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# Distributed Pool Mining and Digital Inequalities. From Cryptocurrency to Scientific Research



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# Distributed Pool Mining and Digital Inequalities.

# From Cryptocurrency to Scientific Research

## 1. Introduction

This article ventures to explore the dynamic relations between consumption and production in novel technologies that utilise end-user computing resources, as an implementation of distributed computing and alternative of attention economy, and the promises and opportunities it provides from the perspective of digital inequalities to promote dialogue on the social aspects of distributed technologies. The discussion flows from setting the scene on digital inequalities in the age of widespread access to discussing distributed computing and later to examining cases of distributed computing provided by the masses of users and the promises of opportunities it offers. The cases were selected to represent different applications of distributed computing, including cryptocurrency distributed mining and contribution to scientific research. Finally, the article compiles lessons learned from the cases studied into a suggested model for a fair revenue model for content and online service providers that utilises user device computing resources, or computational power, rather than their data and attention.

Relations between content providers and consumers have changed dramatically since the inception of the Internet (Yuan et al., 1998). The relationship has shifted from an equal peer-to-peer network, to a more centralised and clearly defined dichotomy of content providers and content consumers or audience (Randall, 1997). In the second stage, Internet users started using the web as a means to share their own content production, in what was termed Web 2.0 (O'Reilly, 2005), with a plethora of platforms and services facilitating that (Constantinides and Fountain, 2008). The advent of Web 2.0 reshaped network power relations and gave user-generated content an important value and power in driving Internet use, such as content generated by users, and data generated about the users, as is the case with social media platforms (Kaplan and Haenlein, 2010).

So far, the economy of online content and services largely relies on income generated from online advertisements, opening the path for developing industries to support the delivery of advertising, and the collection and brokerage of users' data to help target advertisements to users, evolving from simple contextual to complex and ethically controversial techniques like Online Behavioural Marketing (Nill and Aalberts, 2014). The spread of reliable Internet infrastructure and the affordability of access fostered the idea of relying on the Internet as a platform we can run software through as well as the opportunity to access content, software, and other services hosted online (Wirtz et al., 2010). This move disrupted traditional business models that associated content and software to medium, as in purchasing a printed newspaper, or a disk to watch a movie or obtain software, towards valuing content and software services as temporal items that can be accessed online. To be able to support income-generation from online content provided 'free', many of the current online business models borrowed the concept of audience labour, as portrayed by Smythe (1981), Schiller (1969) and Mattelart (1996), where the audience is seen as a commodity in itself. Content is provided here in exchange for attention, particularly advertisements aiming to influence purchase (Brynjolfsson and Oh, 2012). This developed greed for user data, aiming to retain their attention by exposing them to advertisements that providers thought would be interesting to users (Gillan, 2010). Developers and content providers usually charge direct payments or, most commonly, run advertisements to generate revenue covering their work and costs in exchange for providing content and services. This shift crowned attention and engagement as the metrics controlling production and distribution of online content (Manzerolle and Wiseman, 2016), and the need for visitor attention created a race between the content the user is looking for and advertisements, sometimes blurring the line between the two (Owens et al., 2011). This race and new attention economy is present across different aspects of online and digital content, from games to news (Nixon, 2017). This model drives the endless need for personal data collection for advertisement purposes (Andrejevic, 2012; Ragnedda, 2011), which in turn creates the challenge of losing control of our personal data (Cleff, 2007), raising privacy and ethical implications (Lyon, 2003). Sir Tim Berners-Lee described this issue as one of three challenges facing the Web in a letter sent on the 28th anniversary of launching their invention, the World Wide Web (Berners-Lee, 2017).

The economy models that rely on advertisement favour users with spending power, portraying classical inequalities on the user side. At the same time, content providers with the ability to monetise and receive payments are favoured in a representation of inequalities on the creator/provider side. Therefore, this economy model tends to exacerbate inequalities, both in the social and the digital realms. This model will still be relevant in the near future, with developers and content providers charging users directly, or running ads to generate revenue in exchange for providing content and services to cover their work and costs. However, this article argues that the advent and acceptance of distributed mining, and the trend towards the re-decentralization of the Internet, allowed room for a different revenue model, a model that works through consensually harnessing the power of user devices to generate value for developers and content providers, following cryptocurrency mining models. This new model, which became renowned with the revolutionary advent of blockchain technologies, challenges the attention economy model by offering an alternative to monetisation in return for computer use.

The advent of models that reward the use of computer power with value lowers the need for personal data collection. While attention economy and privacy issues are far from being solved, we are now entering a new stage of the Internet's development. Regardless of whether this might be seen as a second phase of Web 2.0 or as a new phase of the Internet recently portrayed as Web 3.0, it seems clear that we are now moving towards a more decentralized platform powered by blockchain technologies (Ragnedda and Destefanis 2019). In this new revolutionary context, many features and aspects are changing, including the attention economy and participatory culture that not only enables participation through content, but also through computer power. This third phase of the development of the Internet has the ability to change the power dynamic by emphasising decentralization and reducing online inequalities, at least potentially, as will become clearer throughout the article.

