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

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

Background
oooooo

System Model
●ooooo

Preliminary Results
oooooo

Plan
ooo

Timeline
oo

System Model

Process

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

IPFS Network as Graph

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

Background
oooooo

System Model
oooo●oo

Preliminary Results
oooooo

Plan
ooo

Timeline
oo

Game

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

Reputation

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

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

Strategy

- Reciprocation function
    - *Input*: peer debt ratio
    - *Output*: peer weight
    - $S_j(d_{ji}^t, \mathbf{d}_j^{-i,t}) \in \{0, 1\}$
- Peers served via weighted round-robin

Background
oooooo

System Model
oooooo

Preliminary Results
●ooooo

Plan
ooo

Timeline
oo

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

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?