MOP Framework For Actor Systems

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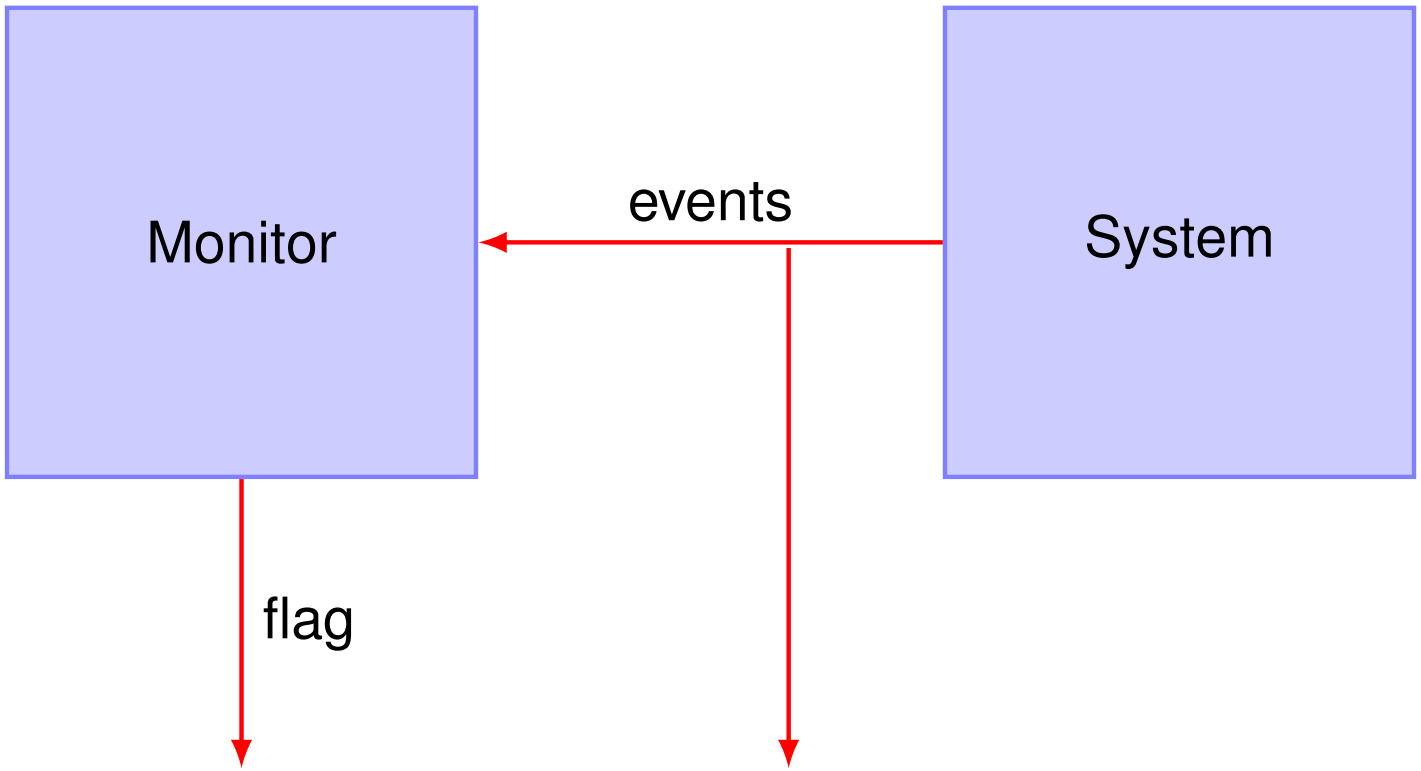
Monitor Oriented Programming (MOP)

- Incremetal (layered) architecture.
- Separation of concerns.
- Software customisation.
- Augmenting functionality.

MOP: Verification, Adaptation and Enforcement



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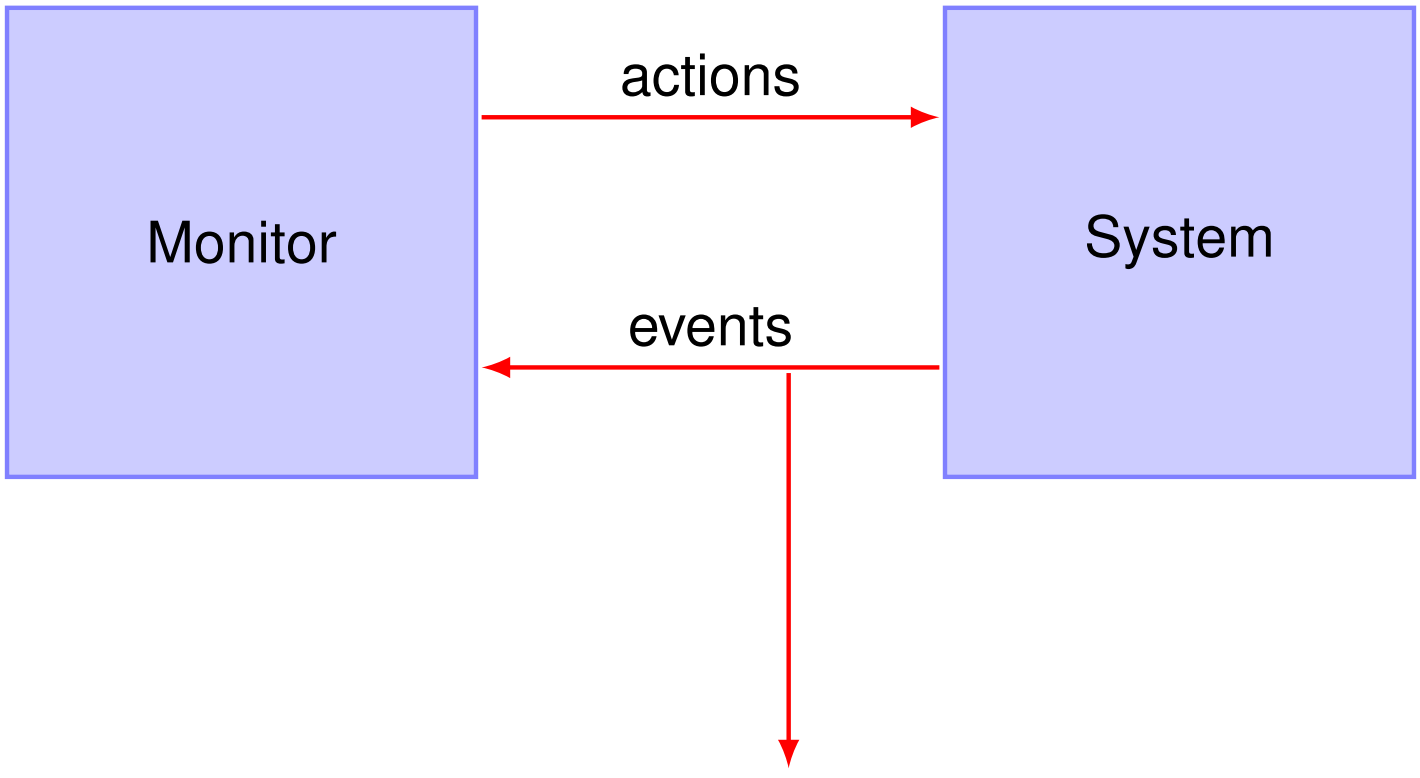

