Universiteit van Amsterdam

Leibniz Center for Law

Faculteit Natuurkunde, Wiskunde en Informatica

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What is going on: Utility-based Plan Selection in BDI Agents

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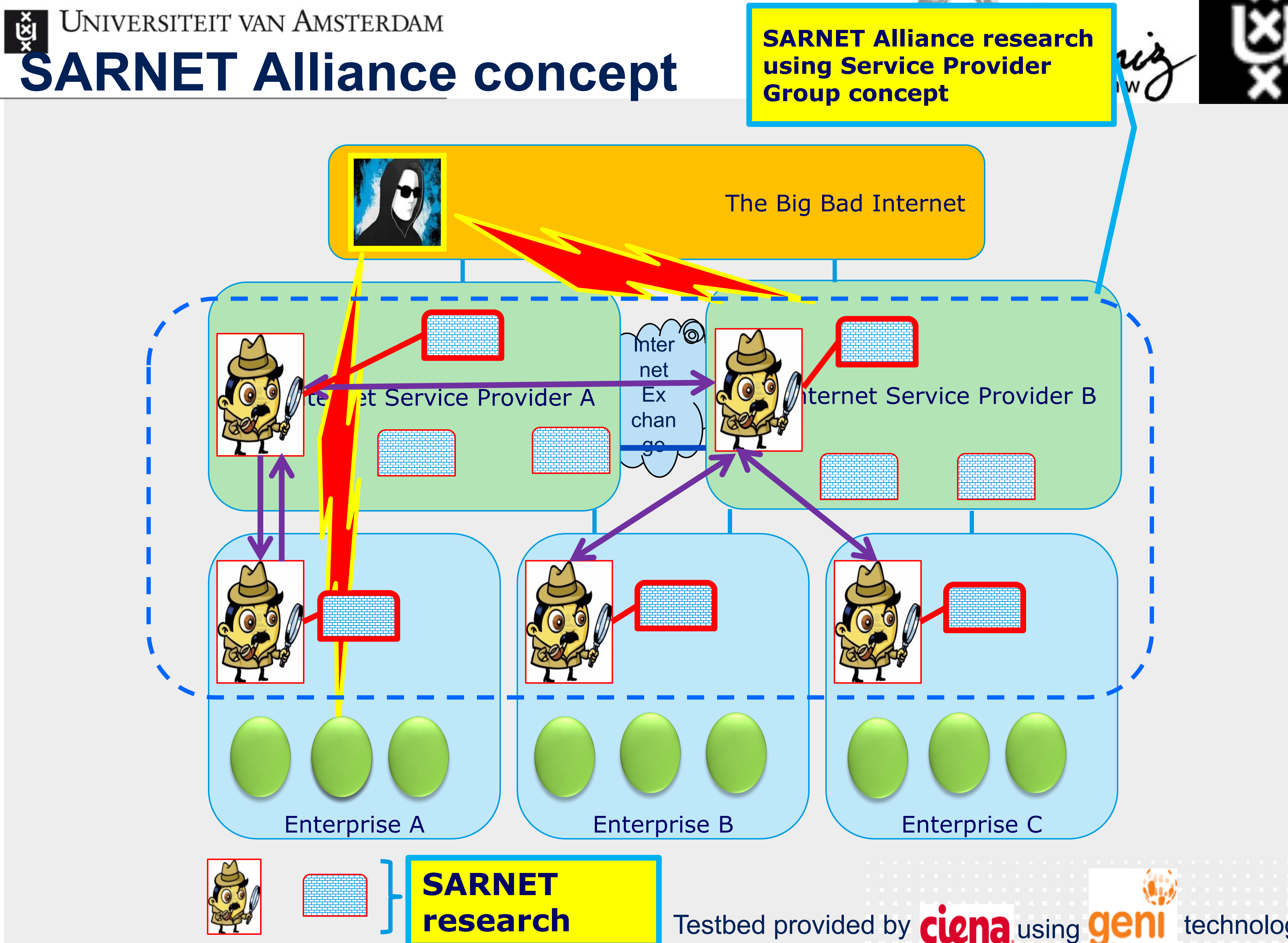
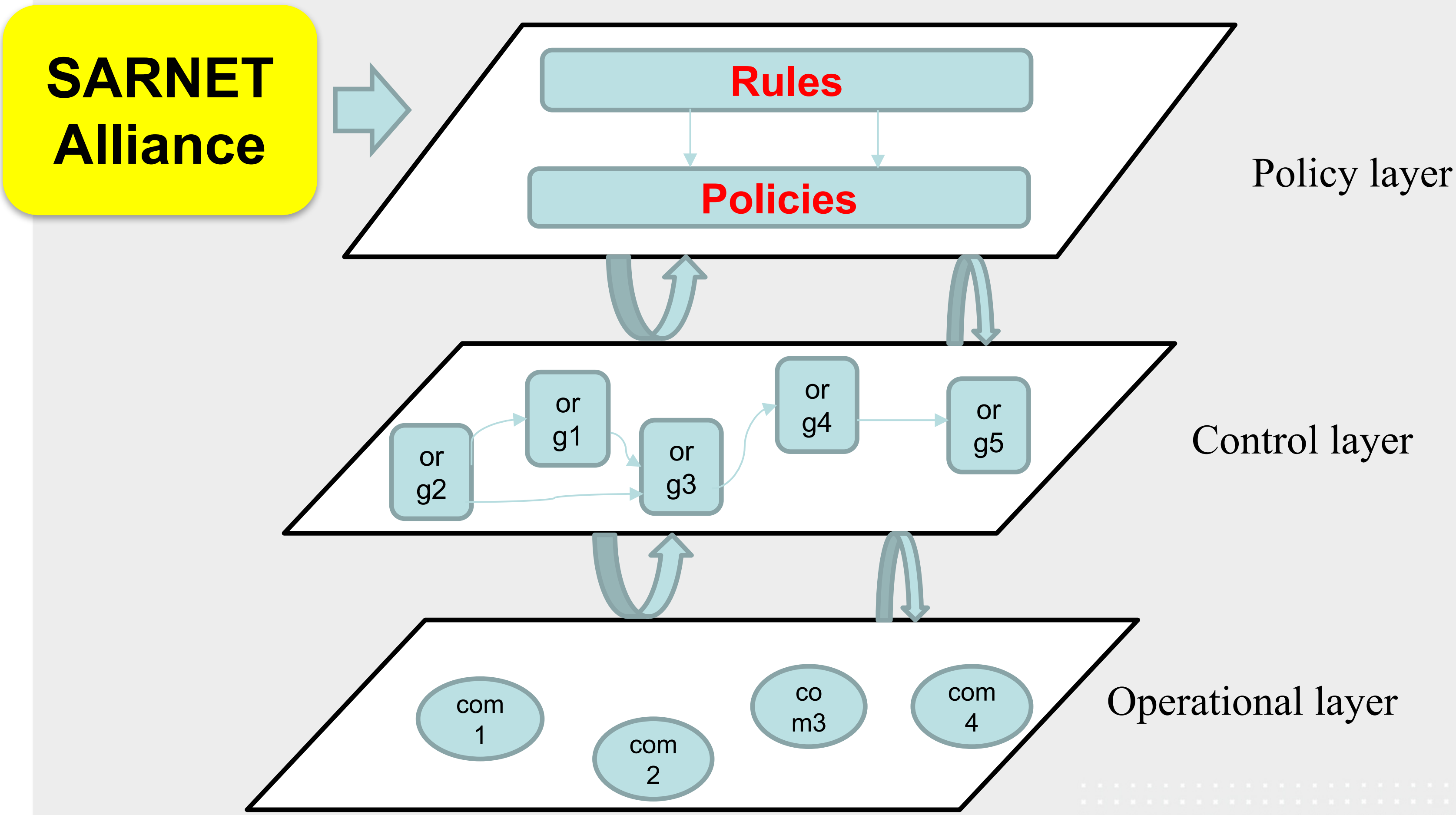
SARNET Alliance concept