Without overemphasizing the revolutionary potential of this new Internet phase, we will underline how some online service providers might help in overcoming some digital inequalities, criticising this platform's shortcomings, with regards to what the computing resource is used for and lack of consent and control from the user end. The goal of this article is twofold: first to discuss how utilising the mining hype may reduce digital inequalities, and secondly to demonstrate how these services offer a new business model based on value rewarding in exchange for computational power, which would allow more online opportunities for people, and thus reduce digital inequalities. Finally, in addition to these two aims, this contribution discusses and proposes a method for a fair revenue model for content and online service providers that utilises user device computing resources, or computational power, rather than their data and attention. The method is represented by a model that allows for consensual use of user computing resources in exchange for accessing content and using software tools and services, acting essentially as an alternative online business model.

To show how these services may reduce digital inequalities by affecting the three levels of digital divide[1], we need first to introduce the phenomenon of the digital divide, going beyond

[1] Although the different levels of the digital divide may reflect the existence of multiple divides, we refer to them as singular to reiterate how they all are connected and, in effect, demonstrate a division in opportunities regardless of the viewpoint of these opportunities, while appreciating the nuanced approach needed to address it.

the simple binary classification of access vs no access. Once the digital divide's multidimensionality has been introduced, the article will shed light on distributed mining, by discussing how it could potentially help in overcoming several barriers that are at the root of digital inequalities. Then, to study the effect of services that rely on distributed computing and mining on digital inequalities, we will look at three different case studies - Coinhive, Gridcoin, and Cryptotab - that promise to provide value in return for user computing resources. The article will discuss how these services may reduce digital inequalities by affecting the three levels of digital divide, namely access to ICTs (first level), skills and motivations in using ICTs (second level), and capacities in using ICTs to get concrete benefits (third level). Finally, we will suggest a model that allows for consensual use of user computing resources in exchange for accessing content and using software tools and services. We will outline both the benefits and limitations of this model, by analysing the revolutionary aspect of this model, where the user can control when and how many resources mining can run, and for whom, while taking into consideration issues such as privacy and anonymity.

## 2. Digital inequalities in the age of widespread access

One of the main challenges facing humanity in relation to technology, and the Internet in particular, is the digital divide, even when access is widely available. Those excluded from access to the digital world cannot enjoy the benefits that ICTs might offer, including those offered by modern distributed ledger and blockchain technologies. Digital exclusion does not only negatively affect the digital realm, but also influences the social realm, in a kind of vicious circle (Ragnedda and Ruiu, 2020). Indeed, those individuals already suffering from the social consequences of a low position in the social strata are further discriminated against due to lack of access to information and communication technologies. A lack of or limited access to digital technologies, and a lack of or limited capacities and skills necessary to gather benefits from the use of ICTs, contribute towards increasing the risk of social exclusion (Mansell, 2002; Selwyn, 2004). The rise of ICTs privileges those who are already included in the digital realm, further reinforcing inequalities already present in society. (Castells, 2004; DiMaggio and Hargittai, 2001; Norris, 2001)

After an initial euphoria about the equity potentialities of the Internet, it soon became evident that citizens with more resources in terms of skills and social and economic capital would gain greater advantages than others (Castells, 2004; DiMaggio and Hargittai, 2001; Norris, 2001; Rogers, 2003), further reinforcing already existing social inequalities. The possibilities for an individual to access and use ICTs are at the root of the first level of the digital divide. Many features such as age, income, gender, education and employment determine who uses the Internet and who does not (Helsper, 2012; Norris, 2001; Vicente and López, 2011). However, this approach to understanding digital inequalities provides a partial analysis of the phenomenon, because the focus is restricted to structural/infrastructural issues. The digital divide, indeed, should not be seen in black and white terms or as an inclusion/exclusion dichotomy, but in terms of several degrees of e-inclusion (van Dijk, 2005). These different levels of inclusion are based on the opportunities, skills, and motivation that make users' online activities "valuable".

Various dimensions of inequalities exist in the digital realm, based on different access, digital skills, self-confidence and motivation in using ICTs. In this vein, Van Dijk (2005) and later with Van Deursen (2013), underlined several divides, including ICT skills, physical aspects, motivations and purpose of use. All these dimensions constitute the second level of the digital divide, defined as inequalities in using ICTs. Digital skills and digital literacy are crucial to nurturing well-informed citizens, more engaged with the political and cultural environment, but also aware of the economic opportunities offered by ICTs, such as the one offered by blockchain technologies. Users' backgrounds are one of the main components of the second level of the digital divide, since they influence not only the ways people search for information and their motivation to do so, but also the skills they have to elaborate and process them (Lee et al., 2015; Pearce and Rice, 2013; van Deursen and van Dijk, 2015).

