December 8th, 2020

Cryptocurrency Mining on Blockchain Networks

Introduction

While the term “mining” typically conjures images of people in hard-hats sifting through rock deposits to extract commodities and precious metals, it takes on somewhat of a different meaning in the context of decentralized blockchain networks and cryptocurrency. The purpose of this report is to provide insight into the fundamentals of blockchain mining (with examples particularly pertinent to Bitcoin’s blockchain network), as well as highlight some established and emerging players in the space.

Mining Fundamentals

Overview

In the context of blockchain networks, mining explicitly refers to the process of continuously adding transaction records to a publicly-available ledger (i.e., a blockchain) which is native to a specific network. In turn, this ledger provides validation to the network concerning the legitimacy and integrity of this transaction’s occurrence on the network, which permits network nodes to reach consensus about these transactions. Moreover, mining is also used to introduce network cryptocurrency into the system, as miners are rewarded fees for their efforts in the form of a portion of newly created cryptocurrency, which effectively results in an influx of this cryptocurrency to circulate in the network.

The essential, primary purpose of mining is to record network transactions in such a way that modifications by any single entity are computationally infeasible based on the required scale of computing operations and capacity. A central aspect of miners’ function in this regard is preventing

the classic double-spend problem: a situation wherein a cryptocurrency owner illicitly spends the same, duplicated cryptocurrency for two disparate transactions.

The Computational Problem

The mining process, specifically in Proof-of-Work (PoW) consensus implementations, is designed to be inherently difficult and resource-intensive in order to keep the number of blocks found by miners over a given period of time relatively constant.

From a basic technical standpoint, the intrinsic difficulty in mining stems from the fact that the hash (i.e., a unique numeric value of fixed length that uniquely identifies data) of a given block's (i.e. a set of transaction(s) on a given network) header is required to be less than or equal to a specific target value in order for this given block to be validated by the network. The lower this target value is, the more difficult it is to find a suitable hash that fits the constraint. In order to maximize their individual probability of arriving at a hash that satisfies the target constraint, miners must make a substantial amount of rapid attempts at essentially guessing different hashes. This substantial, rapid guessing process requires an enormous amount of computing operations and power, as has come to be associated with mining cryptocurrencies like Bitcoin.

Difficulty Level

The exact amount of difficulty associated with mining at any given time is represented by the difficulty level: this metric represents the level of difficulty in finding a new block compared to the easiest level that it was at any point in time. In the case of Bitcoin, this metric is recalculated every 2016 blocks in such a way that the previous 2016 blocks would have been generated in precisely two weeks had everyone been mining at the given difficulty level. At the time of writing, the difficulty level of the most recent block is approximately 18,000,000,000,000 (trillion), which implies that the chance of producing a hash below the target on any given attempt is about 1/18,000,000,000,000. As alluded to earlier, extremely rapid hash guessing coupled with working in "pools" (see *Mining Techniques*), increases these odds considerably.

As the number of miners participating in the network increases, the rate of block creation increases as well. In turn, the difficulty level rises to compensate. On a net basis, this process is designed so that the average time it takes for a block to be validated (i.e., block time) is roughly 10 minutes.

