

Automated Negotiations in Supply Chain Management

SCML ANAC IJCAI

Yasser Mohammad^{1,2}

¹ NEC Corporation, AIST, and RIKEN, Japan

² Assiut University, Egypt

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Outline

1 Negotiation

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2 ANAC: A brief history

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- 3 NegMAS: The platform

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- Unmediated Protocols
- The Simplest Negotiation

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3 NegMAS: The platform

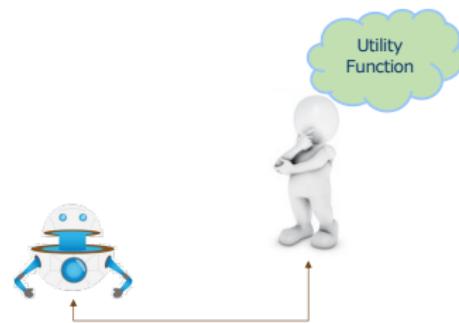
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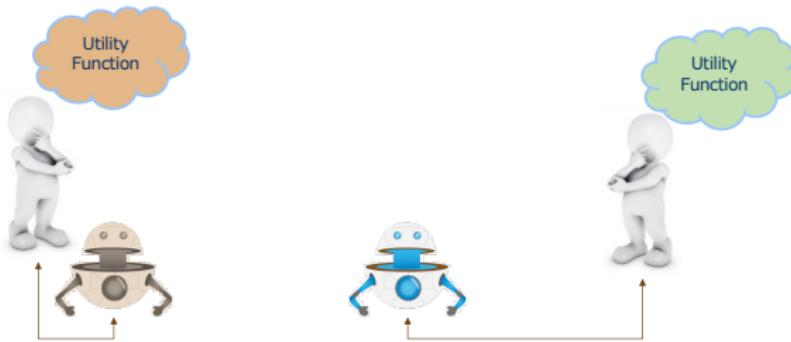
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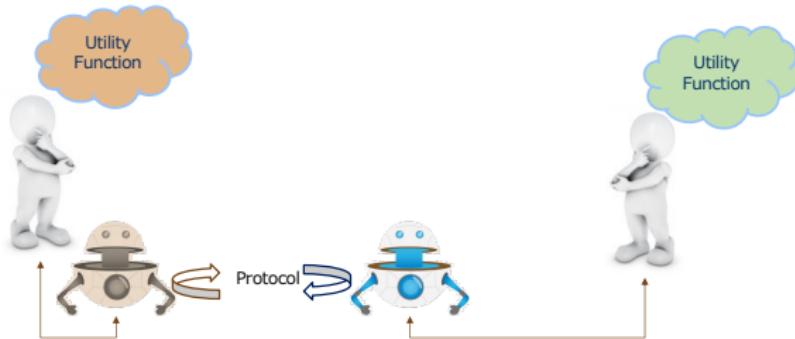
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- Negotiation is important → win-win agreements.
- Automatic Negotiation → \$\$\$
 - smart contracts, resource allocation, SCM, etc



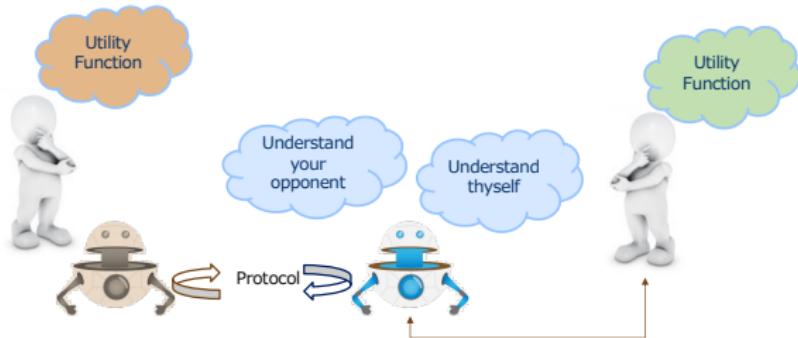
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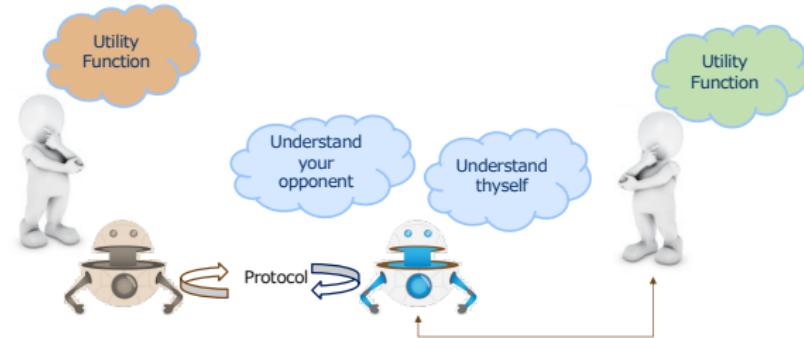
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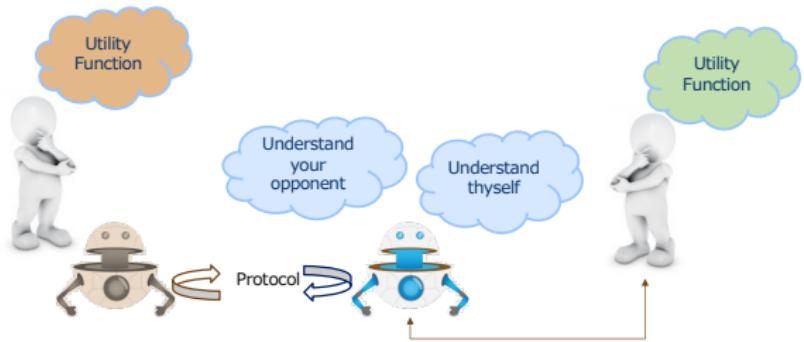
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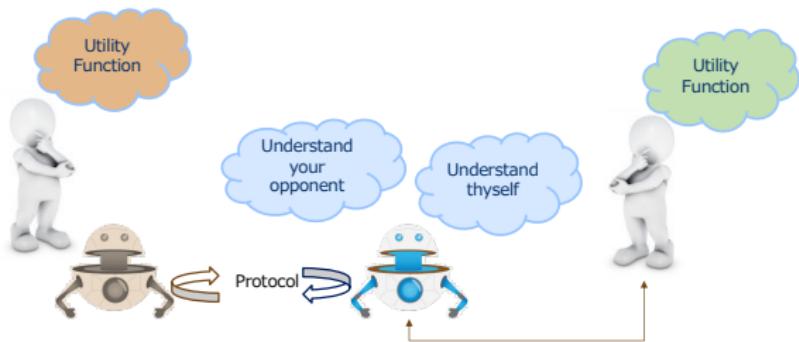
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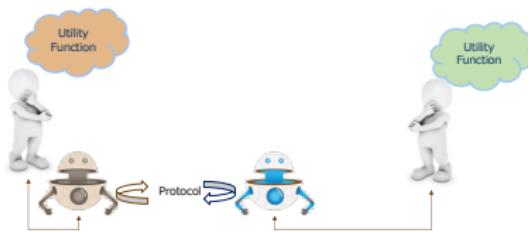


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Components of the Negotiation Problem



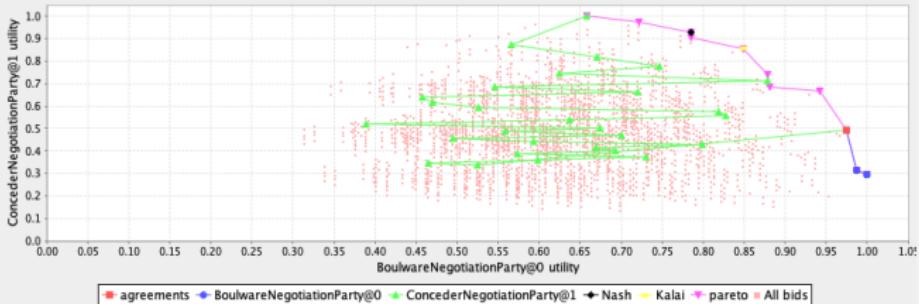
Negotiation Protocol Defines how negotiation is to be conducted [Mechanism Design Problem].

- Alternating Offers Protocol
- Single Text Protocol
- ...

Negotiation Strategy Defines how an agent behaves during the negotiation [Effective Negotiation Problem].

- Time-based strategies: Boulware, conceder, ...
- Tit-for-tat variations
- ...

Important Concepts



Pareto Frontier Outcomes that cannot be improved for one actor without making another worse off.

Welfare Total utility received by all actors.

Surplus utility Utility above disagreement utility.

Types of Automated Negotiation Problems

Negotiator type

- ① Agent-Agent negotiation
- ② Agent-Human negotiation

Number of negotiators

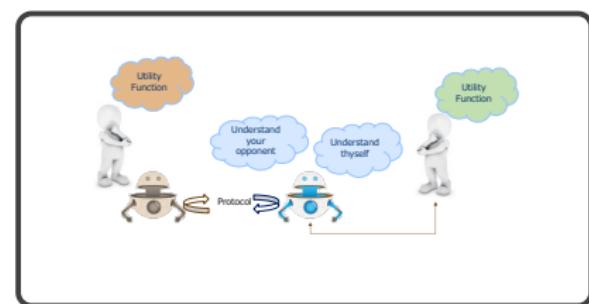
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Outcome Space

- ① Single Issue: $\Omega = \{\omega_0, \omega_1, \dots\}$
- ② Multiple Issues: $\Omega = \prod_{i=1}^{n_i} I_i$

Protocol Type

- ① Mediated
- ② Unmediated



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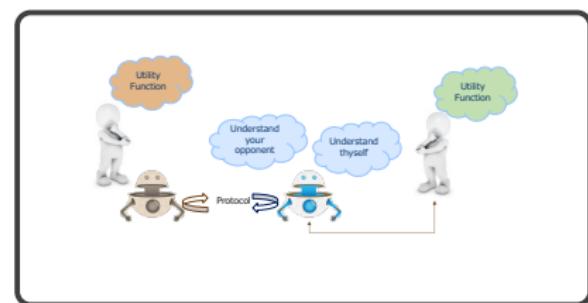
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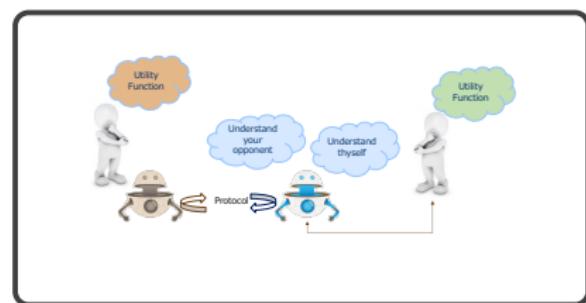
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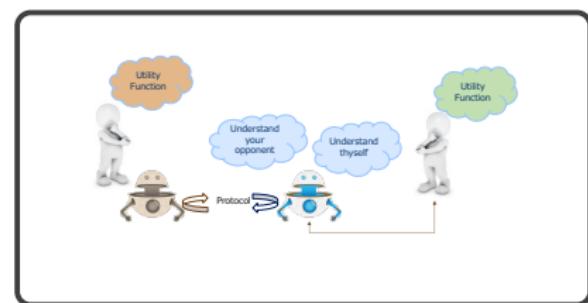
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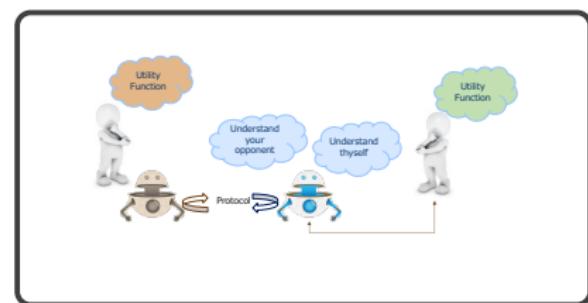
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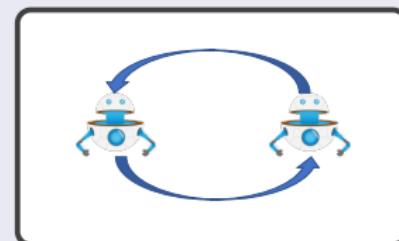
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Unmediated Protocols

Main Features

- No central coordinator.
- Agents negotiate by exchanging *messages*.
- All proposals come from negotiators.



Examples

Nash Bargaining Game Single iteration, single issue, bilateral protocol with complete information.

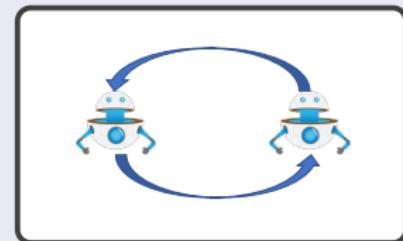
Rubinstein Bargaining Protocol Infinite horizon, single issue, bilateral protocol with complete information [Rubinstein, 1982].

Stacked Alternating Offers Protocol Finite horizon, multi-issue, multilateral protocol with partial information [Aydoğan et al., 2017].

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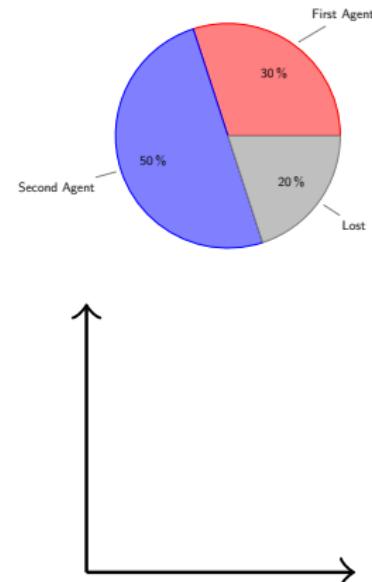
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A single-step full-information bilateral negotiation with $\Omega = [0, 1]^2$ and two utility functions $(\tilde{u}_1, \tilde{u}_2)$ such that:

- A (usually convex) feasible set of agreements F . A common example is to define F as all the outcomes for which the total utility received by negotiators is less than or equal to one:

$$F = \{(\omega_1, \omega_2) | \tilde{u}_2(\omega_2) + \tilde{u}_1(\omega_1) \leq 1\}.$$

- A disagreement point $d \equiv \tilde{u}_1(\phi) + \tilde{u}_2(\phi) \in \mathbb{R}^2$ which is the utility value received by the two players in case of disagreement (reserved values).



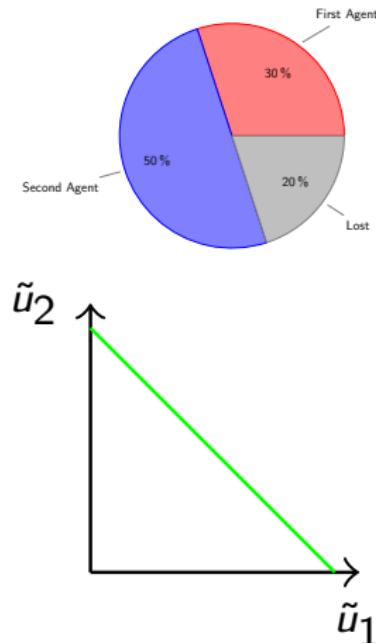
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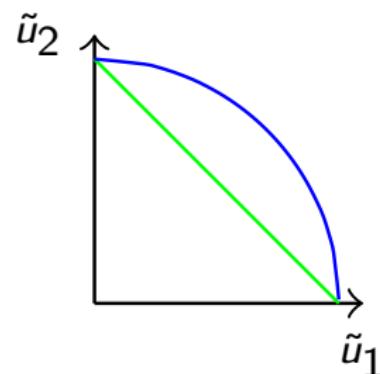
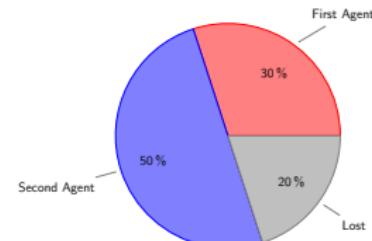
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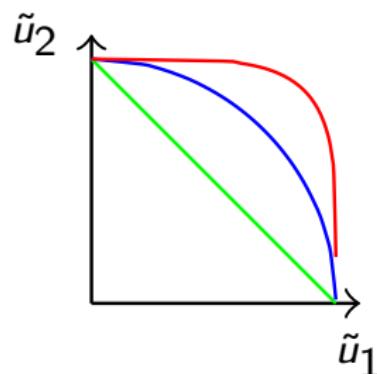
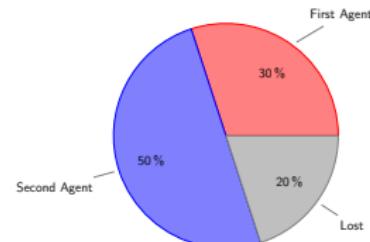
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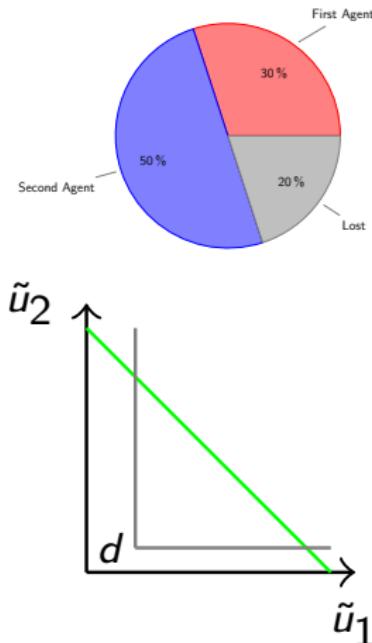


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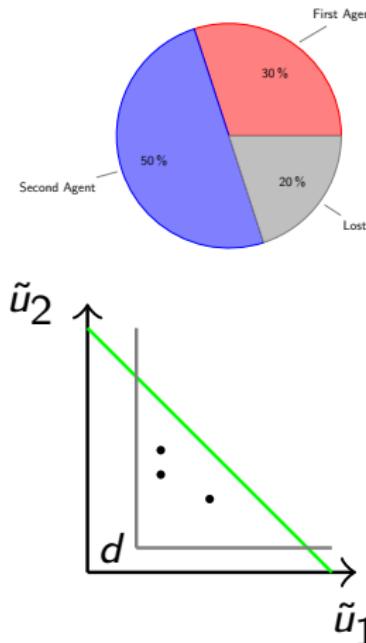


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A brief history of ANAC

- The Automated Negotiating Agents Competition (ANAC)
- Started on 2010 and is currently in its 11th incarnation.
- Was conducted in conjunction with AAMAS but currently IJCAI.

