# A Decision-Analytic Approach for P2P Cooperation Policy Setting

G.Vakili[1], Th. G. Papaioannou[2], S. Khorsandi[1]
[1] Amirkabir University of Technology
Tehran – Iran
[2] Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne – Switzerland

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# Outline

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# Our Motivation & Goal

- Overall performance of P2P systems depends on resource contributions of individual peers.
- Rational peers decide on their cooperation policies according to their individual utilities.
- Inherent conflict among individual utilities of the rational peers results in
  - free-riding
  - unfair contribution
  - low participation
- Our goal is dealing with the inherent individual utility conflicts to improve overall performance of the system.

# Our Approach

- We employ decision-theory to model cooperation policy setting of participating peers:
  - Each peer chooses its strategy according to observable strategies of the other peers.
  - Through a swarm-based iterative learning process:
    - Rational peers set their cooperation policies so as to maximize their own utility.
    - Their decisions are coordinated in a distributed manner to improve the social welfare of the system.

- The game-theoretic analysis lacks an explicit and tractable handling of the individual strategy dynamics present in the interactions among individual peers

# SYSTEM MODEL

# Individual-based Lagrangian Swarm Model

- Interacting participants of a P2P system exhibit general properties of an individual based Lagrangian swarm model:
  - composed of many individual peers;
  - the interactions are based on local information exchange;
  - emergence;
  - self-organization.

- We made two modifications to adopt this model in the context of a P2P system:
  - Distributed local objectives (utility functions) are defined for individual peers.
  - The interaction of particles is represented as a non-cooperative game.

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# Definitions

- We assume that $N$ peers $p_i$ ; $i: 1,\ldots,N$ participate in the system
- Policy ($d_i$)
  - a peer's policy is its level of cooperation (a numerical assessment of the peer's contributed resources to the system)
- Strategy ($s_i$)
  - the strategy of a peer reflects its decision on the change in its cooperation level (policy)
- Utility ($U_i$)
  - A peer's utility is determined by its strategy choices and depends on several parameters - discussed as follows.

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# Utility Function

- Cost and Benefit
  - the total cost for participating in the system with cooperation level of $d_i$ will be $c_i d_i$
  - the benefit of cooperation of $p_j$ to $p_i$ is represented by $b_{ij} d_j$ ; where $b_{ij}$ is measured (e.g.) as the inverse of latency
- Incentives for high contribution
  - it is modeled by a monotonically increasing function of the cooperation policy of a peer $p_i$, denoted by $bc_i$
- Utility:

$$U_i = bc_i . \sum_{j \in N} b_{ij} . d_j - c_i d_i \qquad ; b_{ii} \equiv 0$$

# DECISION-ANALYTIC APPROACH

# Overall

- Observable strategies of other peers are monitored by each peer in a sequence of iterations.
- Based on this empirical evidence, each peer can decide rationally on a strategy in every iteration.
- This chain of decisions are made based on a method inspired by particle swarm optimization (PSO).
- Through this chain of decisions each participating peer concludes its final cooperation policy with respect to the other peers' behavior.

# More Formally

- To maximize its expected utility $U_i$ , each peer $p_i$ sets its final cooperation policy through an iterative decision making process:
  - $p_i$ monitors the strategies of the other peers in its neighborhood $N_i$ locally and evaluates their strategies.
  - It chooses its strategy $s_i^{next}$ in the next iteration with respect to the evaluation result and to its own experience:

$$s_i^{next} = s_i^{current} + r_1 c_1 (d_p - d_i^{current}) + r_2 c_2 (d_n - d_i^{current})$$

  - $d_p$ is the best previous policy of $p_i$ and $d_n$ denotes the best policy of the other peers in $N_i$.