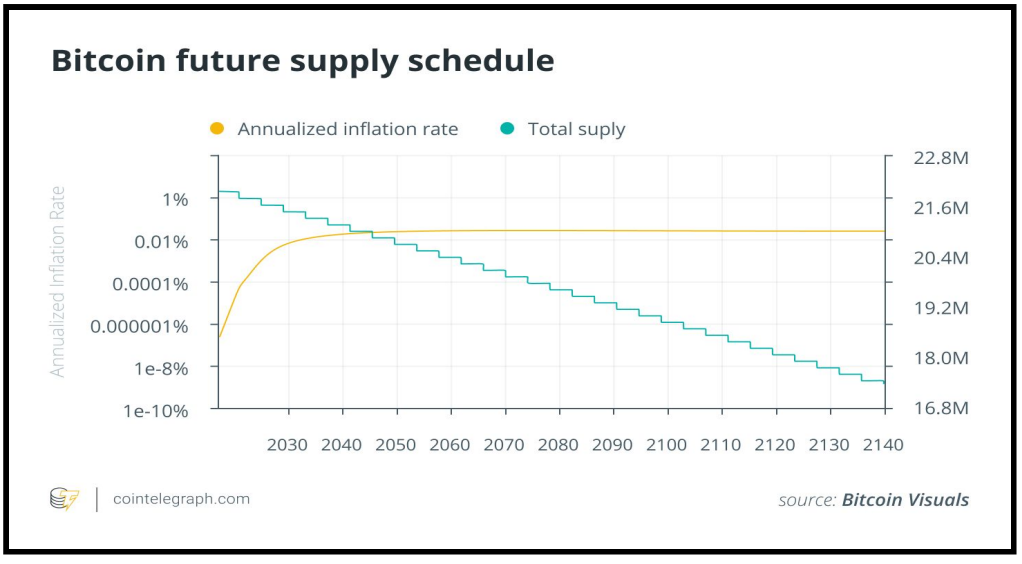
Reward

In exchange for successfully validating a block (i.e., 1 MB worth of Bitcoin transactions), eligible miners are awarded a network-specific amount of

cryptocurrency for their efforts. Note that not all miners working on a given block receive this cryptocurrency "reward": you have to both verify the transaction and be the first to solve the previously described Proof-of-Work problem (see *The Computational Problem* above). In the event where multiple miners verify the transaction and solve the Proof-of-Work problem simultaneously, the Bitcoin network decides which miner to honor via simple majority (i.e., 51%); the winner is typically the miner who has historically verified the most transactions in this case.

It's worth noting that, in addition to validating transactions on the network, mining also serves as the mechanism by which new Bitcoin (and cryptocurrency more generally) is introduced into circulation. For Bitcoin, the reward is designed to halve every 210,000 blocks (i.e., currently an average of every four years), with the current reward standing at 6.25 BTC. This halving mechanism for the mining reward ensures that there is an adequately controlled supply of Bitcoin so as to not exceed slightly less than 21,000,000 circulating units.

In addition, miners are awarded the fees that are paid by users in initiating transactions. This fee serves as an incentive for miners to include the specified transactions in their block. In the future, these fees will comprise a much more significant portion of mining income as the amount of new bitcoins that miners are able to create in each block drops off. By approximately 2140, all Bitcoin will have been circulated and miners will be entirely compensated for their efforts in validating network transactions through user transaction fees.



Risks

The first key risk associated with mining is that of financial risk: as alluded to previously, one could invest thousands of dollars worth of equipment only to have no return on their investment, given that their individual hash

power represents an infinitesimal amount of the network's total. Note that this risk can be mitigated through miners' participation in mining pools (see *Mining Techniques* below).

The second key risk stems from the legality of cryptocurrency mining across geographical jurisdictions. Fundamentally, cryptocurrencies such as Bitcoin are largely perceived to threaten the dominance of fiat currencies and government regulation of financial markets. Accordingly, though predominantly legal, there are numerous geographical jurisdictions in which Bitcoin and associated mining are illegal, including: Algeria, Pakistan, Egypt, Nepal, Bolivia, and Ecuador.

Mining Versus Staking

While somewhat similar, it's important to draw the fundamental distinction between mining and a concept known as staking.

Staking is a concept under the Proof-of-Stake (PoS) consensus mechanism in which participants pool their cryptocurrency (i.e., stakes) in a wallet for a certain period of time, delegating it to a specific pool's staking balance. The underlying network selects a predetermined quantity of staking pools as a function of the size of their staking balances, and allows these selected pools to effectively act as miners to validate network transactions for a reward. In turn, the rewards generated by a pool are disbursed among its delegators in proportion to their respective stakes.

Unlike mining, staking demands significantly less computing power in the form of only stable, fast internet for validating network transactions in a relatively short time span (i.e., which can be as short as seconds). In this way, staking is considered much more energy-efficient than mining, which has spurred many altcoins to utilize staking as a result. Moreover, this eliminates the need for costly hardware like ASICs, FPGAs, or high-end GPUs as in the case of mining (see *Mining Techniques* below). Additional advantages of staking relative to mining include:

- Generally less technical competence required to participate
- Greater price stability in coin prices due to user incentive to hold staking coins
- Stake growth, reward increases, and consequent price escalation causes wallet value to appreciate

That being said, staking does come with some downsides relative to mining as well. These include:

- Staked cryptocurrency is automatically locked for a period of time without the option to sell
- Staking can lead to centralization where large actors dominate networks by accumulating relatively massive stakes

Mining Techniques

Perhaps one of the most important considerations for miners is the computational technique they use in the mining process. While there are many variations, the most significant implementations have historically included some that are described as follows.

