Infnote: A Decentralized Information Sharing Platform Based on Blockchain

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ABSTRACT

Internet censorship has been implemented in many countries to prevent citizens from accessing information and suppress discussion of specific topics. A number of circumvention technologies are available, but none of them is completely satisfactory. This paper presents *Infnote*, a platform that helps eliminate the problem of sharing content in these censorship regimes. It is a decentralized information sharing system based on blockchain and peer-to-peer network, aiming to provide an easy-to-use medium for users to share their thoughts, insights and views freely without worrying about anonymity, data tampering and data loss. Infnote provides a solution that is able to work on any level of Internet censorship, even in area without Internet. It uses a multi-chain architecture to store and access information, and builds an implicit reputation system to ensure the quality of content on the platform.

KEYWORDS

Web, Blockchain, Decentralization, Peer-to-peer Network

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1 INTRODUCTION

Freedom of speech is considered a basic human right under Article 19 of the *Universal Declaration of Human Rights* [8]. The evolution of the digital age has brought with it both opportunities and challenges for freedom of speech.

On the one hand, we can access or deliver information faster and more reliably. On the other hand, regulators can use both technical or non-technical methods to control or suppress what can be published or viewed on the Internet. While Internet users could utilize circumvention technologies to bypass the Internet censorship to access or publish information, regulators around the world have significantly increased their efforts to control the information flow on social media[19].

The current Internet infrastructure model is heavily centralized. There are only 13 logical DNS root name servers. The IP address space is directly controlled by ICANN. These are apex players that control the Internet and are involved in delivering messages to the masses. This is being challenged by complex censorship techniques such as DNS/IP blocking and hacking attacks on content hosting websites (e.g.: blogs, social media platforms and more). Hence, there is an urgent need to solve the challenges related to this blockade by employing better circumventing approaches.

There are many techniques that allow users to circumvent Internet censorship. As reviewed in Section 3, there are multiple methods to evade Internet censorship, but they all come with their own pros and cons.

Bitcoin caught everyone's attention since it appeared as a whitepaper in 2008 [31]; various cryptocurrencies based on blockchain have emerged since then - some improving bitcoin and others more innovative like Ethereum and Hyperledger. Today, the applications of blockchain and their respective peer-to-peer (P2P) network are designed to function much more than a decentralized currency.

Blockchain, as an append-only global ledger, has already been used in a decentralized version of the DNS[28] and data storage. The append-only ledger is ideal for an information sharing platform aimed to circumvent Internet censorship, since no one would have the authority to delete the content stored in the ledger. IPFS [10] and Blockstack [3] are two existing data storage platforms based on blockchain. However, IPFS currently does not support the publish-subscribe pattern, and Blockstack utilizes centralized cloud servers to store data [4].

Infnote, is our answer to the world and its citizens who are looking to share information without having to think about data tampering, data loss, and anonymity. It combines the learnings that were developed by open-source architects to provide a reliable and effective solution as part of the anti-censorship movement. The name Infnote means providing **inf**inite power through the **note**s that the user publishes. Infnote will be helpful in providing a tool to content creators, social activists, journalists and others who simply want their voices to be heard.

Infnote, based on blockchain and P2P technologies, aims at providing a platform for users to share their thoughts, insights and views through an easy-to-use medium with varying levels of Internet censorship, even in areas without Internet. Infnote is a decentralized platform that can provide the user with full anonymity (if required) and transparency, and allow this content to travel and be viewed freely across a network of users. Unlike conventional blockchain, which uses a single chain to store information, Infnote uses multiple chains, which bring an implicit reputation system among chain owners and ensure the quality of contents in Infnote.

In this paper, we first introduce the current situation of Internet censorship around the world and define the different levels of Internet censorship mainly from a technical point of view in Section 2. Different circumvention technologies are then compared in Section 3. Next, several related projects are contrasted in Section 4. Then, various popular consensus mechanisms are analyzed in Section 5. A detailed design and implementation of Infnote is presented in Section 6. Finally, the performance and the result of evaluation is demonstrated in Section 7.

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2 INTERNET CENSORSHIP

The Internet is supposed to provide an open platform that allows anyone to share information, access opportunities and collaborate across geographical boundaries[33]. However, the Internet is being challenged today by the political systems around the world. Information flow is being manipulated to show propaganda, while the sources of real information are either blocked or redacted, and in many cases citizens remain unaware of the happenings outside their borders. On the one hand, we have the concept of 'open', 'decentralized', 'democratized 'Internet and on the other hand we also have the 'Great Firewall of China', the 'Halal Internet'from Iran, the 'Kwangmyong'intranet from North Korea.

This brings us to the topic of **censorship**, which this paper hopes to address. Before presenting our solution, we first briefly review some of the censorship methods commonly deployed by various countries.

2.1 Censorship Methods

DNS Manipulation or Tampering. In oppressive countries, if the regulator wants to censor websites, they can employ a technique called DNS manipulation/poisoning/tampering, i.e., when a client requests an IP address, the DNS server sends back a false IP address. This means that the client is actually visiting an incorrect website.

Domain and IP Address Blocking. One of the methods to block a user from accessing a website is to block its domain and IP on the internet gateway level.

Throttling. An ISP can control the traffic and speed, which is known as bandwidth throttling. In some countries, this technique is being used during political events so that the word does not spread to foreign sources [6][7]. From a technical perspective, throttling is achieved by slowing down TCP either by dropping packets [17] or by controlling the bandwidth provided to a specific protocol.

Deep Packet Inspection (DPI). Deep packet inspection is another form of packet filtering that is being used heavily in certain countries for the purposes of monitoring, blocking and sometimes throttling data flow through the Internet gateway systems. DPI filtering is used by Internet service providers to scan the payload of the Internet packets along with a normal scan of the headers to determine how to classify and control it, and whether or not to drop it. This is possible in real-time with the equipment that is available today.