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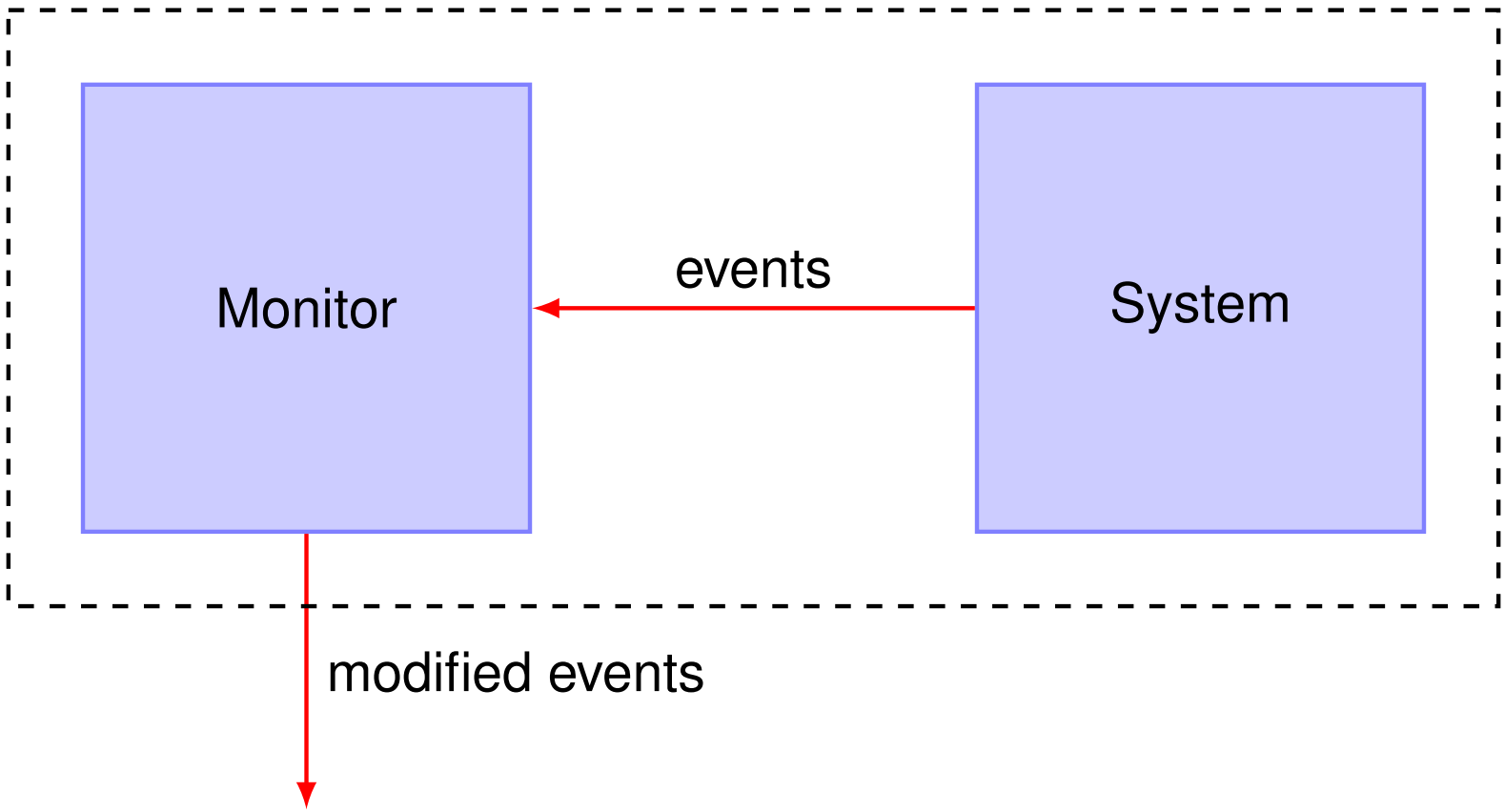
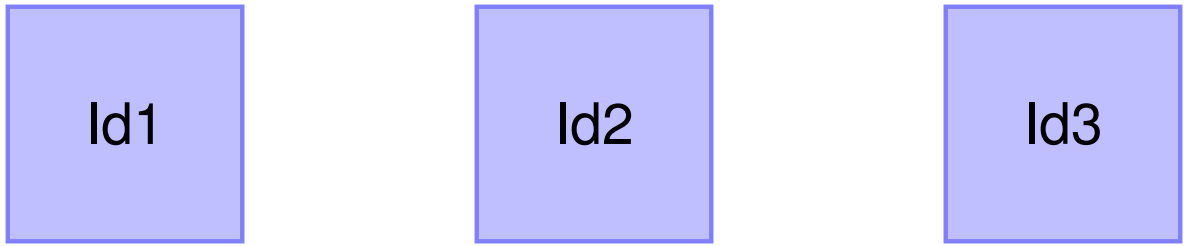
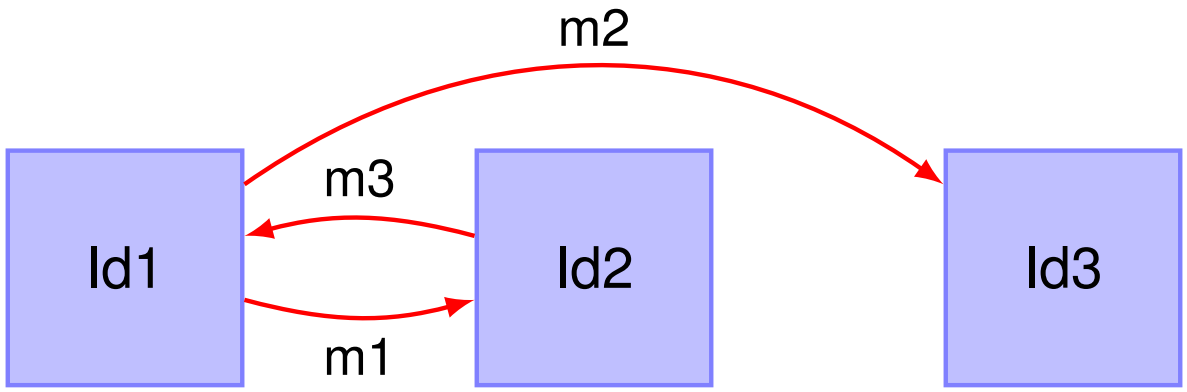


Actor Systems



Components

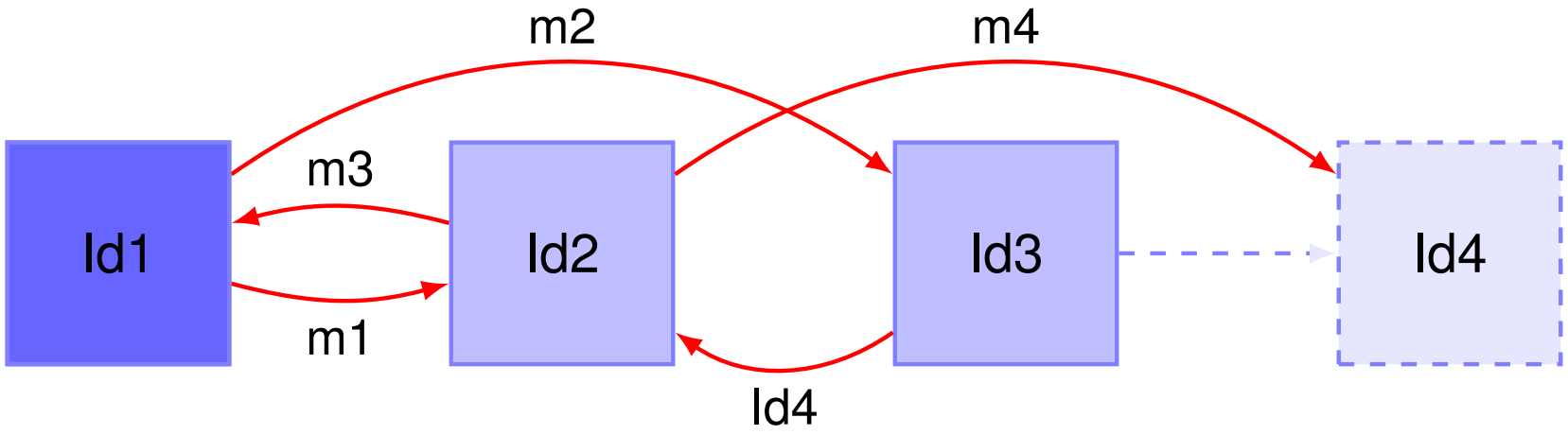
Actor Systems



Asynchronous Components

- Each component executes independently
- No shared data and non-blocking message passing.

Actor Systems



Asynchronous Dynamic Components

- Each component executes independently
- No shared data and non-blocking message passing.
- Spawn new processes
- Terminate independently

Technologies and Characteristics

Actor Languages/Frameworks

- Erlang
- Akka for Scala and Java
- Salsa (JVM)
- Stage (Python)

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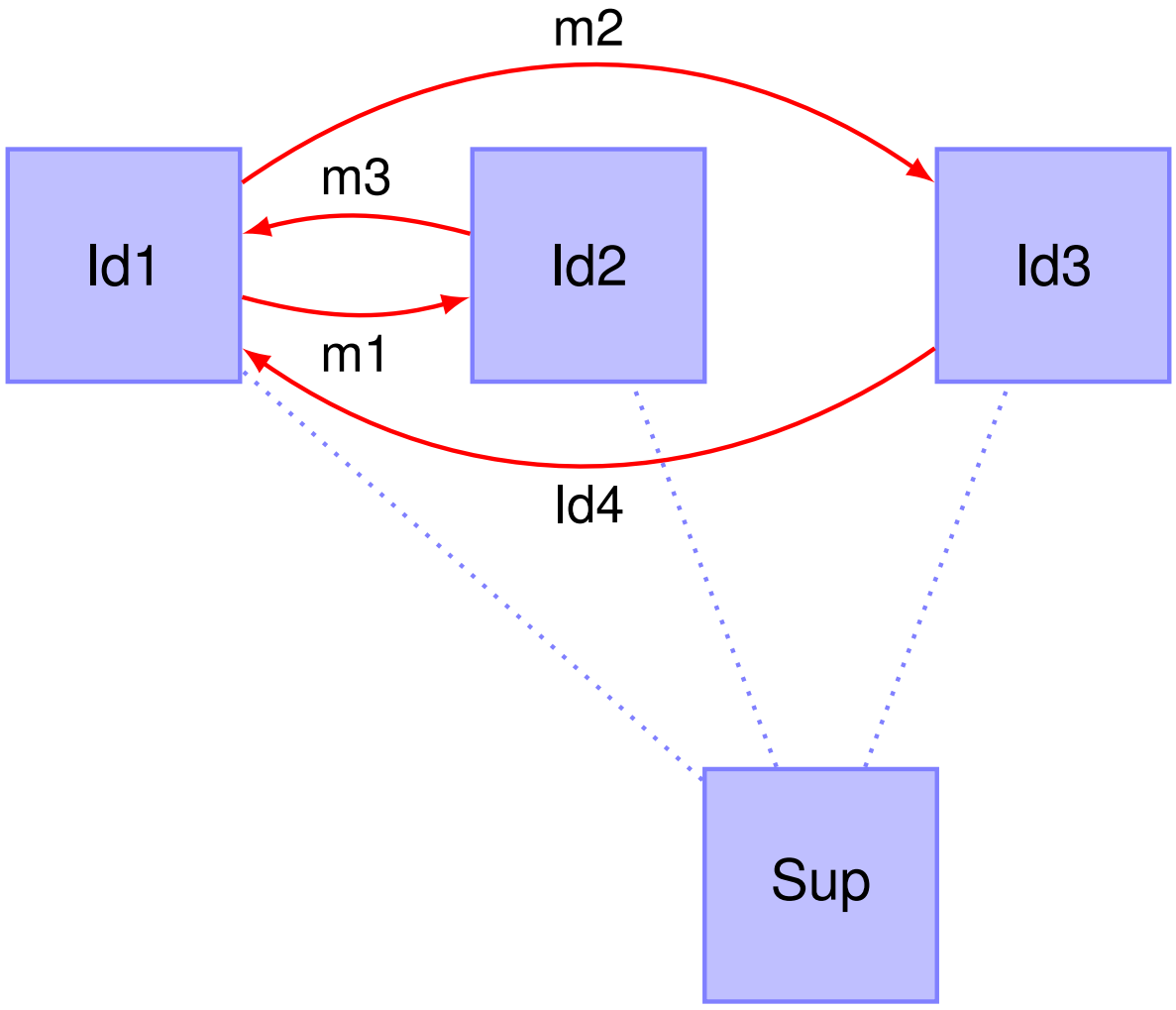
Characteristics

