Market Design for a P2P Backup System
(Extended Abstract)⋆

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1   Introduction: A P2P Backup System

Peer-to-peer (P2P) backup systems are an attractive alternative to server-based systems because the immense costs of large data centers can be saved by using idle resources on millions of private computers instead. This paper presents the design and theoretical analysis of a market for a P2P backup system. While our long-term goal is an open resource exchange market using real money, here we consider a system where monetary transfers are prohibited. A user who wants to backup his data must in return supply some of his resources (storage space, upload and download bandwidth) to the system. We propose a hybrid P2P architecture where all backup data is transferred directly between peers, but a dedicated server coordinates all operations and maintains meta-data. We achieve high reliability guarantees while keeping our data replication factor low by adopting sophisticated erasure coding technology (cf., [2]).

The Market Design Problem. Using decentralized peers to store data also comes at a cost, raising two market design challenges regarding *incentives* and *efficiency*. Every user must provide a certain amount of all three resources, even if he currently only consumes one or two resources. Consequently, balancing a user's consumption and supply *per resource* does not make sense. Furthermore, it is natural that each user has different preferences regarding how much of each resource he wants to supply. Thus, a rigid accounting system that enforces the same resource ratios across all users is undesirable. Consequently, a sophisticated mechanism is necessary to first elicit users' preferences regarding their resources and then assign work to users in a way that maximizes overall efficiency.

Related Work. One of the early research projects investigating distributed file systems was Farsite [2]. However, in Farsite there were no incentives for users to contribute their resources. More recently, researchers have looked at the incentive problem and proposed market-based solutions (e.g., for computational

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⋆ A long version is available at http://eecs.harvard.edu/~seuken/AMMA09_long.pdf

grid networks). The proposed solutions, however, generally require sophisticated users able to specify bids in an auction-like framework. The two papers most similar to our work are [1] and [3]. They analyze exchange economies for improving the efficiency of file-sharing networks. While the domain is similar to ours, however, the particular challenges they face are quite different.

2   Research Contributions

In this paper we make five key contributions regarding P2P backup systems:

1. **Design:** We present the complete design of a P2P resource exchange market including a server-based framework for decentralized resource supply and service consumption, an accounting system, and a work allocation method.
2. **User Interface:** We present a UI that hides the market from the user (see Figure 1). The design challenge was to provide market information to the user and to elicit the user's preferences with as little interaction as possible.
3. **Equilibrium Analysis:** We introduce the concept of a "buffer equilibrium", a desirable state of the system that is reached when the ratio of demand and supply is the same for all three resources. We formally prove existence and uniqueness of the buffer equilibrium under quite general assumptions.
4. **Price Update Algorithm:** We present a price update algorithm that uses supply and demand information to move prices towards the equilibrium. We prove analytically and show via simulations that the algorithm converges to a buffer equilibrium under some technical assumptions.
5. **Payment Mechanism:** We introduce a sophisticated payment mechanism that addresses various incentive problems that arise in practice.
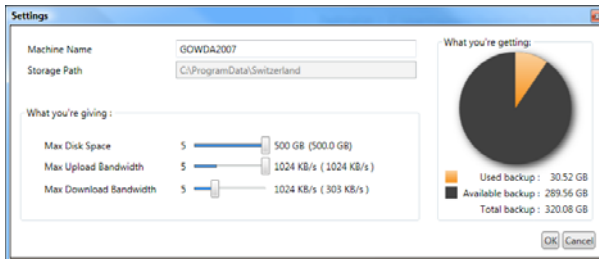

Fig. 1. Screenshot of the Current User Interface: The Settings Window

3   Future Work

The market design described in this paper is already implemented as part of a P2P backup system under development at Microsoft Live Labs. Thus, we are able to complement the theoretical analysis with discussions of implementation challenges. An alpha version of the software has already been released to Microsoft employees. We are currently collecting data on supply, demand and price developments over time to perform an empirical analysis of this market.

References

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