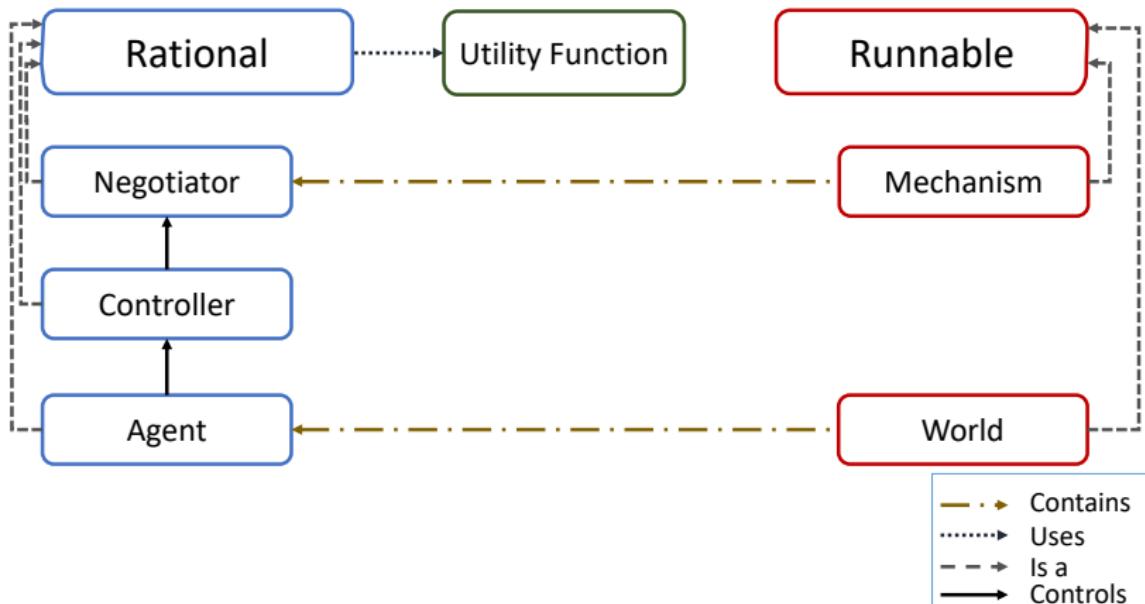


Year	Challenge	Year	Challenge
2010	Domain Independence	2011	Linear Ufuns
2012	Reservation Value	2014	Learning and Adaptation
2015	Three-party negotiation	2016	Energy Grid Theme
2017	Repeated Negotiations, Diplomacy, HAN	2018	Repeated Negotiations, Diplomacy, HAN
2019	Elicitation, Diplomacy, HAN, Werewolf, SCML	2020	Uncertainty, HAN, Were-wolf, SCML , HUMAINE

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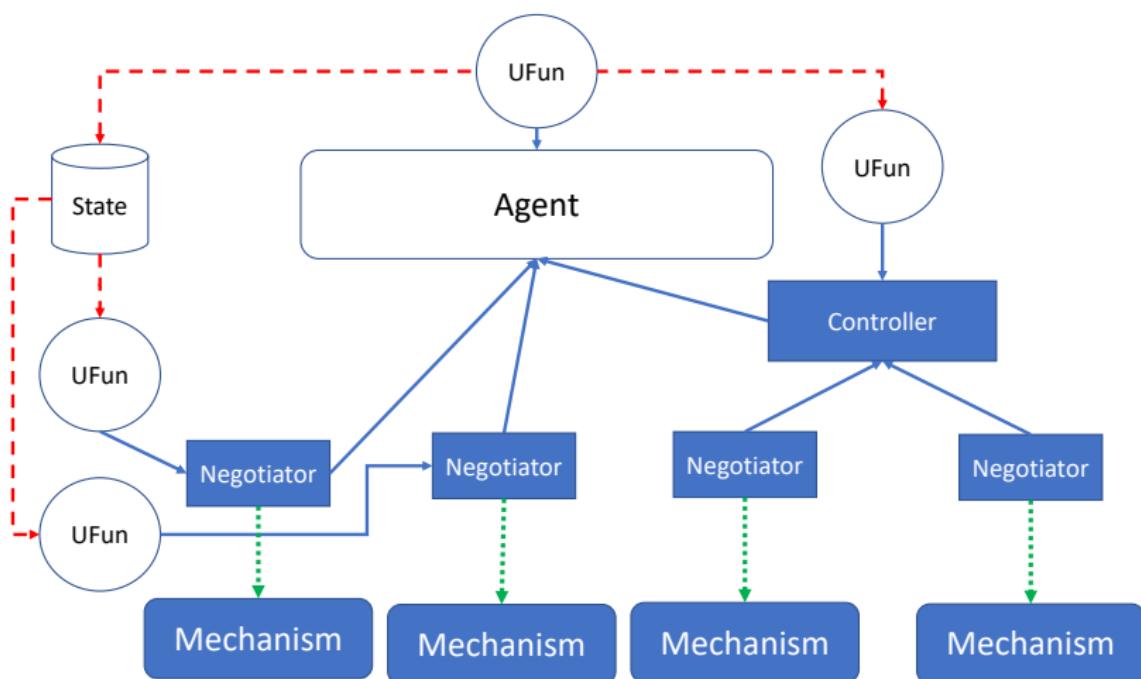
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NegMAS¹ in two slides

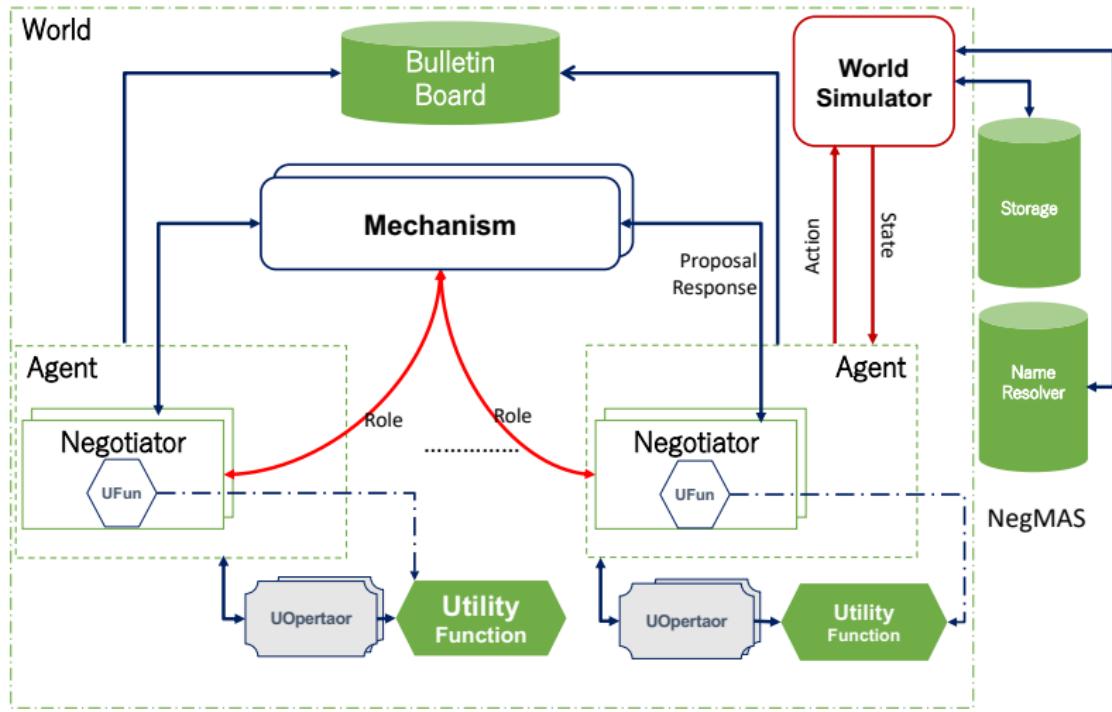


¹<https://www.github.com/yasserfarouk/negmas>

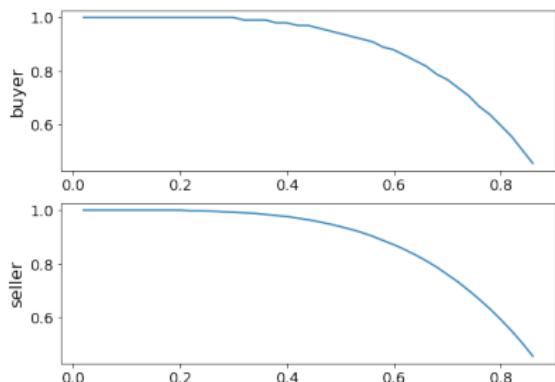
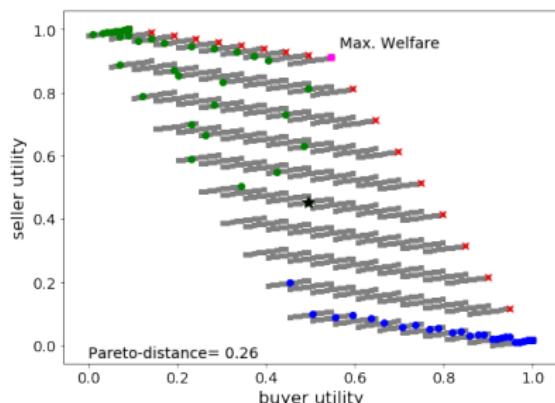
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NegMAS in two slides (... OK 3)



NegMAS in two slides (... really!!!)



- An Example negotiation.
- Can you spot a problem?

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Negotiation in SCM Business

CONTRACTROOM

pactum

- Human negotiations lead to an estimated 17-40% *value leakage* in some estimates ²
- A recent study suggests that at least 15 companies are working in *contracting support systems* ³.
- A recent UNECE UN/CEFACT proposal to standardize negotiation protocols for SCM and other applications ⁴
- More to come [Mohammad et al., 2019].

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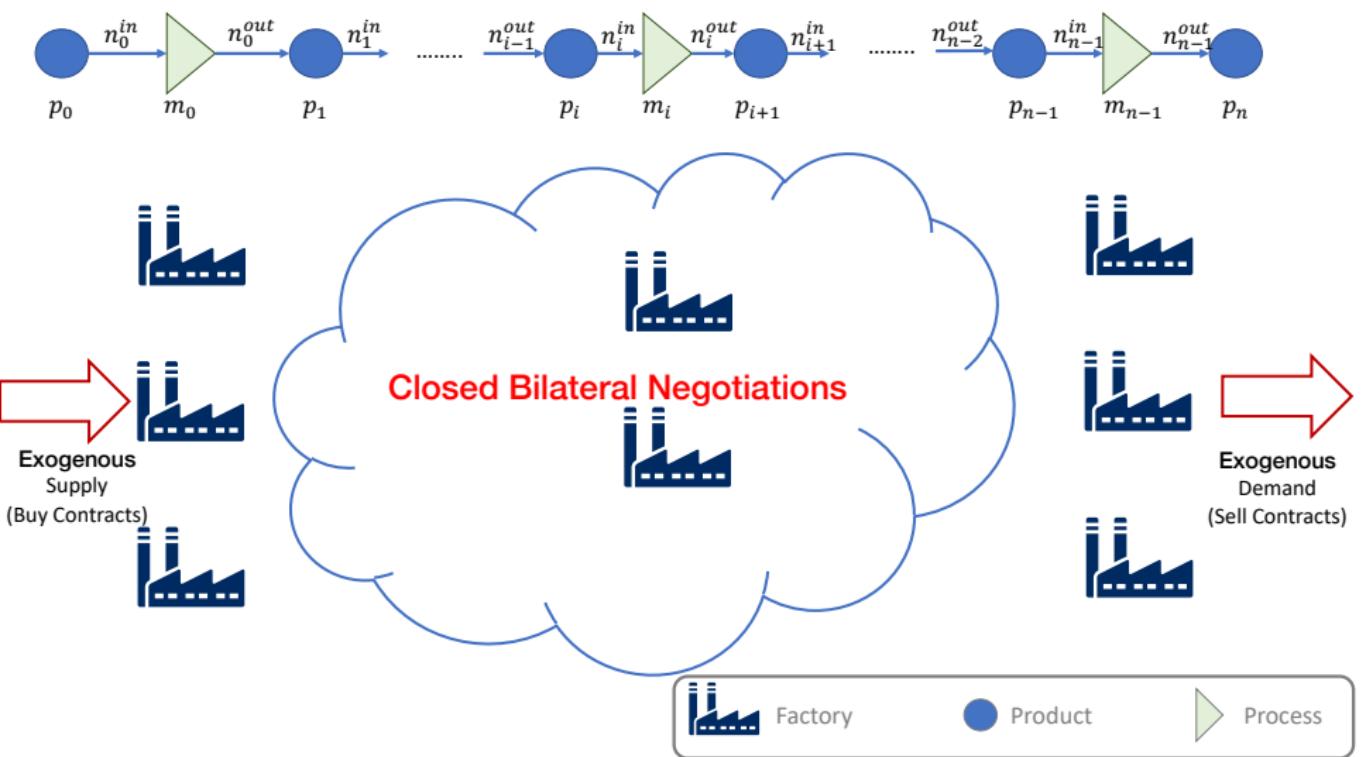
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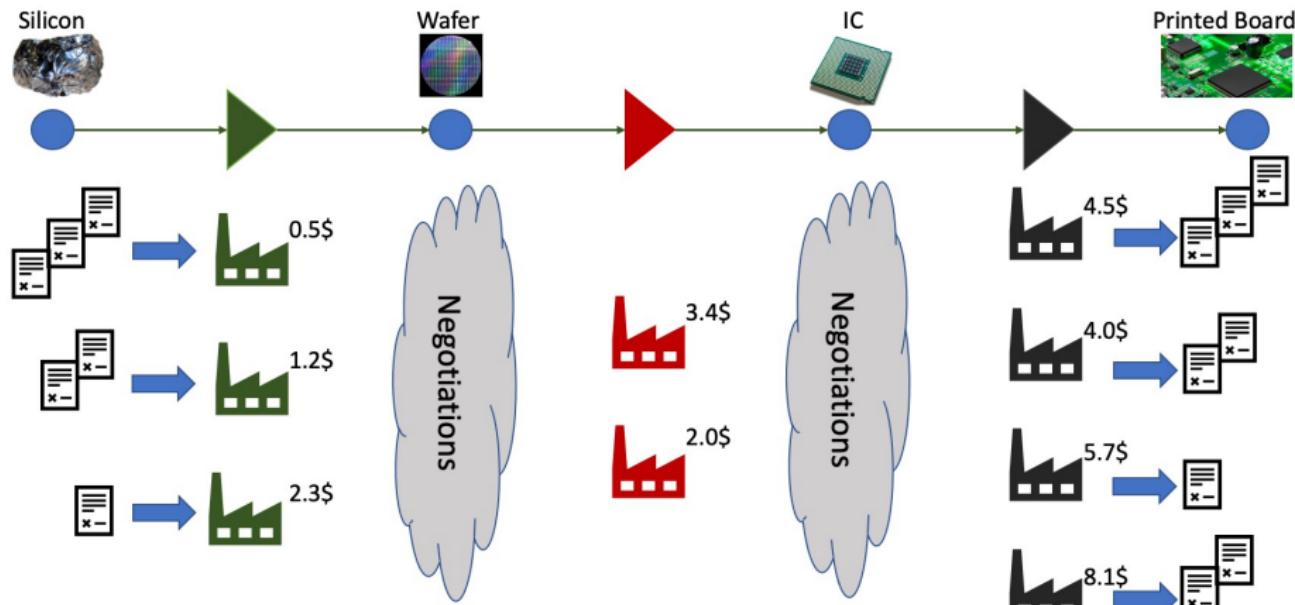
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SCML Competition [Mohammad et al., 2019]



Example Configuration

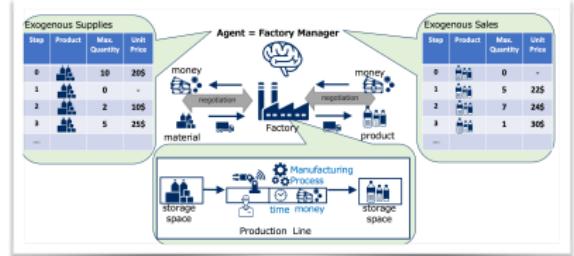
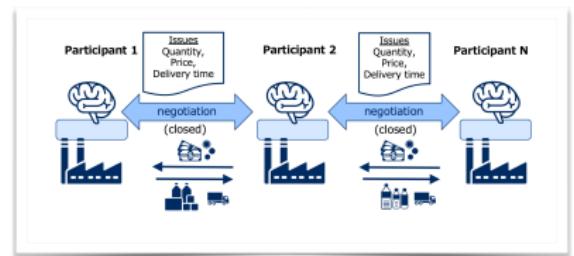
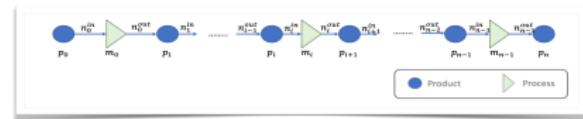


An example of an SCM world showing four products (circles), three processes (triangles) and few factories. Each process consumes one item of its input and generates one output of its output in one day. Each factory requires a different cost to run its process (shown in its top right). Factories in the first level have exogenous contracts to buy raw material (silicon) and factories at the last level have exogenous contracts to sell the final product (printed boards). These contracts drive the market.

SCML World

Challenge

- Turn **maximize profit** into a ufun!!
- Dynamic interdependent ufun.
- Sequential negotiations.
- Concurrent Negotiations.
- Negotiation under uncertainty.
- Adaptation and learning.
- Trust management.



Information

- Website** <https://scml.cs.brown.edu/>
- Code** <https://www.github.com/yasserfarouk/scml>
- Youtube** <https://www.youtube.com/playlist?list=PLqvs51K2Mb8IJe5Yz5jmYrRAwvIpGU2nF>

SCML Competition

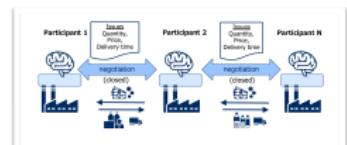
Competition Details

- Runs as part of ANAC IJCAI.
- You control one or more factories.
 - Standard track** → one factory.
 - Collusion track** → multiple factories (3).



Score Evaluation

- Per instantiation: Total profit counting inventory at half the **trading** price.
- Total: median of per-instantiation scores.



Flavors

- Online competition at
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- Official competition as part of ANAC.

