Incentives for Cooperation in the Internet

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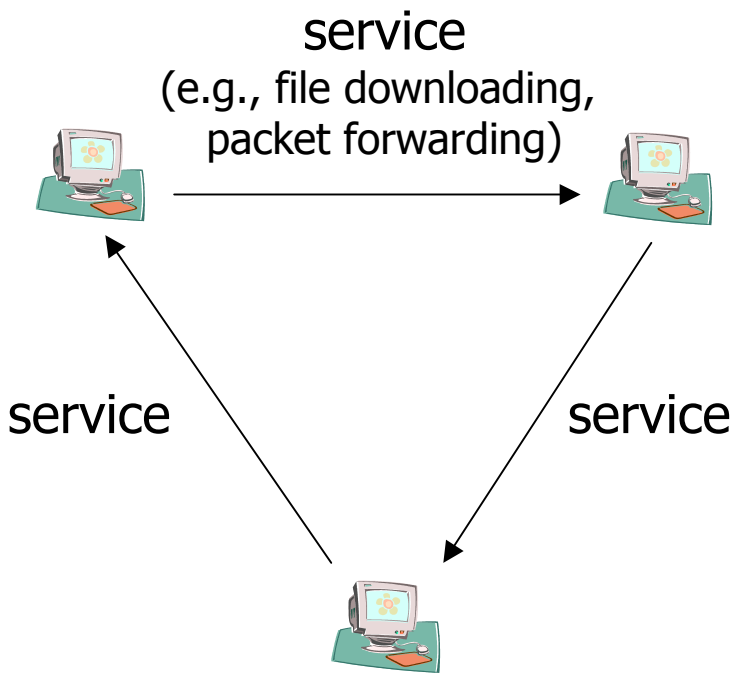
Cooperation and P2P

- Higher cooperation → higher P2P performance
  - file sharing: more sharing → lower latency
- But, cooperation is not automatic
  - freeriding
- Need an incentive system to increase cooperation

