Distributed Scheduling and Equilibrium Dynamics in Wireless Networks with Correlated Fading Channels

Ozan Candogan, Ishai Menache, Asuman Ozdaglar, Pablo Parrilo
Department of Electrical Engineering and Computer Science, MIT

Introduction

Centralized control schemes for wireless networks (e.g., wireless ad-hoc networks) could be practically difficult to implement:

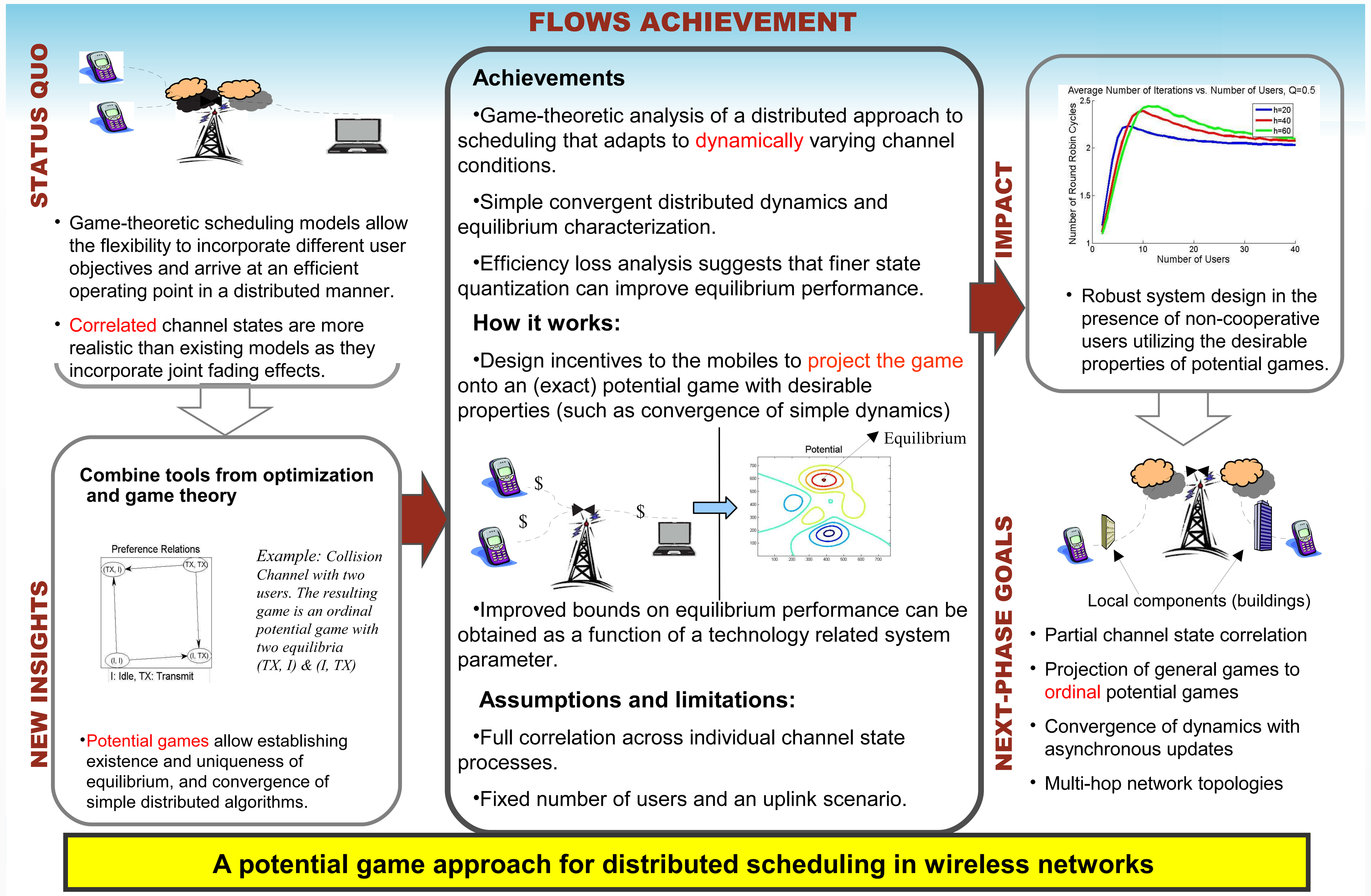
- A central entity may not have access to the required information on the end users, especially in dynamically evolving systems.
- Centralized optimization procedures might be computationally involved.

Distributed approaches are more natural. Competition for network resources can be modeled as a noncooperative game leading to a robust and distributed control paradigm.