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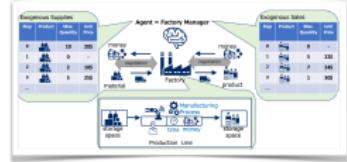
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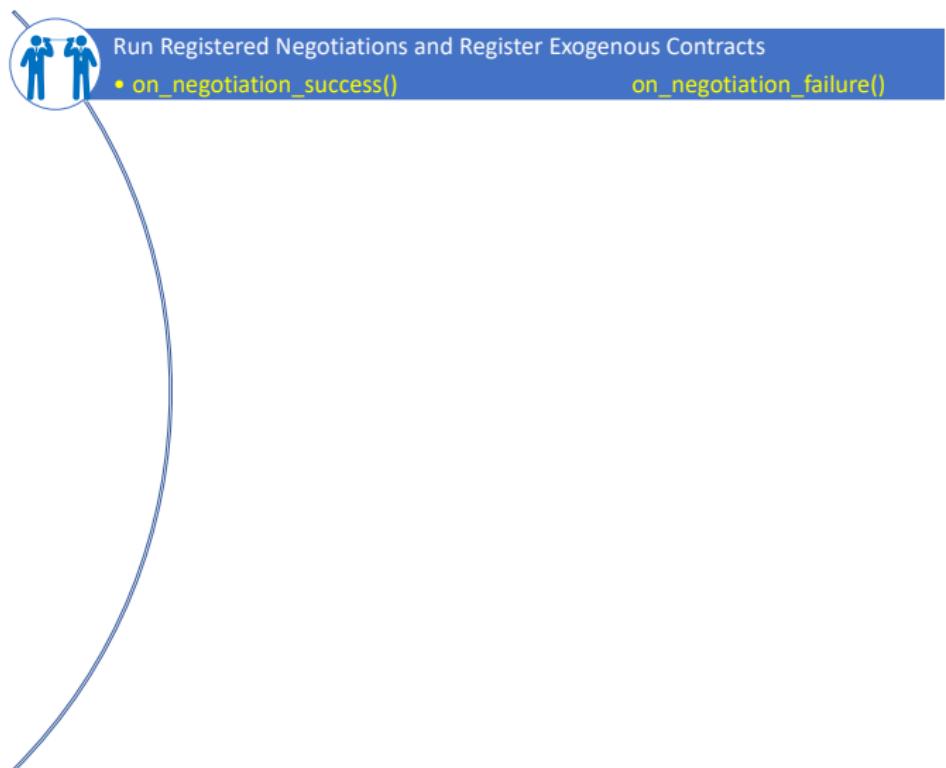
Simulation Steps

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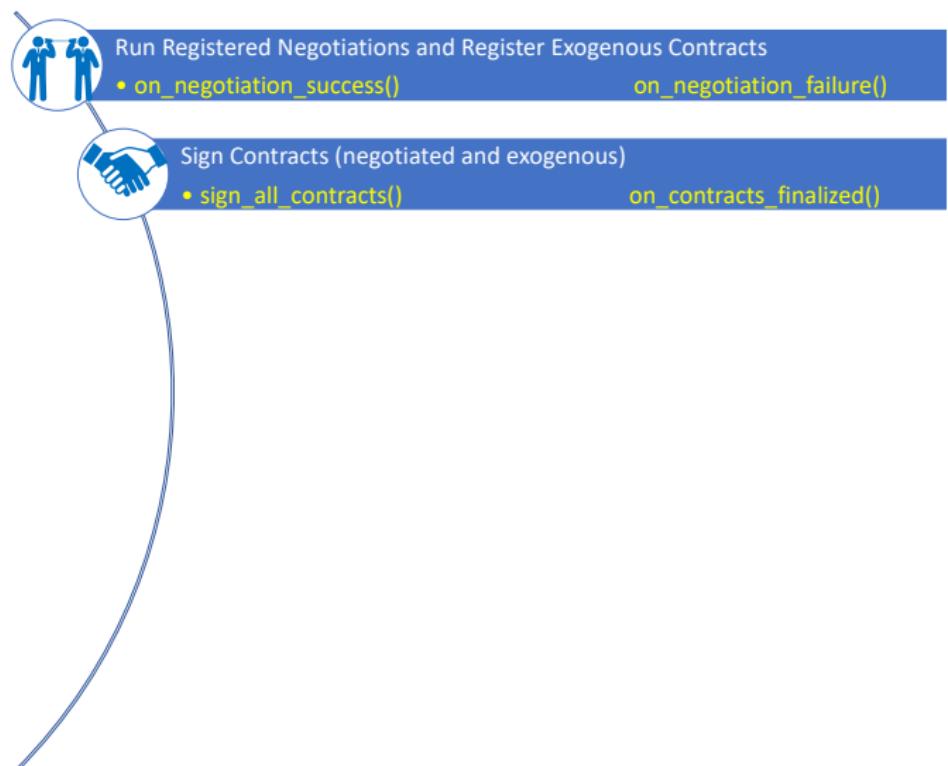
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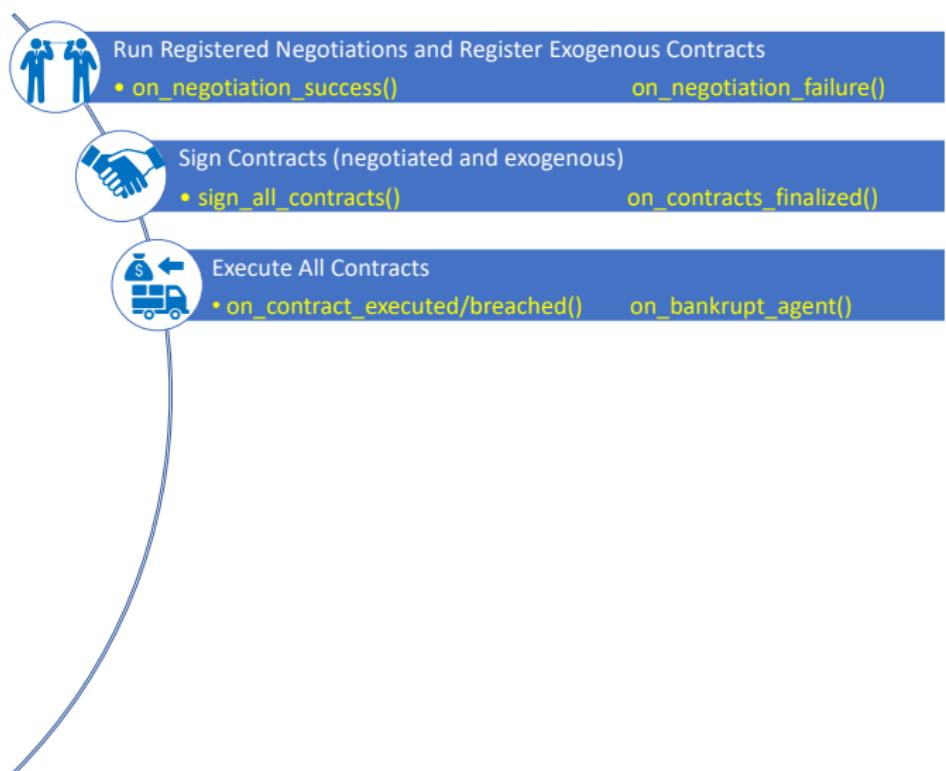
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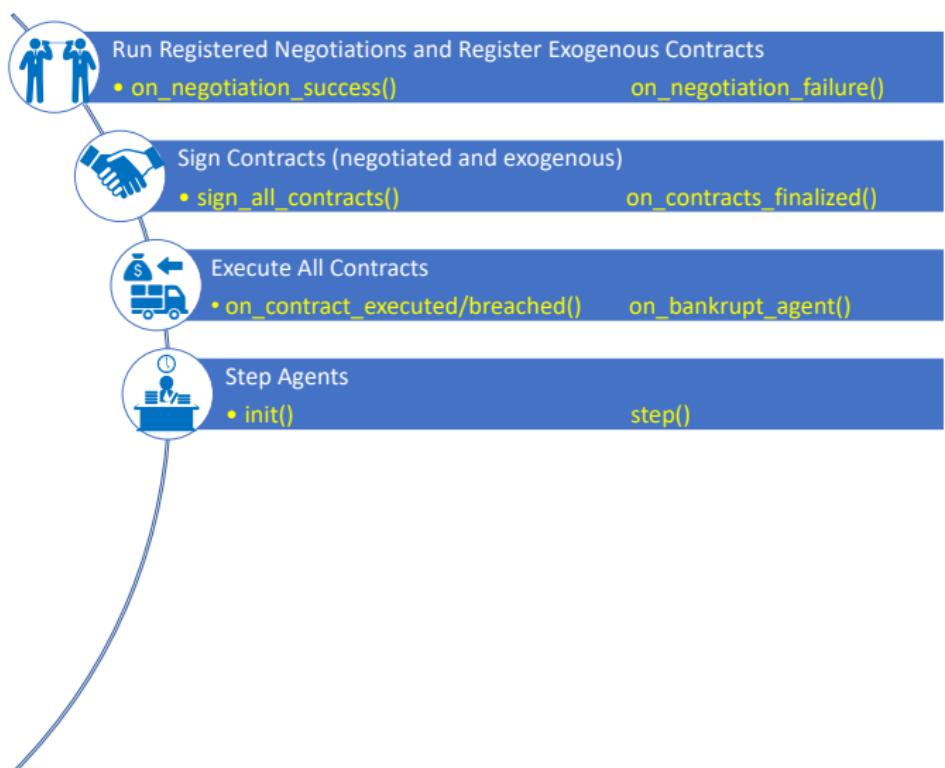
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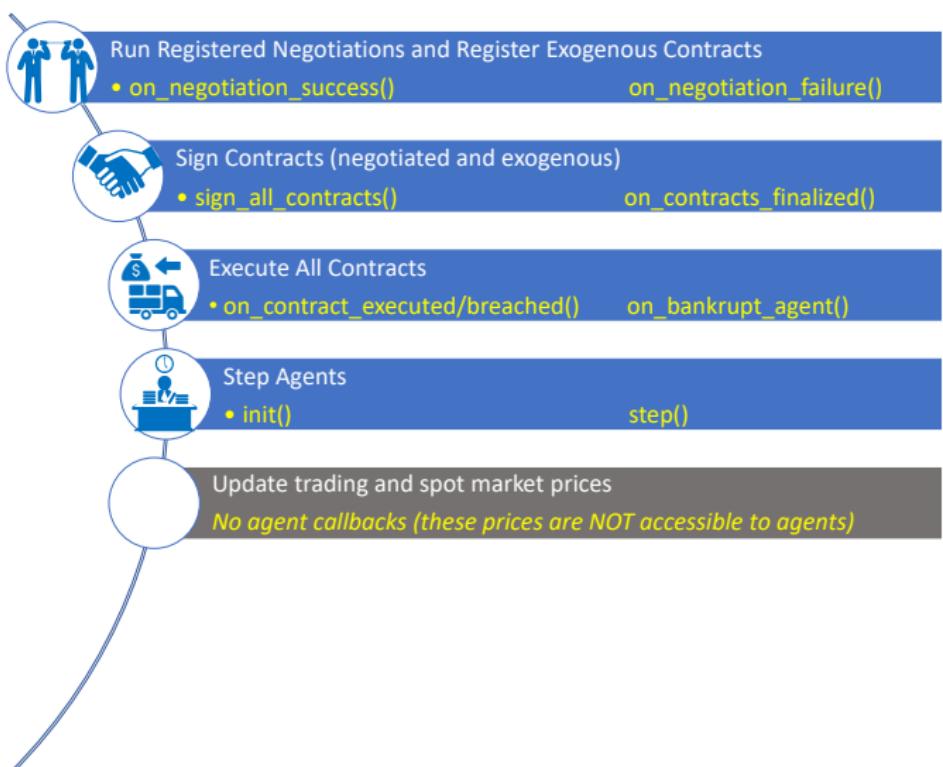
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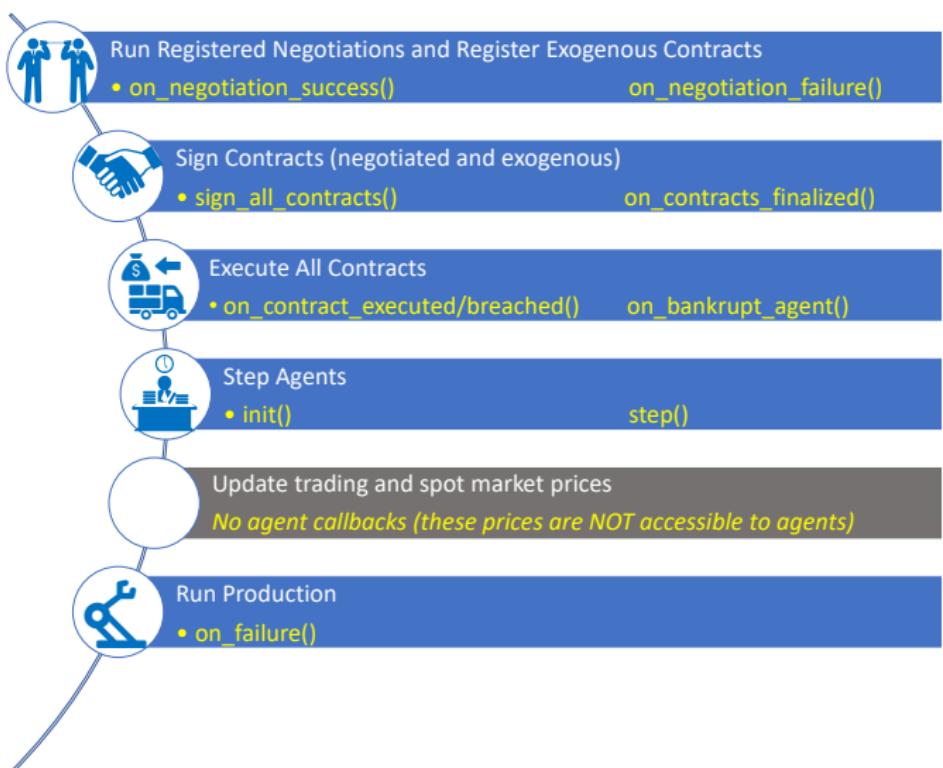
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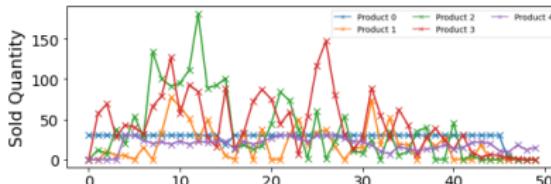
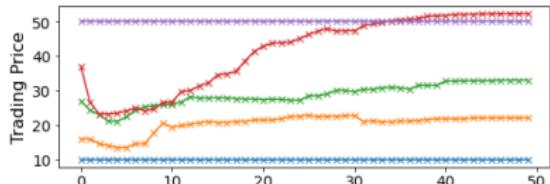


Simulation Steps

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Trading prices



What is trading price and why is it calculated?

- A value calculated by the system **for each product**.
- Represents some estimate of the **current** price.
- **Never revealed** to agents.
- Usages:
 - Used at the end to value inventory.
 - Used when calculating **spot-market price**. during breach processing.

How does the system calculate it?

$$\text{tp}(p, s) = \frac{\beta^{s+1} Q_{-1}(p) \text{cat}(p) + \sum_{i=0}^s \beta^{s-i} Q_i(p) \mu_i(p)}{\beta^{s+1} + \sum_{i=0 | Q_i(p) > 0}^s \beta^{s-i}} ,$$

Trading prices: The details

Quantities and prices

$$Q_i(p') = \sum_{\{c \in C^i | c.p = p'\}} c \cdot \bar{q}$$

$$\mu_i(p') = \frac{\sum_{\{c \in C^i | c.p = p'\}} c \cdot \bar{q} \times c.u}{Q_i(p')}$$

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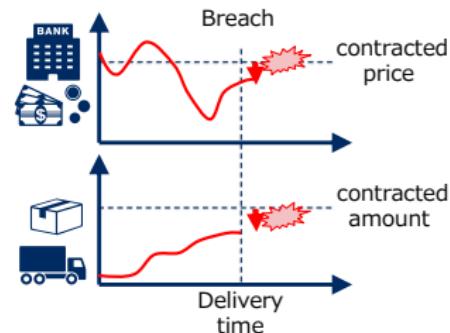
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What is a breach

- Insufficient funds or insufficient inventory.

Breach Processing

- A breach report is **always** published.
 - who and fraction.
- Insufficient products → forced to buy from the spot market.
- Insufficient funds → bankruptcy.



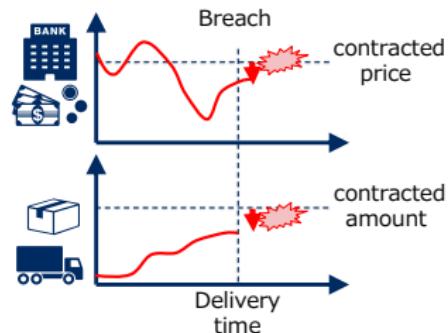
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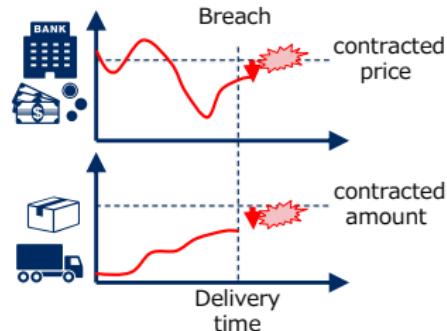
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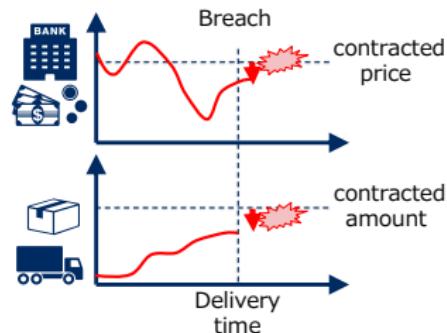
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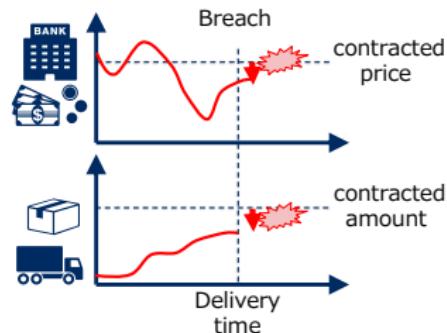
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Spot Market

Spot market

- **No-choice:** Can be used **only** for insufficient inventory breaches.
- **Penalizing:** Entails higher price than the **trading price**
- **Personalized:** More breaches → higher spot price **for you**

Calculation

- Agent's spot price penalty: $ip_a(p, s) = \lambda \sum_{i=0}^s \alpha^{s-i} q_a(p, i)$,
- Breaching agents buy **expensive**:

$$tp(p, s) \times (1 + gp) \times (1 + ip_a(p, s))$$

- Bankrupt agents are liquidated **cheap**:

$$tp(p, s) / ((1 + gp) \times (1 + ip_a(p, s)))$$

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Bankruptcy Processing

Bankruptcy conditions

- Insufficient money for a buy contract.
- Insufficient money to buy from the spot market for a sell contract.

What exactly happens?