Content and Keyword Filtering. Politically repressive countries pro-actively block foreign news websites, pornography, propaganda websites and content that do not match their political principles and philosophies. One easy way of censoring websites is based on their content, domain name, and specific keywords. Any website that matches a specific criteria or filter, are automatically censored for violation of the government policies.

Distributed Denial of Service (DDoS). This type of censorship method has been used in the past to take down several websites that stand against the regime [29]. From a technical perspective, multiple computers on the network are controlled either deliberately or unwittingly and a coordinated series of traffic is sent to a target server or cluster of servers in the cloud. The traffic could be in the form of either ICMP, UDP packets, SYN flooding or a combination of this type of traffic that will exhaust and probably turn off the computers resources of the target.

2.2 Levels of Internet Censorship

The degrees of censorship can be divided into five broad levels from a technical point of view:

Little or No Censorship. (Level 1) Little or no censorship is enforced in these countries. There is no need to use any circumvention technology since the majority of content is open to browse and access. Note: There are several countries who have placed censorship rules against illegal content like child pornography, in a genuine attempt to protect its citizens.

Selective Censorship. (Level 2) A small number of websites are blocked. Simple censorship methods, like IP address blocking or DNS filtering and redirection are likely to be used. Most democratic countries fall under this category, where websites dealing with illegal or illicit activity may be blocked and freedom of speech is well protected by legal systems. Citizens can easily use any circumvention technology to bypass the censorship.

Substantial Censorship. (Level 3) A large portion of content on the Internet is blocked and several censorship methods are implemented simultaneously. A blacklist of IP addresses and domains is likely to be enforced by the firewall, filtering Internet traffic that goes through the border Internet gateway systems. Anti-censorship circumvention tools may also be targets of censorship, making it is extremely difficult for citizens to bypass the censorship.

Pervasive Censorship. (Level 4) In this category, a whitelist is enforced by the firewall, implying that only approved Internet traffic will be allowed to pass the firewall. This makes it theoretically impossible to use any proxy or VPN to bypass the censorship because the proxy server would not be in the whitelist.

No Internet. (Level 5) In extreme situations, the Internet service may be completely cut off. Any circumvention technology that relies on the Internet will not work. It is very hard for citizens to access or distribute digital information. Currently, most citizens in North Korea cannot access the Internet and during the Arab Spring, the Egyptian government shut down the Internet in Egypt temporarily.

3 CIRCUMVENTION TECHNOLOGIES

Given the censorship scenario and the evolution of such censorship systems on the web, there has been an uptake in the anti-censorship movement as well. Some circumvention technologies are simple, while others require more advanced knowledge of systems to implement and make it work.

Cached Pages. Search engines like Google or the Archive.org save or cache pages through its set of crawlers. Users can simply search for the webpage they are looking for and access the cached versions of them. This is an easy and quick way to access blocked and censored content. Websites like Archive.org save multiple versions of a webpage and so the user can access the past versions of a specific website. Webpages that have been taken down or gone offline can be accessed via this service as well. It claims to have cached 338 billion web pages as of today. However, these websites and services can be blocked by censors as well, making this circumvention method effective only for Level 1 and Level 2 censorship.

Proxy. A proxy server is a server that sits in between a client (requesting information, content, images etc.) and a server (that contains the information). A proxy server needs to be configured on the user's browser or application. A proxy can provide encryption and other forms of security to the user. The regulator can easily ban these proxy servers and hence this method is only effective for Level 1 and Level 2 censorship.

Virtual Private Network (VPN). Initially, VPN was being used to access the internal networks (e.g. office intranet) from the public Internet. Recently, we have seen rapid growth in the deployment of VPN's [40]. A VPN works by creating a virtual end-end connection through virtual tunnel protocols. By using a VPN, a user residing in a censorship regimes can access blocked content by setting up a secure connection to another country with little or no Internet censorship. However, it requires additional software to set up connections and the software may be banned in substantial censorship regimes.

Peer-to-Peer (P2P) Network. One widely used P2P network is BitTorent, which is a robust protocol for file-sharing that allows users to download content from multiple sources in a swarm that contains seeders, peers and leechers. From a technical perspective, BitTorrent breaks down a single file into several pieces or chunks of data. Peers then pull bits of files from seeders and other peers[14].

Anonymous networks like Onion Router (Tor) [36] and Invisible Internet Project (I2P) [1] offer peer-to-peer communication through its censorship resistant and anonymous networks by relaying traffic through multiple nodes. They are often open-source and use circuit based systems that encrypt the user's traffic end-to-end so that neither the sender nor the receiver need to reveal their respective IP addresses. It supports multiple applications like instant messaging, web browsing, file-sharing and so on. However, it cannot function in a whitelist type of censorship and the speed is lower than the direct connection because of multiple-hops.

Sneakernets. The name 'Sneakernet'has come about because it is easy to carry information in your sneakers and physically transport this digital information from one physical location to another, thereby helping distribute information to other users or groups and circumvent surveillance and censorship. This method can work in countries with no Internet or has pervasive censorship deployed given its little reliance on the Internet. The major drawback is that the source of information and the content itself cannot be fully trusted, and this is a slow method of communication.

Web-to-Email. This is a simple service that takes a snapshot of any website and sends it to directly to your email. In geographies with little to selective censorship, this method can be quite effective. One disadvantage is that if the emails and the website to access this service are blocked on SMTP and IP respectively, this service will no longer be effective.

3.1 Features of Circumvention Technologies

In **Table 1**, these circumvention methods are compared to understand along the following dimensions.

Difficulty Level - Identify and Block (Rating: Easy, Medium and Hard). This rating refers to how easy or difficult it is for the government, regulators, and Internet service providers to block the respective technique on the Internet. For example: To block foreign websites that provide news, the government has to block the IP Address or the Domain name of the website. This is considered an easy task for the government compared to the feature-set of sophisticated firewalls and backbone systems in their inventory.

