Self-Adaptive Automata

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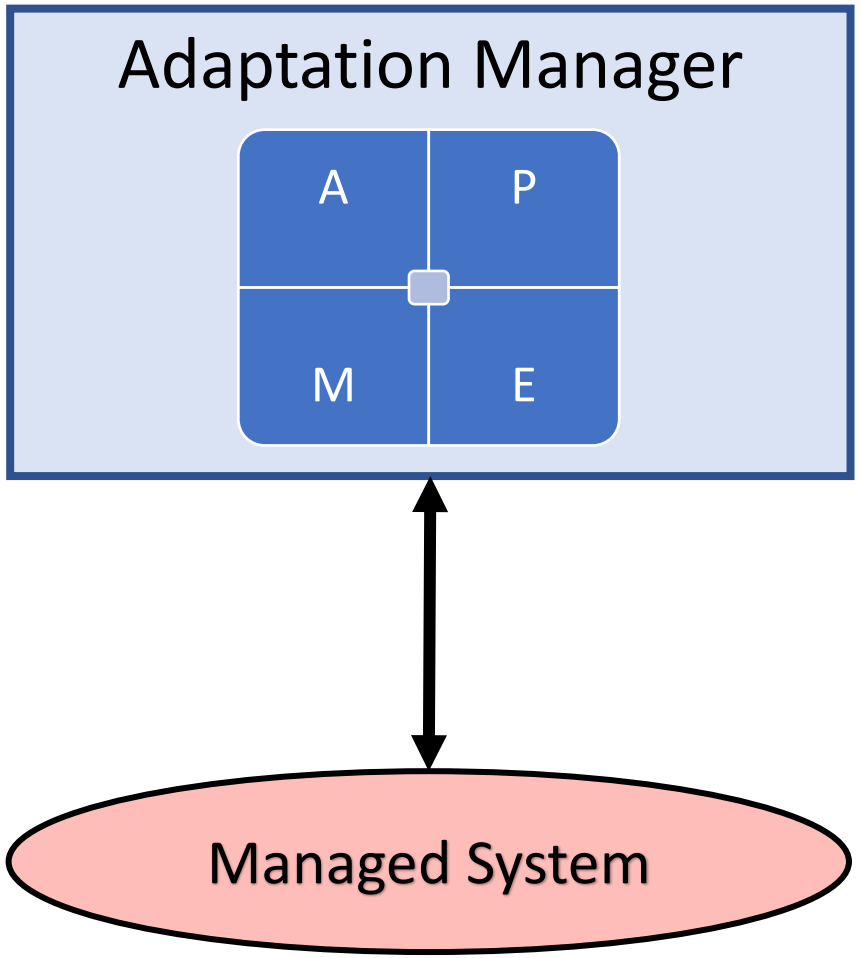
Self-Adaptive Systems

- Systems with the "**ability to adapt** at run-time to **changing** user needs, system intrusions or faults, changing operational environment, and resource variability"

- "Has been proposed as a means to cope with the **complexity** of todays software-intensive systems"

(Dagstuhl Seminar 10431)