- ① The agent is stopped from every buying or selling.
- ② Its inventory is sold on the spot market.
- ③ All agents are informed.
- ④ Agents with future contracts with it are informed about the expected level of breach.
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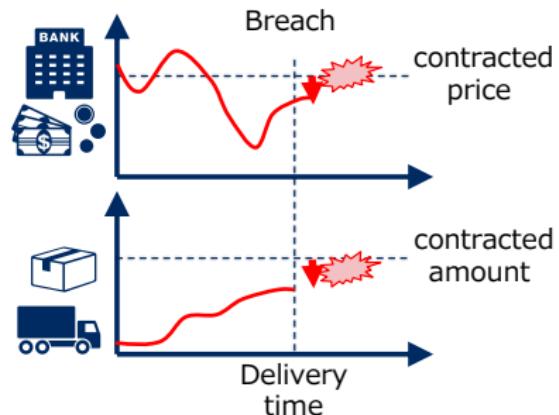
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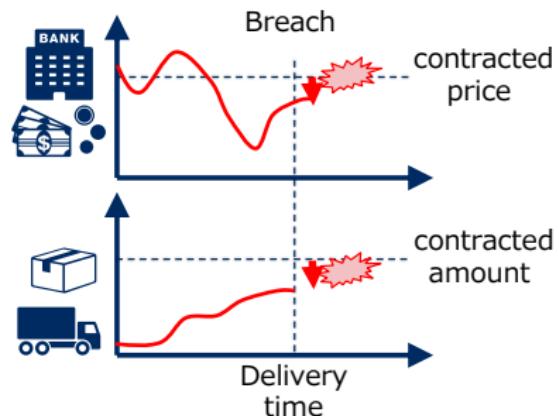
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 - Cannot buy → bankrupt.
- Bankrupt → **really really bad**
 - No more trade.
 - Very low score.
 - All inventory is liquidated.
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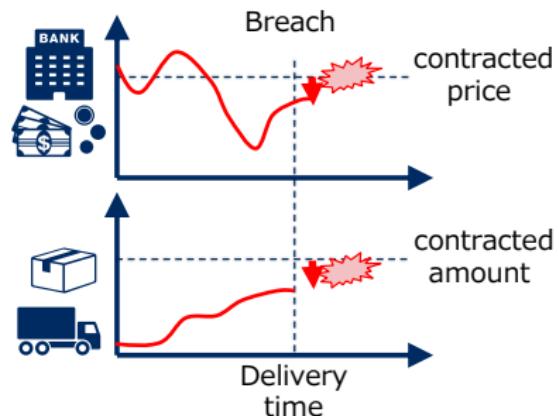
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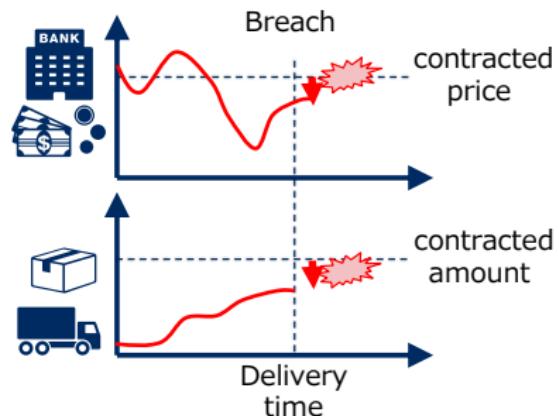
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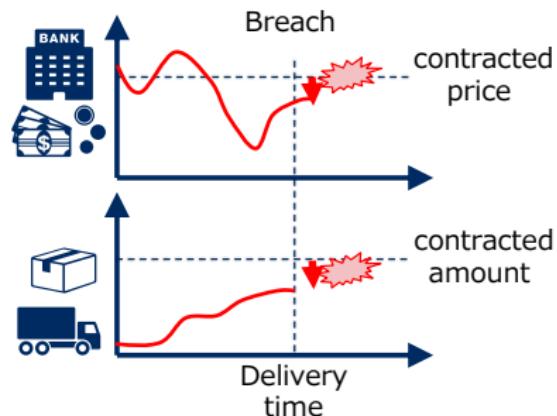
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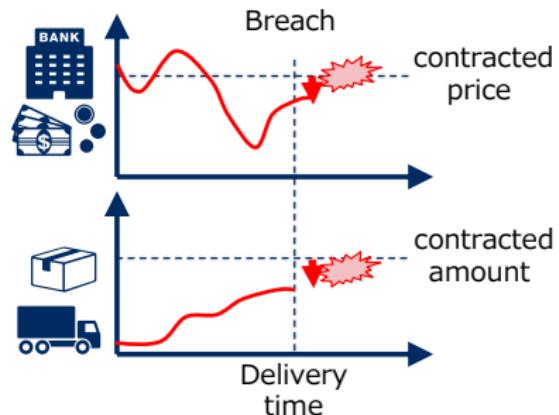
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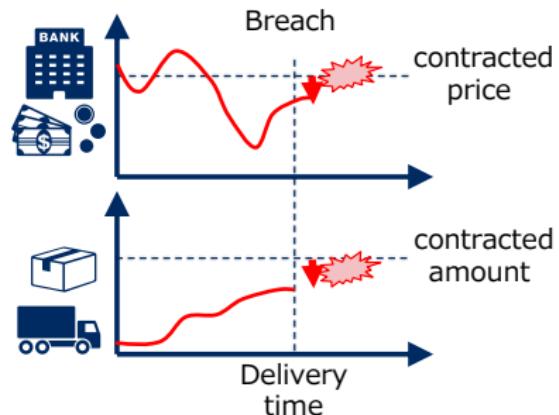
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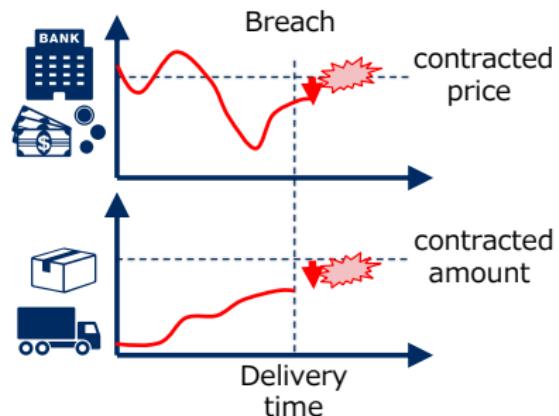
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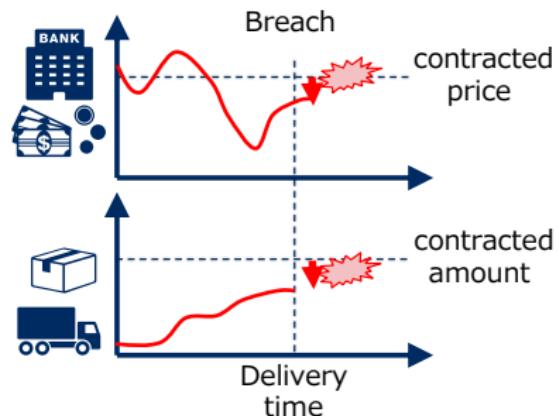
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Outline

- 1 Negotiation
- 2 ANAC: A brief history
- 3 NegMAS: The platform
- 4 Automated Negotiation in Supply Chain Management
- 5 Agent
- 6 Conclusion

Agent Knowledge

About itself

- **Its capabilities:** lines and production cost.
- **Its location:** input and output products.
- **Its partners:** suppliers and consumers (and competitors).
- **Its state:** inventory, wallet, contracts, and negotiations.

About the market

- The production graph and factories at each level.
- Time and simulation length.

About others

- **Financial Reports:** balance, assets, breach fraction/probability.
- **Past Interactions:** negotiations and contracts between itself and that agent.

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- Agents **cannot** pass information between simulations.
- We release datasets from the online competition including:
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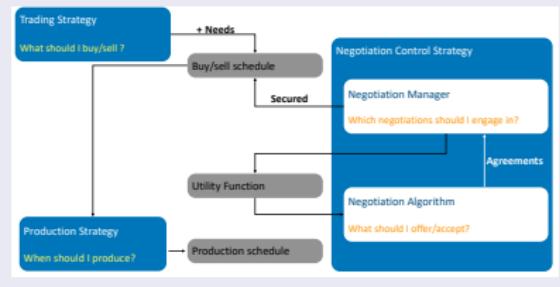
Development Approaches

Monolithic Agent

- Respond to callbacks in the **Agent** class.
- Functionality is distributed **among callbacks**.
- Everything is in one place (the agent class).
- Harder to reuse.

Component-Based Agent

- Divides the agent into **semi-independent** components.
- Functionality is distributed between **components**.
- Easier to reuse.



Callbacks and Timing

Agent



AWI



Negotiator



Mechanism



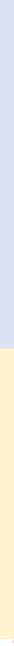
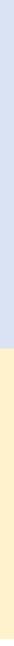
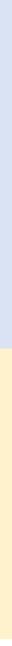
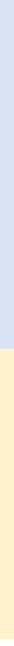
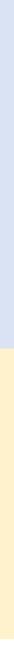
SYSTEM



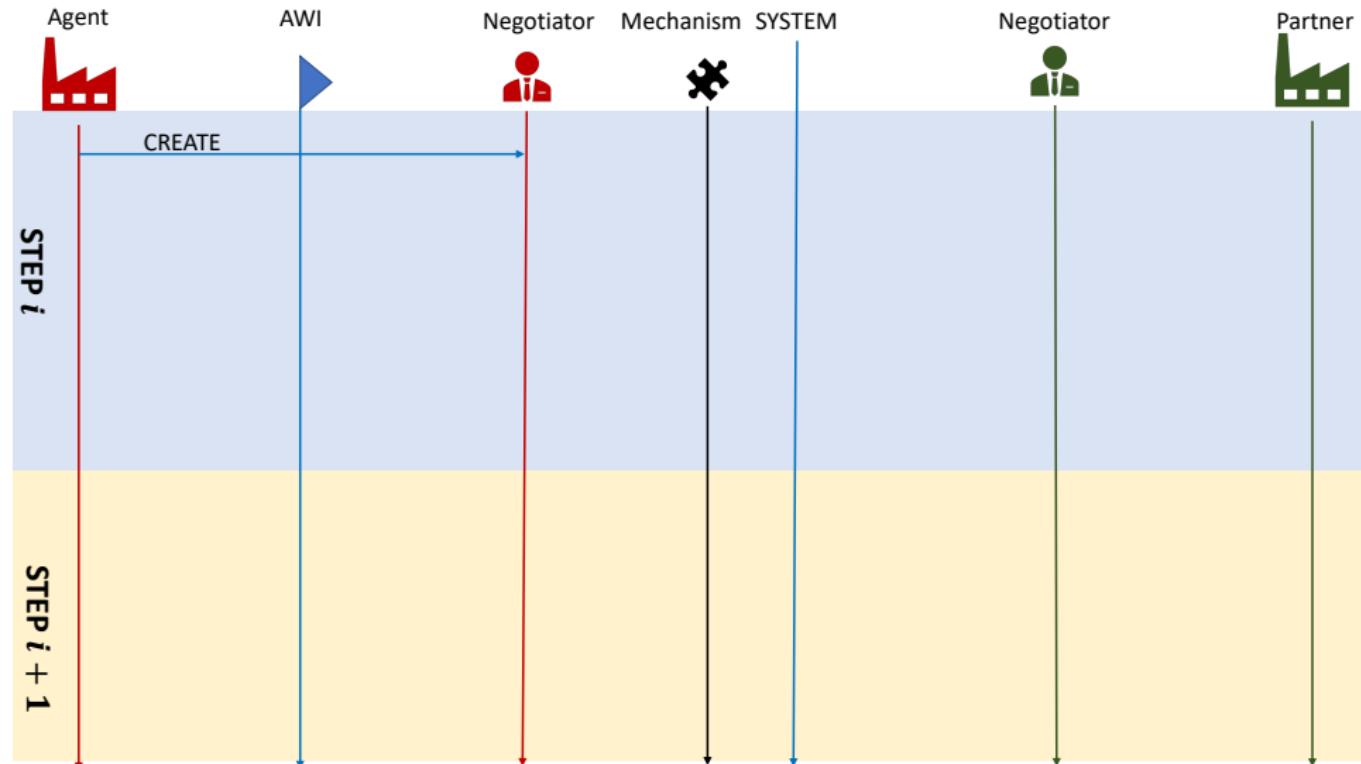
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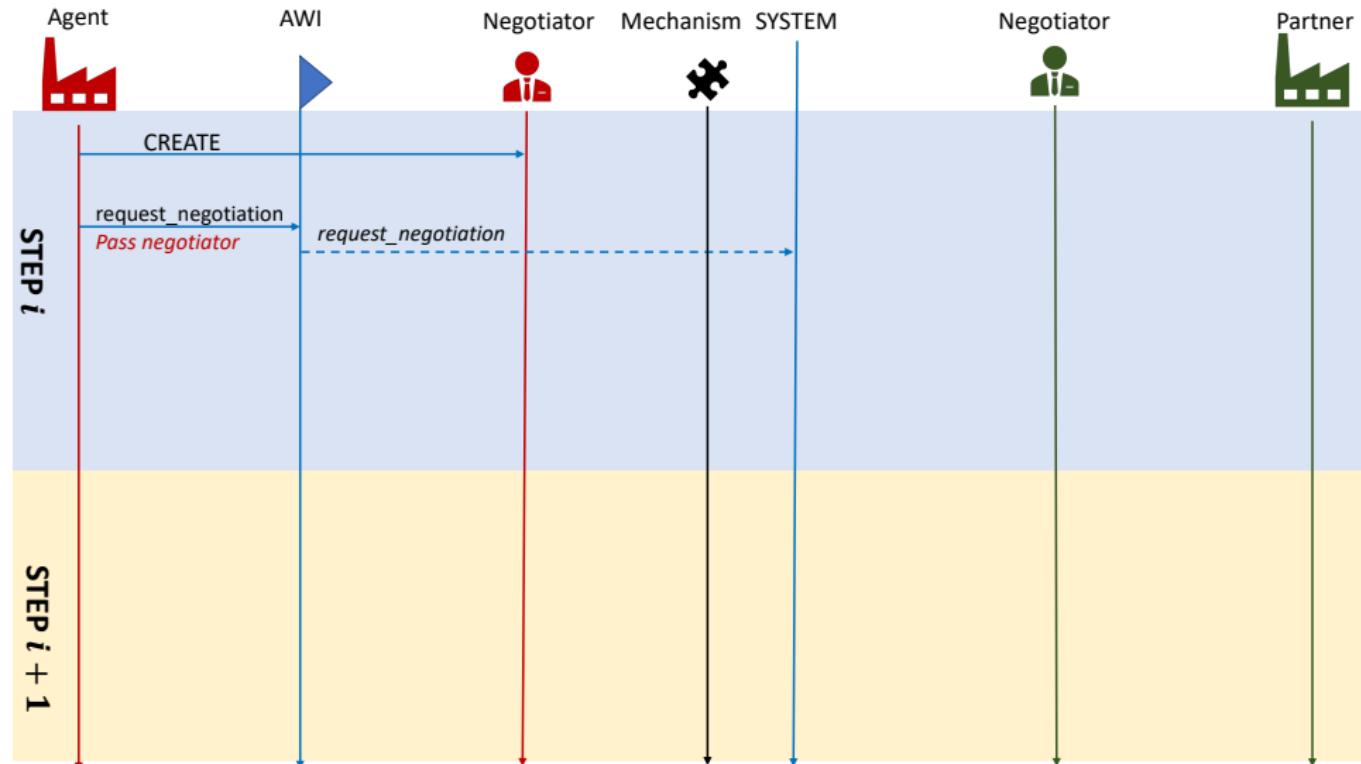
Partner