Recently, scholars have started to focus on the third level of the digital divide (Ragnedda, 2017; van Deursen and Helsper, 2015), defined as the differences between those who are able or capable of transforming digital benefits and advantages into social ones. The third level of the digital divide is related to the tangible outcomes derived from the use of ICTs, and the Internet in particular. To get the most from the use of the Internet, including the benefits deriving from utilising grid computing to mine cryptocurrency, users need to have already built strong social, economic and cultural capital in the offline world and mastered particulars skills online. This new dimension of the digital divide looks at the intertwined relationships between social and digital inequalities and between offline capitals and digital capital (Ragnedda, Ruiu, Addeo 2019) stressing the idea that those already enjoying a privileged position in society also get the most out of using ICTs. The digital divide is, therefore, a form of social and digital exclusion that depends not only on technological, demographic, and geographical factors, but also on economic, cultural, political, personal, and social circumstances associated with social structure. By consequence, those already disadvantaged are further discriminated against, because they have limitations in accessing (first level), using (second level), and enjoying the social benefits provided by ICTs (third level). More specifically, those who are excluded from the opportunities offered by cryptocurrency are those who have limited economic resources (money), those who have limited physical resources (no access to ICTs) and those who have no digital resources (no hardware). However, being included online, as we have seen, is a fundamental but not sufficient condition to fully exploit the resources offered by blockchain technologies, and cryptocurrency in particular. Indeed, to efficiently manage such technologies, economic resources (economic capital), specific digital skills and digital literacy (cultural capital), and strong motivation (personal capital) are required as well.

The intertwined relationships between the three levels of digital divide and the advancements of new phases in Internet and web technologies could be analysed from different angles and perspectives. We do not claim to give a complete overview of it in this paper, but rather analysing the interaction between the three levels of digital divide and one of the aspects of cryptocurrency: mining. As the next paragraphs will attempt to show, distributed mining can partially overcome some barriers or limitations in accessing some services and content (first level of the digital divide), using (second level) and getting tangible benefits from the use of the Internet (third level). In this way, as we shall try to argue, distributed mining can help in reducing digital gaps.

## 3. Distributed computing

Before delving into how distributed mining may help in reducing digital inequalities, there is a need to introduce the idea of distributed computing. The concept represents the use of multiple machines connected as a pool to cooperate in solving problems as if they were one large machine. This concept is not new, with distributed and grid computing having been around since the early days of computer networks and the Internet, with several large-scale projects relying on people donating computing resources to solve problems that would be infeasible, or very expensive to tackle using conventional computing.

One of the earliest projects to utilise the Internet for large scale grid computing was the Great Internet Mersenne Prime Search (GIMPS), launched in 1996 to discover new Mersenne prime numbers, while one of the largest platforms to date is the Berkeley Open Infrastructure for Network Computing (BOINC), launched in 2002. BOINC provides a platform for various projects, from searching for extra-terrestrial life to climate studies. In 2013, people could gain Gridcoin cryptocurrency as a reward for providing computational power to BOINC projects (https://gridcoin.us/). This concept of utilising grid computing to mine cryptocurrency has been tried in other software programs and websites, however, it has been introduced surreptitiously, as in the case of uTorrent in 2005, when developers including Bitcoin mining scripts, caused user uproar (Estes, 2015).

To be able to participate in these projects, users needed to have access to and control of computing devices and connectivity to the Internet, usually a persistent connection, as well as certain digital skills to be able to run the computational tool. The skills needed could be as simple as visiting the BOINC website, selecting the BOINC project the user wants to support, double-clicking on a downloadable program, and accept to install the computational tool as a screensaver running when the computer is idle. Although a clear effort was made to ensure more basic skills were needed to participate, and to be inclusive in that regard, it still limited participation to people with access to persistent Internet connectivity and electricity, and those who could afford to have their computers consuming electricity when they were not using them. The BOINC project proved to be successful, and after 16 years of existence, the project has 4.5 million users, with 1.125 million active computer hosts connected. However, when we look at the map of active hosts, we see it is in line with the map of Internet affordability as in figure 1 below, showing a relationship between the ability and willingness to participate in scientific distributed computing and the ability to afford Internet access.

Figure 1 about here

The map above shows the relationship between Internet affordability and contribution to BOINC projects combined, covering 86 countries where both data is available. It is noticeable that in most countries on the map, indicated by neutral colors, there is no significant difference, while countries with dark green or dark red display significant differences between the two rankings. Countries in darker green represent countries with lower Internet affordability but who contribute significantly to BOINC projects, in contrast to countries in darker red, which despite having high Internet affordability, do not contribute as much as other countries.

