

# 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

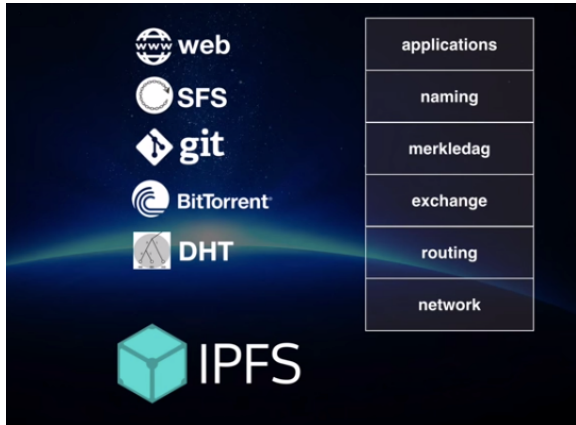


Figure 1: The IPFS Stack

# 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

- 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

# Model Iterations

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

# Game Formulation

- *Players*: Users/nodes
- *Strategy*: Reciprocation function
- *Infinitely repeated*
  - Discrete rounds, denoted by  $t$
- *Static*
- *Incomplete information*

# Goal

## TODO



## 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

# Go-IPFS and IPTB

- 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?**