Towards Adaptive Energy Plan Aggregation over a Peer-to-Peer Tree Overlay

Evangelos Pournaras, Martijn Warnier, Frances Brazier
Intelligent Interactive Distributed Systems
VU University Amsterdam

Elth Ogston
Department of Computer Science
University of Warwick

IIDS Intelligent Interactive Distributed Systems

AGENDA

- Stabilization problem of global energy consumption
- Peer-to-peer tree overlay for aggregation
- Adaptive energy plan aggregation properties
- EPOS: Energy Plan Overlay Summation

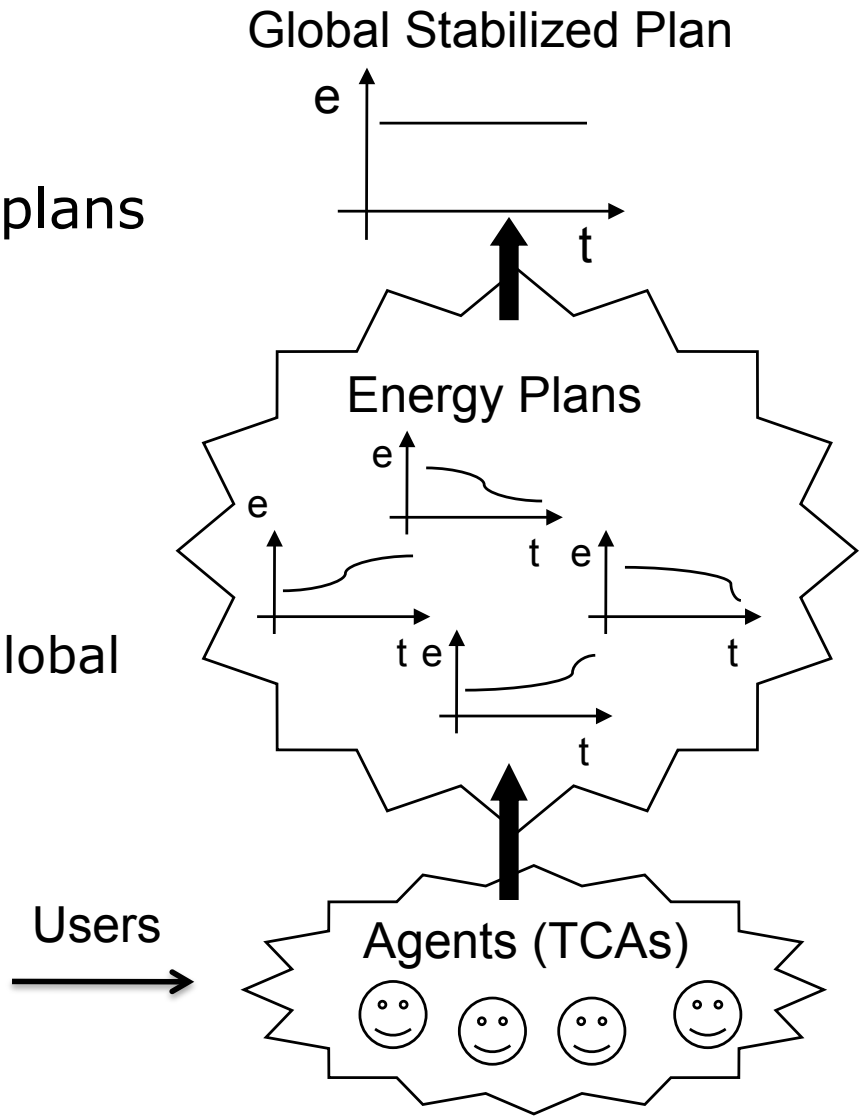
Problem and Goal

- Energy demands heterogeneity
  - Different machines
  - Different user consumptions
  - Different operational environment
- Oscillations in global energy consumption
- Central aggregators do not scale
- High economical cost (managing supply stations)

- Global stabilization of energy consumption
  - Focus on consumers
  - Minimization of energy oscillations
  - Focus on Thermostatically Controlled Appliances (TCAs)

Approach

- Agents represent TCAs
- Agents generate potential energy plans (functions) to execute
  - Energy values in time intervals
- Energy plans coordination
- Selected plans
  - Contribute in the stabilization of global energy consumption