CPU Mining

This was the first implementation of mining that enabled miners to use their computers' central processing units (i.e., CPUs) to mine cryptocurrency. Note that a CPU is the part of the computer that provides the computing power for the proper execution of operations performed by the software installed on a given computer. CPUs are inherently designed such that they are suitable for rapidly switching between different tasks, and also follow logic-based instructions for algorithm execution via arithmetic logic units (i.e., ALUs).

However, it's worth noting that the hashing required for mining in a Proof-of-Work system (i.e., like those employed by Bitcoin) requires a large amount of repetitive mathematical calculations; a relatively weaker point for CPUs given that they have a greater focus on rapid-task switching and fewer ALUs to carry out these repetitive calculations relative to other implementations, therefore being relatively slower in this regard. For this reason, CPU mining tends to be more profitable for earlier-stage, low hash rate networks but has lost its use case in more established, higher hash rate networks (e.g., Bitcoin).

GPU Mining

Note that "GPU" refers to a Graphics Processing Unit, or the chip on a computer's graphics card that does repetitive calculations associated with rendering and processing graphics. Prior to mining, their most popular use case was for providing smooth renderings of animation and video for gaming purposes. Designed by companies such as Nvidia and AMD for better graphics, GPUs have observed a spike in demand over the last few years particularly for mining Ethereum, in turn resulting in a massive shortage of gaming graphics cards and an accompanying price increase in high-end GPUs.

Note that video processing is inherently extremely repetitive work (i.e., rendering constant results for large groups of on-screen pixels) as opposed to rapid-task switching work (i.e., as with CPUs), and that GPUs have significantly more ALUs than CPUs do. As a result, GPUs can perform a high number of repetitive calculations associated with mining with considerably greater quantity and efficiency in comparison to CPUs. GPUs' relative dominance to CPUs in this regard rendered the former relatively obsolete for more established, larger networks, though GPUs themselves

have seen a decline in use with the advent of ASIC chip implementations for cryptocurrency mining (see below).

ASIC Mining

Note that "ASIC" stands for an "application-specific integrated circuit". In relation to cryptocurrency, ASICs are microchips that are specifically designed to perform a hashing algorithm for Proof-of-Work mining as quickly as possible. To give an idea of the relative performance of ASICs in relation to CPUs, note that a Bitcoin ASIC can calculate hashes at a rate 100,000x faster than the best CPU.

Given that ASICs are custom built for a single hash algorithm, you would need to buy different ASICs for each coin that you'd intend to mine. Due to the custom and niche-specific nature of ASIC applications, a single powerful ASIC chip with high-end hash power could cost thousands of dollars. Prominent ASIC design companies in the cryptocurrency mining space include Bitmain, Canaan, MicroBT, and Ebang.

It's worth noting that due to the intense hashing characteristic of ASICs (i.e., performing trillions of hashes per second), such implementations emit significant sound and heat, and require fans for adequate cooling. They also consume tremendous amounts of electricity and by extension incur significant electricity costs, so miners typically look to set up these ASIC-based mining operations in countries with cheap electricity as well as cooler environments to reduce associated cooling costs.

The costs and logistics associated with ASIC mining tend to invariably lead to large, powerful mining operations (i.e., "farms") usurping a significant portion of a network's hash rate, somewhat countering the notion of a decentralized network ecosystem and potentially leading to suboptimal network outcomes (e.g., 51% attacks).

Some cryptocurrencies market themselves as ASIC-resistant, using hashing algorithms for mining that require more memory, thereby making the size and cost of ASIC hardware implementation considerably more expensive and lowering miners' incentives to use them as their mining implementation. The chief purpose behind this is often to preserve network democratization by ensuring that ASIC implementations do not incur a massive advantage over GPU or CPU mining. In this same vein, some networks have also promised to hard fork in the event that ASICs are developed and dominate their hash rates.

FPGA mining

The term "FPGA" stands for "Field Programmable Gate Array", and refers to a chip that can be reprogrammed after it has been shipped to a user in the real world (i.e., hence "Field Programmable"). This lack of built-in programming during production means that it can be programmed for

use in a wide spectrum of industries, such as aerospace, high-performance computing, medicine, and more. This is in contrast to ASICs, whose function is fixed after it has been manufactured and is non-reconfigurable thereafter.

