

Automated Negotiation

A Tutorial

Yasser Mohammad^{1,2}

¹ NEC-AIST Collaborative Lab., AIST, 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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- 6 Conclusion

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- Unmediated Protocols
- The Simplest Negotiation

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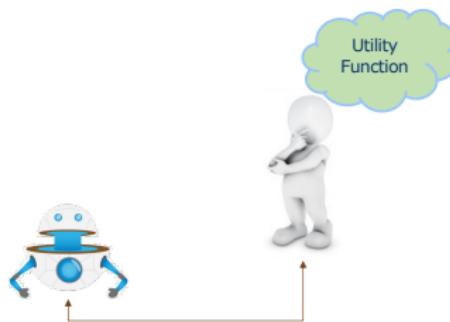
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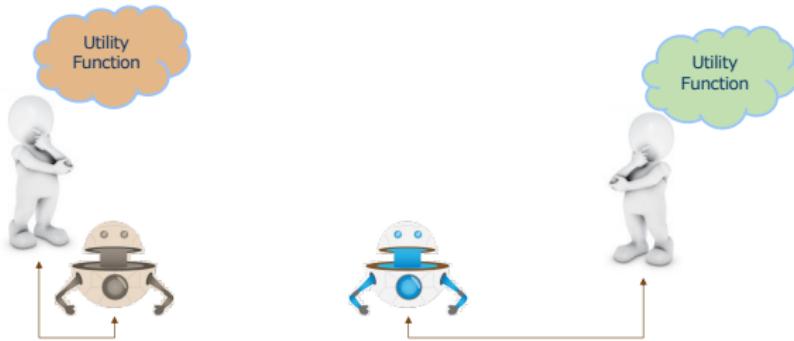
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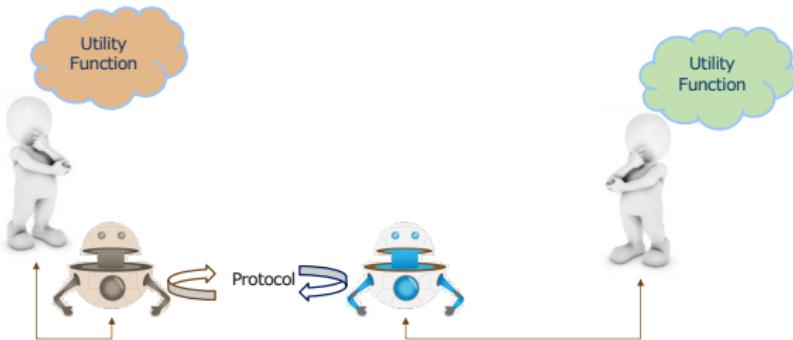
- A method to achieve agreement among self-interested actors.
- Negotiation is important → win-win agreements.
- Automatic Negotiation → \$\$\$
 - smart contracts, resource allocation, SCM, etc



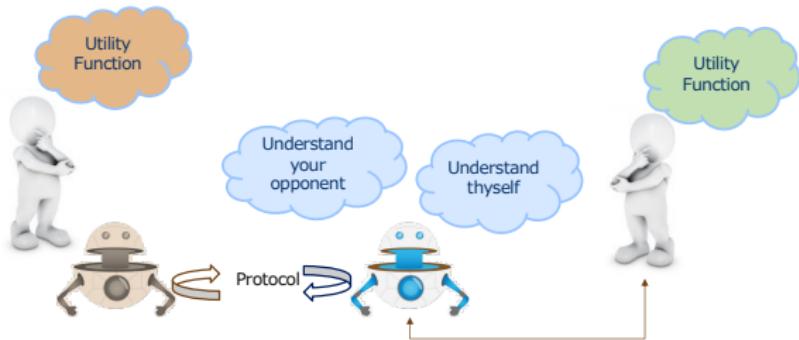
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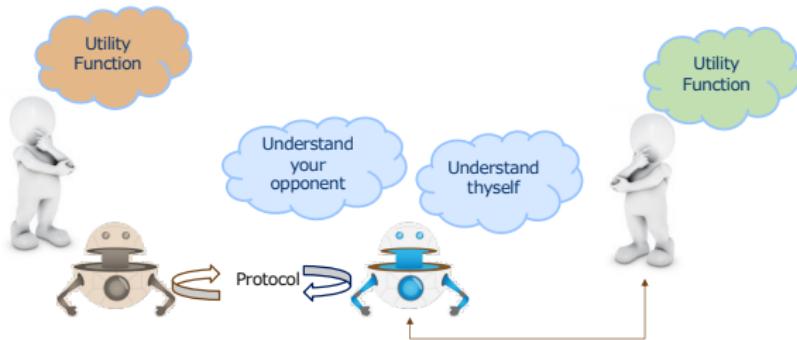
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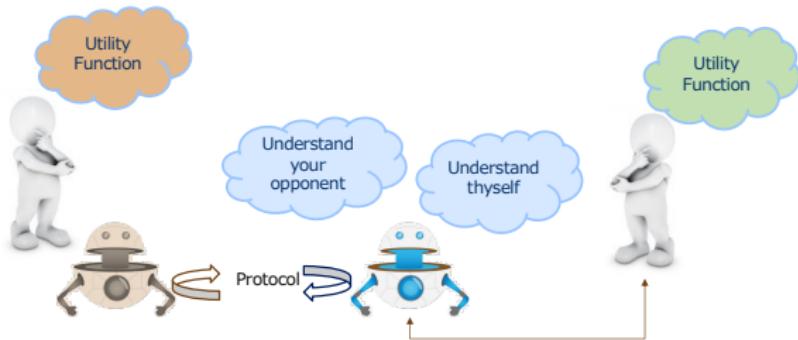
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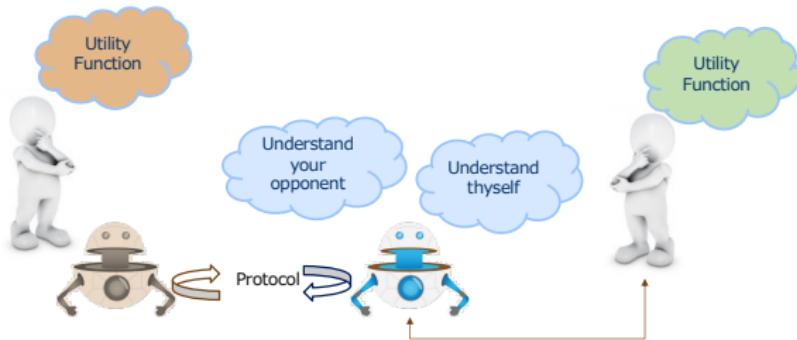
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Components of the Negotiation Problem



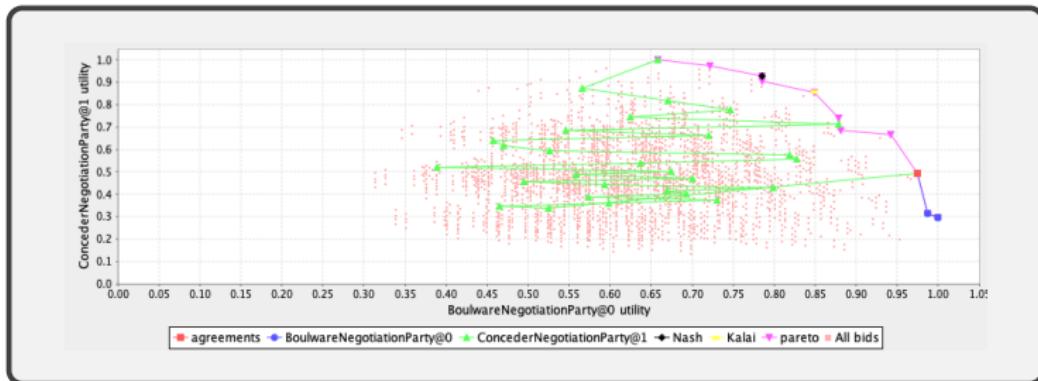
Negotiation Protocol Defines how negotiation is to be conducted [Mechanism Design Problem].

- 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



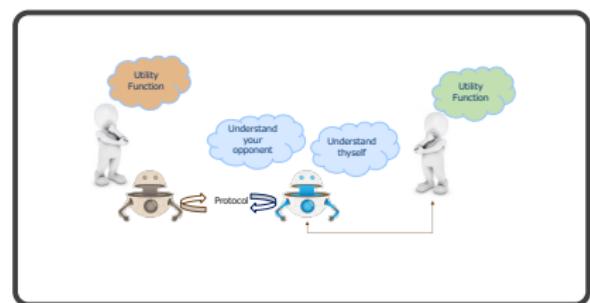
Pareto Frontier Outcomes that cannot be improved for one actor without making another worse off.

Welfare Total utility received by all actors.

Surplus utility Utility above disagreement utility.

Nash Equilibrium Strategies that are best responses to each other.

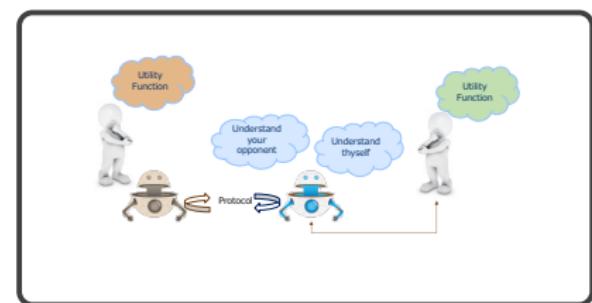
Types of Automated Negotiation Problems



Types of Automated Negotiation Problems

Negotiator type

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



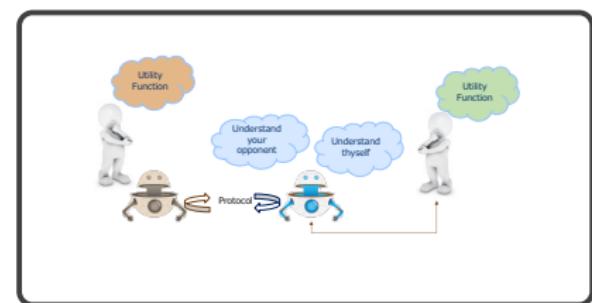
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Number of negotiators

- ① Bilateral negotiation
- ② Multilateral negotiation



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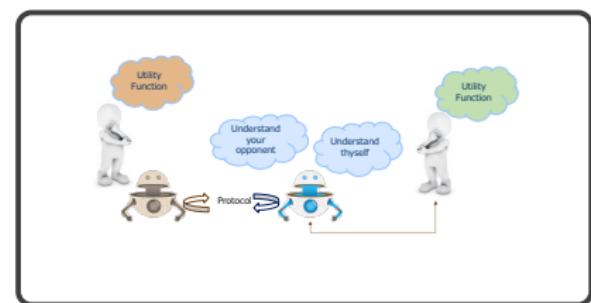
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Outcome Space

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



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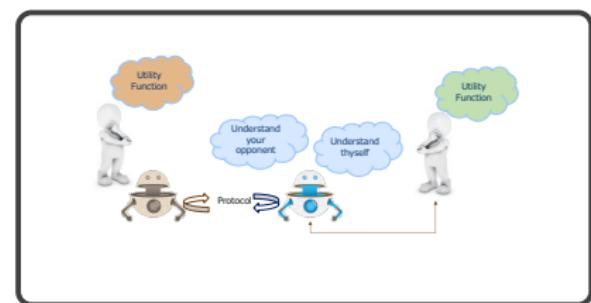
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Protocol Type

- ① Mediated
- ② Unmediated



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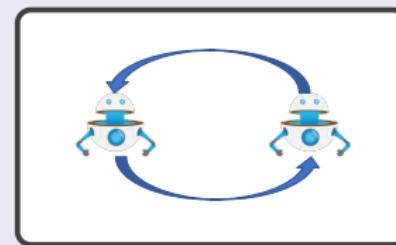
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Unmediated Protocols

Main Features

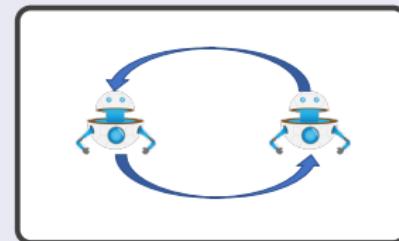
- No central coordinator.
- Agents negotiate by exchanging *messages*.
- All proposals come from negotiators.



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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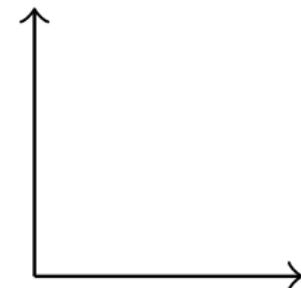
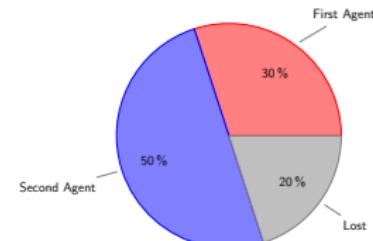
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Nash Bargaining Game: Description

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

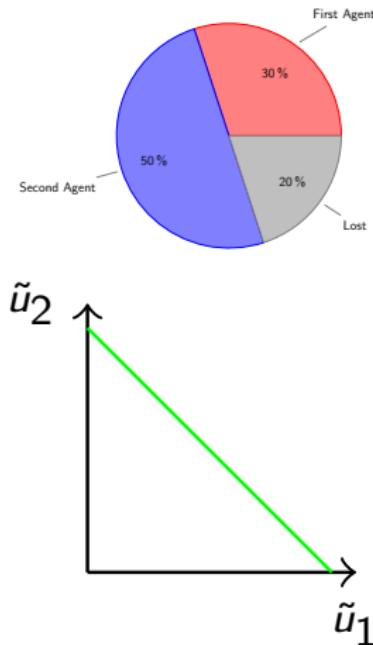


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A single-step full-information bilateral negotiation with $\Omega = [0, 1]^2$ and two utility functions $(\tilde{u}_1, \tilde{u}_2)$ such that:

- 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:

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

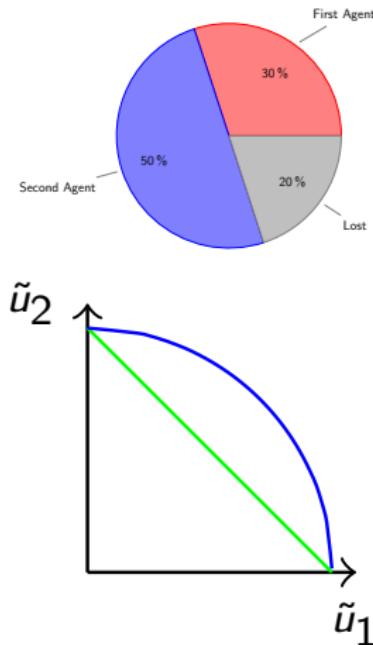


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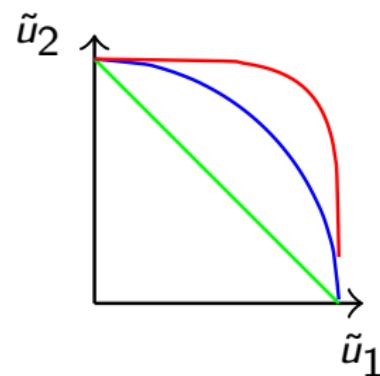
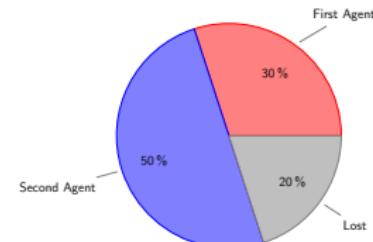


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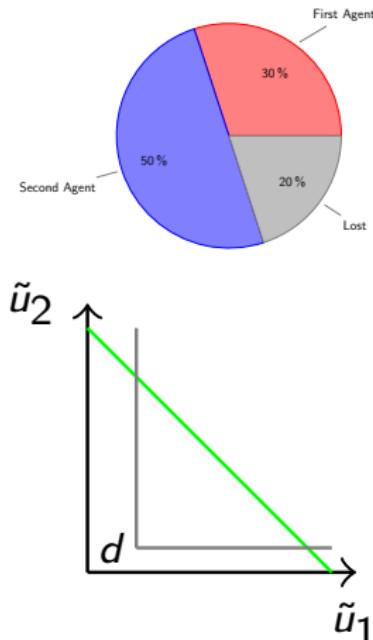


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- A disagreement point $d \equiv \tilde{u}_1(\phi) + \tilde{u}_2(\phi) \in \mathbb{R}^2$ which is the utility value received by the two players in case of disagreement (reserved values).

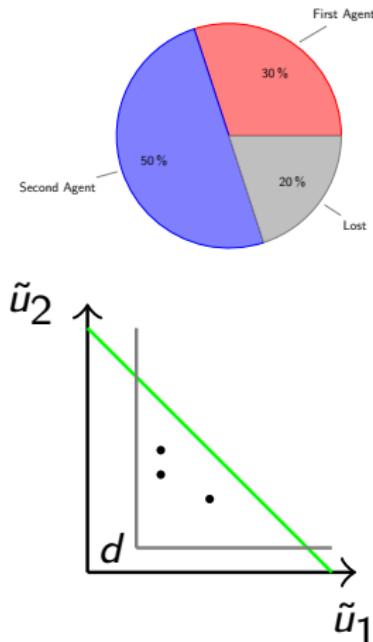


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A brief history of ANAC

- 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.

