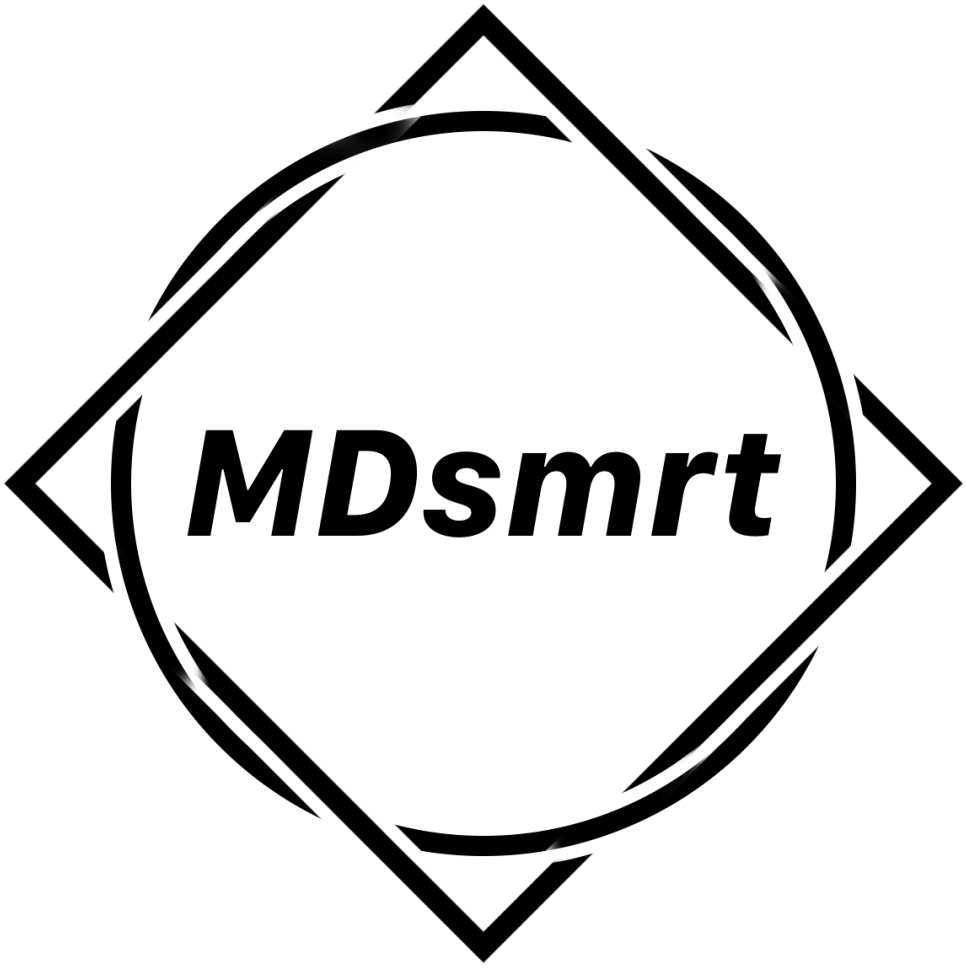
Functional Specification



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INTRODUCTION

OVERVIEW

Lung cancer is one of the most common cancers, accounting for over 225,000 cases, 150,000 deaths, and $12 billion in health care costs yearly in the U.S. It is also one of the deadliest cancers; overall, only 17% of people in the U.S. diagnosed with lung cancer survive five years after the diagnosis, and the survival rate is lower in developing countries [1].

The purpose of this project is to create a decentralised platform, MDsmrt, which powers modern healthcare to create a healthier world. Here, I will create a platform for lung cancer patients that improves the portability of scan images through the blockchain, creating a decentralised platform and the ability to analyse these scans through a convolutional neural network. Each patients scan image, with their consent will be stored on a peer to peer network which will be only accessible through the blockchain, making it an anonymous, tamper-proof platform. The first problem I am addressing with this solution is the loss of data, such as MRI and CT scans in the healthcare system today, leaving people vulnerable by exposing such personal data. The second problem, is the accurate reading of scans by doctors as seen in the Irish news lately is not up to a high enough standard. A platform like this will not only provide a peace of mind for patients and doctors, but in the long term would save companies, and countries a vast amount of money in the long run.

This project will be made up of two clients and a backend which communicates with both. These clients will be a “Doctor” and “Patient”.

- Traditionally a **Doctor** is sent a patient's MRI scan to be read, and then they notify the patient of the outcome. This approach takes a long time. With this new approach, a doctor will immediately upload the images to the platform, where they are stored on the blockchain. Here, both doctor and patient can view these images, but only the doctor and analyse them.
- Traditionally a **Patient** is given the scan results on a CD, which are unreadable to the untrained eye, and in most cases useless and have a high risk of getting lost. Here the patient is able to store and retrieve their scan images in a tamper proof and safe way.

BUSINESS CONTEXT

Through a combination of two internships with Mastercard and Optum, both world leading companies in security and healthcare respectfully I noticed where they could be combined to develop a platform which will enhance the everyday lives of patients and doctors. For an individual to be able to instantly access previous healthcare data, saves time and effort for both patient and doctor, especially the person in between who has to find that data to pass it on to the doctor. Having a service would allow a patient and doctor to work in conjunction with each other, eventually moving forward to a decentralised world phasing out and replacing the CD that is distributed after a scan, and eventually even phasing out doctors reading scans and giving their opinion on what they see. On a large scale, it saves hospitals thousands in investing in different types of storage software that is not secure and removes the need for the government to be spending large amounts of money on healthcare systems that we can see are not working.

We can see the benefit of this system in a simple example of one person who moves hospital, who is expected to have previous medical data at hand alongside many other possible types of identification documents. If the patient does not have this information at hand, their previous medical state is unknown. Currently there is no service like this available in Ireland, or across the world, however if this information was all stored in a secure platform where a doctor can see previous scan results and get an accurate analysis on them , it will benefit both the doctor and patient saving valuable time.

GLOSSARY

IPFS - Is a protocol and network designed to create a content-addressable, peer-to-peer method of storing and sharing hypermedia in a distributed file system. IPFS was initially designed by Juan Benet, and is now an open-source project developed with help from the community. [2]

P2P network - In its simplest form, a peer-to-peer (P2P) network is created when two or more PCs are connected and share resources without going through a separate server computer. A P2P network can be an ad hoc connection—a couple of computers connected via a Universal Serial Bus to transfer files. [3]

Blockchain - A blockchain, originally blockchain, is a growing list of records, called blocks, which are linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a merkle tree root hash). [4]

Convolutional Neural network (CNN) - In deep learning, a convolutional neural network (CNN, or ConvNet) is a class of deep, feedforward artificial neural networks, most commonly applied to analyzing visual imagery. CNNs use a variation of multilayer perceptrons designed to require minimal preprocessing. [5]

DICOM - Digital Imaging and Communications in Medicine is a standard for handling, storing, printing, and transmitting information in medical imaging. It includes a file format definition and a network communications protocol. [6]

Ethereum - Is a decentralized platform that runs smart contracts: applications that run exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference. These apps run on a custom built blockchain, an enormously powerful shared global infrastructure that can move value around and represent the ownership of property. [7]

GENERAL DESCRIPTION

PRODUCT / SYSTEM FUNCTIONS

This platform will be split into three main components. These components will backbone the platform and perform the necessary tasks to facilitate MDsmrt. The platform will consist of a backend component that will be linked into a blockchain network. A web application that both doctors and patients will use, and a prediction model to analyse scan images that connects to the backend, which will then communicate and interact with the blockchain. Communication between the backend and web application, along with any necessary interactions with the blockchain and decentralised network can be facilitated.

WEB APPLICATION

Patients and doctors will access their scan image information through this web application. A doctor will be able to upload any of the supported file types to the blockchain to be secured, with this both patient and doctor can then access their confidential medical information. Once uploaded patients can use this application in place of a traditional CD to store their scan images. Every upload of patient information, no matter what file type must be accepted by the patient

before it is uploaded. This ensures that the platform is patient owned and patient generated, and has full control over what information is available.

