ALGORITHMS FOR THE SHARING ECONOMY

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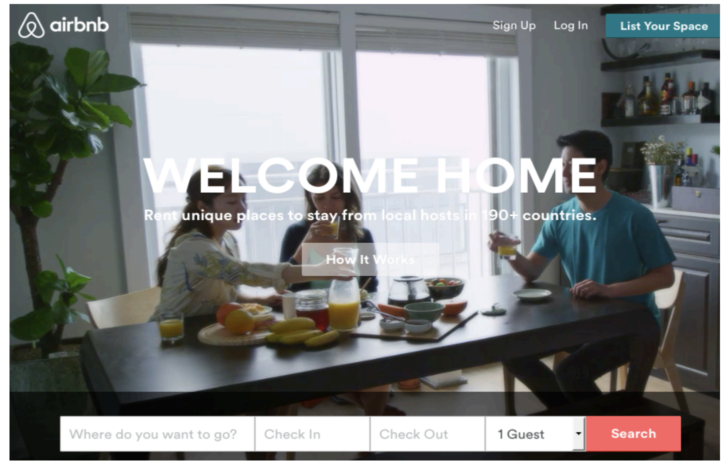
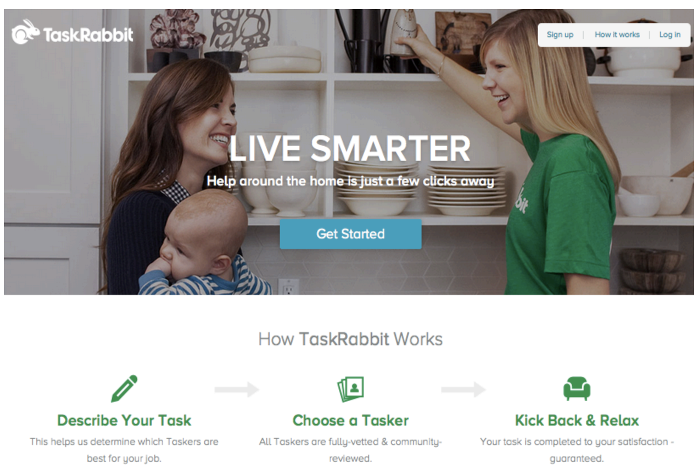
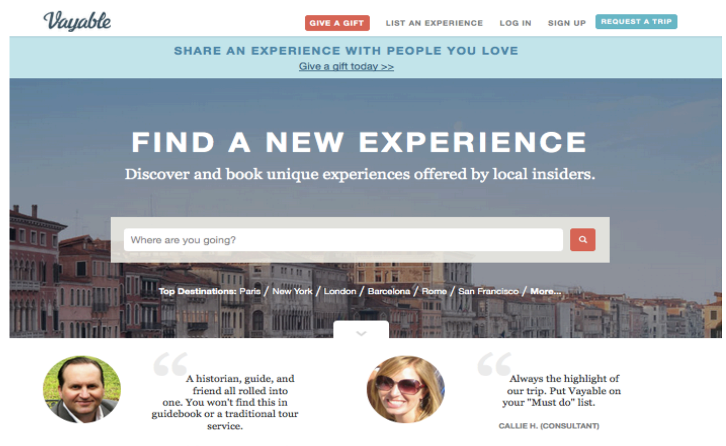
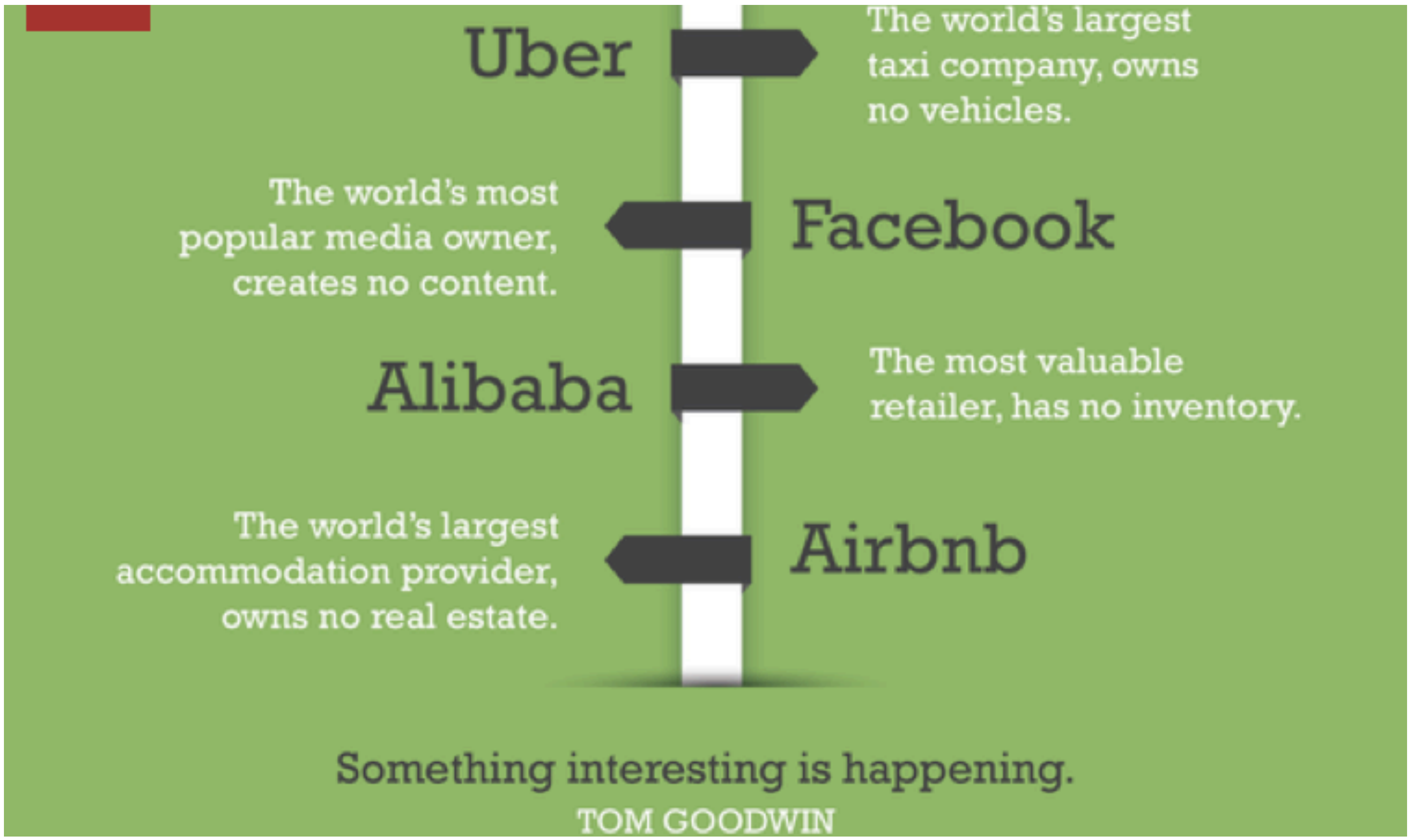
The Sharing Economy





