ON THE EXTERNAL CONCURRENCY OF CURRENT BDI FRAMEWORKS FOR MAS

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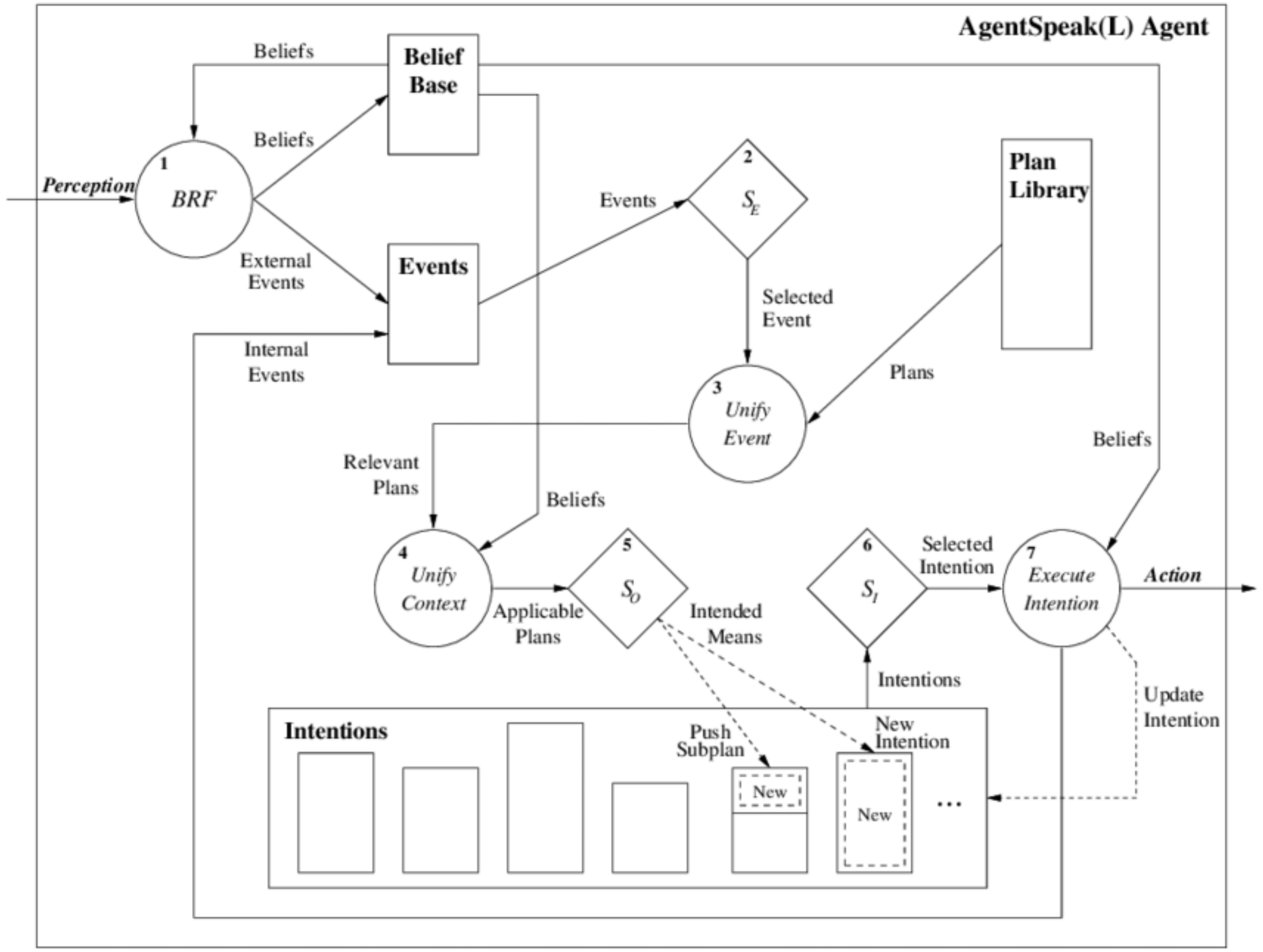
CONTEXT

BDI AGENTS PROGRAMMING

- most famous semantics: AgentSpeak(L)
- most famous architecture (see picture)
- several implementations
  - focus on: Astra, GOAL, Jadex, JaKtA, Jason, PHIDIAS, SPADE-BDI