Doctors will interact with this web application, not only to upload to the platform, but to analyse the image to detect whether lung cancer is present in the image or not, aiding the doctor in the diagnosis of the patient.

Although patients cannot upload to the platform, doctors have the ability to upload many file types, including scan images, DICOM data, and analysis file data all which are associated to a patient.

PREDICTION MODEL

The only user of this component will be the doctor. Requests to the blockchain will be made to retrieve the scan image, this will then go through the prediction model, giving a percentage result of the diagnosis and how likely it is that cancer is present. This prediction model, will be a convolutional neural network trained on a dataset of 65,000 scan images that are cancerous and 172,000 images that are not. The doctor will then receive an analysis result through the UI in the form of a file, which will then be stored on the blockchain, corresponding to the specific scan image. Storage of this analysis, will speed up diagnosis in future cases.

APPLICATION BACKEND

The backend of this application will be hosted on a P2P network called IPFS. Here this will facilitate communication between the web application and doctor or patient. This will also allow for the uploading of files from a doctor, the web application UI. Through this IPFS backend the web application can interact with the blockchain network, where information can be queried and stored. In this way, the application will be fully decentralised, meaning it is flexible, transparent, distributed, resilient and will have a better incentivized structure than current software used in hospitals.

USER CHARACTERISTICS AND OBJECTIVES

Today, doctors have quite a tough job of accurately applying their knowledge in reading specific scans, meaning the smallest mistake can have a large impact. While, patients are insecure about how their medical data is being stored and if it is really secure. The idea behind this platform to provide a quick, easy way for patients to view and keep track of their scan images, while also assuring them that their data is now anonymous, tamper-proof and secure. While on the other hand, it will assist and help doctors in the diagnosis stage resulting in a more accurate reading, while also having access to every scan the patient has had in the past, meaning the doctor will get a deeper understanding of the patients background.

With this, as the platform is quite complex, one of the main functionalities of the platform must be that it will be easy to use and understand for the user. While this is true for patients, usability on the doctors side must be consistent, clean, and have easy transitions so that the doctor can carry out their job efficiently. To create an image of exactly what is needed I have created two sample personas. Each persona shows what a patient and doctor need from the platform.

<table>
<tr><td>Name: Mary
  </td><td>Biography
Mary is a 67 year old lung cancer patient, who is currently undergoing her second round of chemotherapy. She was cancer free for 10 years, while living in the US. She now moved back to Ireland changing hospitals. She does not own a smartphone and does not use social media. She forgets exactly the outcome of her diagnosis each time she had a scan in America, and it's wasting time trying to get this information for her doctor in Ireland.</td></tr>
<tr><td>Information
Age: 67
Technical Literacy: Very low</td><td>System Expectations
In the knowledge that her data is in a secure and tamper proof platform.
Ease of use
Not a lot of passwords
Access vital past information to speed up her new diagnosis</td></tr>
</table>

Name: Dr. John	Biography
	Dr. John has been a doctor for the past fifteen years. He works in a busy hospital and specializes in lung cancer patients. He owns a smartphone, and uses LinkedIn to read new articles about upcoming medicine breakthroughs. He uses a computer everyday to keep track of his day and keep notes of his patients, while reading scans, however, from small old monitors. He is currently Marys doctor, and is trying to track down her previous data.
Information	System Expectations
• Age: 46 • Technical Literacy: Medium	• In the knowledge that data is secure and images are recorded and analysed correctly, increasing learning capabilities • Easy to use, with minimum effort • Improve productivity

With each of the personas in mind, it is clear that there needs to be some main characteristics that must be adhered to, this way both patient and doctor will have an easy transition to this platform and can efficiently put it to use, and overall have a pleasant experience for both users. Below, the main characteristics of the platform are outlined to fulfil the expectations of the above.

- SECURITY
    - As this platform handles sensitive data it is indispensable that users know it is being handled in a secure manner. This is a a high priority, so the platform must be secured through a password.
      The platform will have a two-factor authentication helping to address the vulnerabilities of a standard password-only approach, in this way it will also enhance the user experience while the user knows their data is secure.
    - Hospitals will have a deep concern as they will not want to be subject to large data breaches. As this platform is decentralised, hospitals won't have a local database meaning that data will be difficult to acquire. IPFS makes it possible to distribute high volumes of data with high efficiency, while maximising security issues.
    - You can address large amounts of data with IPFS, and place the immutable, permanent IPFS links into a blockchain transaction, meaning the image

itself will not be stored on the blockchain, they are stored on the P2P network enhancing security

- USER FRIENDLY
  - The transition into using this platform needs to be as seamless as possible. The design of the platform will need to accommodate a wide range of individual preferences and abilities.
  - It must be simple and intuitive. The design must be easy to understand, regardless of the user's experience, knowledge, language skills or current concentration level.
  - The design must communicate necessary information effectively to the user while minimising hazards and the adverse consequences of accidental or unintended actions.
  - The design of the web application must also ensure it can be used efficiently and comfortably with minimum fatigue.

- ACCURATE
  - From a doctors point of view the platform must accurately read the images and give a thorough diagnosis as if not, can cause consequences.
  - As a patient, you want the best possible advice from your doctor, the CNN must produce accurate results to ensure a patient is diagnosed early resulting in proper treatment being given.

- PERFORMANCE
  - When a patient gets a scan, a large amount of images are taken to get every possible angle and not to miss anything, this results in a lot of data being sent to the doctor. It must be ensured that the platform can handle a large workload and it is managed and processed as quick as possible.
  - This platform needs to be as accurate as possible, but it must also be able to effectively give accurate results at speed, meaning when analysing a scan it must go through the model and output the result as quick as possible, improving the productivity levels of doctors.

- UNPRETENTIOUS
    - For doctors, the platform should not ask for any additional workload. The aim of this platform is to minimise the workload of a doctor, not increase it. In this way, we are not changing the workload of a doctor, meaning the transition to a new system would be seamless and can get up and running as quick as possible.

- ADAPTABLE LEARNING
    - This platform is an aid to doctors, it can read scan images much quicker than the human brain meaning that if a doctor misses something they will learn, thus, becoming a better doctor.

Each characteristic above indicates how this platform needs to be designed, although with every platform some of these are minimum requirements, but as this is a medical platform extra measures need to be taken into consideration to protect the data of its users, this will be a priority with each design idea made going forward.

OPERATIONAL SCENARIOS

This platform has two main components, namely the web application and the CNN which analyses the scan images. The web application which, the doctor will upload and store images on and the CNN which will analyse these images. Although both components will be integrated, they both form two major aspects of the application. Below I will be outlining scenarios in relation to both.

WEB APPLICATION SCENARIOS

- REGISTERING ON PLATFORM
    - A user, whether a doctor or patient must first register for the platform before the first usage. A patient, will identify itself with their doctor on the platform, this way each person's data will be stored under their given details given at registration. Once saved, this initial information can be viewed by the doctor at any time.

- VERIFICATION BY DOCTOR
    - A doctor must verify that they are indeed the patients doctor. They will

submit a legal file to keep in regulation and when this is complete the patient and doctor will be paired. The doctor associated with the patient can be changed at any time, meaning moving hospital is as smooth as possible for the given patient.

- UPLOADING OF FILES
    - A doctor will upload files securely from the UI, as a result of this the patient will now be able to see these images and information about their scan when logged in to their account.

- REQUESTING FILES
    - A doctor will be able to request files from their given patient to assess them and to also run analysis if the file is an image through the CNN. When a patient's file, is requested from the blockchain they will receive a notification on the platform, ensuring the patient knows exactly when their data is being used.
    - When a patient requests data from previous scans, the doctor associated with the patient will not be notified. All request are handled by the web application which in turn requests the file from the blockchain.