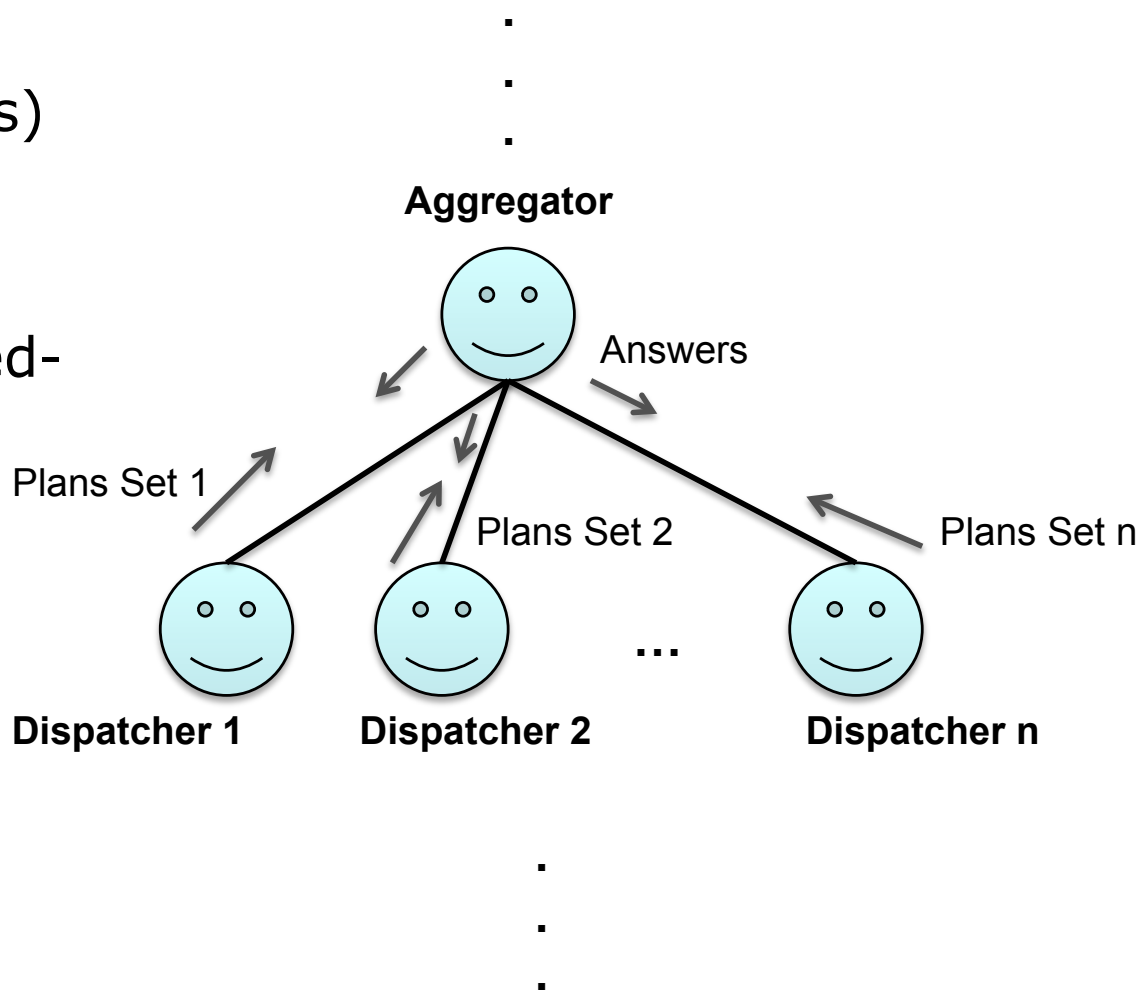


Aggregation over a tree overlay

- Tree aggregation:
  - Low communication cost, sensitive to failures
- Robust tree overlays:
  - Reliability-driven construction and maintenance
  - Robust nodes are moved up in the tree
  - Lower failure rates in TCAs
- Build and Maintenance:
  - Autonomously by the TCA agents
  - Higher level entities (feeders, substations)

Decentralized aggregation

- Aggregation rounds (leaves->root->leaves)
  - Aggregation steps (level transitions)
- Information exchanged- various plans:
  - Supported
  - Cumulative
  - Old
  - New
  - Global