Anonymity (Rating: Yes and No). This rating refers to whether anonymity is provided to users by the circumvention tool or method.

Data Tampering Protection (Rating: Yes and No). Data like files, html pages, music, videos and so on can be tampered with once they are away from their original source. Only in some cases, through algorithms like hashing, one can be assured that the data is from the original source and that it has not been changed or modified in any way.

Encryption (Rating: Yes and No). To prevent any unauthorized access, users can encrypt data with algorithms. This classification provides a simple yes or no to the question : can the data be encrypted while being stored at the source and viewed by decrypting it.

Censorship Category (Rating: Level 1 to 5). Each circumvention technology has its limitations when it comes to deceiving the censors or simply finding another route to access or distribute content. The category level (1 to 5) at which the circumvention technology can be effective at, is mentioned through this feature. Below are categories that have been defined in the previous section. Each level is consecutive in nature and hence includes features of the previous level.

4 RELATED PROJECTS: PEER-TO-PEER WEB HOSTING

Infnote is a peer-to-peer web hosting project, that uses peer-to-peer networks to distribute and access webpages without the need for any intermediary hosting providers. This feature makes this technique very suitable for circumventing Internet censorship . Here are some popular related projects.

Interplanetary file system (IPFS). IPFS is a distributed file storage system [10] that tries to combine the power of decentralization and the web by providing features like strong data integrity by using merkle trees and distributed hash tables and availability by replicating data across the networks [38]. Hashes of content would be stored within the blockchain [5]. It is a good platform, built for evading censorships because the access to IPFS is difficult to block[2]. Currently, IPFS does not support the publish-subscribe pattern, which is necessary for real-time information sharing (pubsub is an experimental implementation for it). It is possible to implement Infnote on top of IPFS. However, in order to gain more flexibility, we decided to design our architecture from the ground up.

FreeNet. FreeNet, similar to IPFS, uses a distributed data storage mechanism where the storage space is distributed amongst all nodes on the network. It is both anonymized and decentralized thereby making it difficult to take down in censorship driven countries [13]. However, unpopular files might disappear from the network

Table 1: Censorship Technologies - Comparison Table

	Cached Pages	Proxy	VPN	P2P	Sneakernets	Web-to-Email
`Difficulty (identifying and blocking)`	Easy	Medium	Medium	Hard	Hard	Easy
`Anonymity`	No	No	No	Yes	Yes	No
`Data Tampering Protection`	No	Yes	Yes	Yes	No	No
`Encryption`	No	Yes	Yes	Yes	No	No
`Censorship (applies to)`	Level 2	Level 3	Level 3	Level 4	Level 5	Level 2

[18], which does not fit the use case of discussion forum for which browsing old posts is needed. With Infnote's architecture where we use blockchain, we can guarantee that data cannot be removed or lost from the system.

ZeroNet. ZeroNet is based on the file system and BitTorrent protocol where sites are recognized through a public key unlike the traditional web where sites are recognized by domains and IP Addresses [24]. The site owner can sign files with their private key to make modifications and authorize other users to make modifications to support multi-user sites. Each user would request other nodes' addresses from the BitTorrent tracker and share or receive the site files with them. As long as a site is supported by peers, the content is alive and can be accessed by ZeroNet users. However, a site owner has full control over the content of the website, resulting in excessive power with the site owner. Currently, the sites cannot be directly accessed from the web browsers unless using the ZeroNet application, and the history of modification would not be stored. Due to the ZeroNet BitTorrent trackers being blocked, the ZeroNet sites are inaccessible in China. In Infnote's case, the site owner's power is limited as no one can delete the data in the blockchain and users can directly access the content from their respective web browsers. In addition, Infnote could work in different levels of censorship and support various approaches to find and get content from peers making the system difficult to block.

Blockstack. Blockstack is a project that provides decentralized key/value storage, similar to Namecoin [28], built on top of the bitcoin blockchain. It is a strong solution for deploying a decentralized public key infrastructure (PKI), as demonstrated in [3]. However, one disadvantage is that the values are stored in a centralized cloud storage system [4], which makes it less ideal for Internet censorship circumvention. At its core, Infnote uses a decentralized storage system to store data on the network similar to bitcoin.

5 BLOCKCHAIN

Blockchain is a technology that is set to change how we currently conduct business in any given sector. Blockchain, in conventional terms, is a public ledger that records all events, transactions and exchanges that happen between parties or nodes in the network [34]. bitcoin popularized the concept of blockchain, but blockchain as a baseline platform has far greater implications than bitcoin itself.

5.1 Advantages of Blockchain

Blockchain technology relies on a given consensus method (described in later section) to add information as blocks in the network. These blocks form the distributed ledger that is shared between several computers or nodes within a network. Generally, these blockchains do not have a central authority controlling the information or creation of blocks. The above mechanism brings certain advantages to its users like visibility of data, immutability of data, and the ability to decentralize data over the network and leverage the security aspects of the blockchain.

Data is Safe, Secure and Resilient. Data on a blockchain is stored on a chain of blocks, which is then accessed by the users. Since blockchain is linked using cryptography, it is guaranteed that the information written cannot be tampered with, since it relies on digital signatures and the hashing function. Unless the entire network fails or the cryptographic function is attacked, the information on the blockchain is secure and tamper-proof. This makes the data, which is already encrypted, resilient to outside attacks and power losses to a subset of blocks and so on.

Open And Free-for-all. Not only is the data available for everyone to see on the platform, but anyone with access to the platform can contribute their work for the users to see and appreciate. On a typical transaction-based blockchain, it is possible to see each user's (through their respective public address) transaction history, currency exchanged and their holdings.