IMAGE ANALYSIS SCENARIOS

- ANALYSE IMAGE
    - A doctor will navigate to the analysis section of the platform where they will request files in the same manner as outlined above. When retrieved the image will then be analysed through the CNN, this will then output an analysis result file. Notifications will not be sent to patients when their scan is passed to be analysed however.

- UPLOADING OF RESULTS FILE
    - After analysis the results file must be then attached an uploaded to the blockchain creating a decentralised file, meaning that each time a doctor sees an image they do not have to keep passing the image to the CNN, this way a doctor will not be repeating themselves and wasting time.

CONSTRAINTS

As the area of blockchain technology with sensitive data is quite new and upcoming, this platform has many constraints that should be looked at. Below I document these constraints which will be thought about during any platform functionality decisions.

- ### PERFORMANCE
    - It is very important that any request for information from the blockchain made on the UI is handled quickly. It's imperative that there is not a time lag between a user requesting the file on the UI and the file being illustrated for them on the UI. The performance element of the CNN is of high precedence also has any time lag here may have a doctor having second thoughts on the platform.

- ### SECURITY AND RISK
    - After the uploading of a scan image to the blockchain it is imperative that the correct recipient is read by only them. If it is not, this is an instant fault in the platform. To make sure this does not happen, each file after uploading, will be given a cryptographic hash ensuring maximum security and lowering the risk of data being in the wrong hands.

- ### TECHNICAL
    - As this is a fully decentralised application using the blockchain, integrating this with healthcare data can become tough. This application integrates convolutional neural network technology with blockchain technology, here the use of the IPFS P2P network can bring both of these technologies together in a quick and easy way to enable the creation of diversely resilient networks which enable persistent availability with or without Internet backbone connectivity.

- ### EASE OF USE
    - Sensitive data is the main element of this platform, users should know at all times what they are doing and what their next steps are. It is imperative that a user understands and smoothly finds information that they are

looking for. This platform will make its features easy to use and aesthetically pleasing for all user types while remembering the “simple is always better” approach when adding new features.

- EFFICIENCY AND EFFECTIVENESS
    - The platform must use the data inputs as expected by the platform, meaning they must be used in the right way. The output of this data must be of the highest quality, therefore the doctor can give the correct diagnosis to the patient.

FUNCTIONAL REQUIREMENTS

Below lists all the functional requirements of the platform. These specify specific things the platform must achieve in order for it to be fully functional for the user. All of these requirements must be accomplished in order for a user to get the best possible experience.

ID	1
Description	The user must be able to upload files to the platform.
Critically	This is a key requirement as without this feature the platform would not work.
Technical Issue	Using IPFS and Ethereum to communicate to upload files.
Dependencies	IPFS and Ethereum blockchain

ID	2
Description	The platform must be able to store data cryptographically in a decentralized manner.
Critically	As the data is sensitive it is imperative that it is stored in a secure way.
Technical Issue	Involves ensuring IPFS is creating the correct cryptographic hash and storing it on the blockchain.
Dependencies	This is dependent on requirement 1, as data must be uploaded in order to securely store it.

ID	3
Description	The platform must be able to interact with IPFS to retrieve data.
Critically	To allow the user to retrieve their data
Technical Issue	Using the Infura API, this provides infrastructructure and access the Ethereum network and IPFS.
Dependencies	This depends on requirement 1 & 2 as data must be uploaded and secured.

ID	4
Description	The platform must be able to store different file types.
Critically	To allow the user to not only store the data, but also have the ability to store the analysis results.
Technical Issue	The attachment of the analysis file to a given scan image and storing it on the blockchain.
Dependencies	This is dependent on requirement 1 & 2 as the platform must be able to upload and store data securing.

ID	5
Description	The platform must have two factor authentication log in for both doctor and patient.
Critically	To ensure sensitive data is protected and the correct people are accessing it, an extra layer of security will be put in place.
Technical Issue	Connecting the both authentication types together.
Dependencies	N/A

ID	6
Description	The platform must be able to retrieve and analyze images.
Critically	For the analysis feature of the application to function, it is important that an image can be retrieved from the blockchain and analysed through the CNN.
Technical Issue	The accuracy of the CNN model, trained on the dataset will be crucial to the overall usability and performance for the diagnosis by the doctor.
Dependencies	The is dependent on requirement 3. IPFS and the blockchain must be working correctly.

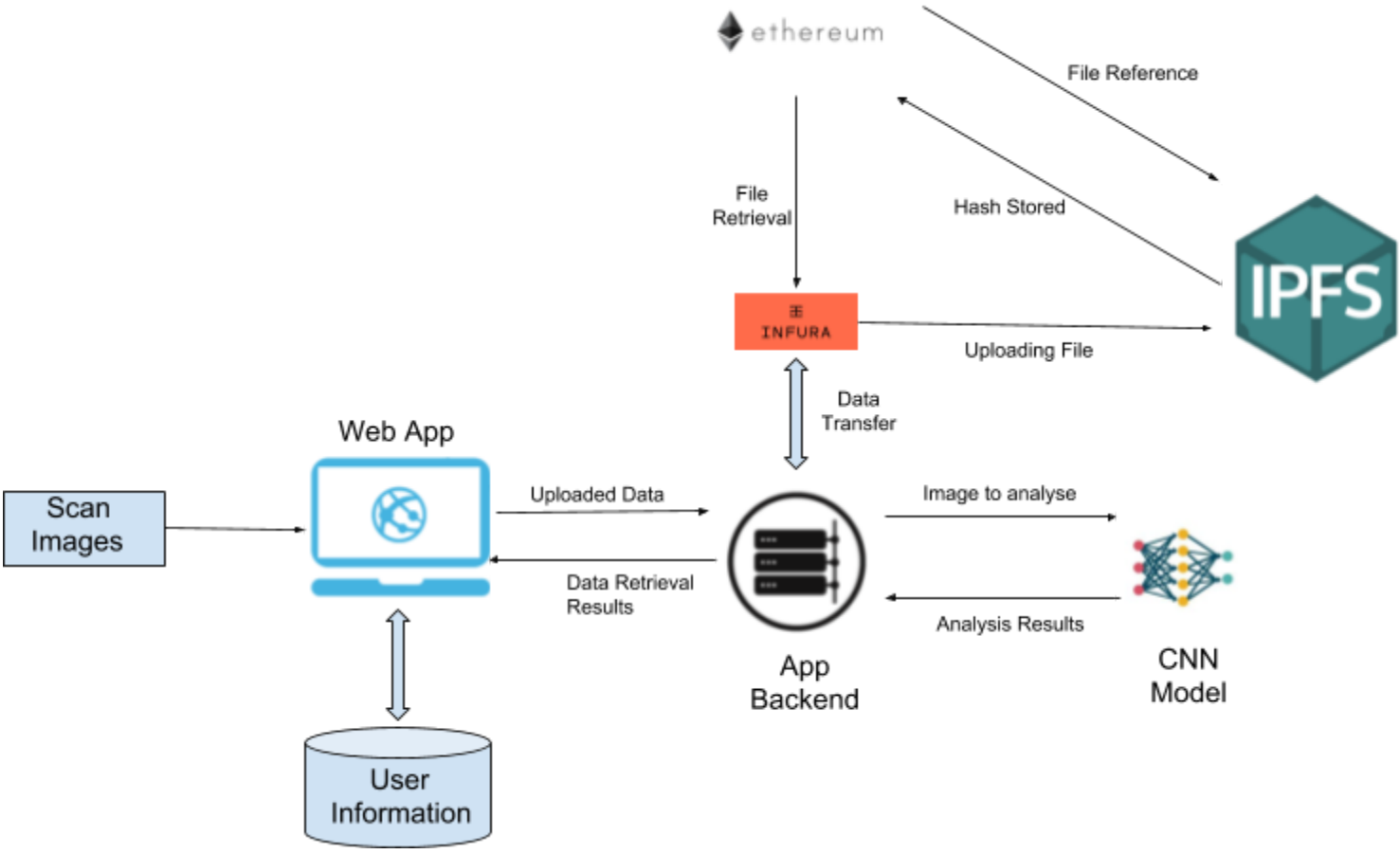
ID	7
Description	The analysis feature must interact with the user and produce a result.
Critically	After analysis the CNN must produce an analysis results file to attach to the given scan image.
Technical Issue	The production of the file after analysing and the attachment to the scan image.
Dependencies	This will be dependent on requirement 5 as the analysis phase must take place first.

