Exploring retail energy markets through competitive simulation

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Energy Disasters

People and nature are suffering because our energy supply is unsustainable.

Need for renewable energy sources!

The problem

Fundamental changes are coming in the energy sector.

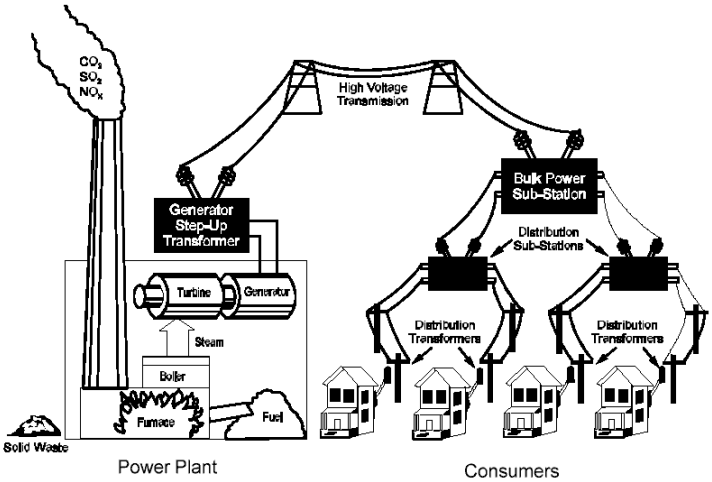
- Energy sustainability
- Carbon emissions
- Distributed renewable sources
- Electric vehicles
- Energy markets

New thinking is needed.

Today's grid
Top-down control

The current system for delivering electrical power –

- Assumes power flows from large plants to end-users.
- Is controlled and monitored only at the top level.
- Must be closely balanced in real time.
- Insulates most users from the real costs.



Today's grid
Challenges

Control and stability

- Top level is organized into multiple interconnected grids.
- During peak demand periods, many elements of grid are capacity-limited.
- System is marginally stable, depends on human intervention.

Energy markets

- Power is traded among major producers and distributors.
- Controllers must anticipate shortage/surplus in advance.
- Trade quantities constrained by grid capacity.
- Short-term balancing requires "spinning reserves".
- Dynamic pricing used only in wholesale markets.

Today's grid
Challenges

Renewable sources

- Typically much smaller than base-load plants.
- Many are distributed, not connected to top-level grid.
- Intermittent, partially predictable.
- Poorly integrated into existing control system.
- Output capacities are correlated.

Plug-in electric vehicles

- Correlated fast-charge load threatens stability.
- No existing mechanism for using battery balancing capacity.

Renewable sources

- Plenty of power available, but it is dispersed.
- Much of it is not close to consumption centers.

New balancing capacity

- Vehicle batteries have potential to even out intermittent renewable capacity.
- "Battery Arbitrage" opportunities with variable pricing.

Demand elasticity

- Consumers are willing to reduce/shift demand.
- Large users are very price-sensitive.

A Market-Based approach

Needed: a mechanism for real-time allocation of scarce resources.
This sounds like a market problem

Resources

- Power from local renewable sources.
- Power from regional grid, contracted in advance.
- Local demand and balancing capacity.
- Local spinning reserve, if needed.

Mechanism: local, competing brokers

- Acquire capacity by offering contracts to local suppliers.
- Bundle capacity into "tariffs" offered to local consumers.
- Surplus capacity sold into regional market.
- Capacity shortage purchased from regional market.

Real-time balancing

Unlike most markets, players must balance supply and demand in real-time. They cannot carry inventory.

Demand management

- Tariffs may specify time-of-use pricing.
- Dynamic pricing with variable lead-time.
- Loads may be "throttled" – e.g. vehicle charging.

Supply management

- Local renewable sources.
- Long-term ($>$ 15 minutes) capacity acquired on regional/national spot market.
- Real-time balancing managed by grid operator.

Risks

There is considerable risk in setting up such a market.

Potential for unintended consequences

- Poor design encourages strategic misbehavior.
- Enron debacle in California.

Mechanism design matters

- Encourage utilization of renewable sources.
- Discourage carbon emission.
- Encourage load patterns that match availability of renewables.
- Encourage competitors to balance each other dynamically.

Proposal: A Competitive Simulation

Building on experience with the Trading Agent Competition

Broker agents

- Play the "broker" role
- Motivated by potential for profit

Real-world data

Much of the data to drive the simulation will be from recent historical records in Germany and the Netherlands.

