In-Browser Cryptocurrency Mining as a Web Monetisation Model

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Abstract

The monetisation of digital media has been dominated by advertisements since the creation of the modern internet. As internet based digital media industries have grown, select providers of targeted advertising, such as Google and Facebook, and subscription services, such as Spotify and Netflix, have created monopolies on the monetisation of digital media that have been protested by consumers because of their invasive use of personal data and restrictions on creators. Previous research on in-browser cryptocurrency mining shows promise as an alternative theoretical model for monetisation of digital media although yields disappointing results in practice, including small payouts and large side effects. This study explores the practical limitations of mining in the browser by implementing a platform for music streaming while browser mining. The results find similar economic results that were found in previous studies due to the limitations of hardware available to the browser, however, the opinion towards in-browser cryptocurrency mining has positively changed. Moreover, this study subsequently defines a novel cryptocurrency consensus algorithm, Proof of Traffic, that is more suited to in-browser mining and that proposes to overcome the disappointing returns from browser mining linked to the Proof of Work algorithm which emphasises hardware utilisation for block production.

Contents

1 Introduction

1.1 Advertisements

Traditionally, website owners use advertisements to earn revenue for the digital content they are providing. This agreement between content provider and content consumer allows for the 'free' consumption of digital media. Recent developments in computer science has combined the power of data collection and artificial intelligence, creating adverts that are related to users' personal information and search history, known as targeted advertising [1]. A rise in personal information stored by companies such as Facebook and Google has brought concern to internet users [2]. Substantial efforts are being made by users to reduce their digital footprint, negatively impacting the advertisement website monetisation model. Therefore, content providers are searching for new methods of generating income, by using a different, or a combination of models. Alternatives include subscriptions and donations. For example, the global video streaming service, YouTube, released the subscription service 'YouTube Premium' (formerly YouTube Red) in 2014, which, when subscribed, removes all advertisements from the website and gives access to new services such as YouTube Music [3].

Despite the advertisement monetisation model being imperfect, companies are still heavily dependent on it. Digital advertising spending worldwide amounted to 235 billion pounds in 2019 and is expected to grow to 282 billion pounds in 2021 [4]. Large companies are still participating in the advertisement business. This constant growing of interest causes advertisement suppliers to keep pushing the boundaries. The collection of user data has become increasingly forced and has even started to interrupt the consumer's browsing experience [5]. Various defense mechanisms have been developed to increase user's privacy whilst using the internet [6]. With the cost of advertising increasing and over 763 million of devices using ad-blocking software [7], one must question the future of digital advertising. This rise in ad-blocker software has forced websites to deploy ad-blocker detection techniques and deny the use of their website to anyone attempting to block ads [8]. This arms race has undoubtedly caused publishers to ineffectively monetise their websites.

1.2 Cryptocurrencies

Over the recent years, cryptocurrencies have gained a lot of attention for their potential to change the way we handle financial affairs. Using blockchain technology, they are highly decentralised, meaning there is no central authority to control, slow down or interfere with the network. Experts state that this quality has the potential to globalize digital currencies [9]. However, the idea of a decentralised currency is still a new idea, and there are problems that still need to be overcome. For example, the instability of a cryptocurrency's value and the large amount of energy required to mine new blocks [10].

Mining is one of the core foundations of blockchain technology. A block on a cryptocurrency blockchain contains a set number of transactions, like a ledger, as well as information about that block. In order for a new block to be added to the chain, the transactions need to be validated. Miners use their computing power to solve a complex cryptographic problem. The miner that solves the problem first, validates the block and then receives a block reward - an amount of the currency that is being validated. This is known as Proof of Work (PoW) consensus, as miners have to prove they have put in a substantial amount of work to be chosen to validate the next block. There are other consensus algorithms such as Proof of Stake (PoS), which are starting to become more popular due to the large amount of energy required by the growing network of PoW miners.

The difficulty to solve these cryptographic problems changes to ensure the average time between block creation is steady. Satoshi Nakamoto, the creator of Bitcoin. states in his initial proposal, "to compensate for increasing hardware speed and varying interest in running nodes over time,

the PoW difficulty is determined by a moving average targeting an average number of blocks per hour. If they're generated too fast the difficulty increases" [11]. Figure 1 shows the sharp rise in difficulty which has caused miners to invest in specialist hardware known as application-specific integrated circuits (ASICs), that can generate a significantly greater number of solutions per second than general hardware, such as central processing units (CPU) and graphics processing units (GPU). Therefore, mining a cryptocurrency such as Bitcoin in the browser, using consumers' hardware is not viable.

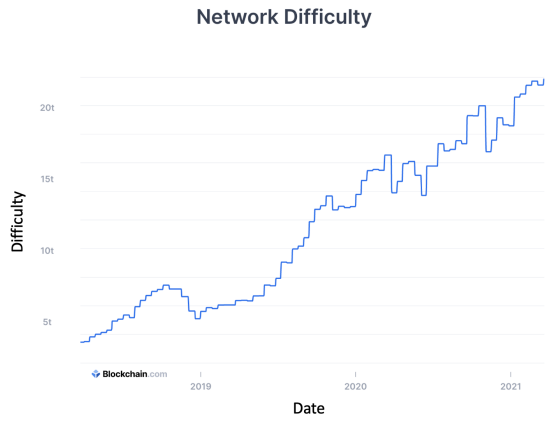

Figure 1: Bitcoin Mining Difficulty over the past 3 years [12].

The large increase in mining difficulty has inspired users to 'pool' their mining power. Pooling is when miners work together in order to increase their probability of solving the cryptographic problem, where rewards are split between pool members depending on how much work they did towards mining that block. The amount of work is measured in shares - the greater number of shares, the greater the cut of the block reward. Pools give miners with a small amount of computer power a chance to make some profits for their effort, no matter how little. The current Bitcoin mining pools can be seen in Figure 2.

However, one of the initial principles of blockchain based cryptocurrencies is decentralisation, which mining pools contradict. Large mining pools will have greater power over the network and could ultimately manipulate the blockchain via a 51% attack. As the name suggests, a 51% attack is where one entity (pool or person) contributes more than half of the network computing power, and uses this to validate false transactions due to the workings of blockchain consensus [13]. Currently, networks rely on the mining community to distribute the computing power evenly across pools, however researchers have developed mechanisms to defend against these types of attacks [14].

