Decentralized Lightweight Methods for Coordination in Peer-to-Peer Networks

Stefano Arteconi

Ph.D. Thesis Proposal

Bologna, 28/03/06

Outline

- ## Problem
  - ☐ Coordination and cooperation in Peer-to-Peer (P2P) networks

- ## Proposed Approach
  - ☐ Slacer algorithm

- ## Open Issues
  - ☐ Detecting cheating nodes

- ## Future Work
  - ☐ Distributed motif analysis

Stefano Arteconi

P2P Networks

- No distinction between client and server
  - Every node is able to ask for and to provide certain services

- Overlay (physic links assumed)
  - Overlay links: logical labels
  - Network topology easy to modify

- Open systems
  - No centralized control
  - Possibility of free-riding

Slacer: Introduction

- Evolutionary algorithm
- Inspired by computational sociology
  - Tag systems
- Tested with Prisoners' Dilemma
  - Simple 2-players game
  - Represents contradiction between selfish and global interest

Slacer: Outline

- Nodes characterized by
  - Strategy: application level behavior
  - Utility: application level performance measure
  - View: list of immediate neighbors
    - Analogous of tags in original tag systems
- Nodes selfishly try to increase their utility
  - Better performing nodes are copied

Slacer: Pseudocode

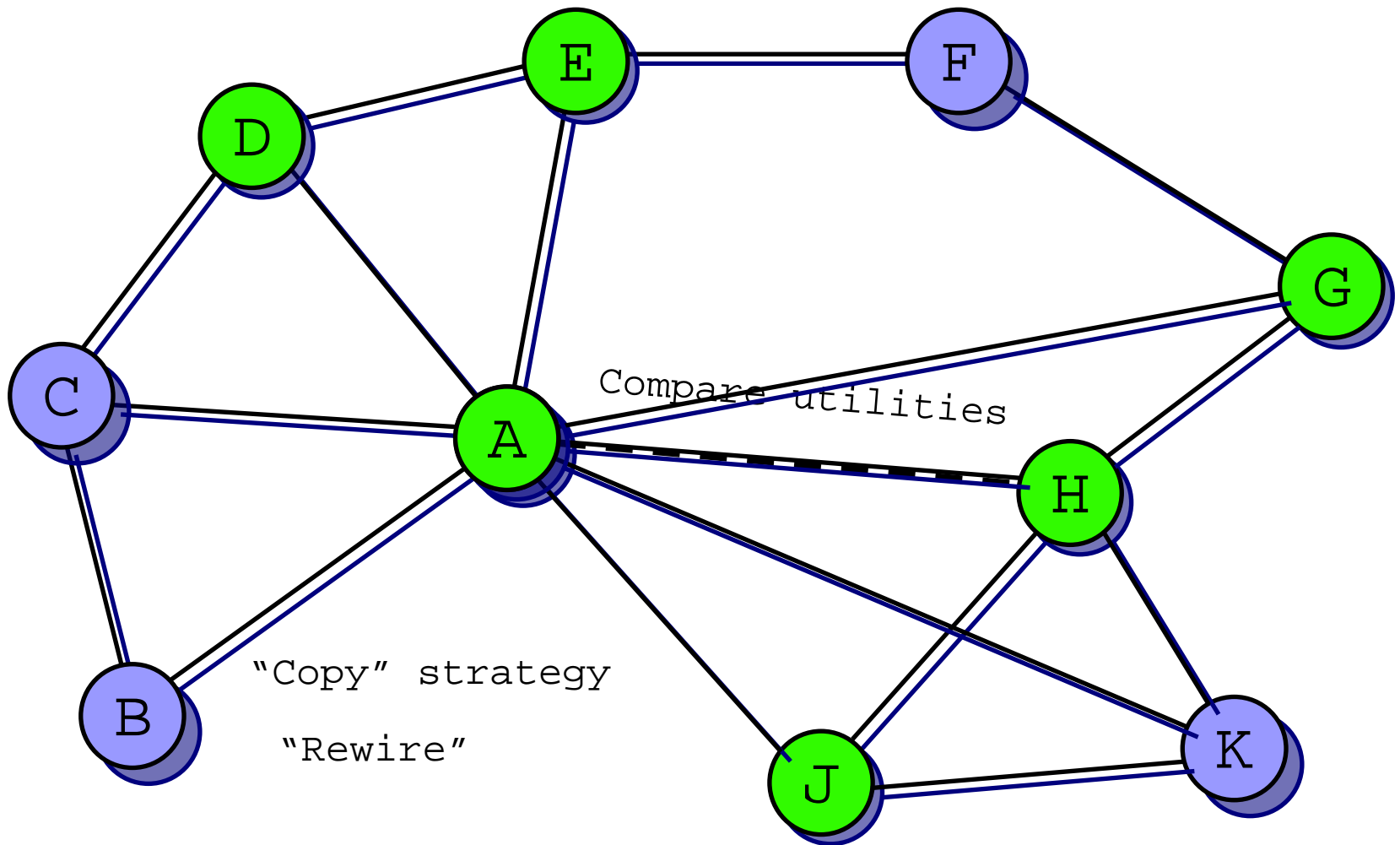Generic node p periodically executes the following:

q = SelectPeer()
if utility$_q$ > utility$_p$

   drop each current link with (high) probability W

   link to node q and copy its strategy and links
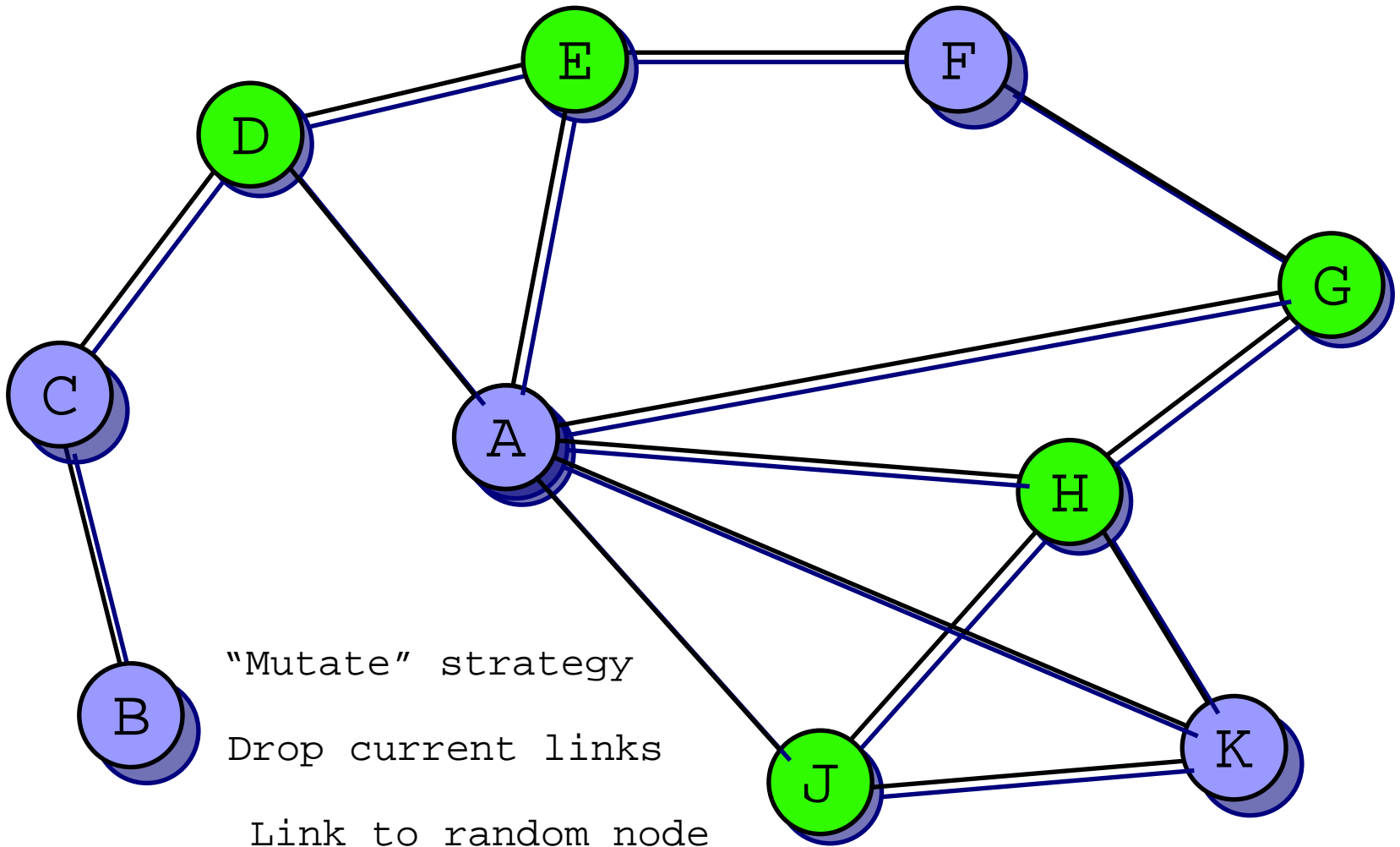
   mutate (with low probability) strategy and links