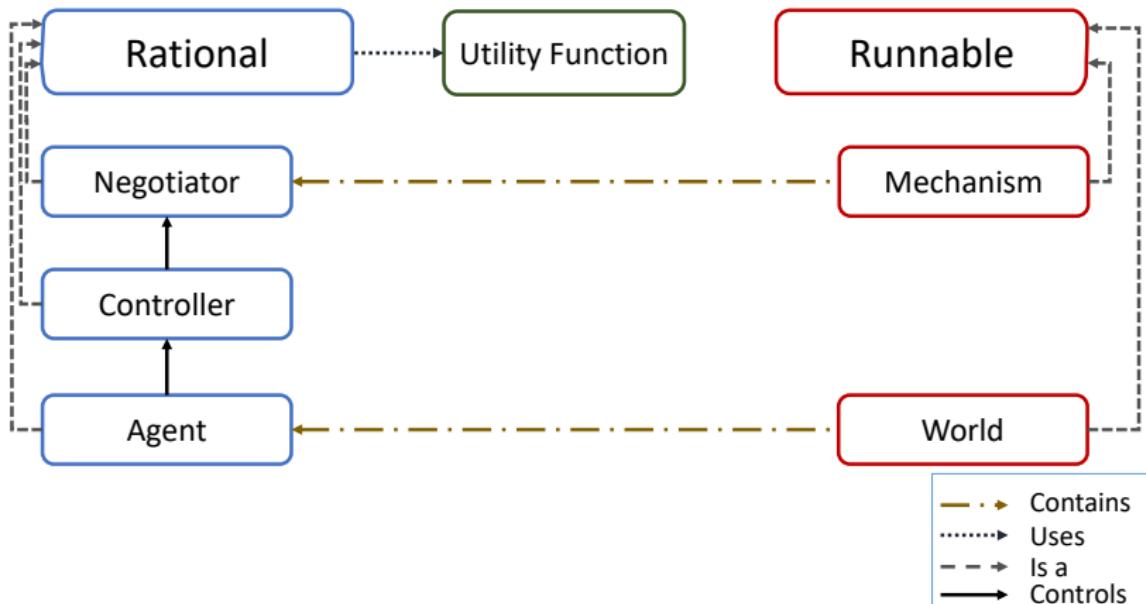


Year	Challenge	Year	Challenge
2010	Domain Independence	2011	Linear Ufuns
2012	Reservation Value	2014	Learning and Adaptation
2015	Three-party negotiation	2016	Energy Grid Theme
2017	Repeated Negotiations, Diplomacy, HAN	2018	Repeated Negotiations, Diplomacy, HAN
2019	Elicitation, Diplomacy, HAN, Werewolf,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

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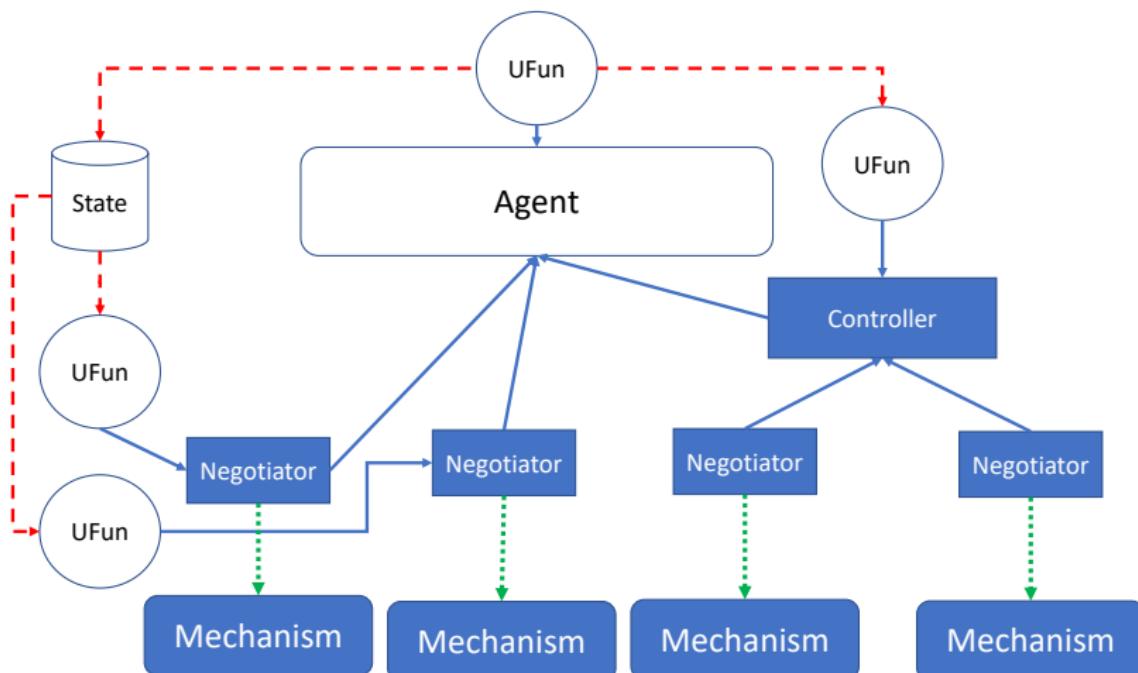
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NegMAS¹ in two slides

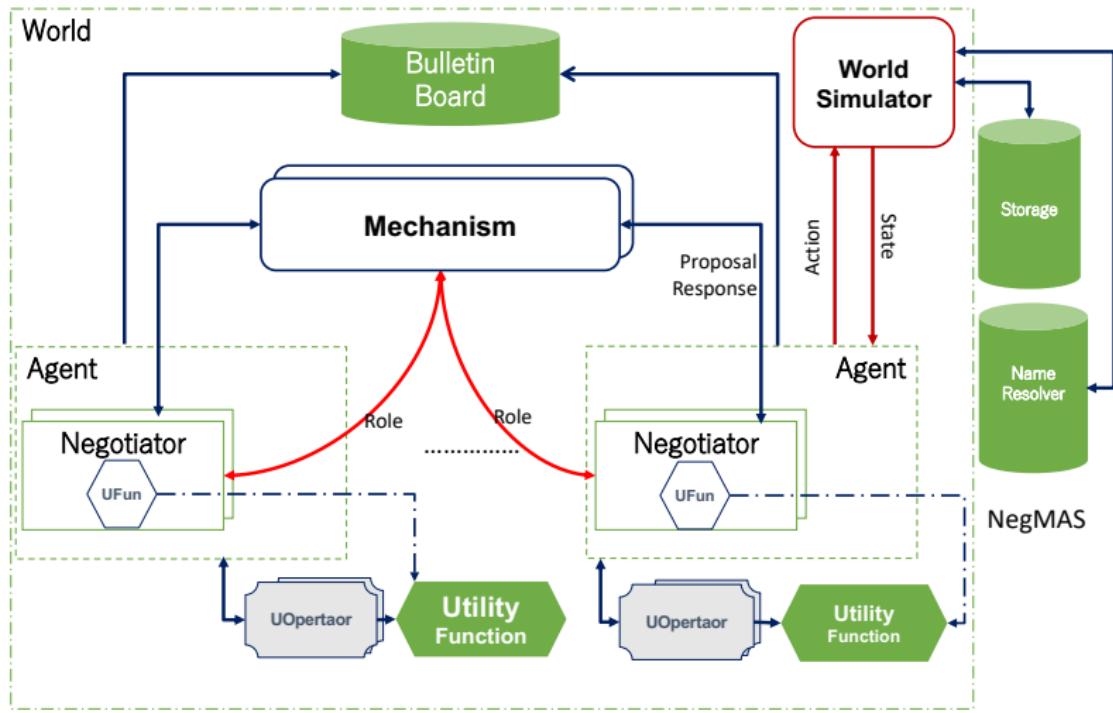


¹<https://www.github.com/yasserfarouk/negmas>

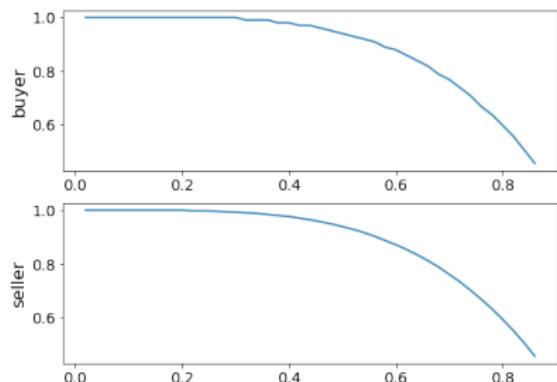
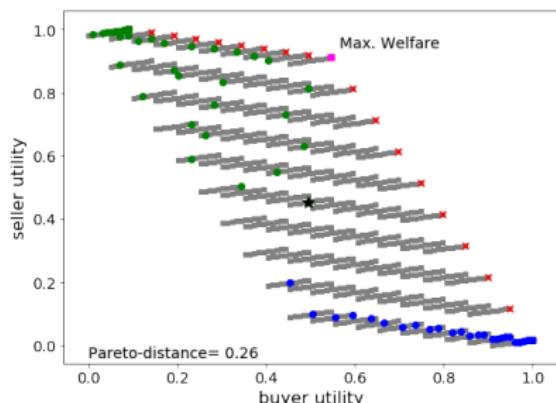
NegMAS in two slides



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].

²KPMG report: <https://bit.ly/3kDRy6l>

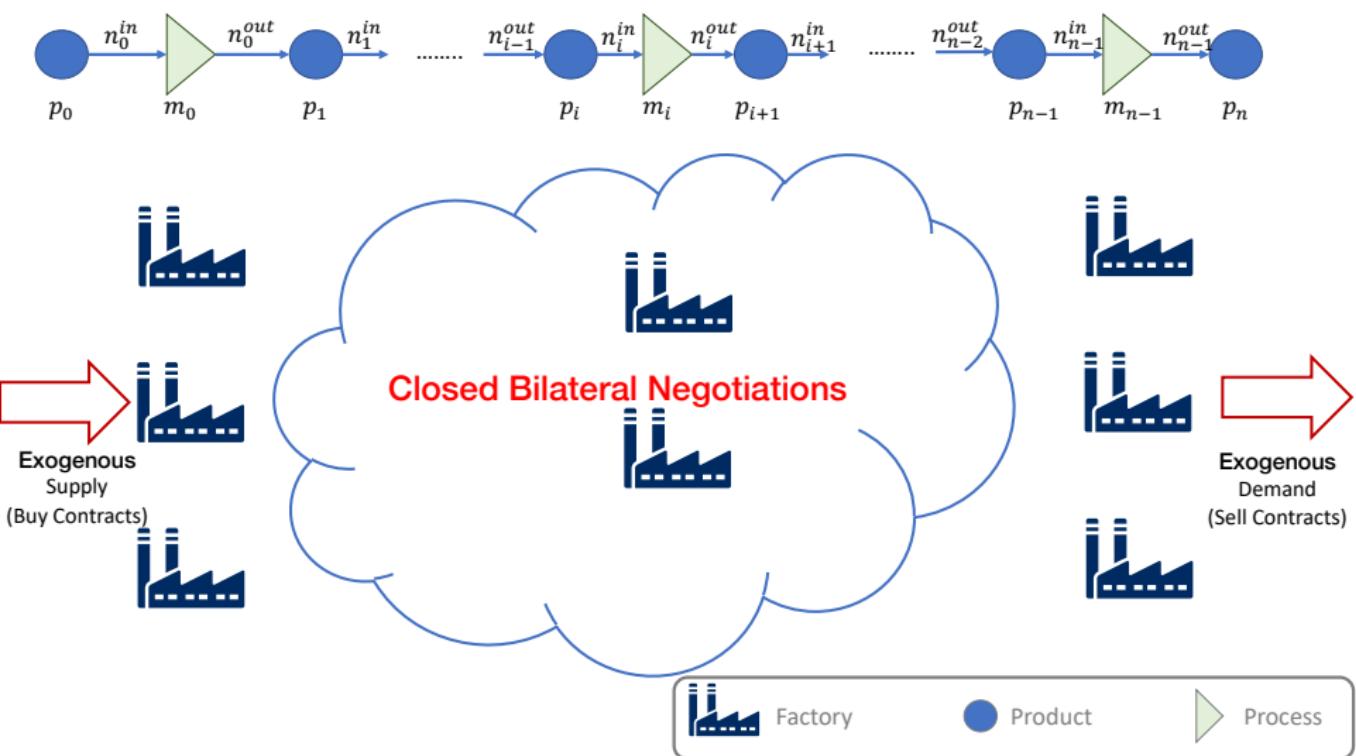
³Forrester report: <https://bit.ly/3nwXEaY>

⁴UN/CEFACT Project website: <https://bit.ly/38LOsLX>

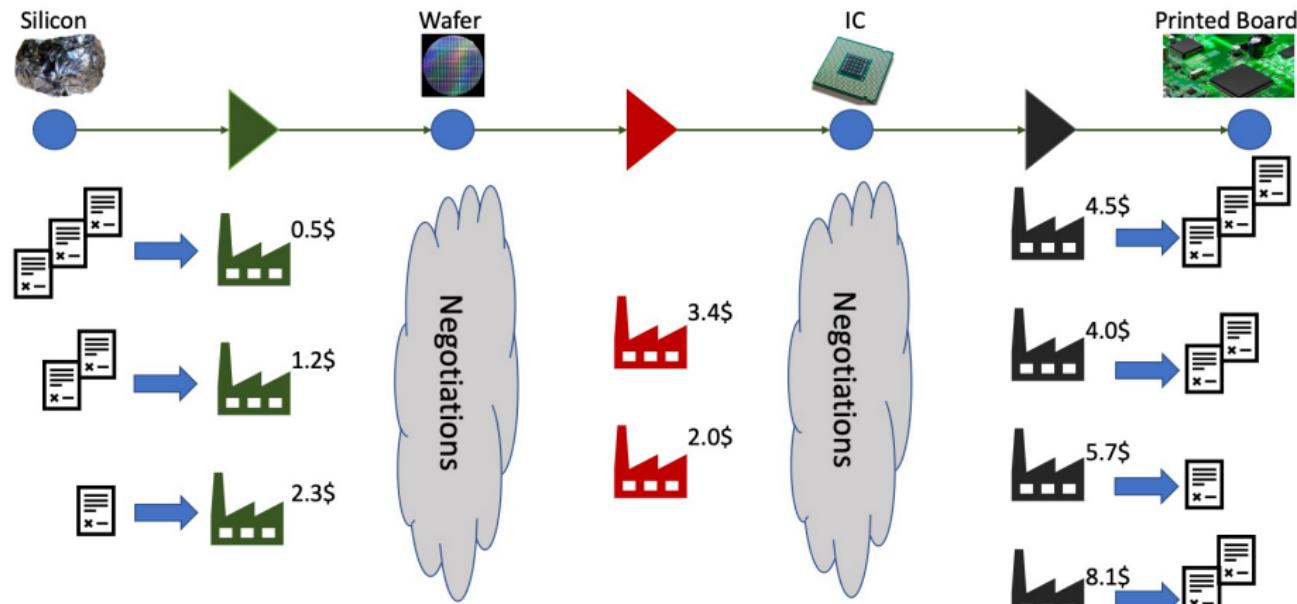
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SCML Competition [Mohammad et al., 2019]



Example Configuration

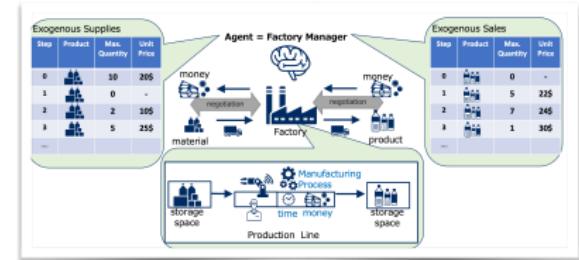
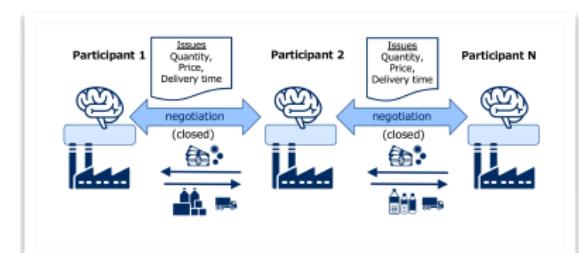
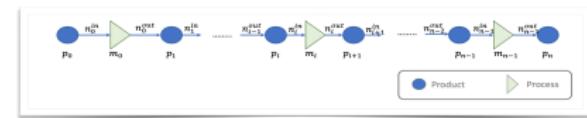


An example of an SCM world showing four products (circles), three processes (triangles) and few factories. Each process consumes one item of its input and generates one output of its output in one day. Each factory requires a different cost to run its process (shown in its top right). Factories in the 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>