1.3 In-Browser Mining

A cryptocurrency named Monero is thought to be ASIC resistant and can be efficiently mined by a CPU. Privacy is one of Monero's core values and is backed by their blockchain implementation of security, hiding the identities of the sender and receiver [16]. Consequently, Monero has become the go to cryptocurrency for in-browser mining. There are many APIs that can easily be added to websites, the most well known was CoinHive [17]. CoinHive shutdown in 2018 after being unable

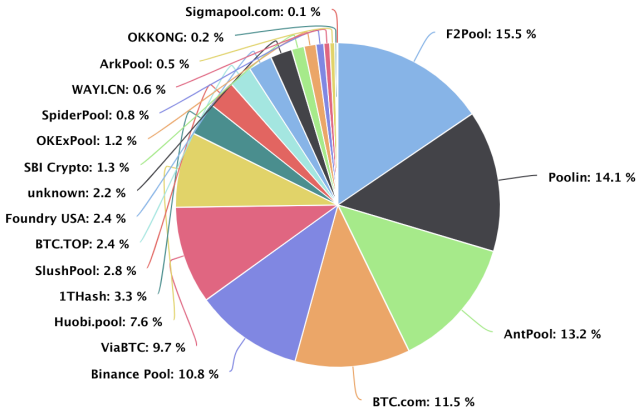

Figure 2: Bitcoin Mining Pools as of 5th April 2021 [15].

to cover server costs [18]. This is most likely due to nefarious use of their services, such as the popular torrenting site "The PirateBay". Cryptojacking is the act of using computing resources to mine cryptocurrencies without consent from the owner of the hardware. This most likely harmed CoinHive's reputation and deterred ethical customers.

Sadly, as cryptocurrency mining technology advances, the malicious possibilities also increase. Docker is an open platform for developing, shipping, and running applications. It is being used by more and more developers to help containerise their products. 30 malicious Docker images with a combined 20 million downloads have been used to spread cryptomining malware [19]. Docker allows opportunists to take advantage of the cloud's large number of CPU's and virtual machines. Moreover, Monero's anonymity allows abusers to be hidden from administrators. Evildoers such as these, harm the reputation of cryptocurrency mining.

Employing browser mining in a transparent and legitimate manner is arguably preferential over advertisements due to growing legal pressure on models such as programmatic advertisements that rely on the exploitation of large amounts of personal data. Laws such as the General Data Protection Regulation (GDPR) [20] and ePrivacy Directive (ePD) [21] will have less conflict or restrictions using the web mining monetisation model. Some research has stated that in terms of the law, web-mining is feasible if not preferable to advertisements [22].

Due to the exponential advancements in CPU speeds and the call for a new digital content monetisation mechanism, this study will explore the views of digital content consumers, towards different methods of monetisation. Mainly, in-browser cryptocurrency mining verses traditional advertisements and subscriptions models. It will measure the economical feasibility of using popular PoW mining algorithms and the current state of the cryptocurrency market. Will the method of monetising digital media ever change from the current industry standards, such as advertisements and subscriptions? This paper attempts to answer this question by suggesting a new form of monetisation, in-browser cryptocurrency mining. The main issue of mining in the browser is the use of general purpose hardware to mine new blocks. The computing power produced is not enough from low end computers. Therefore, this paper will design and deliver a functional system for the monetisation of digital content using in-browser cryptocurrency mining, and define a new consensus algorithm that will overcome the known problems of PoW algorithms. Moreover, this new algorithm will explore the possibility of streamlining payments to content creators.

2 Methodology

2.1 CryptoListen

A music streaming web application is used as the main tool to evaluate internet user's opinions of in-browser cryptocurrency mining. The website, named CryptoListen, utilises a JavaScript cryptocurrency mining API to monetise its content, this API is provided by Monero Miner [23]. CryptoListen also mocks a subscription model to create a combination of monetisation methods. Each user that signs up for the site would have to pay a monthly subscription fee. Throughout the month, the user is allowed to enable the in-browser cryptocurrency mining, where all rewards go to reducing the monthly subscription at the end of the month. If a user does not mind the full monthly subscription, they do not have to mine and can still consume the digital content. On the other hand, a user can mine all month and pay as little as possible at the end, depending on how much Monero they have mined.

The cryptocurrency mining is supported by the subscription model to give the user a choice of using another monetisation mechanism. It allows for a direct comparison between one of the most common methods used by similar services, such as Spotify and Apple Music. The aim of CryptoListen is not to increase the revenue earned by digital content providers, but to replace current systems with a more privacy based web experience. Therefore, at the end of a month, the user will always 'pay' the provider the same amount. The only difference is that they are paying a portion in standard currency and the other portion in mined cryptocurrency. It is up to the user what the proportion is, based on their time spent mining.

This implementation allows the user to control how they pay for their web experience. Large digital content providers are already giving users the choice between monetisation methods, but most only consider advertisements and subscriptions. CryptoListen is attempting to add in-browser cryptocurrency mining to this list. Cryptocurrency mining is not being forced upon the user, this will help with the notoriety of in-browser mining. Transparency is vital as it will help build trust between the content providers and content consumers. CryptoListen states exactly how the digital content is monetised and how each user's computing power is put to use.

2.2 Ethical and Legal Considerations

The law on digital media is ever changing with new technologies forcing the law to react by creating new rules to stop its abuse. The EU Data Protection and Privacy Law should always be considered when developing a new product. Particularly the General Data Protection Regulation (GDPR) [20] and the ePrivacy Directive (ePD) [21].

Cryptojacking or malicious crypto mining is when someone uses a third parties network bandwidth for cryptocurrency mining without the user's consent [22]. Every CryptoListen user needs to be fully aware of the monetisation system in place and the effect it could have on their PC. The ePD requires the web application to ask consent for the use of the user's computing power, and when consent has been given, the mining can begin [24].

CryptoListen has to abide by copyright laws, ensuring the code is not stolen from existing websites. Moreover, the site must have the correct rights to stream the music. The music used is royalty free music from Bensound [25], and can lawfully be used as long as it is credited on the site. The GDPR is in place to protect all personal data processed during the use of the application. In order to prove valid consent for browser mining, data needs to be processed so that the person deploying the miner can prove it collected lawful consent.

The ethical issues are very closely linked to the legal requirements. It would be ethically wrong to collect any unnecessary data about the user and/or process the data in a malicious way. The website

displays exactly what data the web application is collecting and how/why it is being processed. Moreover, it would be ethically wrong to start using computing power without consent. It would also be wrong to keep using the computer power once the user has left the web application and assumes the mining has stopped. To ensure this does not occur, there are strict start and end conditions when dealing with the user's computing power.

2.3 Technology

CryptoListen uses a JavaScript API named Monero Miner [25] to allow users to mine in their browser. The library is simply imported inside of the HTML header which allows the use of their public methods to control the Monero mining. The creator of Monero Miner takes a 12% mining fee, meaning only 88% of Monero mined will be returned to CryptoListen. A company would be able to create their own in-browser JavaScript miner to avoid the fees of third party software, therefore, the 12% Monero Miner fee is negated when calculating the revenue of CryptoListen. The Monero Miner is configured to connect to the MoneroOcean mining pool [26]. At the time of writing, Monero Ocean contributes 1.3% to the Monero network hashrate. The pool takes a 0% mining fee. A site could create their own private mining pool using their active users, however this would require a large number of miners to accumulate the hashrate needed to compete with the other mining pools. The mining power of one pool cannot exceed 50% of the networks power, to prevent the possibility of a 51% attack, though this is very unlikely.

