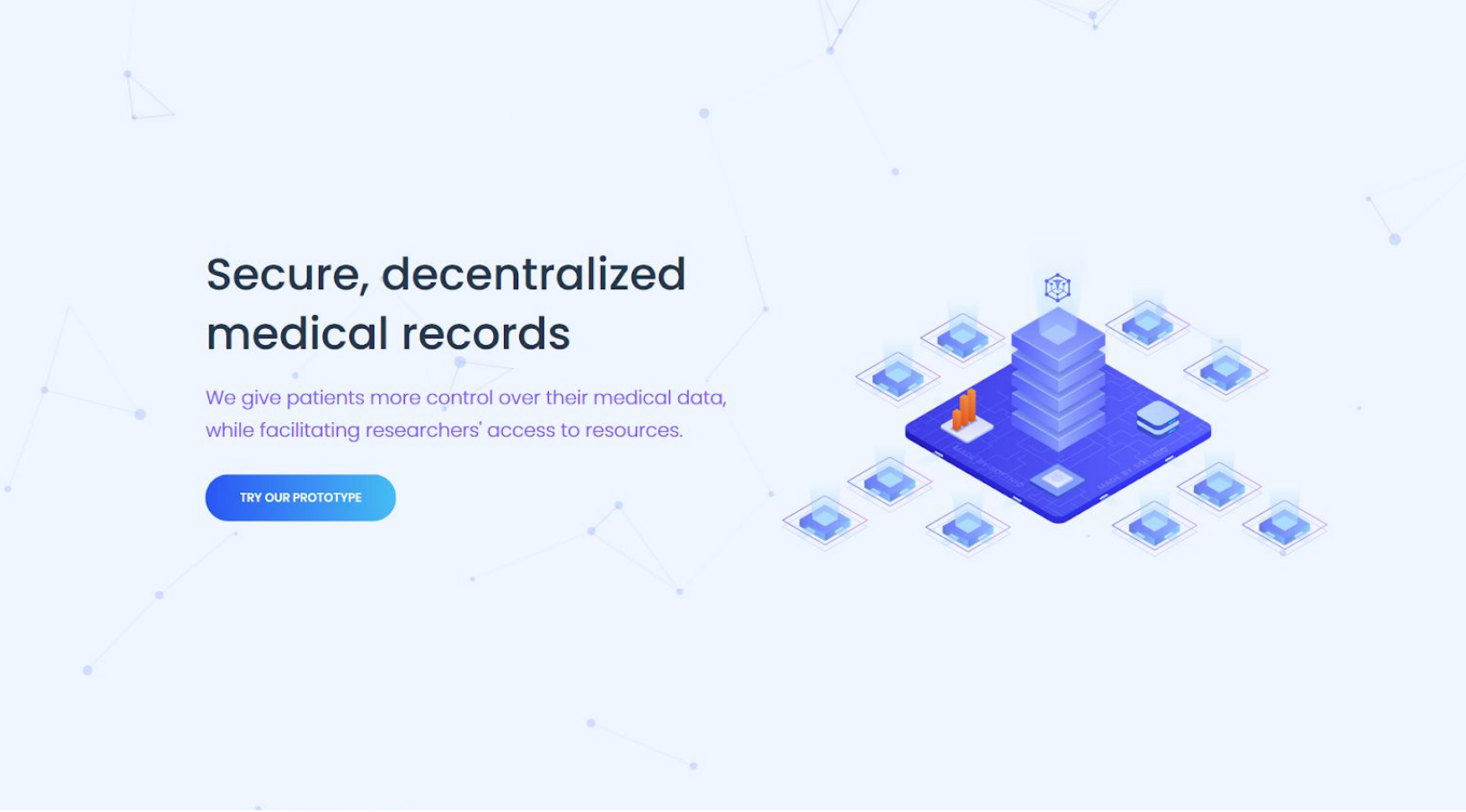

OpenMed
Blockchain Technologies

Whitepaper 1.0

Enabling data ownership and accessibility in healthcare through blockchain database networks

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1.0 **Abstract**

OpenMed uses blockchain technology to create a user-centric network of crowdsourced medical data, to enable data ownership and accessibility. Data is a non-rival and public asset, and with an increasing need for more data in the medical space, there must be a more secure method to create a distributed database.