FPGAs did not pick up use in cryptocurrency mining until only a few years ago due to high price/scarcity, difficulty in configuration (as it far exceeds the programming skills of the average cryptocurrency mining enthusiast), and due to the rise of ASICs. In essence, despite its lack of mainstream popularity, FPGAs offer the "best of both worlds" in terms of combining the power of the ASICs with the flexibility of GPUs. However, as previously alluded to, it lacks in relation to these alternatives in price, availability, and user-friendliness. A comparison as such is depicted for reference in the table below.

Type of hardware	Power	Adaptability	Price	Availability	User friendly
ASIC	✓			✓	✓
GPU		✓	✓	✓	✓
FPGA	✓	✓			

It's worth noting that there are companies composed of programmers and cryptocurrency enthusiasts that work specifically on the software required for FPGA mining provided that consumers provide the hardware from third party suppliers (e.g., Xilinx VU9P FPGA boards, etc.), as described below under *Mining-Related Companies*.

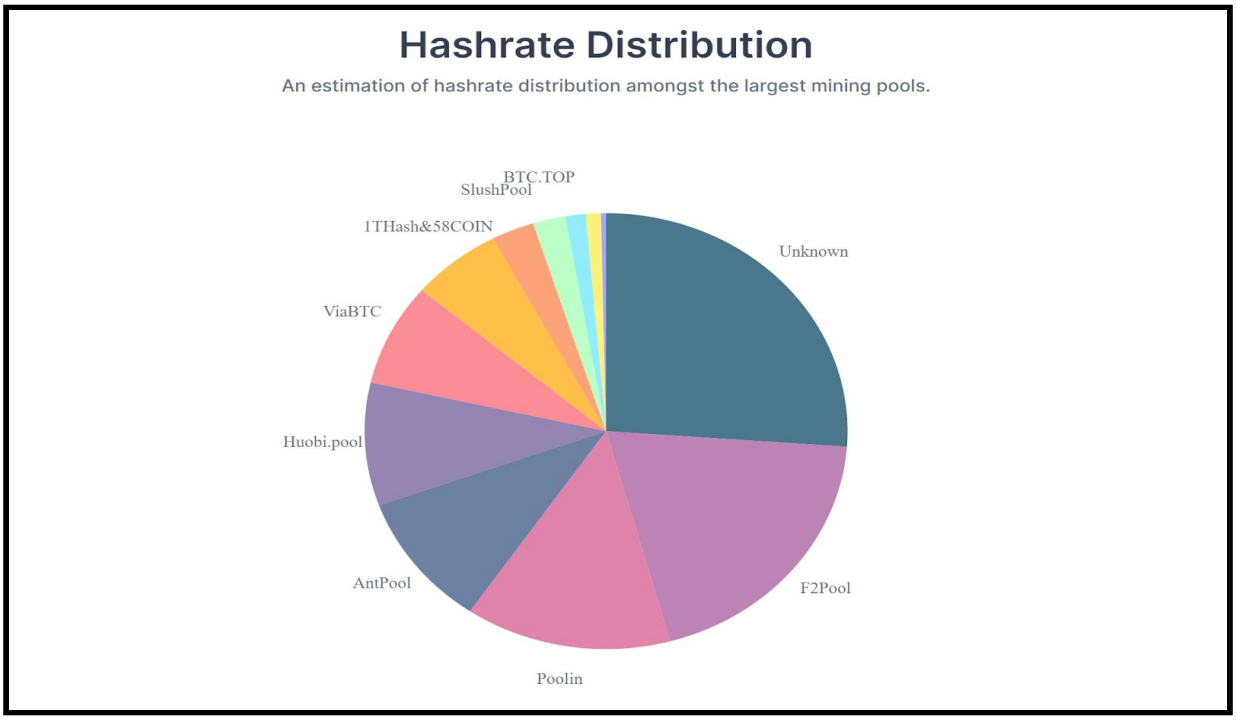
Mining Pools

Recall that mining rewards are issued to the miner that verifies the transaction and solves the Proof-of-Work problem first. The probability that a miner will be the one to earn a block reward in this regard is equivalent to their mining power divided by the total mining power on the network. Consequently, miners with a very limited proportion of the total mining power have a very low probability of discovering a given block on their own.