5.2 Consensus Mechanisms

In a blockchain system, the underlying assumption is that there is no centralized node and nodes generally do not trust each other. A consensus mechanism is a fault-tolerant mechanism to achieve necessary agreement on a single state over the network. In this section, we provide an introduction to some popular consensus mechanisms.

Proof of Work (POW). Proof of work is to solve mathematical puzzles with answers easily verifiable. Bitcoin uses proof of work to achieve consensus[31]. The node that wishes to insert a block into the chain, is called a miner. Mining process is based on a cryptographic hash function, which involves scanning for a value that when hashed, the hash begins with a number of zero bits. Other nodes can easily verify it by hashing a single value. After a miner produces a satisfying hash value, they have the permission to insert a block (with transactions) into the chain. The bitcoin mining process currently needs a huge amount of computational resources as well as electricity to power these computers. The use of application-specific integrated circuit (ASIC) can solve the mathematical puzzles much faster than CPU and GPU, in both speed and efficiency, making it almost impossible for personal computers to join the mining process. In order to resist ASIC, new puzzles have been proposed, which do not only rely on computational power, but also other computational resources, such as memory and disk space. In POW, nodes having sufficient computational resources are more likely to solve the mathematical puzzles and therefore have a higher chance of inserting blocks into the blockchain.

Proof of Stake (POS). Proof of stake states that a node needs to stake an amount of its token so it has the chance to insert blocks into the chain [23]. The more tokens a node stakes, the higher the chance of inserting blocks into the chain, because it is believed that more token a user has, the less likely he would attack the network [11].

Instead of competing using computational resources, in proof of stake, nodes compete based on the number of tokens they stake, therefore reducing the energy requirements. Similar to POW, the node with tokens (rather than computational resources) has a higher chance of inserting blocks into the chain.

Delegated Proof of Stake (DPOS). Unlike proof of stake, in which every node has the chance to insert blocks into the chain, Delegated Proof of Stake only allows delegated nodes to insert blocks [26]. Delegated nodes are chosen by voting processes. Votes are weighted according to the number of tokes each voter stakes. The first tier of nodes (usually less than 100 nodes) who receive most of the votes will earn the right to insert blocks into the chain.

Voters can acquire the tokens through Initial Coin Offering (ICO) or trade platforms. The price of the tokens is determined by the market. The value of these tokens comes with the power to vote for delegated nodes and deploy smart contracts onto the chain. The more tokens a voter has in their possession, the more power they have to elect the delegated nodes and therefore have more indirect control over the chain. To attract votes, potential delegated nodes need to demonstrate their abilities and identities.

Proof of Authority (POA). In a Proof of Authority (POA) network, only approved nodes can validate blocks and insert them into the chain [21]. Unlike delegated nodes in the DPOS mechanism, approved nodes are not chosen by voting.

Currently, POA is mainly used in private networks, where every node knows each other and therefore trust approved nodes to maintain the chain. However, approved nodes have to maintain an uncompromised state given the power vested in them. Approved nodes need to gain their reputation through their work in the network. Any negative activity recorded can destroy the reputation of the approved node.

Practical Byzantine Fault Tolerance (PBFT). Numerous protocols have been proposed to solve the problem of Byzantine Fault Tolerance (BFT)[25]. Practical Byzantine Fault Tolerance (PBFT) [12] is one solution, which can handle up to 1/3 of the malicious nodes.

A block will be generated in a round and each round can be divided into three phases: pre-prepared, prepared and commit. Each node has to receive 2/3 nodes from other nodes in order to enter the next phase [12]. Therefore, PBFT requires every node to be known to the network.

Delegated Byzantine Fault Tolerance (DBFT). Delegated Byzantine Fault Tolerance (DBFT) is another solution for the BFT problem. The whole process is similar to PBFT, except only a small number of delegated nodes are voted to insert blocks into the chain [15].

5.3 Consensus Mechanism Comparison

Different consensus mechanisms have different advantages and disadvantages. **Table 2** gives a comparison between them and we use the prototype given by [39].

Node Identity Management (Rating: Permissionless and Permissioned). In POW, POS, DPOS and DBFT, everyone can download the code and participate in the network generating new blocks by only knowing a single peer in the network. In POA and PBFT, only certain identifiable nodes can generate new blocks and each node needs to know the whole node list participating in the consensus.

Latency (Rating: Low and High). Latency is the amount of time for a transaction to be confirmed and accepted in the network. The blockchain systems based on POW need multi-block confirmations, causing high latency [39]. Current implementations of POS either hybridize with POW or need checkpoints signed under the developer's private key, causing high latency. In DPOS, POA, PBFT and DBFT, the number of nodes participating in the consensus is small, leading to practical network-speed latencies.

Throughput (Rating: Limited and Excellent). Due to possibility of chain forks, POW has limited throughput [39]. Some of the implementations and variations based on POS outperform bitcoin when it comes to throughput but POS still has its limitations. EOS is based on DPOS consensus mechanism, that can support millions of transactions per second [9]. PBFT and DBFT can sustain tens of thousands of transactions [39]. As the throughput of POA is bounded by hardware not consensus, it has excellent throughput.

Energy Saving (Rating: Yes and No). Among all the consensus mechanisms, only POW needs extensive amount of energy. Estimated annual electricity consumption for the entire bitcoin network currently is 73.12 TWh, about 30% annual consumption of Australia, as of Oct 2018 [37].

Scalability (Rating: Limited and Excellent). Here we discuss the scalability in number of nodes participating in the consensus mechanism. POW and POS have excellent scalability, which easily supports thousands of nodes. PBFT has only been tested on a small numbers of nodes [39]. DPOS, POA and DBFT mechanisms rely on a few delegated or approved nodes.