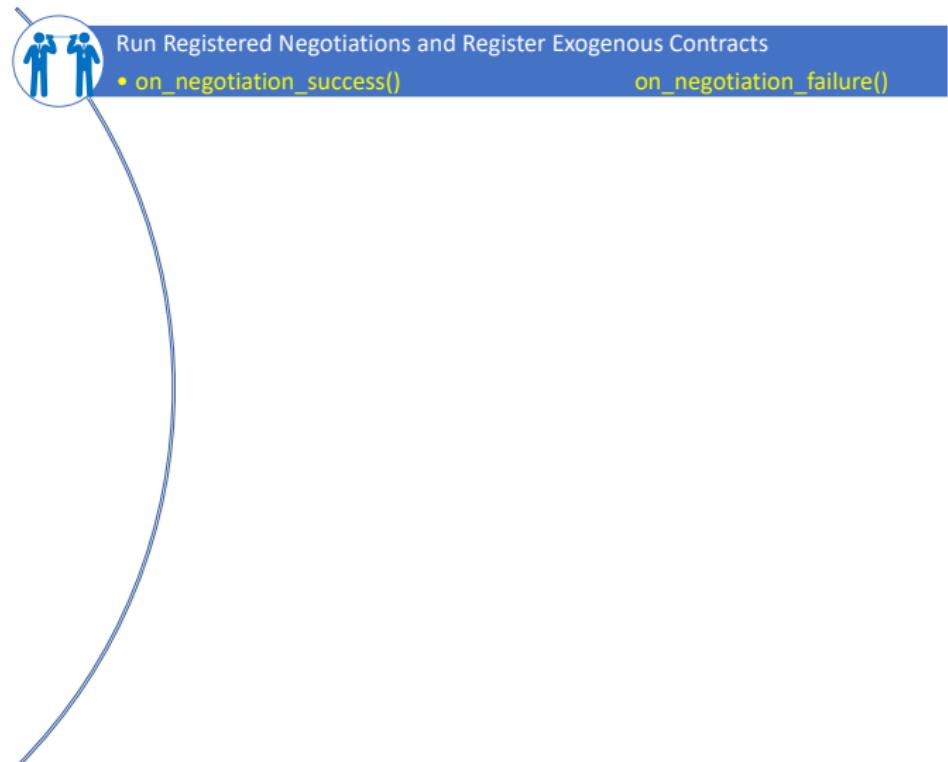
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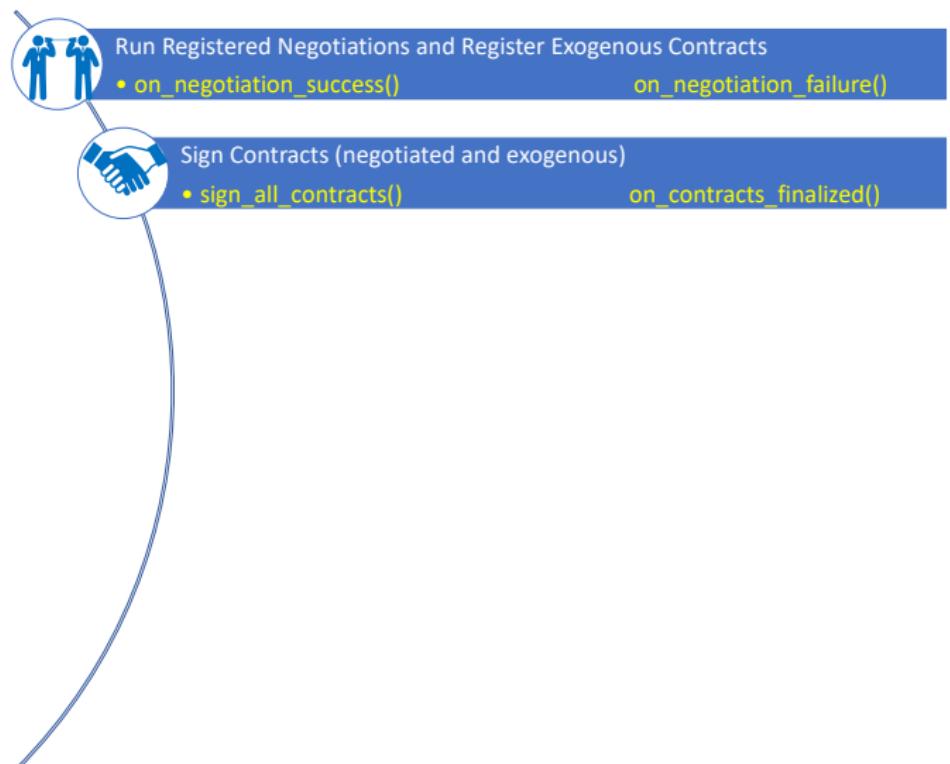
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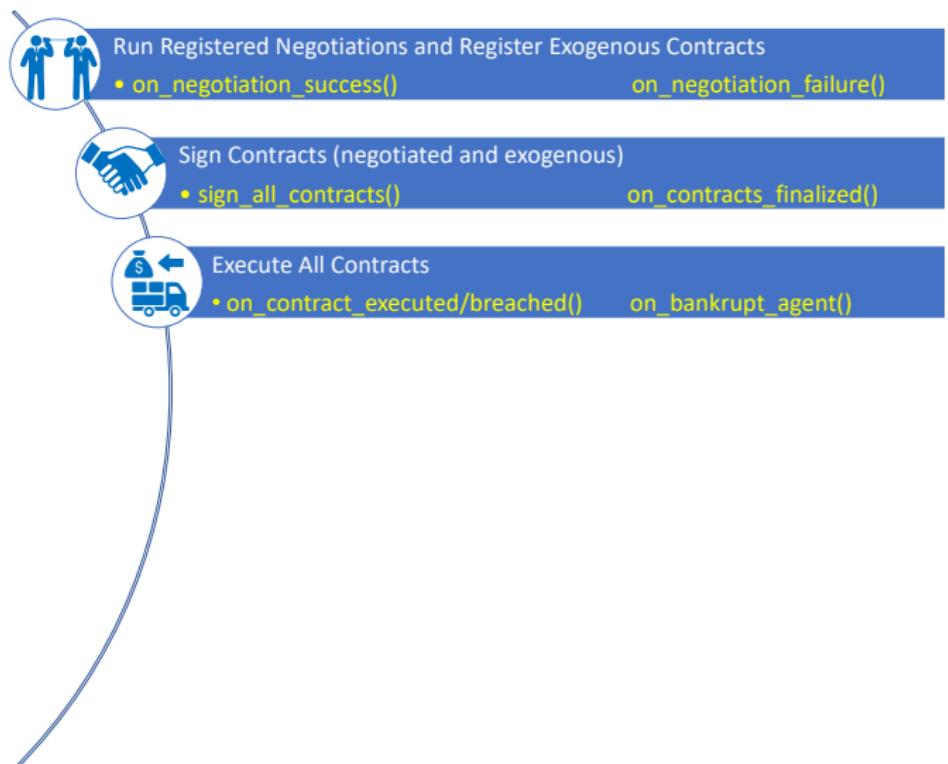
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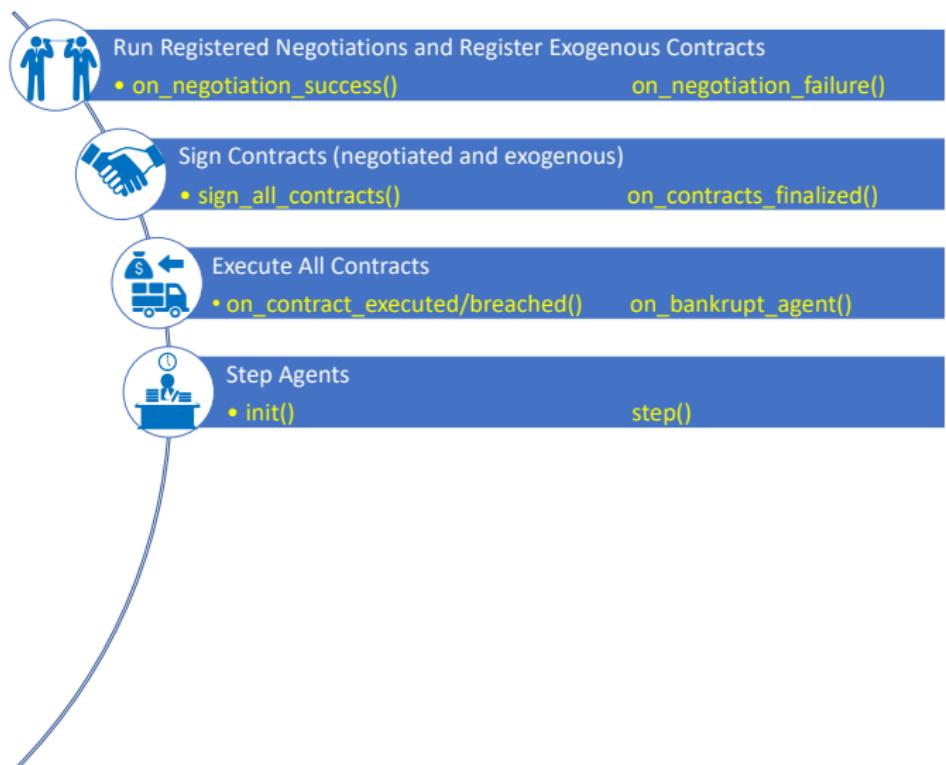
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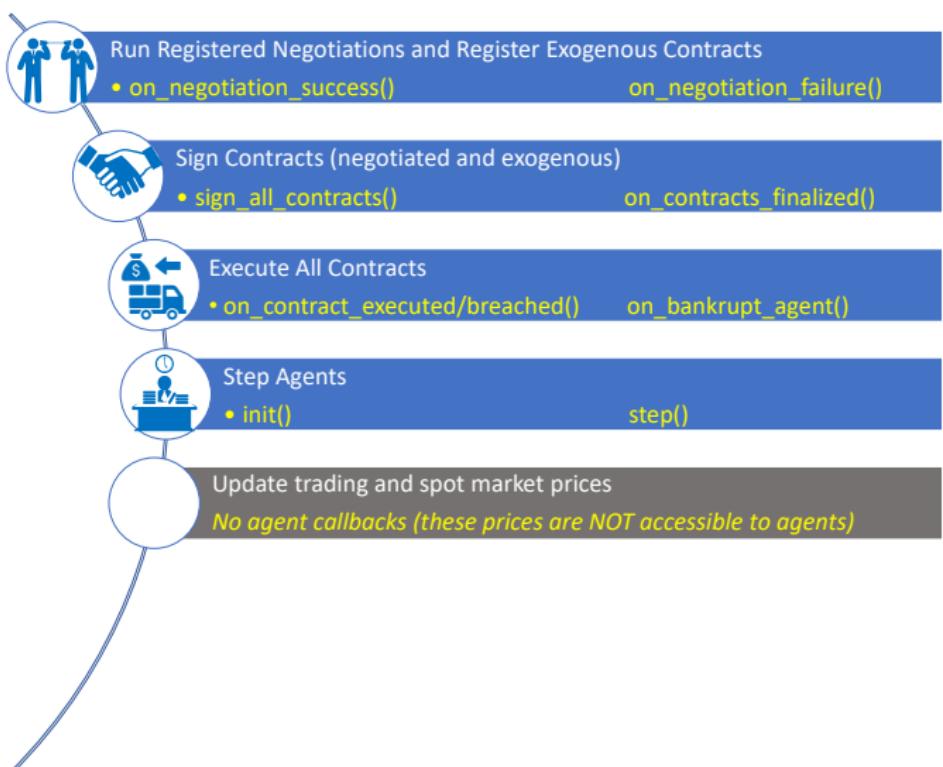
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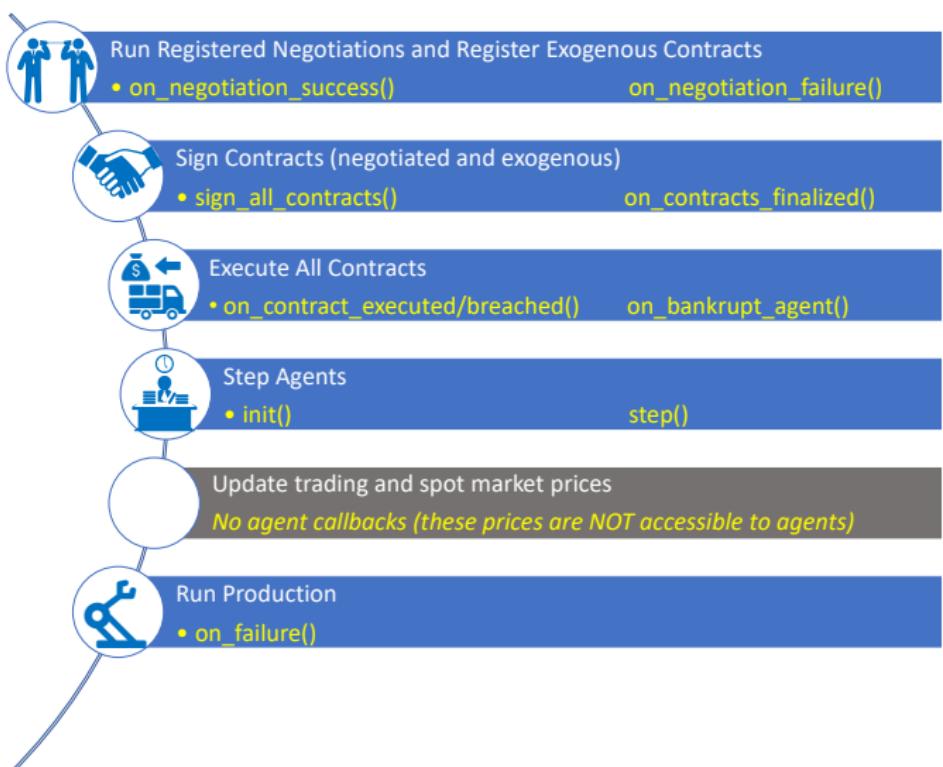
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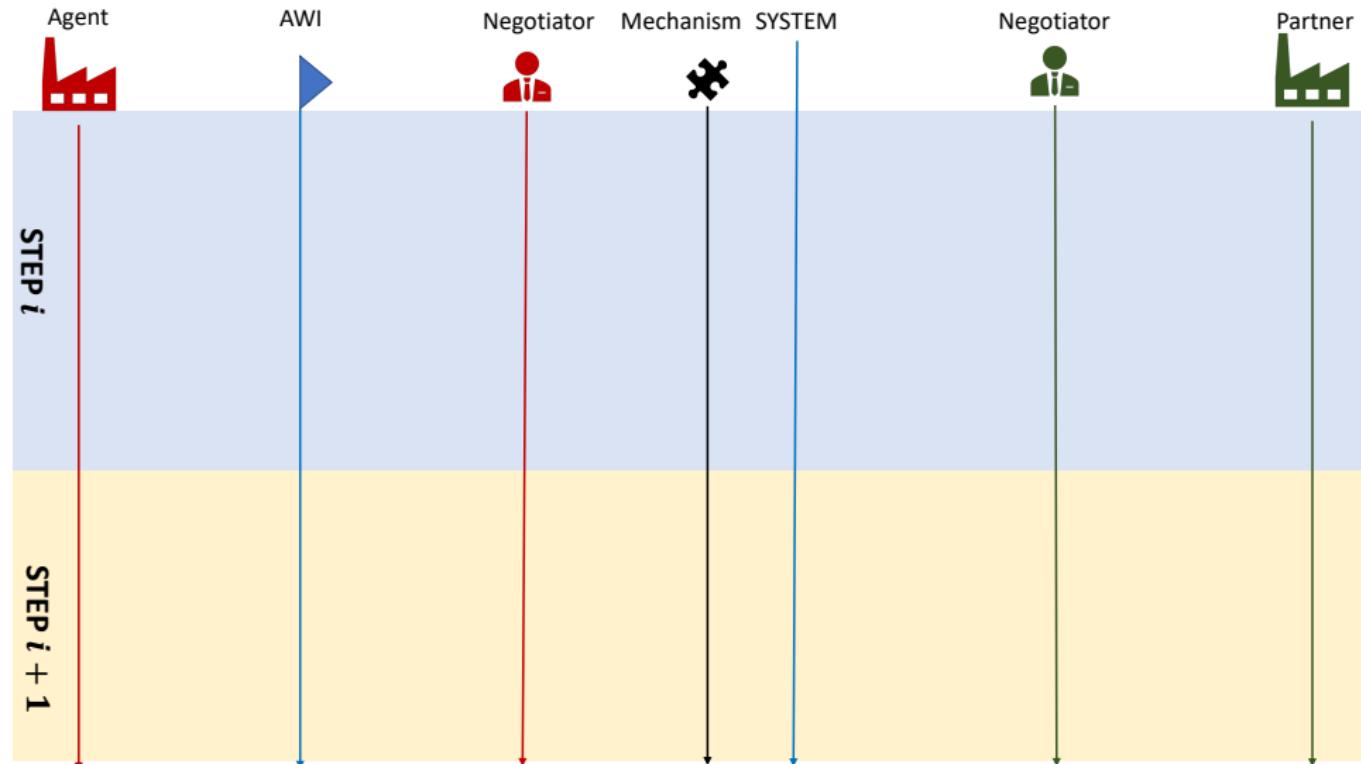