Model

- A finite set of mobiles, $\mathcal{M} = \{1, \ldots, M\}$.
- Fading effect: A global channel state process $H(t) \in \mathcal{H} = (1, 2, \ldots, h)$. Example of global effects may include common weather conditions in satellite communications, and thermal noise at the base station.
- The state process is stationary (e.g., block-fading), state i is observed with probability π_i.
- Collision channel: Simultaneous transmissions collide and data is lost.
- The average rate user m can sustain in state i (assuming no collision) is denoted by R_i^m.
- Per-user average power constraint $\bar{P}^m$.
- We consider stationary strategies: p_i^m is the (stationary) transmission probability of user m at state i.
- Utilities capture tradeoff between power (P^m) and throughput (T^m): $u^m(\mathbf{p}^m) = T^m(\mathbf{p}^m, \mathbf{p}^{-m}) - \lambda^m P^m(\mathbf{p}^m)$

Summary



Main Results

- Characterization of the social welfare problem, and useful reduction of our game to a finite game.
- Let $\pi_{max} = \max_{i \in \mathcal{H}} \pi_i$, $P_{min} = \min_{m \in \mathcal{M}} \bar{P}^m$, and define a technology-related parameter: $Q = \frac{\pi_{max}}{P_{min}}$.

  Theorem 1. *Fix $Q < 1$. Then,*

  i The performance ratio between the best equilibrium and the social optimum is bounded above by $(1-Q)^{-2}$.

  ii The performance of the worse equilibrium point could be arbitrarily bad.

- Implication: With finer quantization, equilibrium efficiency can be improved.

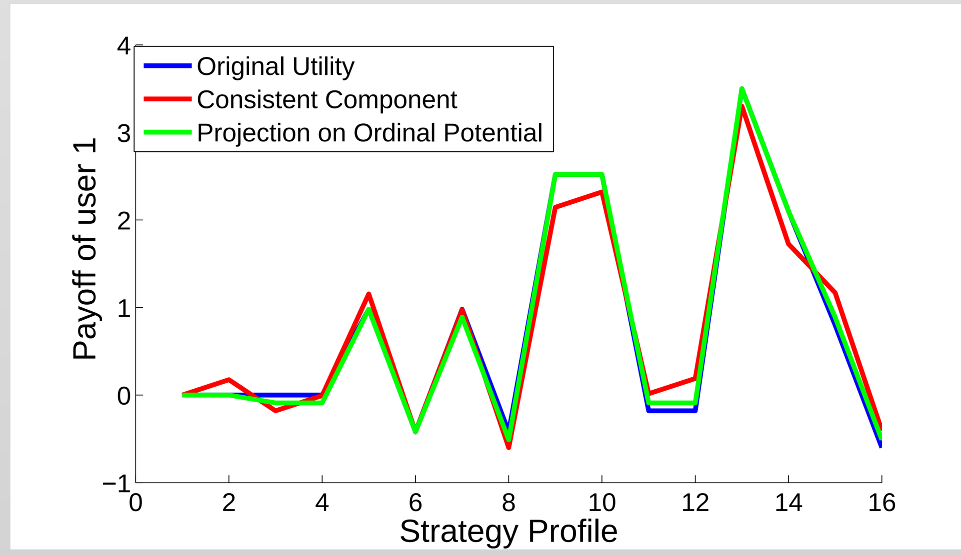
  Theorem 2. *If $R_i^m = R_i$ for all users m, then the game is a potential game, which in our case implies convergence of best-response mechanism to an equilibrium point in finite time.*

- We further show that under general rate values R_i^m the game is not a potential game.

Potential Games

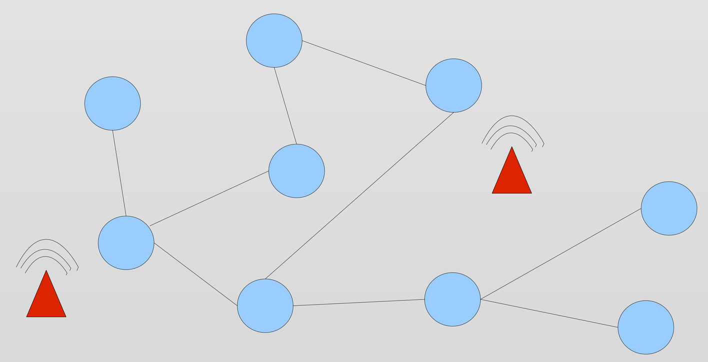
Potential games have desirable convergence properties.

- Thus, in order to guarantee convergence of simple myopic dynamics, a game can be projected onto a potential game.
- Ongoing research focuses on a general framework, in which the original user utilities are slightly modified (e.g., in the form of incentives) to form a potential game.



Future Work

- Exploit the idea of projection onto a potential game in our framework.
- Partial correlation of the state processes.
- Multi-hop architectures.



- Additional channel models (e.g., CDMA)
- Convergence of dynamics with asynchronous updates