Local Production, Local Consumption Storage Economics for Peer-to-Peer Systems

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Abstract

Autonomy of peer-to-peer (P2P) systems requires some form of economies. Forwardable storage claims of Samsara[1] can define a common value in computer networks, and possibly be a "commodity money"[1] in P2P systems. However, without managing how far the claims can be forwarded, they would not form an efficient, dependable and sustainable economic chain.

We propose to use i-WAT[5] tickets to represent storage claims to form "drafts in real terms"[2] so that a claim can be dynamically replaced by its equivalent in the vicinity, allowing the accesses to the storage to be fast and robust.

1 Introduction

1.1 Needs for Peer-to-Peer Economies

Designs of P2P systems are characterized by their usage of overlay networks such that participants can potentially take symmetrical roles. This implies distribution of authorities, not only preventing introduction of single points of failure, but also possibly assuring the level of autonomy for self-organization, where any subsystem can spontaneously start, maintain itself, or recover from its failures.

To make use of under-utilized computing resources in such an environment, since the resources are distributed over autonomous entities, exchanging needs to be performed in an incentive-compatible way: the coordination must be accomplished by collection of selfish behaviors.

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[1]Money whose value comes from the commodity itself. For example, in old Japan, rice was a common value being used as a medium of exchange; anyone (any farmer) with facilities to produce rice could generate a medium of exchange themselves.

[2]Drafts exchangeable with a common value other than money. For example, in old Japan, a certificate to receive a specific amount of rice of a specific grade was also used as money. If we are to receive rice in exchange for such a medium, the nearer the producer is, the cheaper the transactional cost is. Therefore this medium implied the concept of LPLC.

1.2 Problems

1. We need an economy to avoid the tragedy of the commons[3], in which the shared resources are depleted through over-exploitation because participants are motivated to maximize their own benefits while the costs of exploitation are equally distributed among them; we need an economy that does not tolerate those participants who do not pay appropriate costs in return for their benefits.
2. This economy needs to be autonomous, efficient and tolerant of failures.
3. This requires an exchange medium conforming to the principle of local production, local consumption (LPLC)[6] – what consumed locally are to be produced locally, and only when they are unavailable, they are to be conveyed from the nearest producers.

1.3 Contributions of This Work

Recent studies in P2P economics have shown that a decentralized digital medium of exchange is possible by representing debts: Samsara[1] and *i*-WAT[5] are two examples. But, Samsara alone cannot implement LPLC, and *i*-WAT does not have a credible way to bind debts with resources.

This work is an attempt to design a new medium of exchange for P2P systems, called *Storage-Standard Currency (SSC)*, based on storage claims adopted from Samsara, and representing them in the form of digital tickets adopted from *i*-WAT. The medium conforms to the principle of LPLC.

Possible applications of this work include any P2P activities, such as file sharing, data aggregation/dissemination, bandwidth sharing and distributed computing.

2 Background

2.1 Samsara

Design of Samsara (Figure 1) is based on an observation that symmetry is rarely found in P2P exchanges, and that

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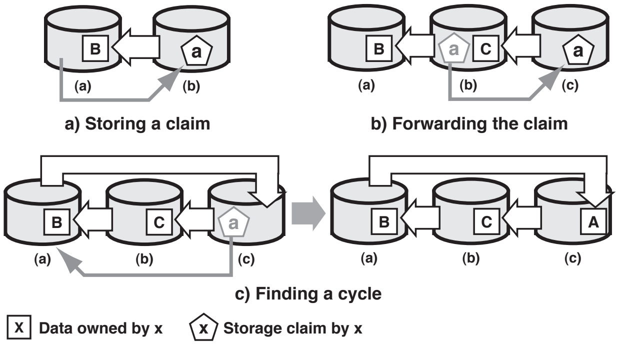
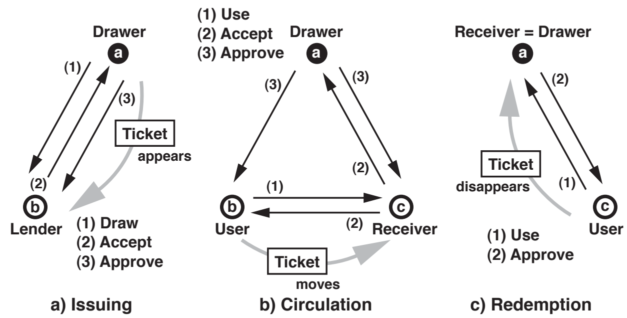