ID	8
Description	The backend must be able to communicate with the user.
Critically	When a doctor retrieves a scan image to analyse the patient must get a notification to alert them to this.
Technical Issue	Using the Google firebase service, this will have to be configured into the application.
Dependencies	This is dependent on requirement 3 as data must be retrieved in order for the patient to be notified.

ID	9
Description	The platform must be able to run on all operating systems and web browsers.
Critically	This platform must be able to run on a all operating systems and browsers.
Technical Issue	Code convention for the various OS and browsers must be taken into consideration.
Dependencies	N/A

SYSTEM ARCHITECTURE

Below outlines the high level overview of the platform architecture, showing the distributed functions.



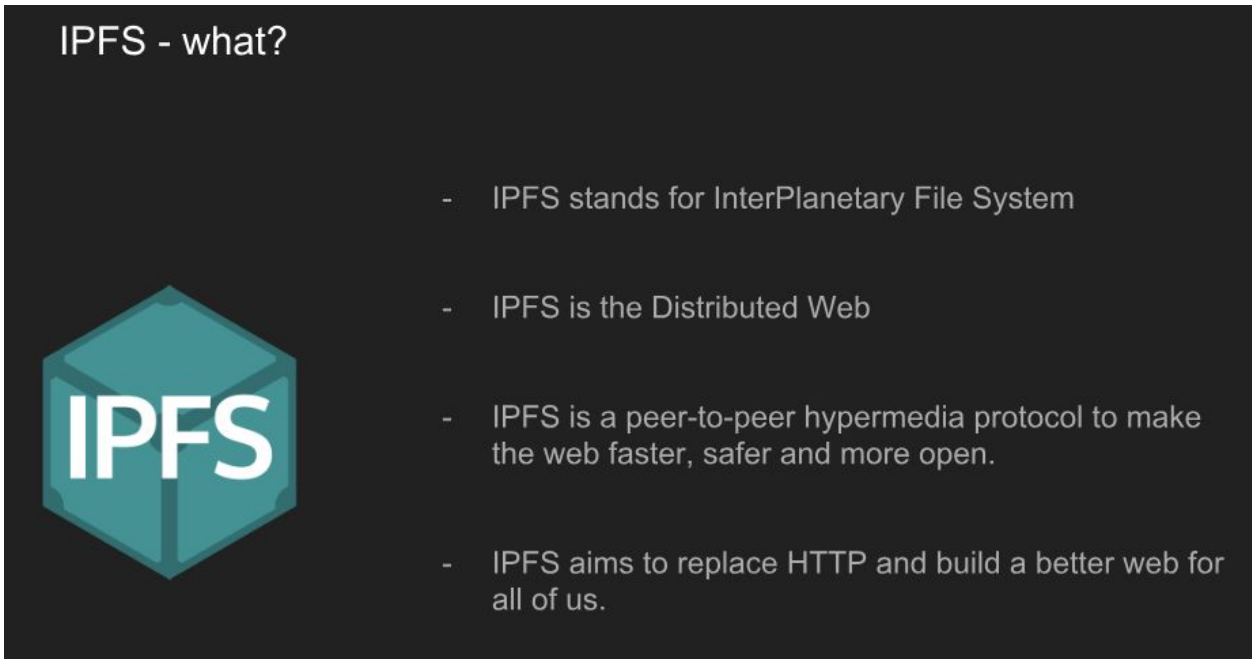
Here we can see the main components of the platform, how they will be used and how they communicate. The web application is the main source of the platform, as here is where a doctor will upload, retrieve and analyse images and data. When a doctor uploads an image to the web application, the images gets passed to the application backend which interacts with Infura. Using Infura API's to access the Ethereum network and IPFS, the image is then passed to IPFS. Each file and all of the blocks within it are given a unique fingerprint called a cryptographic hash. This cryptographic hash is then stored on the blockchain. From the web application we can retrieve data for viewing and analysing. To do this we request the data from the web application, this requests goes

through the application backend and accesses the blockchain. The file that has been requested will be fetched from IPFS, finding the nodes storing the content behind its unique cryptographic hash. In order to then analyse the image, it is passed to the CNN model which analyses the image and outputs a result, which is then attached to the image in the application backend, and stored on the blockchain through IPFS.

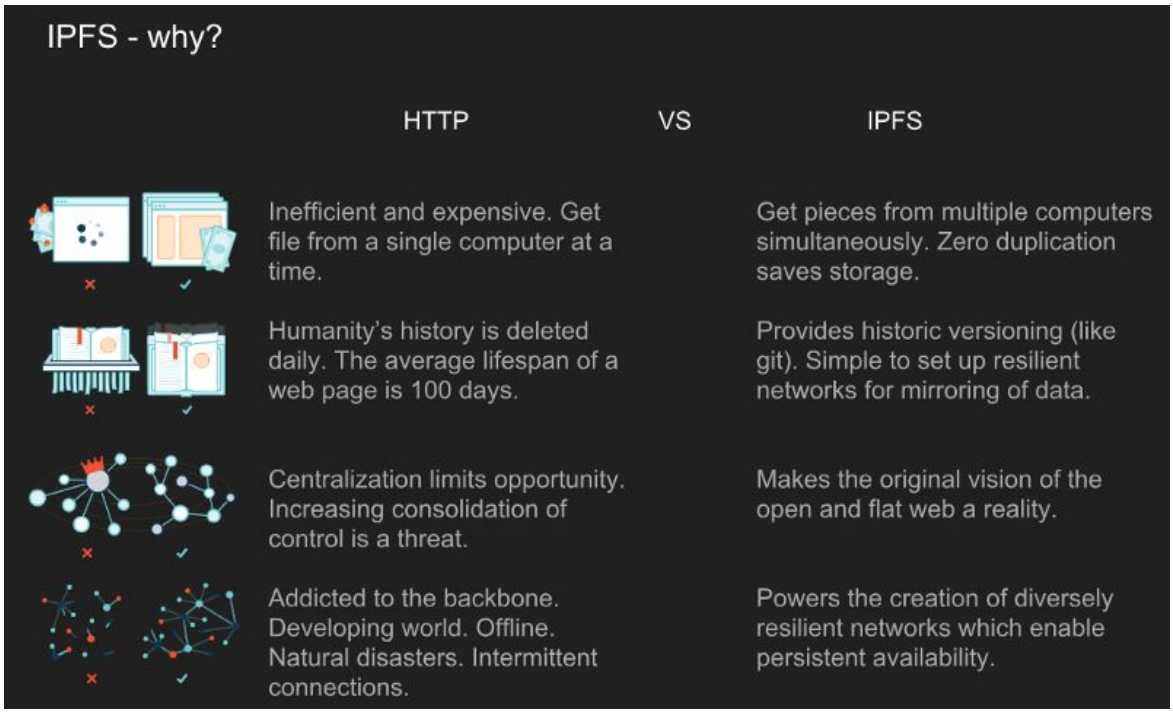
HIGH LEVEL DESIGN

In this section, IPFS and Ethereum will be explained at a high level so a user or developer can get a deeper understanding of the platform. Here we will also look at what is a CNN and how it works, while also looking at the architectural overview diagram, system context diagram and a sequence diagram to outline the steps involved in uploading and requesting data.