Applying the concept

EPOS: Energy Plan Overlay Summation

Self-optimization and self-adaptation

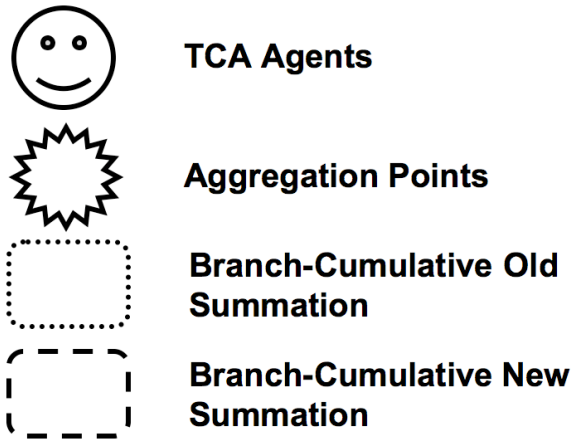
- **Goal:** global stabilization of energy consumption
- **Environment:** TCA agents that generate energy plans
- **Infrastructure:** A peer-to-peer tree overlay
- **Operation:** Energy plans aggregation (fully decentralized)

1. Dual peer role
2. Plan-driven overlay formation
3. Overlay memory -> knowledge of previous aggregation rounds
4. Local-to-global stabilization
5. Node-to-branch-to-tree convergence

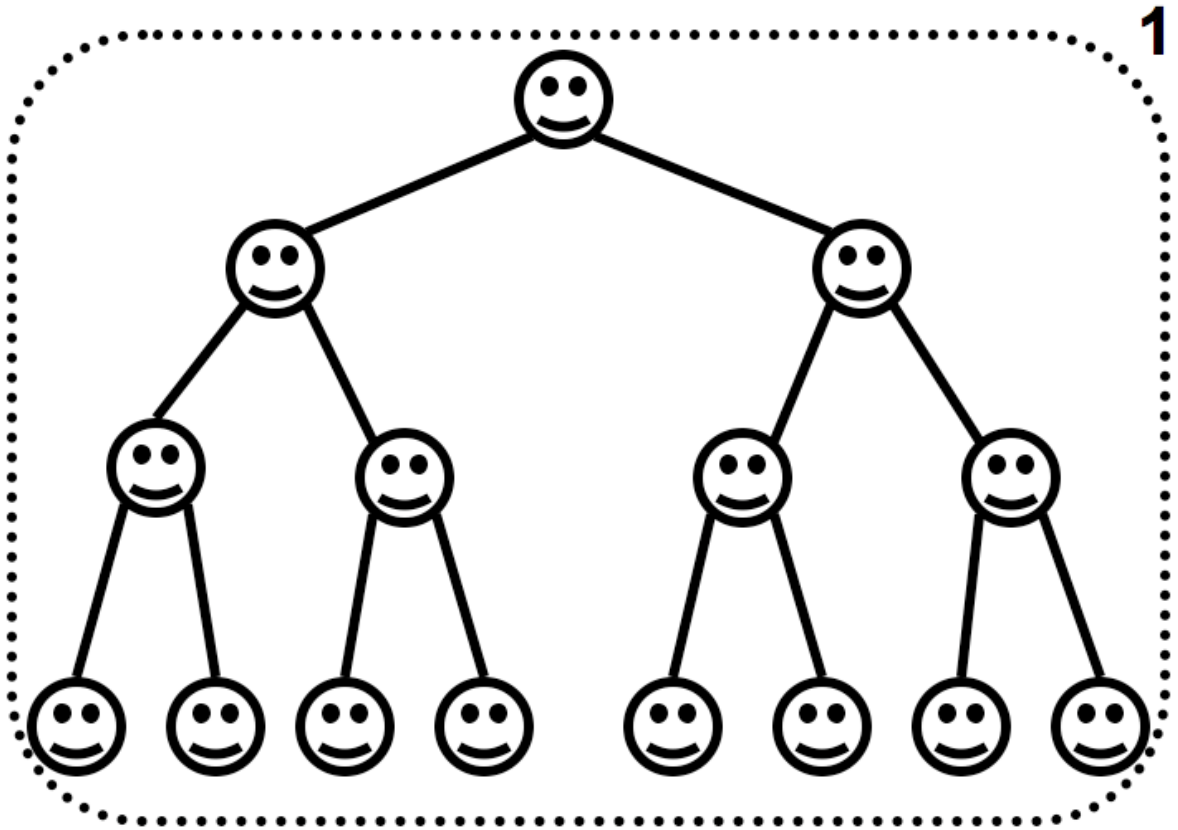
Emerging properties

Self-optimization of energy utilization through the self-adaptation in the selection of energy plans