Voting Process (Rating: Yes and No). Here we discuss whether the nodes need to vote in order to achieve a consensus about writing or inserting blocks. In DPOS, PBFT and DBFT, the nodes participating in the consensus would vote for a block, deciding on whether to insert it into the blockchain.

5.4 Incentive of Blockchain System

Most public blockchain systems rely on its cryptocurrency to motivate its network and users. The cryptocurrency can be exchanged into fiat money through exchanging platforms. The blockchain system maintains a transaction ledger, where the balance of each account can be calculated. The cryptocurrency can be transfered to another account through a transaction, which will be written into

Table 2: Consensus Mechanism Comparison

	POW	POS	DPOS	POA	PBFT	DBFT
Node Identity Management	Permissionless	Permissionless	Permissionless	Permissioned	Permissioned	Permissionless
Latency	High	High	Low	Low	Low	Low
Throughput	Limited	Limited	Excellent	Excellent	Excellent	Excellent
Energy Saving	No	Yes	Yes	Yes	Yes	Yes
Scalability (no. of nodes in consensus)	Excellent	Excellent	Limited	Limited	Limited	Limited
Voting Process	No	No	Yes	No/Yes	Yes	Yes

the ledger. By generating new blocks, miners can receive transaction fees and block rewards. It is the cryptocurrency system which keeps most of public blockchain systems working well, since any misbehavior would cause the loss of cryptocurrency and therefore lose fiat money.

6 DESIGN AND IMPLEMENTATION

Infnote is an information sharing platform that offers flexibility to its users. It can be used as a portal to share information, a blog to write short or long articles, or even a discussion forum to discuss specific topics. The features that distinguish Infnote from existing platforms is that we are able to provide users access to content in censorship-driven countries, limit the power of the site owner, verify and trust that the source of the data is from the original author, provide assurance that data will not be tampered or lost once published and offer access to the platform to all kinds of clients. This is provided through the use of peer-to-peer (P2P), blockchain and our unique architecture.

6.1 Blockchain

Infnote utilizes blockchain technology to store information. When a user wishes to publish a post on the platform, the post will be signed with the user's private key. Later, the post will be bundled with other posts and additional information (like timestamp etc.) together into a block. The *chain owner*, who has the authority to insert blocks into the blockchain, will sign the block with his private key. **Figure 1** demonstrates the process of posts inserted into the blockchain. The block will be broadcasted to the P2P network, and every node in the network will verify it.

Cryptography. We utilize a Digital Signature Scheme (DSS) implemented using *ECDSA* with *secp256r1* curve [20] and a cryptographic hash function *SHA-256* [32].

Multi-chain. Infnote uses a multi-chain architecture, which means there are several independent parallel chains, as demonstrated in **Figure 2**. Each chain is controlled by its chain owner and everyone can become a chain owner simply by creating a new chain. However, whether it will be maintained by enough nodes depends on the reputation of the chain owner and the quality of the information in the chain. The community of Infnote would maintain a default list of chains recommending the users to follow. With this mechanism, the chain owners are given the incentive to follow the code of conduct. Any chain owner who violates the general rules set by the community would be removed from the default list. If the user disagrees with the community's decision, a user can simply override the default list to maintain or drop certain chains. In this model, each participant only has limited power and the ultimate decision is made by the users themselves.

ID chain. One type of chain is an ID chain that is used to store all the users' information. Without an ID chain, the users' identification would be their public key of the digital signature scheme, whose length is too long to remember. By utilizing an ID chain, a user can map its public key to an easy-to-remember unique user name. Users can also store additional personal information on the ID chain. Note that Infnote does not restrict the number of ID chains or the owner of the ID chain. Different ID chains would compete with each other and only the chains which gain users support would survive.

Consensus mechanism. Infnote, as an information sharing platform, must ensure its quality of information, such as not allowing machines or bots to automatically send advertisements onto the platform. As Infnote does not include any currency system, sending advertisements to the platform is almost free. Unlike the automated verification process utilized during transactions in cryptocurrency systems, there are no standards defined to determine if a post should or should not be published to the Infnote platform. The two common consensus mechanisms POW and POS are not compatible with Infnote, since there is no guarantee of who (which node) will generate the next block and insert it into the blockchain, therefore no guarantee of what kind of posts will be published on the platform. PBFT does not allow many nodes to participate in the network, thus does not suit Infnote's requirements either. In DPOS and DBFT, only delegated nodes can insert blocks into the blockchain. However, when determining whether a post should be published on the platform or not, delegated nodes may have conflict making it harder to reach a consensus. This would cause a significant delay in writing information into the blockchain.

Therefore, Infnote uses POA as its consensus mechanism. POA only allows authorized nodes to insert blocks into the blockchain. For a chain, only its chain owner can insert blocks into it and therefore control the information on the platform. Just like a miner in bitcoin, a chain owner's role is to generate new blocks signed with his private key and broadcast it to the nodes that are connected to him. Due to the append-only property of blockchain, the chain owner's power is limited. Once the chain owner decides to insert a block into the blockchain, it will be broadcasted to the P2P network, and thus it becomes impossible to remove from the blockchain. The chain owner can still 'soft delete' a post by inserting another block to

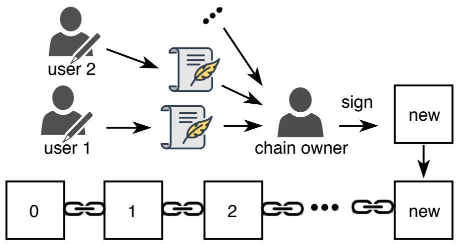


Figure 1: The process of publishing a post and inserting it into the blockchain.

