# Game Theoretical Analysis of Resource Allocation in the InterPlanetary File System

David Grisham

TBD

# Background

# IPFS (InterPlanetery File System)

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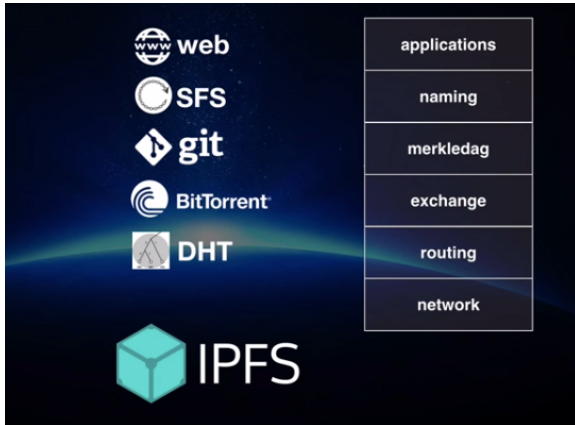    - **Goal:** Replace HTTP, decentralize Internet

## 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?*

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

## Objectives

- Discover Bitswap peer behavior that gives desired behavior
    - Will depend on conditions
    - Break down Bitswap dynamics
- Analytical and empirical analyses
- Implementation

Background
oooooo

System Model
●oooo

Game Formulation
ooooo

Preliminary Results
oooooo

Plan
ooo

Timeline
oo

# System Model

Background
oooooo

System Model
oooooo

Game Formulation
ooooo

Preliminary Results
oooooo

Plan
ooo

Timeline
oo

IPFS Network as Graph

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

## Reputation

- Each user distributes $B$ bits among peers in each round
- $b_{ji}^t$: Total bits sent from user $j$ to peer $i$ from round 0 to $t-1$
- $d_{ji}$: *debt ratio* of $j$ as viewed by $i$
  - Used as peer-wise reputation

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

## 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

$B$ bits distributed among peers via weighted round-robin

$$w_{ij}$$

**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
- **Empirical work:** Simulations

# 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

**❶ Repeated game analysis**
  • Balances model accuracy with complexity
**❷ Evolutionary game theory** (if time allows)
  • Good model, but high complexity

## Simulations

❶ **Strategy simulator**
   • Complements repeated game analysis
❷ **Bitswap tests**
   • Test actual IPFS nodes

# Timeline

## TODO

**TODO: need this**