The user interface of CryptoListen is developed using React.js, a popular JavaScript library. Each section of the interface (Sidebar, navigation etc.) is split into components. Components are encapsulated building blocks and typical React applications will have many components in order to create complex user interfaces. Each component is either a class or a function that returns HTML to be rendered to the document object model (DOM). React.js is popular because of its built-in state object. The state object is where property values about the component are stored. When the state object changes, the component re-renders, allowing you to create dynamic websites with efficient load times and memory usage. Design packages allow developers to create professional web interfaces easier and faster. Predefined styles and design tools improve consistency and usability of the site. This project uses IBM's open source Carbon design system [27]. Carbon has its own NPM (Node Package Manager) package, which allows for an easy integration into the website. The server of CryptoListen is written in Node.js and the Express library. Node.js is used by many tech giants such as Microsoft [28] and Netflix [29], due to its lightweight and efficient implementations. Both React.js and Node.js are published in the NPM registry, meaning they are both easily updated and stored together.

User log-in details and mining statistics are stored by the site. This is achieved by the third party software, MongoDB. MongoDB is a document-oriented database program. It is a 'No Structured Query Language' (NoSQL) database service, using JSON-like documents instead of traditional rows and columns. This service is very easy to integrate into applications and flexible to changes, unlike Structured Query Language (SQL) based databases. Moreover, NPM has a practical package named Mongoose, which can be utilised by Node.js to optimise database manipulations in a straightforward manner [30].

Version control is vital to any software development project as it offers many advantages such as providing an overview of all changes to the source code. Git is the leading version control software and is used in this project. Git allows developers to track changes and revert to old versions when needed. The source code is available at all times, as long as developers have the correct permissions. During the creation of CryptoListen, a branch was created for each section of development (authentication, About page etc.). These were then merged into the main branch when completed, which could be reverted if these changes caused problems once deployed.

CryptoListen is hosted by the Heroku platform [31]. Heroku provides a container-based cloud Platform as a Service (PaaS). It can be used to deploy, manage, and scale modern applications. Deploying a small Node.js application with Heroku is achieved by linking a GitHub repository to the deployment profile. This allows Heroku to directly take a specified branch and deploy it to the cloud. The developer must ensure that the branch selected is in a deployable state and any tests have passed. Figure 3 shows the technology stack for the CryptoListen app.

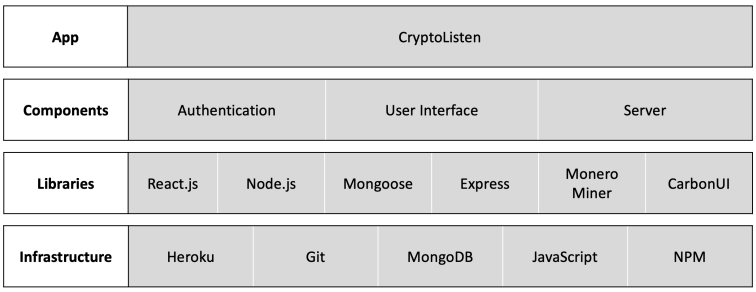

Figure 3: CryptoListen Technology Stack.

2.4 Design

2.4.1 Log-in and Registration

When a user first accesses CryptoListen, they are presented with the log-in/register page. When a user tries to access another part of the website, they are redirected to this page, until they are authenticated. In order to register to the site, the user must provide a unique username, a password and confirm the password by retyping it. The password is encrypted twice using the SHA256 hashing algorithm [32]. Both username and password are sent to the server which creates a new entry in the MongoDB database. When a user wishes to log into their account, they must supply their username and password which are checked against the database. If correct, they are redirected to the landing page, otherwise they are asked to re-enter their details.

There is a simple tab system allowing the user to switch between log-in and registering, as seen in Figure 4. If the user attempts to log-in with incorrect details or register with a taken username, red text is displayed informing the user what is wrong. Finally, there is a message displayed on the page, informing users to turn off any AdBlockers that they have installed. Some AdBlockers deny applications the ability to mine in the browser, due to cryptojacking.

If this site was to be published as a full product, a user would also need to provide an email and payment details in order to pay for the monthly subscription. The site would need to automatically detect if there is an AdBlocker installed, and must deny access if present.

2.4.2 Landing Page

Once the user has successfully logged in or registered, they are presented with the dashboard/home screen. This screen comprises of two components, the banner and the main content, as seen in Figure 5. The banner has the name of the application, the name of the currently logged in user and a logout button. When a user logs out of the website, they are returned to the initial log-in page. If the user tries to access this page directly, they are redirected to the log-in page.

The main content component has three children components: About, Music and Mining. There is a tab system allowing the user to change between the three. This system is efficient because it

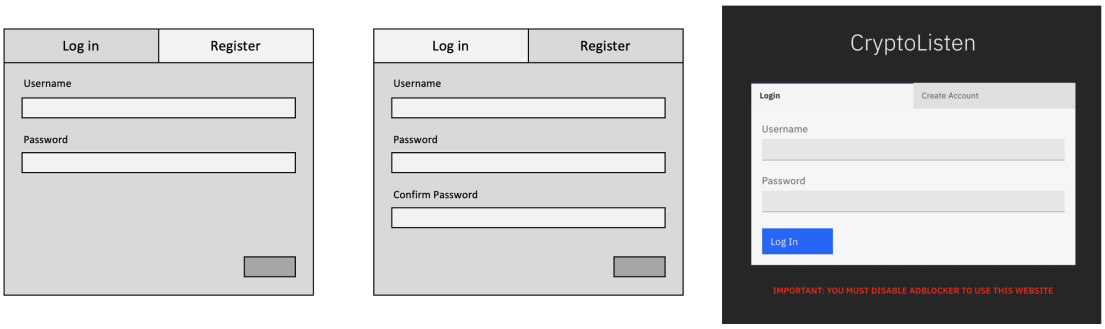

Figure 4: Log-in and Register design and production layout.

does not have to re-render the banner each time the user changes tab. When the user first logs into the website, the About content is on display. The banner is a set height and the main content comprises of the rest of the view port.

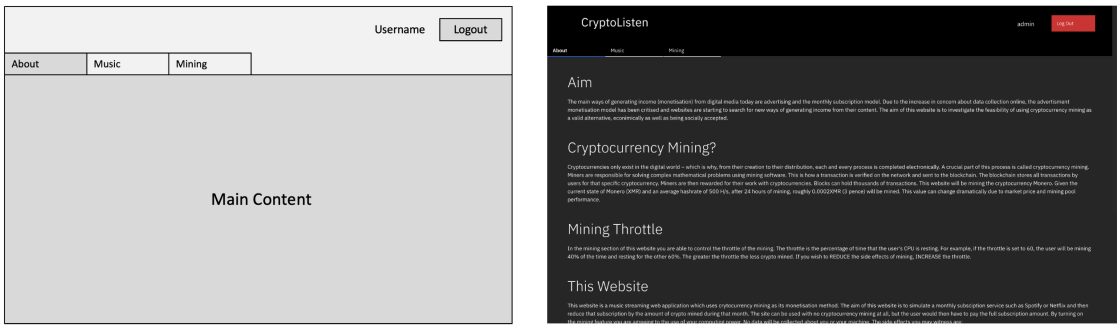

Figure 5: Landing Page design and production layout.