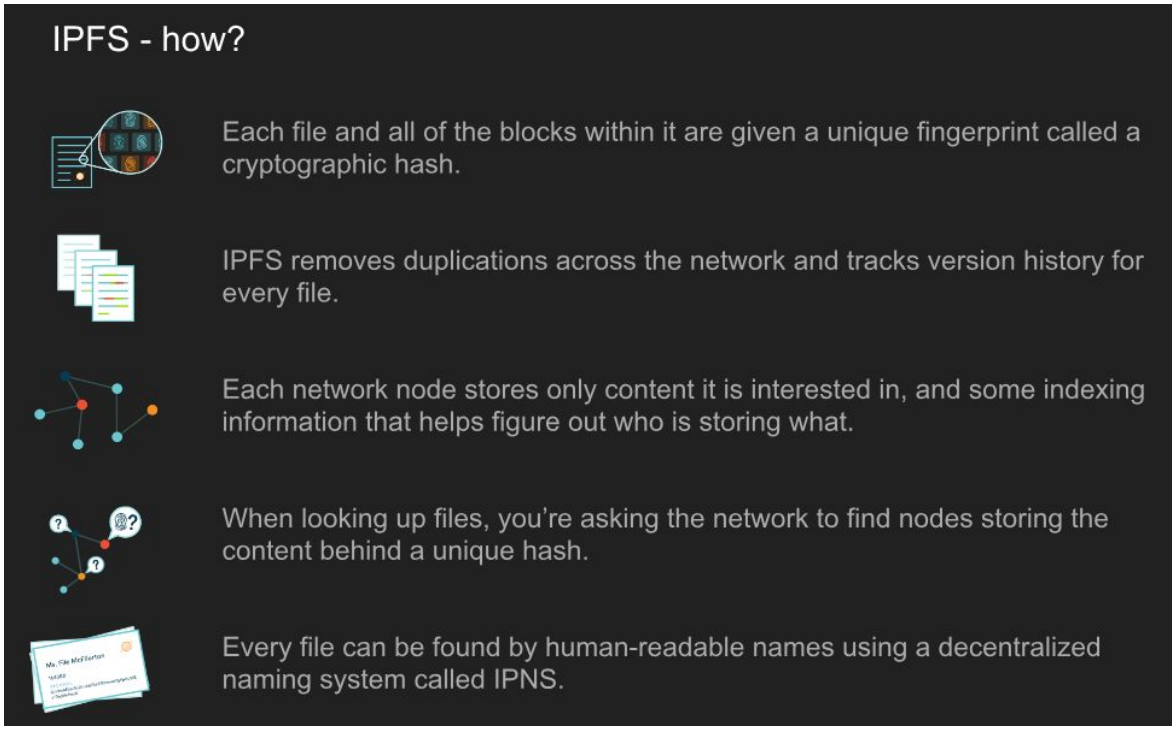
IPFS AND ETHEREUM



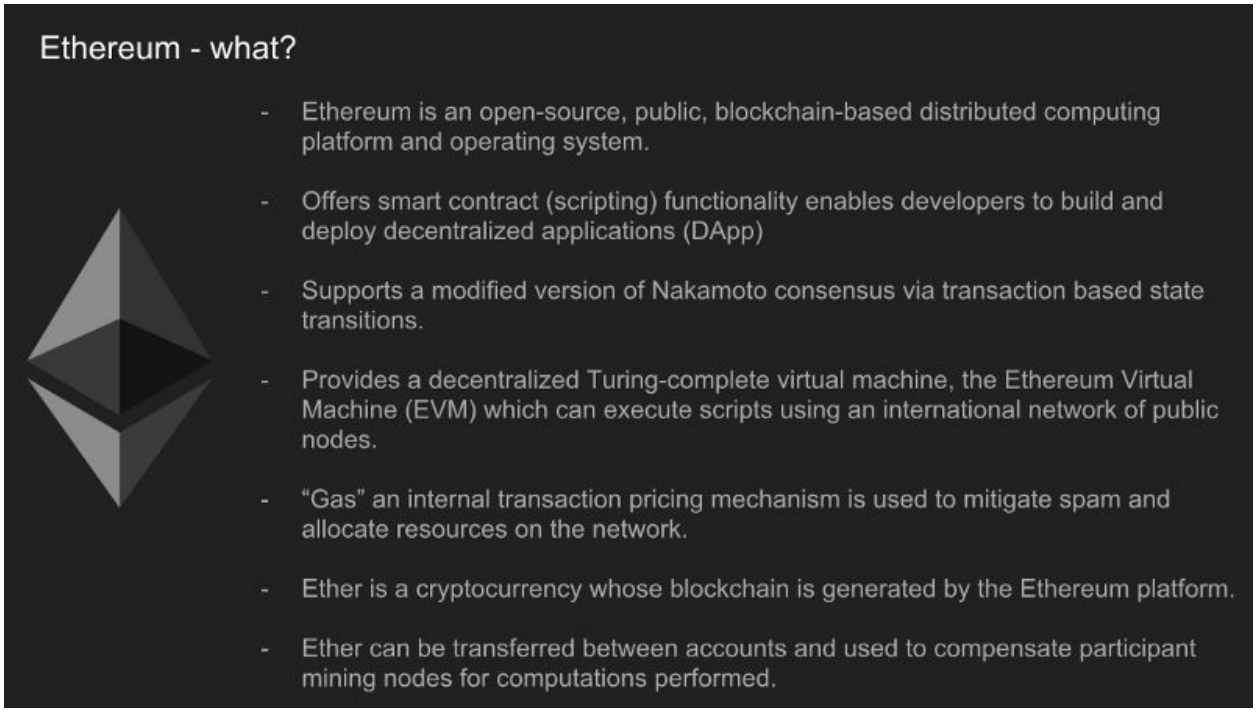
[8]


IPFS - why?
HTTP
VS
IPFS
Inefficient and expensive. Get file from a single computer at a time.
Get pieces from multiple computers simultaneously. Zero duplication saves storage.
Humanity's history is deleted daily. The average lifespan of a web page is 100 days.
Provides historic versioning (like git). Simple to set up resilient networks for mirroring of data.
Centralization limits opportunity. Increasing consolidation of control is a threat.
Makes the original vision of the open and flat web a reality.
Addicted to the backbone. Developing world. Offline. Natural disasters. Intermittent connections.
Powers the creation of diversely resilient networks which enable persistent availability.

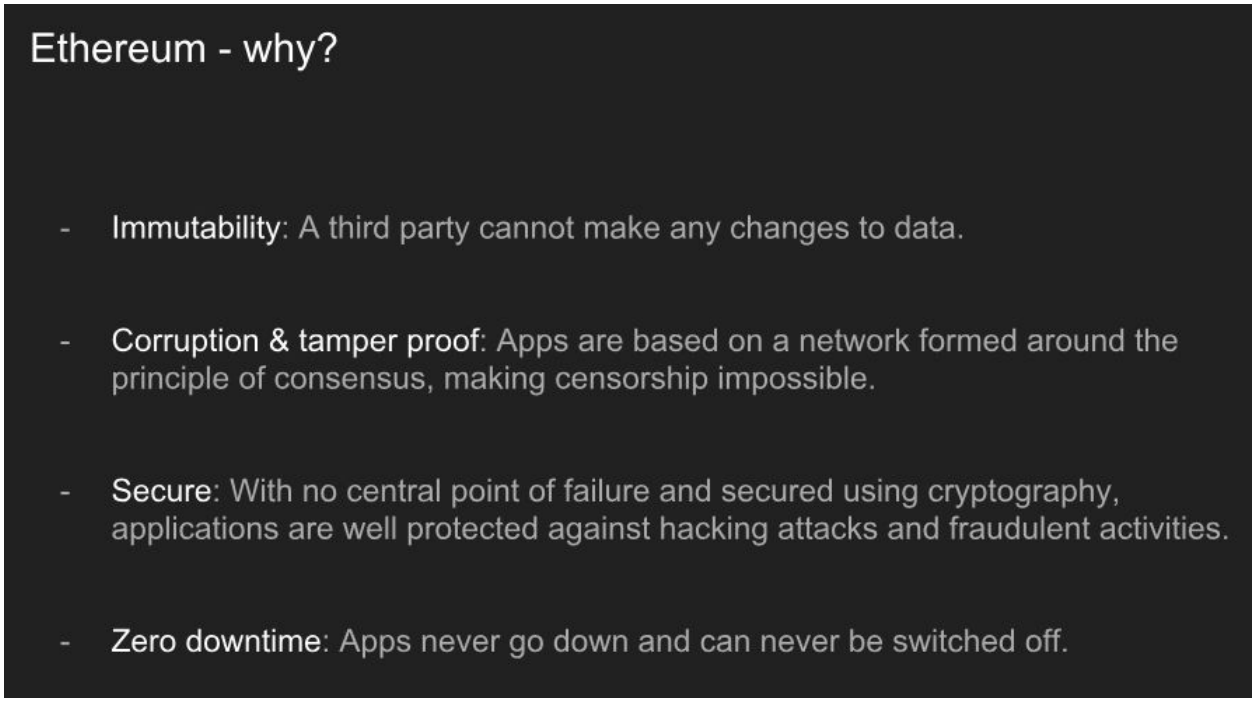
[8]