Testbed provided by ciena using geni technology

SARNET Alliance



We use an ABM approach to study collective behavior and the effectiveness of policies

- Collaborative network of organizations are bounded by collaborative rules.
- Complex relationships and dependencies.
- Need to act in open, dynamic, and unpredictable environment.
- Demand for selecting an appropriate plan.
- Bounded rationality.

"How to integrate uncertainty/probabilities in the agent model to take an appropriate action and keep the system within acceptable boundaries."

Goal of the subproject presented

- Development of an extended version of the BDI agent model
- Integration of utility and the probability in the agent planner component
- Extension of the BDI control loop
- Enabling us to study CAS effects of the adaptation behavior of agents

Decision Theory and Expected Utility

Decision theory

Expresses as a set of mathematical techniques for making decisions about which action to take when the outcomes of the various actions are not known.

Writing *S* (*S refers to states*) for the set of all S_n reads:

$$\Pr(Si) \in [0\ 1],$$

Where,

$$\Pr(S1)+\Pr(S2)+\Pr(S3)+\&+\Pr(Sn) = 1$$

Expected Utility

A utility represents the value that the agent places on that state of the world (or environment).

It also provides a convenient means of encoding the agent's preferences.

$$EU(P) = \sum_{si \in Si} \Pr(Si|P) \times U(Si)$$

And the agent selects a plan with: $P^* = \arg\max_{p \in P} \sum_{si \in Si} \Pr(Si|P) \times U(Si)$

Basic Control Loop

Agent Bob Tuple = $\{O, B, G, P, A_p\}_{i^*}$

i=current state i*

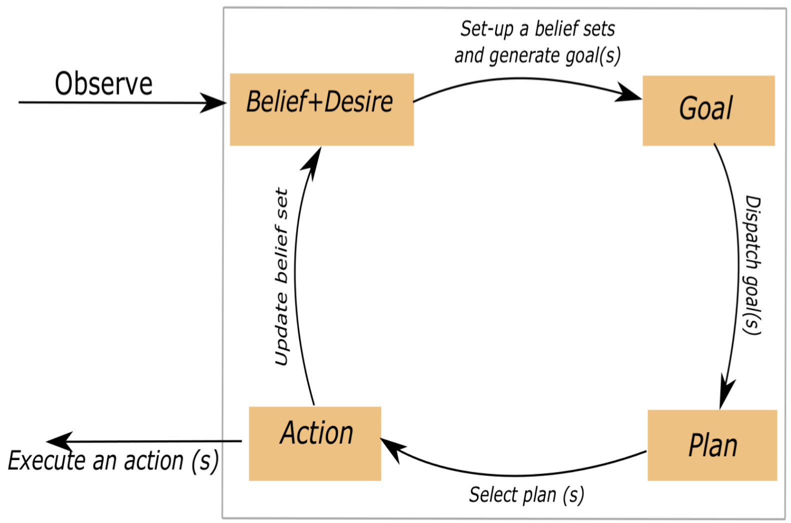
Set of Observations

Agent's belief set

Set of Goals

Set of plans

Set of Actions



Algorithm 1: Control loop for the classic BDI agent.

Given an agent $\{O, B, G, P, A_p\}$

repeat

$O := Observe(O);$

$B := Revise(B, O);$

$G := Generate\ G_g\ (B);$

$P := \forall g \in G \rightarrow generate\ P(B, G);$

$take\ (A_p);$

$revise(B);$

until *forever*;

Approach to Extend the BDI agent model

A plan: $pi^* \in Pi$ $\{pi, A_{pi}, \text{Contributionvalue}\}$

Plan Utility: $PU(pi) = \sum_{pi \in Pi} \Pr(Si \mid pi) \times U(Si)$

Where: $U(Si) = \Pr(Si) \times \text{Contributionvalue}(\text{Gi},\text{Si})$

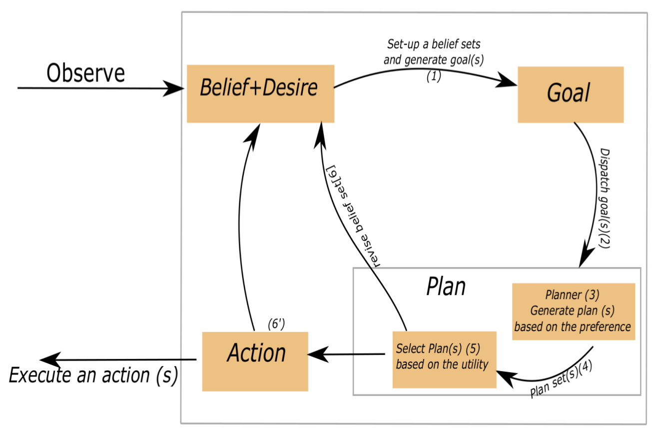
Plan Expected Utility Preference:

$$\Pr ef(Pi, Si) = \arg\max \sum_{pi \in Pi} \mathrm{P}U(Pi, Si)$$

Modified Control Loop

Divided an agent planner component in two sub-components:

1. Planner to generate plans based on the agent preferences
2. Select the most appropriate plan based on the plan utility



Algorithm 3: Modified control loop for the extended BDI agent, (1-6) are referring to Figure 2. In the extended BDI model, *6 and 6'* are executed simultaneously. *i* is the current state of the agent.