STEP i STEP $i + 1$ 

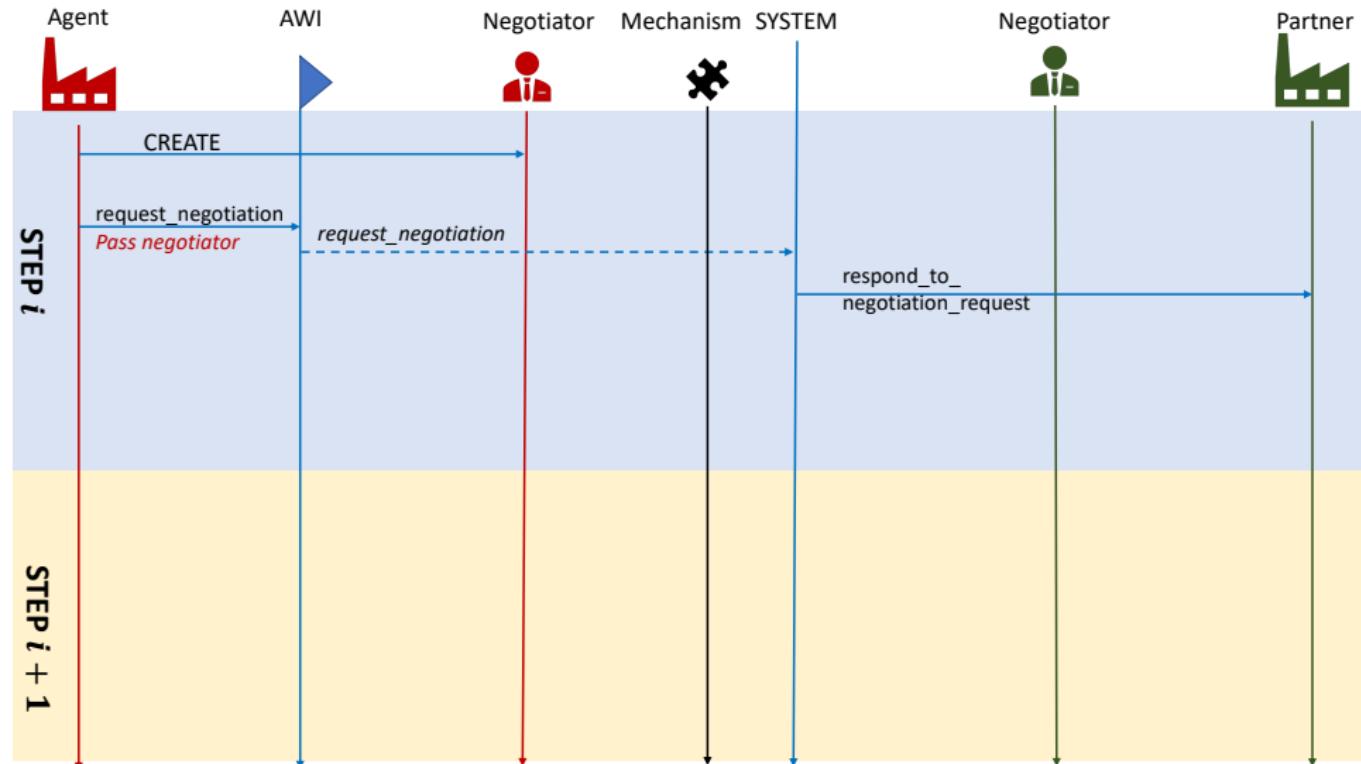
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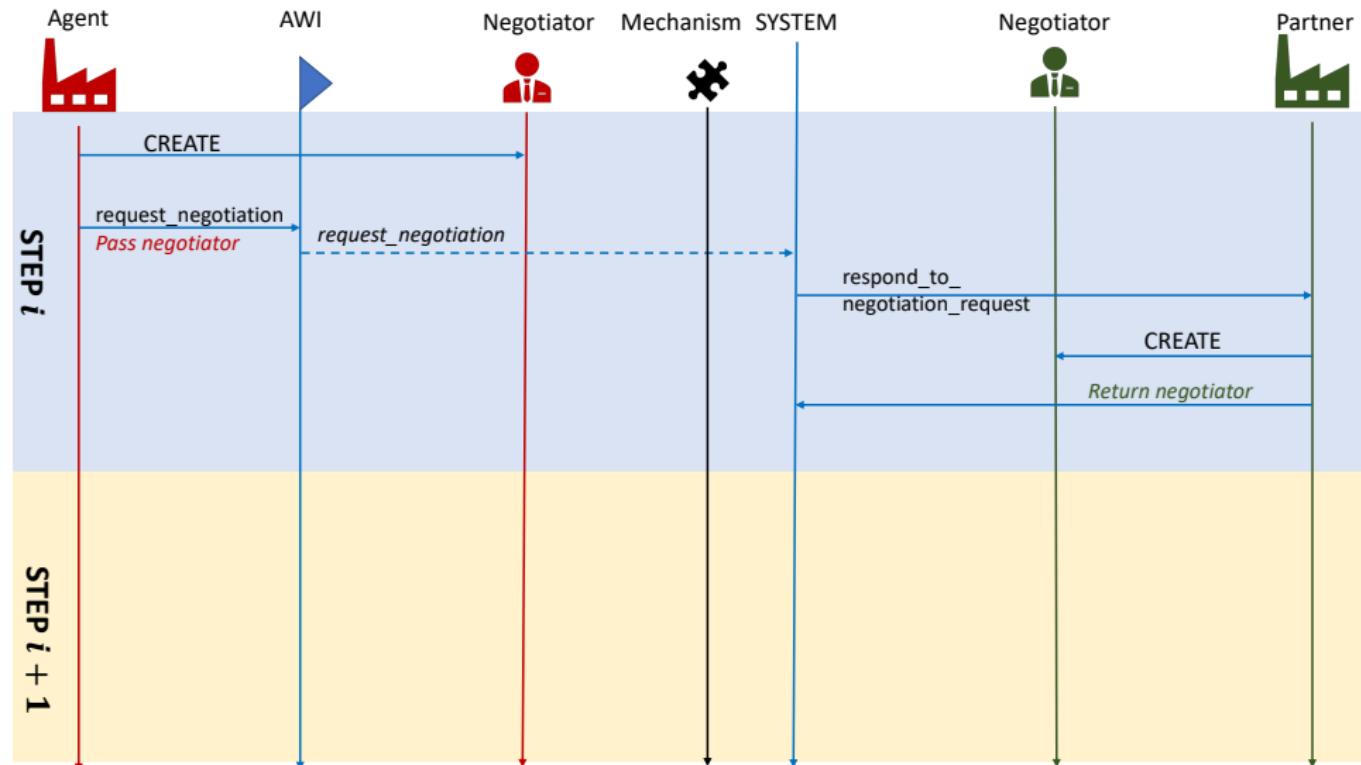
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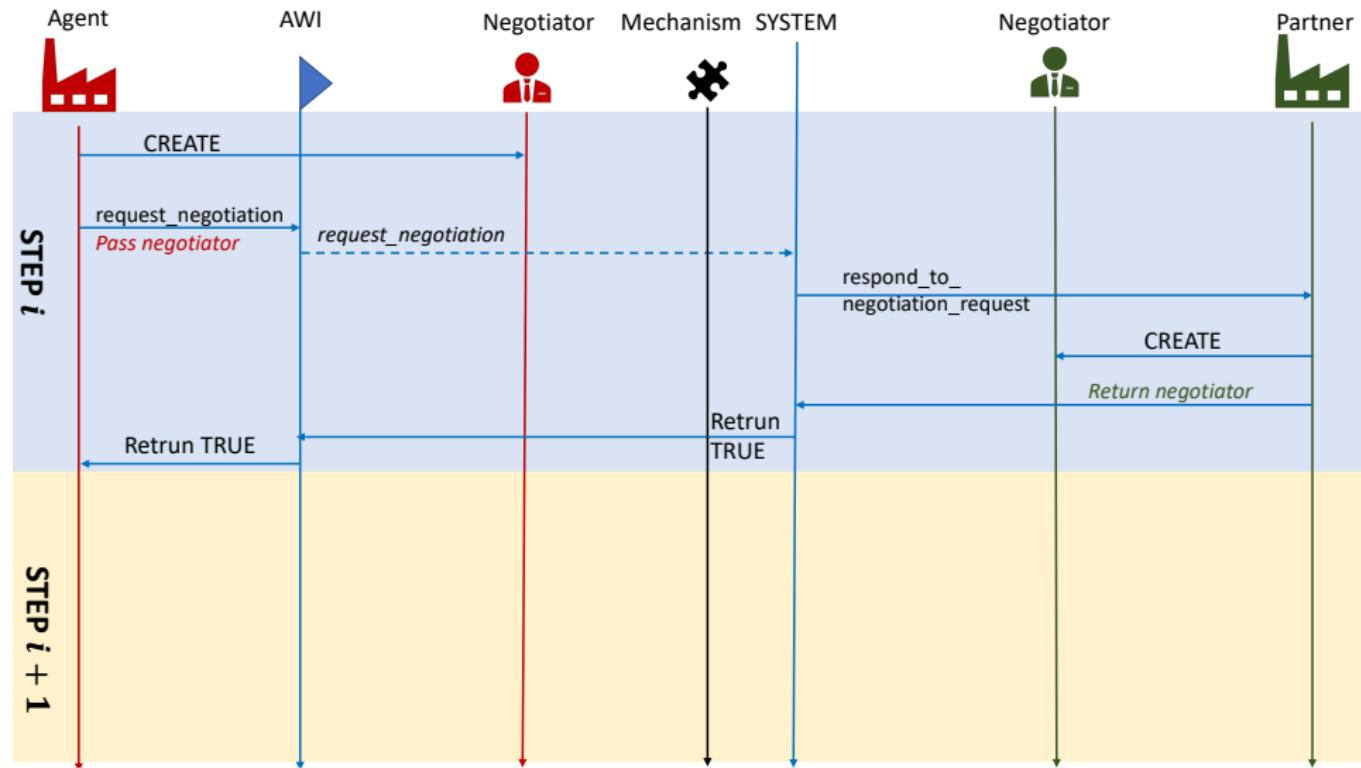
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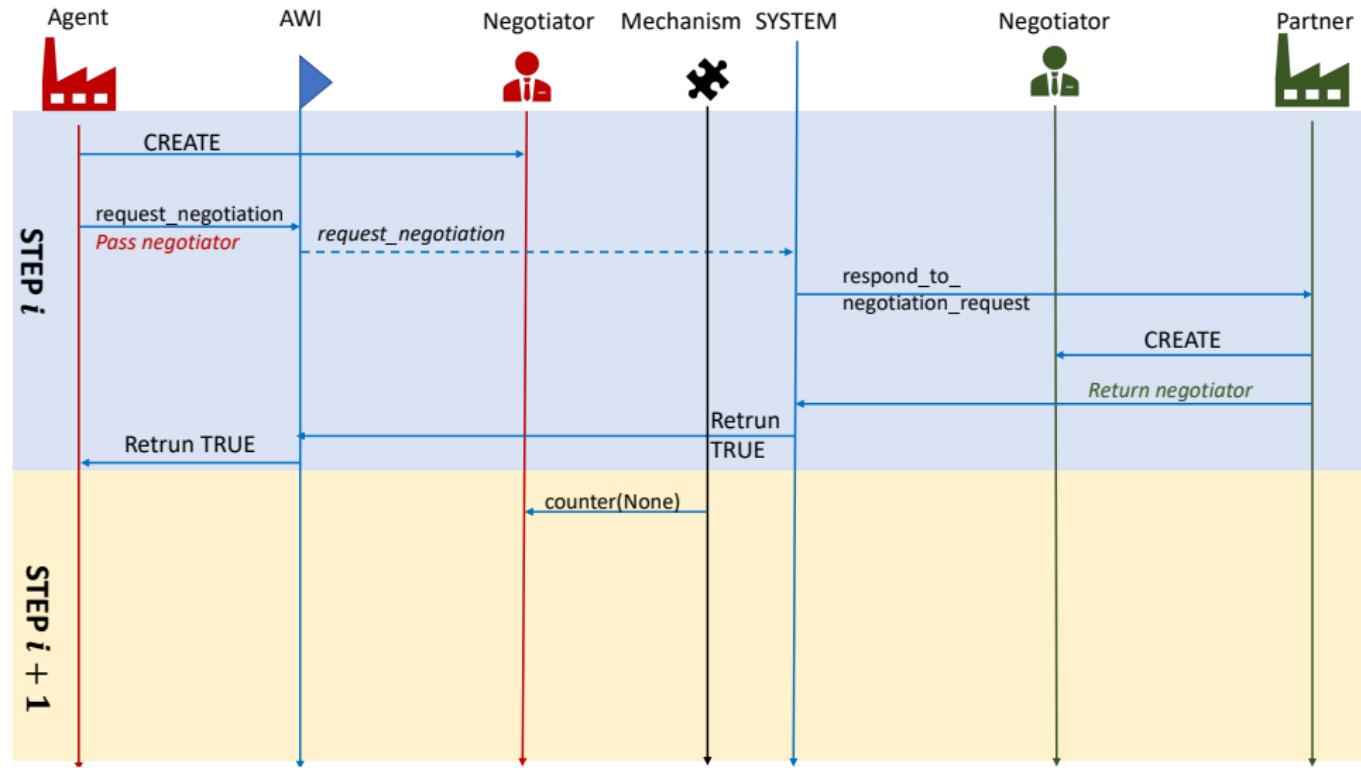
Callbacks and Timing