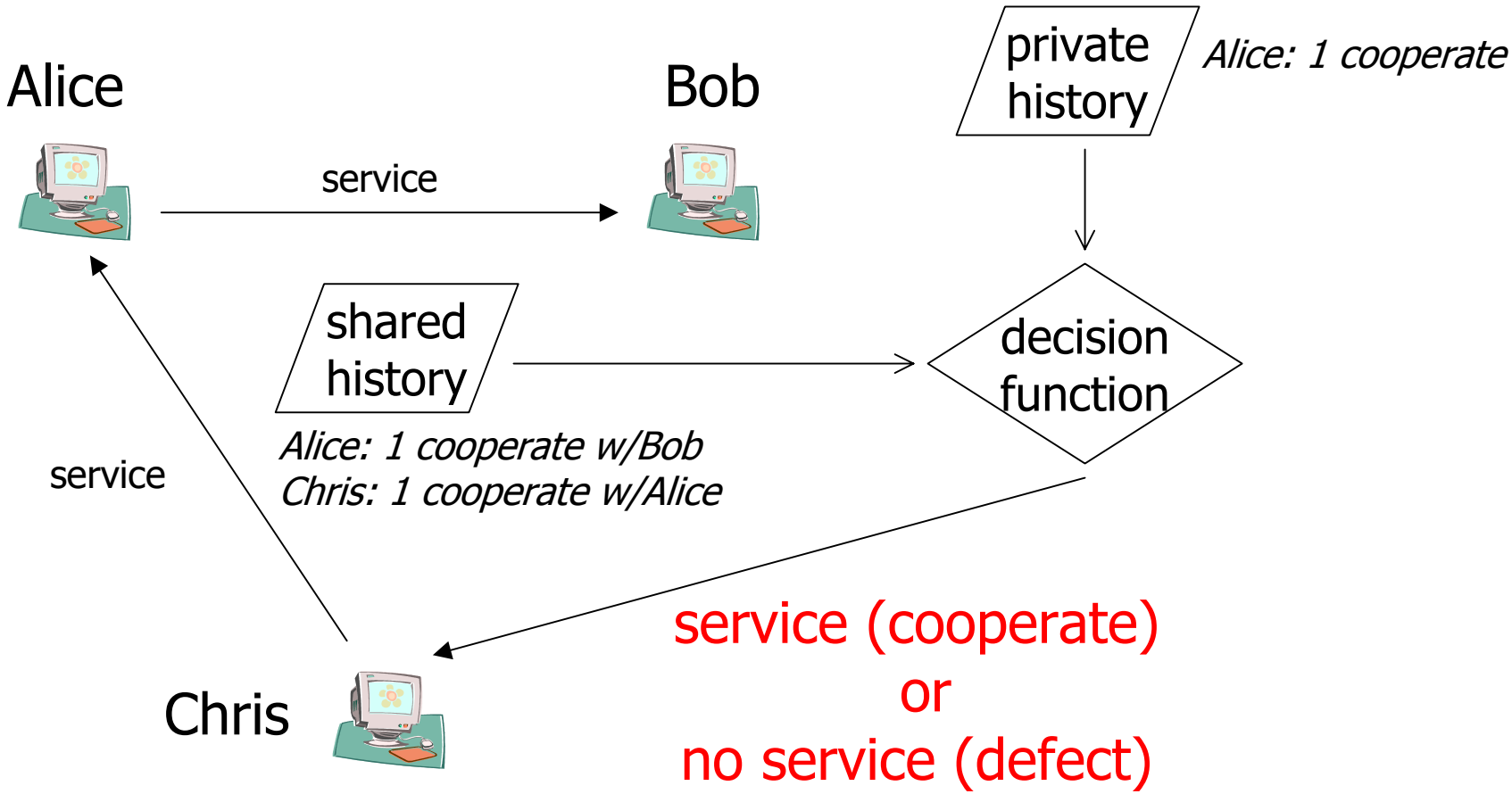


Oath

- Goal: design an incentive system applicable to many applications
  - P2P storage
  - wireless adhoc forwarding
  - grid/utility computing
  - online auctions
  - discussion forums
- First step (of many): understand the tradeoffs in the design space of solutions

Oath Architecture

- Keep track of nodes' actions and give them what they themselves have given



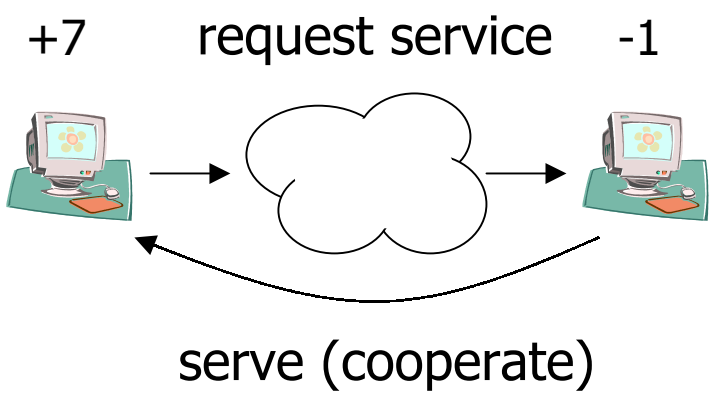
Internet Incentive Challenges

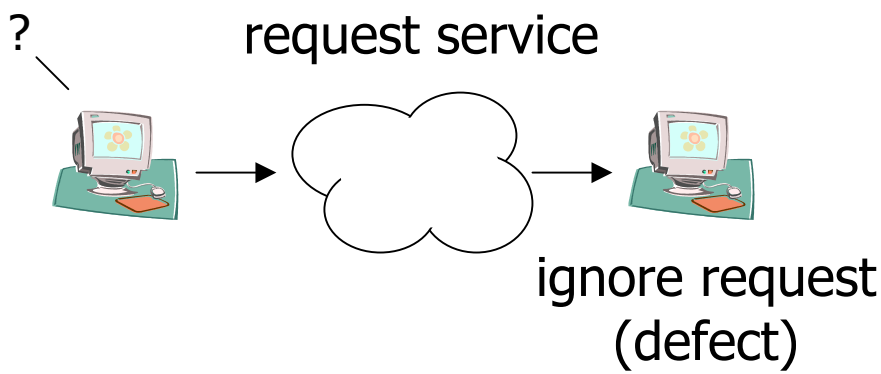
- **scalability**
  - file sharing networks have >100,000 participants
- **zero-cost identities**
  - being able to easily change identities subverts history
- **collusion**
  - cannot verify records in shared history

