

Game Theoretical Analysis of Resource Allocation in the InterPlanetary File System

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TBD

Background

IPFS (InterPlanetary File System)

- P2P hypermedia distribution protocol
- Content-addressed, versioned filesystem
- Git repo in a torrent
- Many use-cases
 - **Goal:** Replace HTTP, decentralize Internet

IPFS Stack

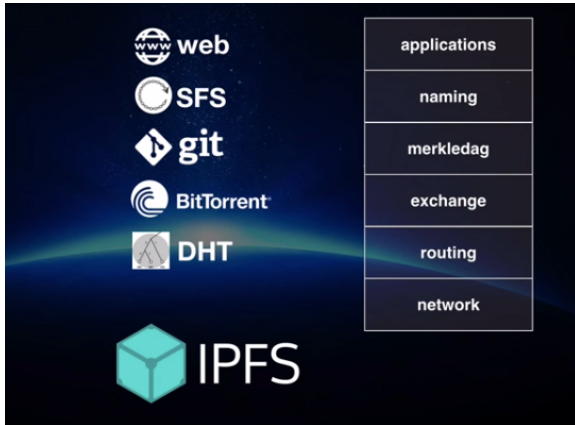


Figure 1: The IPFS Stack

Bitswap

- IPFS's block exchange protocol
- Inspired by BitTorrent
- *Given a set of peers who want data, how to allocate resources?*
 - Reciprocation function

Bitswap

Given a set of peers who want data, how to allocate resources?

- Every user maintains reputation for each peer
- Very complex dynamics

Objectives

TODO: describe using terminology defined already, no more

- Classify Bitswap strategy functions
 - Conditions where useful
- **Analytical work:** Repeated game model
- **Empirical work:** Simulations

System Model

IPFS Network as Graph

- *Nodes*: Users
- *Edges*: Peerings; unweighted, undirected

Reputation

- b_{ji}^t : Total bits sent from user j to peer i from round 0 to $t - 1$
- d_{ji}^t : *debt ratio* j to peer i

$$d_{ji}^t = \frac{b_{ji}^{t-1}}{b_{ij}^{t-1} + 1}$$

Reciprocation Function

- *Input*: Peer debt ratio
- *Output*: Peer weight
- $S_j(d_{ji}^t, \mathbf{d}_j^{-i,t}) \in [0, 1]$
 - e.g. $S_j(d_{ji}^t, \mathbf{d}_j^{-i,t}) = d_{ji}^t$

Data Distribution

- Peers served via weighted round-robin
 - B bits distributed to peers based on relative weights

TODO: show this with math

Game Formulation

- *Players*: Users/nodes
- *Strategy*: Reciprocation function

TODO: utility function

Model Iterations

- *Complexity vs. accuracy*
- Attempted formulations
 - Evolutionary game theory
 - Statistical mechanics
 - **Repeated games**

Game Characteristics

- *Infinitely repeated*
 - Discrete rounds, denoted by t
- *Incomplete information*

TODO: remember to mention simultaneous moves

Objectives

TODO: be more clear about goals here

- Classify Bitswap strategy functions
 - Conditions where useful
- **Analytical work:** Repeated game model
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Preliminary Results

Strategy Simulator

- 3 node network
- Parameters
 - Resource distribution
 - Initial peer-wise reputations
- Tests whether given strategy function is NE

Strategy Simulator

TODO: figures illustrating full exchange example

Strategy Simulator

Conclusions

- Homogeneous resource distributions
 - Any RF (trivially) NE
- Non-homogeneous resource distributions
 - NE not yet found

Symbolic Analysis

- Verified results of strategy simulator
- Mathematica notebook
- Intractable for nontrivial strategy functions
 - **Next step:** Alternative functions/representations

Implementation

- Beta strategy-integration into go-ipfs
- IPTB: IPFS nodes in Docker containers
- Scripted tests

Plan

Analytical Work

- ① **Repeated game analysis**
 - Balances model accuracy with complexity
- ② **Evolutionary game theory** (if time allows)
 - Good model, but high complexity

Simulations

①. Strategy simulator

- Complements repeated game analysis

②. Bitswap tests

- Test actual IPFS nodes

Timeline

TODO

TODO: need this