- Weather (wind, sun, temperature) records.
- Power demand and supply statistics.
- Spot market prices.

Impact

Society

- Completive simulation uncovers a range of broker behaviors.
- Given a broker profile space, mechanism design can maximize social welfare.

Science

- New approaches to decentralized energy management.
- Preference models for complex dynamic domains.
- Dynamic prediction models that combine history, preferences, and pricing.

Simulation Design

Alternating "contracting" and "execution" phases.

Contracting

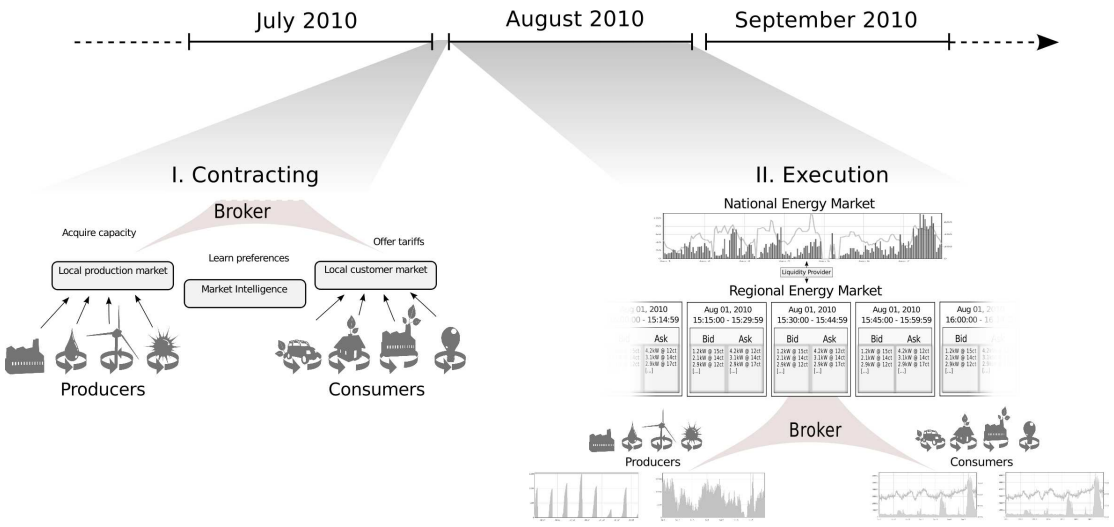
- *Tariff market*: Develop and advertise tariffs, sign up small customers.
- *Contract market:* Negotiate contracts with large customers.

Execution

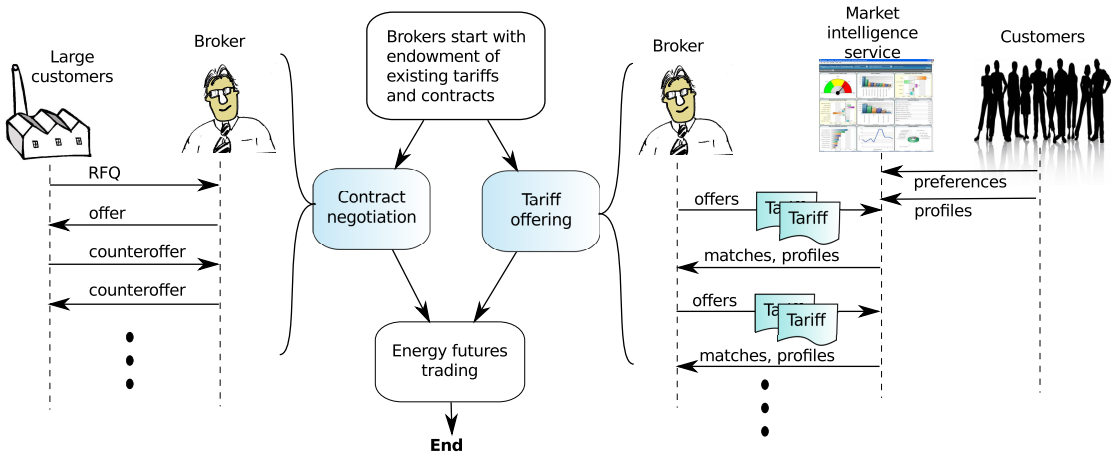
Simulate at least several days of operation.

