Controlled Matching Game for Connectivity Management with Nash Bargaining Resource Allocation

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Problem

Design a decentralized mechanism providing the players the incentives for some core stable associations knowing that in each coalition the resource is shared by the Nash bargaining. Apply to WiFi with a decentralized load balancing mechanism.

Nash Bargaining

- Let $B \subset \mathbb{R}^N$ be the convex compact subset of **jointly achievable utility points** and let $\mathbf{t} = (t_1, \ldots, t_N)$ be the fixed threat vector.
- The **Nash solution** to the bargaining problem consists in looking for a payoff vector $(u_1, ..., u_N)$ in B satisfying **five axioms**.

Theorem 1 (Two-person Nash Bargaining Solution)**.** *There is a **unique solution** function $\Phi(.,.)$ that satisfies the **Nash's axioms**. This solution satisfies, for every two-person bargaining problem $(B, \mathbf{t})$,*

$$\Phi(B, \mathbf{t}) \in \underset{\mathbf{u} \in B, \mathbf{u} \geq \mathbf{t}}{\operatorname{argmax}} (u_1 - t_1)(u_2 - t_2) \tag{1}$$

- The Nash bargaining solution achieves a **generalized proportional fairness**. The **proportional fairness** is achieved in the **utility** space with a **null threats**.

Matching Games

- The **matching theory** relies on the existence of individual's order relations $\{\succeq_i\}_{i \in \mathcal{N}}$ giving the player's ordinal ranking of alternative choices. Each **player emits preferences** over some **subsets** of players.
- Many-to-one bi-partite matching: A **matching** μ is a **function** from the set $\mathcal{W} \cup \mathcal{F}$ into the set of all subsets of $\mathcal{W} \cup \mathcal{F}$ such that: (i) $|\mu(w)| = 1$ for every mobile user $w \in \mathcal{W}$ and $\mu(w) = w$ if $\mu(w) \notin \mathcal{F}$; (ii) $|\mu(f)| \leq q_f$ for every AP $f \in \mathcal{F}$ ($\mu(f) = \emptyset$ if f isn't matched to any mobile user in $\mathcal{W}$); (iii) $\mu(w) = f$ if and only if w is in $\mu(f)$.
- Domination: A matching μ' dominates another matching μ via a coalition C contained in $\mathcal{W} \cup \mathcal{F}$ if for all mobile users w and APs f in C, (i) if $f' = \mu'(w)$ then $f' \in C$, and if $w' \in \mu'(f)$ then $w' \in C$; and (ii) $\mu'(w) \succ_w \mu(w)$ and $\mu'(f) \succ_f \mu(f)$.
- Core: The **set of matchings** that are **not dominated** by any other matching.

Control

- We search for the **operators modifying the characteristic function** v to provide players the **incentives** to form **stable structures** of given properties (e.g. coalitions of sizes $\hat{\mathbf{q}} = (\hat{q}_1, \ldots, \hat{q}_F)$).
- A **lever** for controlling our matching game and designing operator $\mathbf{\Omega}$ is the **fear-of-ruin** (FoR). Formally, the FoR of user i in coalition C is defined as: $\chi_i(s_{i,C}) \triangleq \frac{u_i(s_{i,C})}{u_i'(s_{i,C})}$.
- Two interesting characteristics of the FoR,
  - (i) In a coalitional game **with N.B.** as sharing rule, the FoR is **constant over the players in a coalition**, i.e., $\chi_i(s_{i,C}) = \chi_C$ $\forall i \in C$ at the bargaining solution point $s_{i,C}$
  - (ii) with concave increasing utility functions, the **individual payoffs increase in the common FoR**

Numerical Results

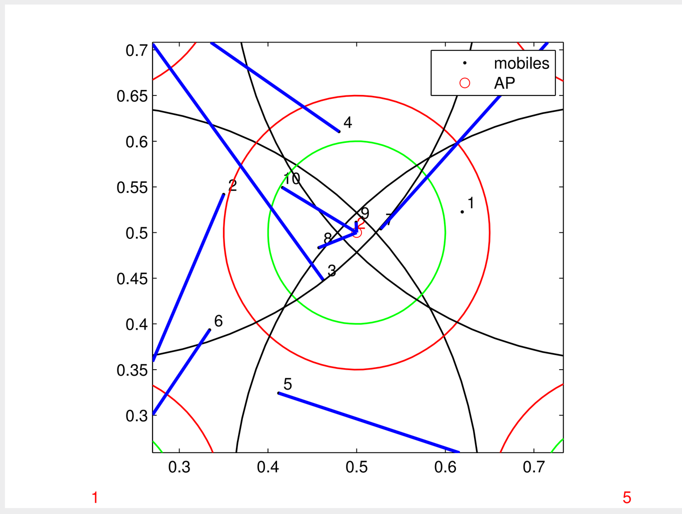

Figure 1: Association obtained using the proposed mechanism.