- Resilient
- Long-running
- Analysable
- Reconfigurable

Runtime Adaptation in Actor Systems through Supervisors and Linking



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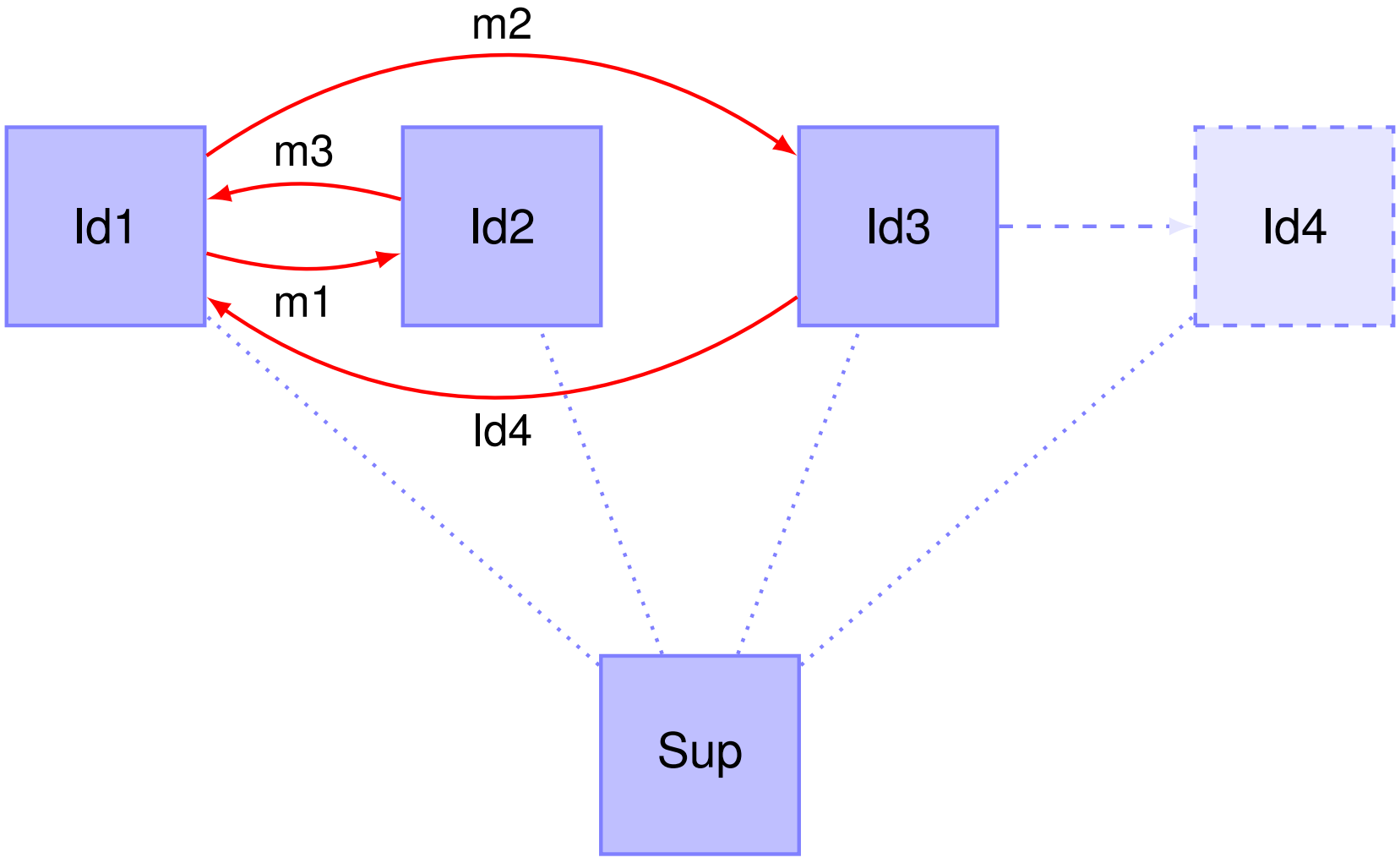

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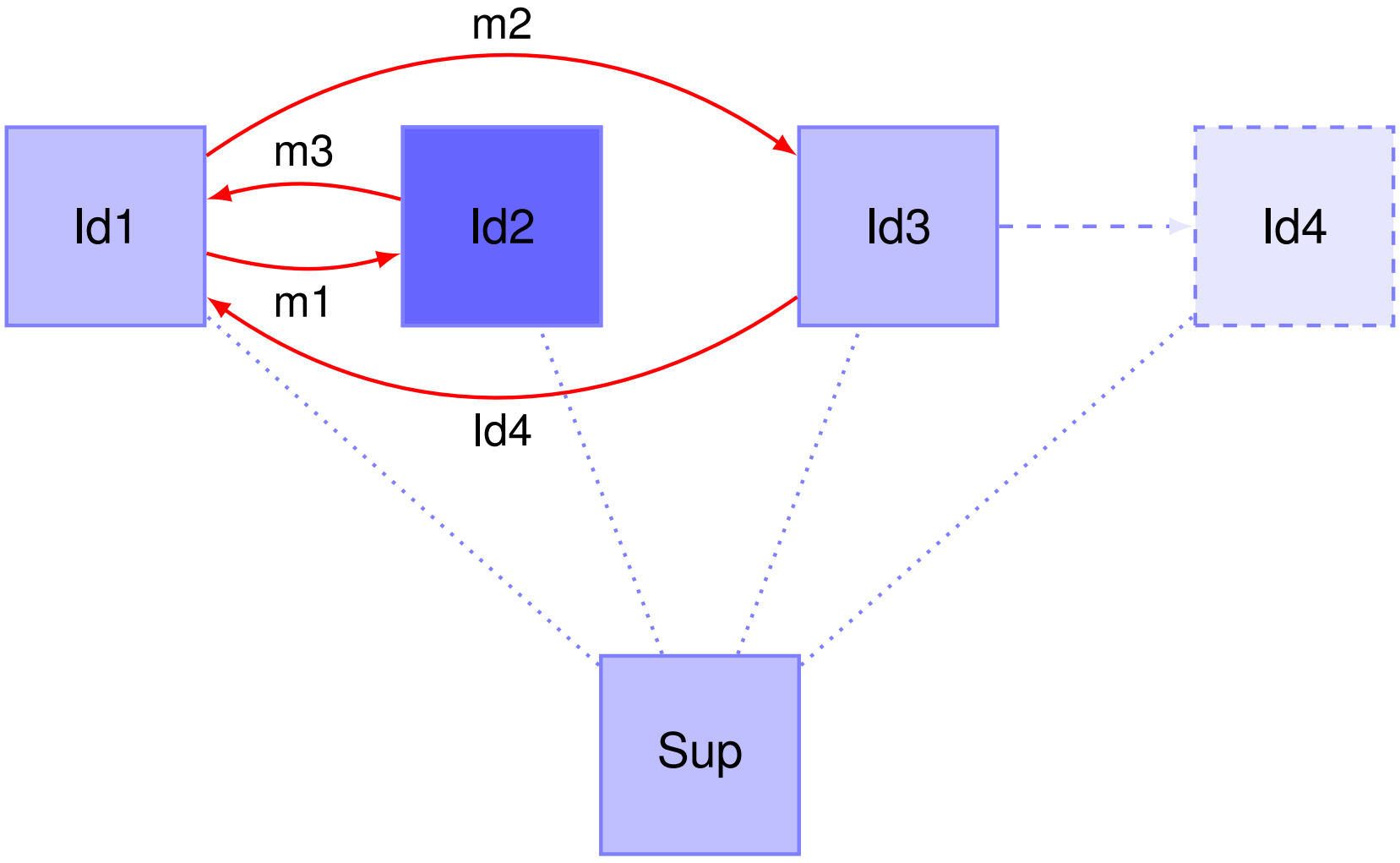