The growth of networks and advances in computing such as machine learning have led to an explosion in the improvement of tools to analyze big data in all fields, especially in the automation and streamlining of the healthcare industry.

OpenMed enables consumers to balance their concerns for data privacy against economic gains that result from distributing the aggregate data to all interested parties.

OpenMed Whitepaper 1.0 will outline the vision of OpenMed and how it uses blockchain technology to address current challenges in healthcare.

2.0 **About Us**

Medical data, from electronic health records to clinical studies, is a valuable digital asset that is heavily exploited.

> 32 ***million*** *patient records were breached in the first half of 2019*

That is more than double the 15 million hacked in all of 2018.[1]

To solve this problem, we created OpenMed. Our mission is to ensure data privacy and accessibility in the digital transformation of healthcare.

OpenMed's focus is to help create a patient-centric system, to ensure quality of care for everyone.

As visionaries who *aim to create a better future for the world by leveraging exponential technologies to solve some of the world's most complex problems*, we zeroed in on the healthcare industry to enact this vision. Our mission is to empower patients with an immersive platform that will enable them to gain full control over their personal health data.

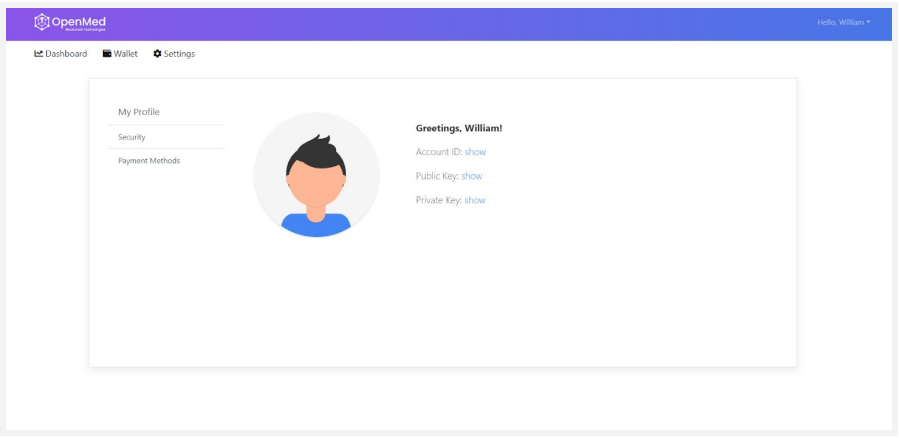
We each have a burning passion to create disruptive and innovative applications of technology in fields ranging from blockchain and autonomous vehicles, to artificial intelligence and quantum computing. By combining our unique skill sets, we developed OpenMed.

William Law | Ruhani Walia | Matthew Ao | Maggie Li

[1] "2019 Breach Barometer Annual Report." Protenus, https://www.protenus.com/

3.0 **Executive Summary**

OpenMed's platform enables the user to give healthcare professionals, ranging from clinicians to researchers, access to their personal health data via smart contracts to create transparent and immutable transactions. Every point of transaction, thereon forwards, is consumer-based to guarantee data profitability and ownership.



OpenMed is integrated with **Bigchain DB**'s software to create a blockchain database, which has database and blockchain properties. The platform is based off owner-controlled digital assets in a decentralized and immutable blockchain network, with features like a high transaction rate, low latency, indexing and querying of structured data.[2]

Users are able to give conditional access, based on a transaction in the blockchain network, to medical agents such as hospitals, laboratories, and individual medical personnel. Each transaction is transparent and secure, ensured by the immutability of the network. Thus, every transaction can be audited for verification and authentication purposes.

[2] BigchainDB, https://www.bigchaindb.com/whitepaper/bigchaindb-whitepaper.pdf

The platform leverages **Tendermint** and **MongoDB** to retain both blockchain and database properties in the network. Tendermint is used for all networking and consensus protocols, and ensures that the system is byzantine fault tolerant (BFT) given Tendermint's architecture. As a result, a corruption of the local database on MongoDB would not affect the MongoDB database on the blockchain node. Any node can fail and the rest of the network will continue to operate, regardless. MongoDB is a cross-platform document-oriented database program, which helps facilitate efficient indexing and querying of structured datasets.