- Contracted sources provide supply.
- Contracted customers require energy.
- Predicted imbalance ($>$ 15 minutes) handled by pricing, and by trading on spot market.
- Real-time net imbalance handled by grid operator, using controllable resources or spinning reserves.

Timeline

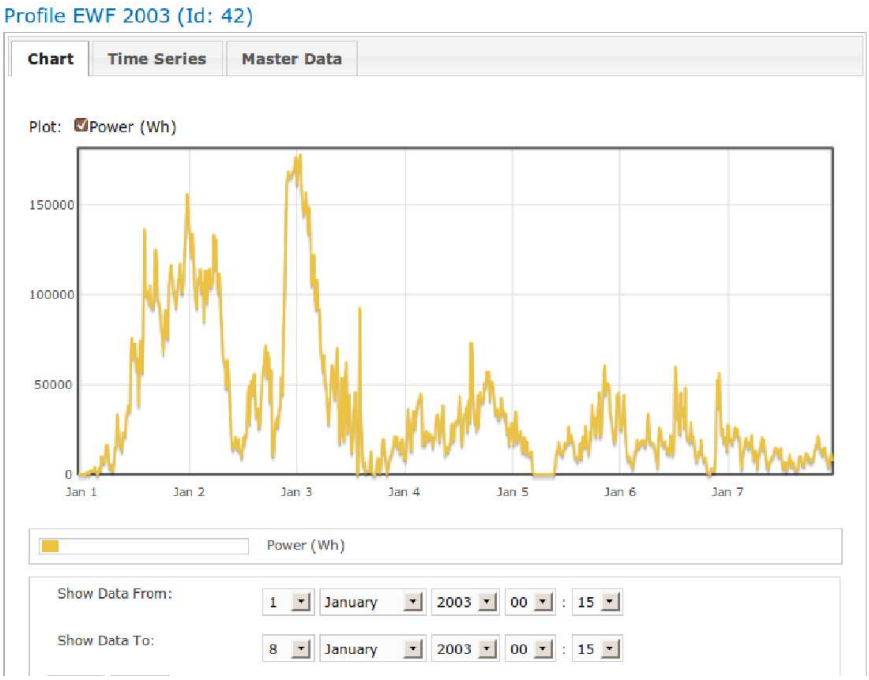


Contracting process



Market Intelligence Service

Sample wind turbine generation timeline

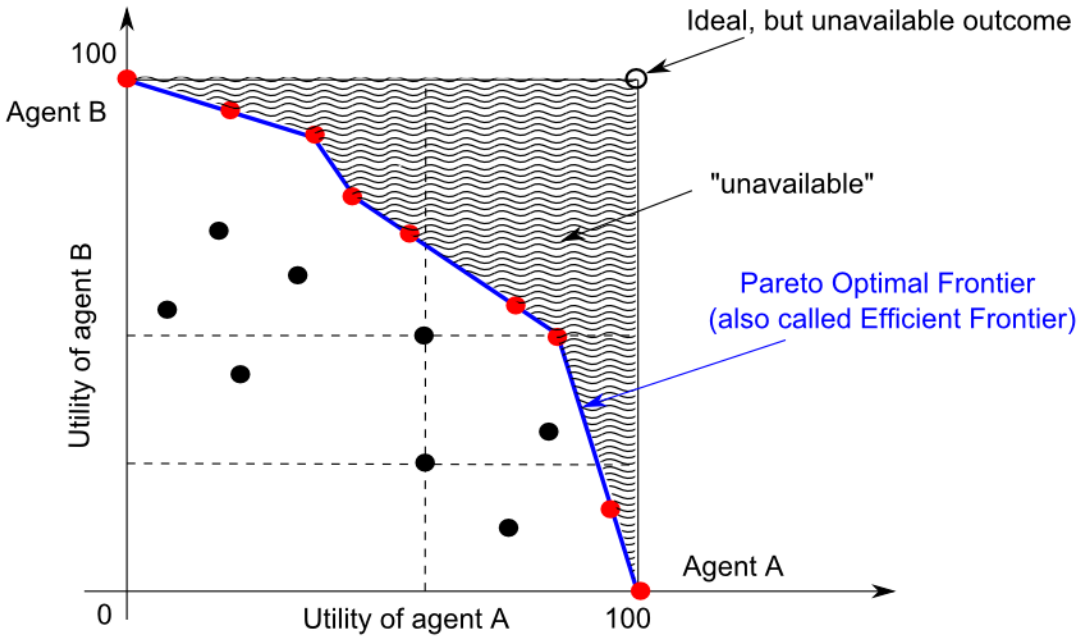


Negotiation between Broker and Producer (1)