Given an agent $\{O_i, B_i, G_i, P_i, A_{p_i}\}$

repeat

$O_i := Observe(O_i);$

$B := Revise(B, O);$

$(1) G_i := Generate\ G_g\ (B);$

$(2) P_i := \forall g \in G \rightarrow generate\ P_i(B_i, G_i);$

$(3,4) P_i := Calculte\ U_P\ \forall\ p_i \in P(B_i, G_i, P_i);$

$(4,5) PrefP_i := Update\ P\ to\ PrefP_i(B_i, G_i, A_{p_i}, P_i);$

$(6,6') B_i := revise(B_{i-1}, PrefP_i);$

$(6') take\ (A_{p_i});$

$i := i + 1;$

until *forever*;

Plan Selection Algorithm

- A planner receives the current state S_i where $S_i \in S$ and produces the states $S_1, S_2, \ldots, S_i$;
- For each state we generate the probability value $Pr \in [0,1]$, which is assigned to $S_1, S_2, \ldots, S_i$.
- The utility function applies to these states and the preferred plan $Pre\, f_P$ regarding that states is chosen.

Algorithm 2: Select Plan

input : (sub)Goal, Set of plans ($p_i \in P_i$), the Probability of each plan

output: Selected P_i, Plan that has the best utility.

$SelectedPlan(P_i) := null$;

for $p_i \in P_i$ **do**

  $U(p_i) := Pr(p_i) \times U(s_i)$;

  $PU(P_i) := setofPU(p_i)$;

end

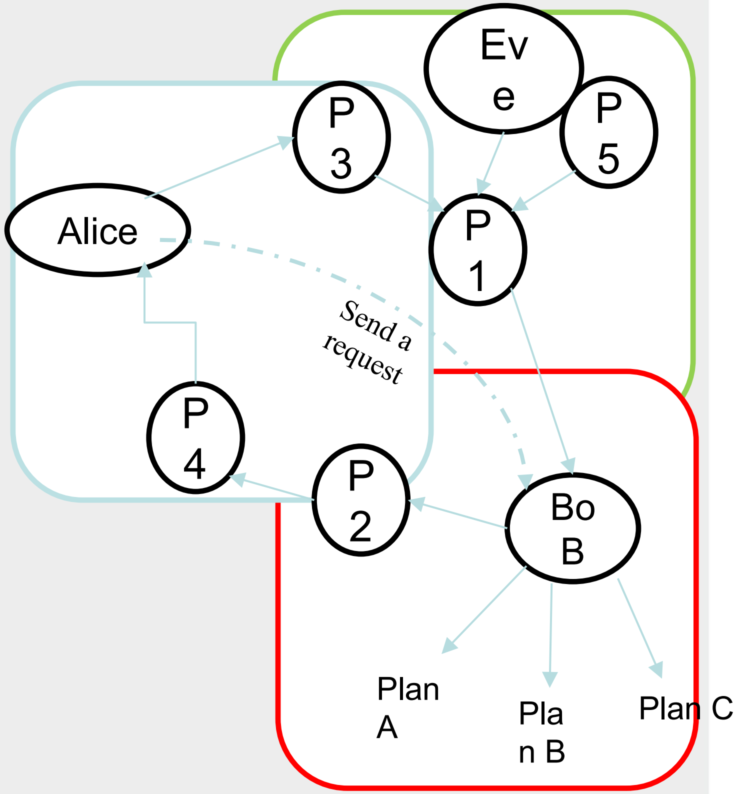
$PrefP_i := argmaxPU(P_i)$;

$SelectedPlan(P_i) := PrefP_i$;

return $SelectedPlan(P_i)$

Scenario

- **Alice** is looking for a way to collaborate with **Bob.**
- Alice and Bob **are not** part of a collaborative group.
- Each agent needs to **plan** its **actions** and **estimate risks** and **benefits**.
- Bob's Plans:
  - Plan A: Give overall access
  - Plan B: Request a certificate
  - Plan C: Deny Alice's



P = Peer

Goal: Share with Alice
Sub-goals: Estimate Benefits
and calculate Risk

Assumption

- Alice and Bob have not collaborated before.
- Each plan has a unique **probability**.
- Each plan consists of different **sub-plans** with different **contribution values** and **probabilities**.
- Each plan is associated with a particular **response time** and requires a different **amount of work**.