Each exchange is centered around **Ethereum**'s smart contracts. The specific terms are modified to fit each possible type of transaction to enable OpenMed users to negotiate commercial terms with healthcare agents, as well as third parties such as companies who wish to access medical data.

A **digital and consumer-centric model** (a health data marketplace) would not only increase accessibility, *but it would also help drive economic growth and stability*[3].

OpenMed is currently developing this infrastructure to create a more secure and accessible platform, for all parties. There are **two additional applications** undergoing development:

1. A digital healthcare platform: to enable better healthcare access in developing countries: creating secure medical records and universal access via a digital health card.
2. An integrated data analytics platform: to provide researchers and other agents easy accessibility to data analytics tools, such as machine learning based image segmentation tools.

Each transaction and interaction on the network is secured, such that the patient's privacy is protected at all times.

[3] 'Nonrivalry and the Economics of Data', Standford GSB and NBER https://christophertonetti.com/files/papers/JonesTonetti_DataNonrivalry.pdf

4.0 **Tomorrow's Healthcare**

OpenMed's solution to challenges in today's system

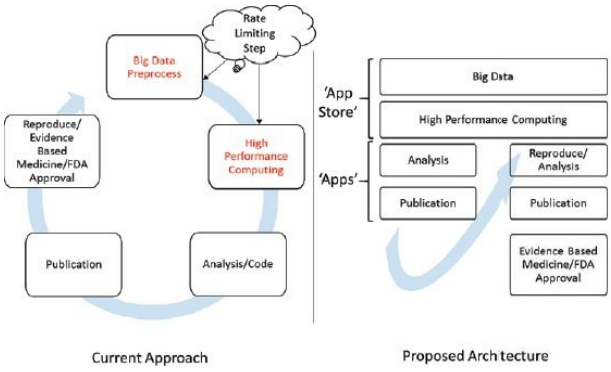
4.1 Consumer Expectations and Data

High consumer expectations drive progress in almost any industry. Many users in the 21st century expect an instant and seamless access and ability to use data, from personal uses to academic uses in workplaces. Many industries have begun to develop platforms and networks, based on emerging technologies, to create an integrated flow of data for users. However, legacy systems in healthcare have prevented the same digital transformation to occur.

4.2 Challenges of Big Data in Healthcare

Big data in health informatics can be used to predict outcome of diseases and epidemics, improve treatment and quality of life, and prevent premature deaths and disease development.[4] Big data enables researchers to gain a deeper level of insights into fields such as genomics and image segmentation.

4.2.1 Current Approach vs Systems Approach to Big Data[5]



Scalability: **OpenMed aims to kickstart an ecosystem of community driven software-hardware systems to empower big data analysis in healthcare and medical research.**

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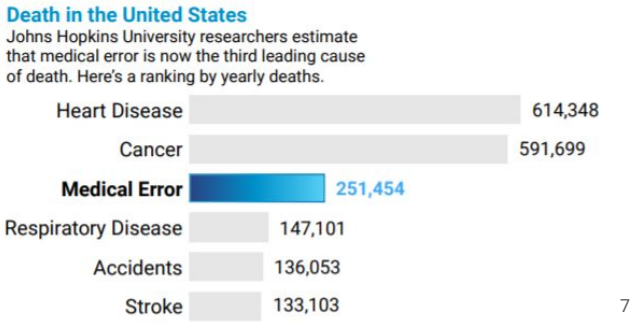
[4] Forbes, 'How Big Data is Changing Healthcare'

[5] 'Big data in healthcare - the promises, challenges and opportunities from a research perspective', https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5977694/

4.2.2 Fragmentation in health systems - current data does not fully capture temporal and process information

The electronic health record is primarily used for documenting patient care and was designed to facilitate insurance company billing.[6] As a result, data systems often do not capture essential temporal and process information for understanding of disease progression, therapeutic effectiveness and patient outcomes. Missing data not only hinders consistency across implementation of protocols in clinical studies, but also hinders the ability of healthcare professionals to accurately diagnose and treat patients based on an abundance of datapoints.