MOTIVATION

Insight: *the same architecture may be implemented in so many ways* (e.g., w.r.t. **concurrency**)

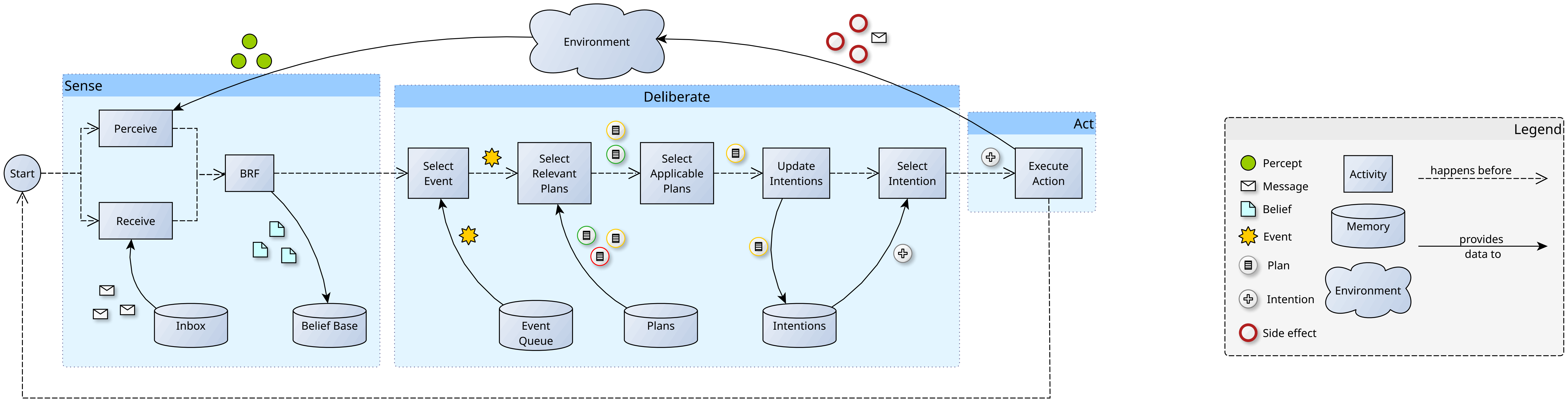
- semantics *unaffected*
- impact on practical properties such as efficiency & reproducibility

GOALS

1. Devise concurrency patterns from the state-of-the-practice
2. Classify BDI technologies accordingly

BACKGROUND

- Agents lifecycle, in general, is a control-loop
    - sense, *then* deliberate, *then* act, repeat
- BDI agents are more *complex*
    - e.g. sense implies collecting percepts, revising beliefs, etc.
    - e.g. deliberate implies selecting plans, updating intentions, etc.



WHICH CONCURRENCY?