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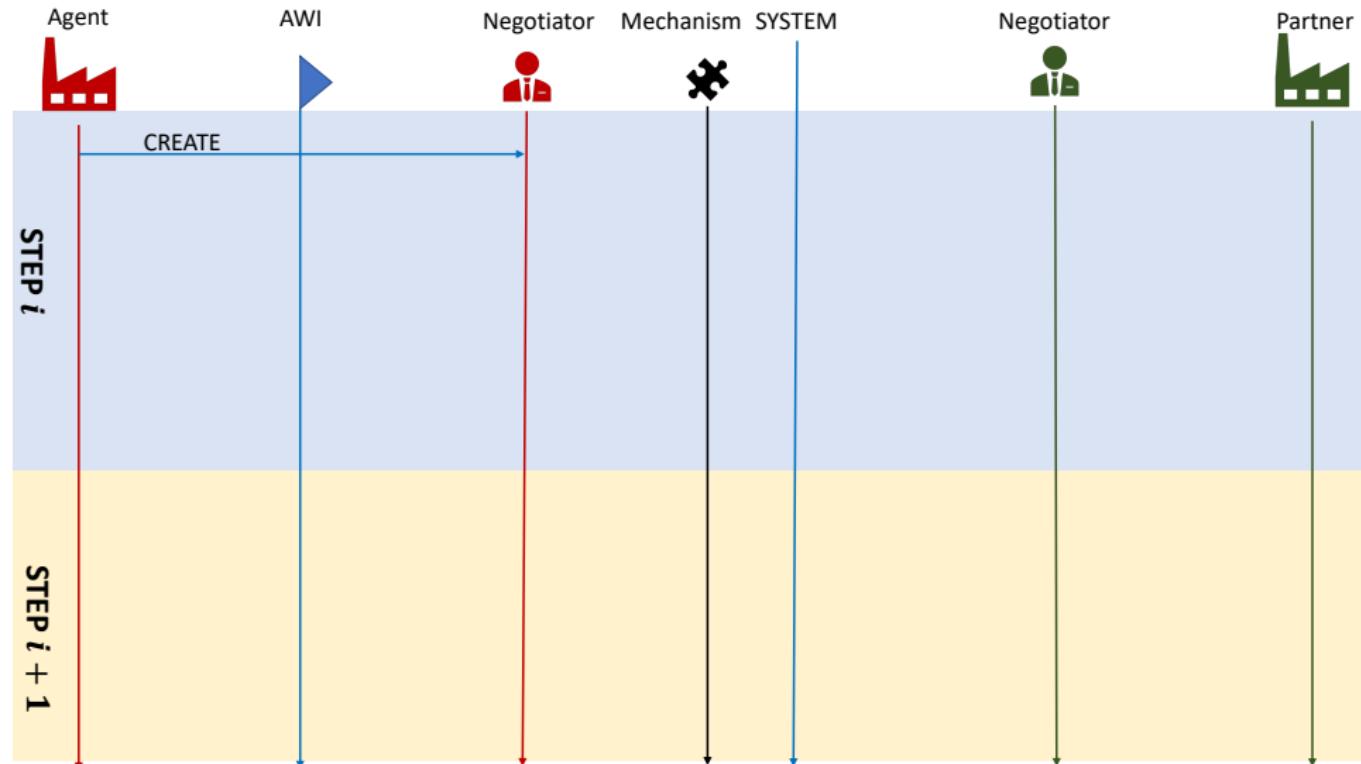
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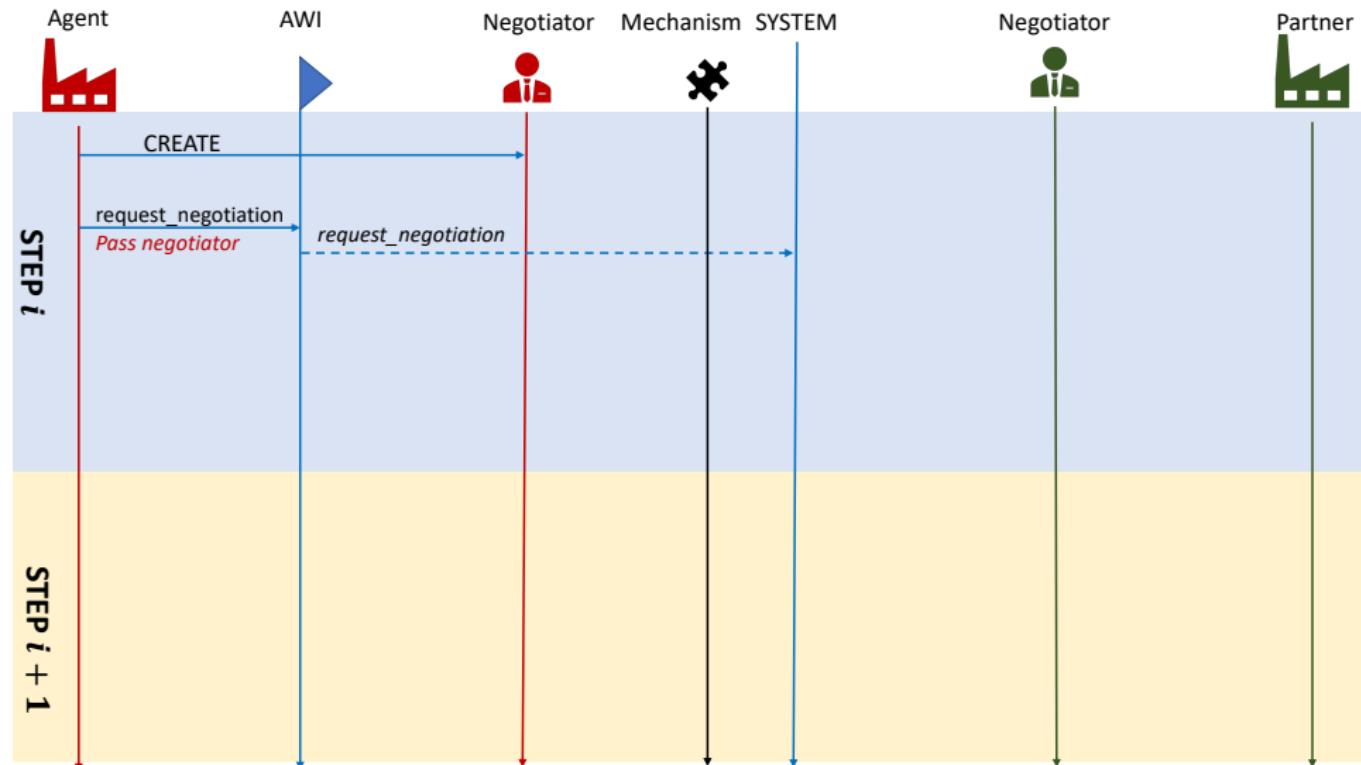
Callbacks and Timing