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A patient's quality of care, therefore, directly suffers due to the fragmentation of the healthcare system. There is limited cross-institutional communication and this could lead to lack of awareness of a patient's complete history, resulting in incorrect or delayed decision making, as well as unnecessary costs for both the patient and the institution.

Scalability: **OpenMed aims to streamline the data collection, storage, and sharing process by creating a decentralized platform that guarantees patient privacy while increasing accessibility for all parties involved in the healthcare system.**

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[6] 'Definition, structure, content, use and impacts of electronic health records', https://www.ncbi.nlm.nih.gov/pubmed/17951106/

[7] Yearly death rate, as per John Hopkins University research in 2016, https://hub.jhu.edu/2016/05/03/medical-errors-third-leading-cause-of-death/

4.2.3 Data security and privacy

Healthcare data often contains sensitive information, both on the patient's personal information and health history. Thus, it is important to protect the database from hacking, cyber theft and phishing, wherein the stolen data could be sold by third parties for incredibly profitable gains.

Before the platform is scaled, it is necessary to ensure that the administration, privacy, security of the big data are well protected. Protection health information via transmission security, multilayer authentication, using anti-virus software, firewalls, data encryption are vital.[8]

Medical records are to be considered not just as medical documents, but also legal documents. Alteration of existing medical records, removing records, or adding false information puts healthcare professions at risk of medical and legal repercussions. Additionally, healthcare fraud also incurs an incredible cost every year.

The total cost of **insurance fraud** is estimated to be more than $40 billion / year. This costs the average U.S. family between $400 - $700 / year in the form of increased premiums.[9]

Scalability: **OpenMed aims to create a secure blockchain network that prevents against tampering during the transaction process. Once scaled, every action that impacts the medical data can be tracked and is immutable.**

[8] Kruse SC, Smith B, Vanderlinden H, Nealand A (2017) Security Techniques for the Electronic Health Records. J Med Syst 41: 127.
[9] https://www.fbi.gov/stats-services/publications/insurance-fraud

The current architecture supports off-chain data via MongoDB, however, on-chain data (an increased level of security) can be implemented with the following methods:

1. Encrypt the data with a symmetric key and store the ciphertext (encrypted data) on-chain. The public/private key pairs would be used to encrypt and decrypt the symmetric key.
2. Use proxy re-encryption such that the proxy only sees the ciphertext, which acts as a third party in the transaction to prevent sharing of private keys.
3. Use erasure coding to split the data into n pieces, each one with its down respective encryption key. When data needs to be retrieved and decrypted, all keys for the n pieces would be shared.
4. Create a special node that has access to all the data, which generates a keypair that is used specifically to decrypt encrypted data. No users can decrypt the data.

If the platform is scaled, likely one of these methods will be chosen to be implemented.

4.3 Patient Centricity in Healthcare

Overtime, as the digital transformation occurs in the healthcare industry, medicine will become more democratised as patients become more empowered.