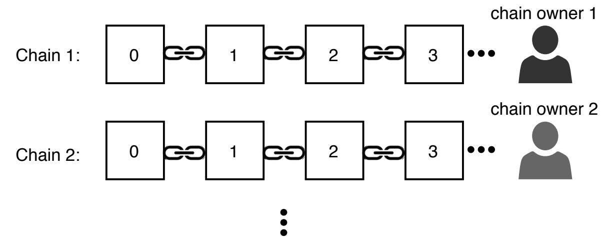


Figure 2: Multi-chain structure

mark the deletion of that post, but the history will be permanently recorded in the blockchain and there is no way to remove it.

Fork. It is possible that a chain owner signs two blocks causing the blockchain to diverge into two paths, like a fork in bitcoin [27]. However, this is strictly prohibited in Infnote. If any node detects that two blocks of the same height are signed with the correct signature of the chain owner, it will stop trusting the chain owner and stop broadcasting its blocks. Without the support of the P2P network, the chain owner cannot send the information out. In case of a scenario where the chain owner's private key is stolen, this provides a termination method for the chain owner to permanently close its blockchain.

Implicit reputation system. Unlike traditional information sharing platforms, like Facebook or Twitter, where the identity of the owners is open to all. In Infnote, a chain owner can choose to hide its identity by using an anonymous communication technology like Tor [35]. Each chain owner gains its reputation on the network by the work conducted so far. Even if a chain owner decides to hide its identity, users are able to observe the chain owner's behavior in the blockchain and decide whether or not to use its services. Generally, it is expected that the higher the reputation, the more peers will join the network.

Incentive. Cryptocurrency based platforms are not an ideal solution against censorship. On the one hand, governments can spend money to buy cryptocurrency and use it to destroy the blockchain system, by sending too many transactions (similar to DDoS) into the network, or by investing huge amounts of computational resources to become miners and therefore control the generation of new blocks. On the other hand, to gain entry into the platform, users must obtain or hold the cryptocurrency or token before using the platform, adding an additional barrier of entry for normal users.

Therefore, we do not want to introduce any monetary elements into Infnote. It is our belief that, as a free-for-all information sharing platform against censorship, freedom of speech is an incentive that is already strong enough for people to join and contribute to Infnote. Many open-source communities around the world have adopted the same principle, where the contributions are recognized and the work is shared amongst people as part of the community.

6.2 Nodes

We fully expect multiple types of devices to join the network, such as laptops, desktops, servers, smart-phones and so on. The front end interface can be through a web browser, a stand-alone program, or a smart-phone app. However, different devices have different capabilities. It is necessary to analyze the features of each kind of devices and design different strategies for them. In Infnote, there are two kinds of nodes, full nodes and light nodes.

Full Nodes. Personal computers and servers can be full nodes. Same as bitcoin, full nodes are devices that have sufficient bandwidth and computational resources to support all the functions of Infnote which include: storing all the data in the blockchain, providing logic to view and publish content and acting as a server by listening for connections and providing services to clients. People and organizations can run full nodes by using their spare resources. A full node client can be a desktop, a server, or a virtual machine. Full node client is written in python, which provides us cross-platform interoperability. The database layer is powered by MongoDB, which is a leading NoSQL database engine.

Light Nodes. Many devices, such as smart-phones or web browsers cannot be full nodes, due to limited resources and processing power. Hence, they must rely on the full nodes to provide comprehensive services. At the same time, light nodes can still use their limited resources to contribute to the system.

Smart-phones usually do not have enough storage space, therefore it is unreasonable for a smart-phone to store the all the data in the blockchain. It is also unlikely that a smart-phone will run the Infnote software for a long time. Most of the smart-phone platforms allow software to make the Internet connection, making it possible for a smart-phone to join the P2P network. For a smart-phone device, it can cache some recent blocks and broadcast them to the P2P network. By caching recent blocks, the phone user is able to view the data stored in recent blocks. We have developed an iOS app in Swift to demonstrate the functionalities and features of a light node.

Web browsers are restricted environments. A program written in *JavaScript* can be run on web browsers, but with more restrictions. We had to resolve two main issues: storage and communication protocol. Before *HTML5*, application data had to be stored in cookies, which would be sent to the server upon on every request. *Web storage* is a more secure method to store data locally, supporting larger amounts of data, and the data will never be sent to the server. Today, most web browsers support web storage. Same as smart-phones, it is impossible for web browsers to store entire blockchain data, but by utilizing web storage, the program running on web browsers can cache some recent blocks and the user can view the information in those blocks. The communication protocol is strictly

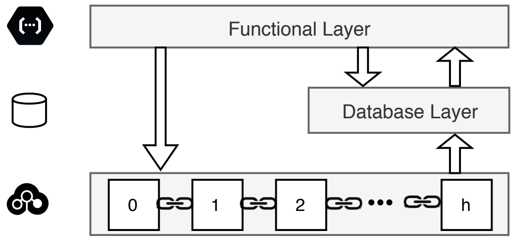


Figure 3: Three layer structure

restricted in web browsers. Since *UDP* and *TCP* protocols are not directly allowed in most web browsers, Infnote uses *Websocket* as its communication protocol, which is currently supported by most major browsers. Current implementation of Infnote's web client can run on any web browser without additional software.

Multi-layer Structure.

Infnote has implemented a number of user-friendly functions on top of the blockchain which are supported by a multi-layer structure. A full node has three layers, while a light node may only have two layers. **Figure 3** shows a typical three-layer structure. An arrow in the figure represents the direction of a data flow.

(1) Blockchain Layer: All nodes have this layer. The blockchain layer serves two purposes: It stores all the data of the Infnote in sequence and provides the advantages of using the blockchain as described in earlier sections. A full node is expected to store all the blocks while a light node is only expected to cache a few recent blocks, due to limited storage space.
(2) Database Layer: All full nodes would have this layer. It is necessary to reorganize the data into the database, since relying only on sequence data, a full node cannot provide services efficiently. Light nodes may also run a database to improve the efficiency.
(3) Functional Layer: Both types of nodes have this layer. This layer provides various operations to the users, like publishing or viewing an article in Infnote. The function layer verifies the operation based on the data in the database, but updates are applied to both the database and the blockchain accordingly. For a light node, since it is only expected to cache some recent blocks, the functions it can provide is limited.