Monitor-Oriented Programming

Adaptations

- Preemptive actions **before** something bad happens

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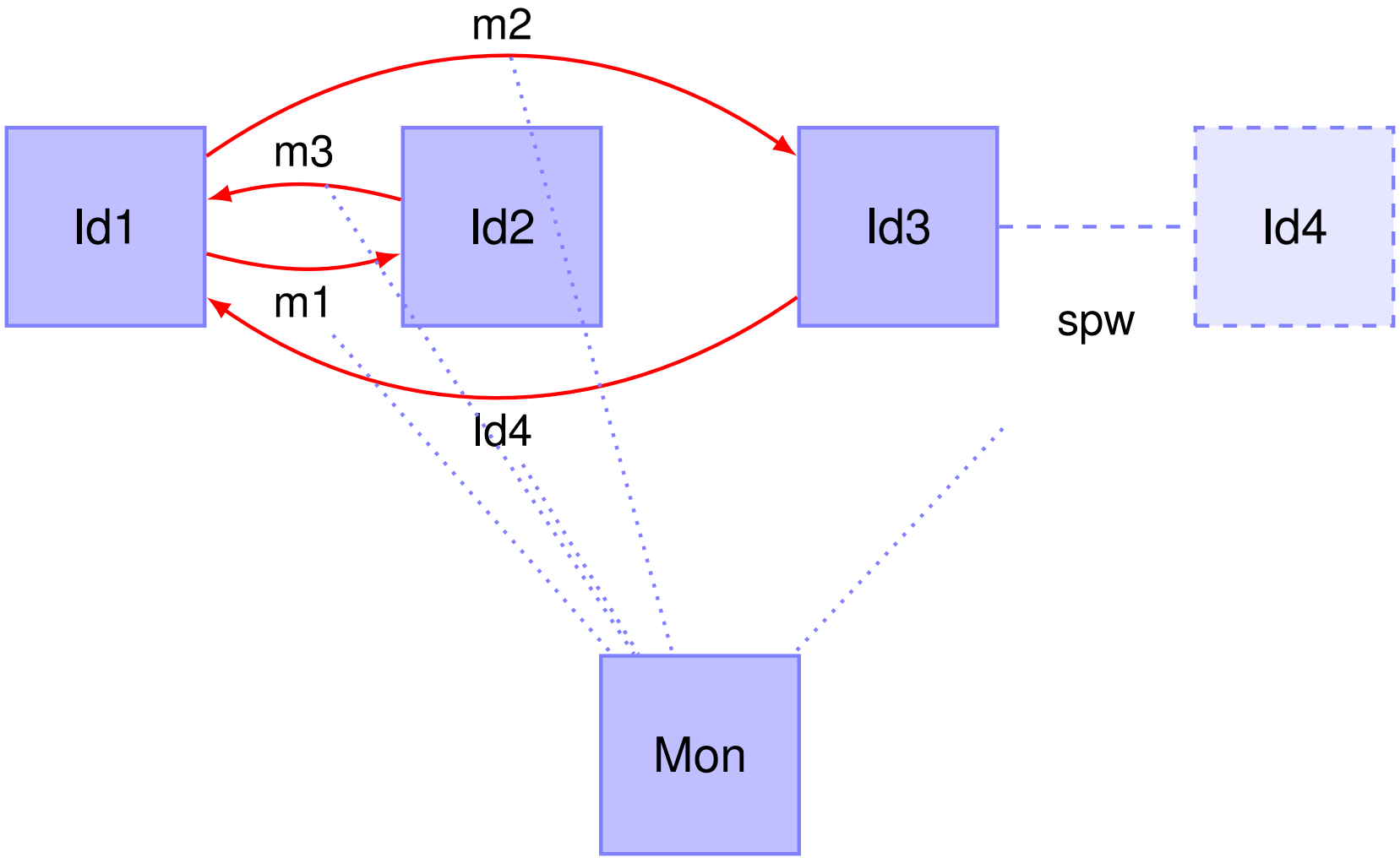
- **Corrective** actions when something bad happens.
  - ✗ *Limited set* corrective actions
  - ✗ *Restrictive definition* of bad.
- Fine-tuning actions to **improve** resource usage.
  - ✗ Has nothing to do with bad behaviour/failure.

General Monitors in Actor Systems



Aims and Challenges

1. **Specify** abstractly adaptation mechanisms
2. **Automate** (as much as possible) the monitor generation.
3. **Implement** efficiently the mechanism in a **minimally-intrusive** manner.

The Specification Language

$$
\begin{array}{lll}
c, d \in \mathtt{SPEC} ::= & \mathtt{flag} & \text{(detect)} \\
\mid & \mathtt{end} & \text{(terminate)} \\
\mid & c \,\&\, d & \text{(conjunction)} \\
\mid & \mathtt{if}\, b\, \mathtt{then}\, c\, \mathtt{else}\, d & \text{(branch)} \\
\mid & \mathtt{rec}\, X.c & \text{(recursion)} \\
\mid & X & \text{(recursive call)} \\
\mid & [p]\, \mathtt{rel}\, \vec{v}.\, c & \text{(guard)} \\
\mid & *[p]\, \mathtt{rel}\, \vec{v}.\, c & \text{(blocking guard)} \\
\mid & A(x)\, \mathtt{rel}\, \vec{v}.\, c & \text{(asyn. adaptation)} \\
\mid & S(x)\, \mathtt{rel}\, \vec{v}.\, c & \text{(sync. adaptation)}
\end{array}
$$

Specifying Adaptations

Example

$$\texttt{rec}\, X.[i{>}x\,!\,y].\,[j{>}x\,!\,z].\,\texttt{if}\, y{==}z\ \texttt{then}\ X\ \texttt{else}\ \texttt{flag}$$

Specifying Adaptations

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$$\texttt{rec}\, X\,.\,[i\!>\!x\,!\,y]\,.\,[j\!>\!x\,!\,z]\,.\,\texttt{if}\, y{=}{=}z\ \texttt{then}\ X\ \texttt{else}\ \texttt{flag}$$

$$\begin{aligned}&\texttt{rec}\, X\,.\,{*}[i\!>\!x\,!\,y]\ \texttt{rel}\ []\,.\,{*}[j\!>\!x\,!\,z]\ \texttt{rel}\ [i]\,.\\ &\qquad\texttt{if}\, y{=}{=}z\ \texttt{then}\ X\ \texttt{else}\\ &\qquad\ \mathit{kill}(x)\ \texttt{rel}\ []\,.\,\mathit{restart}(i)\ \texttt{rel}\ []\,.\,\mathit{restart}(j)\ \texttt{rel}\ [i,j]\,.\,X\end{aligned}$$

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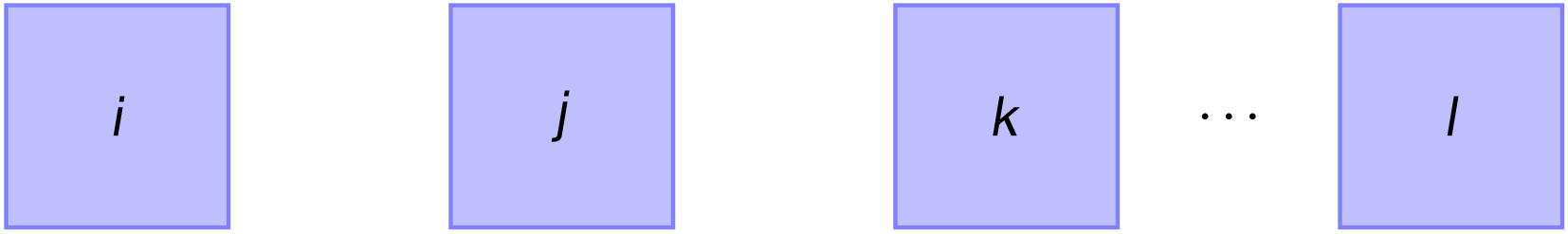
Adaptation Monitors in Actor Systems



Mon

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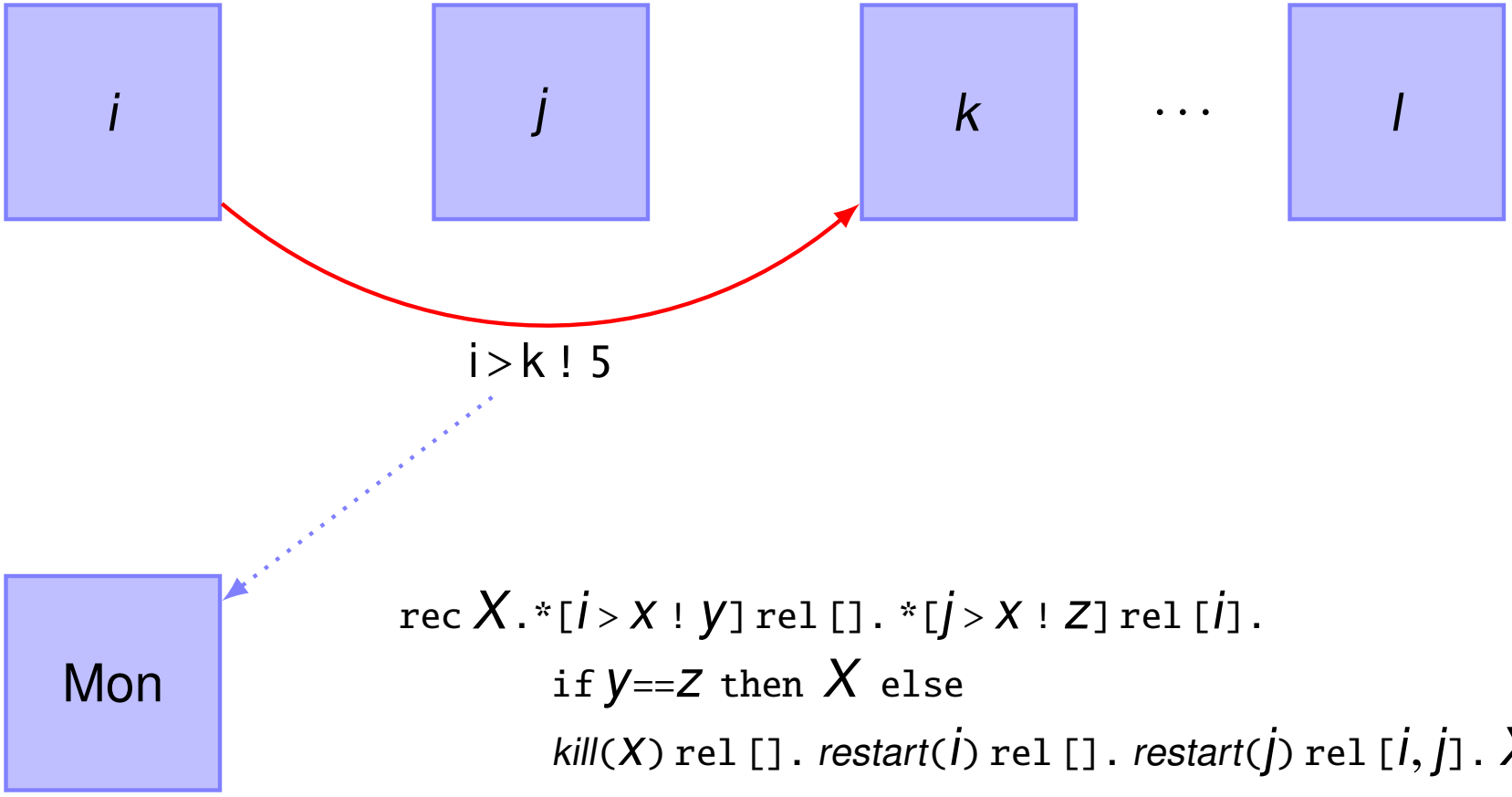