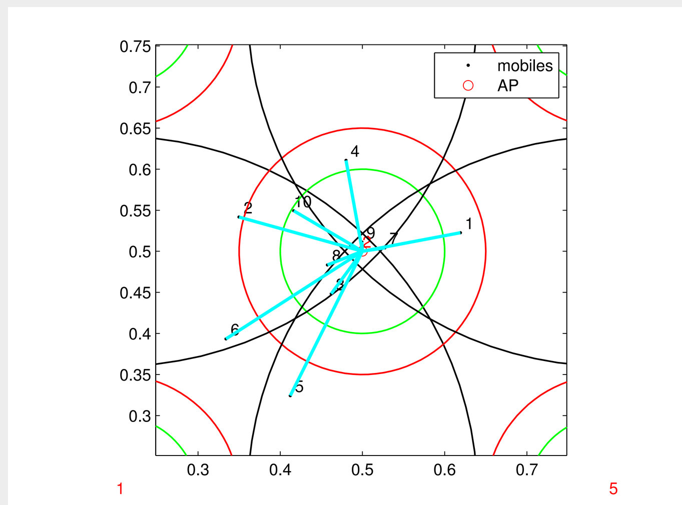

Figure 2: Association obtained from best-RSSI association scheme.

- **Assume a decentralized load balancing mechanism LS** (e.g. Nash bargaining) giving objective $\hat{\mathbf{q}}$ in the size of the coalitions. The mechanisms incentivizes the players for coalitions of such sizes.
- The mechanism gives individual gains from +211% to +356%.

Mechanism

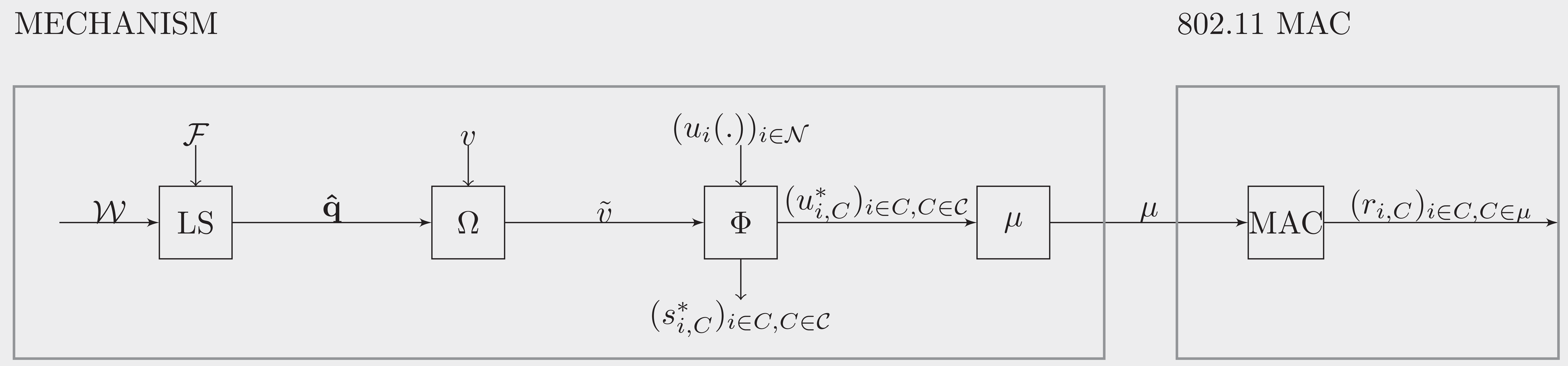

Figure 3: Block diagram of the mechanism. The APs share the load in the block **LS** which gives the APs' quotas. The characteristic function v of the original coalition game is controlled in $\mathbf{\Omega}$ and gives the modified characteristic function $\tilde{v}$. The NB $\mathbf{\Phi}$ is played in each coalition for the allocation of the worth of the coalition among its members. The players then emit their preferences over the coalitions on the basis of their shares and enter a stable matching mechanism in block μ. This block outputs an AP-user association μ. Finally, in the block **MAC** the nodes transmit their packets according to the unmodified IEEE 802.11 MAC protocol.

References

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