2.4.3 About

The About page contains information on what the site is trying to achieve and how it does that. It explains the basics of cryptocurrencies and cryptocurrency mining. This is to give the user some understanding of what their computer will be doing whilst mining. The About page outlines the risks and side effects of cryptocurrency mining, including an increase in CPU temperature, an increase in fan speed, a possible decrease in computer performance as well as increased power usage. It is important that the user knows all of the side effects that could occur with mining in the browser in order to increase trust of websites that use it as a monetisation model.

Finally, this page states the data that is being collected during the use of the website: the amount of time spent on the website (in the background is included), the amount of time spent mining on the website (in the background is included) and the cryptocurrency mining statistics.

2.4.4 Music

The main motivation of CryptoListen is to be able to stream music. The Music page consists of three separate components: a sidebar, a main panel and a play bar at the bottom, as shown in Figure 6. The sidebar contains the user's playlists and a home button. The home section contains all songs on the platform and the playlists are comprised of subsets of these songs. If the site was to be fully developed, a user would be able to create their own playlists, however, as the music is not the focus of the study they are randomly set to imitate playlists.

The main panel displays the name, artist and length of the available songs, depending on what playlist is selected. If a user wishes to play a song, there is a play button next to each name. When clicked, the song will appear in the play bar at the bottom of the page. Once the song has ended, the next song in the main panel will automatically play. Moreover, the play bar at the bottom will display the controls for the song playing, such as: play/pause, skip to the next song, volume, current song name/artist and a slider displaying how far through the song the user is.

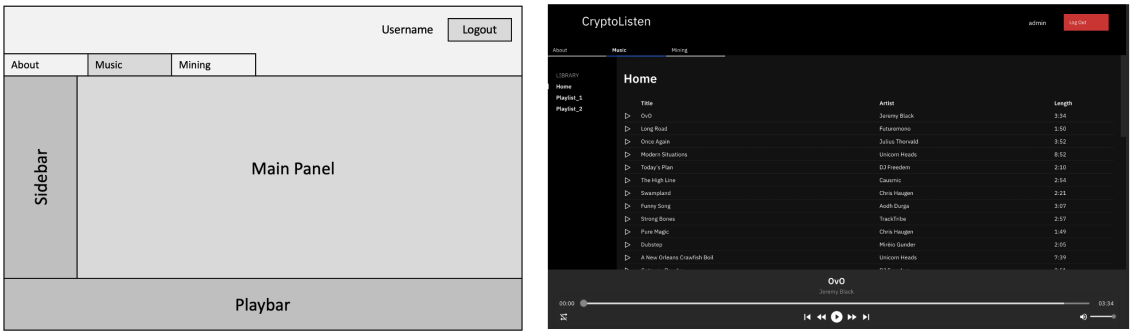

Figure 6: Music Content design and production layout.

2.4.5 Mining

The Mining tab allows the user to toggle the cryptocurrency mining and display statistics based on their current mining performance. In order for the user to start mining they need to give consent for the use of their computing resources. This is achieved by a sliding button, that is either set to yes or no. The user is expected to read the About section and understand the risks of mining in the browser, only then can the user start mining.

The user is able to control the throttle of the mining, this is done via a sliding bar. When the throttle is changed, the mining restarts with the new parameters, however the user should not notice this and their mining time should not be reset. The statistics shown are inside of tile components, that are equally spaced and fixed in size, as shown in Figure 7. The numbers displayed are only able to update as fast as the mining pool API does. Therefore, its accuracy is dependent on the MoneroOcean mining pool API. The statistics that are displayed are:

- The current state of the miner (either on or off)
- The current throttle of the miner
- The time spent mining during the current session
- The number of hashes produced this session

- The total number of hashes produced across all session
- The number of shares received across all sessions
- The raw hashrate
- The pay hashrate

The raw hashrate is the number of hashes produced per second for the mining algorithm being used, whereas the pay hashrate is the Monero equivalent that the miner is getting paid for. The larger the pay hashrate, the greater the payout per mined block.

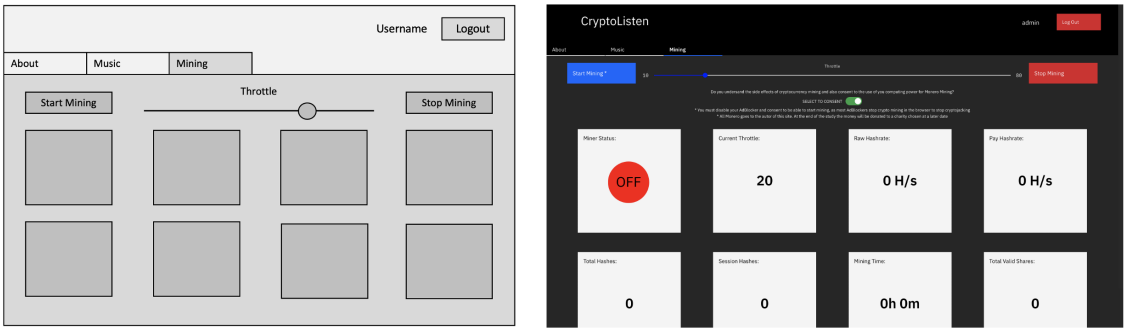

Figure 7: Mining Content design and production layout.

2.5 Testing

Beta testing provided helpful feedback during the development of CryptoListen. Two separate milestones were defined from the expected development cycle, and the product was released to a closed number of users at each checkpoint. Three users were asked to use the site for 24 hours and report any bugs or defects they come across. The users were different for each milestone, and they were also not part of the user trail at the end of development. It is important to not re-use test users, otherwise you will end up with an application designed for a small specific audience. It is better to have a broad range of users to increase the diversity of opinions. Two of the users were using Windows and the other Mac OS. Each were assigned a different browser, either Firefox, Safari or Chrome. This allowed testing across a diverse range of platforms.

The first development milestone was being able to register, log-in and listen to music. All three users reported no significant product defects. However, a few minor points were raised, such as when the browser window was too small, important text would appear off screen. The users were also asked about the look of the website. The response was negative and suggested to change to a darker colour scheme. The change of theme is shown in Figure 8. The users asked for better known music to be added to the site, however this can be disregarded due to need of royalty free music. More royalty free music was later added to the site to increase the diversity of genres.

The second milestone was reached at the end of development, when in-browser mining was operational on the site. The three new test users were asked to use the mining capabilities along with the music streaming service. They were asked the same questions as the previous milestone test group, along with some extra questions about the mining. These questions were orientated around defects and ease of use instead of their mining experience.

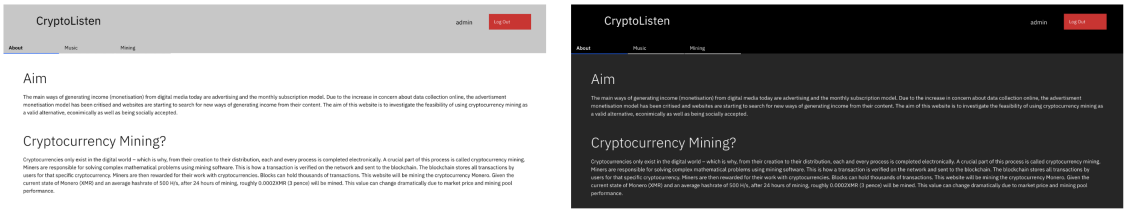

Figure 8: Old light theme (left) next to the new dark theme (right).