fi

   SelectPeer() function based on a peer sampling service
   (*Newscast*) separated from *Slacer* topology

Slacer: Copy and Rewire

Compare utilities

"Copy" strategy

"Rewire"

"Mutate" strategy

Drop current links

Link to random node

Slacer: Performance

- Slacer produces cooperation in P2P networks
  - ☐ Totally decentralized algorithm
  - ☐ Based only on local interactions
- High cooperation achieved even when starting from total defection

Cheating Nodes in Slacer

- Slacer is based on utility comparison and strategy copying

- Cheating nodes can easily report false state

  - Strategy

  - Utility

  - View

Different Kinds of Cheater

- **Greedy Cheating Liars (GCL)**
  - Want to maximize their own outcome
    - Gracefully degrade normal nodes' utility
    - Make cooperation faster
  - Slacer someway benefit from them!
- **Nihilists (NIH)**
  - Want to destroy cooperation
  - Big quantity of them is able to achieve that

Results: Cooperation Level

Stefano Arteconi
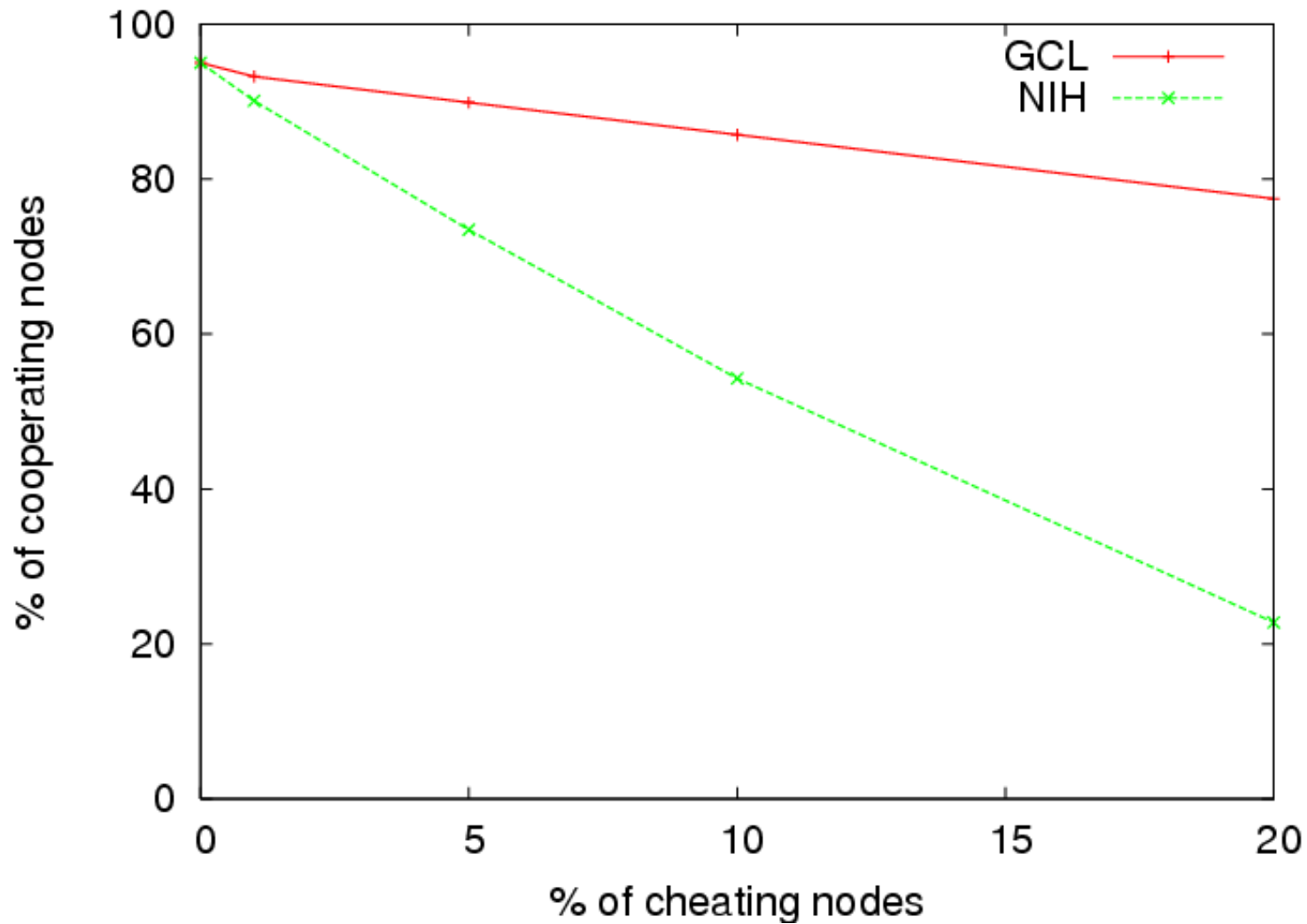
Results: Time to Cooperation
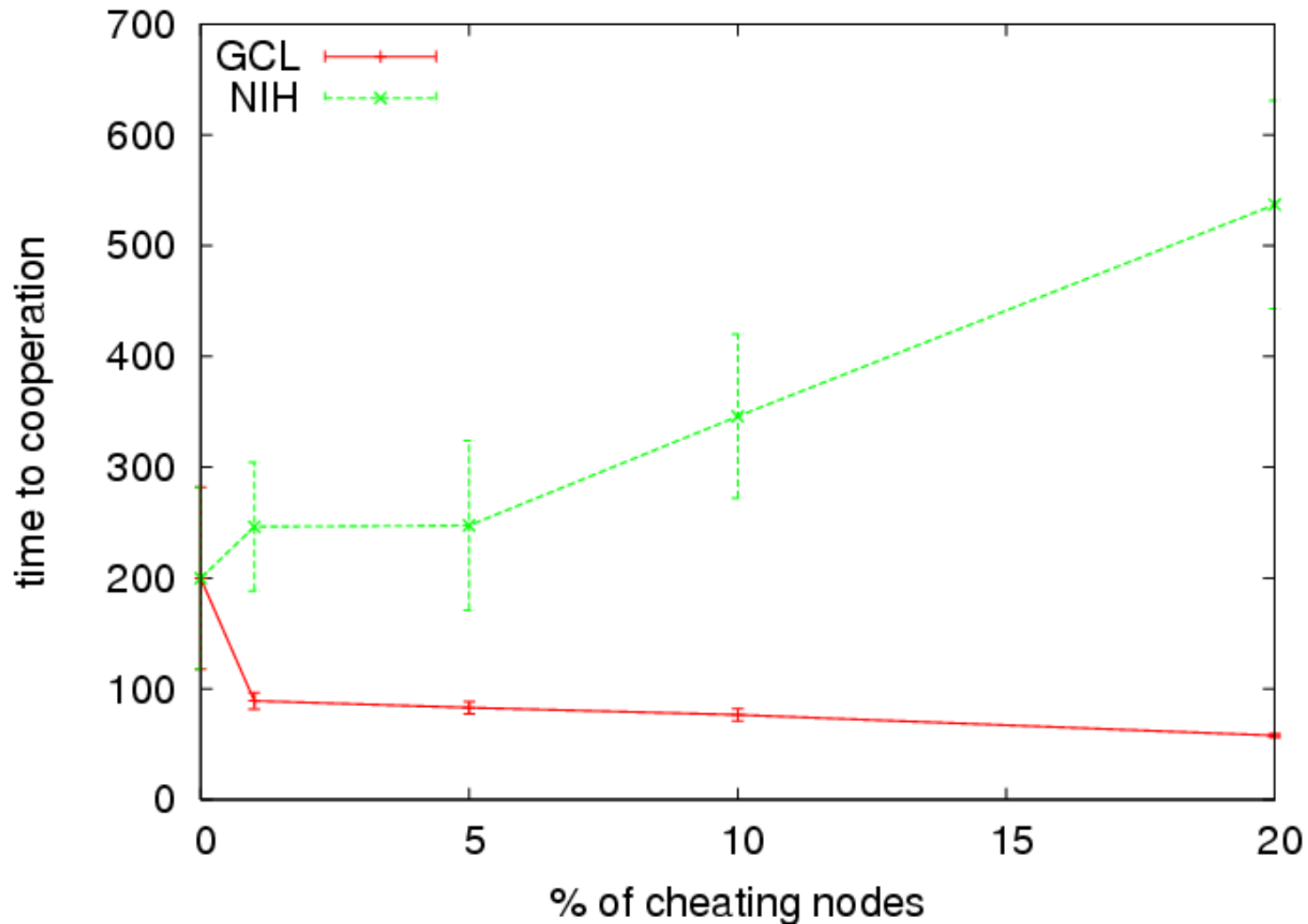
Slacer: Conclusion