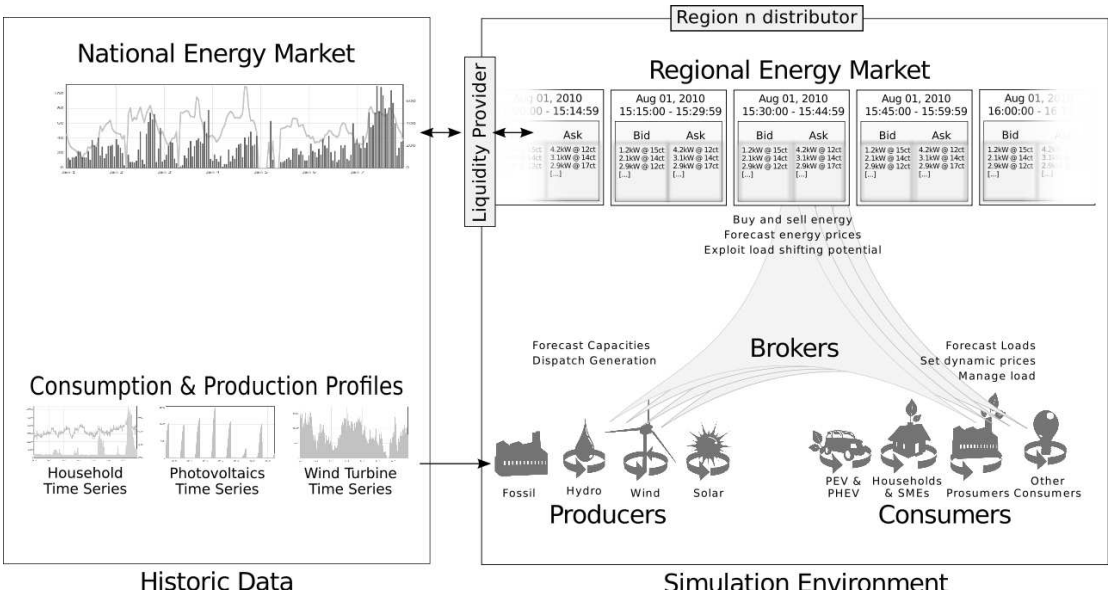
Issue	Description
Sign-up bonus	one-time payment
Base payment	periodic payment, independent of actual production
Generation price	unit price for energy supplied to the grid
Contract duration	the overall duration of contract
Type of energy	e.g., renewable or non-renewable

Table: Sample negotiable issues for broker-producer contract.

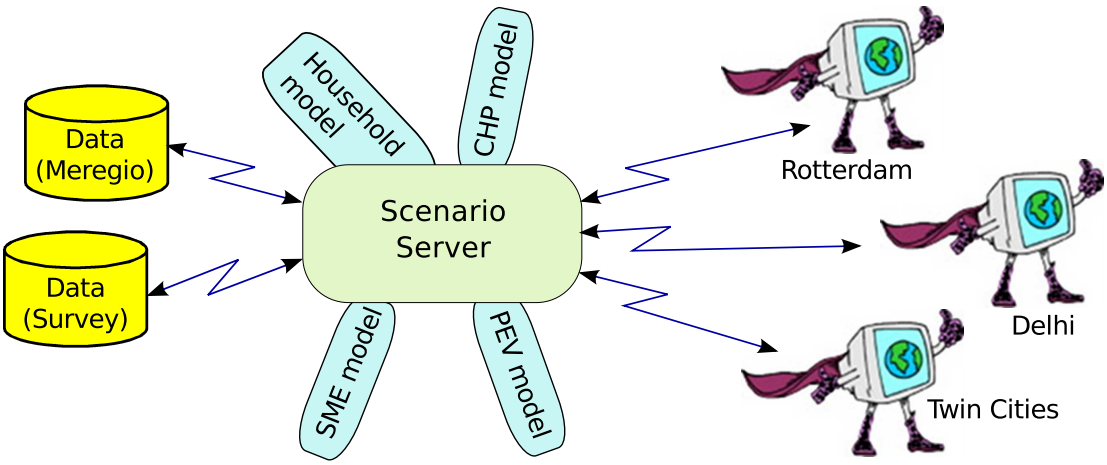
Negotiation between Broker and Producer (2)