6.3 Network

A network allows for nodes to interact with each other. In this section, we discuss the specific characteristics of our network.

Decentralized Network. The P2P network plays a vital role when developing the entire system and laying down the architecture. Similar to bitcoin, Infnote's architecture does not rely on a centralized server. For a censorship resistant platform, this is a necessary condition, since any single server would easily be blocked by censors.

Broadcasting Blocks. Similar to bitcoin, whenever chain owners generate a block or nodes receive a new block, they will immediately send out the new block to the peers that they have direct connections with so that every node can obtain the new block in a short time. It follows the same principle as the publish-subscribe pattern, where publishers (chain owners) send blocks and subscribers receive these blocks. This feature allows nodes to automatically obtain new posts in Infnote in a short time.

Peer Discovery. Peer discovery is extremely crucial for a P2P network to circumvent Internet censorship. How to find the initial peer when a new node wants to participate in the network is known to be a difficult task. For a pure decentralized P2P network, the only way that is guaranteed to succeed is to search on the Internet and send a handshake message to millions of addresses hoping to find one peer who has already joined the P2P network. However, this is not realistic. A more practical solution is to centralize, making the initial peer discovery the weakest link in the entire system. Authorities may simply block the initial seeds and thus prevent new nodes from joining the network. Infnote provides several methods for a node to initially find the peers in the network to relieve this issue.

- Hard-coded nodes: The developing community can hard code several recommended nodes in different geographies. This method, however, may increase the workload of those nodes and they are likely to be blocked.
- DNS Seeding: DNS seeding servers would run a web crawler exploring the stable nodes in the P2P network and maintain a list of them. Whenever a node request is sent to a DNS server, it would return multiple node addresses. DNS protocol is a light protocol, therefore, it would not result in a heavy workload for DNS seeding servers. However, the DNS seeding servers might also be blocked.
- From other nodes: Once a node joins the P2P network, the node can send requests to other nodes asking for more nodes' addresses.
- Address database: A node can store the addresses of nodes in its local database. On the next runtime, the node may not need to do the initial peer discovery given that nodes in the address database are still available.
- User specified address: The users can manually specify a node address into the software. The users can enter the address or simply scan a QR code. Although this method seems less efficient, it is the hardest for authorities to prevent initial peer discovery. This method allows users to join the P2P network by relying on real life connections, which seems like the only solution in pervasive censorship countries.

Obfuscation. Censors may use DPI to detect the protocol deeper inside the network packets. By using obfuscation, our goal is to avoid detection of Infnote packets. Infnote currently uses three approaches:

- Random Port: The regulators may ban some ports, so that certain services will not work. For example, not allowing packets through port 80 can prevent access to http websites. Infnote can support the use of random ports to communicate between each node, so that regulators inspecting and blocking port numbers will not be able to block Infnote.
- Mimicry: With this method, packet payloads are made to look like something that will be allowed by the DPI. A common example would be making the payloads look like HTTP packets, which are rarely blocked, because of its ubiquity [16].

Infnote directly uses WebSocket as its underlying communication protocol. Similar to HTTP, WebSocket is a commonly used protocol, therefore should not be blocked by censors.

- Encryption: Similar to HTTPS, the WebSocket protocol supports encrypted connections, indicated by the prefix wss in the URI. By using encrypted connection, the censor would not be able to obtain the content of the packets by intercepting network traffic.

Anonymity. Similar to other public blockchain platforms, everyone can download the blockchain and view the data stored in it. This feature makes it is possible to reveal the true identity of the users. In countries where substantial censorship rules exist, a user's identity may need to remain anonymous. If more nodes join the P2P network, the difficulty of finding the owner of a post would increase.

For users who need a higher level of anonymity, they can combine the Onion Router (Tor) [36] with Infnote. Once a user uses Tor to make a connection, the data packets will be relayed multiple times over distinct intermediary servers and each server only knows limited information about the packets, making it extremely difficult to trace back the source.

6.4 Modes

Infnote, depending on needs and requirements, can work in different modes. In essence, Infnote provides a solution for different degrees of Internet censorship.

Direct Connect Mode. This mode is the same as the traditional client-server architecture, in which the client is the requester while the server is the service provider. In a client-server model, the server will handle requests and return the information to the client [22]. In Infnote, a full node could be a server, which can provide comprehensive functions. In an area where the server can be directly accessed by users, direct connect mode is the most efficient method. The server normally has powerful computing capacity and more network bandwidth, therefore, can support more clients and provide more functions. The user can easily connect to the server by using HTTP or HTTPS protocol. By using Tor, the user can even establish anonymous communication with the servers [36].

Owing to all the data being stored in the blockchain, the servers are able to provide comprehensive services based on the data in the blockchain. Any node which has adequate capacity can download the blockchain and become a server to handle requests from the client. This feature enables Infnote's architecture to support multiple servers, making the system much more robust and censorship resistant. **Figure 4** demonstrates an example of multiple server handling requests from multiple clients.

Peer-to-Peer (P2P) Mode.

In areas with substantial censorship level or above, a direct connection may not work. The common approach would be to use a proxy service. However, if the whitelist type of Internet censorship is being implemented, the proxy server may not be allowed access.

Infnote can utilize the P2P network to transfer or receive data. Every node in the P2P network would actively broadcast and receive blocks. Once a node receives a block, the node is able to extract and validate the data in the block. Similar to bitcoin, in which the user can send a transaction to any full node to then be broadcasted to the whole network and written into the blockchain, the user can send their data into the P2P network to be permanently written into the blockchain later. **Figure 5** demonstrates a possible scenario of network structure in P2P mode.