One major bug was found by a user - after the site was running in a background tab for a prolonged amount of time, the mining timer would not update correctly. On most browsers, inactive tabs have low priority execution and this can effect JavaScript timers. This bug was solved by decreasing the precision of the timer, updating the timer every minute instead of every second. The test users also gave positive feedback about the look and ease of use of the website across all three browsers.

2.6 User Trail

A selection of users were asked to stream music from CryptoListen for one week. The users created an account and upon first entering the site, their week began. During this week, the user's site time and mining statistics were recorded. This allows for a good analysis of the economical feasibility given the user's hashrate and an average of how long they mined. The number of users is small due to the length of the trail.

Once a test user finished using CryptoListen for a week, they were asked to fill in a questionnaire about their personal streaming habits, as well as their experience using the website. This questionnaire aimed to discover internet users' opinions on current monetisation methods such as advertisements and subscriptions. Firstly, the questionnaire collects some demographic data to ensure that a suitable range of people are selected for testing, as well as their current digital content monetisation opinions. In summary the first section collects:

- Demographic information - age, gender, familiarity of cryptocurrencies and Blockchain technology
- Music streaming habits - number of hours a week streaming music, most popular music streaming platform and main device used to stream music
- Digital content spending - do they currently pay for any digital content subscription service and if so, how much do they cost
- Advertisements and Bitcoin - their views on advertisements, do they have AdBlocker installed and whether they believe Bitcoin could become a global currency

The second and final part of the questionnaire asks the user about their CryptoListen experience over the past week. It aimed to find out the views of using in-browser cryptocurrency mining as a web monetisation model. In summary this section collects:

- Awareness of CryptoListen's monetisation mechanism - the use of their computing resources and any side effects that might occur

- Experience of in-browser cryptocurrency mining - device mainly used, side effects and how invasive these were
- Comparison with current monetisation mechanisms - are advertisements preferable and reputation of cryptocurrency mining

3 Results

3.1 Test Users

13 test users - 8 male (61.5%) and 5 female (38.5%) were asked to use the website as their music streaming platform for one week. The study consisted of a small number of users for a long period of time to a gain an accurate economic analysis regarding people's streaming habits. 46.2% of test users were between the age of 18-21, 30.8% between 22-25, 7.7% between 26-35 and 15.4% were over the age of 35.

Users were asked which device they mostly listen to music on. Mobile phones were selected by 53.8% of users. This negatively impacts the feasibility of using in-browser PoW cryptocurrency mining as a monetisation mechanism, because phones do not have the required hardware or battery capacity to efficiently mine. However, 38.5% of user's selected their PC or laptop. This is a great incentive to use multiple monetisation methods like this project describes, a subscription model that can be supplemented by mining. Allowing users that have eligible hardware to benefit from the cryptocurrency mining.

Music and video streaming subscriptions have become the norm over the past decade. Netflix alone had 203 million subscribers by the end of 2020 [33]. The amount of money spent on digital content among the test users is displayed in Figure 9, the average was £12.77 per month. 84.6% paying for a video streaming service, 69.2% paying a music streaming service, and 61.5% paying for both a video and music streaming service. As more services become available and more websites switch to a subscription model, these numbers will only increase. It only serves as a benefit to reduce these costs via cryptocurrency mining or otherwise.

AdBlocker is a well known browser extension that stops websites from showing any adverts. 84.6% of test users find adverts a nuisance and have installed an AdBlocker for their browsing experience. It serves no purpose for website owners to place adverts on their site if users are not going to see them. Adverts usually generate revenue on a pay by view or pay by click basis, neither will occur when an AdBlocker is present. Currently most AdBlockers deny in-browser cryptocurrency mining due to cryptojacking. However, if large trusted companies integrate optional mining into their monetisation model, it would become less of an unwanted inconvenience. Each test user was asked "If a large company (for example Spotify) were to implement cryptocurrency mining, would you be more trusting in the legitimacy of in-browser cryptocurrency mining?", and 100% of them responded with yes.

Bitcoin has become a global sensation over the past few years, but could a cryptocurrency become a global currency? When asked this question the responses were mixed, equally split between yes and no. The main argument against a cryptocurrency becoming globally accepted was the lack of understanding of cryptocurrencies and Blockchains. Interestingly, the people with greater knowledge about cryptocurrencies and blockchains were more pessimistic than the people that had less knowledge. Others argued that the current economic system in place is far too complex to be replaced, the old monolithic systems would simply be immovable. On the other hand, the argument for a global cryptocurrency revolved around the recent advancements in company usage of Bitcoin. For example, Tesla now allows the purchase of their cars in Bitcoin [34]. Users assume as more trusted companies start to use Bitcoin, more knowledge will be spread to the population. This is

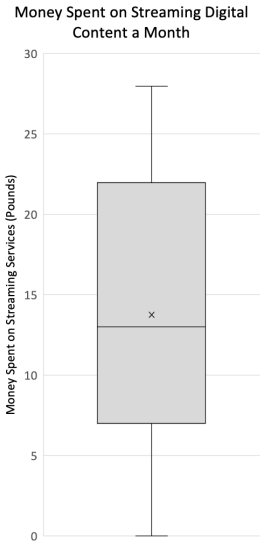

Figure 9: Money spent per month on digital content subscriptions.

a fair assumption, as previously mentioned, 100% of users would trust cryptocurrency mining if a large company was to encourage it.

3.2 In-Browser Mining Experience

Every test user knew how CryptoListen was monetised and knew the potential side effects of in-browser cryptocurrency mining. This is ethically and legally essential, as previously stated in the Ethical and Legal Considerations section of this report.

9 of the 13 users participated with their desktop computer and the other 4 with their laptop. CryptoListen is not available on mobile devices or tablets due to the extensive hardware usage that is needed to mine Monero. Most of the users reported a positive experience using the cryptocurrency mining feature. On a scale of 1 to 10 (1 being very bad and 10 being very good), over half of the respondents rated their experience an 8 or above. However, all laptop users rated their experience between 2 and 5 on the same scale. This implies that cryptocurrency mining on a laptop has more or greater influence on the user experience.

100% of users witnessed an increased fan speed and just under half reported an increase in computer temperature. 38.5% found these side effects invasive and effected their browsing experience. The majority of these were laptop users and reported the heat of their laptop increasing at an alarming rate. This was expected due to the CPU usage incurred by in-browser cryptocurrency mining, however the amount this deterred users was more than expected. Users reported that their laptop keyboard was too hot to touch and they struggled to hear the music over the sound of the fans. Moreover, a couple of test users reported a very large increase in power usage, stating the battery of the laptop was depleted extremely quickly. Laptops with weaker hardware clearly struggle with mining and cause a worrying amount of side effects to the user. On the other hand, desktop PC users did not find the side effects as invasive. 92% of them rated the side effects equal to or below 3 on a scale of 1 to 10 (1 being not invasive at all and 10 being very invasive). This shows some promise for in-browser mining.