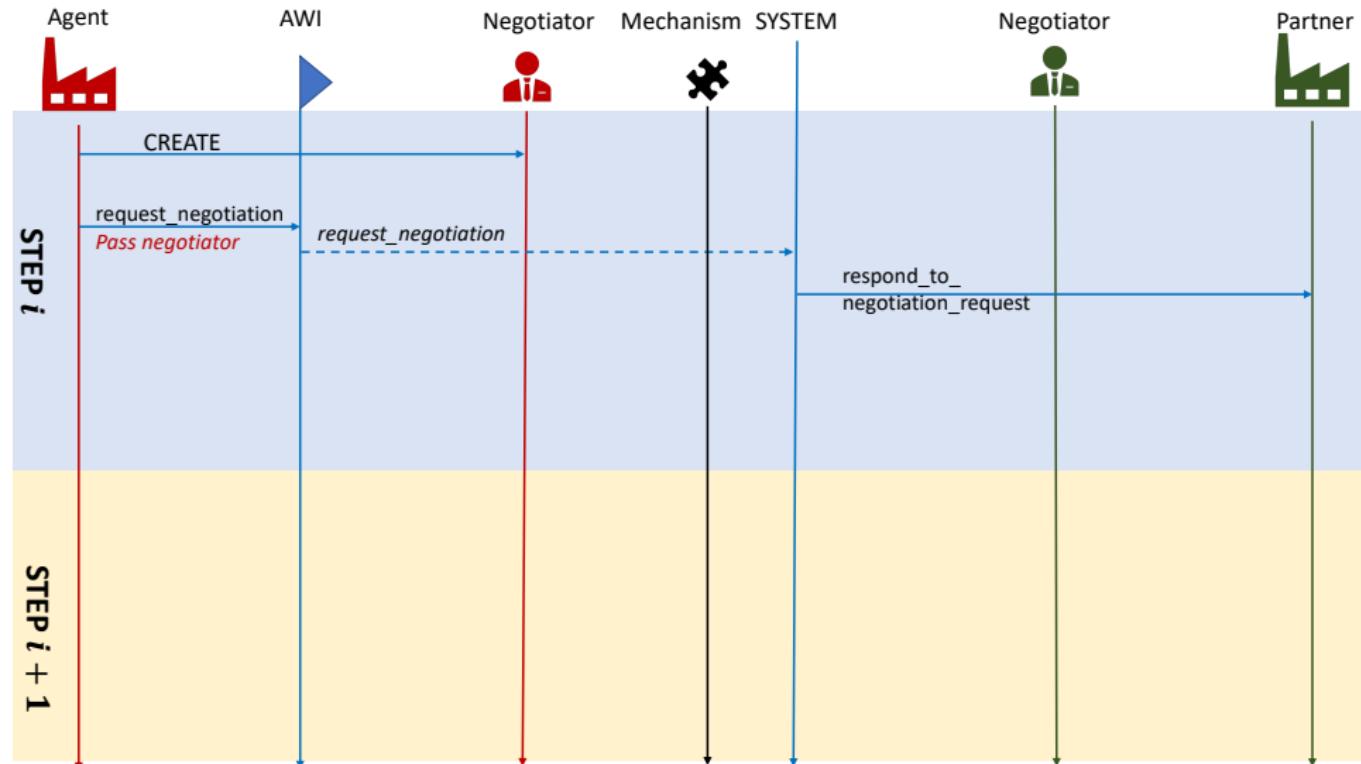
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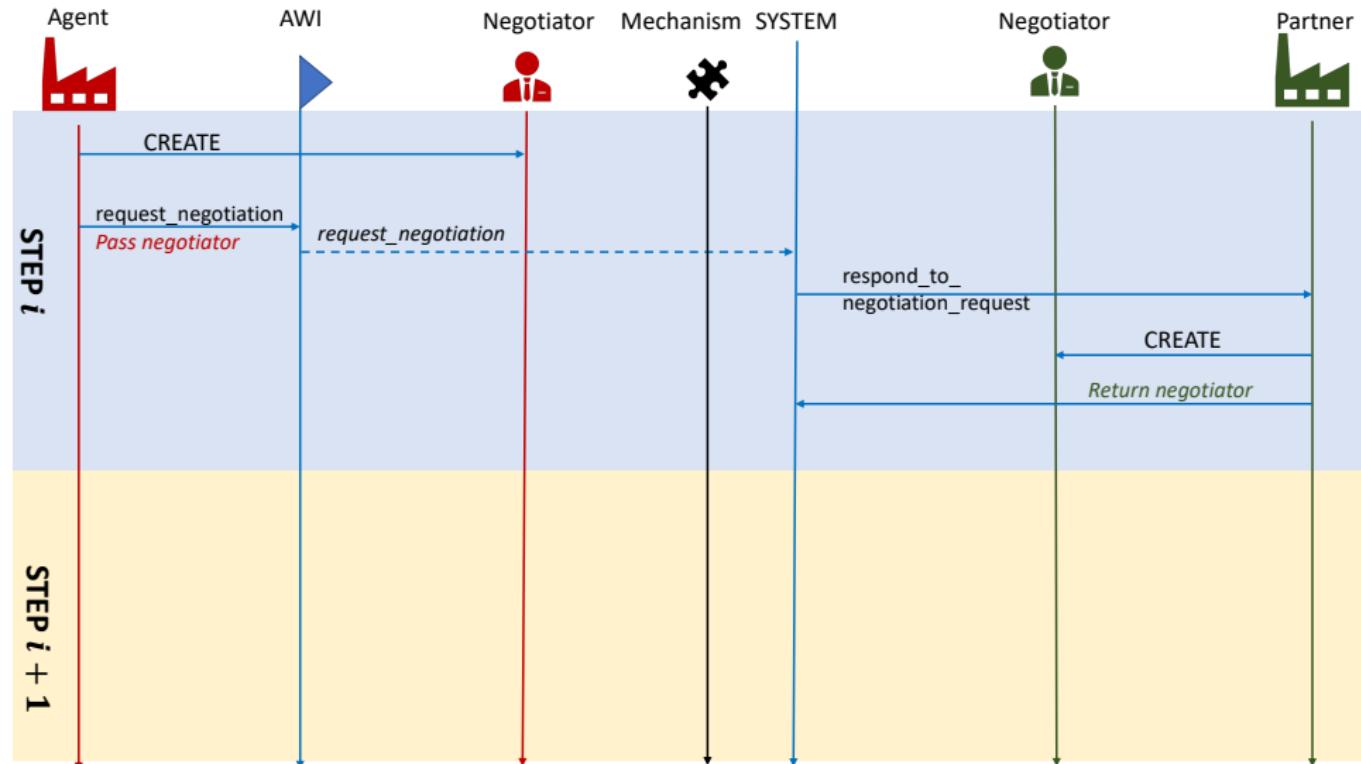
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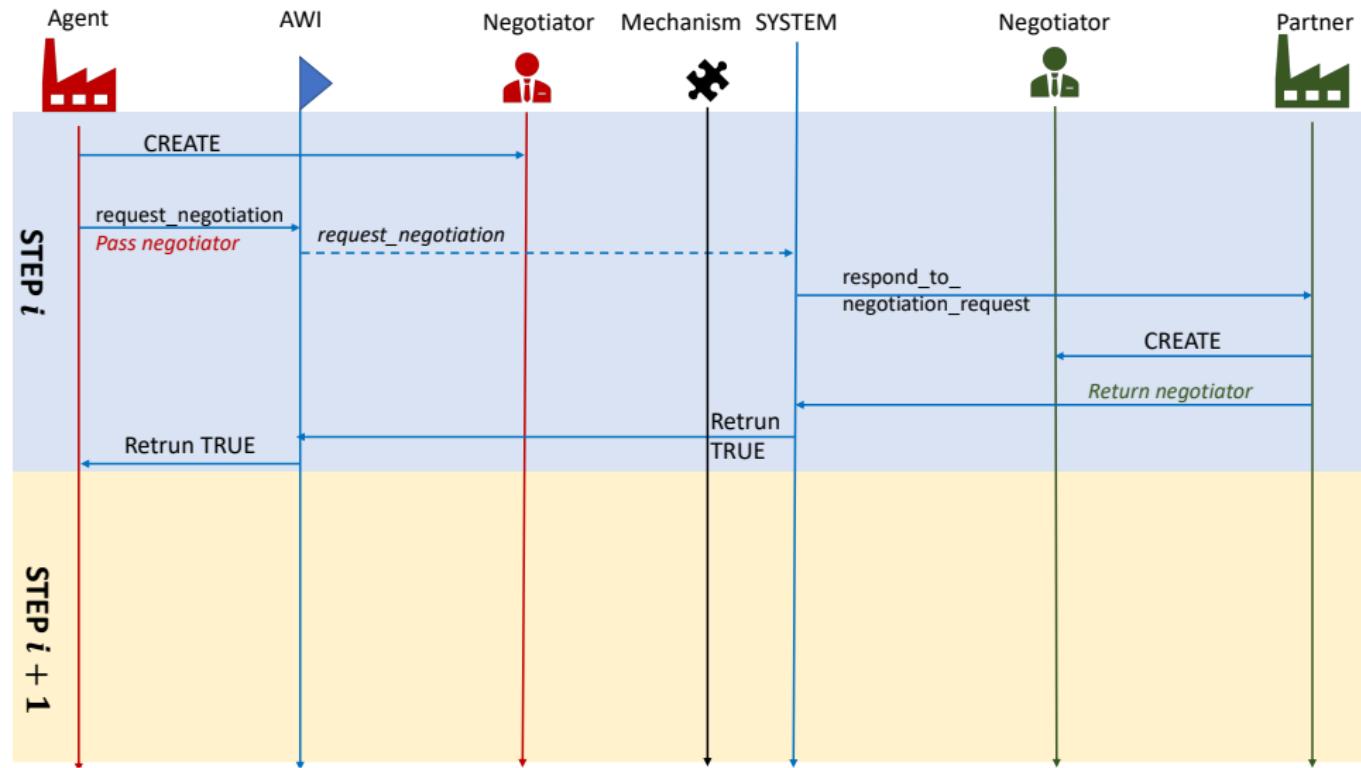
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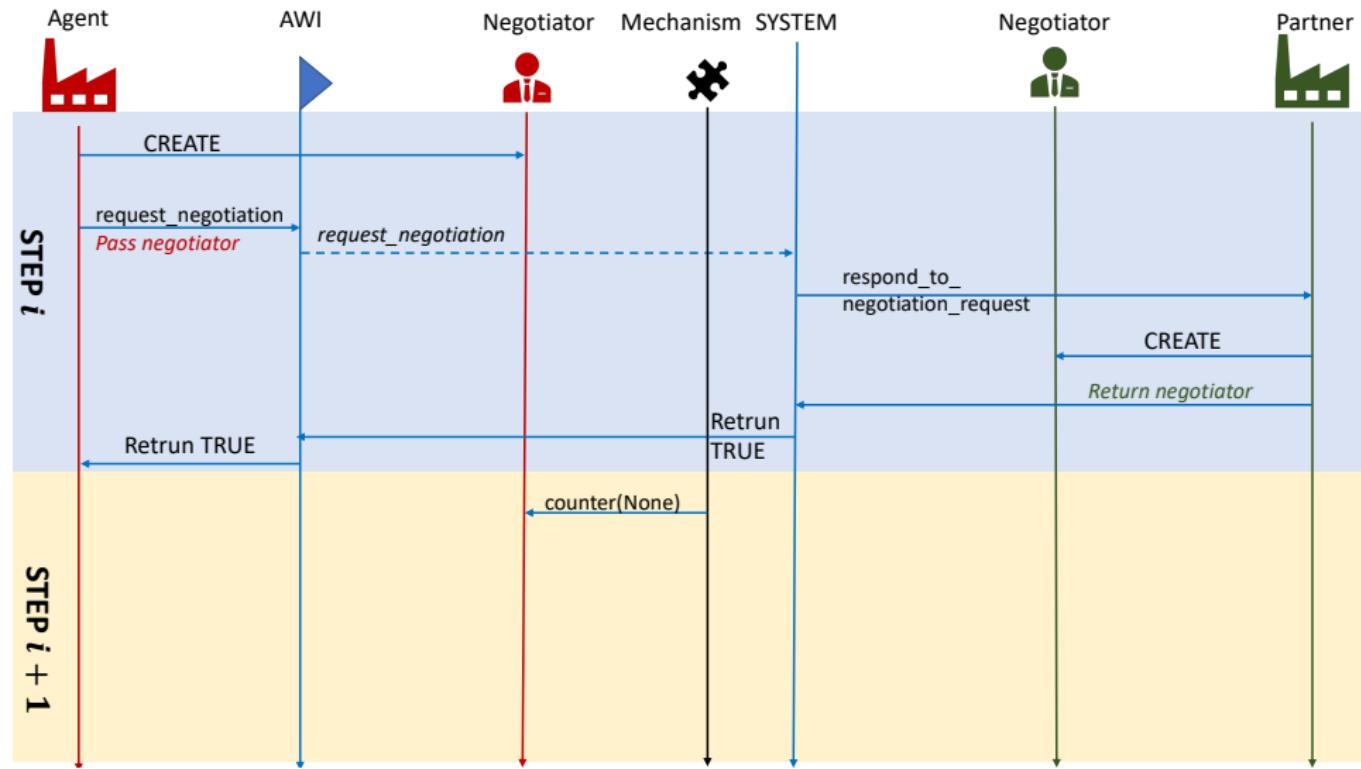
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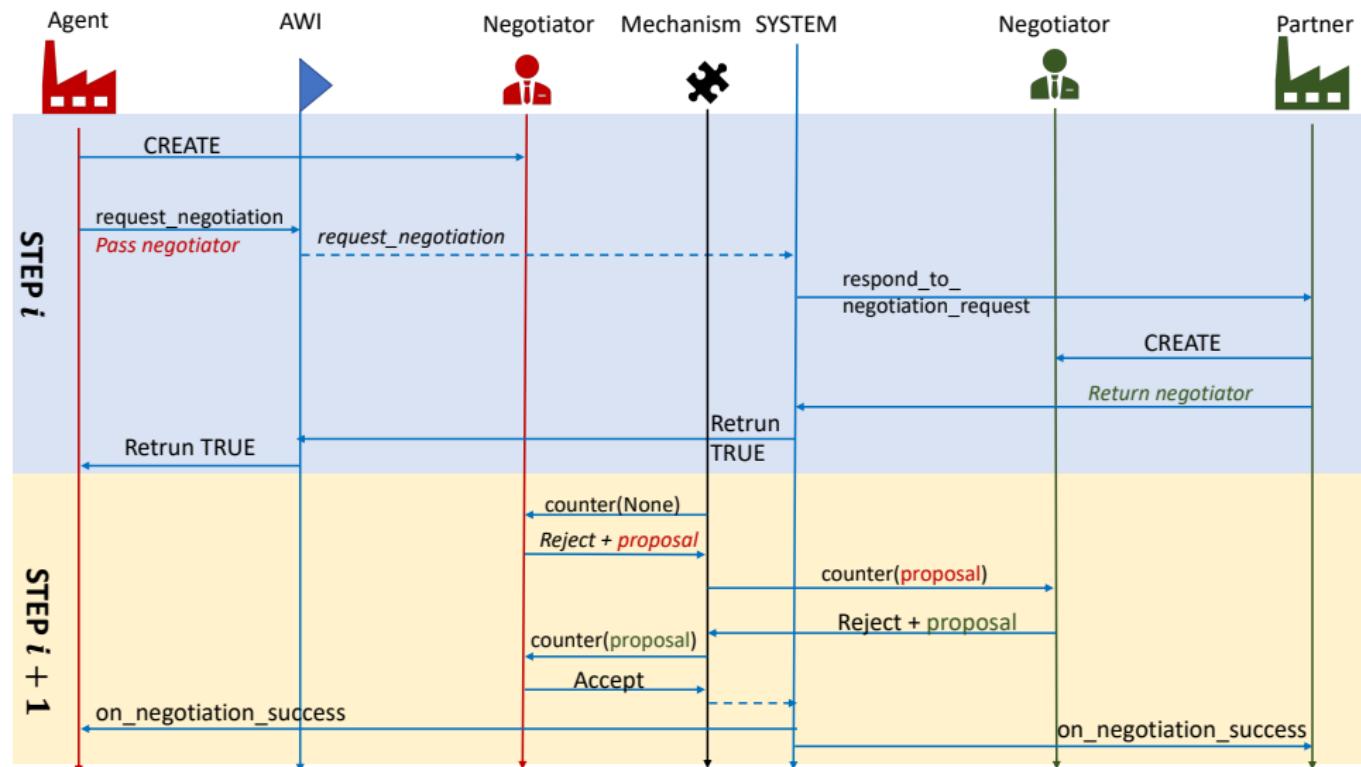
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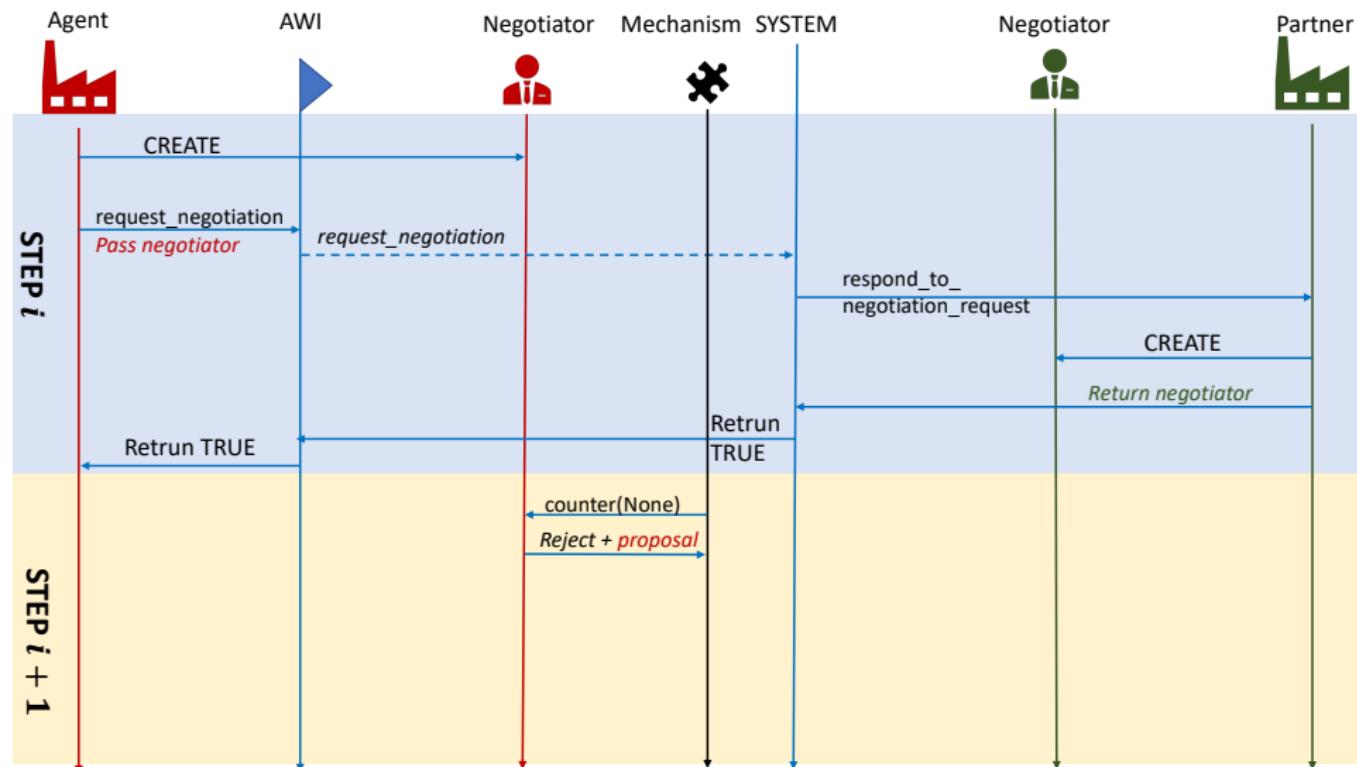
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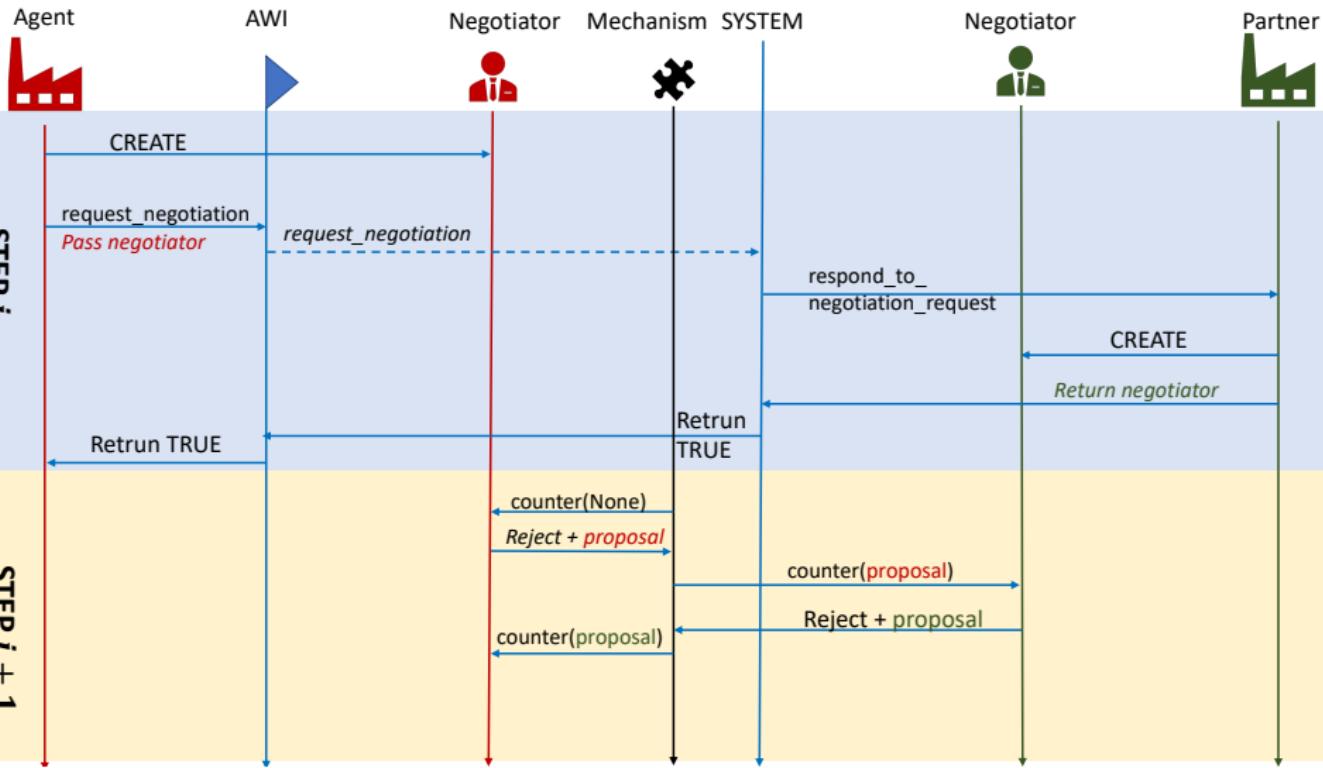
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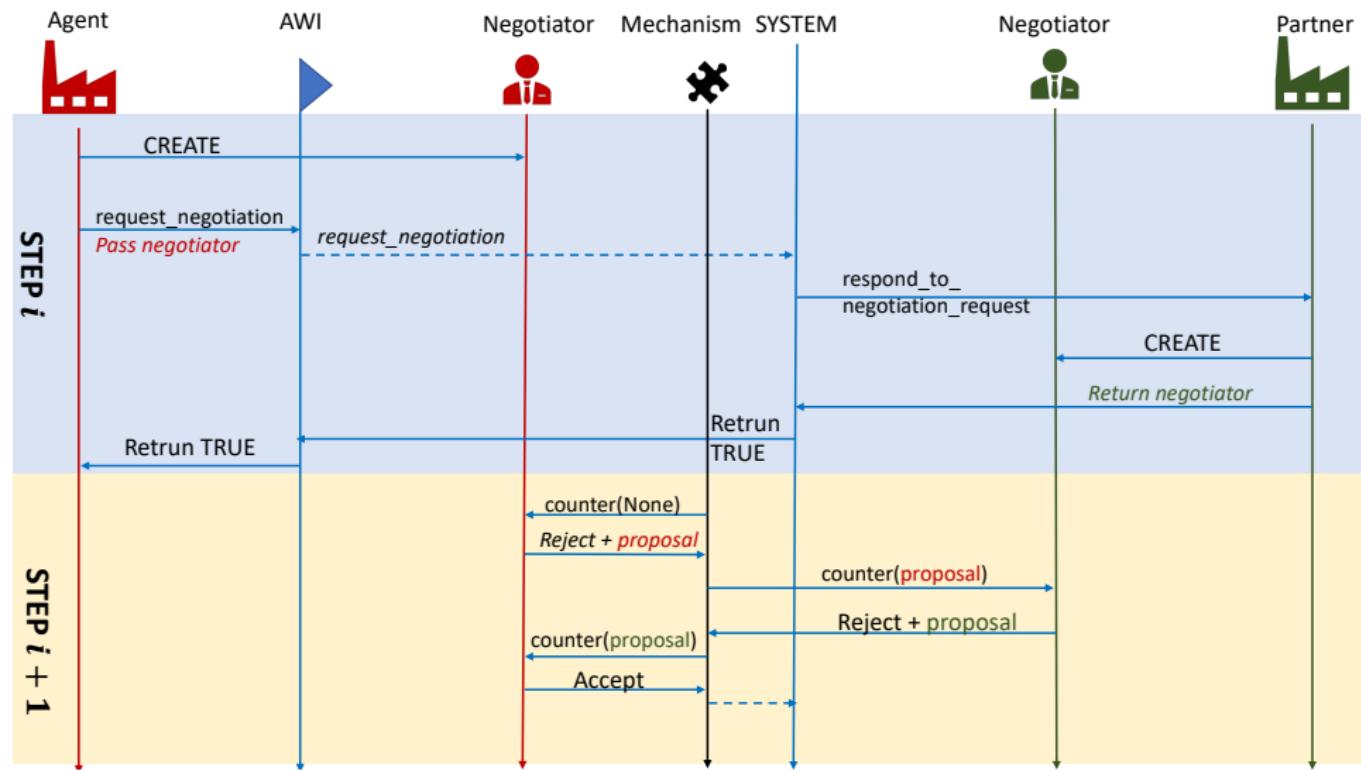
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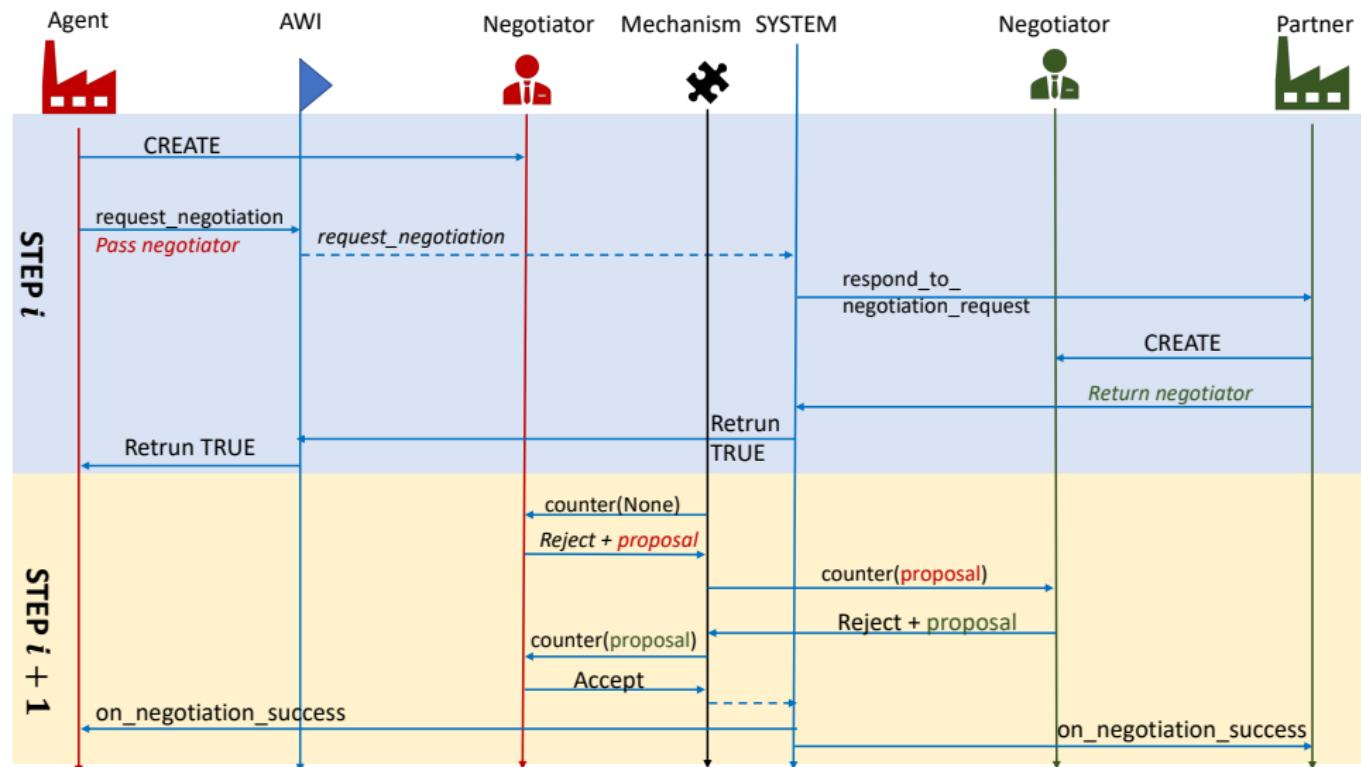
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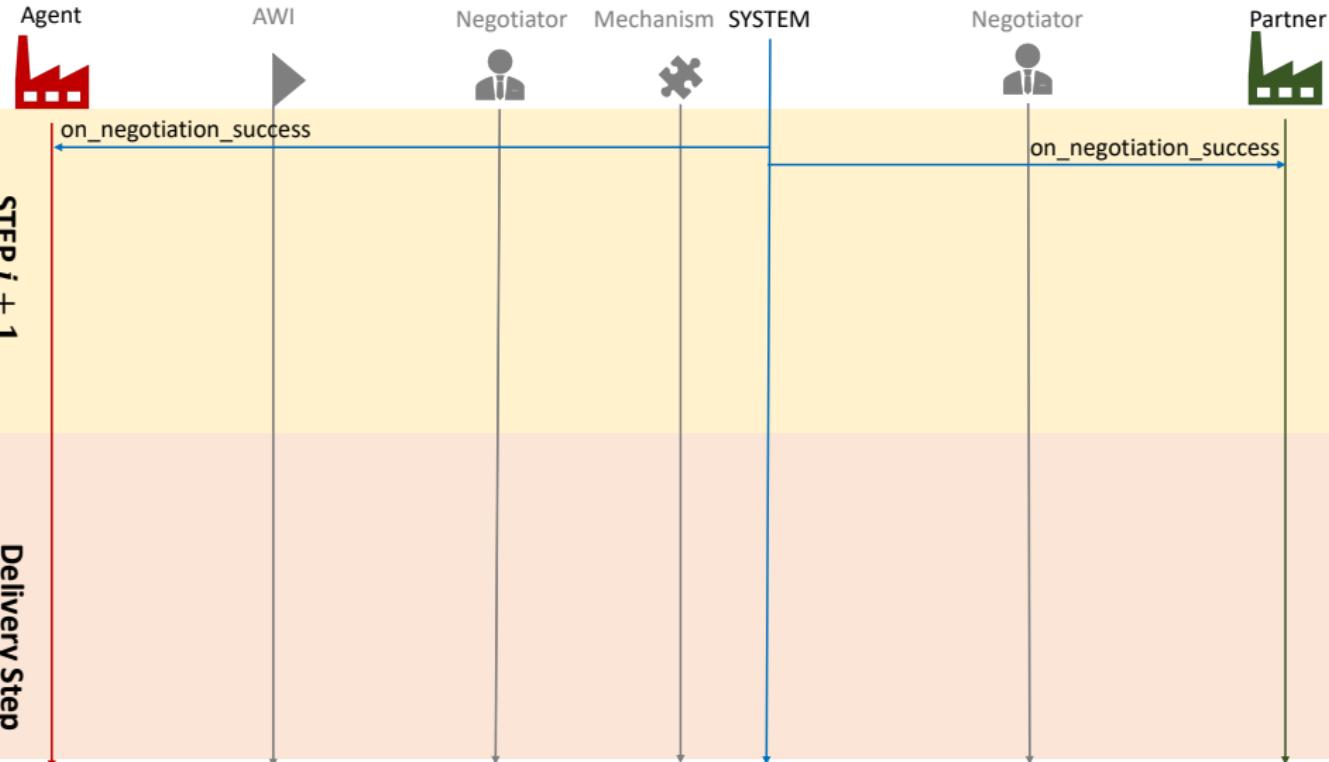
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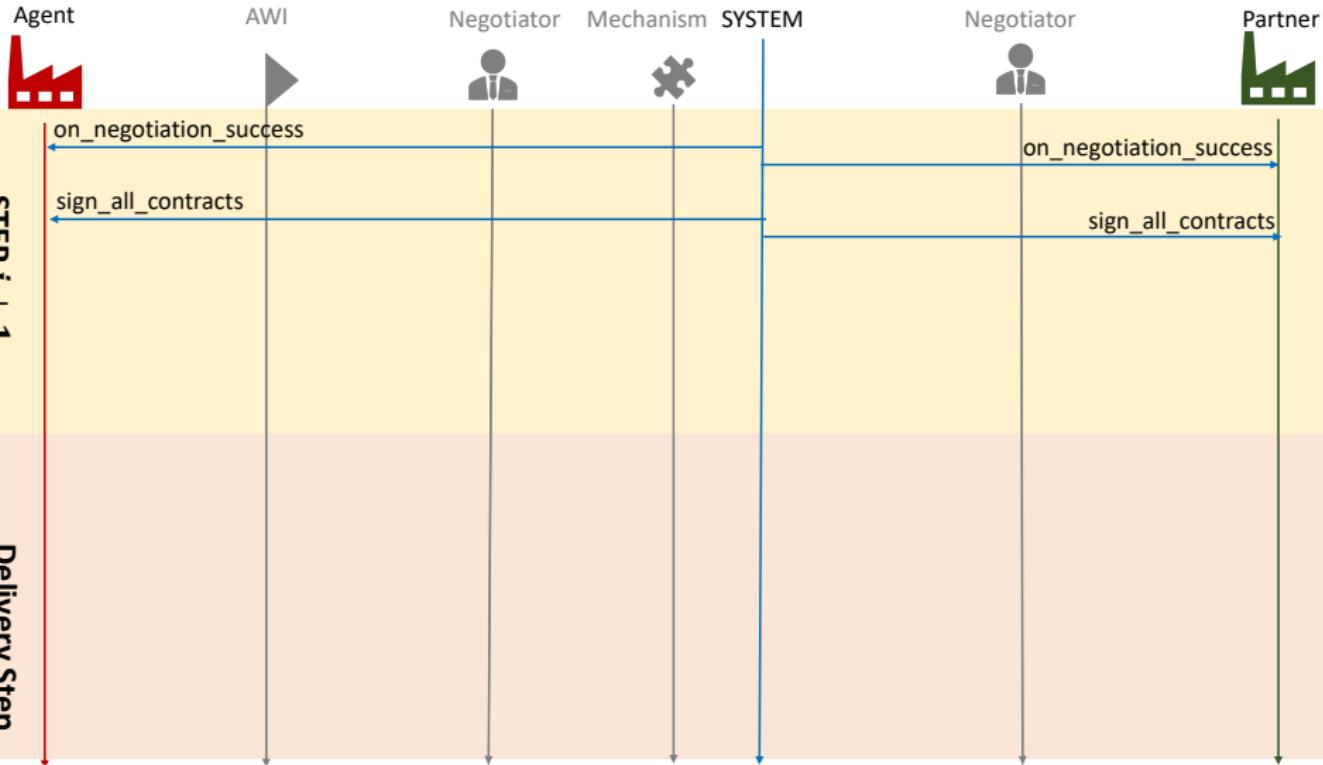
Callbacks and Timing