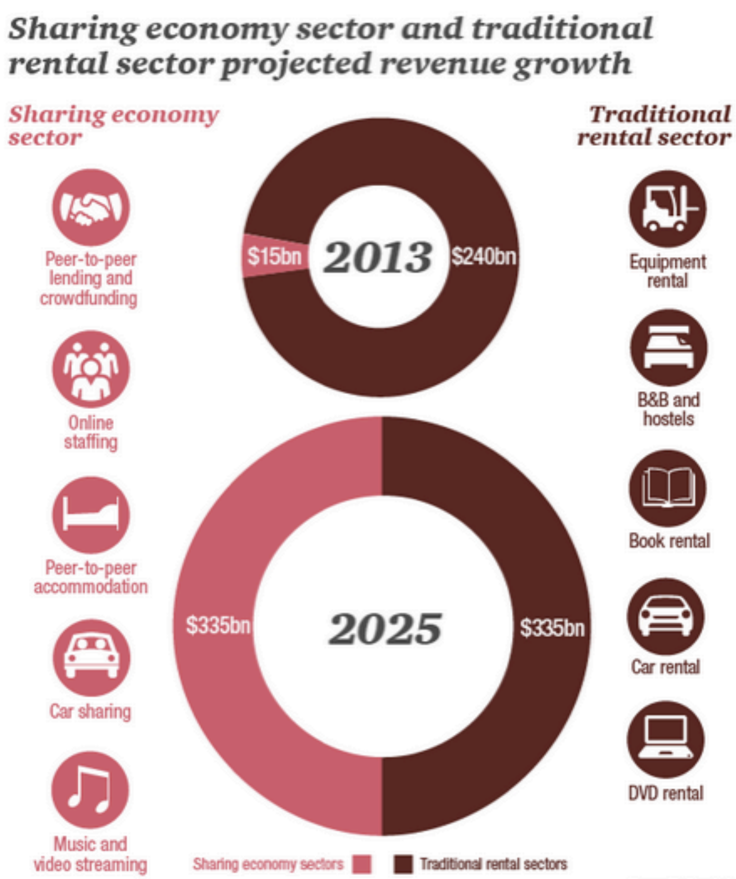


The Sharing Economy



Source: @WetPaintMENA

The Sharing Economy



source: PriceWaterhouseCoopers

The Sharing Economy

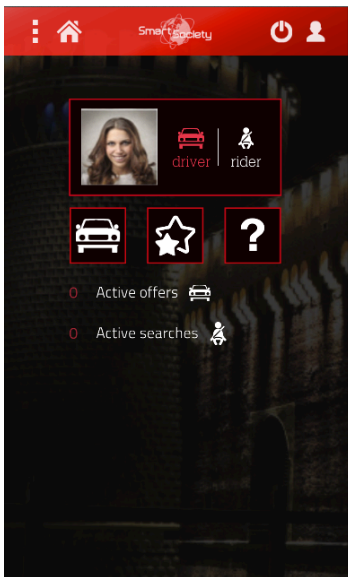
- IT-enabled distribution, sharing and reuse of excess capacity in goods and services
- Web platforms mostly manage search/matching, contracting, remuneration
- Coordination mechanisms used largely ignore game theory/mechanism design/multiagent systems literature
- What can we learn from these emerging systems, and what can they learn from us?

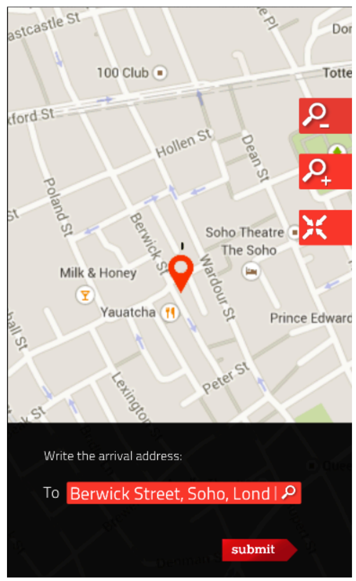
Example: Ridesharing

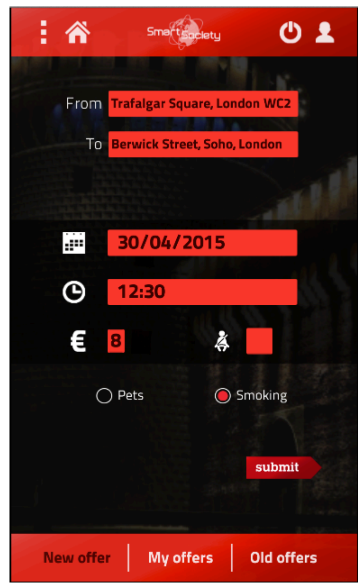
- Over the past two years we've built the web-based ridesharing system *SmartShare*
- Study of human behaviour *in situ* to test models of human collaboration
- Part of a €6.8M project on *hybrid and diversity-aware collective adaptive systems*
- Preliminary user study in Israel, upcoming larger trial in Italy + lab experiments