Finally, the test subjects were asked to compare their experience of in-browser cryptocurrency

mining with traditional web monetisation mechanisms. Every desktop PC user (69.2% of test population) preferred to use CryptoListen's combination of subscription and in-browser mining instead of traditional advertising. Whereas, every laptop user (30.8% of test population) would have preferred advertisements. This comes as no surprise based on the previous questions about side effects and how invasive they are on laptops.

3.3 Economic Evaluation

At the time of this study Monero (XMR) was worth £230.35 per coin [35]. Like most non-stable coins, this value fluctuates regularly depending on many factors. This economic evaluation will be based off of the assumption that Monero is worth £230.35, but this is likely to be outdated quickly. Moreover, this study relies on the MoneroOcean mining pool. A mining pool's hashrate is also prone to fluctuation and impacts the rewards received by miners. The greater the pool's hashrate, the more blocks it mines, meaning more rewards to be split between its members. As previously stated, the use of an external mining pool could be unnecessary, as sites could create their own internal pools with their current miners.

The first point to look at, is how long users spent on the website, and how long they spent mining. Over the length of a week, the average user spent 758.8 minutes (or 12.6 hours) on the website. In 2019 the International Federation of the Phonographic Industry (IFPI) reported that the average person listens to music for 18 hours a week [36]. The test subjects are below that average but that could be due to a number of reasons, such as not having their favourite songs available on CryptoListen, or not being able to use their preferred music streaming device. Figure 10 visually represents the proportion of time spent on the website against the time spent mining. The results suggest that the majority of users fell into two categories - the first being users that mined as much as they could across the week, and the second being users that mined very little. Users {3,5,6,7,8,9,10,11} are part of the first group and mined for an average of 90% of session time. Whereas, users {1,2,4,12} are part of the second group and mined for an average of 10% of their time. The only user not categorised by this assumption is user {13} who mined for 33% of the time. It is also worth noting that users who were part of the first group tended to use the site for longer than users of the second group. Implying that even though they were not forced to turn on in-browser cryptocurrency mining, they were still deterred from using its services.

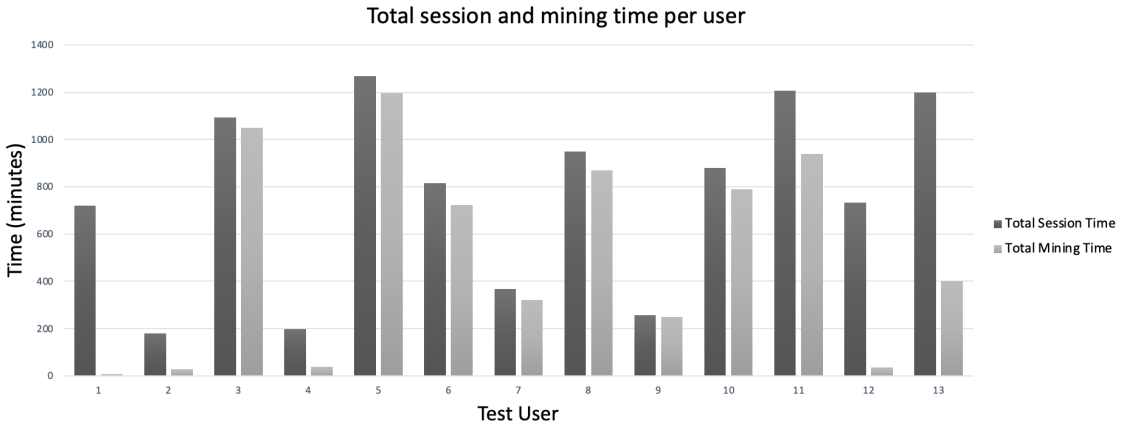

Figure 10: The total session time verses the total mining time of each test user over a week.

Each user's average throttle was recorded throughout the week. Again, users either had a very high throttle or a very low throttle. There is very little correlation between throttle and mining time or hashrate. The throttle seems to be completely user specific, whether they want to reduce side effects by increasing their throttle, or increase their hashrate by decreasing the throttle.

The time spent mining and the users average hashrate are the two main factors needed to estimate how much Monero was mined during the use of the website. The 4 users that did not mine for a substantial amount of time (1,2,4,12) will not be included in the calculations because the amount of Monero mined was under 1 pence. Meaning each of the users would have to pay the full CryptoListen monthly subscription fee. Assuming a month is 30 days long and each user would mine for the same amount of time each week, Figure 11 displays how much money each of the test users would have had deducted off of their monthly subscription. The greatest amount of Monero mined was 0.0005032 (13p) by user 8, who mined for a total of 868 minutes at an average of 450H/s. This is not a substantial amount of money considering the length of time spent mining. The average amount saved by the 9 miners was 6 pence. Hardly significant at all.

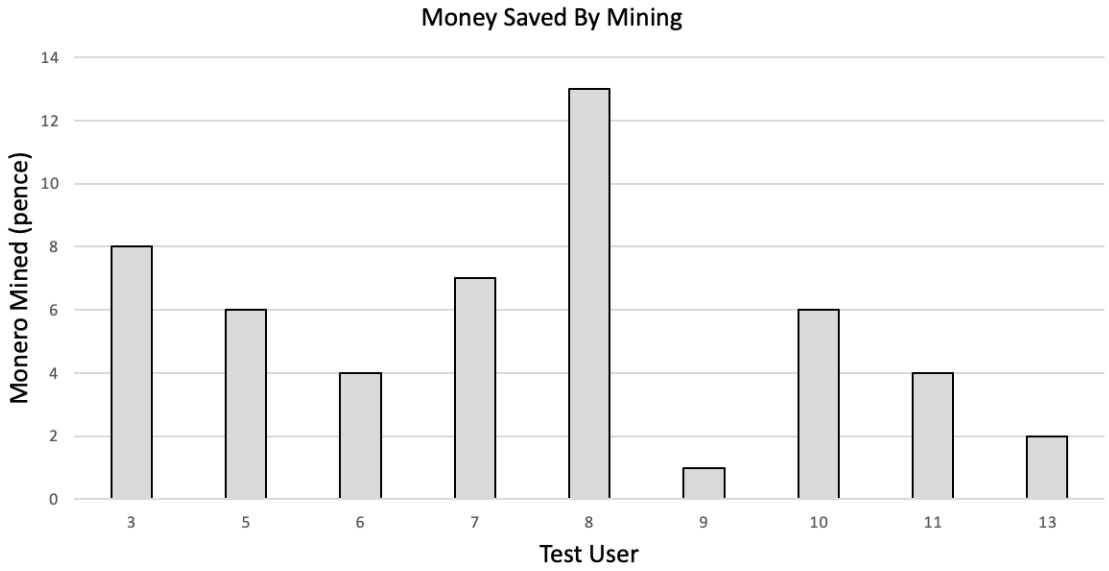

Figure 11: The amount of money saved by each test user via mining.