IPFS - how?
Each file and all of the blocks within it are given a unique fingerprint called a cryptographic hash.
IPFS removes duplications across the network and tracks version history for every file.
Each network node stores only content it is interested in, and some indexing information that helps figure out who is storing what.
When looking up files, you're asking the network to find nodes storing the content behind a unique hash.
Every file can be found by human-readable names using a decentralized naming system called IPNS.

[8]

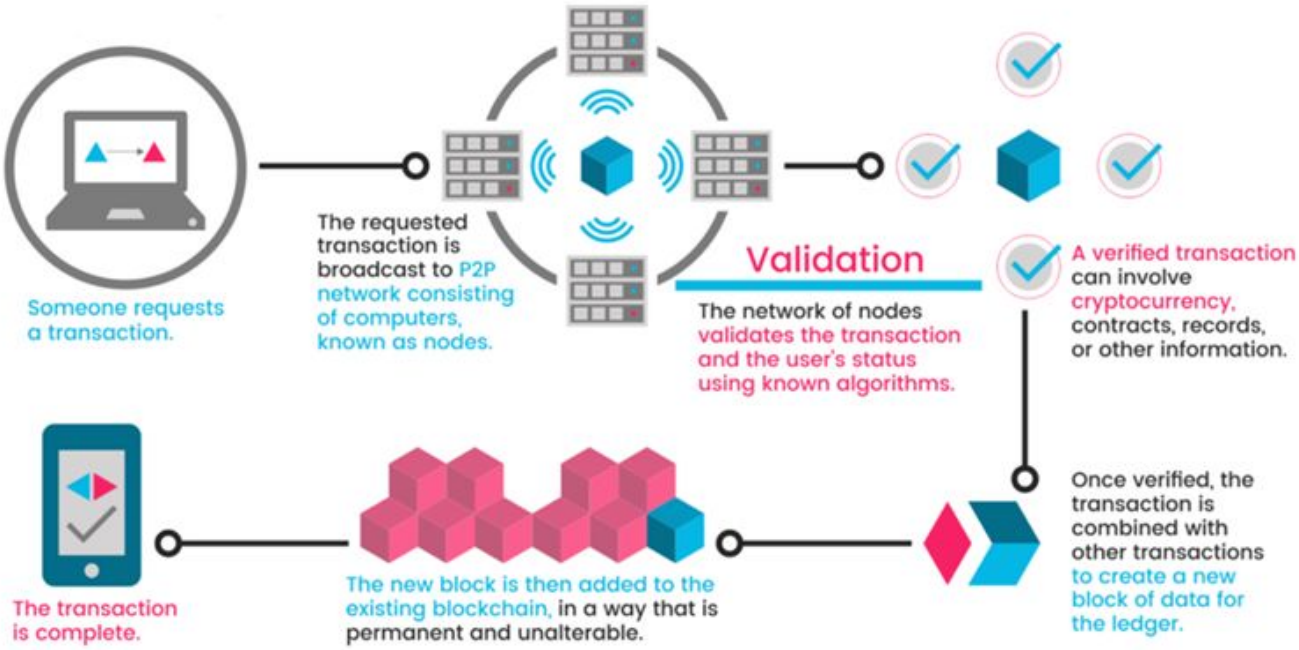

Ethereum - what?
- Ethereum is an open-source, public, blockchain-based distributed computing platform and operating system.
- Offers smart contract (scripting) functionality enables developers to build and deploy decentralized applications (DApp)
- Supports a modified version of Nakamoto consensus via transaction based state transitions.
- Provides a decentralized Turing-complete virtual machine, the Ethereum Virtual Machine (EVM) which can execute scripts using an international network of public nodes.
- "Gas" an internal transaction pricing mechanism is used to mitigate spam and allocate resources on the network.
- Ether is a cryptocurrency whose blockchain is generated by the Ethereum platform.
- Ether can be transferred between accounts and used to compensate participant mining nodes for computations performed.

[8]


Ethereum - why?
- Immutability: A third party cannot make any changes to data.
- Corruption & tamper proof: Apps are based on a network formed around the principle of consensus, making censorship impossible.
- Secure: With no central point of failure and secured using cryptography, applications are well protected against hacking attacks and fraudulent activities.
- Zero downtime: Apps never go down and can never be switched off.

[8]

HOW IT WORKS



[8]

CONVOLUTIONAL NEURAL NETWORK(CNN)

Convolutional Neural Networks (CNNs) are a category of Neural Networks that have proven very effective in areas such as image recognition and classification. CNN's have been successful in identifying faces, objects and traffic signs apart from powering vision in robots and self driving cars.[9]

Currently there are many existing lung cancer diagnostic approaches to classification problems. In [10], CADe and CADx systems based on Houns eld unit and perform the segmentation by combining region growing algorithms and morphological filters. A powerful learning model proposed in [11], which employed back-propagation neural network for classification that would classify the digital X-ray, CT-images, MRIs, etc as cancerous or non-cancerous. [12]

A proposed methodology I will be looking at and improving is from [13] , in this CNN, the pipeline is composed of three stages, preprocessing, nodule detection and lung cancer prediction as shown in Figure 1 below. Preprocessed MRI images are stacked into 3d shapes in the first stage. The second stage will consist of a nodule classifier which is pre-trained on my open source dataset, it will extract 16 candidates of nodules by sliding over all possible regions on the 3d images. In this process, the 256-dimension features of selected nodules are stored. Finally, nodule features are fed into the lung cancer classifier and outputs the probability whether the patient will have lung cancer or not. [13]