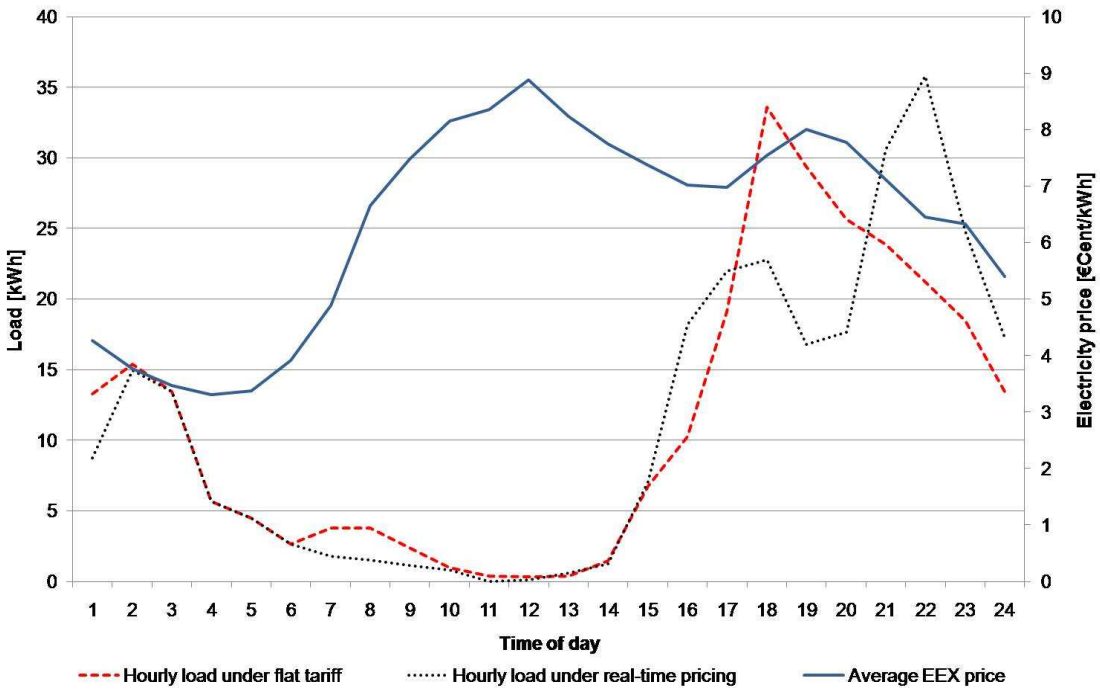
Execution phase



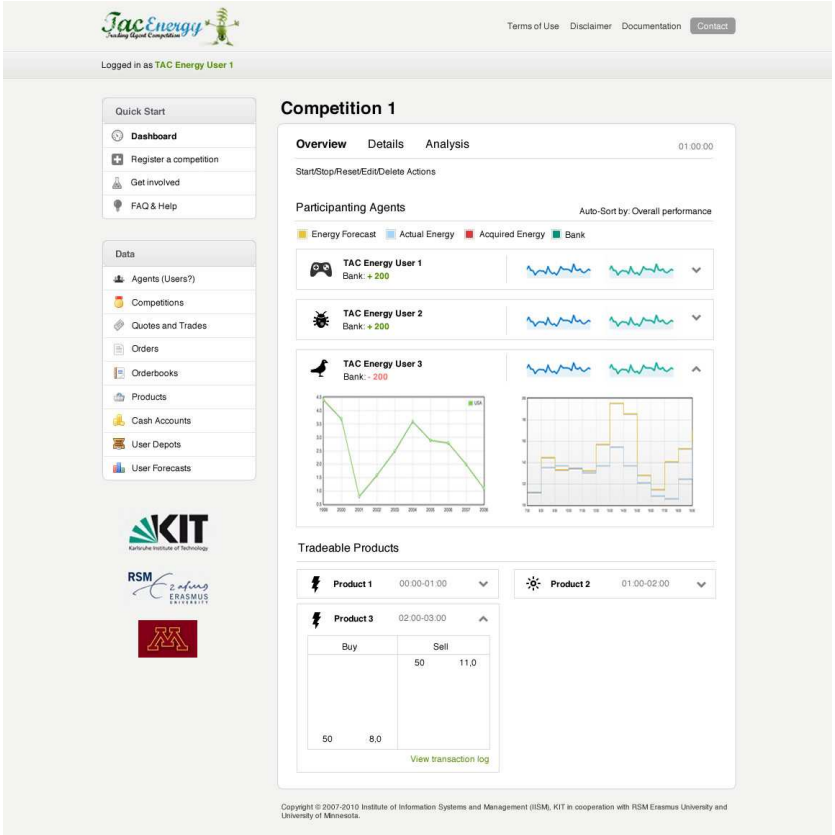
Infrastructure



Plug-in: Energy shifting in private households



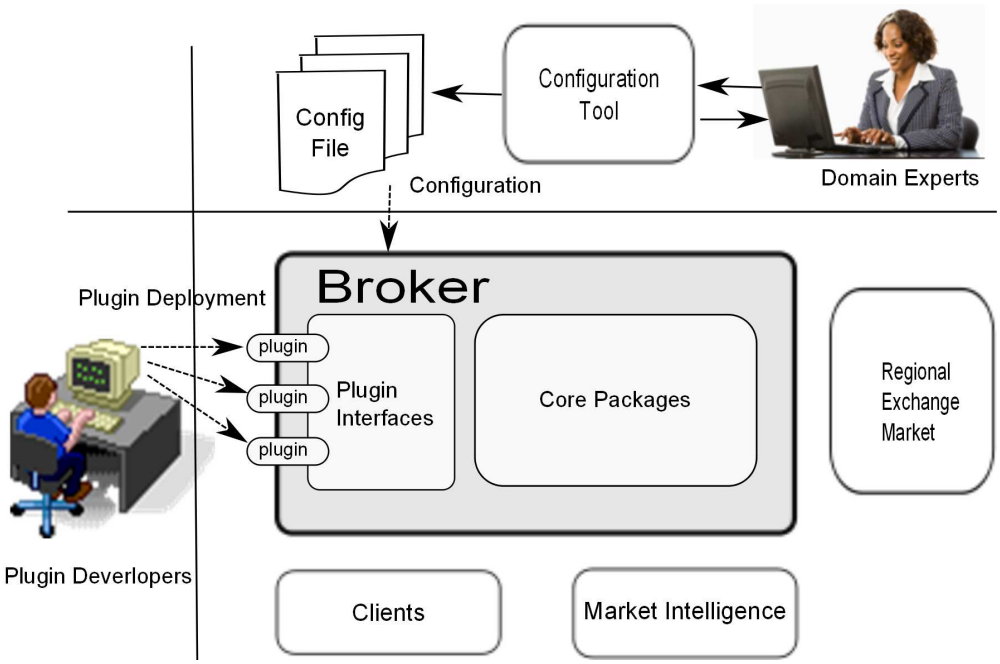
Competition Dashboard



Getting involved!

- International annual competition
- Associated workshops
- Controlled experiment environment
- Accessible to non-programmers
- Visualizers and analysis tools