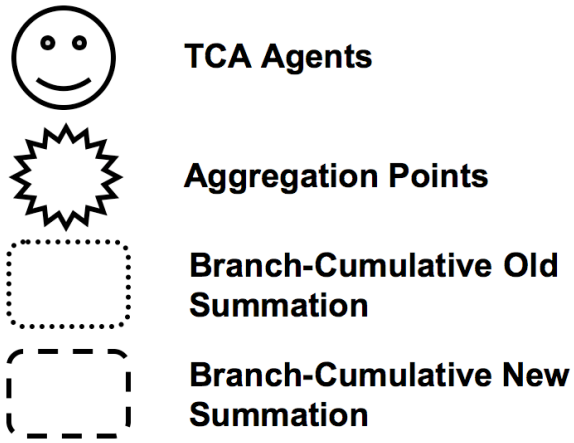
EPOS Algorithm

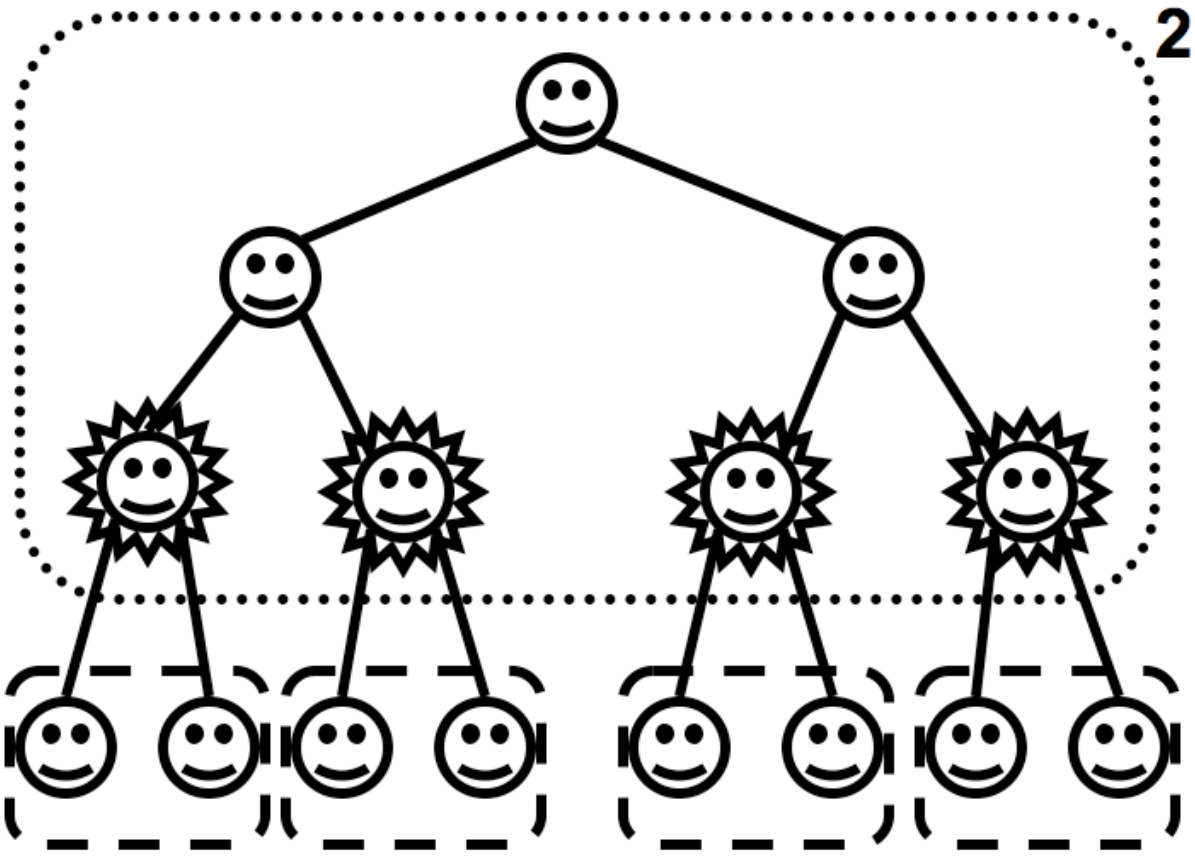


- Pre-existing knowledge (old plans)