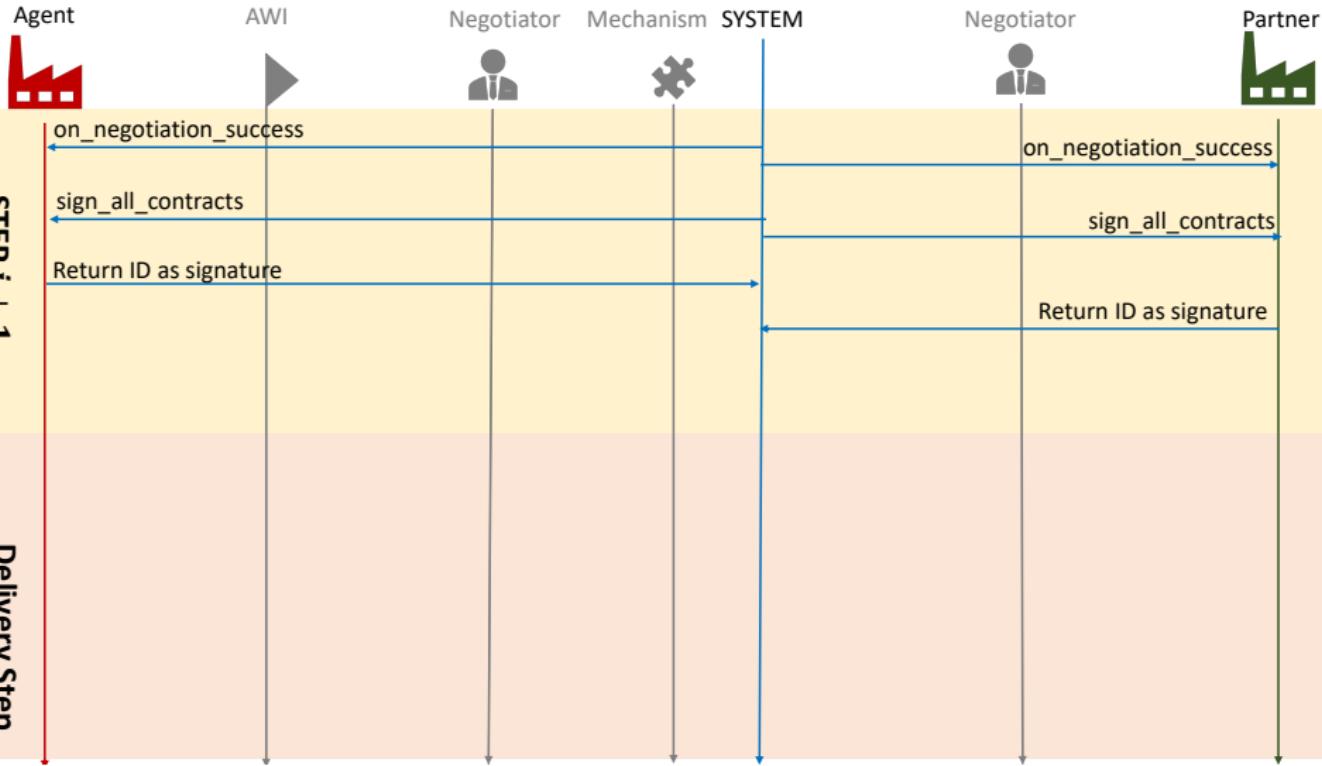
Callbacks and Timing



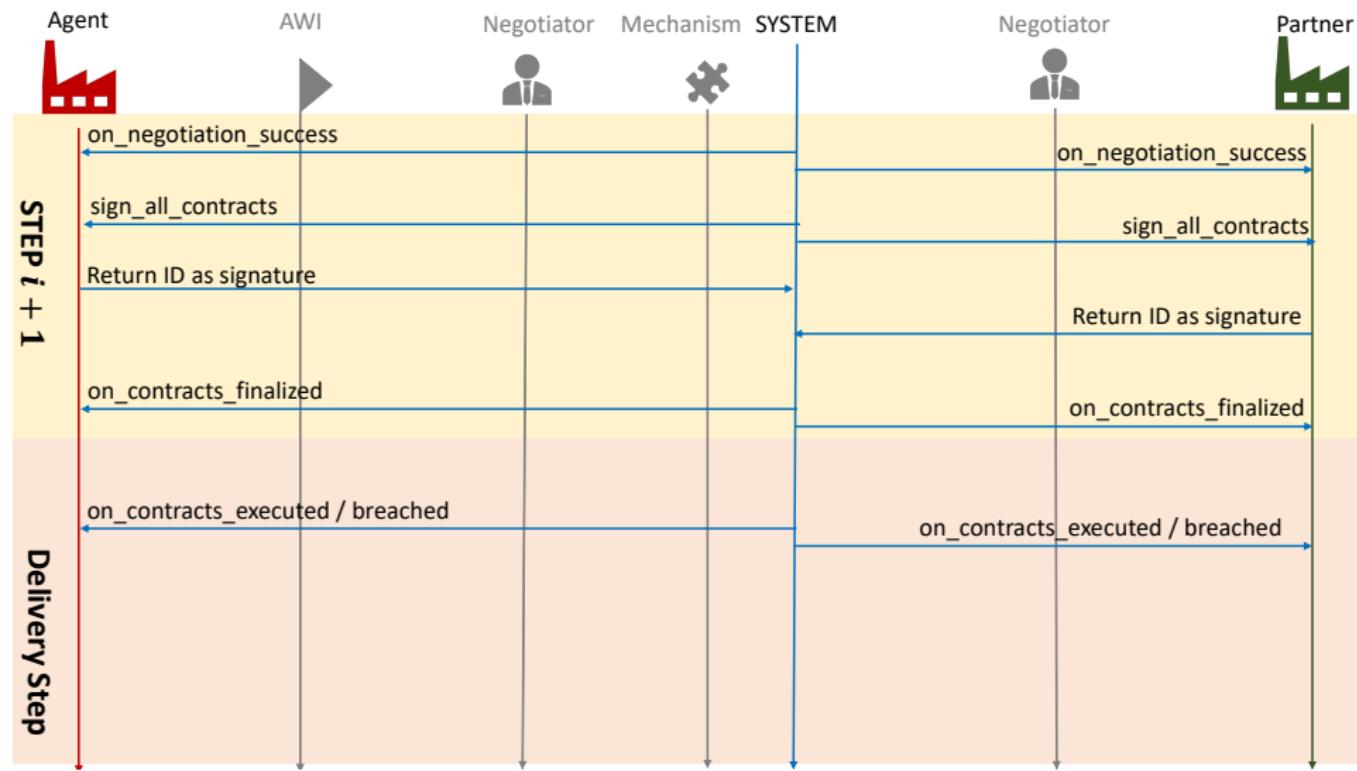
Callbacks and Timing



Callbacks and Timing



Callbacks and Timing



Callbacks and Timing

Agent



AWI

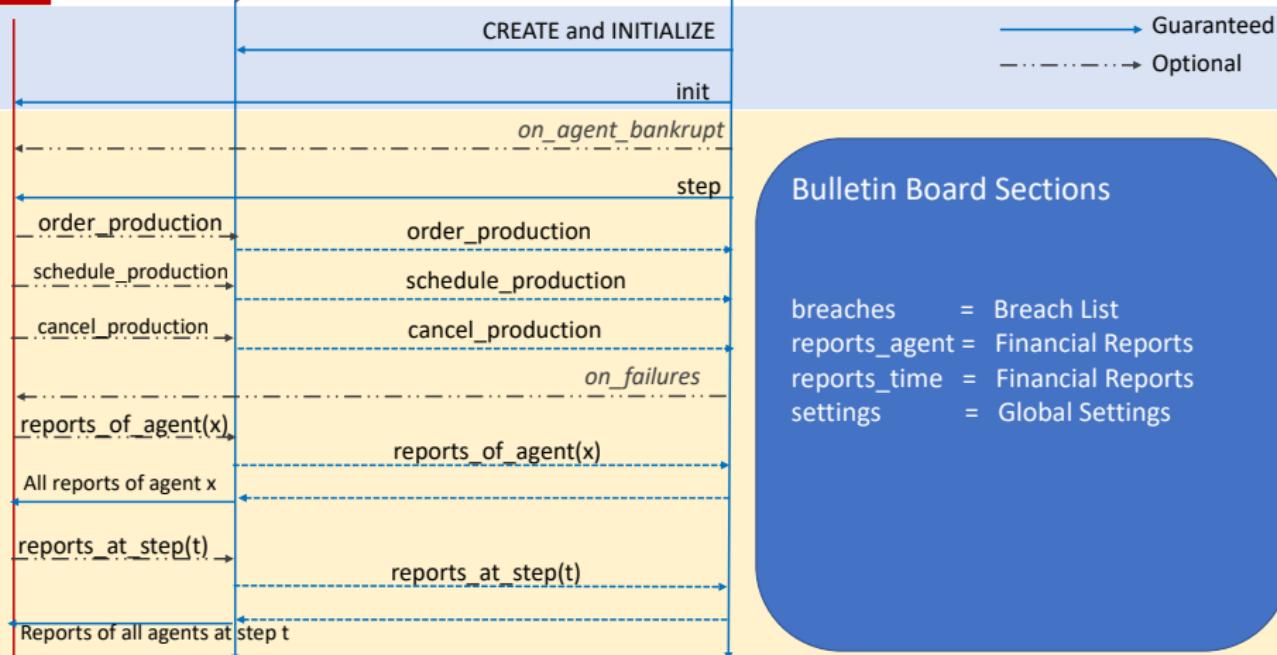


SYSTEM

STEP 0

Every Step

OTHER CALLBACKS



Bulletin Board Sections

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

Outline

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

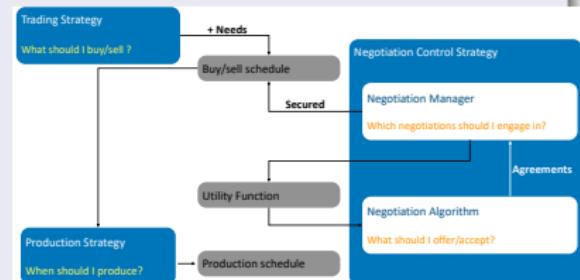
Development Approaches

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

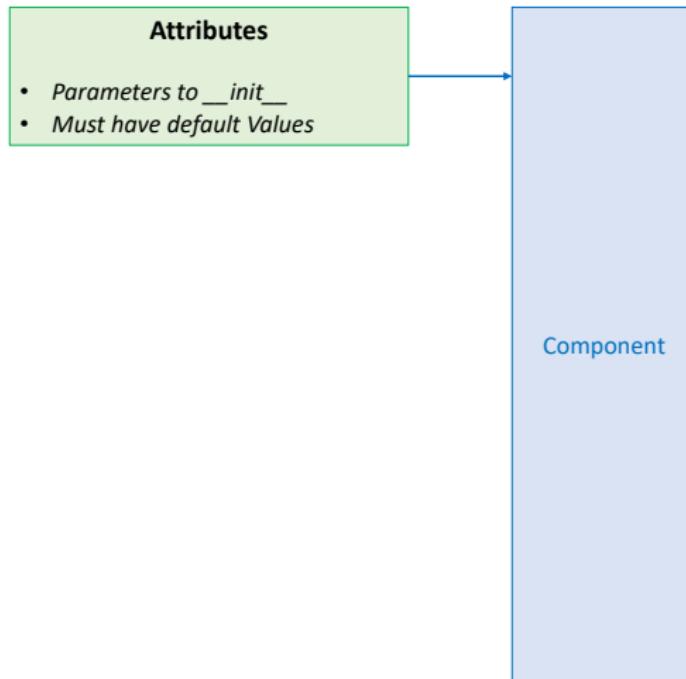
- Divides the agent into **semi-independent** components.
- Functionality is distributed between **components**.
- Easier to reuse.