### 3.1 Distributed pool mining

The success of distributed computing paved the way for projects that rely on the idea of utilising user computing resources to create a peer network of knowledge, as in distributed ledger technologies, including the blockchain, where security and trust is inherent from peer validation and contribution. This is evident in the vast majority of cryptocurrencies implementations, where participants providing nodes to the network produce consent on status and transactions, resulting in a peer-based trust model, strengthening that network. In exchange for contributing to strengthening the network, participants are typically awarded amounts of cryptocurrency in return for their work, in a process called mining. Mining helps in resolving proof of work, or other methods that provide confirmation of contribution (Bentov et al., 2014). Mining can be conducted on a single machine, or the load of a single mining job can be distributed over multiple machines in a pool of devices, each contributing its share to the group mining process, in a distributed pool mining routine. The advent of distributed mining, as we anticipate, may reduce some of the digital inequalities deriving from different levels of cultural, social, or economic capitals. Indeed, for instance, these services may shrink the different levels of the digital divide, either by reducing inequalities deriving from different levels of digital skills (by using distributed mining users do not need to be techno-savvy) or inequalities deriving from different levels of economic capital to be invested online (by giving time or CPU space).

With distributed pool mining, the more computing resources individuals contribute, whether through a single machine or a group of machines, the more rewards they receive. This concept of utilising distributed computing to mine cryptocurrency seemed attractive to people with access to large numbers of computers, especially when considering the audience as a source of computing resources. The bundling of mining code within software and websites to run on user devices has been tried in many instances; however, it has been introduced surreptitiously. As in the case mentioned earlier of the popular peer-to-peer Bit Torrent client uTorrent in 2015, when developers concealed Bitcoin mining scripts within one of the application versions, resulting in the application hogging computing resources to run the mining process, causing user uproar and complaints (Estes, 2015). As a result, UTorrent quickly stopped the mining script, and issued an update with the script removed. This practice of concealed use of user computing resources to mine cryptocurrency is often called "cryptojacking" (Newman, 2017). This act soared in 2017, with an increase of 8,500% compared with previous years, according to Symantec's annual Internet Security Threat Report (Symantec, 2018), the report mentions 1.7 million logged instances in December 2017 alone.

However, not all the attempts to utilise user devices' computing resources were concealed under another use. A mobile app named *Prized,* which launched in February 2014; promised users rewards in exchange for using their time spent on the application, and used that time to run mining scripts. The rewards included clothes and gift cards, and the application in return used mobile device computing resources to mine for cryptocurrency. The mobile app was stopped within a year, and the United States Federal Trade Commission charged the developers with injecting malware in the application and "Hijacking consumers' mobile devices with malware to mine cryptocurrency" (FTC, 2015). This case shows that mining scripts included with applications were classified as malware, a distinction that still runs to date, with antivirus software issuing warnings on calls to known pool mining URLs and browser plugins designed to block mining scripts.

This stigmatisation, however, did not stop many websites from following the infatuation of using their audience as providers of computing resources to mine for cryptocurrency, whether obscure or not, starting from shady websites providing access to controversial content, and later moving to mainstream websites. One of the recent interesting cases where Salon.com, a news and opinion website that started offering users the option to either view ads (content in exchange for attention) or contribute with their device computing resource in exchange for accessing the site and viewing its content (content in exchange for machine power). A popup appears once you enter the site with a tool to block advertisements, or adblocker, turned on, prompting you that in order to access the site, you need to either turn off adblocking, or supress ads by contributing computer power. If the user chooses the latter option, they are introduced to another popup asking for their opt-in, which stays valid for 24 hours, in addition, mining stops once the website tab or browser is closed. In some way, by agreeing to contribute computer power, users get a sort of "premium version" without ads and without paying a subscription. According to Salon's website:

> *"We realize that specific technological developments now mean that it is not merely the reader's eyeballs that have value to our site — it's also your computer's ability to make calculations, too. Indeed, your computer itself can help support our ability to pay our editors and journalists." (Salon, 2017).*

This adds something new to the user's attention economy: indeed, users can either decide to give their attention by being exposed to adverts or give their computer power by allowing computer mining. By paraphrasing Smythe (1981), we can say that computer power becomes a commodity itself. This might be read as another sign of the new phase of the Internet that we are entering.

Until recently, significant programming skills were needed to include mining capabilities within applications and services, but the introduction of services like Coinhive in September 2017, which Salon.com is using, significantly lowered the skills required, and helped to explode the popularity of browser-based cryptocurrency mining. CoinHive acts as a broker that provides easy to embed script-based “cryptominers”, managing the process from mining to paying out to developers. All a developer needs to do is to sign up to the service, copy a piece of code, and include it in their online service or website, and then the script will run on users' machines as they visit the developer's website or run their service.