We distinguish between internal and external concurrency

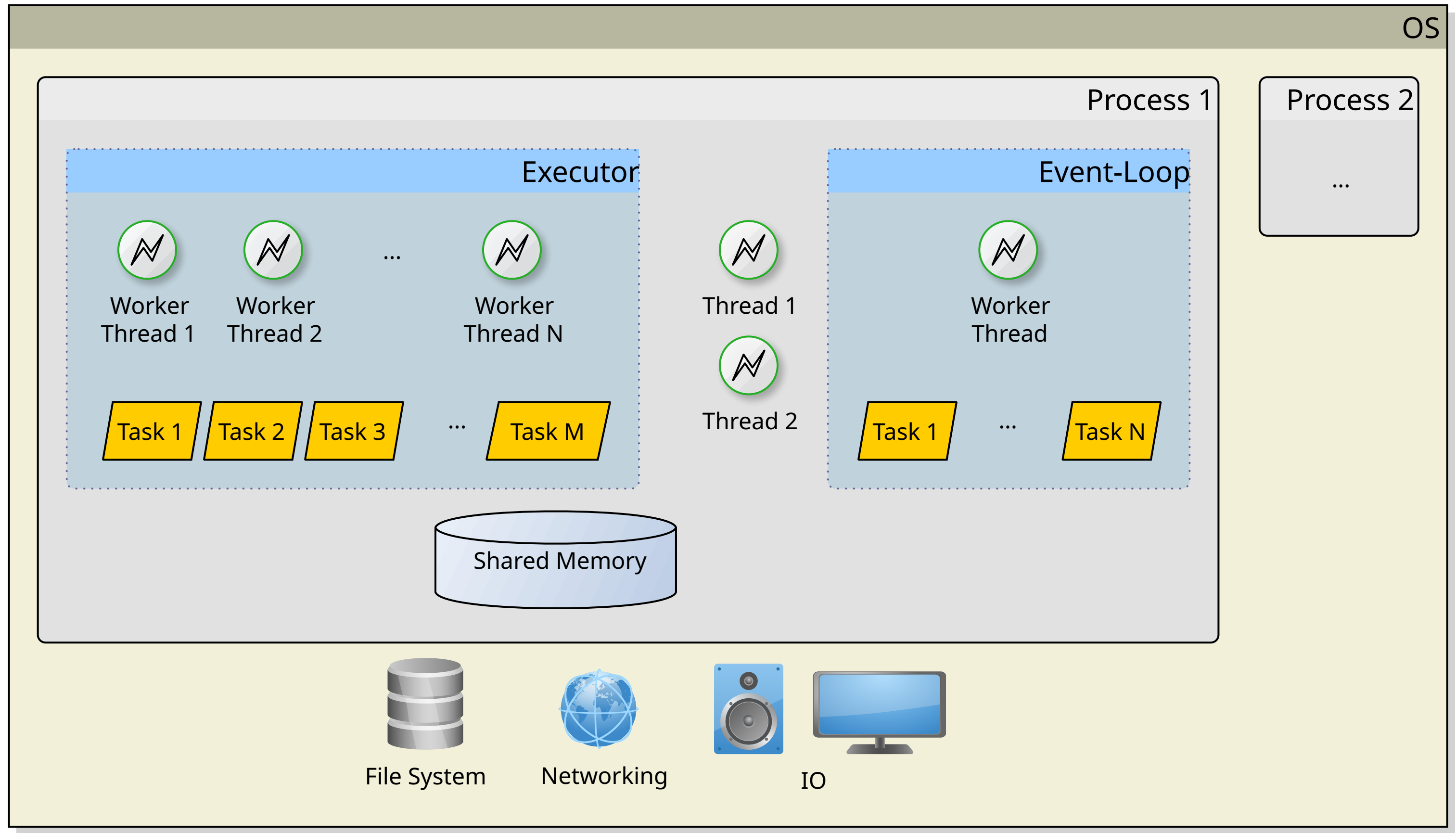
Internal concurrency ≈ how agents schedule intentions internally

External concurrency ≈ how agents' control-loops are scheduled by the underlying platform

WHICH CONCURRENCY ABSTRACTIONS?

IN PRACTICE, TECHNOLOGICAL PLATFORMS SUPPORT:

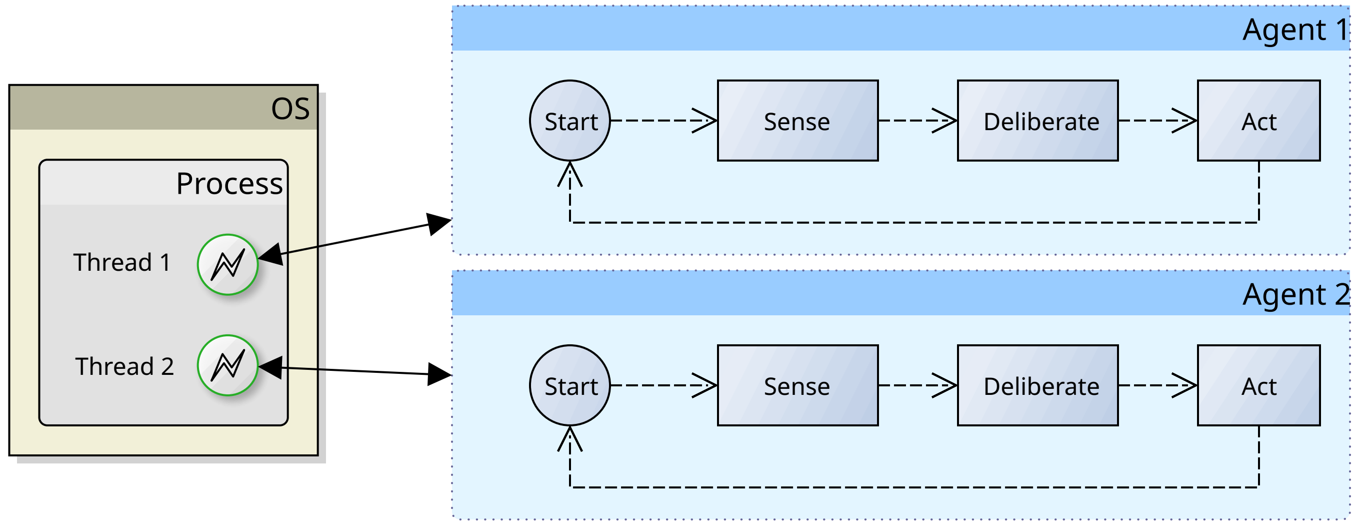
- Processes
- Threads
- Event Loops
- Executors