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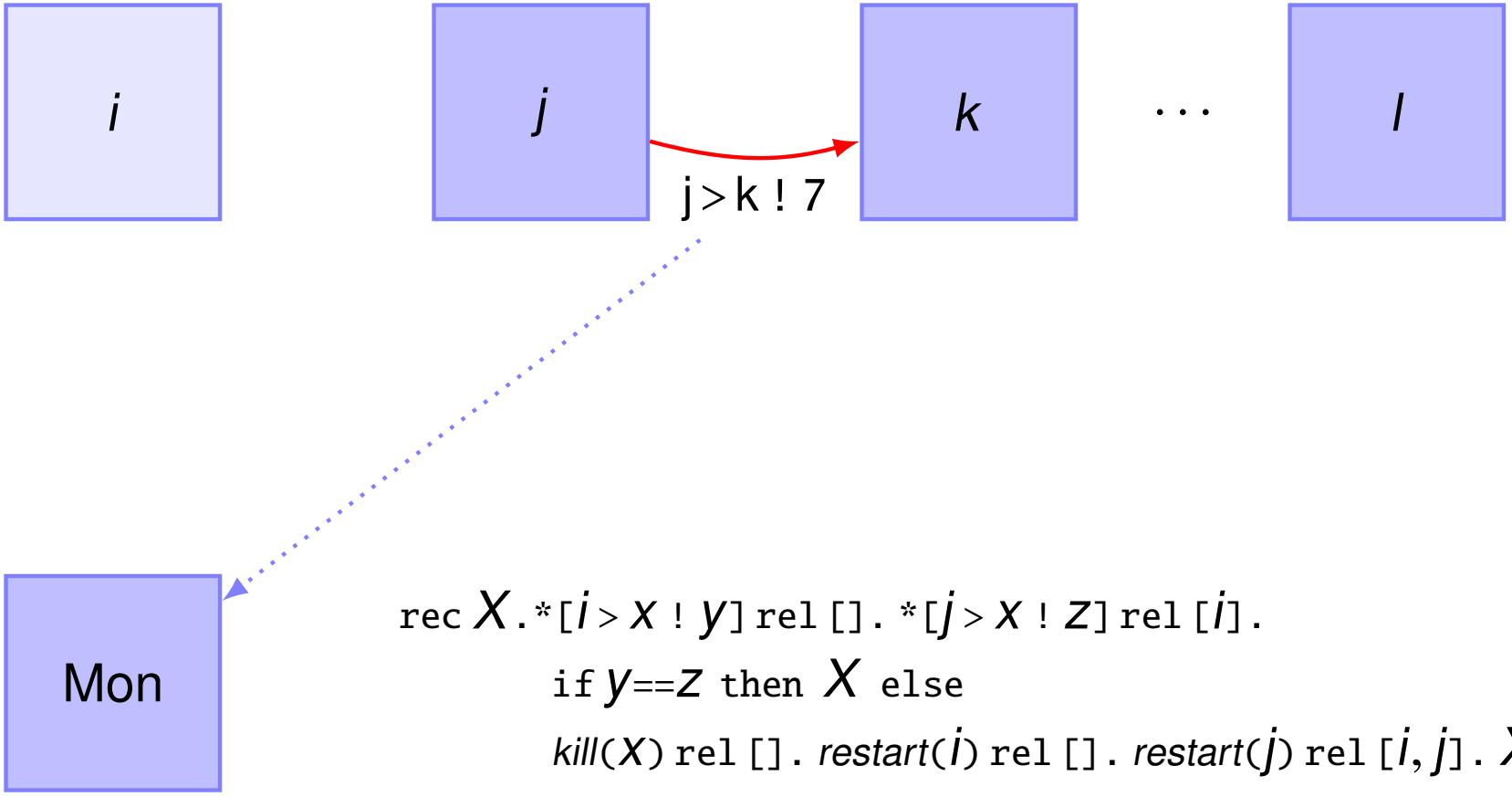

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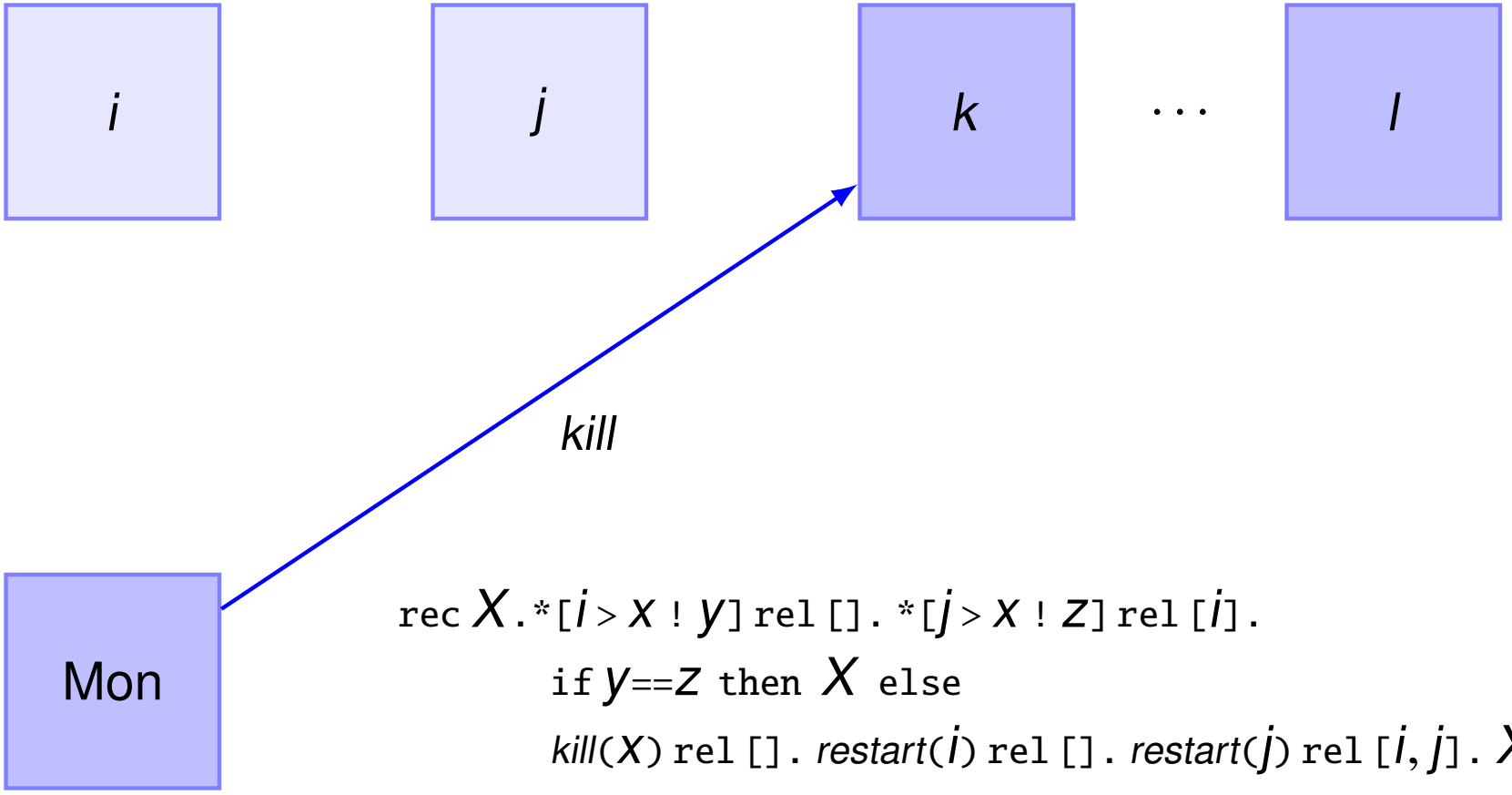

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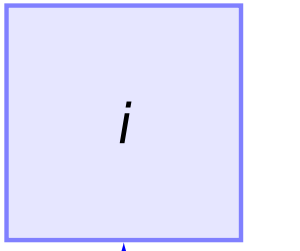