For example, consider a mining card that one could purchase for a few thousand dollars that would equate to less than 0.001% of a network's total mining power. With such a small proportion of mining power, it could take quite a while before this miner individually discovers a block, which is only compounded by the fact that the mining difficulty is increasing over time. In fact, there is a chance that the miner may never recoup their investment.

Mining pools were created to address this issue. In essence, mining pools are coordinated groups of miners operated by third parties that combine their individual mining powers to form a single entity with significant mining power, thereby increasing their cumulative chance of discovering blocks. In turn, block rewards from successfully discovered blocks are shared and paid out among all of the pool's participants in proportion to their individual mining power contributions. This allows miners to receive a steady flow of Bitcoin starting essentially the day they begin mining in the pool. Within this technique, there are many subsets that offer different share and payout schemes (e.g., pay-per-share, pay-per-last-N-shares, solo mining pool, peer-to-peer mining pool, geometric/double geometric mining pool, etc.).

Some of the largest mining pools in the world currently are depicted in the pie graph as follows: F2Pool (116 mined blocks over the last four days), Poolin (82), AntPool (59), Huobi.pool (54), ViaBTC (45), and more.



Cloud Mining*

Cloud mining involves mining cryptocurrency via rented cloud computing power (i.e., computing power relayed through the internet). This is juxtaposed against traditional mining mechanisms in which software has to be run directly on associated, specifically installed hardware.

Cloud mining companies enable consumers to easily and remotely participate in the mining process for minimal cost, knowledge requirement, and hardware infrastructure setup. This in turn adds to

networks' objectives through making mining accessible to a broader scope of participants. Moreover, mining-specific energy costs and mining equipment maintenance fees are reduced considerably in this implementation.

Effectively, cloud miners become participants in a mining pool wherein they purchase a certain amount of hash power. In exchange for their hash power, cloud miners earn a share of the profits proportionate to the amount of hash power rented.

There are a couple predominant forms of cloud mining that are worth noting. For instance, hosted mining is the most popular form of cloud mining and involves customer purchases/leases of mining hardware from a miner's facility. The miner takes on the responsibility of maintaining the equipment and ensuring that it functions in the proper manner. Customers have direct control over their cryptocurrency in hosted mining, and economies of scale associated with mining ensure that associated costs (e.g., electricity, storage, etc.) become increasingly affordable. That being said, there is a significant fixed upfront cost associated with the initial setup of this type of mining.

Another popular form of cloud mining is leashed hash power, wherein computing power that is associated with cryptocurrency (i.e., hash power), is leased from a mining farm. Customers in turn receive a share of the mining farm's total mining profits. This form of cloud mining is particularly popular for altcoins, and requires those looking to participate to open an account with a cloud mining company online and choose certain desired attributes (e.g., contract period, desired hashing power, etc.).

While there are certainly many advantages to cloud computing as discussed previously, there are also some disadvantages worth noting. First, the cryptocurrencies that are particularly popular among cloud miners - altcoins - are particularly sensitive to demand. A reduction in their hash power could then easily and rapidly lead to diminishing profits for miners. Second, given the increasing popularity of cryptocurrencies, industry scams centered around cloud computing have rapidly come into existence (see *Disclosure**). Lastly, cloud mining inherently promotes the consolidation of mining power and thereby the centralization of cryptocurrencies/blockchain networks, which is in fundamental opposition to their key technological objectives.

Mining-Related Companies

There are a slew of both established and emerging companies that operate within the mining segment of the cryptocurrency/blockchain industry. Some of these players are described as follows.

Genesis Mining

Genesis mining is among the largest mining companies that focus on providing services for cloud mining for Bitcoin as well as a variety of altcoins. In particular, Genesis facilitates leasing equipment for mining to customers, as described in the previous section. They enable users to rent out any amount of desired computer power for their Iceland-based servers (i.e., based in Iceland due to cost reductions associated with cooling). Genesis's payouts typically range from $30 - $2000 as a function of the amount of power rented, and there is no payment required from users for electricity or associated fees. The company was founded in 2013 after the founders met each other as traders on the same Bitcoin trading platform.