  - Then the cooperation policy $d_i$ of peer $p_i$ is revised as follows:

$$d_i^{next} = d_i^{current} + s_i^{next}$$

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# ANALYSIS - EVALUATION

# NE Analysis

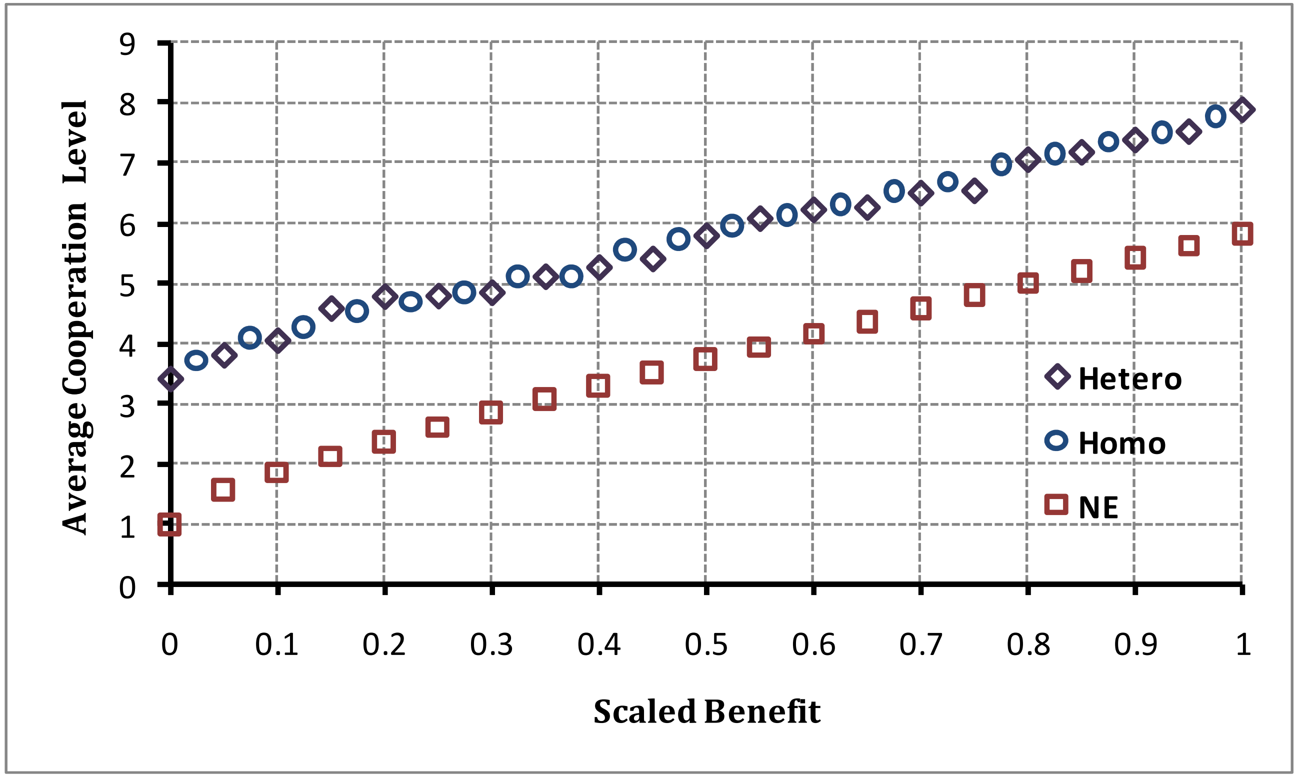
- We employ Nash equilibrium analysis to investigate the predicted strategies for the participating peers by the decision-analytic approach.

- According to [Buragohain et al. P2PComputing03] for a similar quantitative model of the system in a homogeneous setting (for all $p_i$, $b_{ij} = b$, $c_i = c$), the NE is given by:

$$d^* = (b(N-1)/2c - 1) \pm ((b(N-1)/2c - 1)^2 - 1)^{1/2}$$

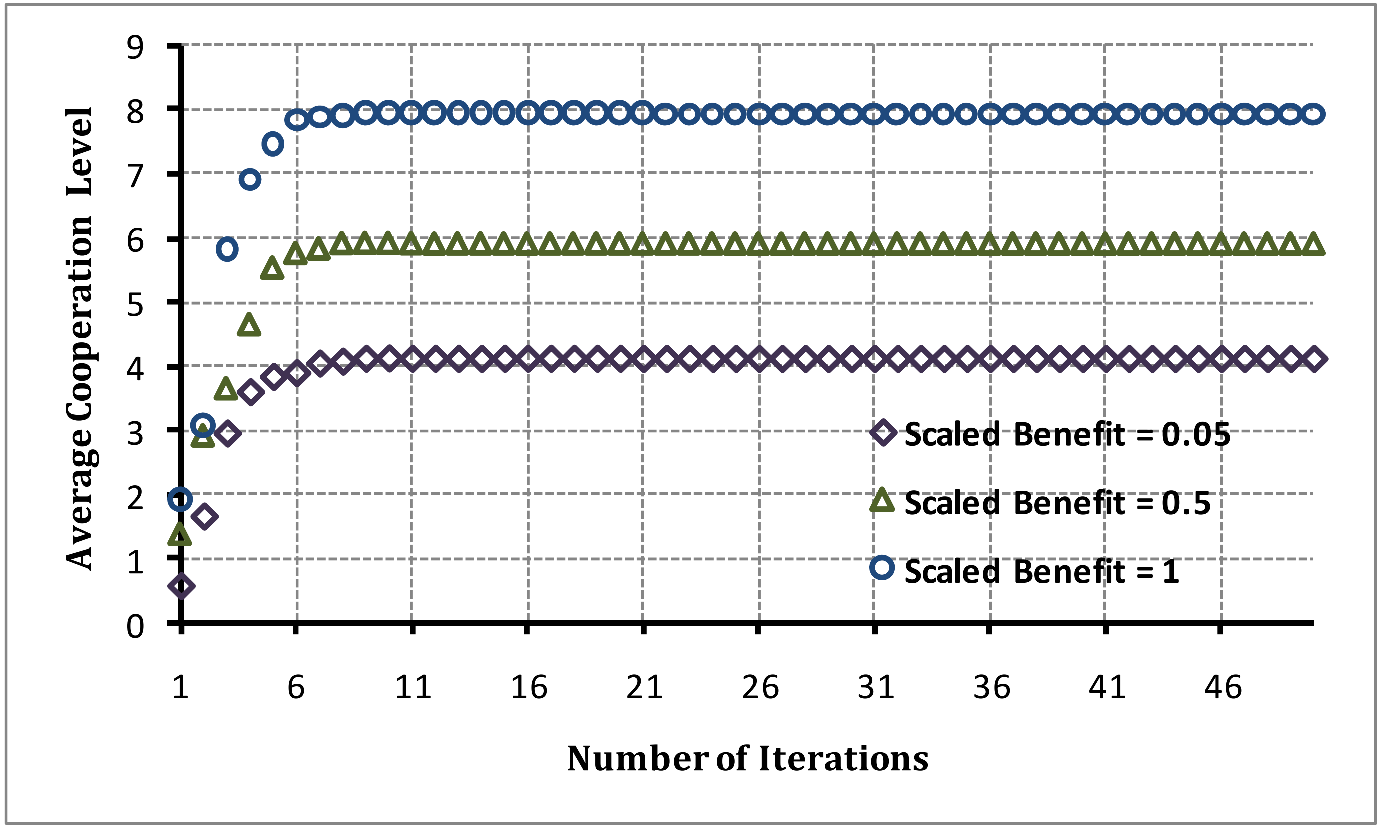
- As we numerically show:
  - The expected NE of the game is not the Pareto-optimal one.
  - The outcome derived from the proposed decision-analytic approach would make all players better-off.

# The comparison of the average cooperation level




- Tendency toward Pareto efficiency
- Better outcome than NE
- Both homogeneous and heterogeneous settings evolve similarly

# Convergence to a set of Pareto efficient strategy




- Fast convergence regardless of the target cooperation level

# CONCLUSION

# Conclusion – Future Work

- We propose a decision-analytic approach based on the modified swarm model, to set and coordinate rational decisions of the individual peers on their cooperation policies in a distributed manner.

- The resulting cooperation policies constitute the final set of decisions that maximize rational peers' utility in-line with the social welfare of the system.
  - Incentive-compatible for peers to follow

- Our approach quickly approximates a Pareto-optimal operating point of the system.

- In our future work, we will investigate information exchange mechanisms that involve incentives for neighbor truthfulness or own observation and verification.

# THANK YOU FOR YOUR ATTENTION.

# MORE QUESTIONS TO:

Golnaz Vakili

g_vakili@aut.ac.ir

Distributed Information Systems Lab, EPFL http://lsir.epfl.ch