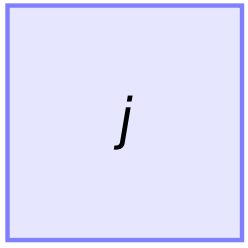

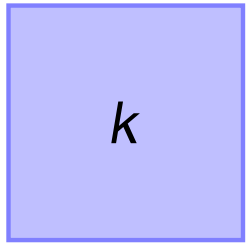

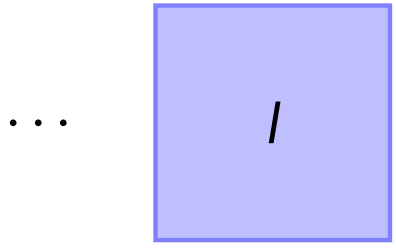

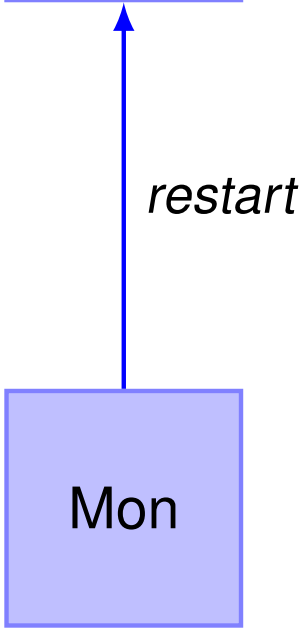

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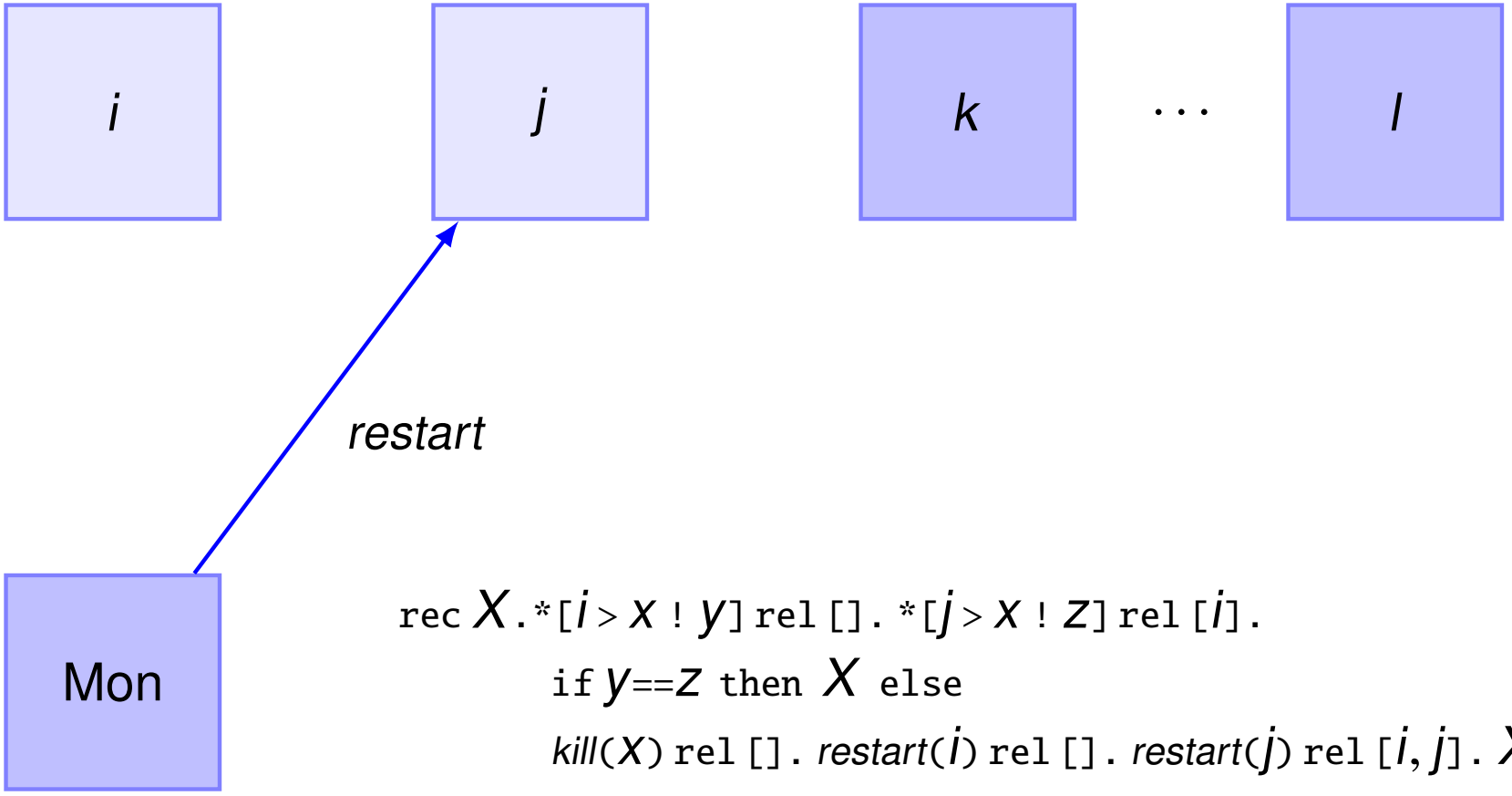

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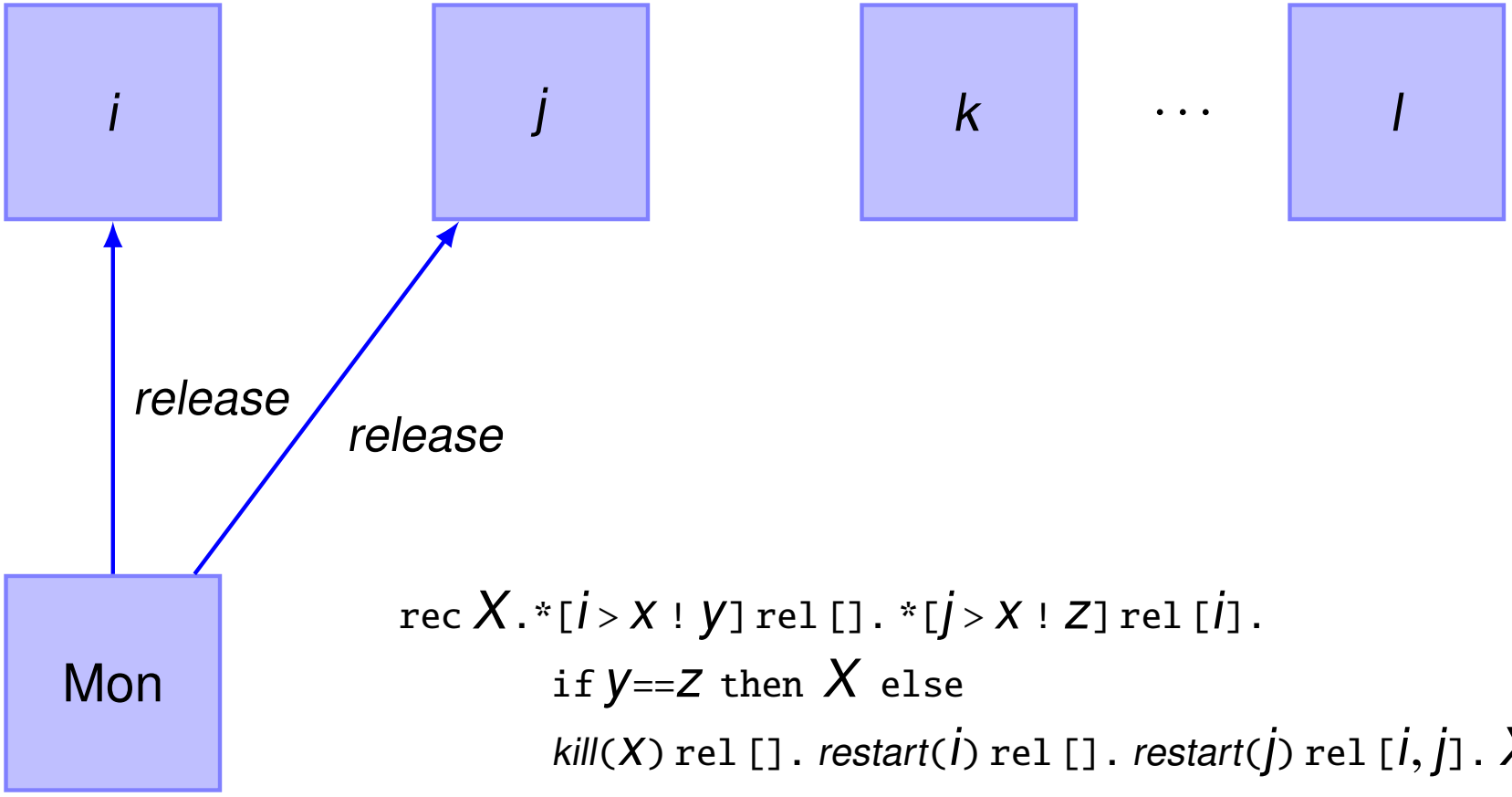