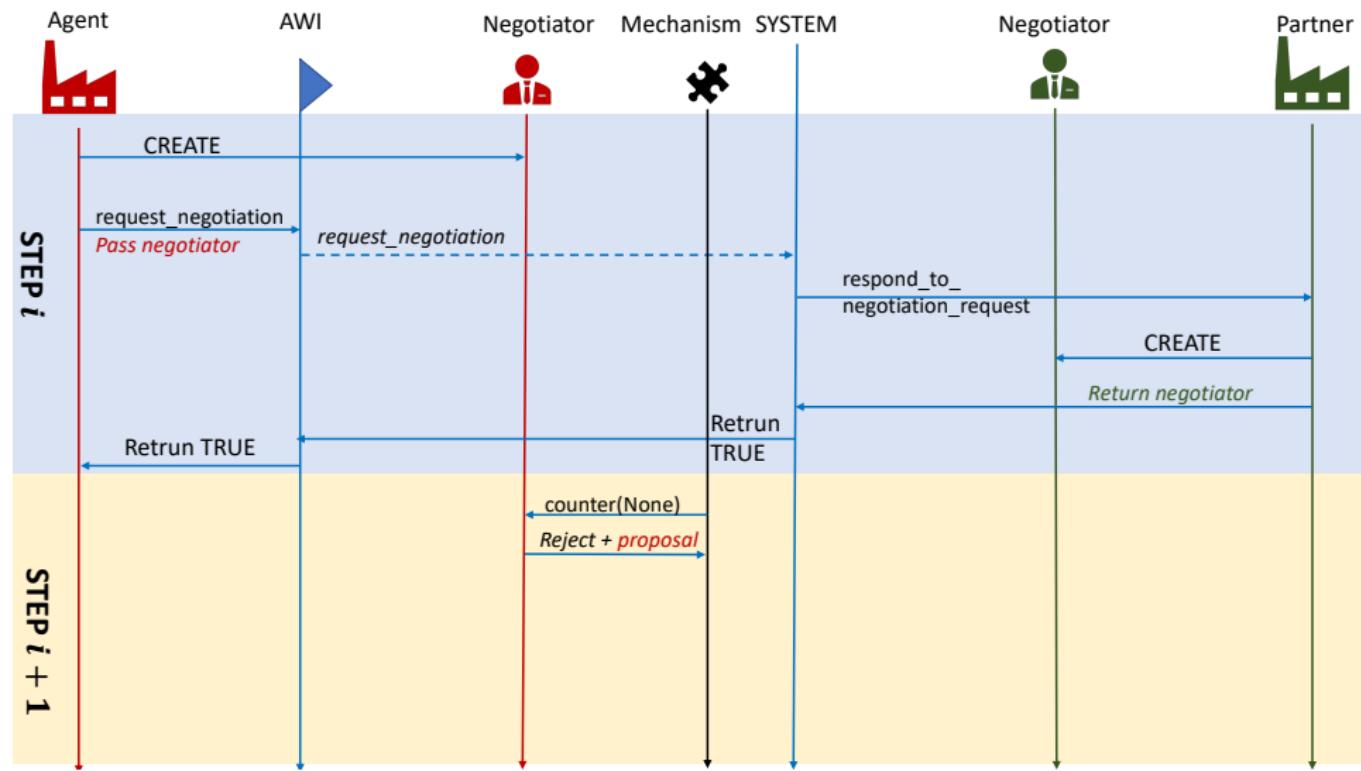
Callbacks and Timing



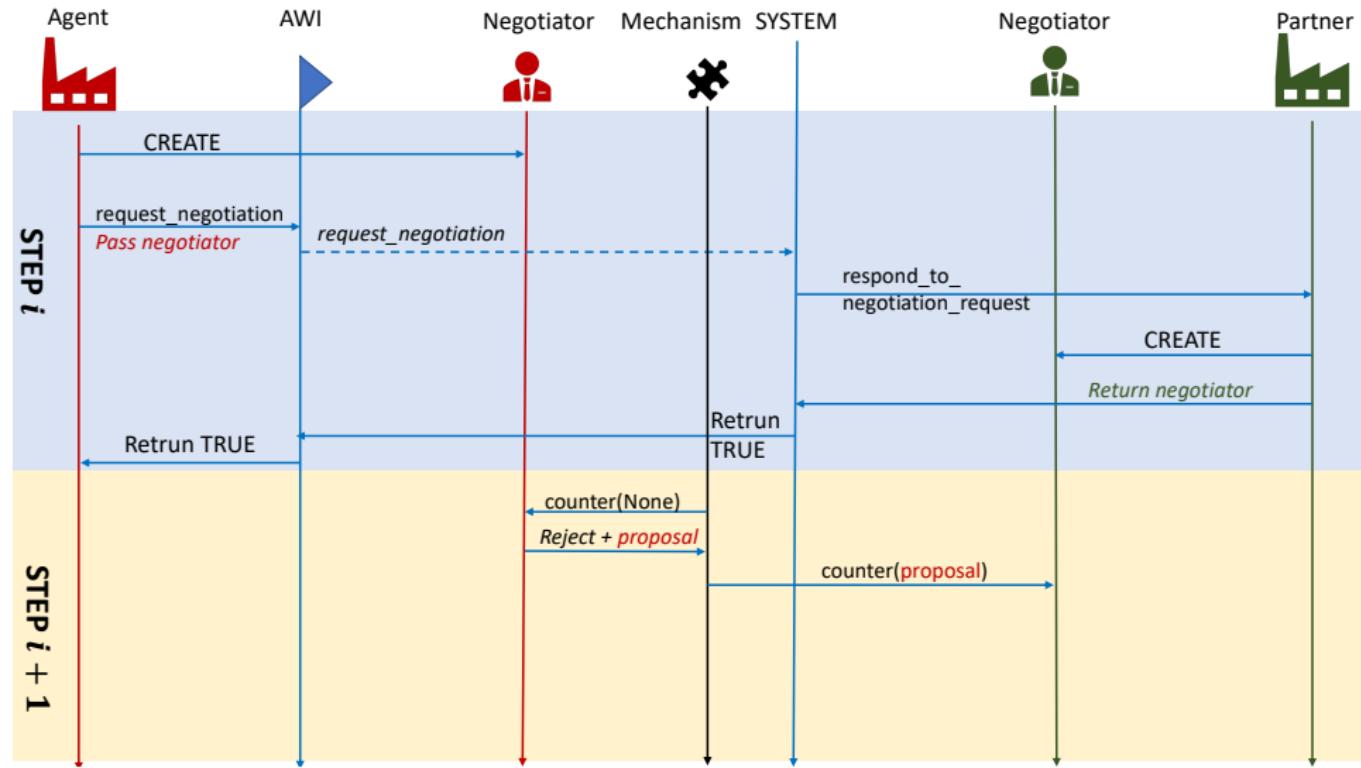
Callbacks and Timing



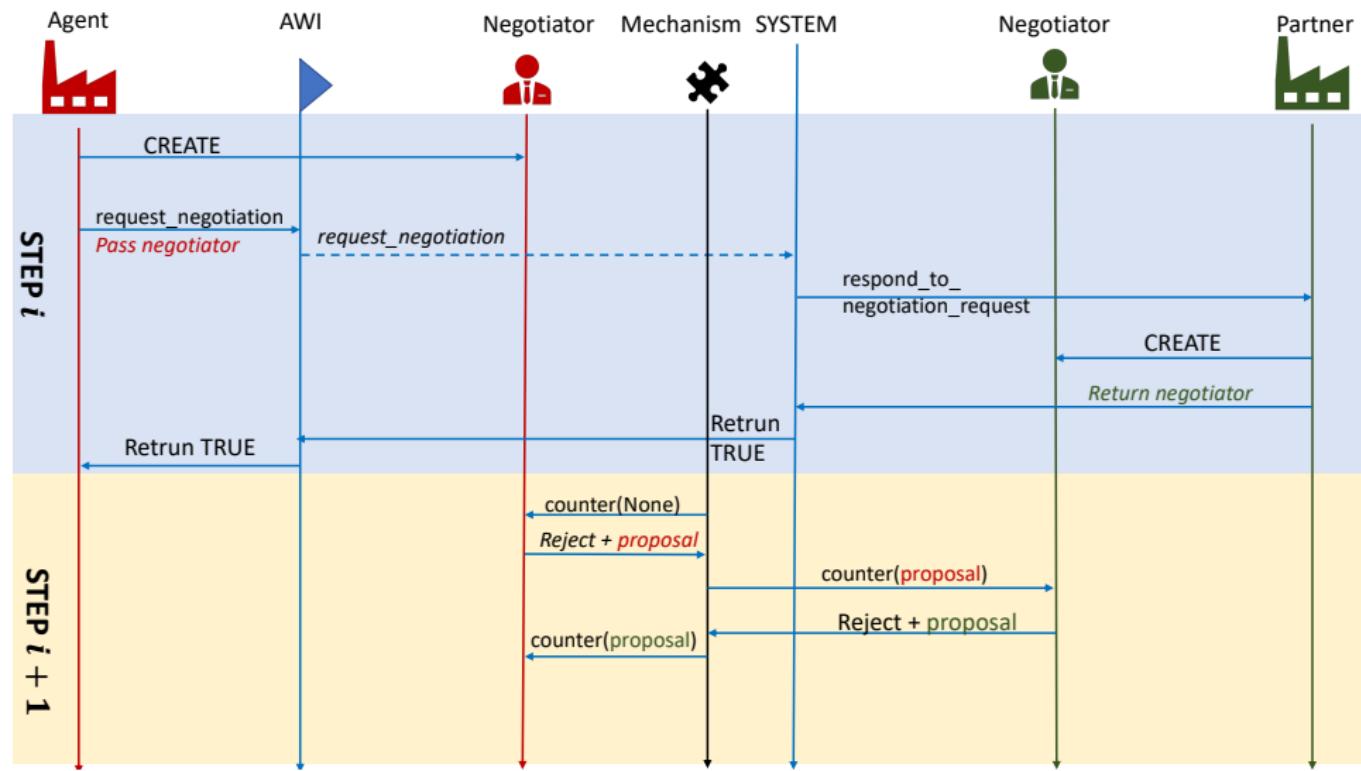
Callbacks and Timing



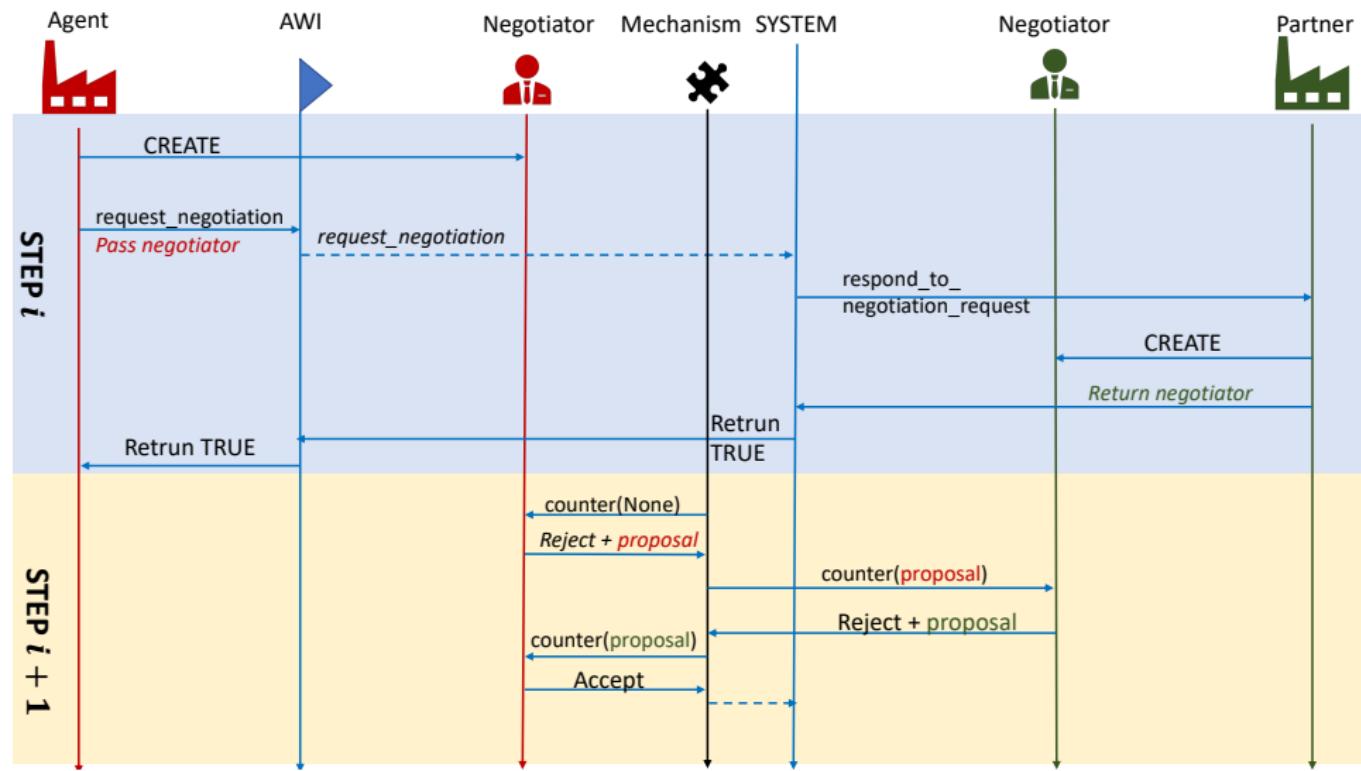
Callbacks and Timing



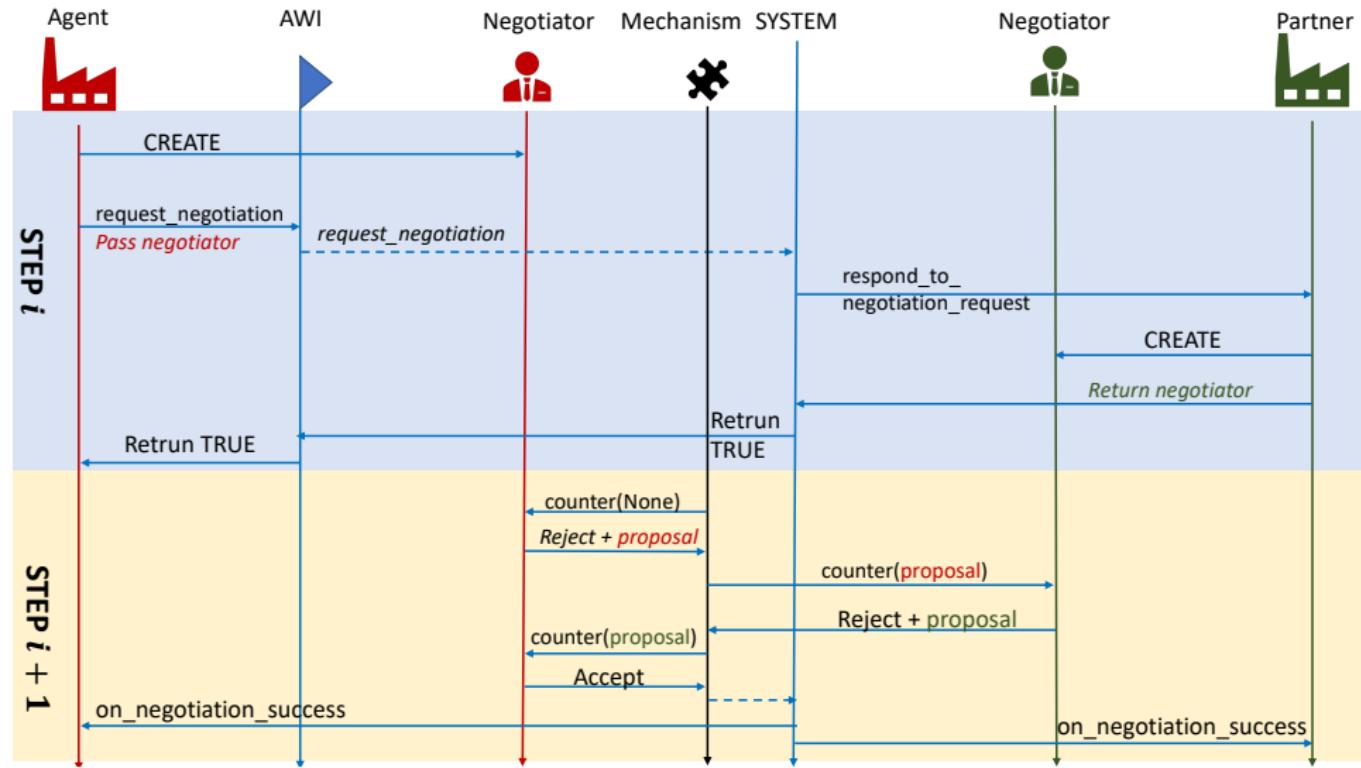
Callbacks and Timing



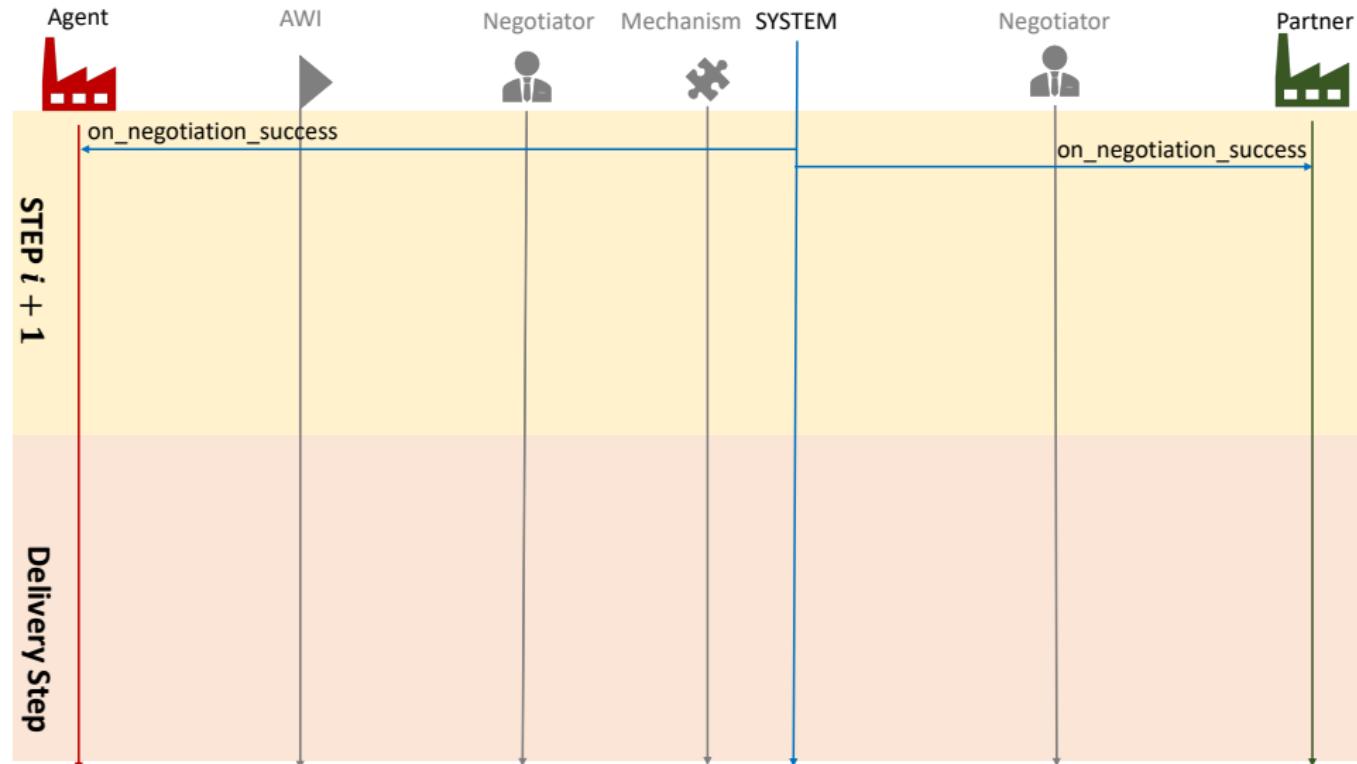
Callbacks and Timing



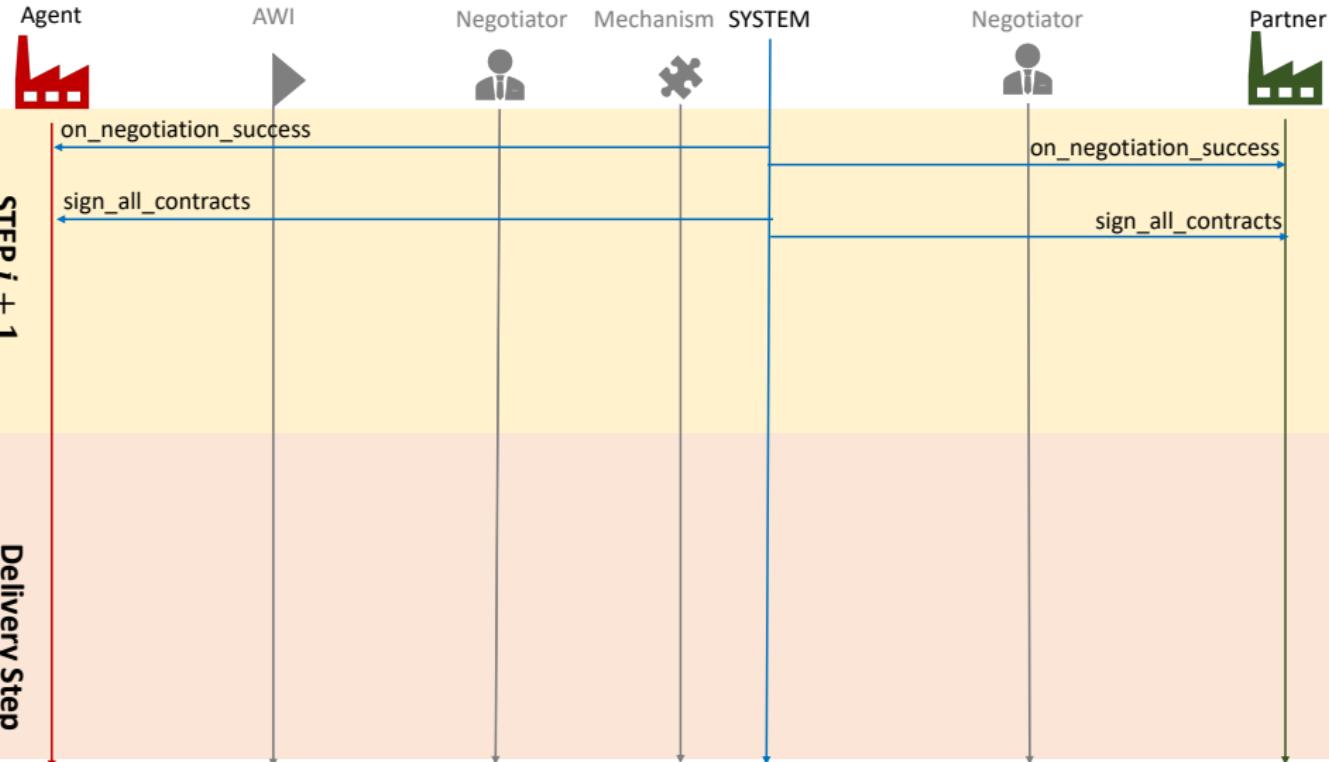
Callbacks and Timing



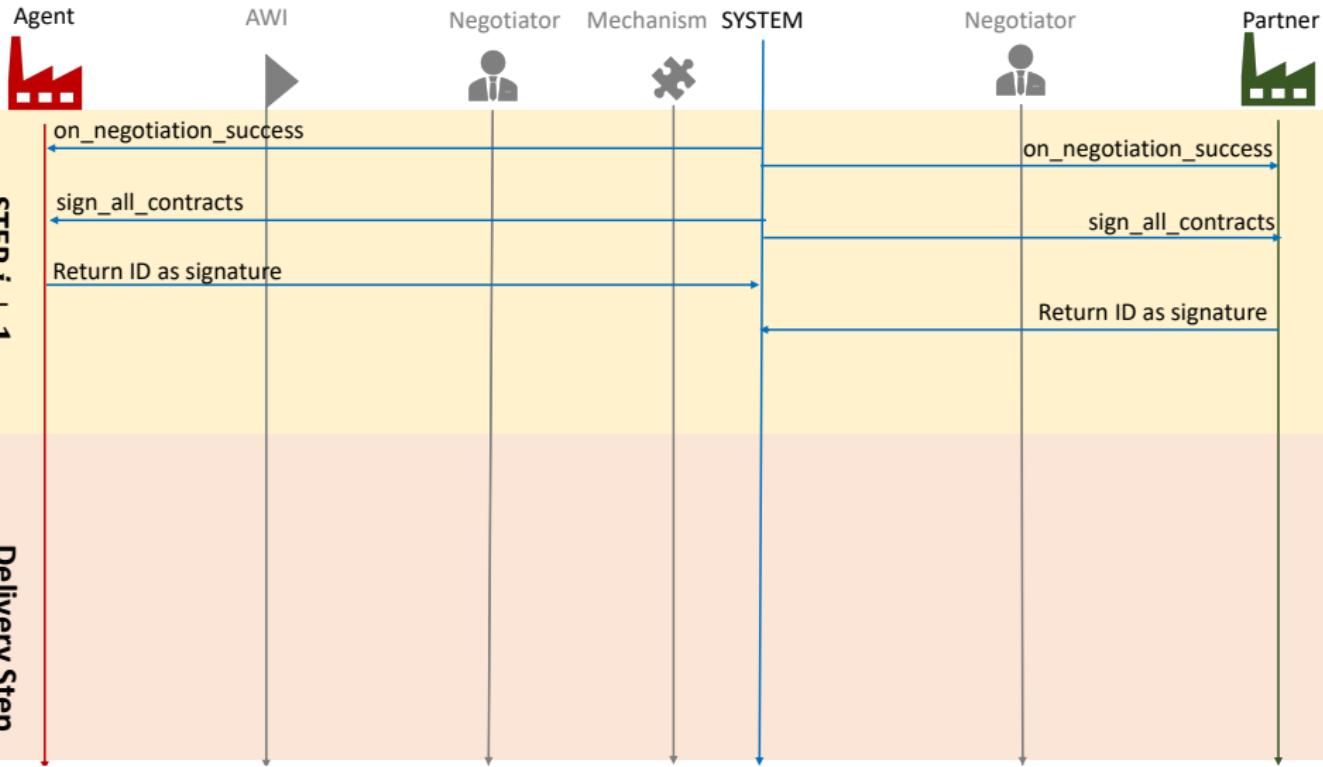
Callbacks and Timing



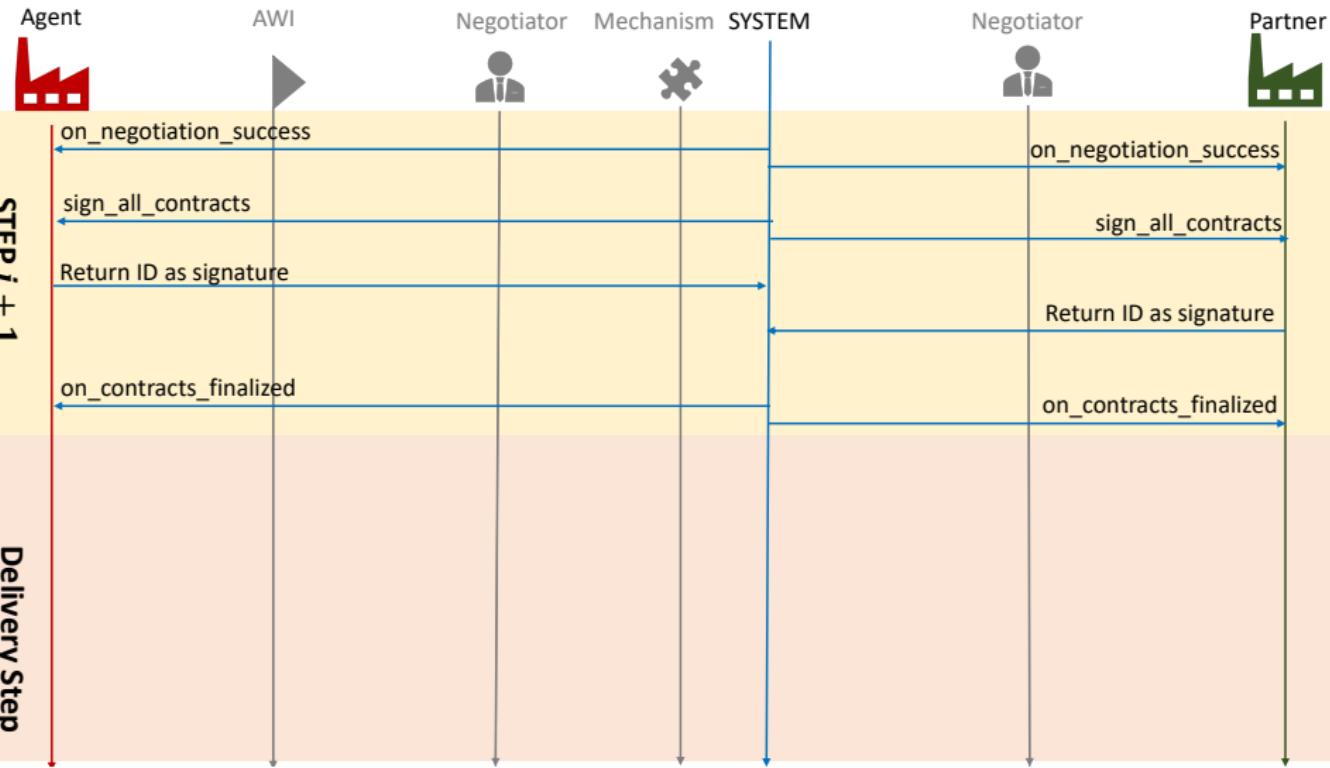
Callbacks and Timing



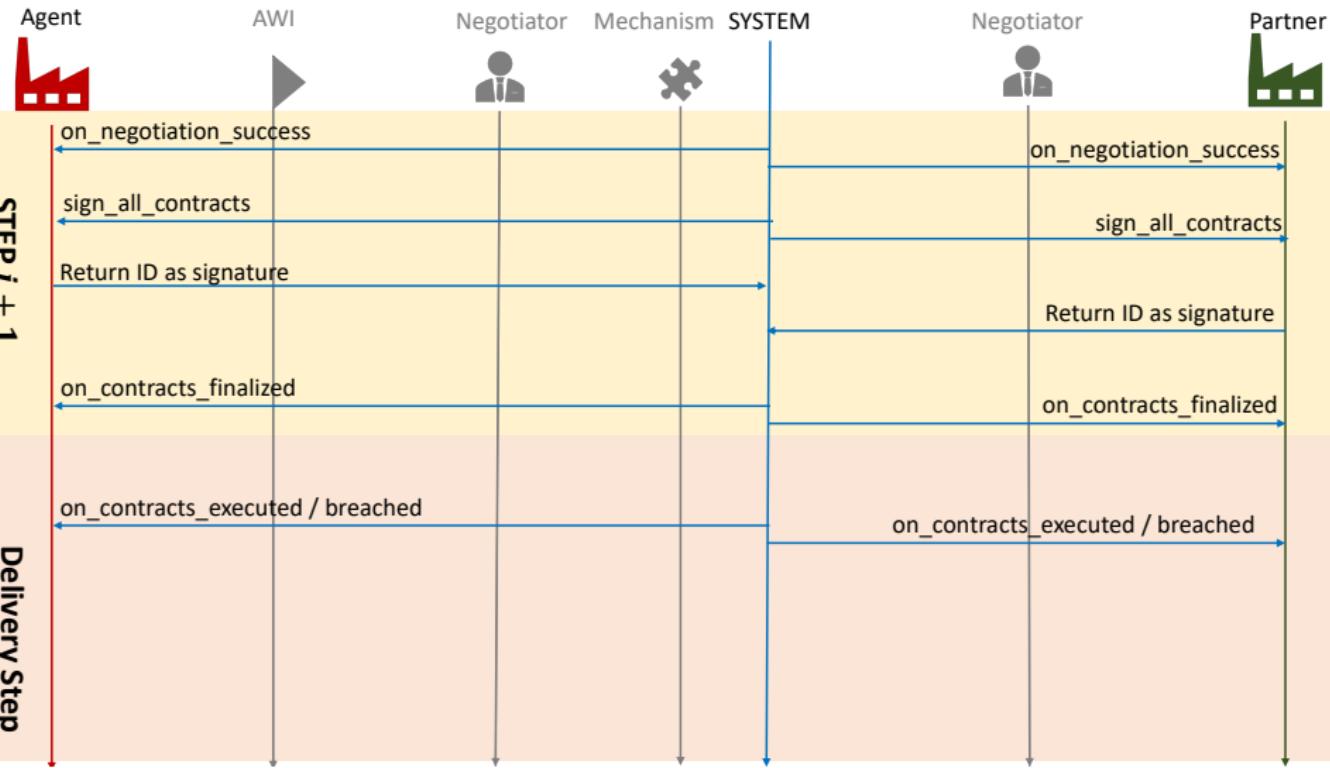
Callbacks and Timing



Callbacks and Timing