a) Data B is stored in (a) for (b). Peers (a) and (b) create symmetry in their transactional relation by placing a storage claim a on (b).

b) Instead of doubling the required storage, the claim a is forwarded to (c) in return for storing its data C in (b).

c) The claim a disappears when forwarded to the original claimer (a).

Figure 1. Overview of Samsara



a) Drawer (a) issues a ticket in return for a service from (b).

b) When the ticket is transferred to a third party (c), the transaction needs to be approved by the issuer (a) to detect double-spending.

c) The ticket disappears when it returns to the original issuer (a).

Figure 2. Overview of *i*-WAT

symmetry can be manufactured. In Samsara, each peer that requests storage of another must agree to hold a *claim*, or an incompressible placeholder, in proportion to their consumption. Claims can be forwarded along the chain of nodes that requests storage of another, eliminating themselves when cycles are found.

Upon forwarding a claim, a peer may want to strategically withhold a copy of the claim, because the peer is responsible for answering queries[3], and the node to which it has forwarded the claim may fail at any time.

This means that consumption of storage is duplicated as the claim forwarding chain is lengthened.

2.2 *i*-WAT

i-WAT (Figure 2) is an electronized version of the WAT System, a real-life barter currency using a physical sheet of paper resembling a bill of exchange (*WAT ticket*).

In *i*-WAT, messages signed in OpenPGP are used for implementing transfers of an electronic version of WAT ticket (*i-WAT ticket*). An *i*-WAT ticket contains a unique number, amount of debt and public key user IDs of the drawer, users and recipients. Endorsements are realized by nesting PGP signatures over canonical XML expressions.

In case the drawer fails to meet their promise on the ticket, the lender assumes the responsibility for the debt. If the lender fails, the next user takes over. The responsibility follows the chain of endorsements (*security rule*). The longer the chain is, the more firmly backed up the ticket is.

[3]The queries are made based on the *claim seed* that was used for generating the claim. To respond to the queries, a node needs to physically store the claim, thus guaranteeing that the space is reserved.

3 Design

3.1 Storage-Commodity Money (SCM)

Samsara's storage claims can be forwarded in exchange with services other than storage, making them commodity money in the context of P2P (Figure 3).

This commodity money has a unique property of service and the medium moving in the same direction. This has an interesting consequence; double-spending is naturally avoided because the medium of exchange is held by the producer of a service instead of a consumer when exchanging is taking place. The consumer cannot *double-receive* the medium to receive the service without paying the cost.

However, this commodity money does not satisfy the principle of LPLC, as illustrated in Figure 3. Efficiency of the storage space is also a problem.

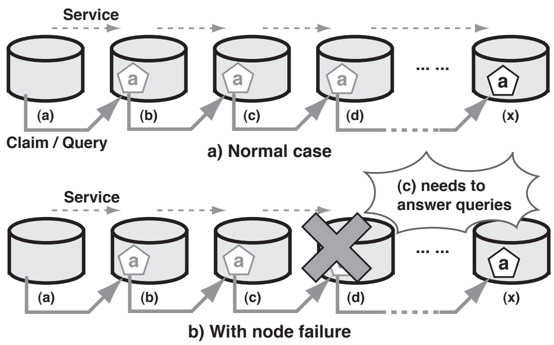
3.2 Storage-Standard Currency (SSC)

i-WAT can implement drafts in real terms in combination with storage claims, as illustrated in Figure 4.