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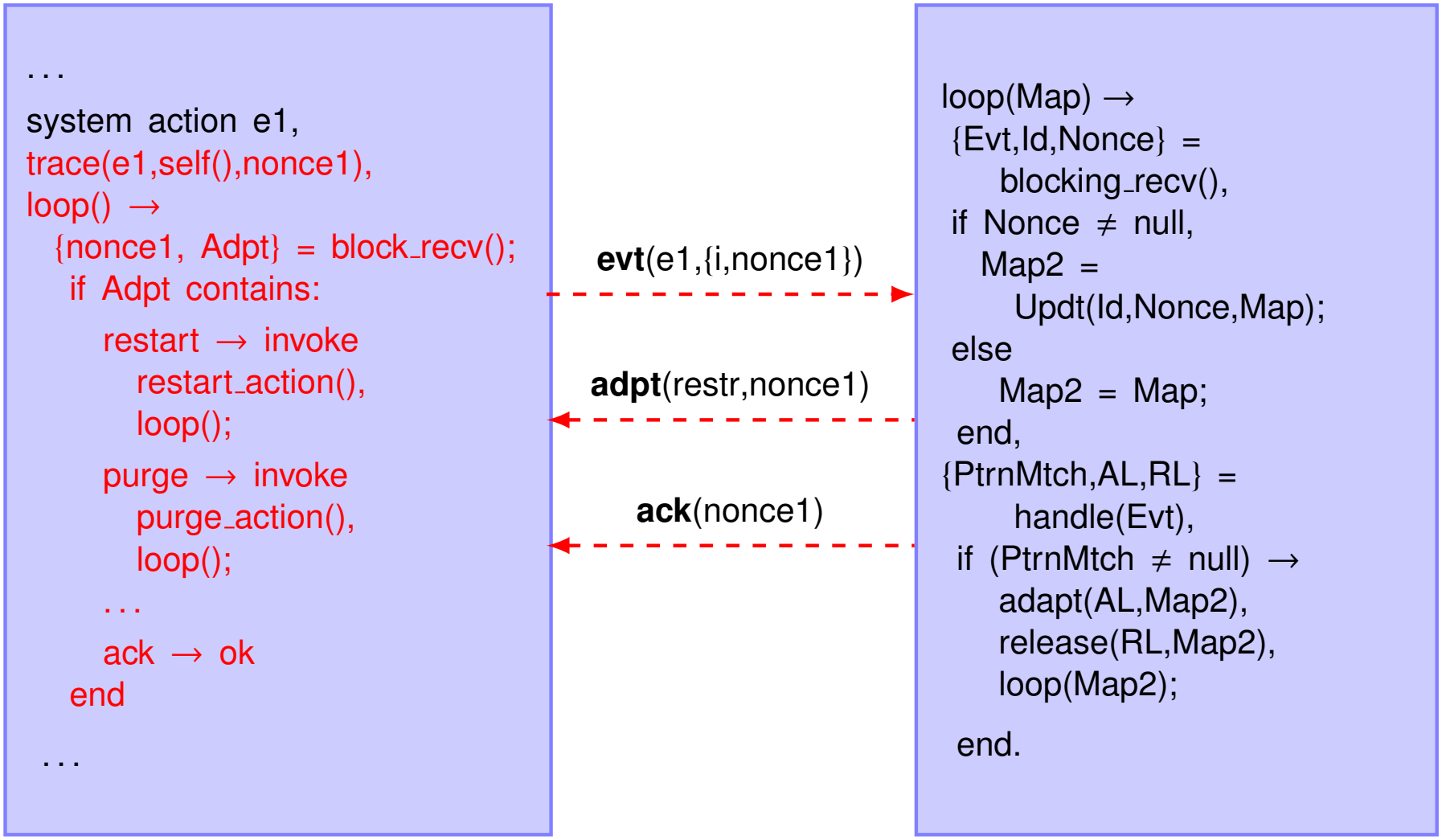
Implementation Obstacles

	Actors	Adaptation
Execution	Asynchronous	Synchronous
Visibility/Accessibility	Encapsulated	Open

Actor Instrumention Protocol



Asynchronous Adaptations

- Actor killing via `exit()`
- Actor name (de)registering via `register()` and `deregister()`
- Memory optimisation via `garbage_collect()`
- Exit trapping via `process_flag()`
- Composite adaptations such as killing all actors linked to an actor using `process_info()`, `process_flag()` and `exit()`.

Synchronous Adaptations

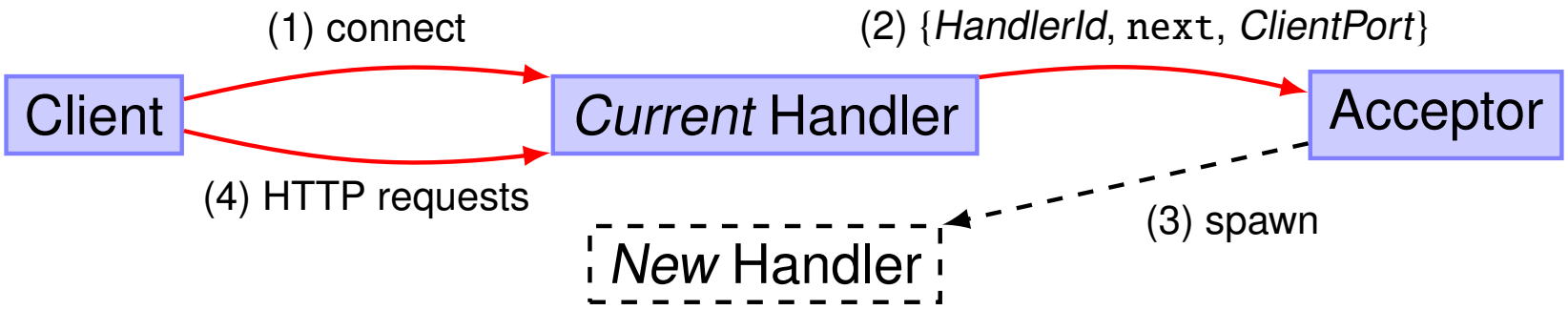
`purge()`: Empties an actor's mailbox.

`silent_kill()`: Composite adaptation made up of smaller adaptations.

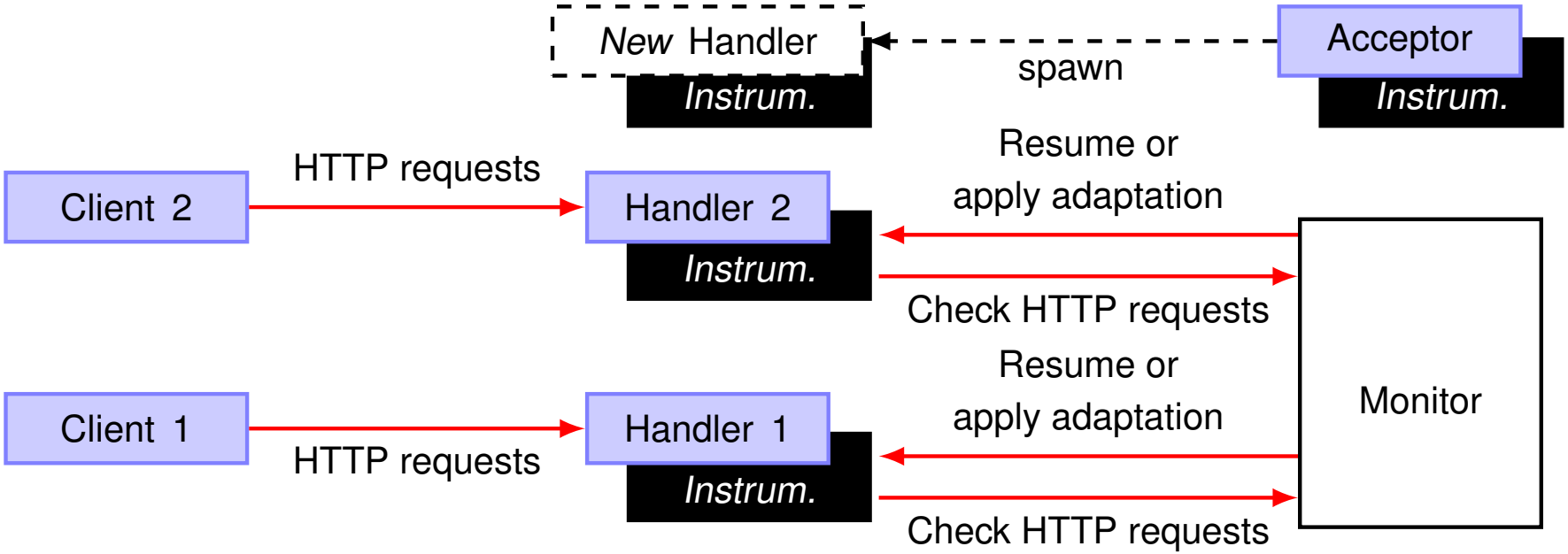
`restart()`: Restarts the execution of an actor with a reinitialised memory.

`untrace()`: Makes events of the actor unmonitorable.

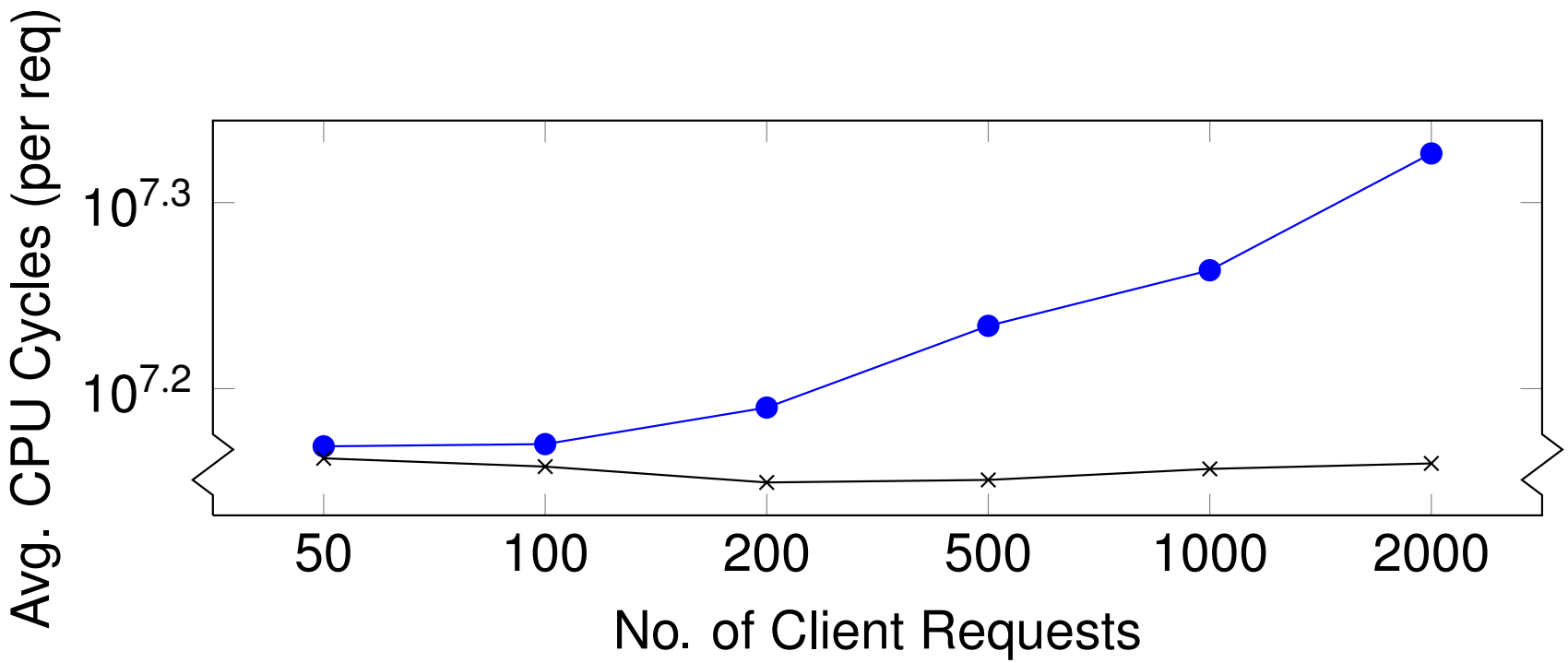
Case Study


(1) connect
(2) {*HandlerId*, `next`, *ClientPort*}
Client
Current Handler
Acceptor
(4) HTTP requests
(3) spawn
New Handler