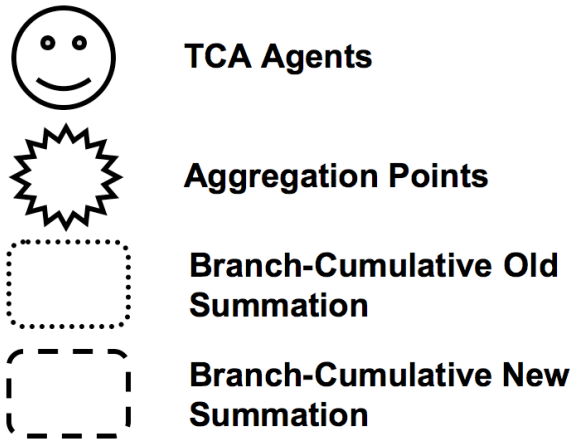
EPOS Algorithm

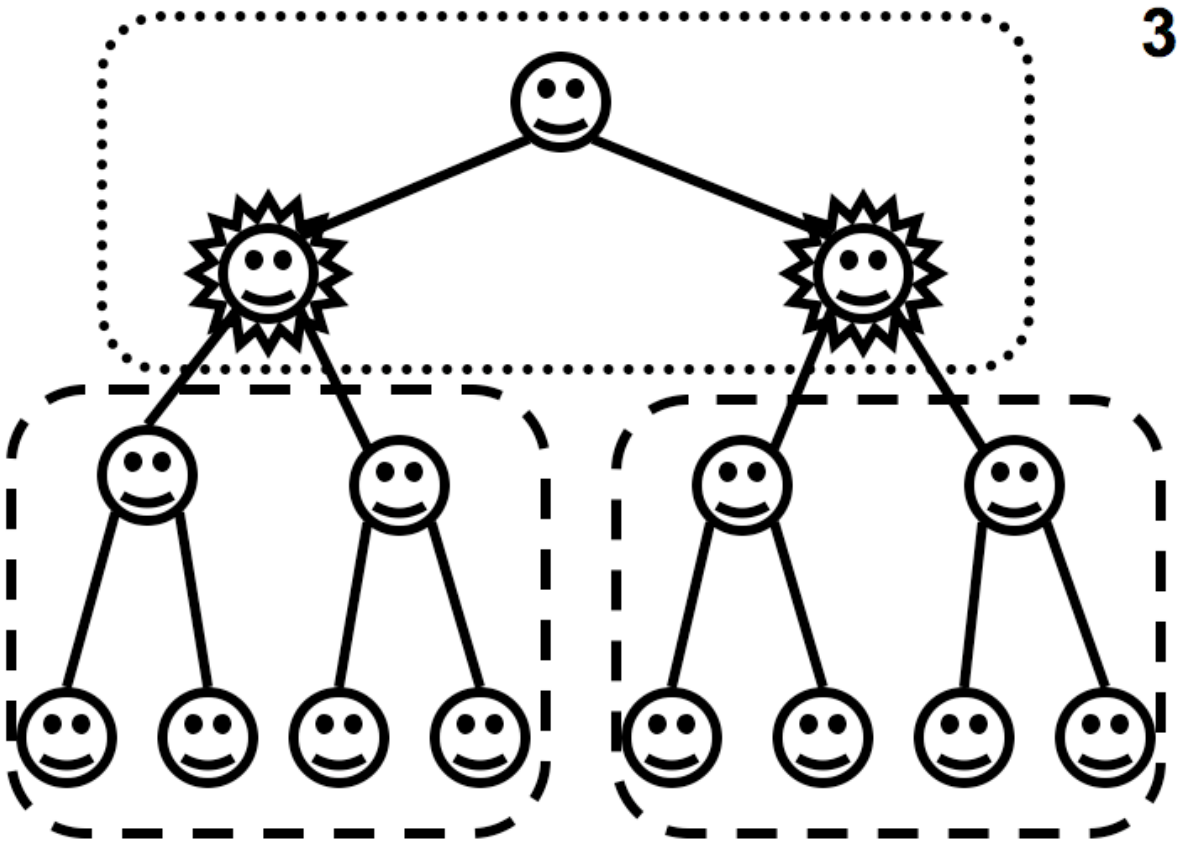




- 4 branches-aggregation points
- Low branches height
- Old knowledge influence decreases