By issuing an *i*-WAT ticket guaranteed by a storage claim, a peer in a P2P system can purchase a service from another. Those tickets can be forwarded along the chain of nodes in exchange with services, eliminating themselves when they return to their issuers.

The security rule of *i*-WAT allows the storage claim to be backed up, as illustrated in Figure 4 b).

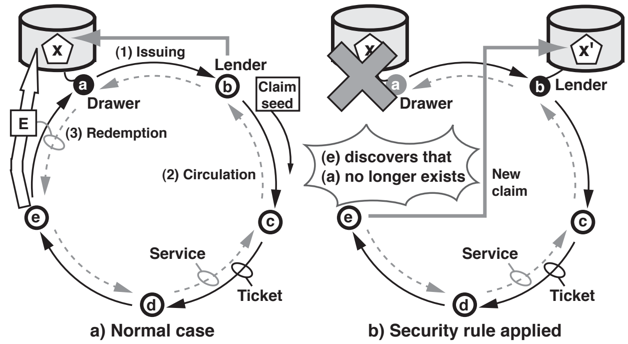
Satisfaction of LPLC Every drawer (therefore the claim holder) advertises their storage capability that they can lend to others to induce redemption of their debts. The peers in



a) The remote storage is likely to be departed from the vicinity of the original claimer (a) as the claim a keeps getting forwarded.

b) The strategy for the peers (b)∼(x) is to keep a copy of the claim a in their storage in case some node in the chain fails.

Figure 3. Storage-commodity money



a) Upon (a) issuing a ticket, the lender (b) requests the drawer (a) to store a storage claim x. Circulation of the ticket involves circulation of the claim seed for x so that receivers of the ticket can query the drawer (a) for the claim x. Upon redemption, the user (e) can have the drawer (a) store its data E.

b) If the drawer (a) fails, the current owner (e) of the ticket requests the lender (b) to store a new storage claim x' compatible with x in place of the drawer (a).

Figure 4. Storage-standard currency

need for a remote storage space listen to the advertisements. When they find one in the vicinity of their location in the logistical network, and if the space is compatible with what is claimable by the ticket they have, they try to rent the space by the ticket.

4 Simulation

A simulation is made under the premises that 1) A proximity-based overlay network is formed, 2) The underlying network has alternative routes, and a node is unreachable only when it is offline, and 3) There is a way to authenticate the identity of a node[4].

4.1 Conditions

The world consists of population P of one of the types (SCM, Simple SSC or LPLC SSC nodes) described below, where time elapses from 1 to r rounds.

- Each node needs to rent maximal k storage units from others. A rent of just one unit can start in one round, and the rent can last for n rounds.
- Each node has k storage units to provide to others.
- Each node is offline in a round by probability p (*failure rate*). The availability of the remote storage is $1 - p$.

SCM: A node tries to rent the storage unit for which it has a storage claim. If it does not have a claim, it tries to rent a unit from a node in vicinity, and stores the claim specified by the remote node. The remote node tries to avoid forwarding claims, and creates a new claim whenever possible.

Simple SSC: A node tries to rent the storage unit for which it has a ticket. If it does not have a ticket, it tries to rent a unit from a node in vicinity, and issues a new ticket (and therefore stores a new storage claim) for the remote node[5].

LPLC SSC: A node tries to rent the nearest remote storage unit that is equivalent to the promise (always 1 storage unit in this simulation) on a ticket it has, and transfers the ticket in return to the remote node. The remote node can lend the unit in which it holds a storage claim; in which case the claim is forwarded to the drawer of the received ticket as a form of redemption.