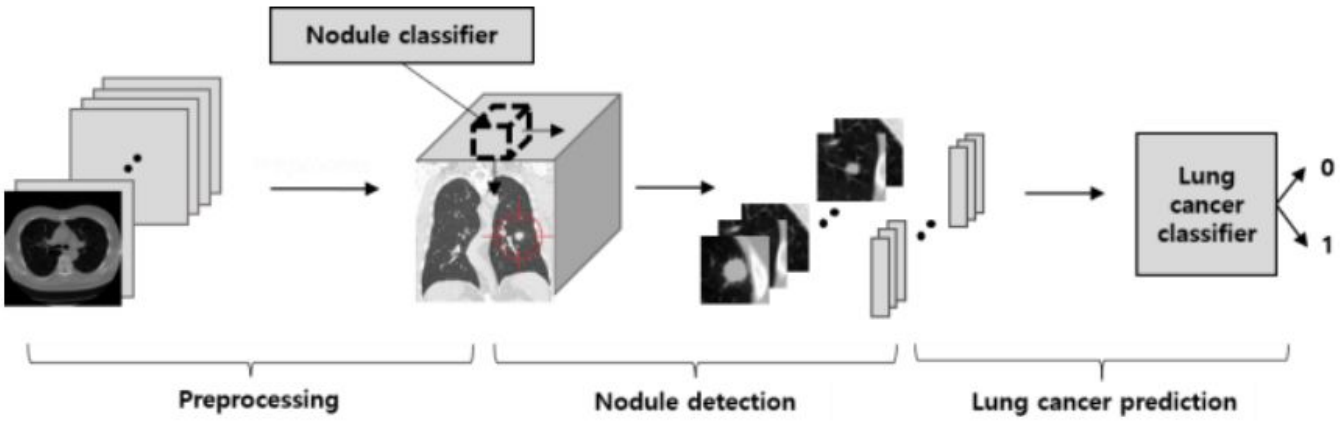
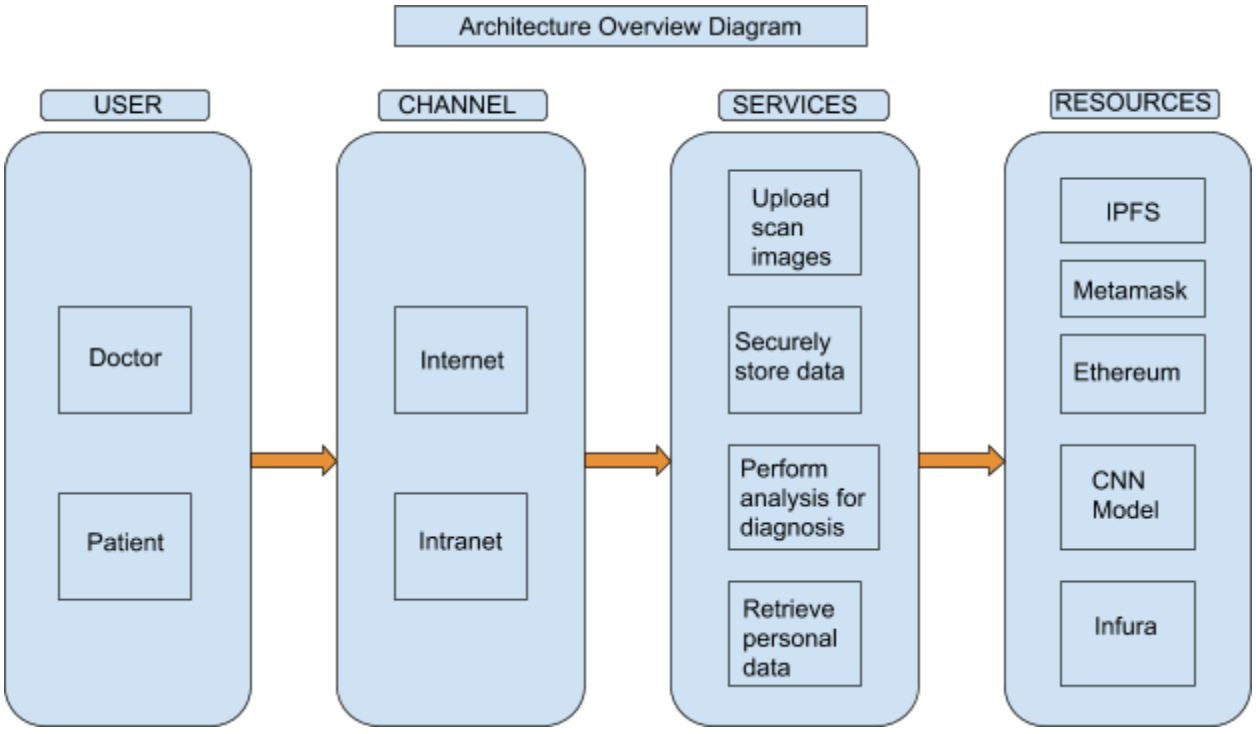


Figure 1. Overview of lung cancer diagnosis system

ARCHITECTURE OVERVIEW DIAGRAM

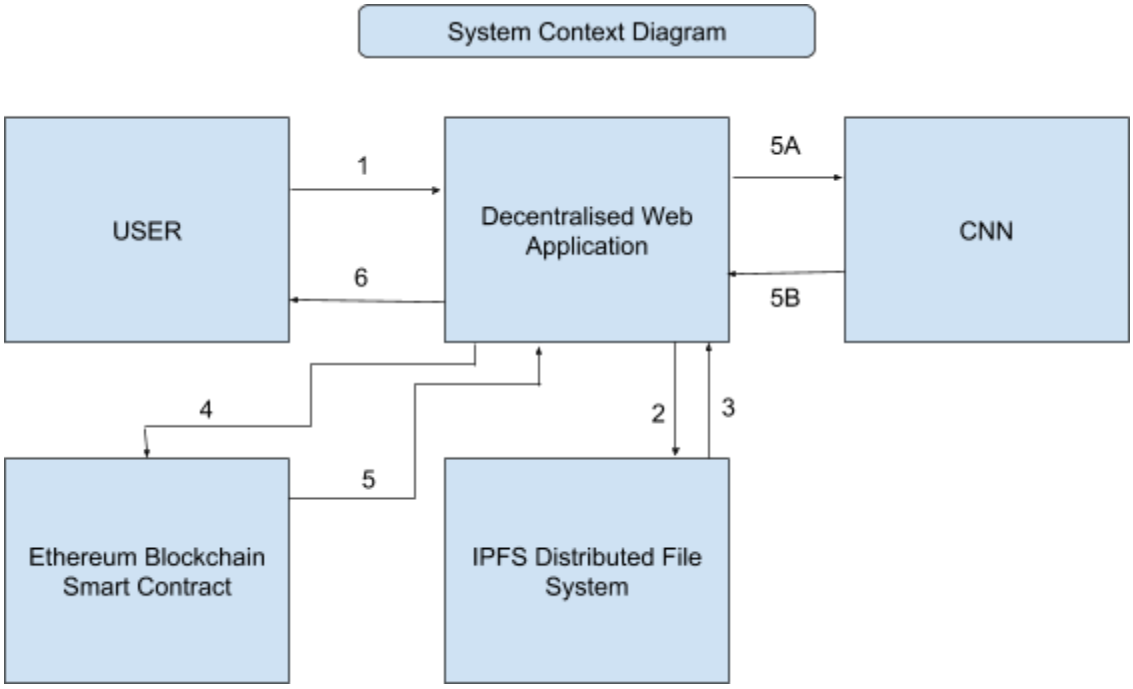
The purpose of an architecture overview model is to provide a high level overview of the solution. The diagram provided below aims to reach out to a wide audience while still retaining enough detail surrounding the key areas of the proposed platform. It should develop a deeper understanding of the platform. The diagram below is broken up into four sections:

- **User** refers to what people will be interacting with the platform on a day to day basis.
- **Channel** refers to how a user would interact with the platform.
- **Service** refers to what functionality the platform will provide for its users.
- **Resources** details what external and internal resources the system will have to use in order to carry out the services it must provide.