Case Study


New Handler
Instrum.
spawn
Acceptor
Instrum.
Resume or
apply adaptation
HTTP requests
Client 2
Handler 2
Instrum.
Check HTTP requests
Resume or
apply adaptation
Monitor
Client 1
Handler 1
Instrum.
HTTP requests
Check HTTP requests

Adaptation Overheads



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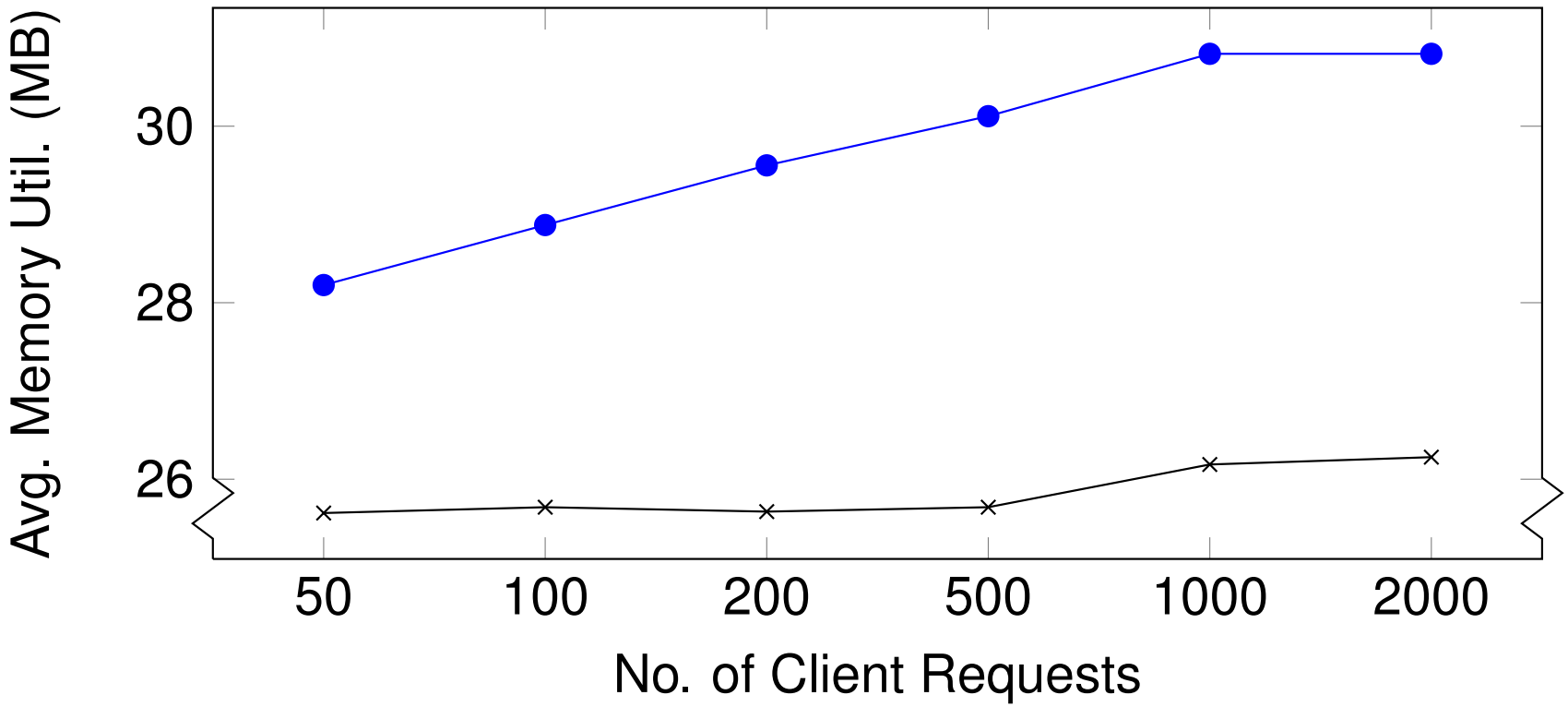

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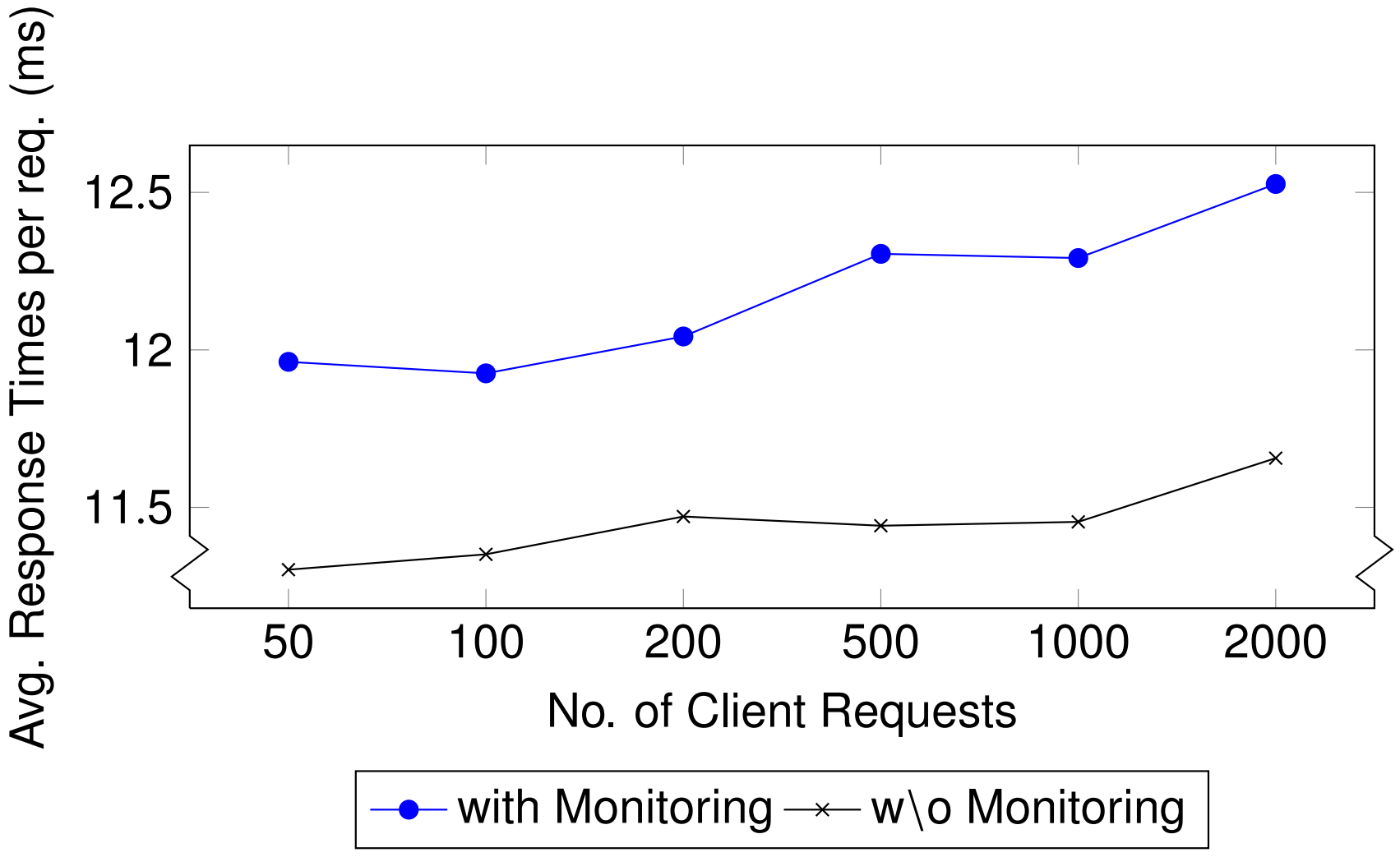

Conclusions

Contributions

1. POC extension of an adaptation framework for Actors that goes beyond failure events.
2. Mechanism for incremental synchronisations keeping overheads to a minimum.
3. Application of MOP to a third-party software.

References

Cassar, I., and Francalanza, A.

On Synchronous and Asynchronous Monitor Instrumentation for Actor Systems.
In *FOCLASA* (2014), vol. 175, pp. 54–68.

Cassar, I., and Francalanza, A.

Runtime Adaptation for Actor Systems.
In *RV* (2015), vol. 9333 of *LNCS*, Springer, pp. 38–54.

detectEr Project.

`http://www.cs.um.edu.mt/svrg/Tools/detectEr/`.