Mining scripts, including those of Coinhive, are being treated as malware, and modern browsers started to include capabilities to detect and stop it, but most of these techniques rely on the blacklisting of leading cryptojacking script links. As is the case with Firefox, who introduced a level of blocking as part of its tracking protection feature and is now exploring the possibility of introducing an explicit feature for cryptojacking. Similarly, Google banned mining extensions, whether explicit or implicit, from being offered through their Chrome web store (Cimpanu, 2018). This ban, however, does not appear to affect dedicated mining extensions available at the store yet and Google announced they might be removed beginning in July 2018, the mining extension was replaced by extensions that entice people to move to browsers that maintain the mining function, or extensions that display cryptocurrency prices. One of these extensions is Cryptotab, which we will discuss later.

Table 1 about here

Table 1 summarises the advantages and disadvantages of distributed pool mining as perceived from both of the use and content provider aspects, one of the disadvantages at the user side is that utilising their computing resources to run mining scripts could result in slowing down of the machine, affecting their usage experience. To test this, we have conducted a small experiment on Coinhive scripts to record the utilisation of computing resources at different settings. The results, as in figure 2 below, show how with two threads of mining running at 100% of computing resources, the computer was operating at full capacity, and there was apparent performance limitation, while with less aggressive settings, the computer was apt to allow other applications to run without much performance impairment.

Figure 2 about here

Furthermore, to test the effect of running mining scripts on computer usage experience, we conducted a small experiment with 10 participants, on computers with different performance levels, and different usage patterns. We sent our participants a link to a page with a mining script, set to use two threads of computing, at 80% of available computing resources, and asked them to keep it running for a whole workday as they conducted their regular work. One of the participants reported that their browser kept crashing every time they ran the script, while another reported that they observed a significant difference in performance that prevented them from effectively conducting their work. The rest of the participants, however, did not notice any significant difference. The results of these two tests indicate the possibility of utilising machine power to a certain extent without interrupting regular computer use or users' experience, by relying solely on discretionary computing power. Nonetheless, it is worth mentioning that for such monetisation to be profitable, it needs to run on a large number of hosts, for our tests, the yield was marginal at an equivalent of $0.002 at the time.

The results of the non-representative experiments described earlier are in line with what other researchers have found, in that the desktop and browser-based distributed pool mining does not cripple machine usability, but also produce thin outcomes compared to what is advertised. Venskutonis, Hao, and Collison (2019), for instance, concluded that browser mining currently generates revenue at a rate 46 times less than what is advertised, however, they find browser mining to have a good potential as an alternative for advertisement, especially that over 60% of their research participants would select browser mining over advertisement if they were invested in the ecosystem by obtaining half of the mined cryptocurrency.

## 4. Effect on Digital Inequalities, case review

### 4.1 Case Selection and Analysis

There are vast applications of distributed computing available that differ in goals, methods, scales, and availability. Some of the distributed computing applications are confined within strict structures, as with applying the concept of distributed computing within a data centre or a closed group of computing resources, however, we are interested in the applications available to the public and promise return, in a form or another, in exchange of utilising computing resources at the end-node. To unpack the implications of current services that rely on distributed computing and mining on digital inequalities, we analysed three different platforms and services representing three different models that promise to provide value in return for user computing resources. For each of the possible models, we have chosen a service that, so far, is the most widely used and known example. To discuss their implications for digital inequalities, we analysed how these services work for both ends, developers and content providers, and users. The idea is to focus on the inequalities these services cover or touch, by comparing and contrasting these three different platforms against the three levels of digital divide. More specifically, we looked at three cases selected to reflect different applications for distributed computing based on their popularity and transparency to allow for the needed scrutiny to take place.

Our first case study is Coinhive, a service that allows website providers and content developers to rely on user computing resources to mine for cryptocurrency. The second model is Cryptotab, a tool that lowers the requirements for users' distributed mining. Finally, the third model is Gridcoin, a service related to incentives in the form of cryptocurrency, provided to users contributing computing resources to distributed scientific research computations. The first two services are rather new and may not be as mature as the third one but are nonetheless gaining momentum and are establishing their grounds among users. Most importantly, they offer practical implementations for conceptual models that can be interpreted as attempts to rebalance power distribution, by giving users the tools needed to utilise their computing powers for direct value.

### 4.2 Coinhive

The first case study analysed here is Coinhive. This service manages the pool-mining process of cryptocurrency, namely Monero (Coded as XMR), and provides multiple ways for utilising user's computers to mine for cryptocurrency and was one of the first publicly available programming interfaces for cryptocurrency pool mining (Carlin et al, 2019). The main method offered is an easily customised code to be embedded in websites, as well as a dashboard allowing easy tracking of accumulated hashing power and amount of rewarded coins. Coinhive advertises that there are several ways for monetisation using their service. The first and the most common method is through embedding a mining script in websites that run as long as the user keeps the browser or browser tab open, or in other words, while the user is reading or viewing the content. Other methods include running script on page redirectors, which is usually a few seconds of waiting added to show a notification that the user is being redirected to a different domain, and with Coinhive, this time can be used to generate hashes.