4.3.1 Transparency and increasing costs

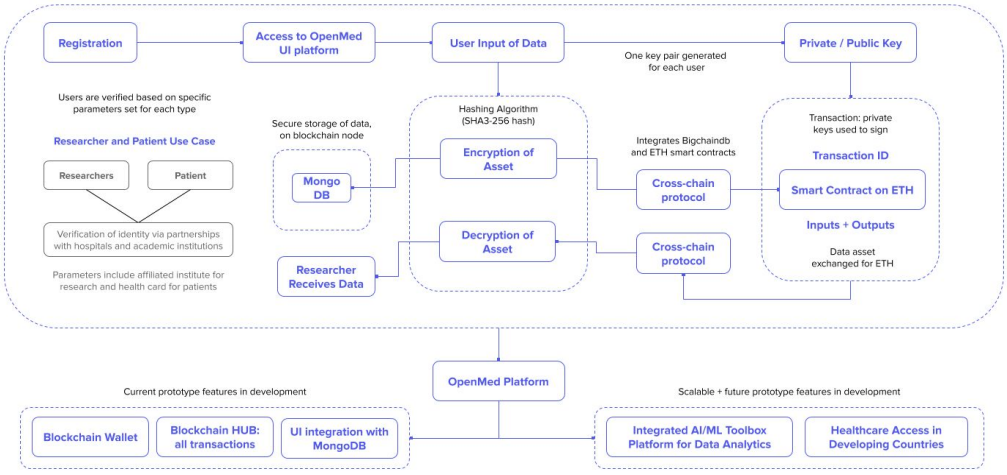
The electronic health record is primarily used for documenting However, the current system lacks efficiency and transparency. Accessing care is difficult and requires both the patient and the provider to be ‘in-network’ with the health plan that ensures patient accessibility. Often, a complex agreement is negotiated (e.g. the claims process), which incurs the provider significant administration costs.

Billing and Insurance Related (BIR) costs include tasks such as maintaining databases and keeping records of delivered services. This process contains many areas for possible errors and miscommunication to occur. For access to care, it often takes multiple archaic agreements against multiple records - a highly efficient process that lacks transparency.

Scalability: **OpenMed aims to scale to a network that can be implemented across healthcare providers and institutions, such that any patient-provider interactions can be logged onto the network. The immutability and decentralization of the network can help increase transparency, which automating some administrative tasks in the process of securing care for a patient.**

5.0 **OpenMed's Infrastructure**

OpenMed's backend and frontend development



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5.1 Consumer verification

OpenMed consumers are either parties who wish to sell or retain medical data. For the prototype, the use case was researchers and patients. The registration and verification process for each demographic varies slightly for each case.

Researchers will either be classified as independents or partner affiliations. Institutional partnerships will register its researchers or students with Openmed. The fee for each individual registrar under that firm will have been paid for. This also aids in validating researchers by acting as a filter. Regardless of if a researcher is an individual or partner affiliate, access is granted in the same way; a code. The code is required in registration.

A secondary component to verifying researchers involves confirming the legitimacy of their credentials. This process is similar to the general vetting process just described.

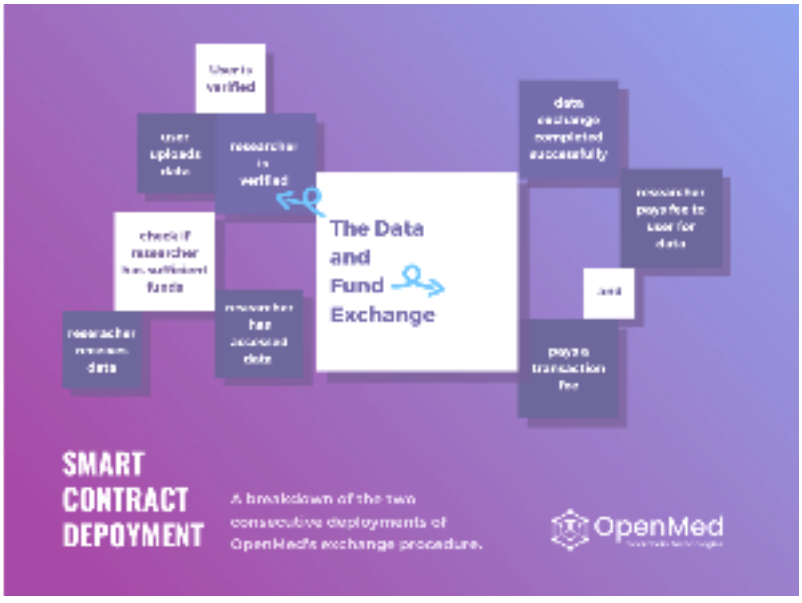
5.2 Database particulars

User data is sorted by miners on the network. Once data has been uploaded by a user, the **proof of work** (PoW) consensus mechanism will be used to sort the data by industry, demographic and other keywords. Miners on OpenMed will be rewarded via transaction fees, such that a portion of the fee paid by the researcher goes to the miner.