4 A New Consensus Algorithm

In any centralised system, such as a database orientated application, only an administrator has the authority to add, delete and update the database. These central authorities are trusted to keep a correct record of the data. However, public blockchains are decentralised, self-regulating systems without a central authority. These publicly shared ledgers need an efficient, fair, reliable, and secure mechanism to ensure that all the transactions occurring on the network are genuine, and all participants come to a consensus on the state of the ledger. This task is performed by the consensus algorithm. The two most significant consensus algorithms are Proof of Work (PoW) and Proof of Stake (PoS).

PoW is used by the most popular cryptocurrency networks like Bitcoin, Ethereum and Litecoin. It requires a participant node (miner) to solve a complex cryptographic problem in order to earn the right to validate the next block, and add it to the chain. As we have seen, this is biased to miners with specialist hardware that can produce a high number of solutions per second. Moreover, the amount of energy produced by miners on a public blockchain is exponentially increasing.

PoS algorithms replace the concept of miners with validators. Each validator on the network pays a security fee of the network currency, which acts like a deposit. Nodes with a larger amount of currency deposited have a greater chance of being selected to validate the next block, and add it to the chain. If a node attempts to harm the blockchain by validating false information, they will loose part or all of their security deposit and kicked off the network. This solution requires very little energy, however PoS is still in its infancy, and less battle-tested, compared to proof-of-work.

As seen throughout this study, cryptocurrencies that implement PoW consensus algorithms come with many significant side effects, due to the large amount of computing power required to join the network effectively. PoS algorithms require a large upfront security deposit which would be unfeasible for digital content monetisation. However, a combination of the two could take the positive aspects from both algorithms to make an energy friendly consensus algorithm suitable for website monetisation.

4.1 Proof of Traffic

I will define a new consensus algorithm, Proof of Traffic (PoT), as it is aimed to benefit websites with a larger amount of traffic, the same premise as advertisement and subscription monetisation models. Figure 12 shows an example of a small internet showing websites connected to a blockchain network and each website's active users. Each website connected to the network is classed as a node on the network. No earnings will go to the user, only to the content provider.

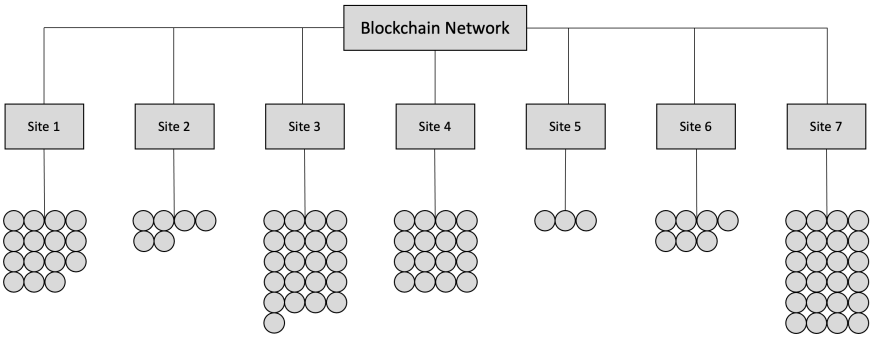

Figure 12: Example of a small internet.

The Bitcoin PoW algorithm involves scanning for a value that when hashed, such as with SHA-256, the hash begins with a set number of zero bits. The difficulty increases exponentially as the number of required zeros increases. Each node (website) has active users. I propose a set low difficulty of the Bitcoin's HashCash PoW system. Each active user attempts to solve the problem until a set percentage of users have found a solution. This initial step of PoW is to prove a sites traffic - the greater the number of active users, the greater the number of successful solutions. Figure 13 shows an example of users who solved the cryptographic problem until a threshold of successful miners was reached.

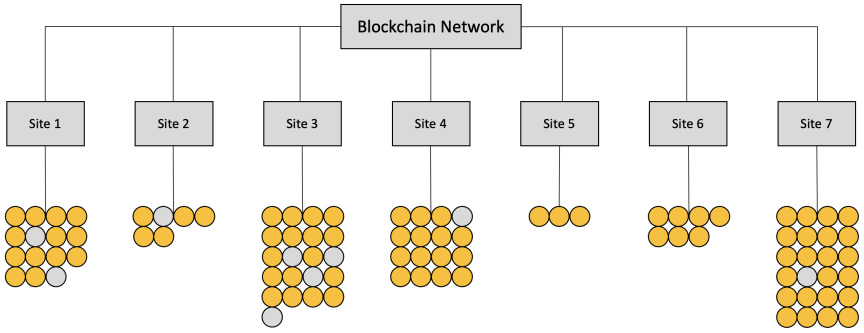

Figure 13: Miners that successfully solved the problem.

The algorithm then switches to a PoS inspired selection process. Sites with a greater number of successful miners will have a greater chance of being selected as a validator. If a site is selected, they arbitrarily select one of their valid miner's (user's) solutions, validate that block and add it to the chain. The site is then compensated with the block reward for validating the block. This process then repeats for the next block.

The block time of a blockchain network is the time it takes to generate a new block. This is usually determined by the time it takes for a miner to find a solution, which is effected by the difficulty of the problem. This is changed for PoT, so that after a set amount of time, a large portion - around 80% - of miners have found a solution to the problem. The difficulty of the problem is adjusted accordingly. Keeping the amount of time that it takes the same percentage of miners to find a valid solution constant.

This solution requires websites to have the ability to validate blocks on their hosting server, however it is not computationally heavy to validate a block. Only a small amount of code will need to be added to the application. It would require a much more sophisticated system to implement a subscription service. If a website attempts to act maliciously by validating an invalid block, their probability of being selected to validate future blocks is significantly reduced. This good behavior system is called reputation. All nodes begin with a reputation of 1. The probability of a node being selected to validate the next block can be shown as

$$\frac{SuccessfulMiners}{NetworkSuccessfulMiners} * Reputation$$

Scaling the PoT algorithm to a large set of nodes could become problematic. The probability of getting selected could become so small, even for larger sites, due to the total active users across the network. This could be counteracted by only letting websites with a minimum number of monthly active users become a node on the network. This would remove redundant nodes from the network, increasing the probability of larger nodes to be selected.

4.2 Security

The threat of a 51 percent attack still exists in PoT, but it would require one website to have over 50% of the total network traffic across the internet. This would be incredibly difficult to achieve. Moreover, the security of Bitcoin's PoW algorithm is replicated in PoT. Each block has a hash identifier, like a fingerprint, which is used by the next block in their hash identifier. If a block is

altered earlier in the chain, it will effect all other blocks that were generated after. This is known as the avalanche effect.

4.3 Extension

This algorithm can be extended to pay content creators directly. Currently all block rewards go directly to the site owner, and then the site owner would have to pay the content creators. However, in PoT consensus, once a miner has found a solution, they could notify the website what digital content they were consuming. If the site was then selected to be the validator of next block on the chain, they distribute the block reward to the content creators according to how many miners were consuming their content. Assuming the website will take a proportion of the reward as profit. This creates a greater decentralised system.