When Coinhive was first launched, sites could start mining scripts automatically without any need for user consent or opt-in. However, browsers, antivirus software, and browser plugins, such as AdBlock, started blocking mining through blocking access to mining URLs. This changed with Coinhive introducing Authedmine, a service from Coinhive that aims at fixing the stigma of illicit mining. Authedmine requires consent from surfers before using their machine to mine for cryptocurrency. Especially after Coinhive old scripts and URLs became blacklisted and an easy target for advertisement blocking plugins and anti-malware tools. The default code provided by Coinhive now uses Authedmine, which is not blacklisted, and requires users to approve running the mining code, by either clicking on an icon, or approving through a message box.

CoinHive service proved to be very popular, with Eskandari et al (2018) estimating 3% of the top 1 million websites on ZMap to be running CoinHive and another 0.26% sites running other miner families. The popularity was largely affected after antiviruses started blocking CoinHive, with only 60 sites running AuthedMine one month after its release. This shows that website developers found it easy to inject their sites with permission-less mining code, but authenticated mining proved to be less appealing to them, thus, despite this effort to obtain user consent, many websites and services still perform illicit mining, either through Coinhive code that does not use Authedmine, or through tricking users into accepting the mining by obfuscating the Authedmine consent process under messages that may sound non-intrusive to users. The obfuscation requires advanced skills on the developers' side, making the process of successful illicit mining harder. But several tools emerged that promise to make it easy to include Coinhive mining, including obfuscated Authedmine, into websites and services, including plugins for one of the most common platforms and Content Management Systems, like Wordpress.

Coinhive is not the only provider of script mining services. Many other providers emerged, some count on the blacklisting of Coinhive mining URLs to attract miners looking for alternatives, resulting in an increase in other platforms with a similar offering, making it harder for browsers and antivirus software programs to detect illicit mining. Detecting illicit mining imposed itself strangely at the development roadmap of Firefox browser as part of the tracking protection (Lestoc, 2018) as well as other browsers and antivirus software. This service helped in repositioning power relationships between site visitors and content providers, through changing the commodity content providers are expecting from visitors, from attention and interaction with advertisements, into computing resources and time. In relation to digital divide, we can argue that Coinhive positively affects the digital divide at all its three levels.

As we have seen, the first level of the digital divide is mainly related to access to Internet and digital content. In this way, we may claim that Coinhive may offer users the possibility of accessing content they would not be able to access otherwise. Evidently, users first need to access the Internet, but thanks to this service they can access further digital content and, thus, it may be considered a sort of access allowance, viewed as reducing the first level of the digital divide. The second level of the digital divide is mainly related to Internet usage and digital skills. In this way, by lowering the skills needed to make use of the Internet more satisfactorily, Coinhive is targeting the second level of the digital divide, making it possible for more and more users to surf the Internet more efficiently. Finally, Coinhive provides the opportunity for people to monetise their content and services, and thus increase the financial outcomes they obtain as tangible outcomes of their Internet use, thus contributing to lowering the third level of the digital divide. In summary, we may argue that this service reduces the three levels of the digital divide and, consequently, affects both digital and social inequalities.

### 4.3 Cryptotab

Traditionally, to conduct blockchain mining, users had to install tools on their devices, usually in the form of a wallet application, generate a cryptocurrency address and either operate mining as a full node, which requires maintaining a copy of the whole blockchain on their devices. Alternatively, users can join a mining pool, which lowers the skills and resources needed to just conduct calculations on the device and send results to the pool controller. The success of the concept of running mining scripts through browsers triggered the launch of several services to develop tools, browser plugins, and even browsers that would make it easier to join the mining forces. This approach worked technically in a manner similar to that of Coinhive, except that the user would run mining on their machines rather than websites running mining scripts on visitors' machines, and thus, users do not have to host their websites or develop their own content.

Running these local pool mining tools allowed users to monetise from computer power through distributed pool mining without installing any software other than a browser plugin. Cryptotab, started as a browser plugin, and then a standalone browser following restrictions on the plugin from main browser families. Cryptotab is one of the tools that offer pool mining without installation of complex tools for mining, and also runs a pyramid scheme where the user gets a share of the mining results of their referrals, promising revenues higher than one Bitcoin (BTC) every month, which is valued at over $6,000 as of April 2020. However, the calculator on their website suggests that to achieve that, a user will need to recruit five friends, and each of these recruit five others, and so on until there are nine levels of referrals. Numbers that are more realistic show that if the user recruited only five first level referrals, they would earn only an estimated $3.