This fee contributes to rewarding miners for verifying user data. However, it is important to note that miners are also compensated via block reward. This is reward generated each time a new block of data is added to the chain on the network. This system acts as the token generation mechanism, similar to that of Bitcoin, in which all existing tokens were initially created as miner reward.

5.3 Blockchain smart contracts with Ethereum

OpenMed currently makes use of BigchainDB and MongoDB for platform and storage purposes. The blockchain technology really comes in the form of the smart contract system which is used in conjunction with the Ethereum network. Using interchain communications protocols, BigchainDB is connected to other blockchain networks. In this case, the secondary network is Ethereum, which supports arbitrary smart contract deployment, unlike BigchainDB.



Smart Contract Specifics: **The smart contract parameters are split into two consecutive branches. The first involves the Data Exchange. OpenMed's use of smart contracts requires an exchange of data for monetary value.**

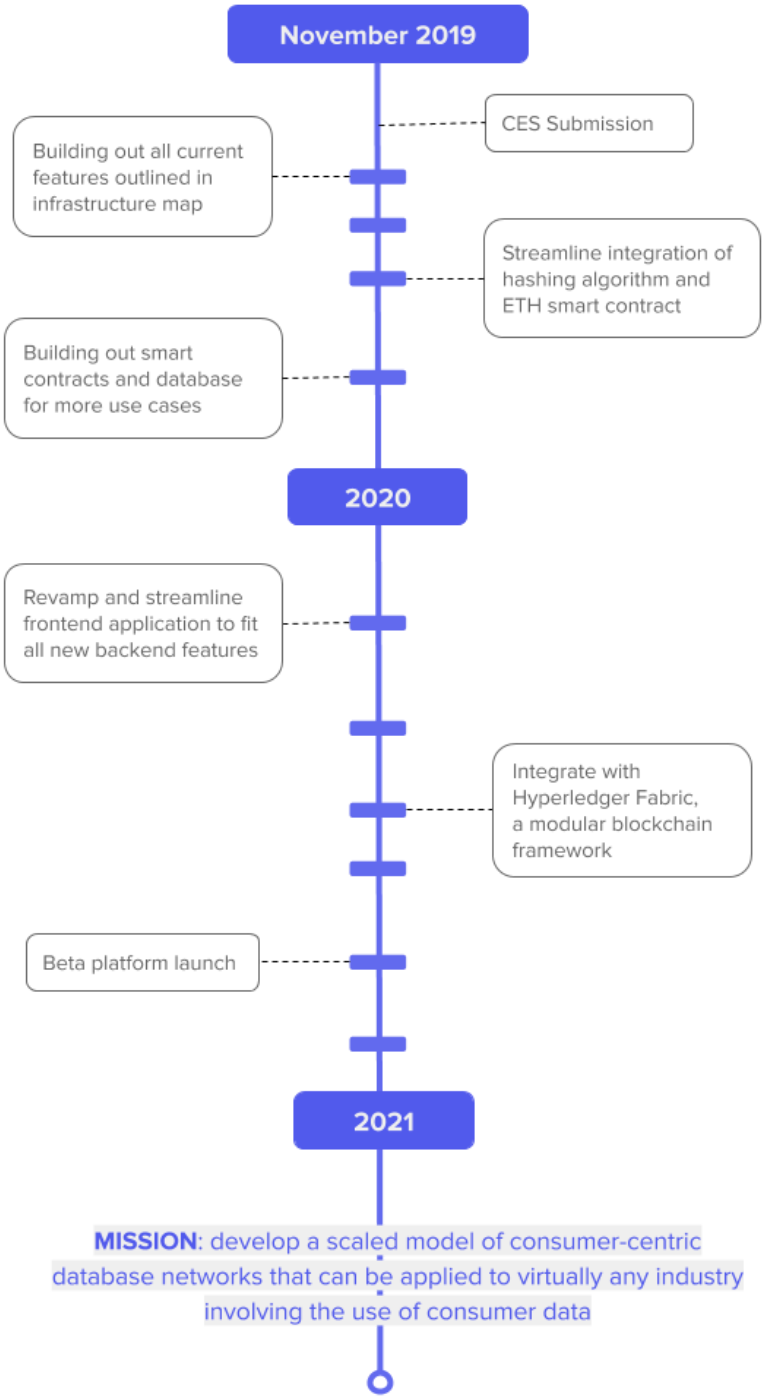
The Data Exchange involves the user's medical data being transferred to the researcher. The parameters involved prior to giving access include ensuring the researcher is verified, the user is verified and that the researcher has sufficient funds loaded into his or her digital wallet to pay for the data. To ensure that the researcher has in fact received access to the data, the researcher must have used his or her private key at least once to access the information.