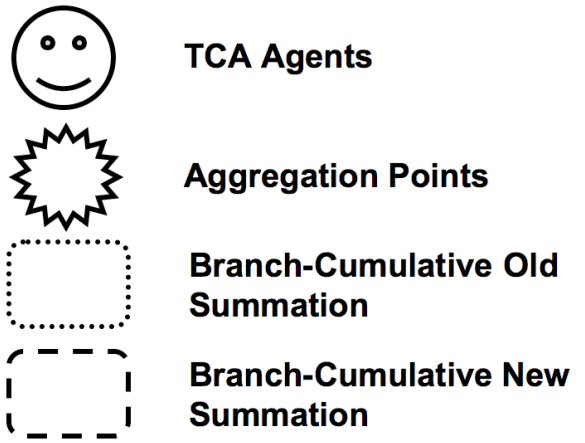
EPOS Algorithm

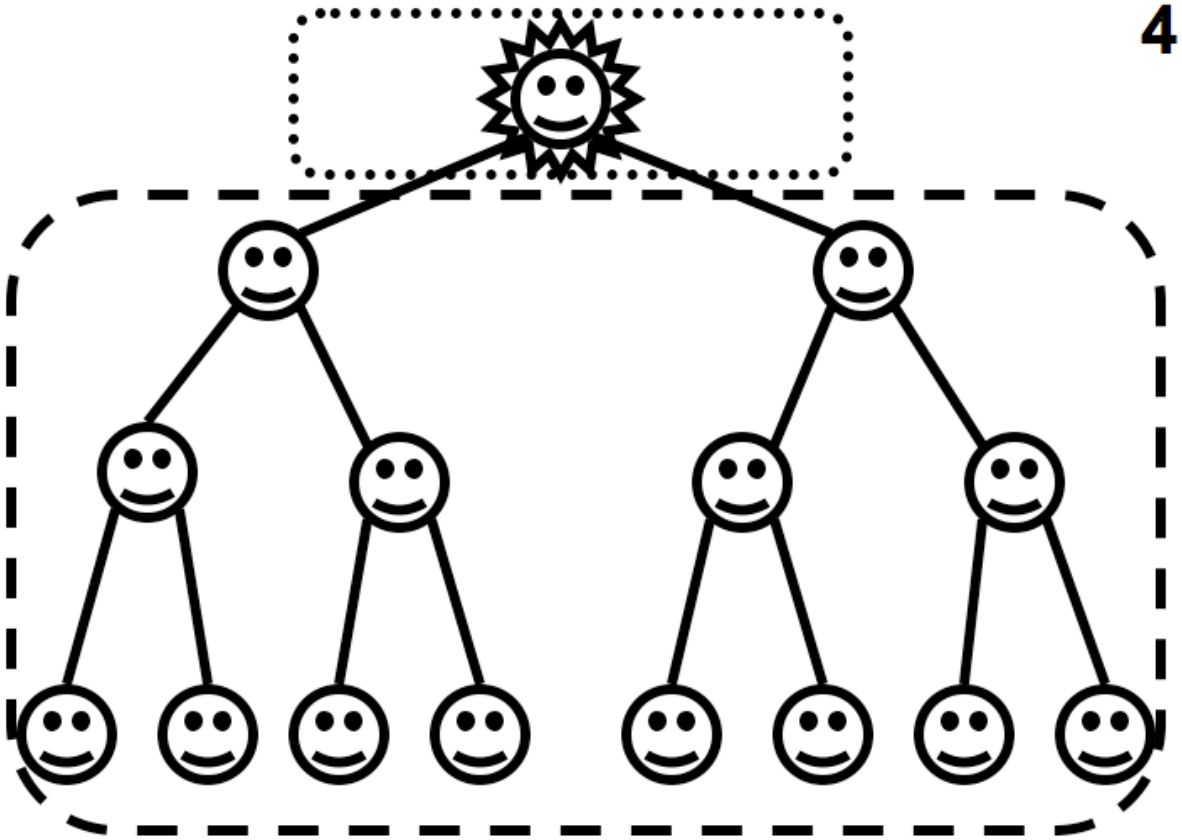




- 2 branches-aggregation points
- Increased branches height
- Influence of old knowledge decreases more