Callbacks and Timing



Callbacks and Timing

Agent



AWI

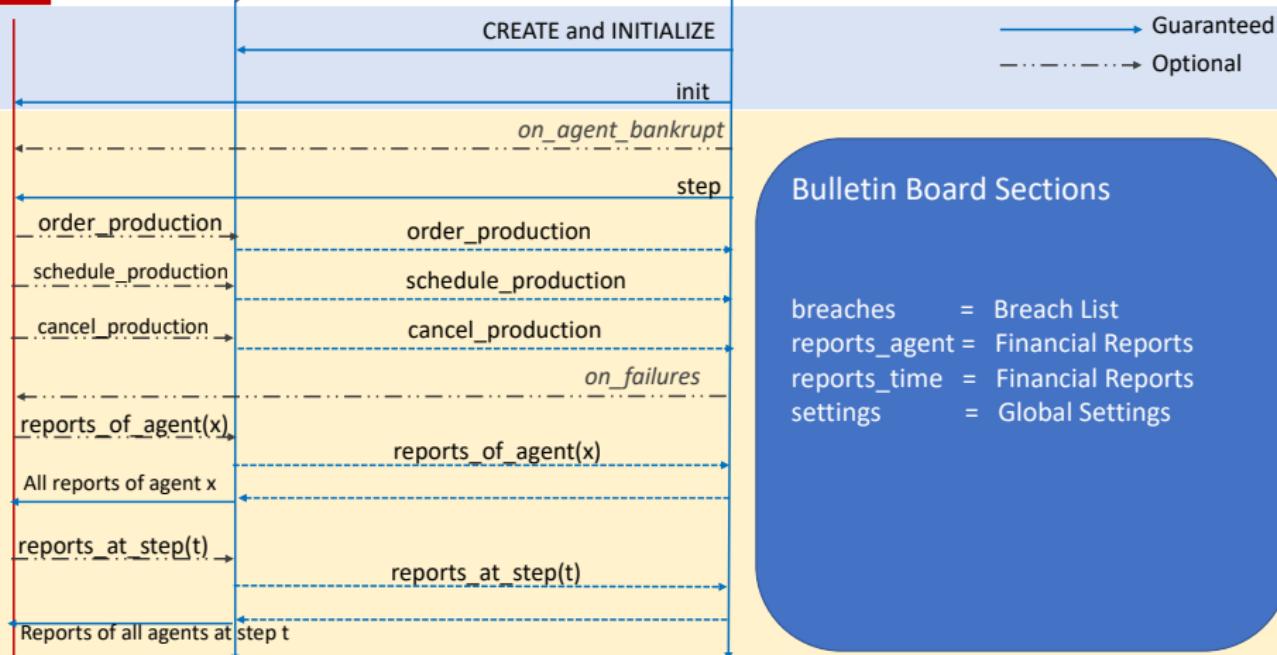


SYSTEM

STEP 0

Every Step

OTHER CALLBACKS



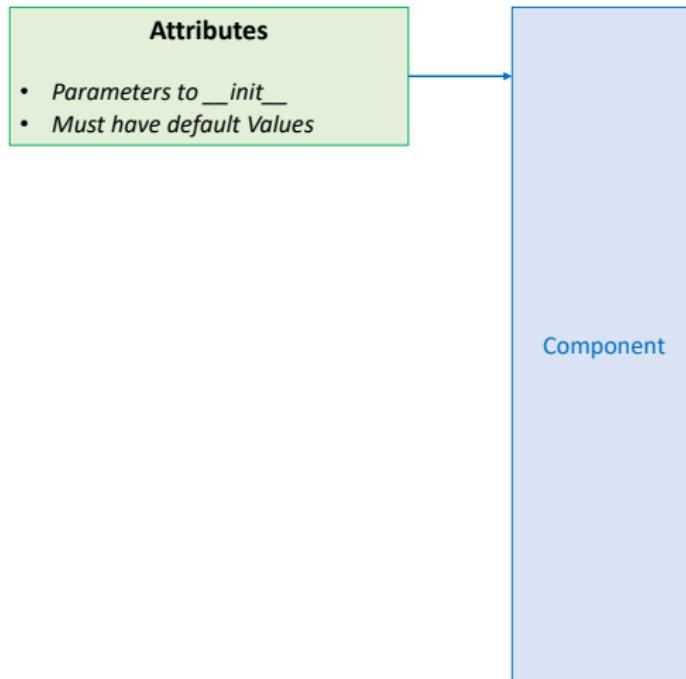
Bulletin Board Sections

breaches = Breach List
 reports_agent = Financial Reports
 reports_time = Financial Reports
 settings = Global Settings

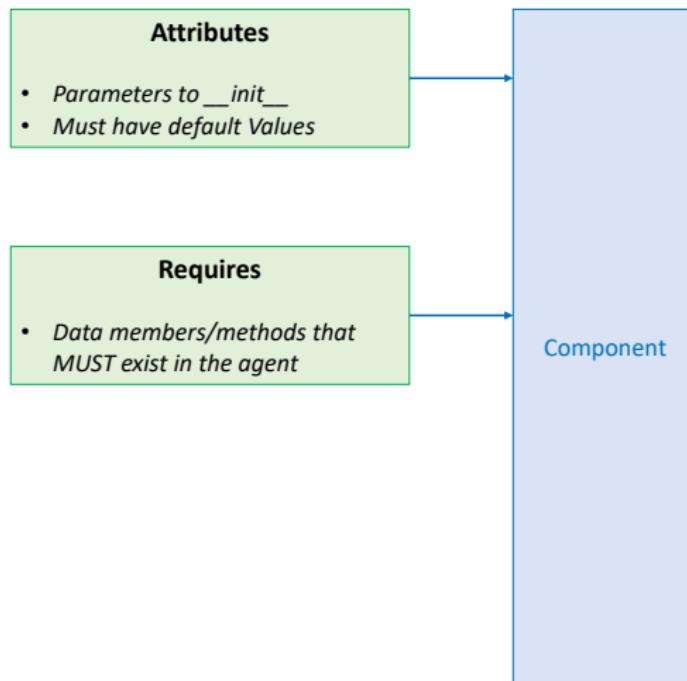
What is a component?



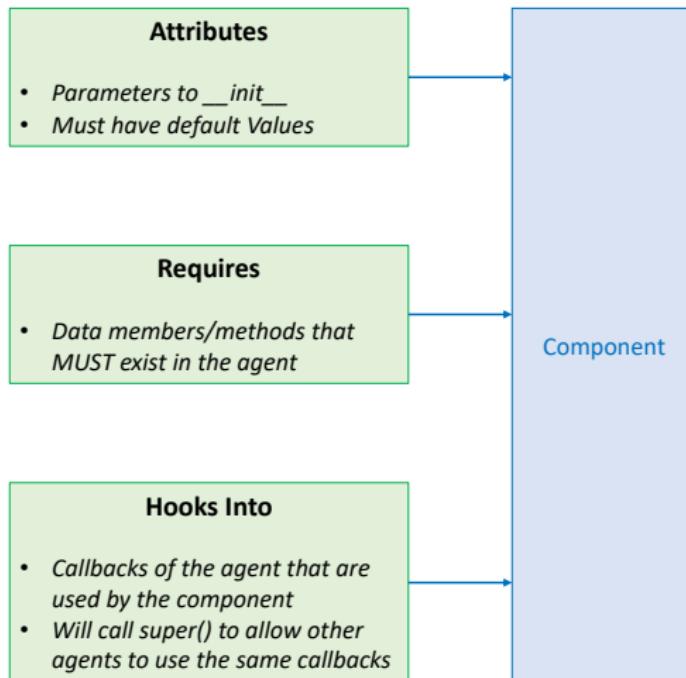
What is a component?



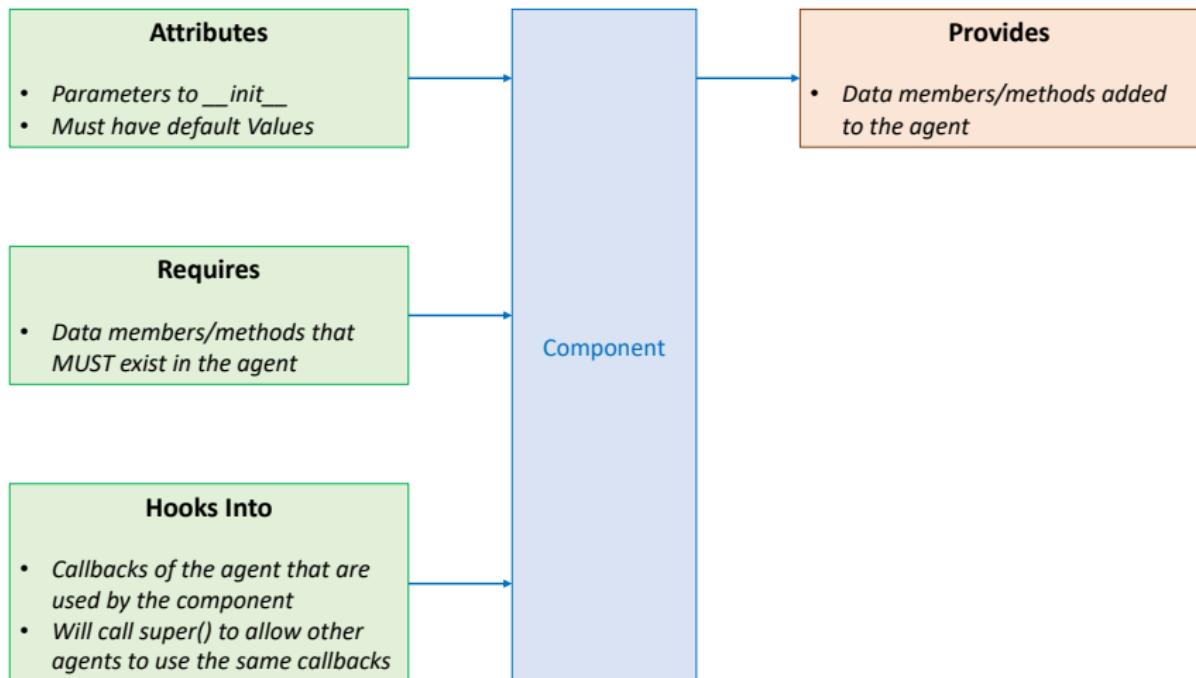
What is a component?



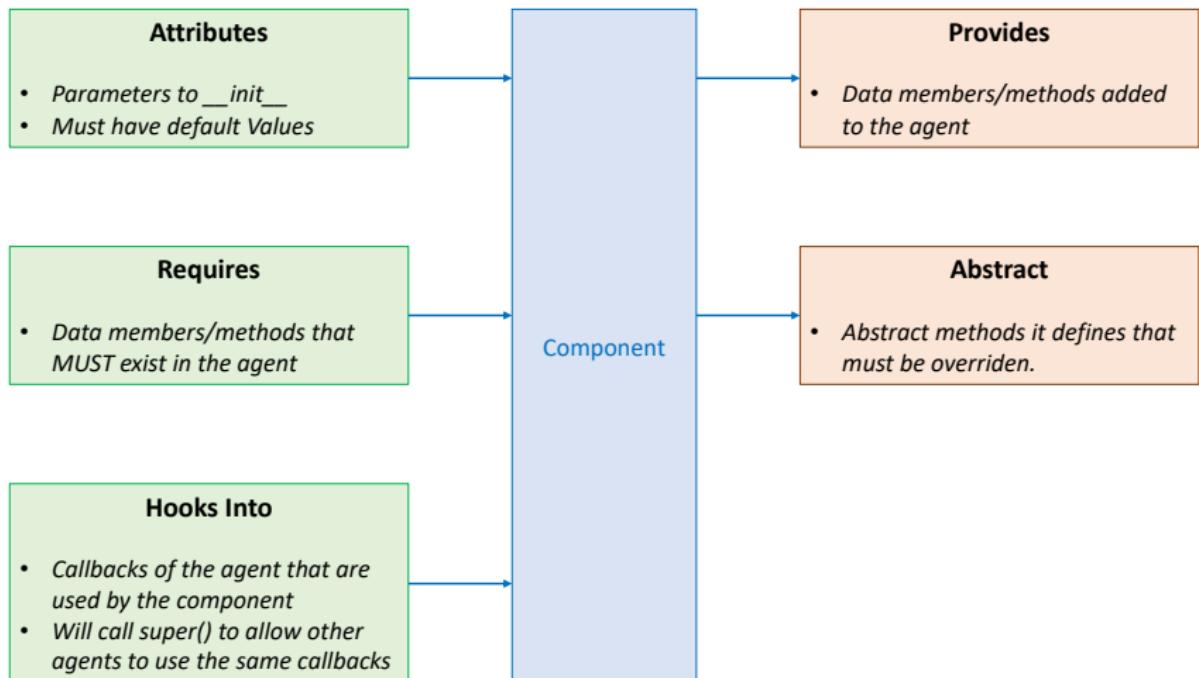
What is a component?



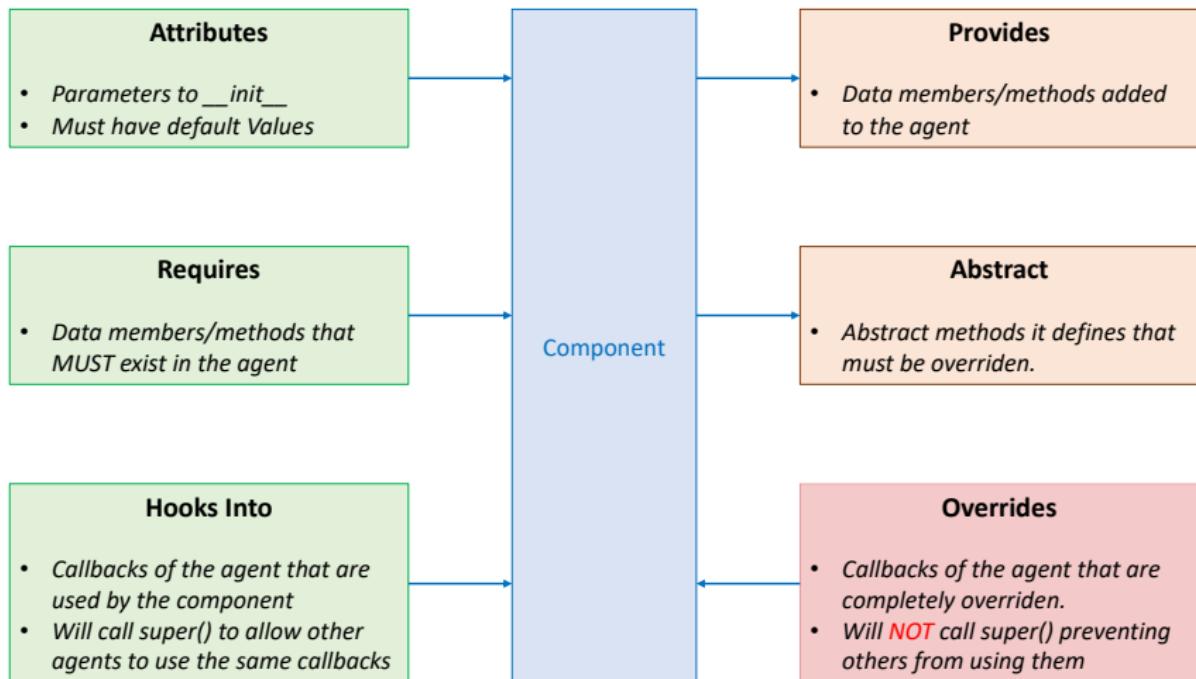
What is a component?