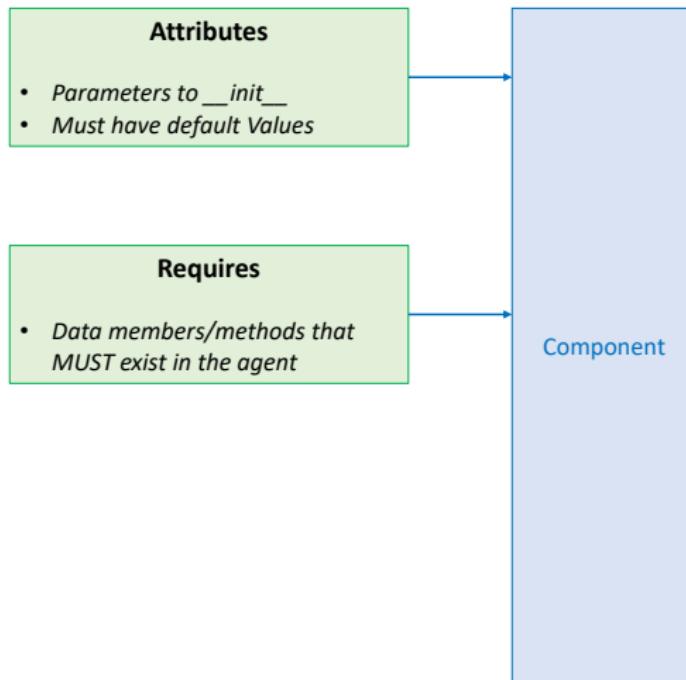
What is a component?



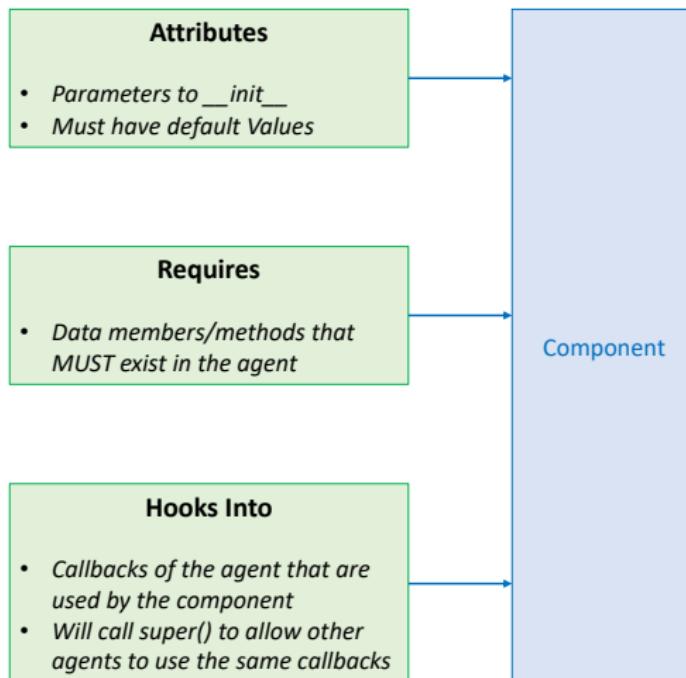
What is a component?



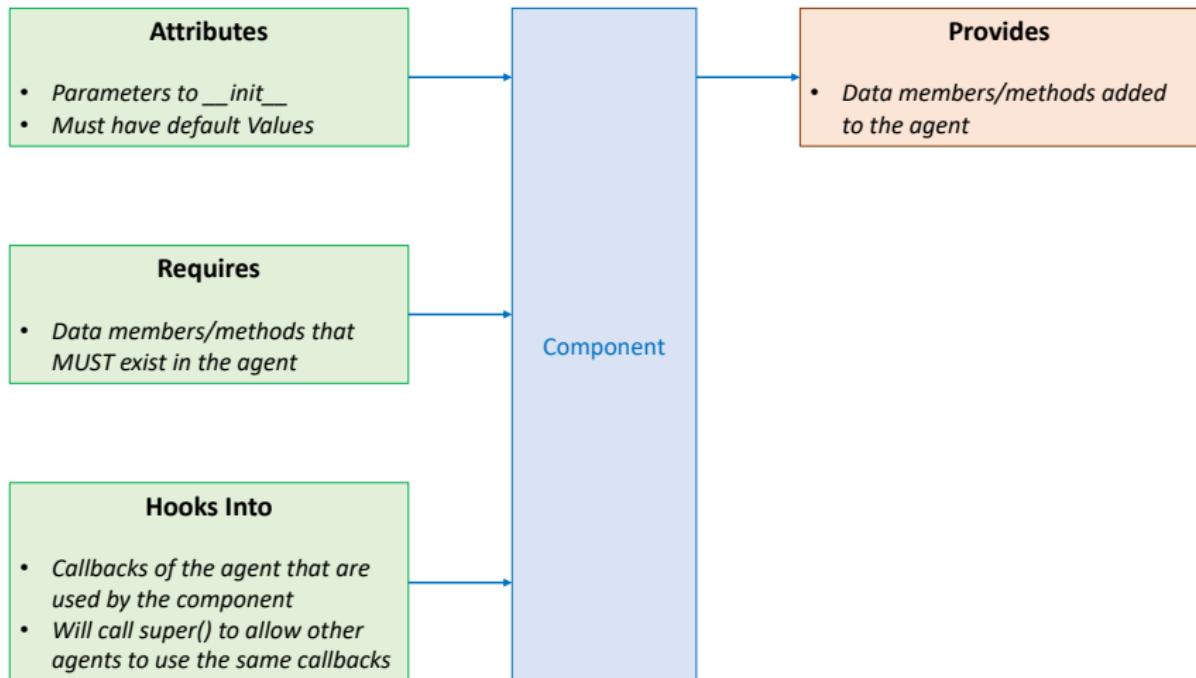
What is a component?



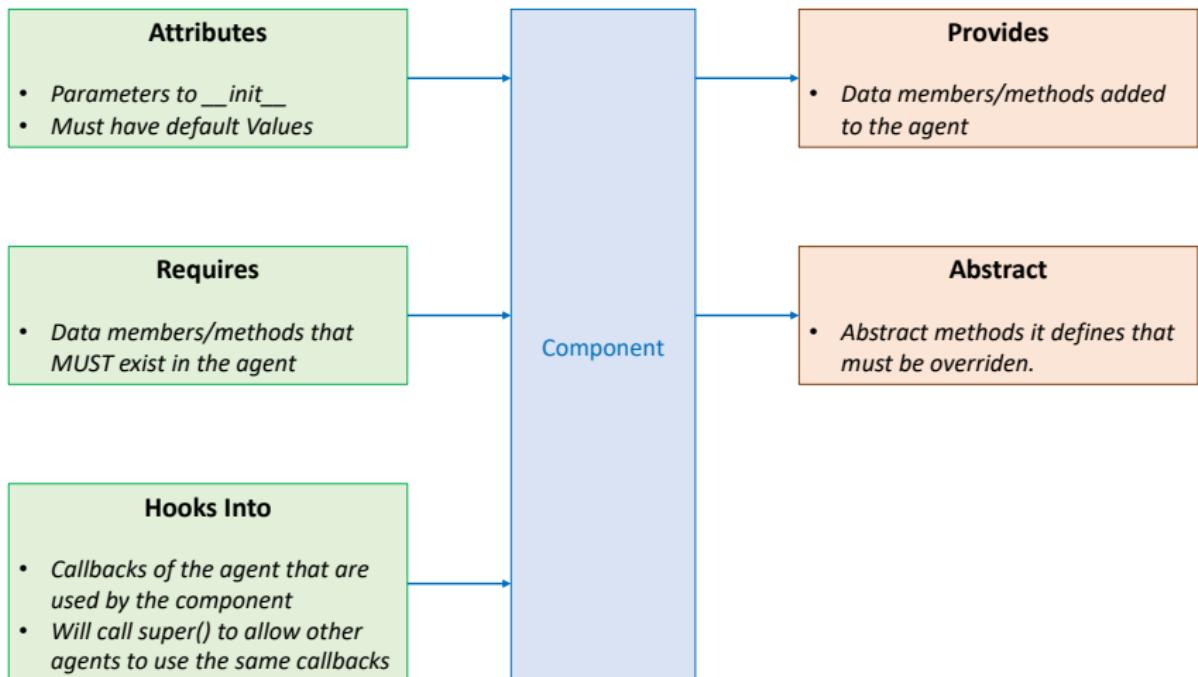
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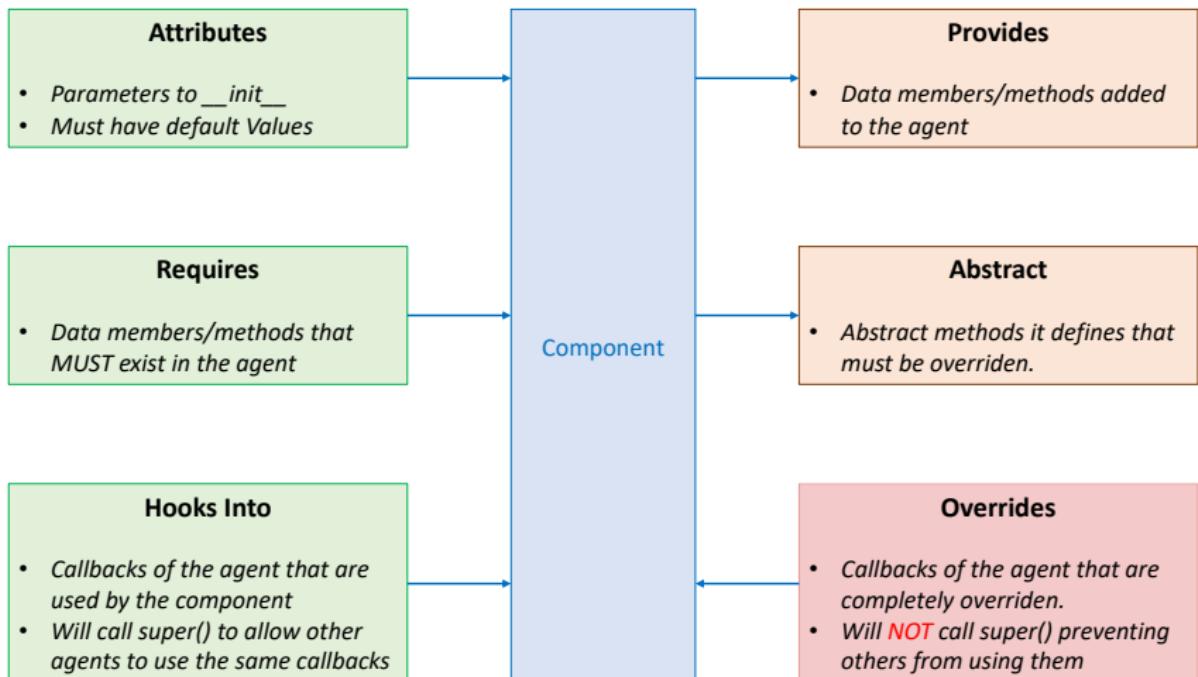
What is a component?



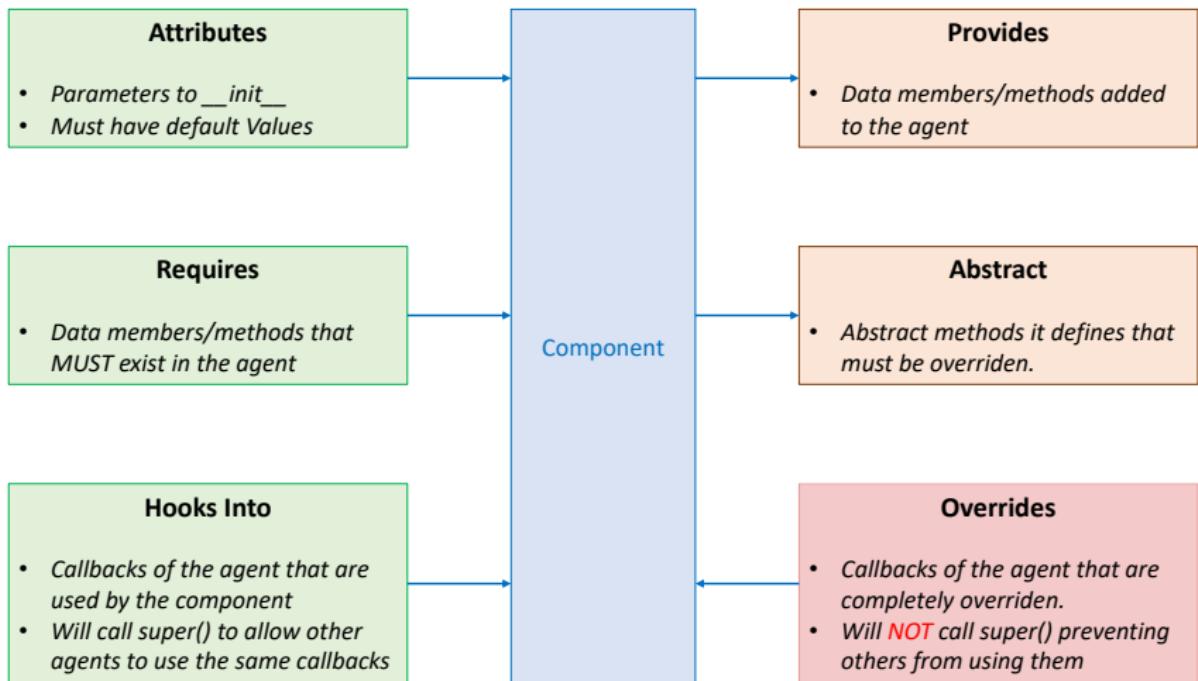
What is a component?



What is a component?

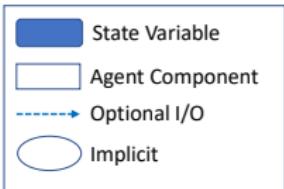


What is a component?