Bitmain

Bitmain is among the world's largest designers of ASICs tailor-made for Bitcoin mining. It also operates BTC.com and Antpool, which are historically two of the largest Bitcoin mining pools in the world. Beyond mining hardware and pooling, Bitmain has diversified to become an investor in mining-based software companies as well as creating chips for artificial intelligence (AI). It's worth noting that Bitmain was involved in the Bitcoin Cash fork, and has also been criticised for its role in centralizing the Bitcoin network and due to its quasi-monopolistic position in mining hardware due to the dominance of its products (i.e., Antminer S9, Antminer T9+). Despite this, Bitmain is among the largest and most influential cryptocurrency companies, setting the standard of hardware technology in the industry, and with offices in China, the U.S., Israel, the Netherlands, and Switzerland. It is a privately-owned company that was founded by Jihan Wu and Micree Zhan in 2013.

F2Pool

As depicted in the pie chart above (see *Mining Techniques*), F2Pool, also known as Discus Fitch, is currently one of the five largest mining pools in the world. There are over 2,000,000 active participants in this pool, of which approximately half are Chinese citizens. In addition to the primary mining rewards, F2Pool users receive a 3% reward for utilizing this pool. It's worth noting that this is the only pool with peer-to-peer (P2P) payments, has withdrawal fees that don't exceed 4%, and has daily payouts that are automatically sent to pool participants' wallets. Since 2014, the company has offered pools for popular altcoins in addition to its core offerings with Bitcoin. The company was established in 2013 by Chinese investors and is currently headquartered in China.

Zetheron Technology

Zetheron Technology is an emerging company in the cryptocurrency space that provides software for mining cryptocurrency with users' third-party FPGA hardware. They are effectively capitalizing on the exceptional ROIs of FGPAs in the mining of certain cryptocurrencies (i.e., typically specific altcoins), offering their core software for free upfront with an embedded 4% development fee with use. In addition to this core offering, they supplement this

with complementary hardware recommendations and modifications, FPGA Bitstream (i.e., binary sequence) programming downloads, and more. They also share a breakdown of the performance and profit of their software implementations across different Bitstreams, hardware setups, and hash rates.

HashRabbit

HashRabbit is a startup that provides safe and reliable enterprise-focused software to facilitate greater security and management in digital asset mining. Their primary target demographic is institutional clients, with labor-intensive mining operations in large data centers (though they also provide offerings secondarily for more generic Bitcoin miners). They have received over $2.3M in funding from the likes of Tim Draper's Draper Associates and Zappos founder Tony Hsieh. HashRabbit partners with hardware manufacturers, like Israeli-based Spondoolies-Tech, to provide mining firmware that is consistently fast, secure, easily updated, and facile to manage. This enables miners to expedite the process of ensuring updated firmware, as well as to power cycle and maintain control of each individual unit from a singular source. HashRabbit also indicated that it may expand its product offerings to include more advanced cloud mining capabilities. The company was founded in 2013 by Chris Shepherd and Gabe Evans in Las Vegas after their personal experience with mining led them to realize the need and utility for management software and the prevalence of security flaws.

Certus One

Recalling the previously described distinction between mining and staking (see *Mining Fundamentals*), Certus One is an example of a staking-based company. In particular, Certus One is a staking-as-a-service company that provides clients with an enterprise-grade architecture for their PoS network validator node setups. The company has staked over $120M on public PoS networks such as Cosmos and Terra, as well as for enterprise clients including Libra, Hyperledger, and Corda. In addition to their core validator management and support services, Certus One has also implemented a software key management service that allows clients to set up and run secure, high-bandwidth, cloud-based validator nodes without the traditional hardware requirements. In turn, this leads to additional cost savings over hardware-intensive mining systems. Certus One was founded by Henrik Hofstadt, Leopold S., and Richard Li in San Francisco in 2018.

MicroBT

MicroBT is a high-end chip development, product design, and sales capability technology company that is focused on designing ASICs for blockchain technology, cloud computing, big data processing, and artificial intelligence. Since its inception in 2016, MicroBT has steadily grown to become one of the leading mining rig producers globally, comprising more than 10% of the total BTC network hashrate. Recently, they unveiled the M30S++: the newest installment in their flagship mining rig model, Whatsminer, that reports processing speeds of up to 112 terahashes (i.e., 112,000,000,000,000 hashes) per second (Th/s) and a power efficiency of roughly 31 joules per terahash (J/TH). Selling for $3900 per unit, The M30S++ is intended to be in direct competition to Bitmain's S19 Pro, which reports 110 TH/s and 29.5 J/TH comparatively. The company puts a very large emphasis on R&D, with over 40% of the company's

personnel dedicated to this function and holding nine significant blockchain-related patents. MicroBT was founded in July 2016 by technologist and entrepreneur Yang Zuoxing, a former lead director behind Bitmain's acclaimed Antiminer series, and is headquartered in Shenzhen, China.