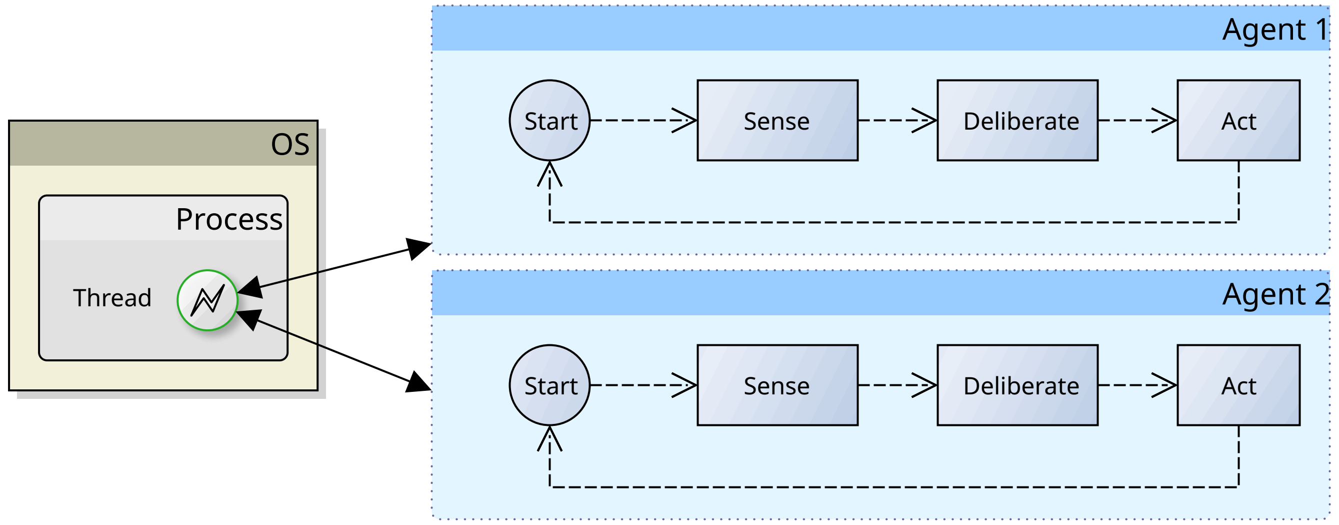
COMMON CONCURRENCY PATTERNS FOR MAS

- One-Agent-One-Thread (`1A1T`)
- All-Agents-One-Thread (`AA1T`)
- All-Agents-One-Event-Loop (`AA1EL`)
- All-Agents-One-Executor (`AA1E`)
    - With a fixed-size thread pool
    - With a variable-size thread pool

ONE-AGENT-ONE-THREAD (1A1T)