- Slacer Algorithm
  - Produces cooperation
  - Lightweight
    - No nodes' history
    - No identities
- Vulnerable to certain kinds of attack
  - Nihilists nodes
  - ...

Open Issues in Slacer

- Complex and meaningful test applications
  - Coordination in PD is straightforward
    - Every node cooperates
  - Coordination could be hard in other scenarios
    - Broadcast
- Dealing with cheating nodes
  - Modify Slacer
  - Define some alternative technique to detect misbehaving nodes

Network Topology Anomalies

- Slacer nodes' behavior and performances are related to network topology
  - Report false view
  - Rewiring mechanism different from algorithm specification
  - Reject new links
  - Continuously move around the network

Network Topology Analysis

- To detect local topology anomalies classic measurement are not good
  - Clustering coefficient
  - Average path length
  - ...

- Local measurement techniques rather than global ones are needed

Motif Analysis

- ## Motif Analysis
  - Analysis of the occurrencies of small subnetworks in the whole network

- ## Used in biology
  - Small local configurations can lead to different functions and stability

- ## Slacer
 - Small local misbehavings could be detected

Network Motifs Measurement

- Small motifs (at most 4 nodes) examined
- Motifs' occurencies are counted
- Such counts are compared with those of a set of random networks
  - Same degree distribution
- A *subgraph ratio profile* (SRP) is evaluated
  - Motifs' frequency with respect to random networks average

Motifs in Slacer Topology

- Motif analysis performed on Slacer at different stages of cooperation formation
- Different SRP obtained
  - Before cooperation formation
  - During cooperation emergence
  - At cooperation stability