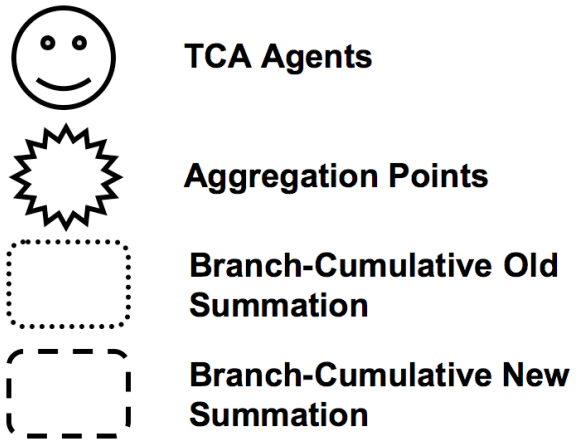
EPOS Algorithm



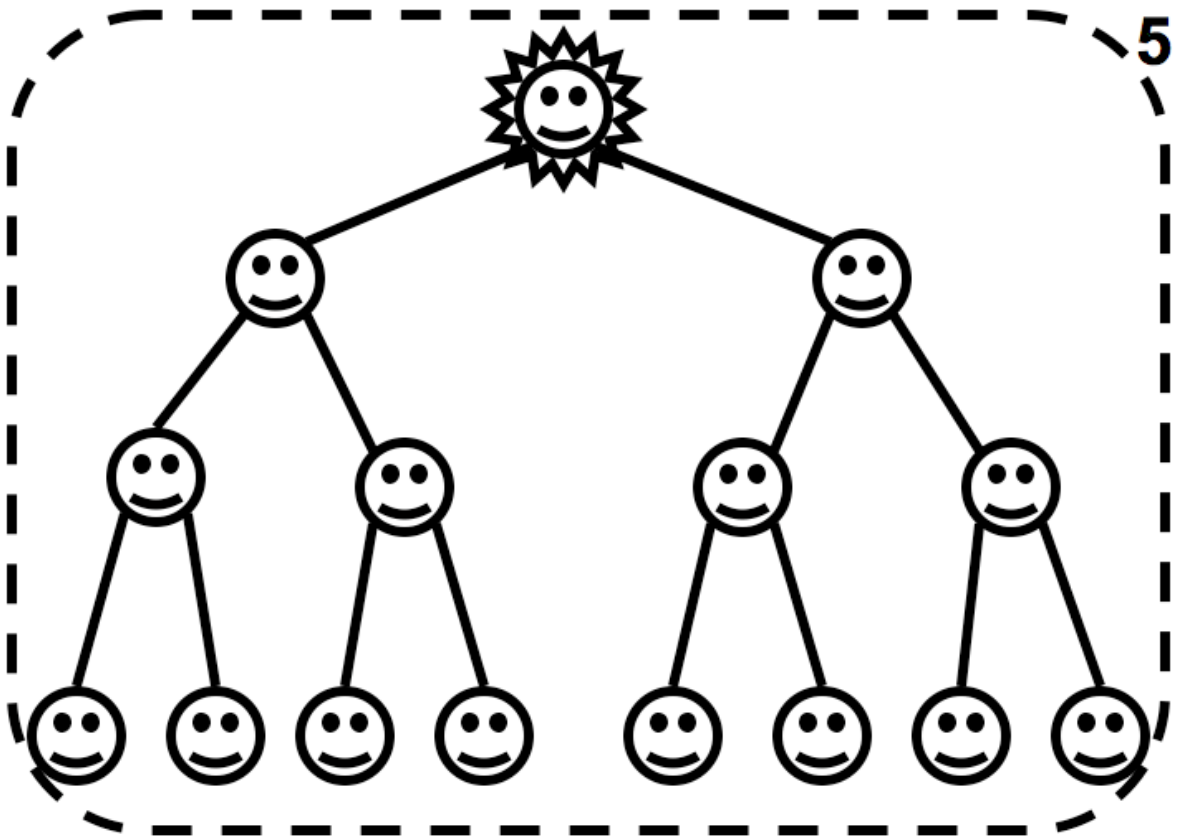


- 1 branch-aggregation point
- High branch height
- Old knowledge influence decreases even more