The Fund Exchange is dependant upon the deployment of the Data Exchange. Once the access has been shared and this has been verified, the second contract is open for deployment. The user is paid once the researcher has accessed the data. The incentive for researchers to use the platform is the access to real, raw, primary data. Data access is a prolific issue within the medical and scientific community. Openmed bridges that gap by incentivizing users to share their data and miners to sort that data.

OpenMed will foster a community of research and development breakthrough. Researchers may notify the network, and the subsequent user's whose data was analysed, of any papers or trials created as a result of OpenMed data use. Not only is OpenMed creating a community, but it is giving researcher's yet another platform to share their discoveries if they so choose.

6.0 **Roadmap**

Long-term scalability and specific use cases



A long-standing issue with accessibility has been that it is not global, regardless of which specific commodity is in question. Access to education, clean water, rights etc. are all limited.

Data is no exception.

Without data, analysis of patterns or trends becomes non-existent. Without those conclusions, new conclusions may not be drawn on how to further improve current systems of process and progress.

6.1 Scalability

Possibly the most commonly understood benefit of blockchain technology is the accessibility factor. Scalability, on the other hand, is typically an issue.

The distributed system has many benefits, but eventually when user population increases, transaction times increase as well. OpenMed has found a way to counter this issue and continue to optimize for all the benefits blockchain has to offer. By using the mini-blockchain scheme and running “mini-chains” on a docker container, traffic migration becomes a hugely successful solution. The traffic is distributed and allows for continuous user growth.

A mini blockchain is quite similar to a typical blockchain but does not have a historic of blocks. This system allows the blockchain to separate its functions into various mechanisms, allowing for quicker transactions and increased bandwidth.

Increasing accessibility of healthcare: this platform can be scaled in developing countries to enable a digital healthcare system, to ensure that all medical documents and records are secured, even in the face of humanitarian crises. A global network of healthcare professionals, accessible over OpenMed’s digital platform can enable healthcare to be delivered, via telemedicine, to those in developing countries who need it the most.

Cross-industry applications: this platform can be scaled across all industries that involve the collection and use of consumer data. Ultimately, a blockchain network would help secure the data to ensure privacy, while creating a sustainable data marketplace that will drive economic growth.

6.2 Use cases

OpenMed's potential implications are extremely widespread, and it all comes back down to our driving purpose; to grant users data autonomy and give researchers access to data.

From the users' perspective, health information is spread across multiple networks and systems. With OpenMed, organizing all this data in one place that is observable by the patient at any time, accessibility and understandability of records increases exponentially.

In securing data and giving consumers control, suddenly data collection becomes a much lesser issue. Companies such as Google or Amazon collect user data and have ownership over it in certain legal standings. If user data has become so prolifically accessible to large corporations, it seems to be a rather valuable market. For this reason, giving users the option to sell access to their data is likely to be a huge step towards progressive and mutually beneficial data sharing between corporations and users.

OpenMed has not only allowed for data to be well protected and accessible to users while also optimizing data as a tool for researchers - **OpenMed has curated a digital community that inspires innovation and celebrates ownership.**

7.0 **The Future of Healthcare**

OpenMed's vision is to improve the quality of healthcare, by building the necessary digital infrastructure for the digital future of healthcare.

By leveraging blockchain, OpenMed mission is to develop a scaled model of consumer-centric database networks that can be applied to virtually any industry involving the use of consumer data.

OpenMed balances the need for privacy against economic gains for data, a non-rival and public asset.