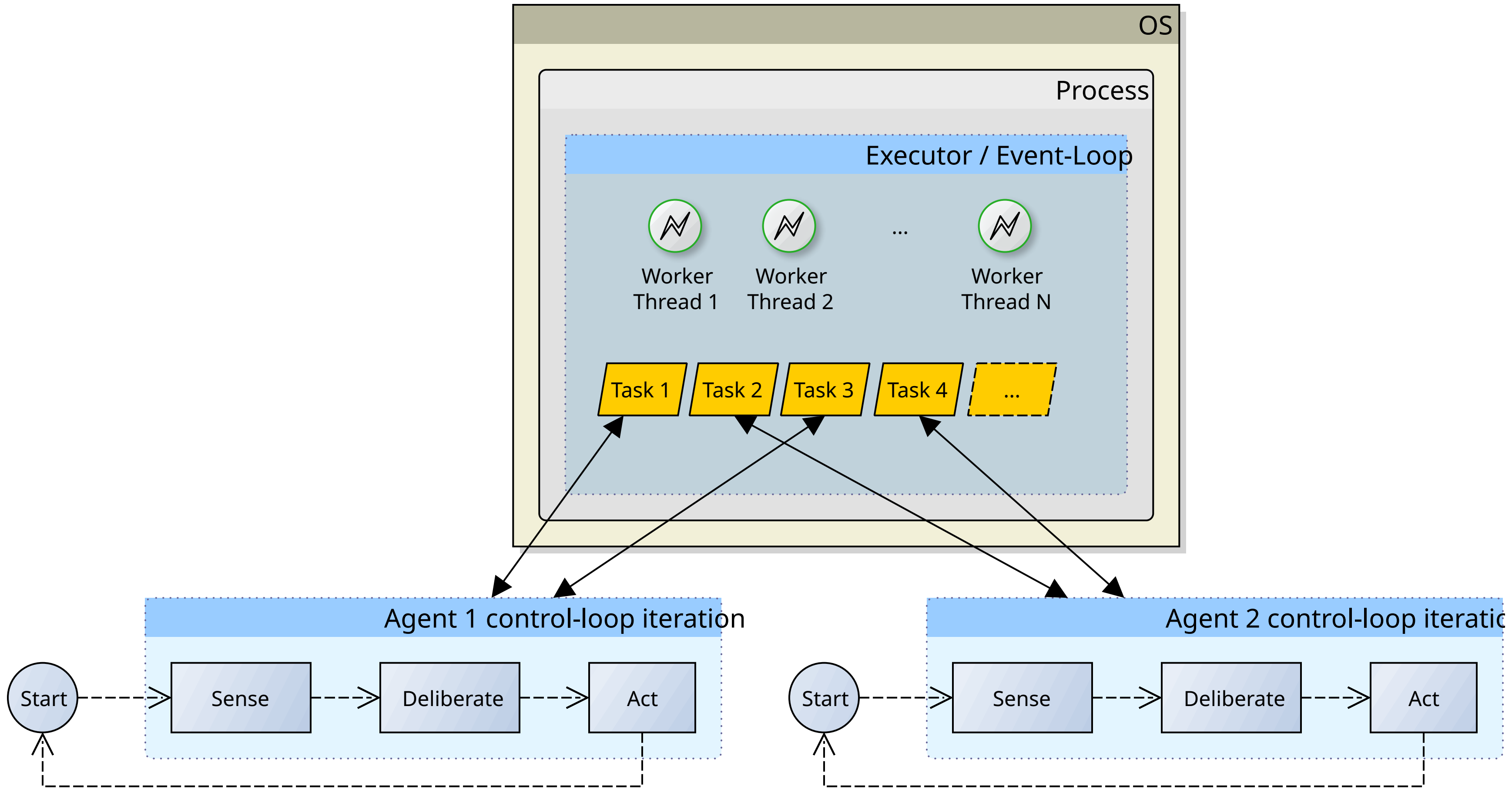


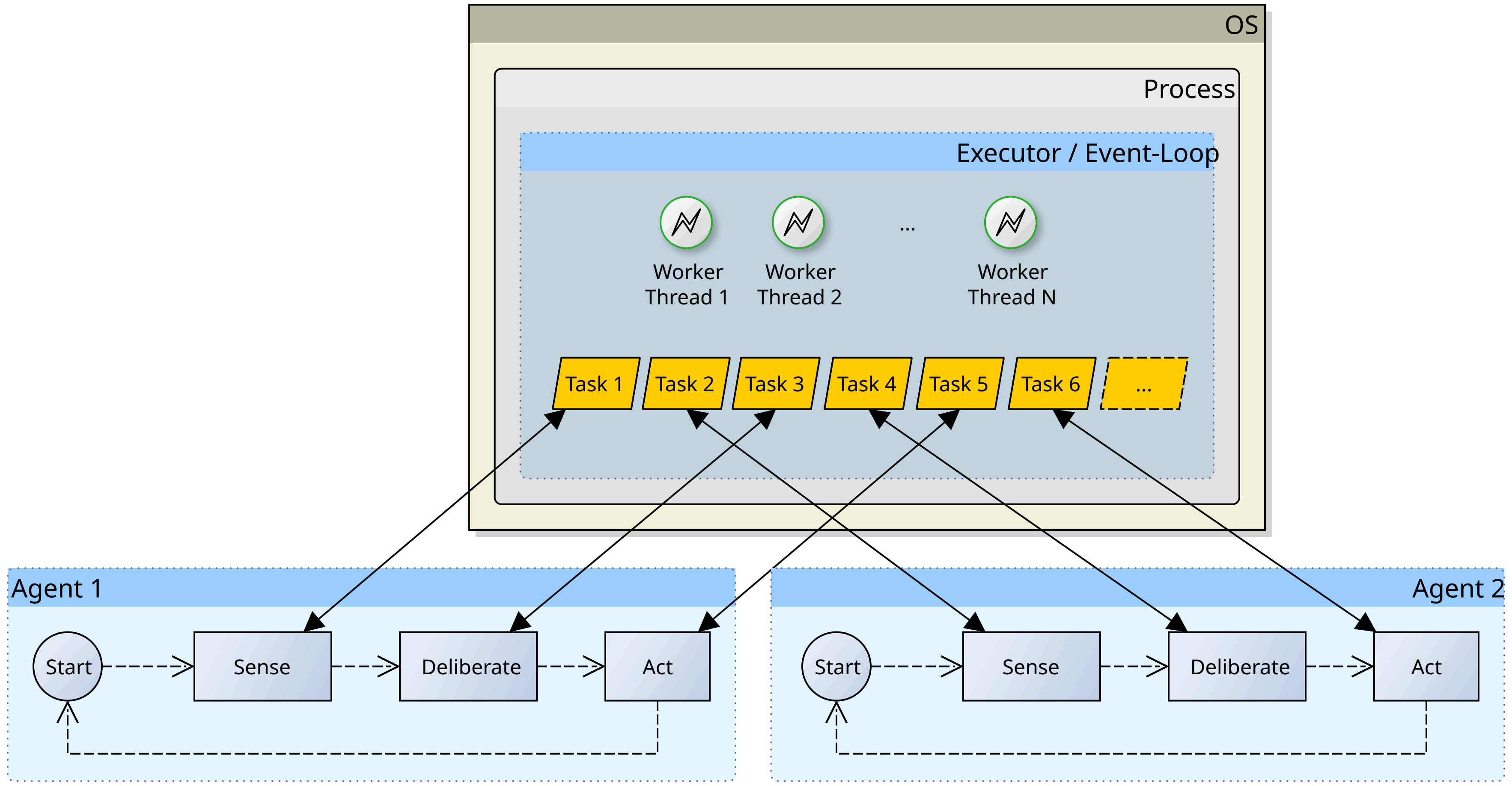
ALL-AGENTS-ONE-THREAD (AA1T)



ALL-AGENTS-ONE-EXECUTOR (AA1E)

Allows for various level of granularity:

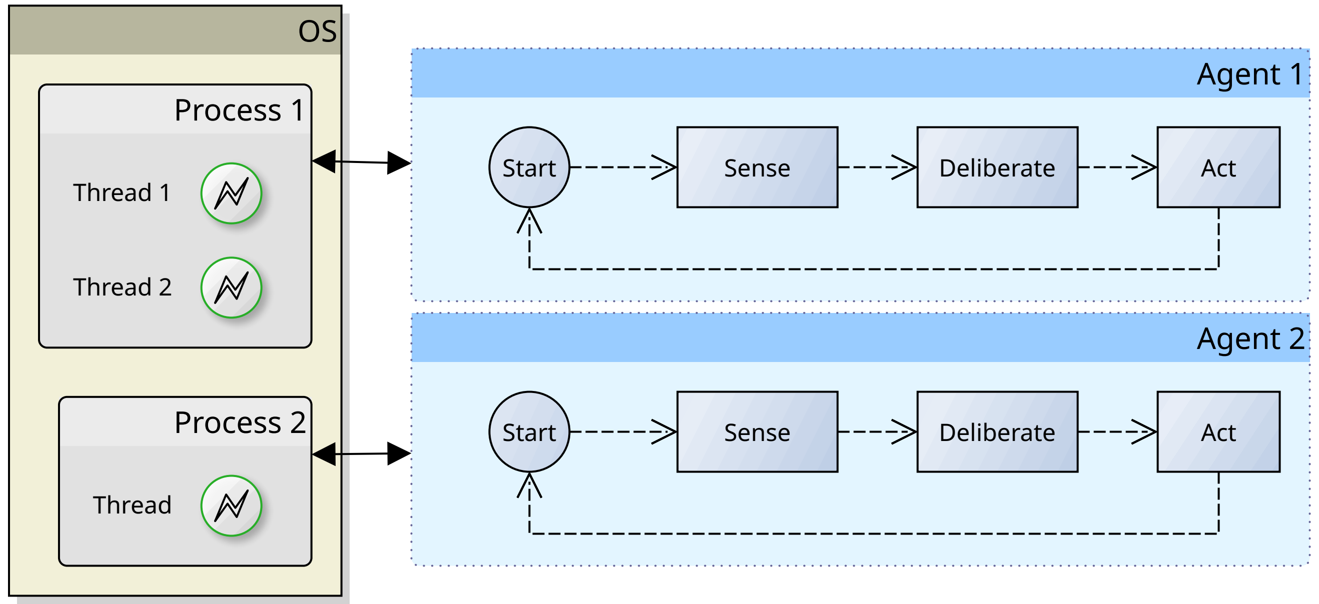




Different properties w.r.t. **fixed** or **variable** amount of worker threads (N)

All-Agents-One-Event-Loop (**AA1EL**) $\equiv$ AA1E with *just one thread*

ONE-AGENT-ONE-PROCESS(1A1P)



WHICH CONCURRENCY ABSTRACTION IS THE MOST APPROPRIATE?

- The selection of an appropriate concurrency model deeply impacts several aspects of the agent programming framework
  - The efficiency of the MAS may improve, but
  - predictability and reproducibility may be affected.
- Capturing and controlling concurrency is crucial,
  and they often are hidden under the framework abstractions

ANALYSIS ON BDI FRAMEWORKS:

METHODOLOGY

We inspected external concurrency in three steps:

1. Empirical Evaluation through a synthetic benchmark
2. Documentation and source code inspection of the selected BDI frameworks
3. Direct contact with maintainers

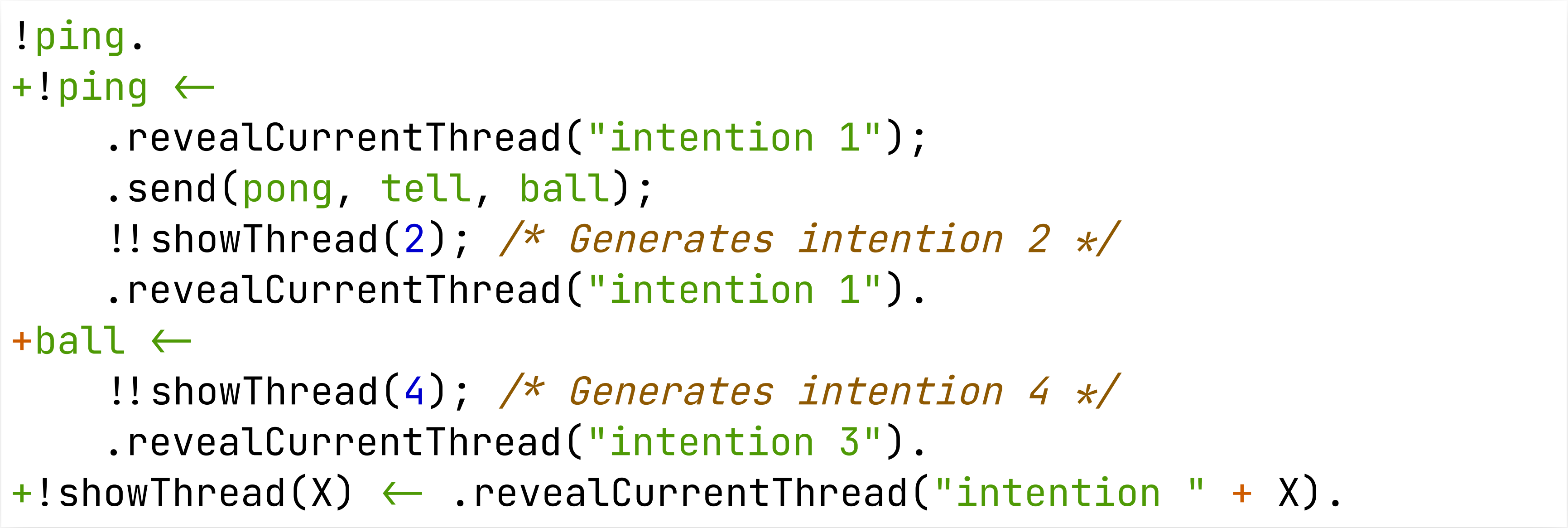
FRAMEWORK SELECTION

We selected actively-maintained and open source BDI programming frameworks:

- Astra
- GOAL
- Jadex
- JaKtA
- Jason
- PHIDIAS
- SPADE-BDI

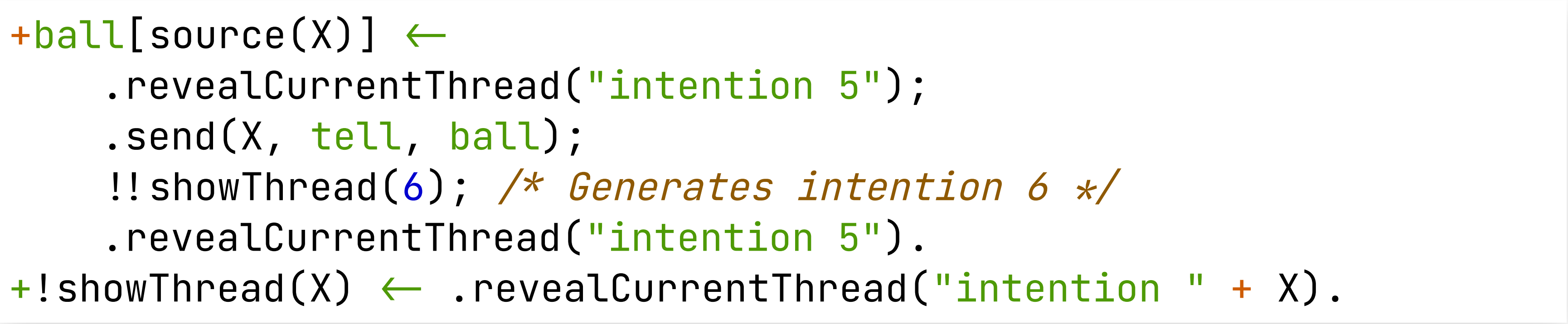
BENCHMARK

AGENT: PINGER



```
!ping.
+!ping ←
    .revealCurrentThread("intention 1");
    .send(pong, tell, ball);
    !!showThread(2); /* Generates intention 2 */
    .revealCurrentThread("intention 1").
+ball ←
    !!showThread(4); /* Generates intention 4 */
    .revealCurrentThread("intention 3").
+!showThread(X) ← .revealCurrentThread("intention " + X).
```

AGENT: PONGER



```
+ball[source(X)] ←
    .revealCurrentThread("intention 5");
    .send(X, tell, ball);
    !!showThread(6); /* Generates intention 6 */
    .revealCurrentThread("intention 5").
+!showThread(X) ← .revealCurrentThread("intention " + X).
```

RESULTS

Model ⇒ Tech. ⇓	1A1T	AA1T	AA1EL	AA1E fixed	AA1E variable	1A1P
Astra	✓	✓	✔	✔	✔	✓
Goal	✔	✘	✘	✘	✘	✘
Jadex	✓	✔	✓	✓	✔	✔
JaKtA	✔	✔	✔	✔	✔	✓
Jason	✔	✓	✔	✔	✓	✔
Phidias	✔	✘	✘	✘	✘	✔
Spade-BDI	✘	✘	✔	✘	✘	✔

LEGEND

- ✔ ≡ supported
- ✘ ≡ not supported
- ✓ ≡ supported in principle, but requires the user to implement it

DISCUSSION

Takeaway 1: better for a BDI framework to support *multiple* concurrency patterns

Takeaway 2: even better for a BDI framework to support concurrency patterns *customisability* on the **user-side**

- supporting e.g. comparing perfomance among different concurrency patterns, for the same MAS
- supporting e.g. *prioritising* determinism over efficiency (AA1T) for testing
- supporting e.g. *prioritising* indipendence of control flows (1A1T) for I/O-bound tasks

CONCLUSIONS

It is necessary to separate BDI architecture from its actual execution

- without impacting the architecture definition
- without necessarily knowing how to program concurrency abstractions
- choosing dynamically which concurrent execution suits the scenario