These services made it easier for people to monetise directly from computing resources they have access to, adding another tangible outcome of being connected to the Internet and this contributed to shrinking the third level of the digital divide, by allowing users to reap economic benefits of Internet use that they may have not been able to otherwise. A big difference between the Cryptotab and Coinhive approaches is the level of control the end user has on how much computing resource and time is dedicated to the mining process. In addition to that, it is not as easy to run mining illicitly under Cryptotab.

In sum, Cryptotab helps in reducing two out of three levels of the digital divide. This model does not offer users an additional opportunity to access content they would not be able to access otherwise, as such we cannot claim that it offers any help in bridging the first level of the digital divide. However, by lowering the skills needed to make the use of the Internet more satisfactory, and by providing tangible opportunities for people to monetise from their content and services, Cryptotab contributes to lowering the second and third levels of the digital divide.

### 4.4 Gridcoin

Years before the introduction of Coinhive, and as part of the BOINC platform, users contributing computing resources to help solve scientific computational problems had the opportunity to be rewarded an amount of a cryptocurrency, dubbed Gridcoin. This cryptocurrency, launched in 2013, is similar to Bitcoin in that it is cryptocurrency, or a commodity that is based on a blockchain. However, it differs in that in addition to using computational power to secure the network, or blockchain, and creating more of its currency units through the Proof-of-Work algorithms, Gridcoin uses a combination of the energy efficient Proof-of-Stake, and their unique Proof-of-Research algorithm. The Proof-of-Stake algorithm allows its network to be secured through having more nodes online, and in exchange new coins are created by adding an interest rate to currency units. While the Proof-of-Research algorithm functions as a proof of computational power donated to scientific research, it also adds interest to currency to produce Gridcoins as a reward, and thus can be considered a form of mining.

This process of using computational power for scientific research adds a use other than creating currency to the process of 'mining' and energy invested. Helping in research projects varies from searching for alien life, fighting malaria and cancer, to helping with other projects under the BOINC platform. One of the main projects under BOINC platform, SETI@Home, announced on the 2nd of March 2020 that it is going to hibernation, after running for 21 year, effectively stopping all distributed computing, because they have analysed all the data needed at the moment, pointing to success of the project distributed model.

So far, to be able to participate in this project, users need to install a specific application that allows them to select the project they would like to donate computational power to. To begin earning Gridcoins in return for computing power provided, or crunching as they call it, you need to opt in and agree to join the Gridcoin team of the BOINC project of choice, and then install the Gridcoin client and wallet.

Although BOINC and Gridcoin do not allow users access to content and services they may not be able to obtain otherwise, they still offer the opportunity to monetise idle computing resources in exchange for a contribution to scientific research, and the satisfaction of contributing to a greater good. The monetisation can be considered a tool to increase the outcomes of being online, and in a manner similar to that of Coinhive-like implementations, contributes to bridging the third level of the digital divide.

Therefore, Gridcoin helps in reducing only one out of three levels of the digital divide. Unlike the first model, this model does not offer users any additional opportunities to access content or services they would not be able to access otherwise and unlike the first two models, does not lower the digital skills needed to monetise computing resources, as a significant level of skill is required to start crunching and receiving Gridcoins. However, by improving the opportunities for users regardless of their economic capital, Gridcoin helps in increasing the tangible outcomes of their Internet use as per the third level of the digital divide through gaining economic benefits. Gridcoin contributes, although slightly, to lowering the third level of the digital divide, but its clear advantage is that the computing resources are used towards solving scientific problems and research.

## 5. Conclusions and a Suggested Model

Allowing users to convert their devices' computational power into value, whether through access to services or content, or receiving cryptocurrency and payments in return for providing services or content, or direct computational powers, contributes to bridging digital divides, even at fairly small levels. Indeed, while comparing and contrasting three different models related to distributed mining, we have noticed how, in the case of Coinhive, access is made available to content and services that may have not been available otherwise, covering a less-studied aspect of the first level of the digital divide, meaningful access. On top of this, both Coinhive and Cryptotab contribute to significantly lowering the skills needed to utilise device computational power for both content and service developers, and end users, thus contributing to reducing the second level of the digital divide.

Finally, we have seen how in all the three case studies here analysed, users might generate value from using the Internet, touching on the tangible outcomes of Internet use, thus lowering the third level of the digital divide. All of the three models shared the concept of utilising end users' device computational power to generate value, whether for the users themselves in terms of cryptocurrency or access to content and services, or value for developers in return for providing content and services. They are, however, not flawless, and have been stigmatised as illicit mining and hijacking of computational power to mine cryptocurrency, or cryptojacking. This is demonstrated in the difference in the level of control these models allowed for at the end user side, in terms of options related to when to run mining, and in deciding the amount of computational power, aggressiveness of mining, or value of it, they opt to provide.