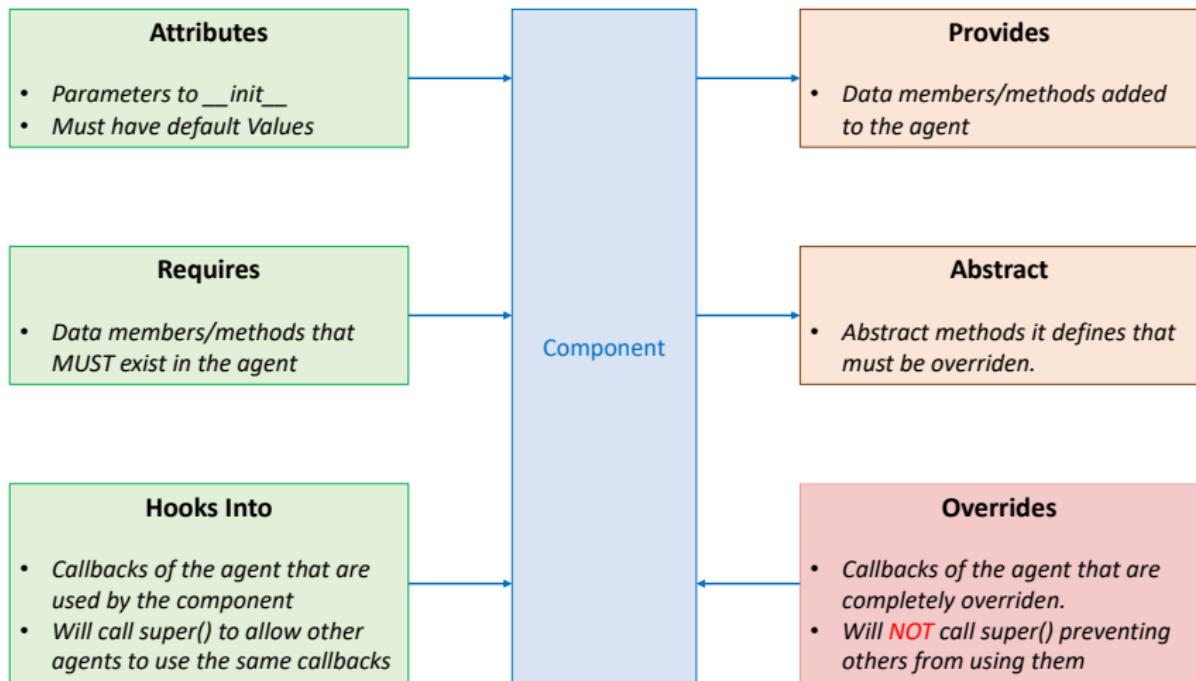
What is a component?



What is a component?

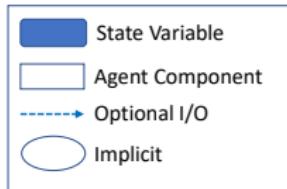


What is a component?



Hook into step, init, and on_* and override anything else

SCML Agent Components

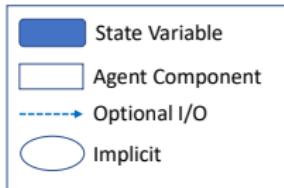


Production Strategy

Trading Strategy

Negotiation Manager

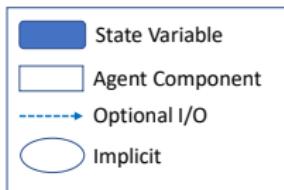
SCML Agent Components



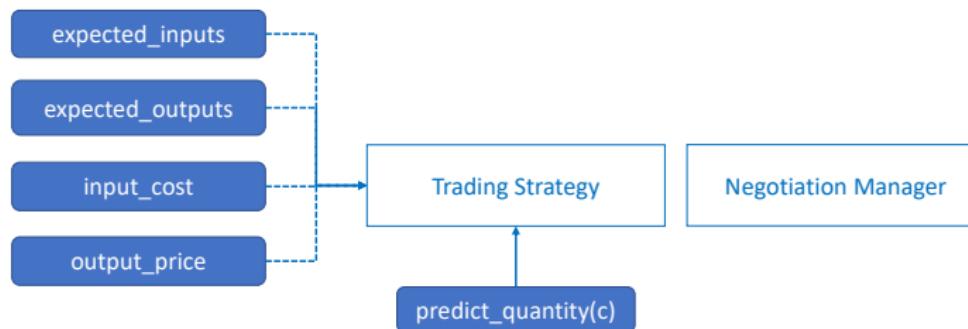
Production Strategy



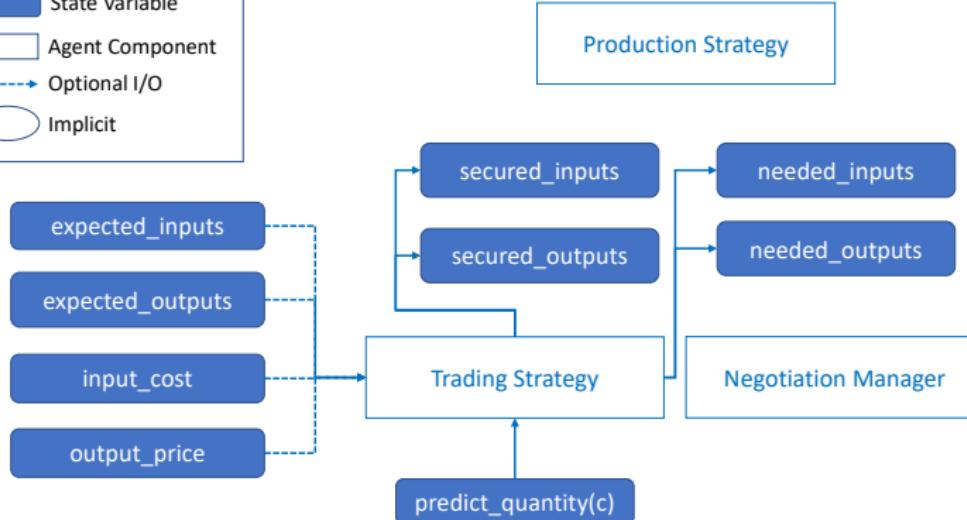
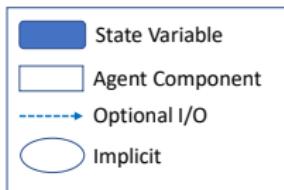
SCML Agent Components



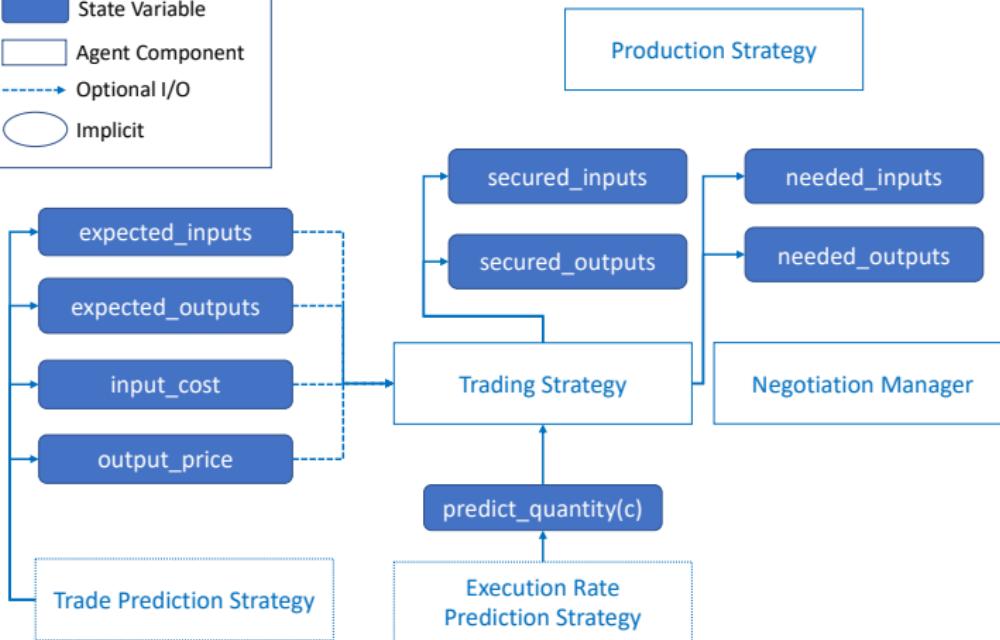
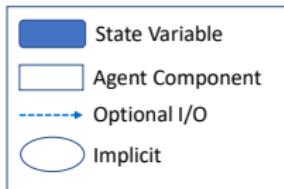
Production Strategy



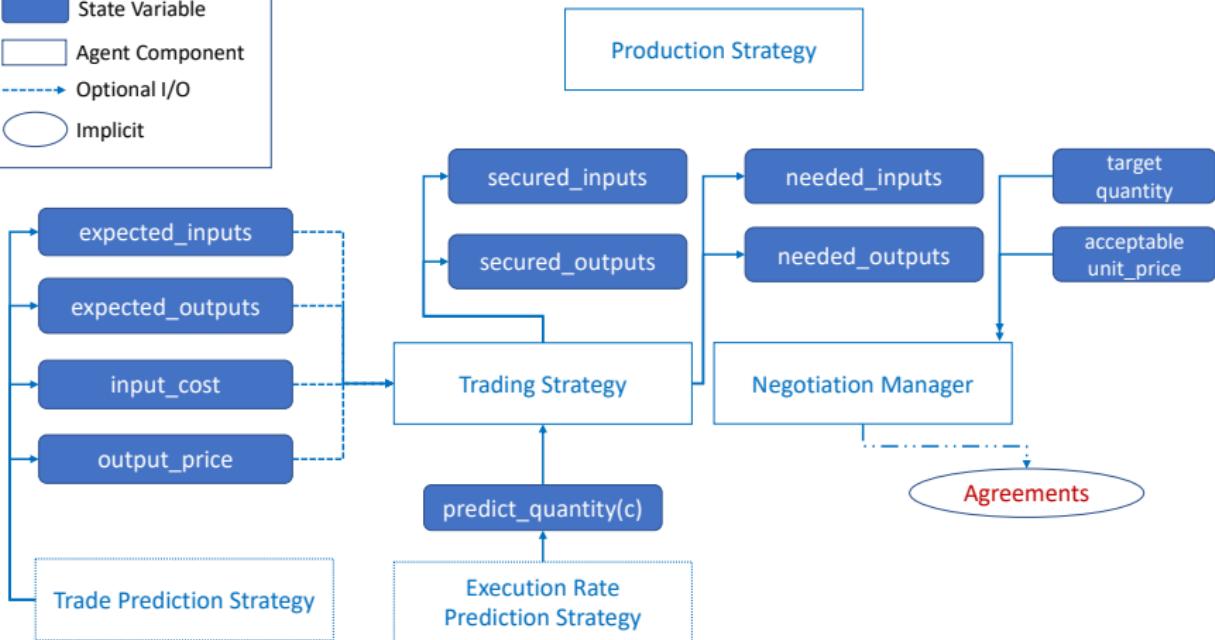
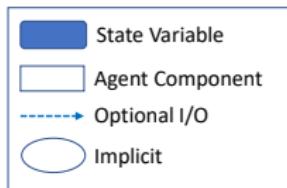
SCML Agent Components



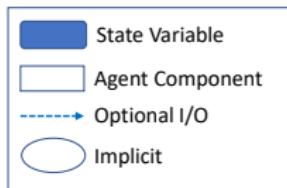
SCML Agent Components



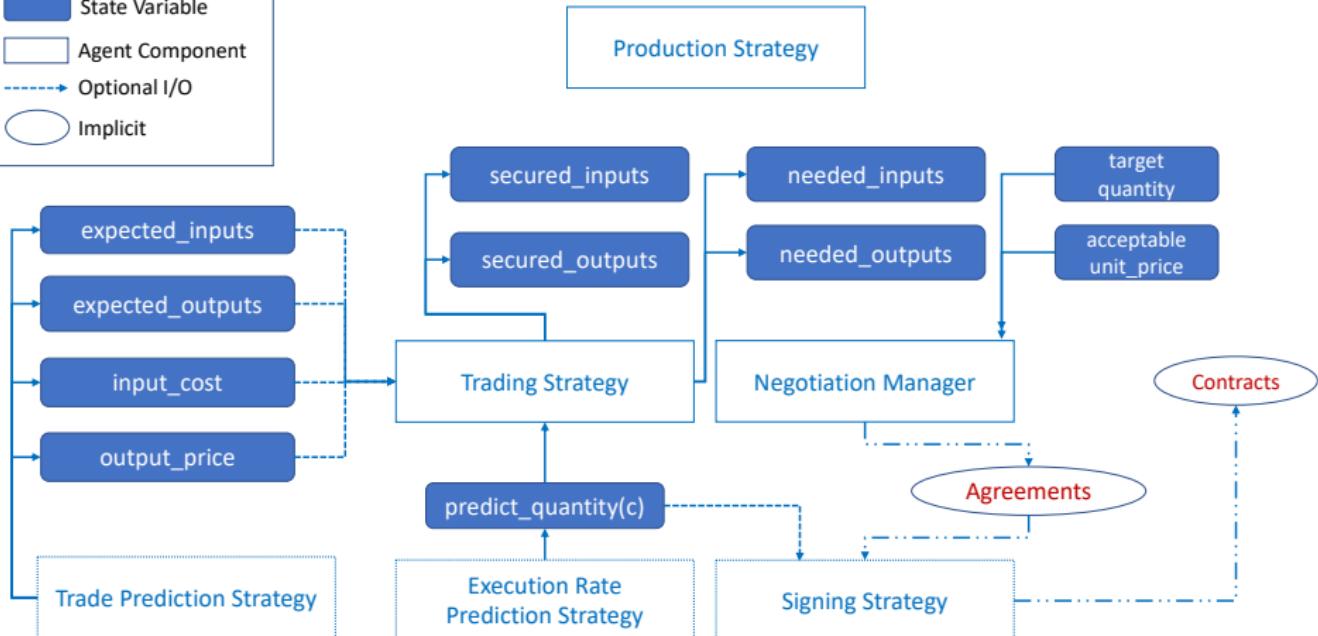
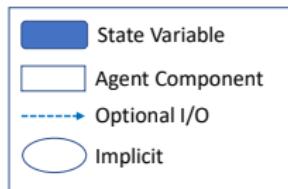
SCML Agent Components



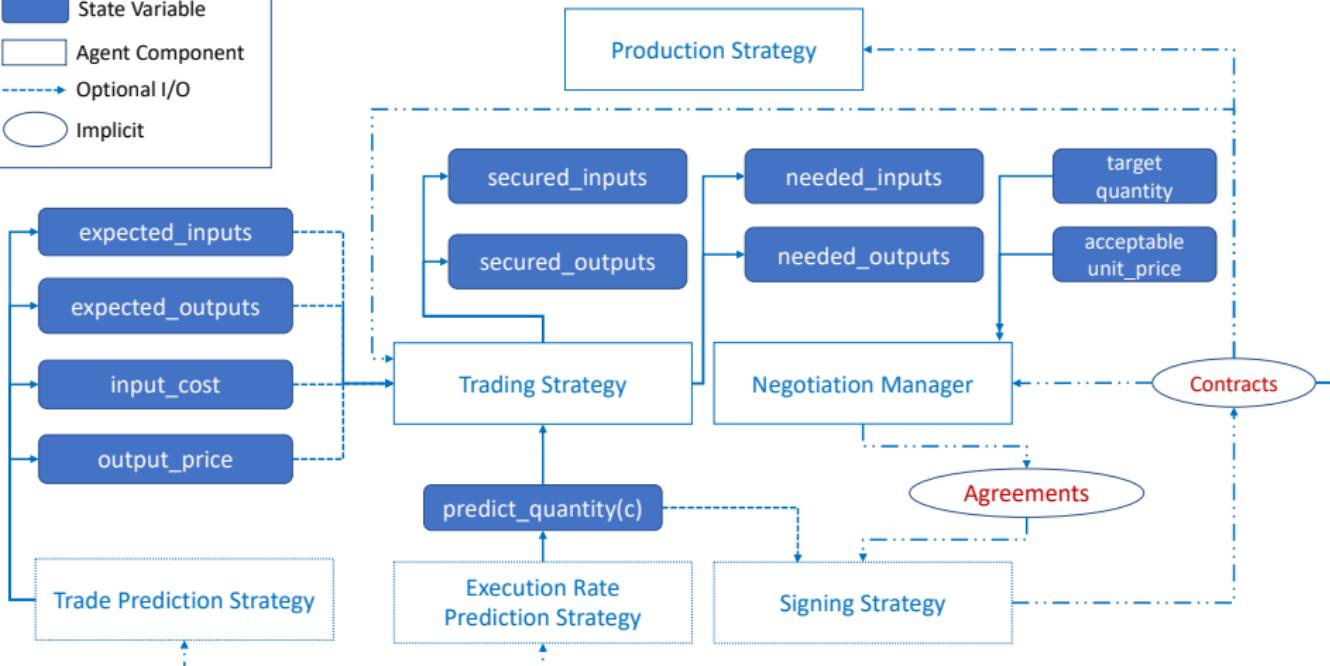
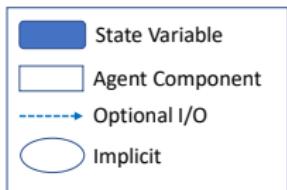
SCML Agent Components



SCML Agent Components



SCML Agent Components



Trading Strategy

Role



- Decides an overall **business plan**.
- Keeps track of buy/sell **needs**.

Built-in Options

No Strategy yes, just do nothing.

Reactive Zero needs.

Prediction Based trade and execution prediction.

- Needs come from trade predictions.
- Secured inputs/outputs come from execution prediction.

Negotiation Manager

Role

Negotiation Manager

target_quantity

For example, Needed – Secured

acceptable_unit_price

For example, catalog_price

Controls negotiation.

- Sets negotiation agendas → **Proactive** .
- Accepts/rejects negotiation requests → **Reactive** .
- Defines utility functions.
- Goal: Achieve the target put by the trading strategy.

Built-in Options

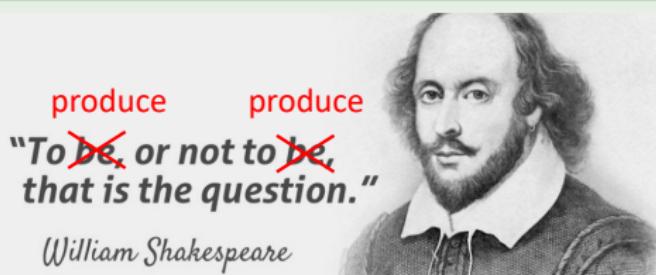
Independent Negotiations buy cheap ASAP, sell expensive ALAP.

Moving Range Creates one controller for selling and another for buying.

Step Manager Creates one controller per simulation step.

Production Strategy

Role



Built-in Options

Supply Driven Produce based on **buy** contracts.

- Inventory is always valued at the end.

Demand Driven Produce based on **sell** contracts.

- ... but inventory is valued at half the *trading* price!

Outline

- 1 Negotiation
- 2 ANAC: A brief history
- 3 NegMAS: The platform
- 4 Automated Negotiation in Supply Chain Management
- 5 Agent
- 6 Conclusion

References I

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