EPOS Algorithm



- Convergence to tree - global plan in the root
- Adaptation based fully on the new knowledge



Experimental Environment

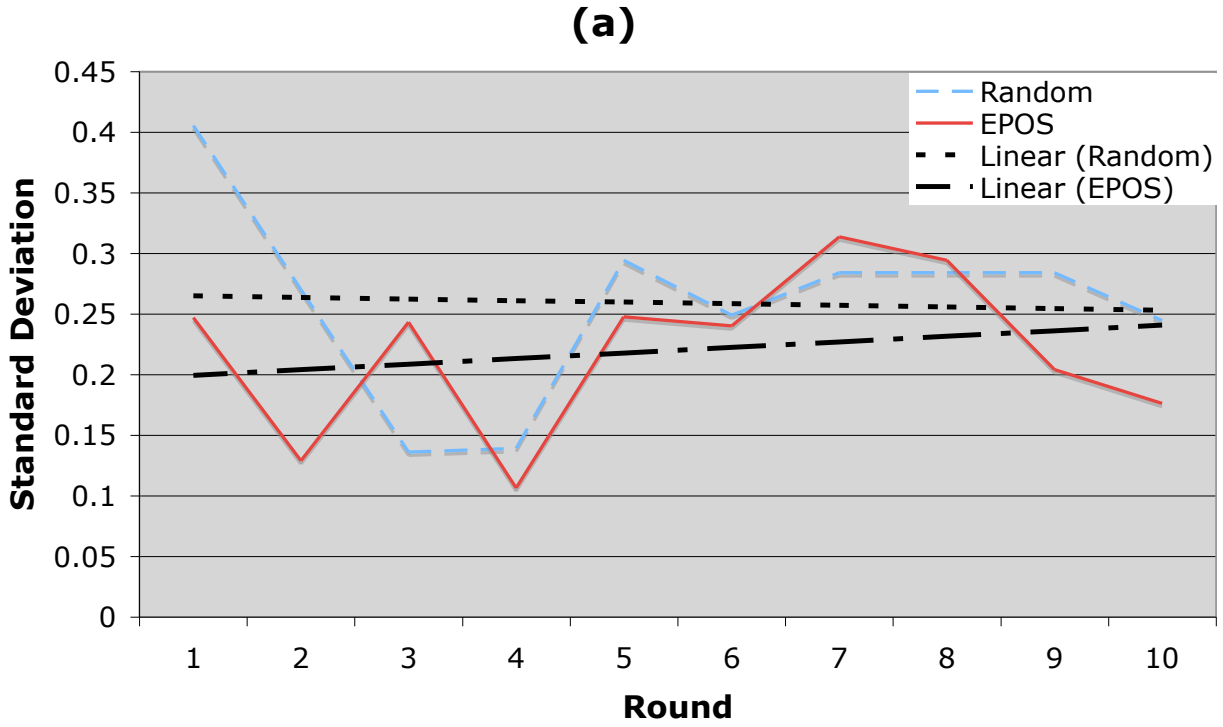
- Binary tree with 7 peers (3 levels)
- 2 generated plans/agent/aggregation round (normalized in [0,1]
  - 10 energy values
  - Random seed/average value
  - +/- 0,2 deviation
- 10 aggregation rounds
- Knowledge of previous round

- 2 methods examining energy stabilization
  - **Standard deviation**
  - Area-based

- Comparison with random plan selection

Results

- 15% improvement



(t=1.20, df=18, p ≥0.13)

Conclusions & future work

- Multidimensionality of decentralized complex energy plans aggregation
- EPOS: Energy Plan Overlay Summation
  - Cumulative plan summations, hierarchy, memory
  - Indications for an effective energy load-balancing mechanism

- Self-organization of tree overlay (build & maintenance)
- Exploring the level of knowledge needed for effective adaptation
- Large-scale experiments

Questions?