Simulation Setup

***Step*1 :** Generate probability for each event randomly in the interval [0,1].
***Step*2 :** Instantiate ascribed scenario for each plan, according to the given probability of events.
***Step*3 :** Compute the utility for each plan. And, select a plan in three different situations:

1. Utility-based plan selection.
2. Randomly plan selection
3. Constantly plan selection.

	Plans and sub plans	Probabilities (Pr [0,1])	Contribution Values* ([0,1])
Plan A	Give overall access	0.35	0.06
	Start to share data	0.65	0.0
Plan B	Request a certificate	0.95	1.0
	Check the certificate	0.05	0.08
Plan C	Deny Alice's request	0.40	0.05
	Use the resources for own purpose	0.60	0.0

*The data for the contribution value for each goal is adopted from (Nunes and Luck 2014)

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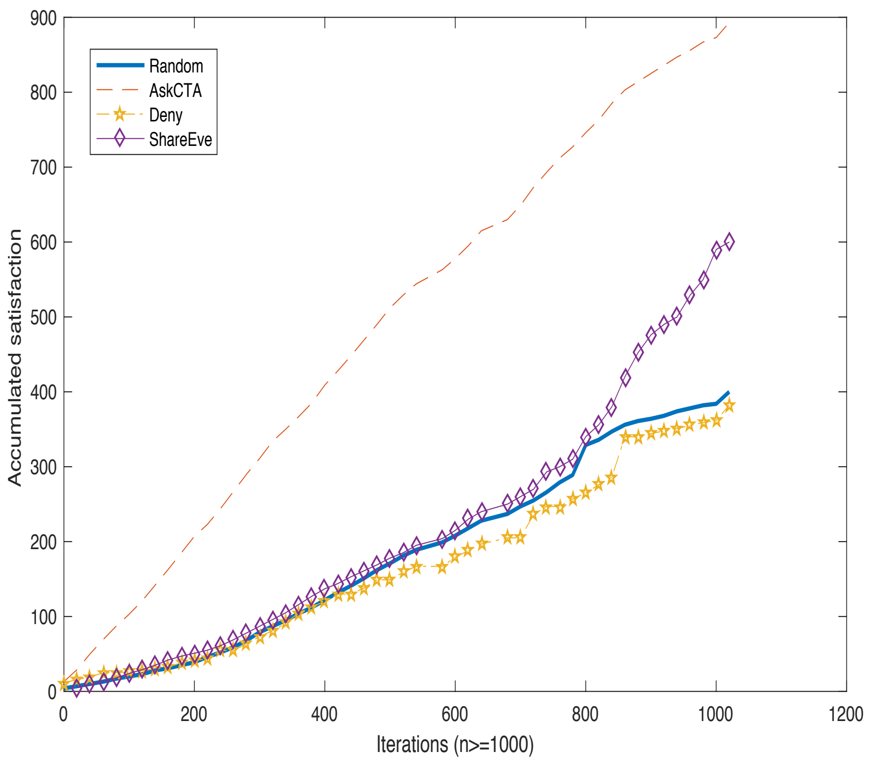
Results



Plans	M	SDV	Min	Max
Randomly	*0.38*	1.59	0.0001	0.44
AskCTA	**0.93**	*0.54*	0.0001	0.98
Share everything	0.41	0.72	0.0002	0.21
Deny	0.53	**2.76**	0.0001	0.60

Satisfaction by Plan Selector (n = 1000). Ask for a Certification (AskCTA) and Share everything are based on the utility plan selection algorithm. Deny plan is the constant plan that agent chooses as a current plan without considering the utility.

Accumulated Satisfaction by Plan Selector (n = 1000). Ask for a Certification (AskCTA) and Share everything are based on the utility plan selection algorithm. Deny plan is the constant plan that agent chooses as a current plan without considering the utility. Randomly plan selection when the agent selects a plan it randomly from a set of possible plans.