Outline

- Model
  - Generalized Evolutionary Prisoner's Dilemma
- Decision Function
  - Reciprocative
- Scalability
  - benefit of shared history
- Zero-cost identities
  - adapt to friendliness of strangers
- Collusion
  - subjective reputation

Generalized Evolutionary Prisoner's Dilemma (GEPD)





- Client requests service
- Server chooses to serve or not
  - based on its strategy and history
- Client benefits from service
- Server pays service cost
- Client cannot trace defections
- Peers change to higher scoring strategies in proportion to the difference in scores

GEPD Properties

- Defection is dominant action for 1-shot game
- Universal defection ruins overall score
- Captures essential tension of cooperative applications
- Flexible
  - assignment of payoff matrix
  - definition of cooperation and defection
  - behavior of strategies

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Decision Function

- Require: converge to cooperation, robust against defection strategies
- Tit-for-Tat: *do to the peer what he last did to me*
  - not effective with shared history, requires tracing of server defections
- Reciprocative: *Cooperate with entity X with probability*

$$\min\left(\frac{cooperation\_X\_has\_given}{cooperation\_X\_has\_received},1\right)$$

  - can use shared history, does not require tracing of server defections

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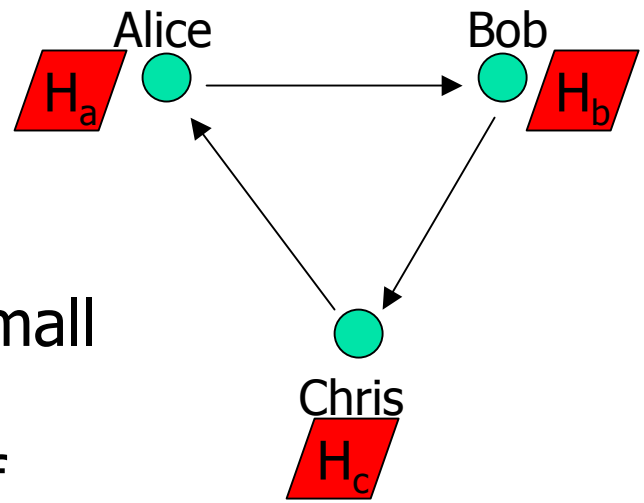
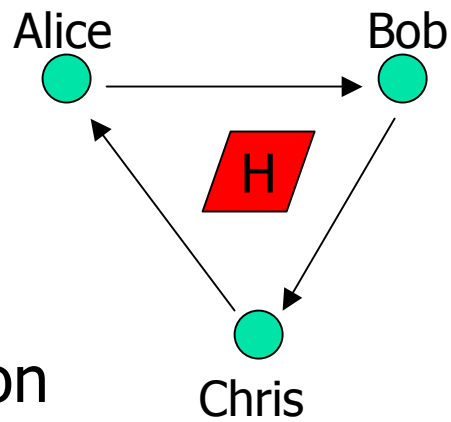
Private History

- advantages
  - implementation is simple and decentralized
  - immune to collusion
- disadvantages
  - requires repeat transactions
    - e.g., low rate of turnover, small populations
  - deals poorly with asymmetry of interest



Shared History

- advantages
  - tolerates few repeat transactions (large populations, high turnover)
  - tolerates asymmetry of interest
- disadvantages
  - susceptible to collusion
  - implementing write-once abstraction requires overhead or centralization:
    - e.g., DHT-based storage w/replication



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Zero-Cost Identities

- History assumes that entities maintain persistent identities
- Problem: most online systems have zero-cost identities
  - lowers bar to entry
  - allows pseudonymity through multiple identities
  - circumvents history-based strategies that always cooperate with strangers
- Whitewash: *100% defection, continuously changes identity*