Stefano Arteconi

Slacer topology SRP
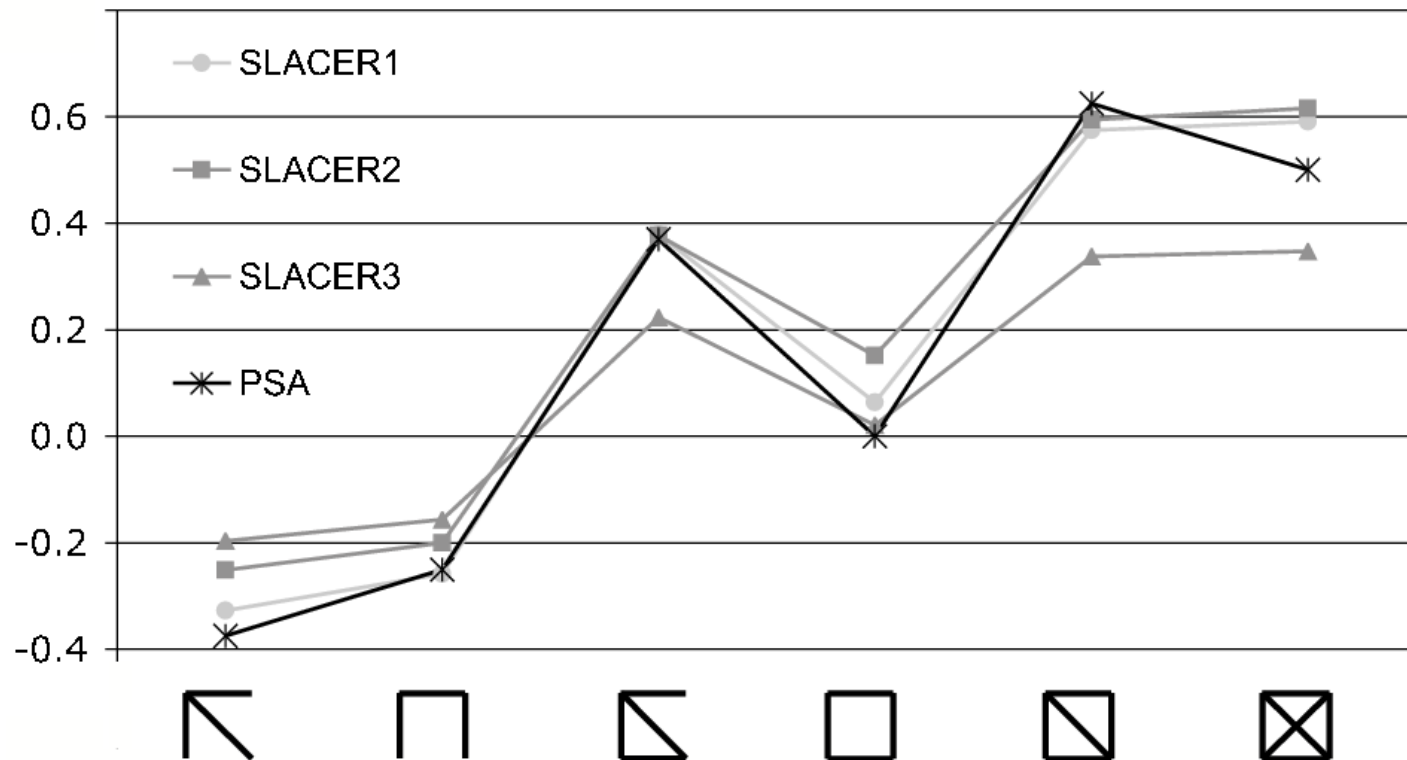
Motif Analysis as a Misbehavior Detection Tool

- Motif analysis seems a good candidate technique to detect network anomalies

- Not feasible in P2P environment

  - Global network knowledge needed

  - Heavy computation

  - Not possible to perform analysis "on the fly"

Distributing Motif Analysis

- **Requirements to perform motif analysis in a P2P network**
  - Decentralization
    - Set of local knowledges
  - Load distribution
    - Computation load to be distributed among peers

Stefano Arteconi

Local Motif Analysis

- Each node only cares about the motifs it is part of
  - Exchange view with limited number of nodes
    - Only immediate neighbors are needed for 4-nodes undirected motifs
  - Analysis performed through view comparisons
    - Check for neighbors to be linked to each other
    - Check for neighbors to share common links
    - ...