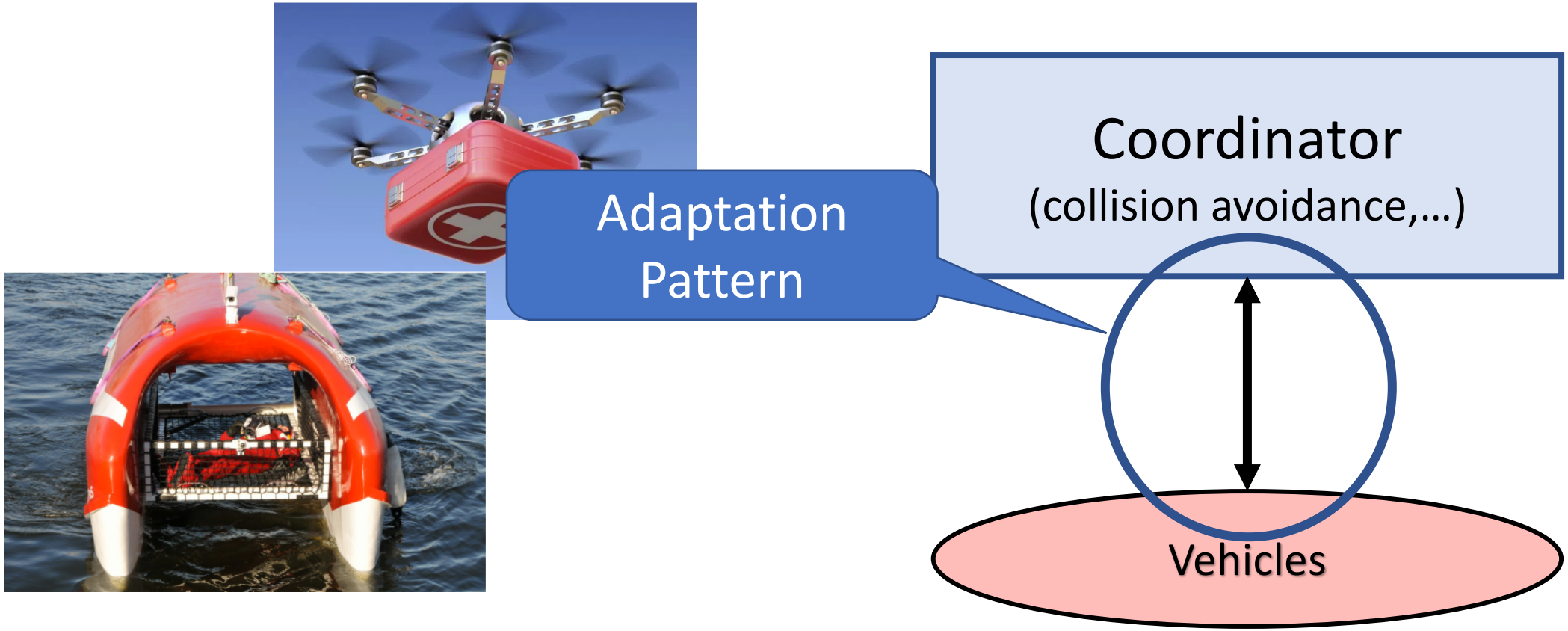


Search Operation by Unmanned Vehicles

Requirements:

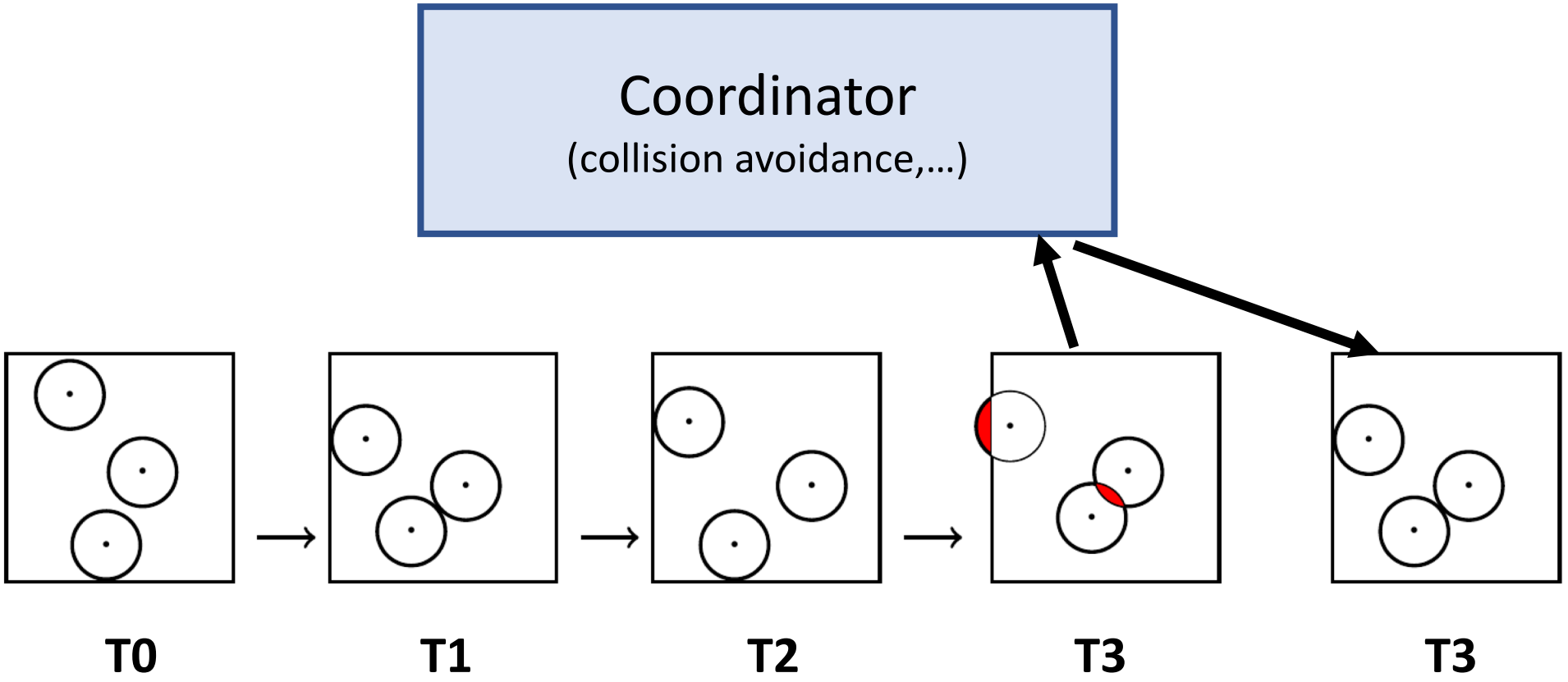
1. No Collisions
2. Vehicles stay in search area
3. Eventually search the whole area