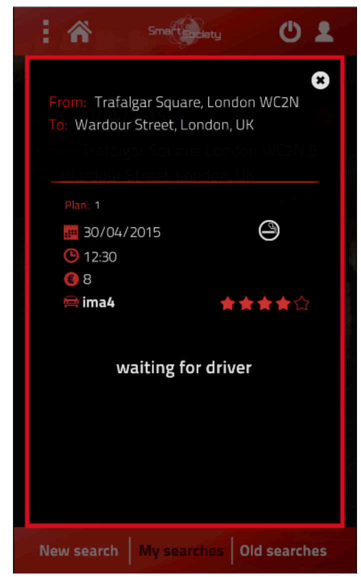
www.smart-society-project.eu
@SmartSocietyFP7

SmartShare

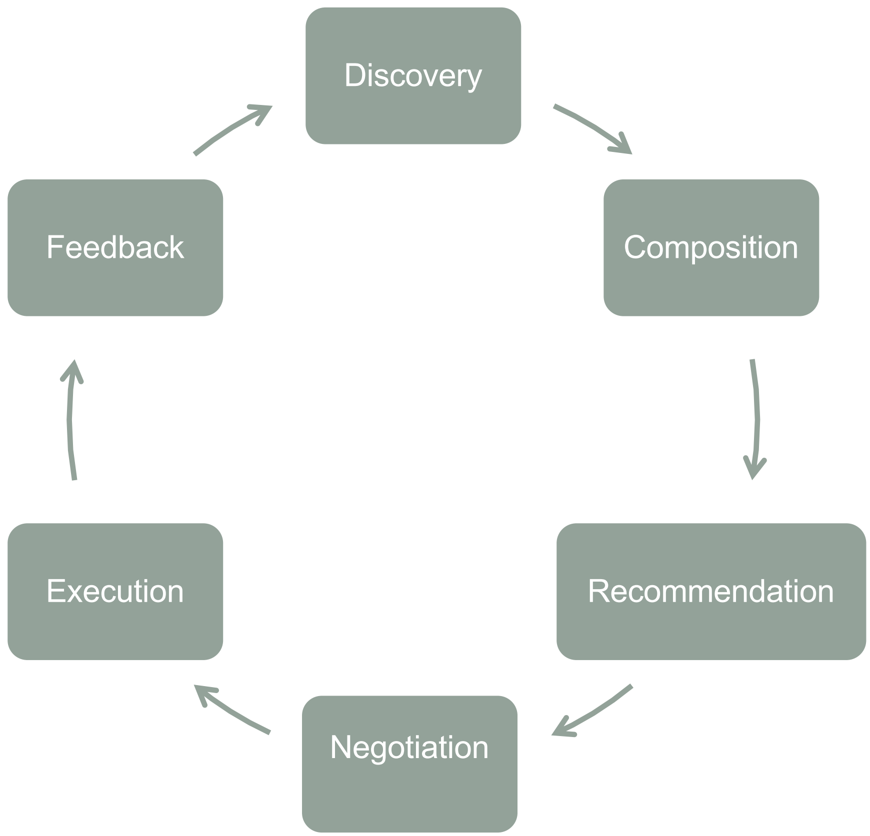

driver
rider
0 Active offers
0 Active searches


100 Club
Hollen St
Dean St
Poland St
Berwick St
Soho Theatre
The Soho
Milk & Honey
Yauatcha
Wardour St
Prince Edward
Peter St
Lexington
Write the arrival address:
To Berwick Street, Soho, Lond
submit


From Trafalgar Square, London WC2
To Berwick Street, Soho, London
30/04/2015
12:30
€ 8
Pets
Smoking
submit
New offer
My offers
Old offers


From: Trafalgar Square, London WC2N
To: Wardour Street, London, UK
Plan: 1
30/04/2015
12:30
8
ima4
waiting for driver
New search
My searches
Old searches

Sharing app orchestration cycle



“Canonical” mechanism design

- Game-theoretic rationality assumptions
- Focus on social welfare maximisation
- Truthfulness and stability as core concerns
- Provable properties obviate agent reasoning

A traditional resource allocation problem?