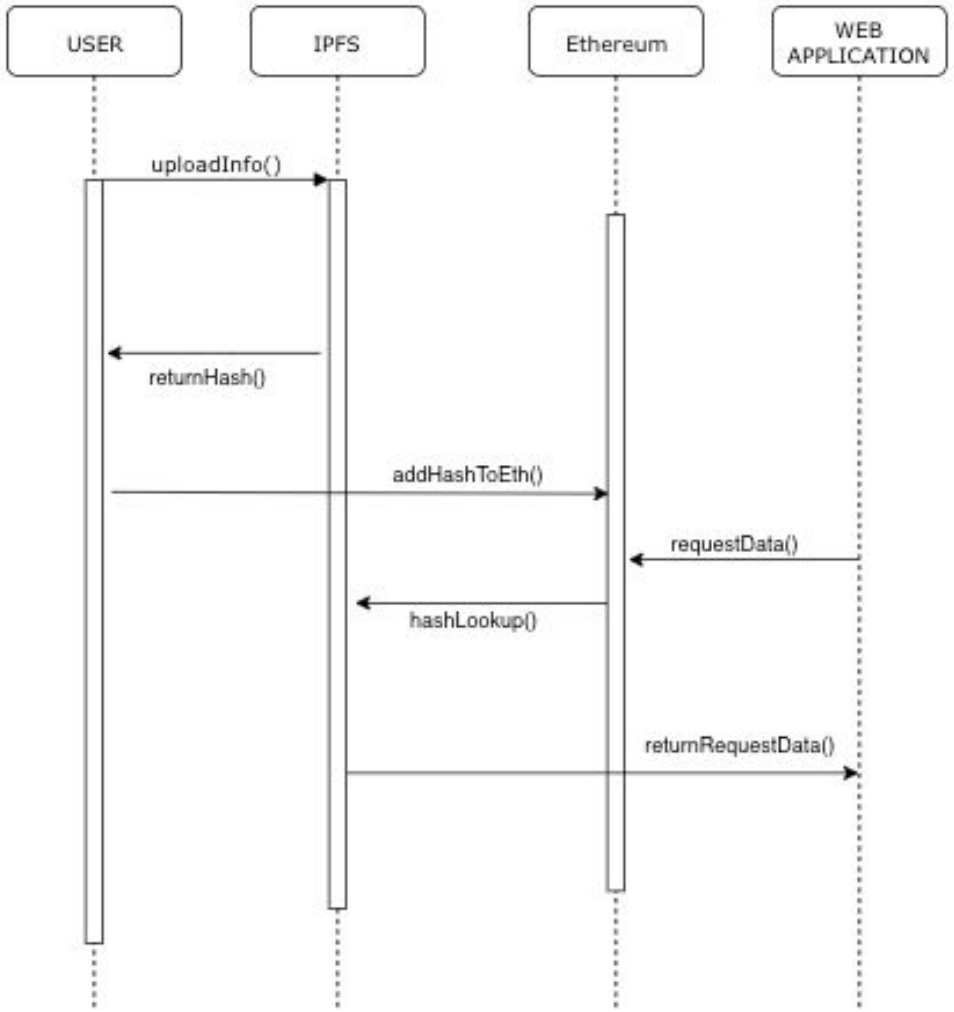


SYSTEM CONTEXT DIAGRAM

A system context diagram shows the system as a single high level process, which shows relationships that the system has with other entities that brings the whole system together. Below we can see the user interacting with the main components of the file system. Its shows the transitions from when a user uploads a file to the web application, to how it is stored on IPFS and the files cryptographic hash is passed to the ethereum blockchain. The file can then be then retrieved by that unique hash and be passed back to the web application in order for the user to view it, or for a doctor to analyse trough our CNN, which is highlighted by 5A and 5B below, as these options are not always used.



SEQUENCE DIAGRAM - UPLOADING AND REQUESTING DATA



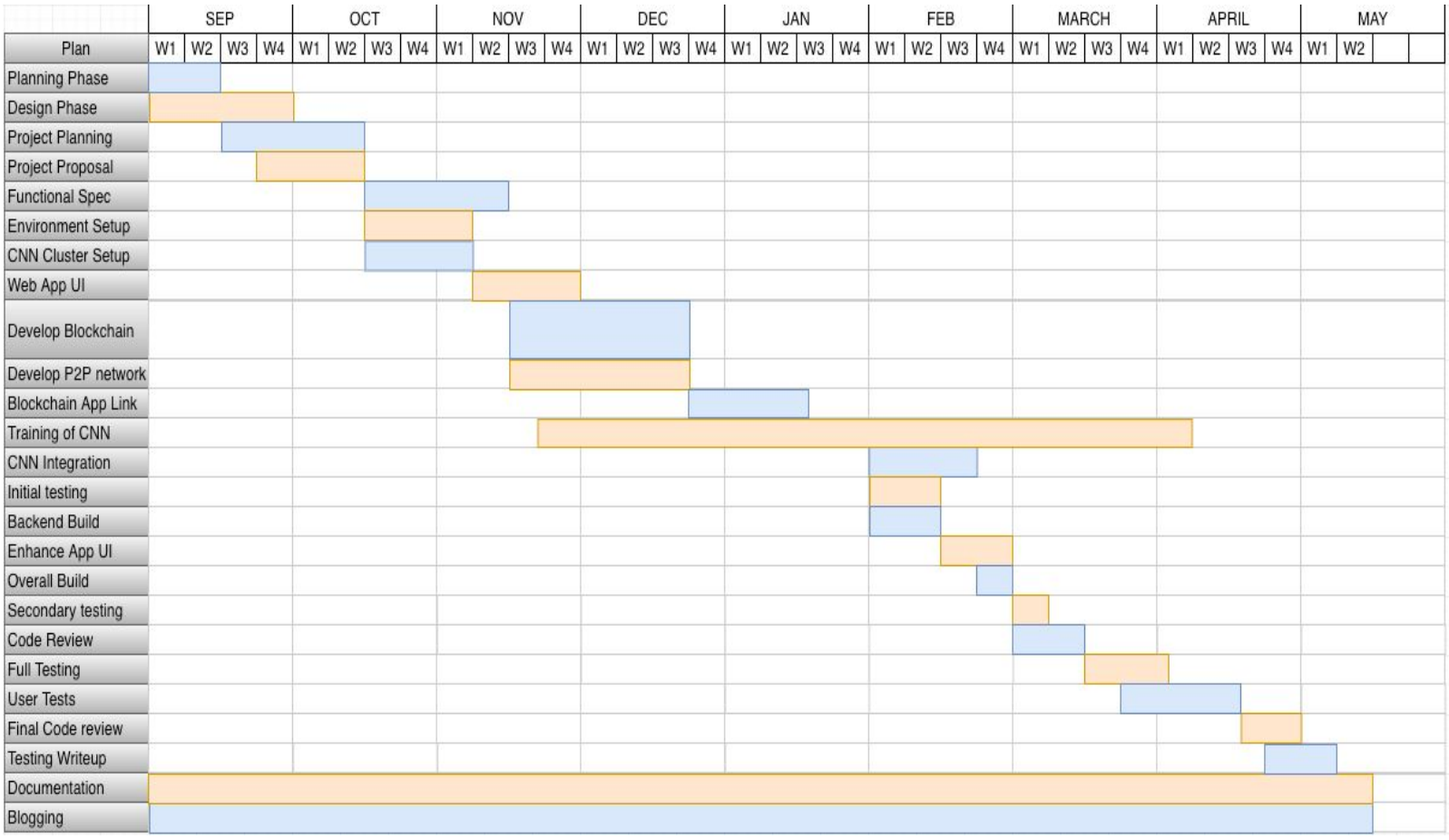
Above is the sequence which a file will be uploaded, stored and retrieved from the decentralised application. A user will upload the data to IPFS, this will create a hash function which will be then stored on the Ethereum blockchain which can be requested by the user from the web application.

PRELIMINARY SCHEDULE

During my time at Mastercard my team and I used the Scaled Agile Framework (SAFe) approach to software development. I will continue to use this approach as I am aware of how it works and happy that it will put me in the right direction. By using this, the project will be structured meaning I will be more efficient of my time, meet my deadlines and have an overall better project in the end. During this project I will also be providing updates in a blog postings and have regular meetings with my supervisor.

As I am working in an Agile environment, I have made a trello board. I will outline my work into iterations that last two weeks, and at the beginning of each iteration, stories will be made that I can develop and work towards, with regular updates on progress through each iteration.

The below chart illustrates my timeline of tasks that I will complete up until the second week of May before exams.



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APPENDICES

Below are links to the specific tools that will be used to produce MDsmrt:

1. IPFS - https://ipfs.io/
2. Ethereum - https://www.ethereum.org/
3. Infura - https://infura.io/
4. Metamask - https://metamask.io/
5. Solidity - https://solidity.readthedocs.io/en/v0.4.25/