Game Theoretical Analysis of Resource Allocation in the InterPlanetary File System

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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

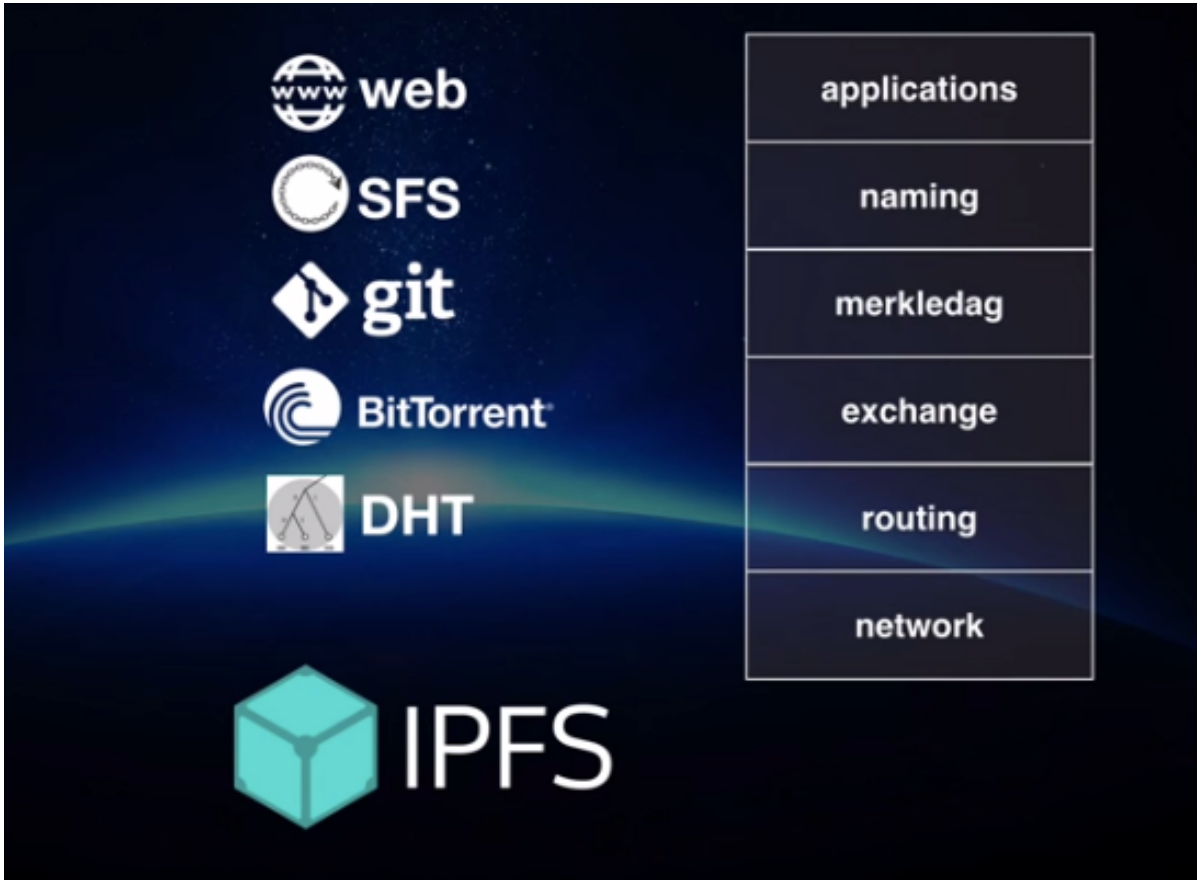

Figure 1: The IPFS Stack

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

System Model

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

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