Novablock

Novablock is a North-American-based Bitcoin mining pool that has quickly risen to be one of the top 10 pools within 6 months of launching. Over the last 12 months, they have sold 10,000+ ASIC mining rigs, built 100+ megawatt (MW) large-scale data centers, hosted 50+ MW of mining machinery, and generated a cumulative pool hash rate of roughly 2.195 quintillion hashes per second (EH/s). Moreover, they have close to 50,000 active users, 70,905 active workers, and have mined 4,930 Bitcoins. With their NOVAPPS+ rewarding system, Novablock ensures solid and stable user revenue through paying users not only the block reward, but also the transaction fees. To support their mining pool infrastructure, they provide Smart Monitor mining management software, a Smart Agent proxy software, a real-time mining profit calculator, as well as a powerful user-interface and dashboard optimized for both desktop and mobile. Beyond their mining pool, they also offer services such as mining equipment purchases, all-inclusive miner hosting, data center design/construction, and customized Bitcoin mining investment plans. Novablock is led by founder and CEO Yuki Sun, a senior practitioner in the Bitcoin industry who has successfully operated many large public and private mining pools and built 200+ MW data centers across North America, Kazakhstan, and China.

Vincent V of NovaBlock provided us with the following comments about the current state of the market and where he sees it going:

"Current market dynamics are closely mirroring 2017 where there is not enough machines for the demand since price of Bitcoin has skyrocketed around 100% in 2 months. The difference this time around is that manufacturers are not receiving enough chip allocation from chip providers like TSMC and Samsung limiting the amount of miners that are being created. In addition, manufacturers are being much more mindful about the amount of units produced since 2018, there was an extreme oversupply of machines and they had to sell at a loss, combined with a depressed Bitcoin price. Combined with the institutionalization of the mining industry, especially in the USA where companies are utilizing financial instruments to leverage their operations like miner financing, miner leasebacks. Large companies are beginning to monopolize the stock of miners purchasing thousands of miners months in advance, leaving less room for the small hobby miners to purchase miners at a competitive price.

There is a distinct difference between operations in the USA versus other countries. The miners in the USA are able to expand at an extremely fast rate through the use of financial tools and will soon become a super power in mining. The market share of North America with regards to total hashrate is growing very quickly. However, with the amount of leverage in place, things can go sideways quickly if facilities and operators do not have enough cash reserves.

Overall, this is a positive trend showing that the evolution of Bitcoin mining in general is heading towards the

mainstream as businesses begin to align with traditional industries."

Printing Capital

The *Printing Capital I, L.P.* is a $1,010,000 joint-fund between GDA Capital and Proof Capital Inc., a private merchant bank and wealth management firm specializing in private investments in alternative asset classes. Honing in on value identification in these alternative asset-classes across emerging industries, Proof Capital has developed a greater interest in cryptocurrency mining and its associated growth potential as cryptocurrency develops greater ubiquity. In accordance with this thesis, Printing Capital is an evergreen fund with a focus on identifying and investing in the highest-returning alternative asset (i.e., Bitcoin/altcoin) mining projects across the globe. Click here to learn more about Printing Capital and some of GDA's other investment strategies.

Conclusion

Mining is an integral component of blockchain technology and networks, ensuring that network transactions are secure/legitimate and introducing new cryptocurrency into circulation on the network. The difficulty level and reward mining offers for solving the computationally hard PoW problem and discovering blocks vary extensively as a function of the total mining power on networks, which seems to be increasing substantially over time for landmark Proof-of-Work networks such as Bitcoin's. There are a variety of mining techniques that have been used at varying frequencies over time and across different networks, with the most salient implementations including: CPU,s, GPUs, ASICs, FPGAs, mining pools, and cloud mining. Lastly, there are a plethora of both established and emerging companies looking to add value in the mining space of the blockchain industry, including one company related to GDA Capital and its partners with respect to Printing Capital.

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