Stranger Policies

- Always defect
  - forces newcomers to allow exploitation by existing players
  - raises bar for entry
- Adaptively cooperate
  - separately estimate stranger friendliness

$$\min\left(\frac{cooperation\_strangers\_have\_given}{cooperation\_strangers\_have\_received},1\right)$$

  - only taxes newcomers when necessary
  - achieves highest level of cooperation

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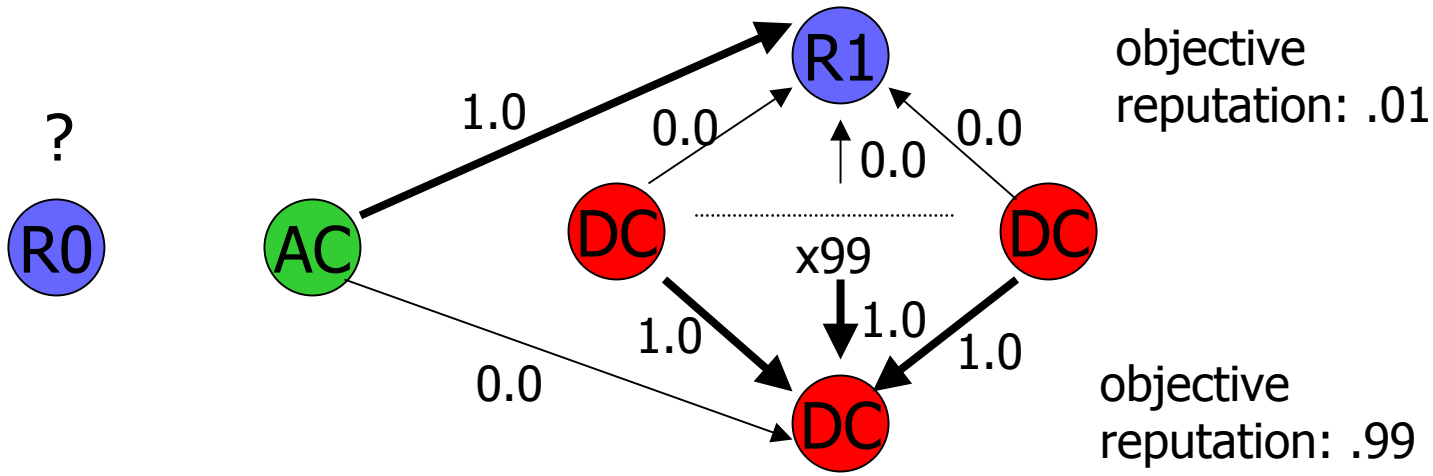
Collusion



- Secure shared history can still be subverted
  - positive collusion
    - Defecting Colluder: *100% defect and claim other colluder gave +100 cooperation*
    - combine with zero-cost identities = Sybil attack [Douceur 2002]
- Most existing reputation systems are vulnerable or depend on trusted infrastructure