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

SCML Agent Components

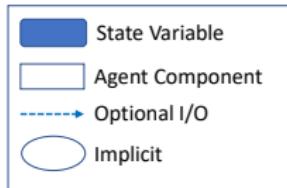


Production Strategy

Trading Strategy

Negotiation Manager

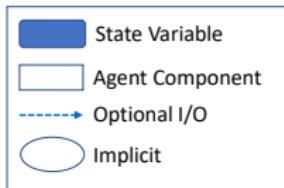
SCML Agent Components



Production Strategy



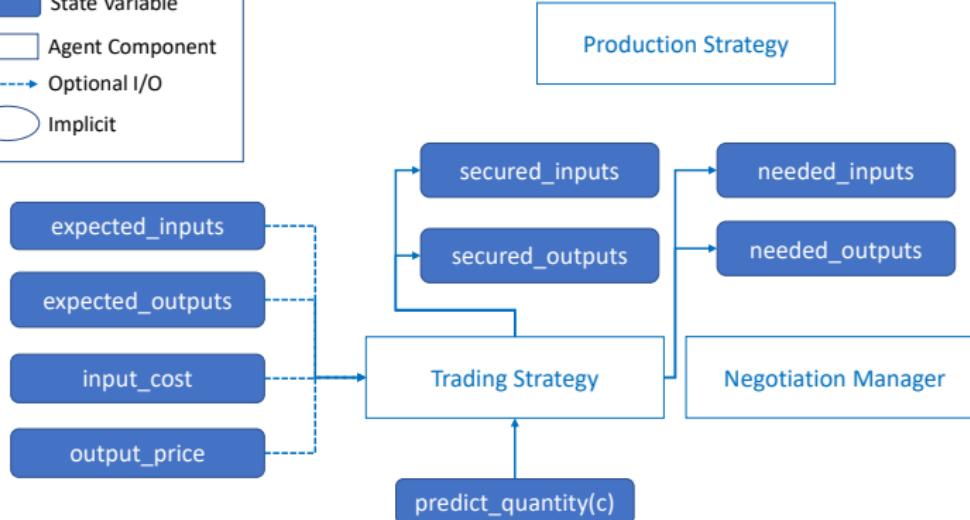
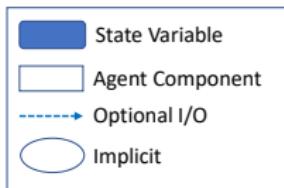
SCML Agent Components



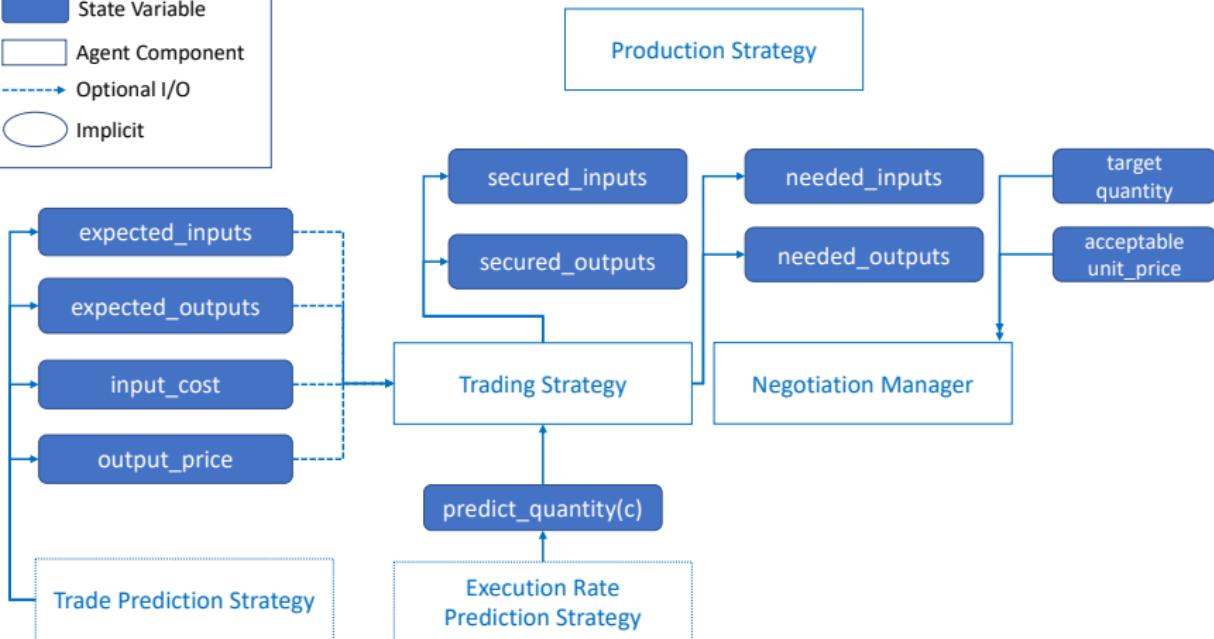
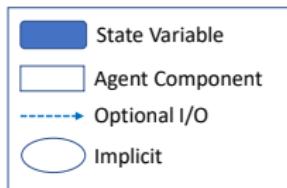
Production Strategy



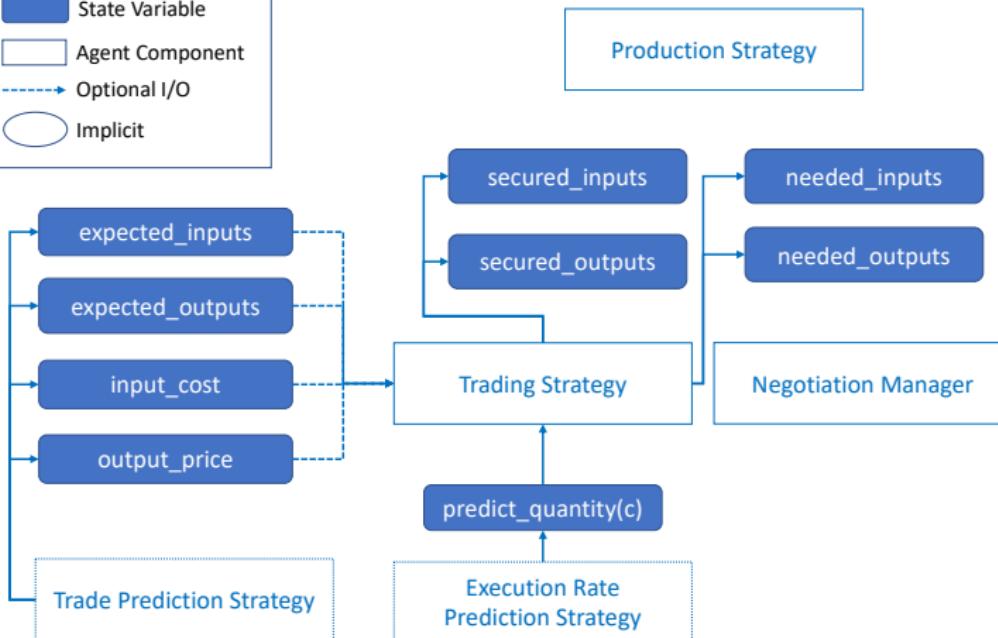
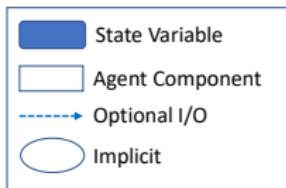
SCML Agent Components



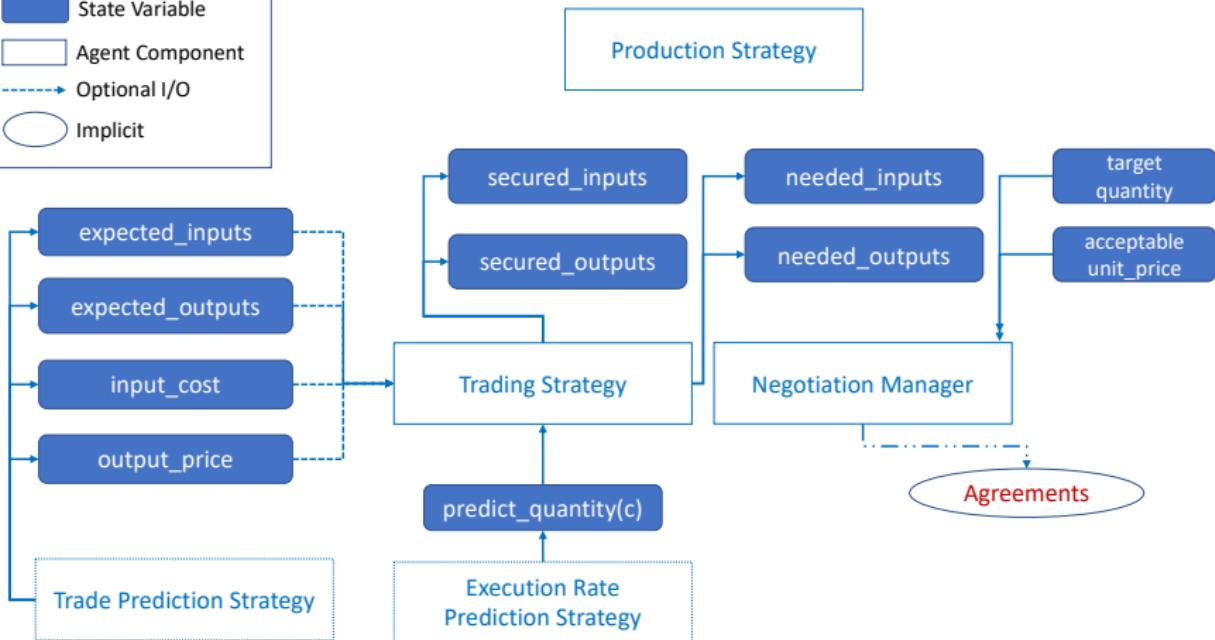
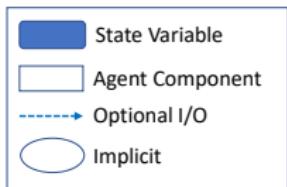
SCML Agent Components



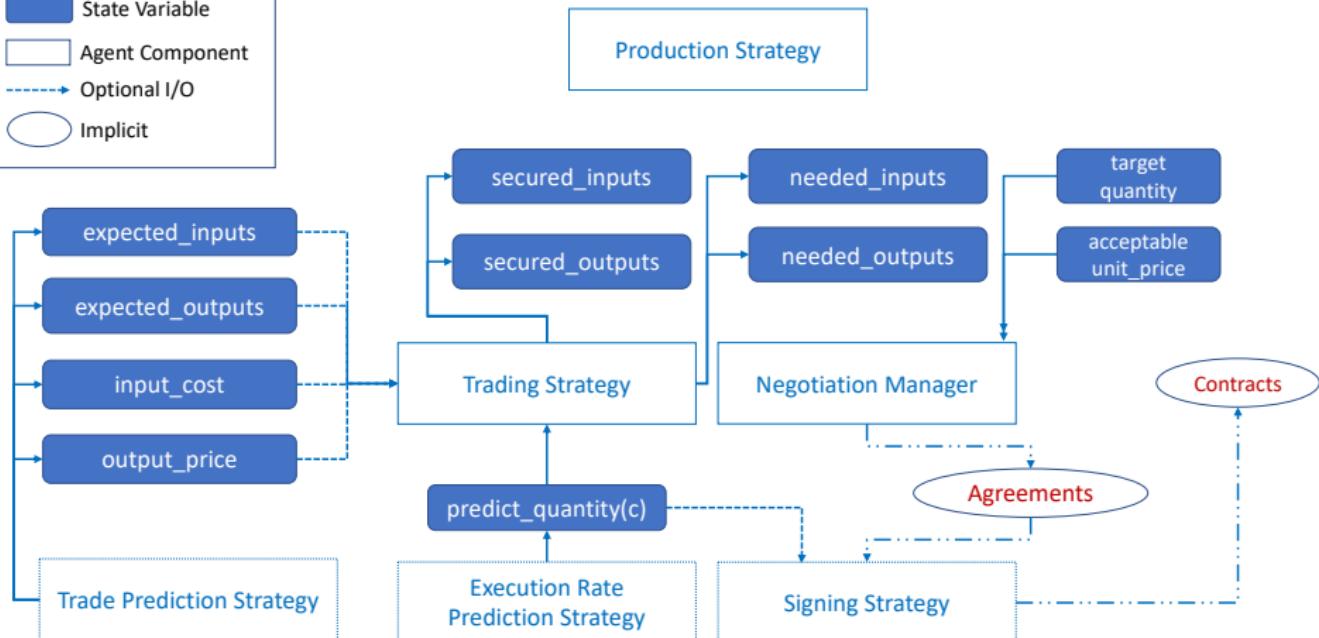
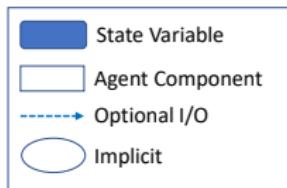
SCML Agent Components



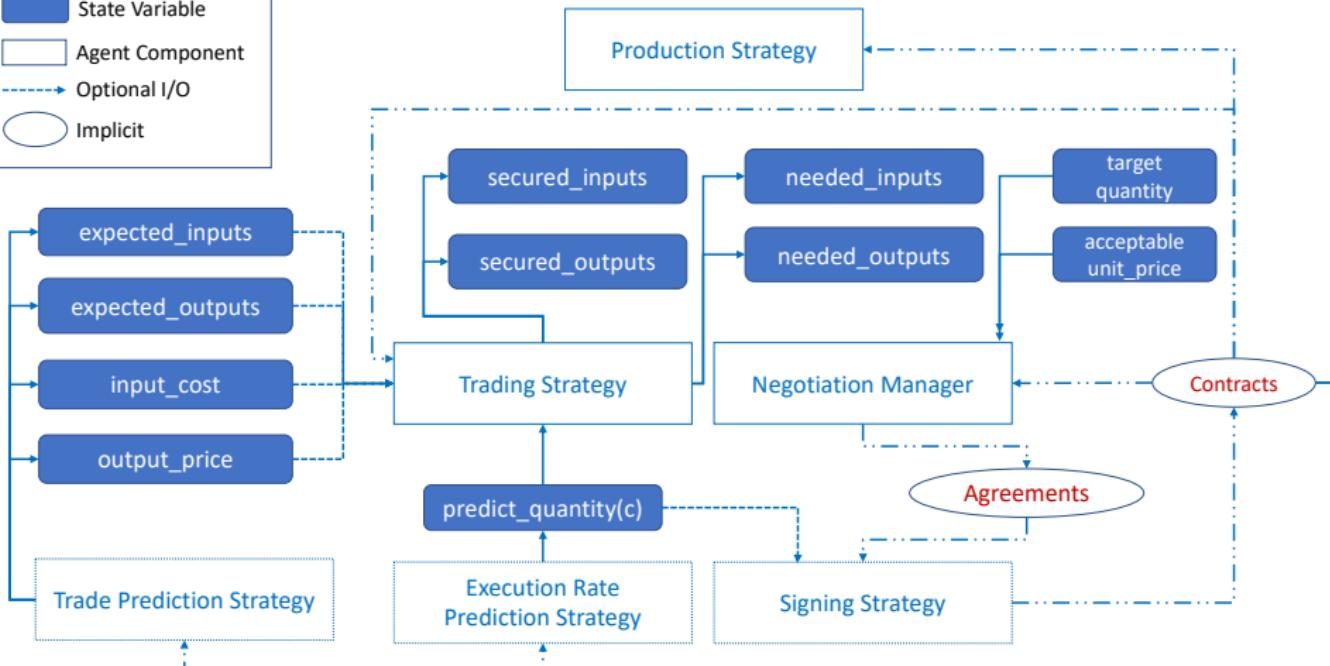
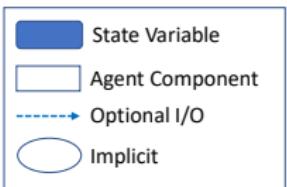
SCML Agent Components



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

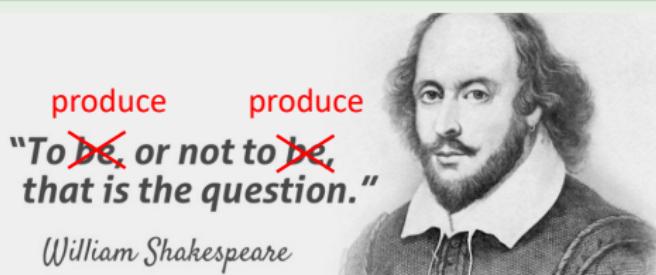
Independent Negotiations buy cheap ASAP, sell expensive ALAP.

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!

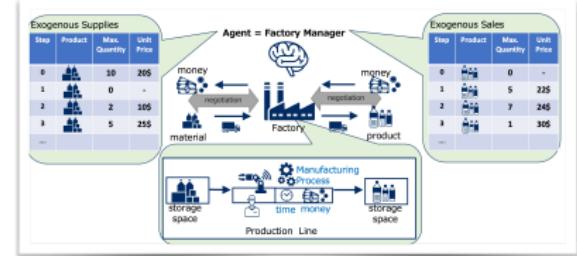
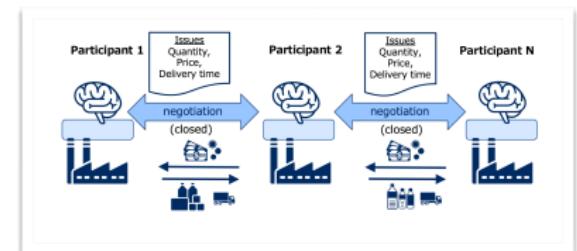
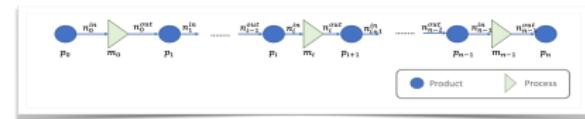
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Summary

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>

References I

- Aydoğan, R., Festen, D., Hindriks, K. V., and Jonker, C. M. (2017). Alternating offers protocols for multilateral negotiation. In *Modern Approaches to Agent-based Complex Automated Negotiation*, pages 153–167. Springer.
- Mohammad, Y., Viqueira, E. A., Ayerza, N. A., Greenwald, A., Nakadai, S., and Morinaga, S. (2019). Supply chain management world. In *International Conference on Principles and Practice of Multi-Agent Systems*, pages 153–169. Springer.
- Rubinstein, A. (1982). Perfect equilibrium in a bargaining model. *Econometrica: Journal of the Econometric Society*, pages 97–109.