Without Internet Mode. We want to emphasize that the Internet is just an efficient way of transferring data. Without the Internet, Infnote will still work, but less efficiently.

In extreme situations, access to the Internet may be disconnected partially or fully due to political reasons, similar to what happened in Egypt during the Arab Spring. Although it is impossible for citizens to access the Internet, the infrastructure of the Internet can still be utilized. Every router can establish an internal network, so that as long as nodes are in the same internal network, they can still send blocks to other nodes. Each smart-phone can be a data trunk that transfers the blocks in different internal networks.

In a more severe environment with no Internet infrastructure, like North Korea, citizens can still physically spread blockchain files, in the same way as Sneakernets. However, unlike traditional approaches, citizens would still be able to verify and trust the data in the blockchain.

7 EVALUATION

The evaluation focuses on two aspects of the system: throughput and latency. Throughput is how many posts the system can sustain per second. Latency is the amount of time for a block to be confirmed by all nodes on the P2P network. Here we assume that the size of a post in Infnote is 250 bytes, around the same size of a basic bitcoin transaction with 1 input and 2 outputs. We also assume that the size of a block is 1 megabyte.

For the throughput, we only calculate the time it takes to validate a block and save it to the database, with the assumption that the network latency is less than validation and saving time, therefore transferring a block in the P2P network would not influence the throughput of the system. Our experiment shows that throughput is 35544 posts per second, running the Python version of the Infnote program on a 2015 version of Macbook Pro. The result could be further improved by deploying better hardware or optimizing the code.

For the latency, we hope to understand the system on a global scale. As it is impossible to deploy a P2P network on a large scale due to limited resources, we try to speculate the performance of a system by using only a small number of nodes. We utilize ten nodes in different geographic regions around the world with eight full nodes and two light nodes [1]. Node No.6 is a light node running on an iPhone 8 and node No.10 is another light node running on a JavaScript program of Infnote on a Chrome web browser. Node No.1 is the chain owner who generates new blocks.

The first part is to evaluate the latency performance of the system up to ten nodes. It assumes that the connections between nodes in the P2P network have already been established. **Figure 6(a)** shows the results of this experiment. On average, the latency is 2376.8ms,

[1]The nodes are located in Tokyo (node No.1), Kuala Lumpur (node No.2), Sydney (node No.3), Singapore (node No.4), Mumbai (node No.5), Hong Kong (node No.6), Dubai (node No.7), Hong Kong (node No.8), Silicon (node No.9), Hong Kong (node No.10)

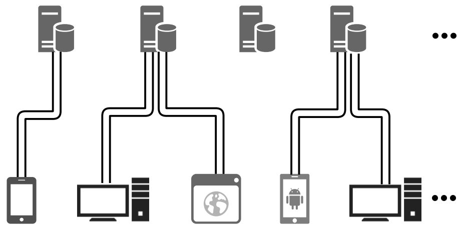


Figure 4: Direct Connect Mode with multiple servers

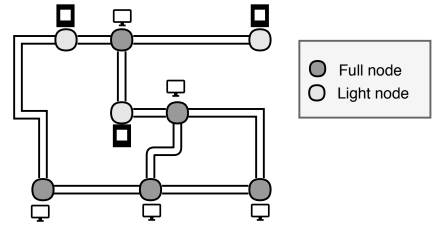
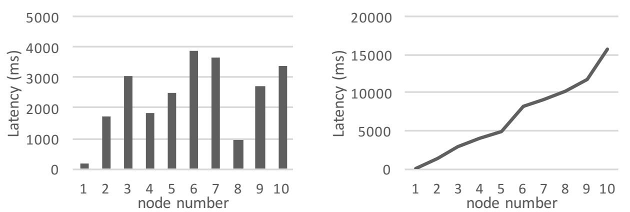


Figure 5: Peer-to-Peer (P2P) Mode



(a) latency with different number of nodes (b) latency with different network diameters

Figure 6: Latency of the Infnote

for every node in the network to receive a 1 megabyte block, which basically matches the network latency.

The second part is to understand the latency performance of the system on a large scale by using only a small number of nodes. We formed a linear topology network, in which each node is connected one after the other in a sequential chain. The experiment would represent the results of the large network with different network diameters. The first node in the chain is the chain owner. We simulate the situation where two internal networks are connected only by the No.6 node, a smart-phone. **Figure 6(b)** shows the results. It took 15665ms to transmit a 1 megabyte block in the network with 10 diameters.

8 FUTURE WORK

In the current implementation of Infnote, in direct connect mode, the servers (full nodes) can provide comprehensive services to clients (light nodes) and access to content that is on the blockchain. However, the servers can feed the clients with wrong information that may not have been written to the blockchain at all. In the future work, we plan to update the architecture to use authenticated data structures (ADS) where responders need to also send back proof that the content came from the blockchain it claims [30].

9 CONCLUSION

In this paper, we began by setting objectives which is to provide a platform to users around the world to share their views and opinions with an underlying assumption that the content shared will remain intact, unchanged and be protected.

We defined a few levels and types of censorship that can be used to put different countries into categories for comparison purposes and for future research. We also compared and contrasted existing circumvention technologies that bypass blockages and filters. Each technology was analyzed on the basis of its effectiveness (to bypass) against all levels of censorship.

Blockchain, as an underlying technology, met several of the objectives. After careful analysis and comparison, we came to the conclusion that POA works with Infnote's plans and vision. To store posts into the blockchain, we developed a multi-chain architecture comprising of full nodes and light nodes.

Infnote program with its unique construction allows it to create a platform for its users which is decentralized, tamper-proof, safe and open to everyone. From the proof of concept of Infnote, the evaluation stage showed immense promise. The Infnote program achieved significant throughput (posts per second) and low latency while spreading the blocks around the world.

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