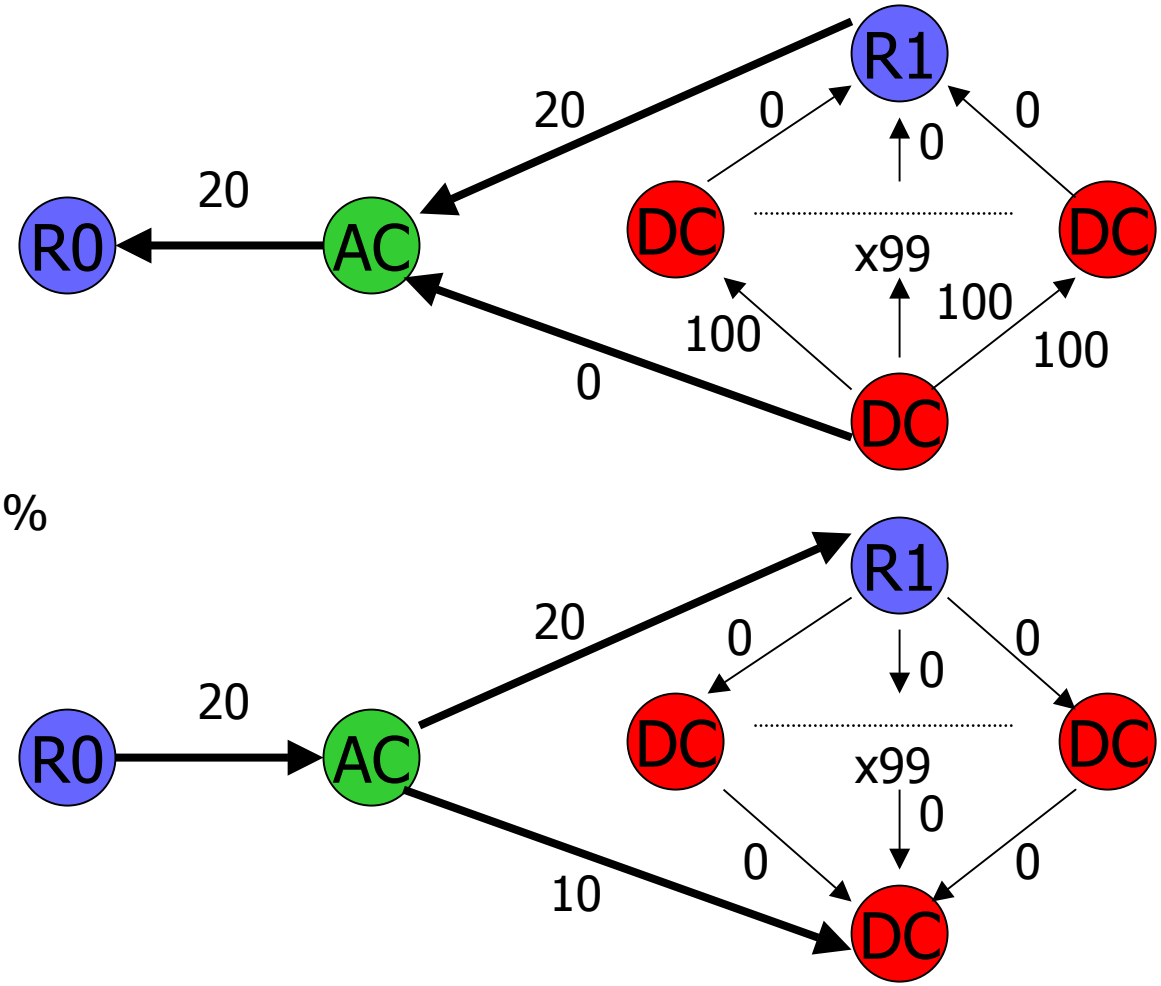
Subjective Reputation

- Objective reputation is meaningless
- Need to account for who is reporting history
  - weigh nodes by how much they have contributed to source
- Calculate how much sink has benefited source, however indirectly
- Compute *max flow* from source to sink
  - *max flow:* using any number of paths, compute the maximum capacity from the source to the sink

$$\min\left(\frac{MAXFLOW\_from\_X\_to\_Y\_of\_cooperation\_X\_has\_given}{MAXFLOW\_from\_Y\_to\_X\_of\_cooperation\_X\_has\_received},1\right)$$

Subjective Reputation Example

max flow DC→R0: 0
max flow R0→DC: 10
R0 cooperates w/DC: 0%



Subjective Properties

- resists any number of colluders
- fully decentralized
  - no trusted peers, infrastructure, etc.
- running time
  - worst case: O(VE)
  - incrementally: O(V)
  - bounded accuracy: O(1)

Recent Related Work

- Prisoner's Dilemma
  - Ranganathan, Ripeanu, Sarin, Foster
- Shared History / Distributed Reputation
  - Dingledine, Mathewson, Syverson
  - Dutta, Goel, Govindan, Zhang
  - Vishnumurthy, Chandrakumar, Sirer
- Stranger Policy
  - Rosenthal, Roussopoulos, Maniatis, Baker
- Intelligent Selection
  - Asvanund, Bagla, Kapadia, Krishnan, Smith, Telang

Conclusion

- Gain the benefits of shared history
  - scalability, tolerates high turnover
- Without the vulnerabilities
  - adaptive stranger policy
  - subjective reputation