4.4 Example - MusicCoin

An example of this PoT consensus algorithm could be a cryptocurrency for music creators, called MusicCoin. There would be all the platforms that stream music, Spotify, Youtube Music, Apple Music etc. that act as nodes on the MusicCoin network. Each website user currently streaming music would try and find a solution to a relatively easy problem, as defined above. Once around 80% of streamers find a solution to this problem, they send the node their solution as well as the music artist they are currently listening to. The number of active users currently streaming music on the platform that have successfully solved the problem, is proportional to the chance of that node being selected to validate the block. The node selected then splits the block reward between artists respective to the quantity of miners that were listening to them at the time of a solution being found. This solution cuts out the streaming service middleman and pays the content creators directly.

5 Conclusion

5.1 Digital Currencies

The rapid pace of advancements in cryptocurrencies and financial innovation hints at a hopeful future for a global digital currency. The first step in this colossal task is countries creating a national digital currency that is effective. In fact, countries have already started researching a 'central bank digital currency' (CBDC). CBDC's are not entirely decentralised because, a central bank will hold and oversee the network. However, the potential benefits include practically eliminating transaction fees, increased storage security, and value stability [37]. China is currently in the process of creating a CBDC, the e-yuan [38]. It's aim is to combat money laundering, corruption and the financing of "terrorism" by being able to see every transaction occurring on the network. If the e-yuan fulfills its high expectations, other countries will follow suit. Two months after China announced the e-yuan, the United Kingdom announced their interest in creating a CBDC to future proof the sterling [39]. Once national economies lay the foundations for digital currency technology, it is not a large step to combine CBDC's into a globally recognised currency. Digital currencies are the future of finance, and the monetisation of the internet will not be left behind. If currencies become digitised, monetary transactions can be integrated with digital media transactions, creating a pay per byte system. Internet users can pay for how much digital data they consume, instead of paying a set fee and consuming as much as possible. This study has shown a system that implements in-browser cryptocurrency mining, and is a great starting point to achieving this and changing the way we monetise digital media.

5.2 Current Framework

This project is an ethical and practical framework for a music streaming service that uses in-browser cryptocurrency mining as a monetisation mechanism. A small group of users consumed the digital media and interacted with the mining mechanism in place. Mining statistics were collected over the course of one week, which were used to create an economic evaluation of the monetisation mechanism. Users were also asked about their experience using the in-browser mining, allowing an exploration of the views on cryptocurrency mining in the browser. The study has provided a good insight into in-browser mining, and we are able to come to some notable conclusions.

This system is based off PoW cryptocurrency mining which requires large amounts of energy and special hardware. It comes as no surprise that users felt adverse effects to their browsing experience - an increase in power usage, increased computer temperature and increased fan speed were the most reported side effects. PC users were predominantly unbothered by these effects whereas laptop users tended to use the website for a shorter period of time. This is concerning due to a large amount of users streaming music on devices with less powerful hardware than desktop PCs. Websites could limit in-browser cryptocurrency mining to users with a substantial amount of computing power, but this is then unfair to people that cannot afford large custom desktop PCs. This is the same as the cryptocurrency mining community at the moment. Miners that can afford this specialist hardware are able to generate a much larger hashrate, which in turn returns more money, this money is then spent on more mining hardware and the cycle continues.

The state of the cryptocurrency market has a huge effect on the feasibility of in-browser cryptocurrency mining as a web monetisation model. Not only will the amount of miners currently viewing the digital content effect how much revenue a website makes, but also the value of the cryptocurrency mined on that day. For example, if a website mines 2 XMR on one day and also mined 2 XMR on the next day, the quantity is the same but the value would most likely be different. Having an income that is so erratic is not a good business model. CryptoListen attempts to counteract this point by combining a subscription model with the in-browser cryptocurrency mining. The content provider will always claim the same amount of money each month from each user, just in different ratios of mined Monero and standard card transactions. Therefore, the main impact of mining for the content provider, is the use of Monero as a global digital currency. This is promising to get more content providers using in-browser cryptocurrency mining to monetise their content, and increasing trust between content consumers and cryptocurrency mining.

Trust is a common theme throughout this study. The lack of knowledge of blockchains and cryptocurrencies by general web users creates uncertainty when giving consent of their computing power. This can only be increased by more exposure to in-browser cryptocurrency mining and large trusted companies integrating it into their monetisation system. The mining needs to be conducted in a transparent manner, ensuring the user knows all possible side effects, but not scaring them away at the same time. User studies such as this one have shown content consumers selecting in-browser mining instead of advertisements [40]. This user study has proven the side effects to be unintrusive to users that have powerful PCs, but users that have smaller PCs such as laptops have found them too invasive. Moreover, content providers are no longer being paid by the amount of users, but instead the collective computing power of the users on their site. This differs from current advertisement and subscription monetisation models, creating more inconsistencies in revenue.

5.3 Summary

New methods of decentralized blockchain consensus are constantly being developed or being changed by computer scientists. To help security or reduce the amount of energy needed to mine the next block. This study has shown the current PoW consensus algorithms struggle to yield substantial

revenue returns. Test users only saved mere pennies from hours of mining work. It would currently be more effective for a user to install a desktop application such as XMRig [41], pay the web content subscription in full and mine independently in the background. The desktop software produces much higher hashrates than mining in the browser. This is because the desktop applications are written in the C programming language, whereas in-browser mining scripts need to be converted to JavaScript, which is a slower language. Multiple digital content streaming platforms such as Spotify and Twitch offer desktop applications outside of the browser, C mining scripts could be integrated there and produce more promising results, however this is outside the scope of this study. If a secure solution arises that allows effective in-browser mining with minimal computing resources, in-browser cryptocurrency mining as a monetisation method could solve lots of current data collection issues, but also help reduce the increasing cost of streaming platform's subscriptions. The Proof of Traffic consensus algorithm defined earlier, is a step towards achieving this. However, these algorithms need to be battle tested before any integration into a cryptocurrency network.

Digital media consumption is changing, however the largest internet companies still dominate the market. As of February 2021, Amazon's market capitalization stood at £1.2 trillion [42], and the top 5 internet companies hold a substantial majority of market capital. However, they all produce revenue in different ways. Facebook is infamous for its data collection and personalised advertising, and in 2020 the company earned £60.7 billion from advertising alone [43]. Spotify and Netflix are leaders in the music and video streaming platforms respectively, and both primarily monetise their content using subscriptions. Spotify earns an average of £3.71 per month, per user [44], and Netflix earns £7.84 per month, per user [45]. Subscriptions are well suited for music and video streaming because users do not want to hear adverts in the middle of a song/movie. Advertisements are suited to social media sites due to the amount of user interaction. The growth of the cryptocurrency market has provided the opportunity to monetise digital media in a new way. In-browser cryptocurrency mining could be more suited for the monetisation of digital content and replace current methods, if developed and implemented correctly.

In-browser cryptocurrency mining is an alternative to currently established web monetisation models. The decentralised nature of Blockchain technology, helps move away from the centralised monopolisation of digital media. Advertising is being protested by internet users because its invasive nature spoils the internet browsing experience, which has caused a large amount of users to install ad blocking software [7]. This project shows that adverts are not the only mechanism to monetise digital media. There are key systematic and structural problems with mining in the browser, including low economic returns due to the PoW consensus algorithm. However, the new PoT algorithm could overcome these issues. This monetisation framework has the potential to disrupt the current systems in place, and change the workings of the internet we see today.

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