- Possible services not known a priori
- Part-route sharing creates vast solution space
- Sequential dependencies
- Complex, context-dependent preferences
- Optimality less important than availability
- Mechanism acceptability culture-sensitive

Interesting problems

1. Unmanageable solution spaces
2. Ad hoc interaction models
3. Designing incentive schemes
4. Group task recommendation

1. Unmanageable solution spaces

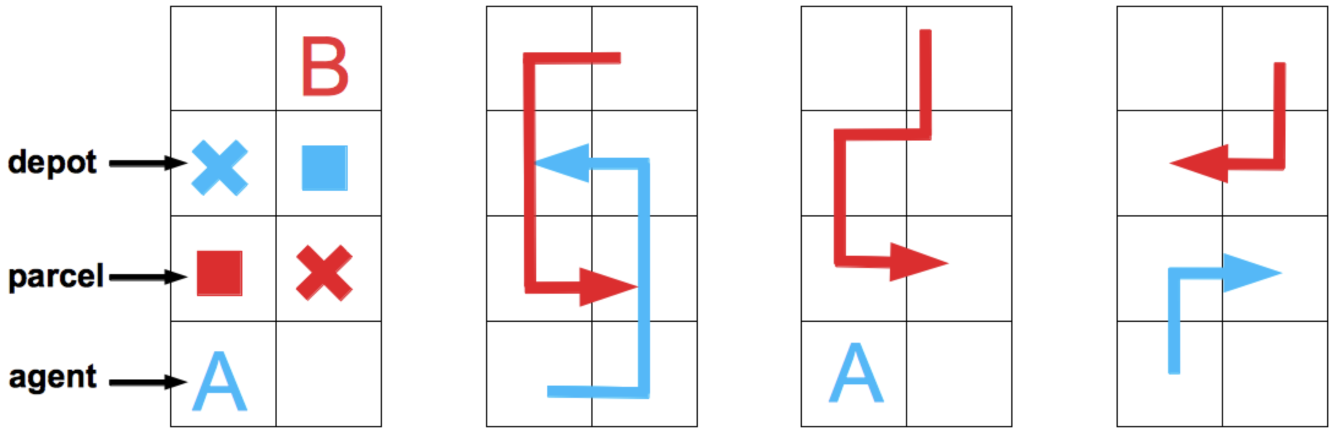
- At finer levels of granularity, there is a vast number of possible collective behaviours
- Synthesising these needs to take strategic properties and user preferences into account
- “Softer” solution concepts might provide some guarantees without excessive computation cost
- **Opportunity**: designing heuristic algorithms that generate “reasonable” solutions

Calculating complex group tasks

- In complex strategic domains, joint strategies cannot be enumerated *a priori*
- Amounts to a strategic multiagent planning problem
  - Like concurrent planning with additional constraints on plan cost to individuals
  - Problem definition depends on whether contracts can be enforced and utility can be transferred
- Hard to define meaningful solution concepts if goals are incompatible or agents untrustworthy