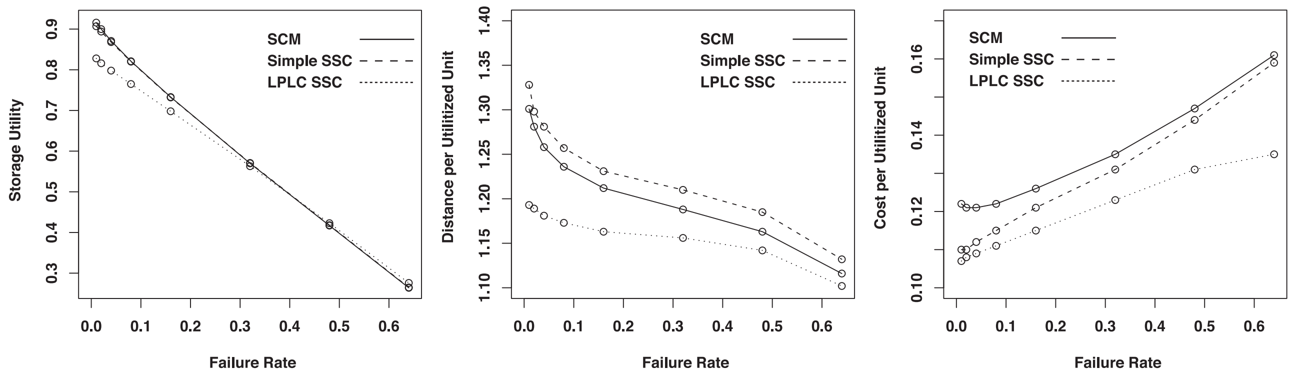
4.2 Evaluation Criteria

Storage Utility: The number of storage units provided to others (excluding those for claims) is counted for every round, divided by the whole capacity.

Distance: The distance (in hops) to the remote storage (excluding those for claims) is counted for every round.

[4]This is to provide a relaxed trust condition so that Samsara nodes do not need to duplicate storage claims or forward data along the chain of nodes, and the simulation results can be comparable with those of SSC, making a pure comparison of claim-forwarding vs. currency approaches.

[5]At the level of this abstract simulation, the behavior of a simple SSC node equals to that of a SCM node without claim-forwarding.



$P = 250, r = 500, k = 5, n = 5, p \in \{0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.48, 0.64\}$.

Figure 5. Simulation Results

Cost: One unit of cost is counted for every occasion of forwarding a storage claim[6].

4.3 Results

Figure 5 shows the results of the simulation. SCM and Simple SSC nodes can maintain above 90% of storage utility when the failure rate is negligibly low. LPLC SSC nodes provide slightly less storage utility, but are less affected by the rate of failures, and in fact provide higher storage utility than others when the failure rate is above 0.4 (the condition is not unrealistic considering the dynamism of P2P systems). LPLC SSC nodes always provide storage with shorter network distance and with smaller transfer cost, regardless of the failure rates.

5 Related Work

Feldman et al.[2] investigates incentive techniques to tackle the problem of free-riding. They found that when penalty is imposed on all newcomers, the system performance degrades significantly only when the turnover rate among users is high. This observation can be applied to this work in such a way that all peers start with relatively small number of trusted acquaintances when joining the network; having a few opportunities for trades is a kind of penalty.

6 Conclusions

This work presented two designs of exchange media based on representation of debts to be used in P2P economies. Forwardable storage claims in Samsara can form a commodity money in P2P systems. However, it does not satisfy the principle of LPLC. On the other hand, in SSC, *i*-WAT tickets represent storage claims to form drafts in real terms, so that a claim can be dynamically replaced by its equivalent in the vicinity, allowing the accesses to the acquired remote storage to be fast and robust.

A simulation showed that SSC nodes satisfying LPLC can provide remote storage in more proximity (and thus expected to provide faster accesses to the storage), which is less affected by the rate of failures, than SCM nodes do.

A work[4] is ongoing to implement SSC over an existing reference platform of *i*-WAT, using which we will continue our study of the LPLC storage economics of P2P systems.

[6]Cost of messaging (multiples of tens of bytes) should be negligible compared to that of claim-forwarding (multiples of megabytes).

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