Distributed Motif Analysis Architecture

- ## Local motif count
  - ☐ Performed by each node through views exchange

- ## Global motif count
  - ☐ Obtained aggregating single nodes' local analysis
  - ☐ All the nodes become aware of the network SRP

Distributed Motif Analysis Architecture (cont'd)
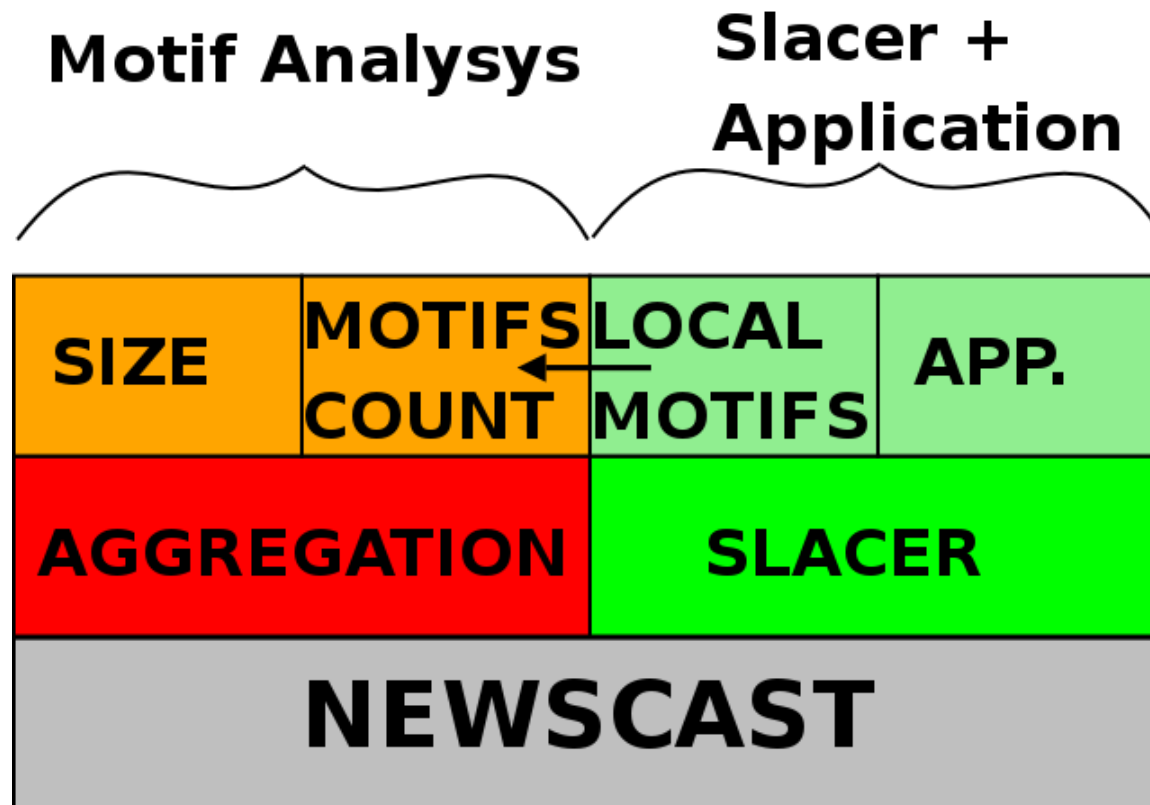
Stuff Done...

- Coordination in open P2P system
- Slacer algorithm
  - □ Cooperation in PD obtained
- Cheating nodes
  - □ Slacer is able to deal with some kinds of cheaters (GCL)
  - □ High quantity of cheaters could destroy Slacer (NIH)

Stuff To Do...

- More complex and realistic applications
  - Broadcast
  - ...
- Motif Analysis
  - Detect cheating through motif analysis
  - Need to be distributed

THANK YOU!!!