Secondly, we reiterate that the advent of blockchain technologies is shifting power relations between end users and content developers and service providers and is a necessity for a decentralization of Internet and Internet services. Furthermore, as we have seen, these new technologies are introducing a more accessible Internet, particularly for digitally deprived individuals, through fairer revenue models for content and online service providers. Models that utilise user device computing resources rather than their information, data and attention, have been looming on both user and provider sides, we have suggested a model that would aggregate benefits from various models, while mitigating the disadvantages of resource hijacking and lack of consent, which we see as beneficial for the future of the Internet.

Based on the above discussion, we suggest a model that would enable access and value for users, while maintaining full control of their computational resources. This model allows for consensual use of user computing resources in exchange for accessing content and using software tools and services, where the user can control when and how much resources mining can run, and for whom. This can be done in the form of a browser plugin or desktop application, where content developers and site owners request a certain value in exchange for content access or service provided, and users decide whether to accept this offer or not. Either through computational power for mining represented by the number of hashes solved as a form of payment, with users deciding the level of aggressiveness of the mining process, or pay through transferring equivalent value in the form of cryptocurrency credit, which may be obtained through running and directly providing computing resources.

User here would also have the choice to decide whether computing resources are used for cryptocurrency mining or supporting scientific research, or for any process that may be of value and requires high computational powers, like machine learning model training. This model helps in providing the end user with control over what value to give in return for content and services, and thus assures consent and fairness in the relationship between developers and users. Nonetheless, it is worth mentioning that this model, particularly when users opt to pay in the form of cryptocurrency credit, does not assure the anonymity of users, as the transaction would need to go through third parties, thus may be traced back to the user. This model is also linked to the market value of cryptocurrency, and as a result, mining and how attractive it is, particularly to content developers and service providers, in comparison to revenue expected through advertisement. Another aspect would be how this model favours users with high computational resources. Although some forms of social inequalities, such as the absence of a strong economic capital to be invested online, could be reduced by the advent and promotion of these models, social inequalities are still a condition in this model, since economic capital is still required to access ICTs and to possess hardware for high computational resources.

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# Tables and Figures


*Figure 1: Difference in Rankings, White: No data, Medium range: no significant difference, Light: BOINC contribution ranking is much higher than Internet affordability ranking, Dark: Internet Affordability ranking is much higher than BOINC contribution ranking*

| | **Users** | **Content Providers/Site Operators** |
|---|---|---|
| **Advantages** | Provide opportunity to access more content and services.<br><br>Potentially provides less privacy intrusive experience by lessening dependence on advertisements. | Provide monetisation opportunities.<br><br>Allow access to return to content and service wherever traditional methods are not available.<br><br>Lower level of skills needed to implement cryptocurrency mining. |
| **Disadvantages** | Require discretionary computing resources.<br><br>Current models may pose the possibility of cryptojacking, or mining with no consent. | Does not provide access to full amounts generated, a percentage is paid for the platform.<br><br>Users with limited computing resources provide marginal return. |

*Table 1: Advantages and Disadvantages of distributed pool mining*

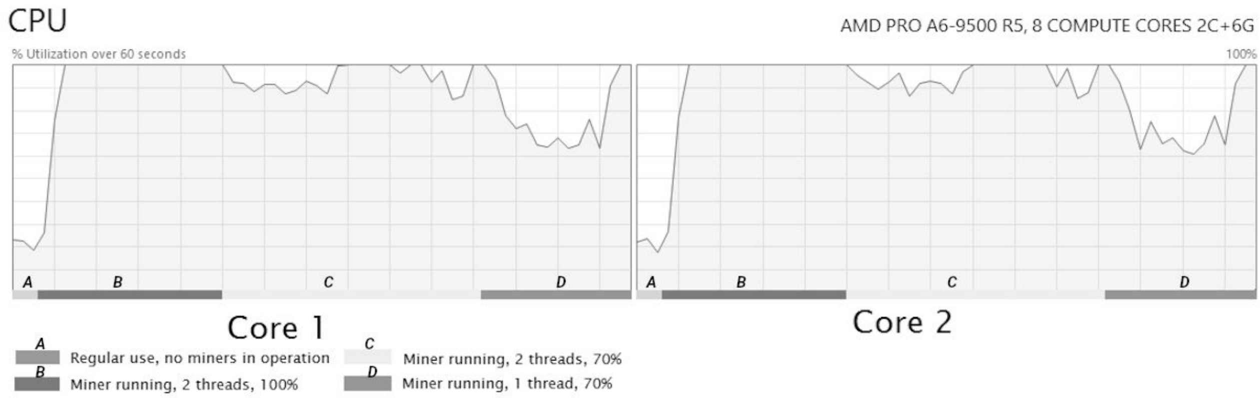


*Figure 2 CPU usage with different settings of cryptocurrency mining script*