Example

- Delivery domain



utility=reward - cost

"isolated" cost: 6/6 *(inefficient)*

"selfish" cost: 0/8 *(irrational)*

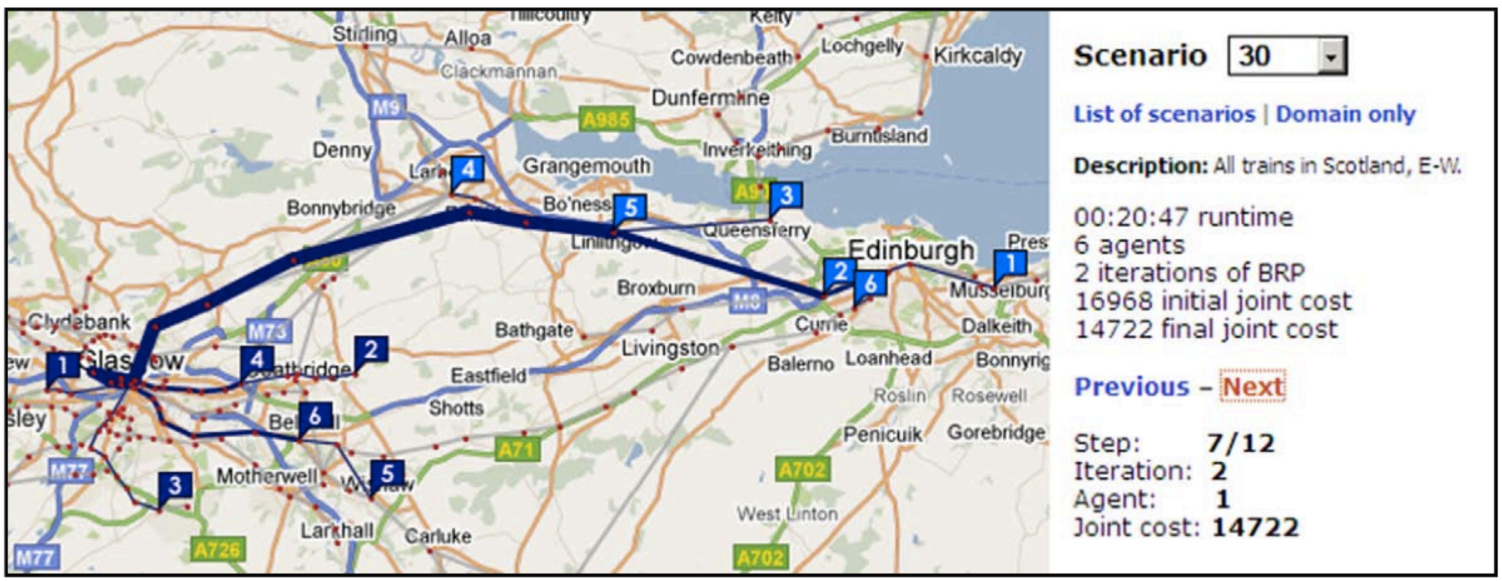
"cooperative" cost: 4/4 *(stable)*

Planning for Self-Interested Agents

- Best-Response Planning (Jonsson & MR):
  - Iterative method of optimising agents' individual plans without breaking others' plans
  - Computes equilibrium plans fast in congestion games, restricted to interactions regarding cost
- Extended by "compress-and-expand" algorithm to produce initial concurrent plan
  - Only for domains where agents can achieve their individual goals alone; where they can't, it's still useful for plan cost optimisation

Empirical results

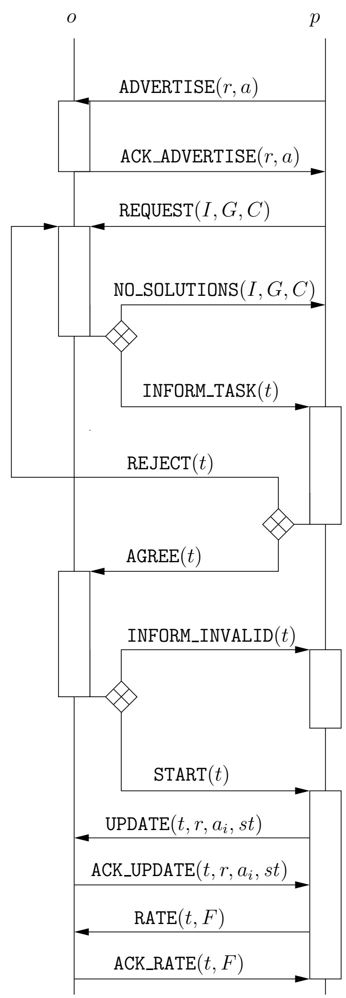
- We used BRP to calculate travel routes using real-world UK public transportation data and private cars (>200,000 connections)



2. Ad hoc interaction models

- Platforms let users design a broad range of interaction models for discovery, negotiation, etc
- Not possible to analyse all of them them mathematically before deployment
- Many of them might fall into known classes of well-studied mechanism design problems
- **Opportunity:** automated mapping/verification of interaction protocol properties