Future work

We use ABM to understand CAS

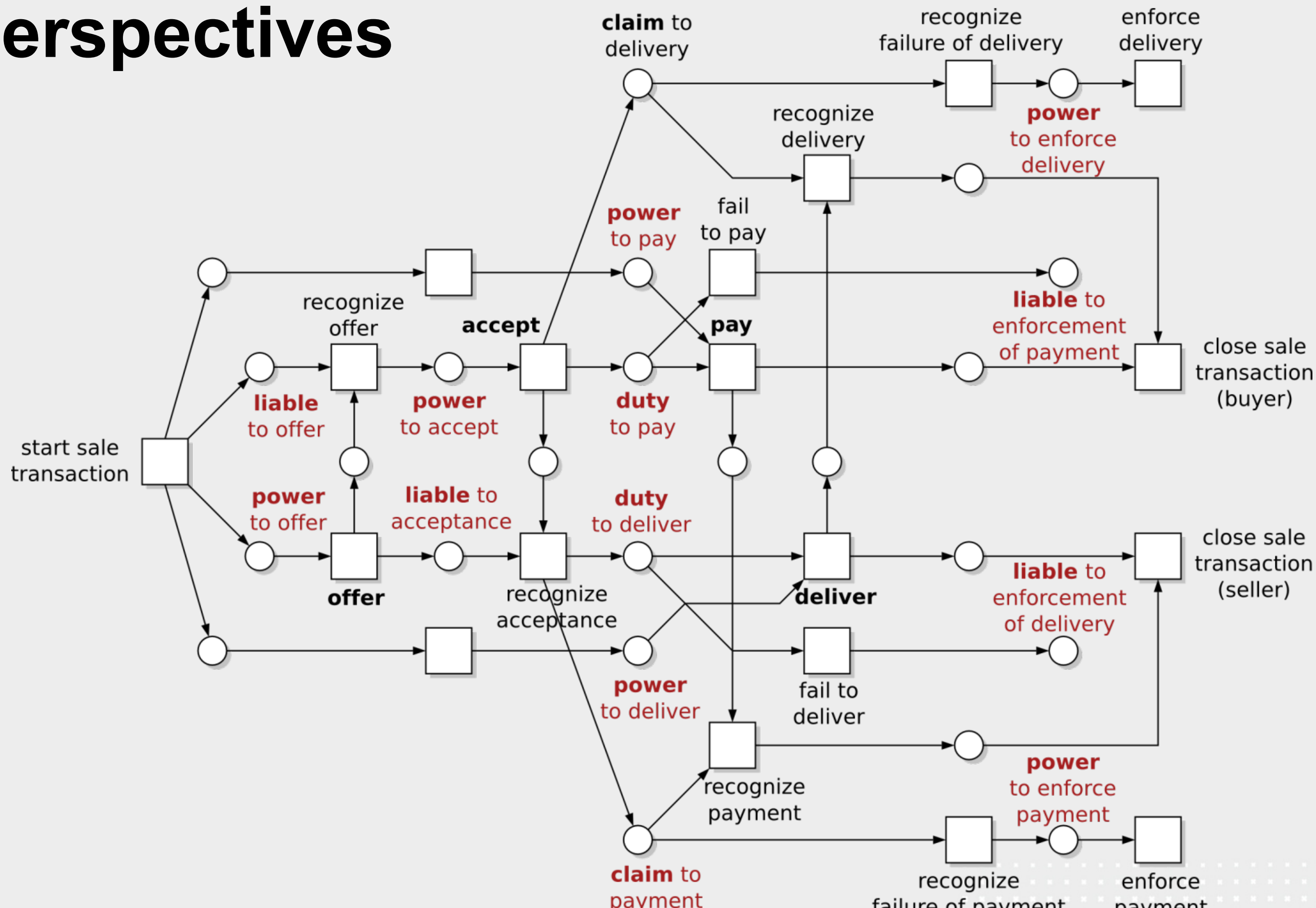
- Multi-agent system: Focus is on the individual agents and how they reason about and adapt to their environment

- Complex Adaptive Systems: Focus is on the dynamic aspects of the society of agents

Modeling Social Reality

- Requires the identification of social roles, their intentions, beliefs, plan operators and plans
- Requires us to think about who have a position to know and what the interests of these agents are and how that may impact trustworthiness of the information
- Requires us to think about the costs of providing/collecting the information and the proportionality/subsidiarity of that.