Lowering the barrier to entry

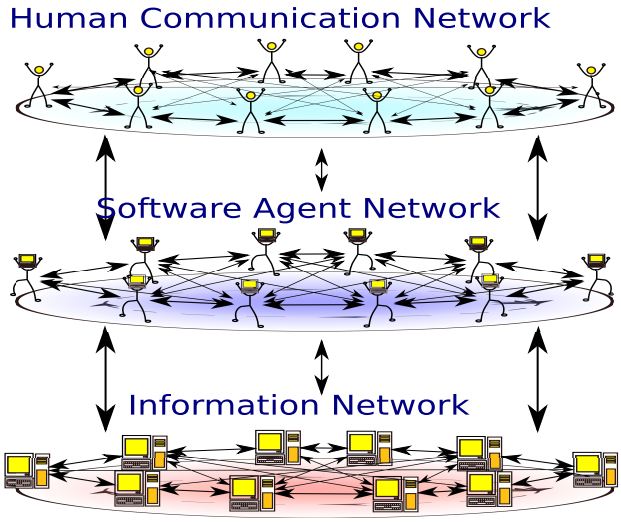


Questions for discussion

- Real-time balancing by competitors? Reputation effects?
- Who administers the local market?
- Representation & management of plug-in vehicles?
- Exploitable weaknesses in market structure?
- Competitive vs. cooperative brokers?

Questions?

Contact



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