Mechanism Design for Ridesharing



Mechanism Design for Ridesharing

- Ridesharing calls for design of preference elicitation and allocation mechanisms
- Achieving low churn rate, i.e. ensuring commuters are willing to use the service again, is a key concern
- Can be interpreted as a *stability* constraint on allocations computed by the mechanism
- Practical mechanisms can only support *incomplete reporting* of commuter preferences
- **Problem: How do we design mechanisms that form stable allocations with incomplete information?**

Mechanism Design for Ridesharing

- Any ridesharing mechanism consists of three components:
    - A signaling protocol to support communication between commuters and providers
    - The message sets that the commuters and provider can communicate
    - An allocation mechanism that matches groups (*coalitions)* of commuters to vehicles
- We consider the *posted goods signaling protocol (PGP)*, motivated by real-world ridesharing websites
- Generalizes signaling semantics for posted price mechanisms, ensures incentive compatible reporting

Posted Goods Signaling Protocol

1) Each commuter sends a request signal to the platform
2) The platform computes an allocation
3) The platform sends a signal to each commuter, consisting of offers
4) Each commuter sends a signal indicating whether they accept
5) At the time of transport, each commuter sends a *commit signal,* indicating they took/liked the service

Stable Mechanisms

- To design Nash stable mechanisms we require:
  - Message sets for commuters to report *incomplete preferences*
  - Allocations of passengers to vehicles that yield stable coalitions, accounting for incomplete reporting
- Key observation: the structure of stable coalition formation mechanisms depends on passenger preferences, e.g.
  - *hedonic preferences:* utility depends on other passengers in the same vehicle
  - *topological preference:* utility depends on pick-up times, locations, and tradeoffs between them

Key Results

- Mechanisms for hedonic preferences
  - For general preference orderings, ensuring Nash stability requires allocating only one commuter at a time
  - Previously allocated commuters need to admit new commuters into their coalition
  - Key design problem is the allocation, not the message sets - any additional commuter might affect stability
  - Limitation not necessary for special types of preferences, e.g. single-subset-peaked

Key results

- Mechanisms for topological preferences:
  - Here all commuters can be allocated simultaneously while ensuring Nash stability
  - But message sets need to be carefully designed - depend heavily on commuter preference topology
  - Requires that provider has side information about bounds on space of preferences that can be reported:

$$\sup_{t,t' \in \Psi_{\mathcal{P}_i}} d_{\Psi_i}(t,t') \leq \alpha$$

  - Message set needs to allow at most one report in the Pareto set to lie within this bound (this makes commuter reporting *consistent*)

3. Designing incentives

- Global goals of interaction platforms can be supported by creating additional rewards
- Monetary and “virtual” benefits (badges, scoreboards etc) can be used – gamification
- Feedback mechanisms affect collective behaviour, provide additional incentives
- **Opportunity**: largely overlooked problem, learning over parametrised mechanisms might be a solution

4. Group task recommendation

- We don't know whether a solution exists for a requested objective a priori (cannot just propose nearest "product")
  - Impossible to compute all possible solutions offline (and annotate them for retrieval), computation takes time
- We require agreement of all parties for a task to happen, i.e. solution must rank high on everyone's preferences
- Data obtained from negotiation/execution/feedback may refers to teams (correlated views), not just individuals
- **Opportunity:** re-think rationality assumptions, consider ranking solutions rather than "solving" problem

Long-term vision

Given

- A protocol graph describing the interaction mechanism
- Prior belief about users' types and preference structures
- A set of feasibility constraints for group tasks

compute

- An ordered list of solutions for each user

such that

- Each combined choice constitutes feasible global solution
- Item n is preferred over item $n+1$ for each user
- Indifference is exploited to maximise global objective
- Ordering takes preference elicitation needs into account

Conclusions

- Sharing economy presents mechanism design with novel, interesting problems
- Adaptive mechanisms and weaker stability/optimality guarantees possibly the answer
- Not covered, but extremely important: ethical issues (privacy, safety, fairness, transparency)
- Opportunities for closer interaction among different communities and across sectors