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A challenging problem in decentralized systems is encouraging long-term cooperative behaviour between strangers. It is often not immediately beneficial to cooperate without the guarantee of direct reciprocity. Cooperation among entities in the long term results in sustainability while selfish behaviour can lead to the collapse and distrust of such communities. This collapse is also referred to as the *tragedy-of-the-commons* phenomena and is notoriously hard to prevent when considering mutual access to resources [2].

Our aim is to incentivize network participants in file-sharing communities to cooperate with each other by introducing monetary rewards for good behaviour. We explore whether a file-sharing ecosystem based on bandwidth tokens is capable of addressing the *tragedy-of-the-commons* and increase cooperation and sustainability in general. Blockchain technology is used to achieve tamper-proof accounting of such bandwidth tokens. While blockchain is often used to securely maintain digital currencies without financial institutions, our goal is to deploy a distributed ledger to promote cooperation amongst content providers and consumers. Based on this goal, we designed a blockchain with superior scalability, compared to existing blockchain solutions [4].

A high-level system architecture of our micro-economy is presented in Figure 1. The key component of our design is a bandwidth token, irrefutably stored and tracked on our deployed blockchain fabric: *TrustChain* [4]. TrustChain is specifically designed to build trust between interacting strangers and has no hard requirement for global consensus, in comparison to popular blockchain applications. Instead, consensus is reached between transacting parties and fraud is guaranteed to be eventually detected by the means of network gossiping. In contrast to existing blockchains like Bitcoin or Ethereum, each user creates and grows their own chain of transactions [3]. Every transaction in TrustChain is dual-signed and stored in the chains of both transacting parties. Our approach yields superior scalability while significantly reducing storage requirements.

Content providers are able to mine or earn bandwidth tokens by uploading content to others using our decentralized file sharing client Tribler [1]. Token mining is an autonomous process that attempts to optimize the amount of uploaded data by first downloading and then uploading a subset of available content. Mining is both beneficial for the provider, who earns spendable tokens, and the community, where contributed bandwidth results in faster downloads and increased availability of content. *Content consumers* pay providers for their provided resources with bandwidth tokens. When the difference between the amount of uploaded and downloaded bytes (the token balance) of a specific user is below a certain threshold, content providers refuse to upload content to these peers, until they contributed a sufficient amount of bandwidth back to the community. This basic but effective free-riding policy makes bandwidth tokens usable and ensures that there is a basic demand for them.

We address privacy issues arising from sharing content with a deployed and tested Tor-like communication overlay. When this overlay is enabled, an end-to-end encrypted path is constructed with other nodes and traffic is routed through these nodes. This allows peers to interact with the community in an anonymous way. In contrast to Tor, the anonymous layer as implemented in Tribler is fully decentralized and does not rely on centralized (directory) servers. The system offers anonymity at the cost of increased bandwidth requirements
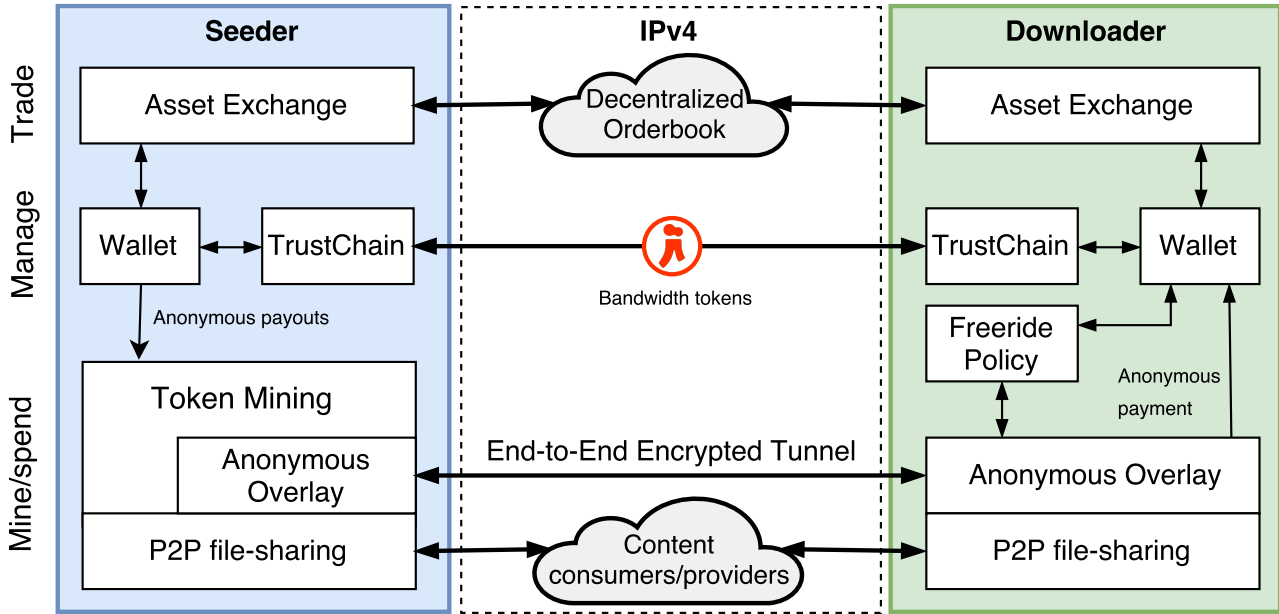
Figure 1: A high-level system architecture of our micro-economy with bandwidth tokens. Content providers are able to mine tokens by (anonymously) uploading content to others. Content consumers pay tokens to seeders for their donated bandwidth. Tokens are stored on our irrefutable blockchain fabric: *TrustChain*. Bandwidth tokens can be traded for other currencies on our decentralized exchange.

and slower speeds. Token payout to providers is based on deferred, aggregated payments to obfuscate exchange of bandwidth between content providers and consumers [5].

Bandwidth tokens can be sold on a two-sided decentralized asset exchange for Bitcoin or other cryptocurrencies. This allows content consumers that are refused services by others, to restore their bandwidth token balance by buying additional ones. Trade proceeds without any central clearing house and all market activity is recorded on a modified TrustChain structure: *TradeChain*. TradeChain, like TrustChain, allows efficient detection of fraudulent behaviour. A novel technique called *incremental settlement* is used when initiating a trade and exchanging assets. Instead of transferring assets immediately, we divide each trade into multiple transactions. This reduces counterparty risk, at the possible expense of additional transaction fees. Trustworthiness of traders is quantified with a scalable and Sybil-resistant reputation mechanism, based on PageRank [6].

Mining, spending and trading of bandwidth tokens are key functionalities of our micro-economy. This work combines a decade of research in distributed systems into a functional system, ready for a large-scale deployment and scientific evaluation during the coming months.

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