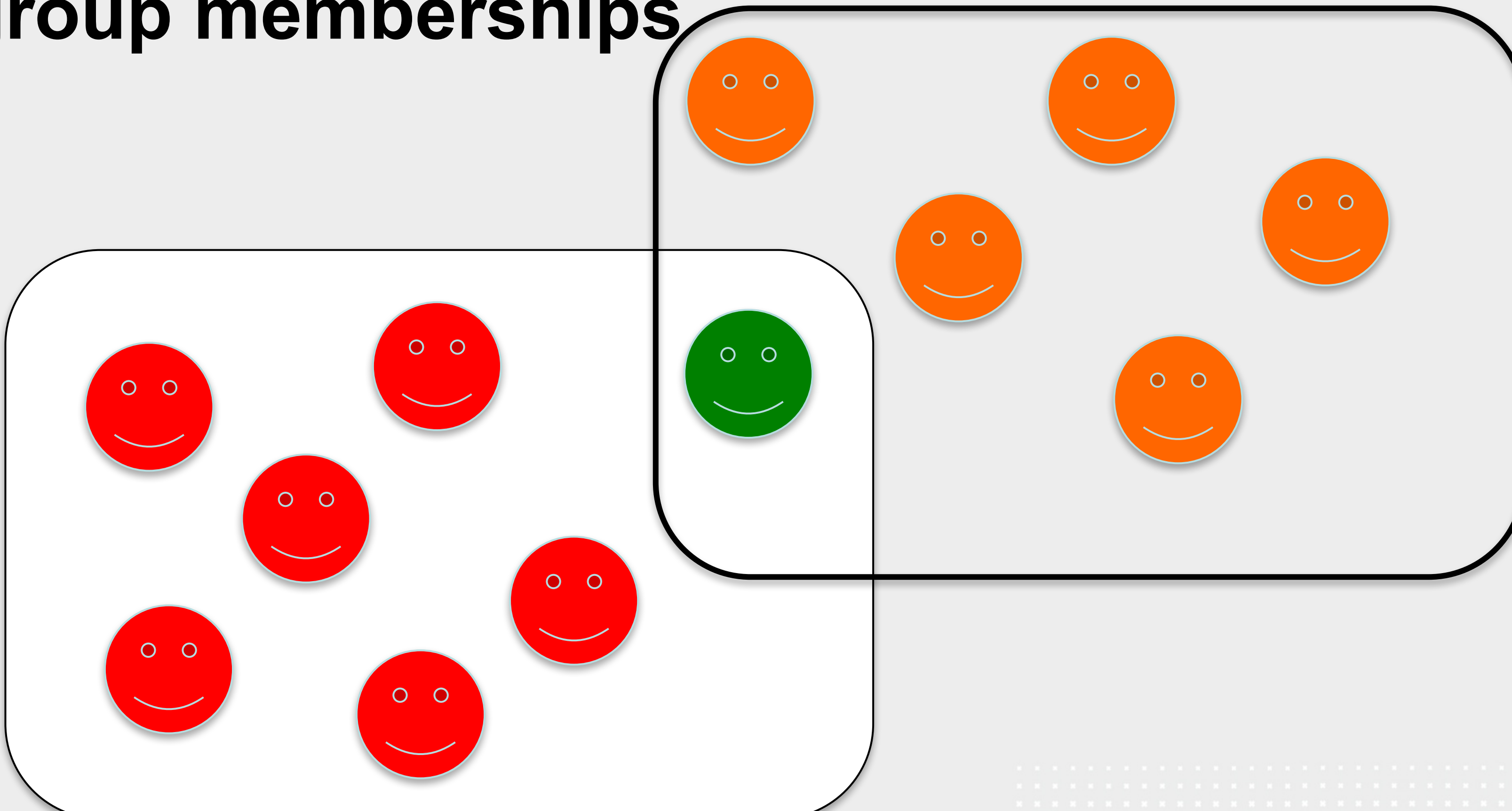
Example of complementary IR & SR perspectives



Typically today…

- Organizations don’t have explicit models of Institutional Reality linked to sources of norms
- Organizations don’t have a set of (non-)compliance scenarios (dynamic models of Social Reality) nor an idea about a method to check the completeness of the set of scenarios.
- There is no method yet to systematically categorize these scenarios and model specific scenarios as subsumed canonical ones (what is a useful abstraction? How could we describe it in such way that we know what we know?)

Our research addresses the interaction between IR and SR in CAS with multiple group memberships



We have come from far and still have a long way to go…

- Want to know more?
- Our next paper will be even better!

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Questions?

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