Search Operation by SA Unmanned Vehicles



Time-Triggered Adaptation

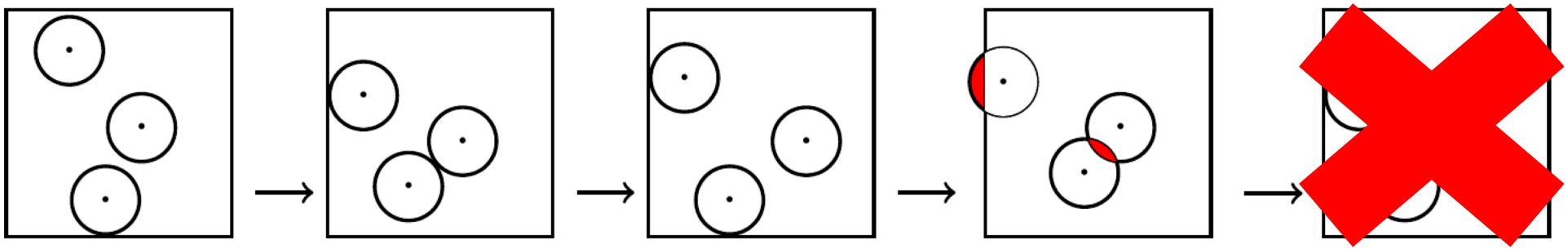
Every 3 time units



Time-Triggered Adaptation

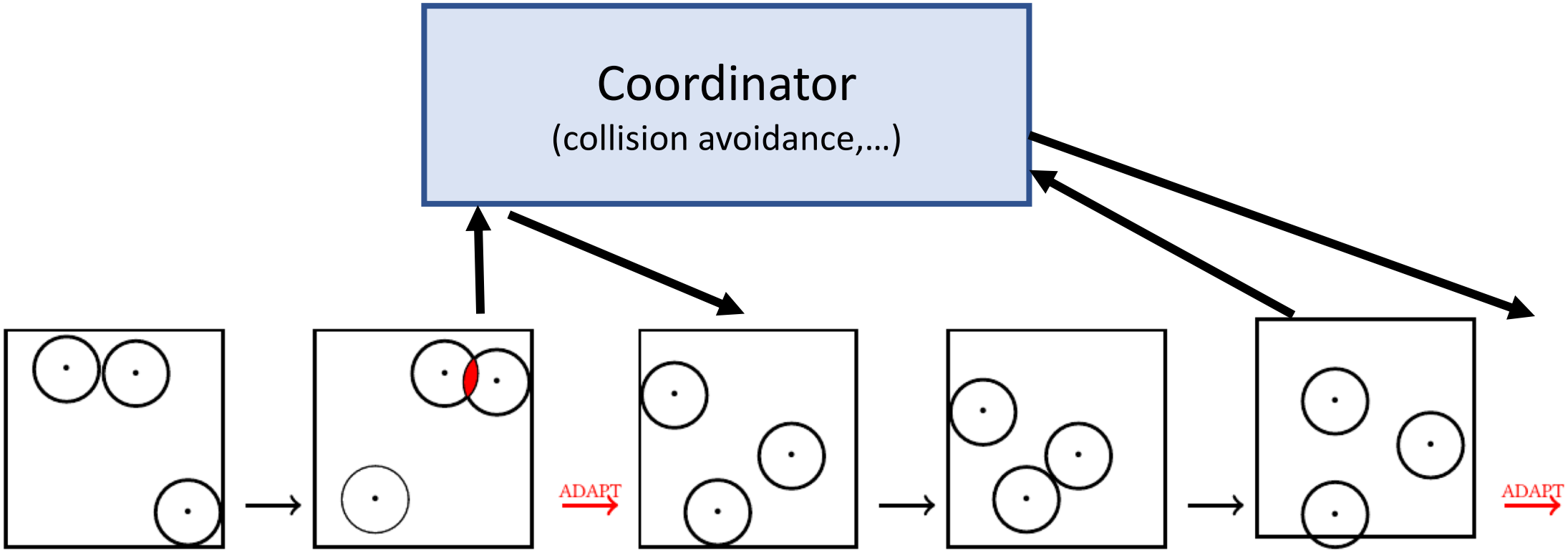
Every 10 time units

Coordinator
(collision avoidance,…)



Event-Triggered Adaptation

Vehicles are dangerously close to each other

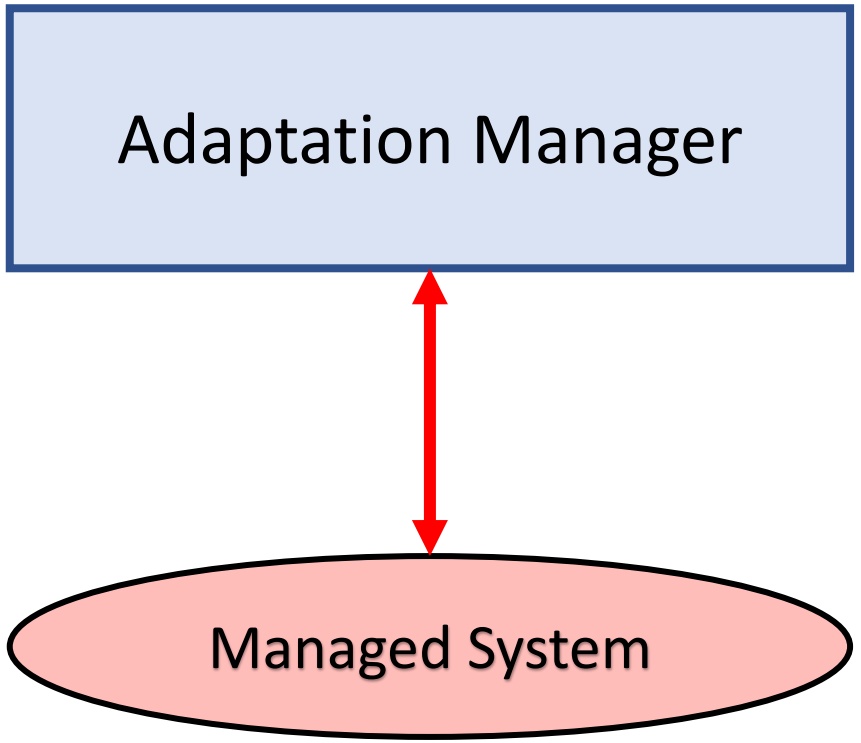


Adaptation Pattern is crucial!

Execution points where adaptation is triggered

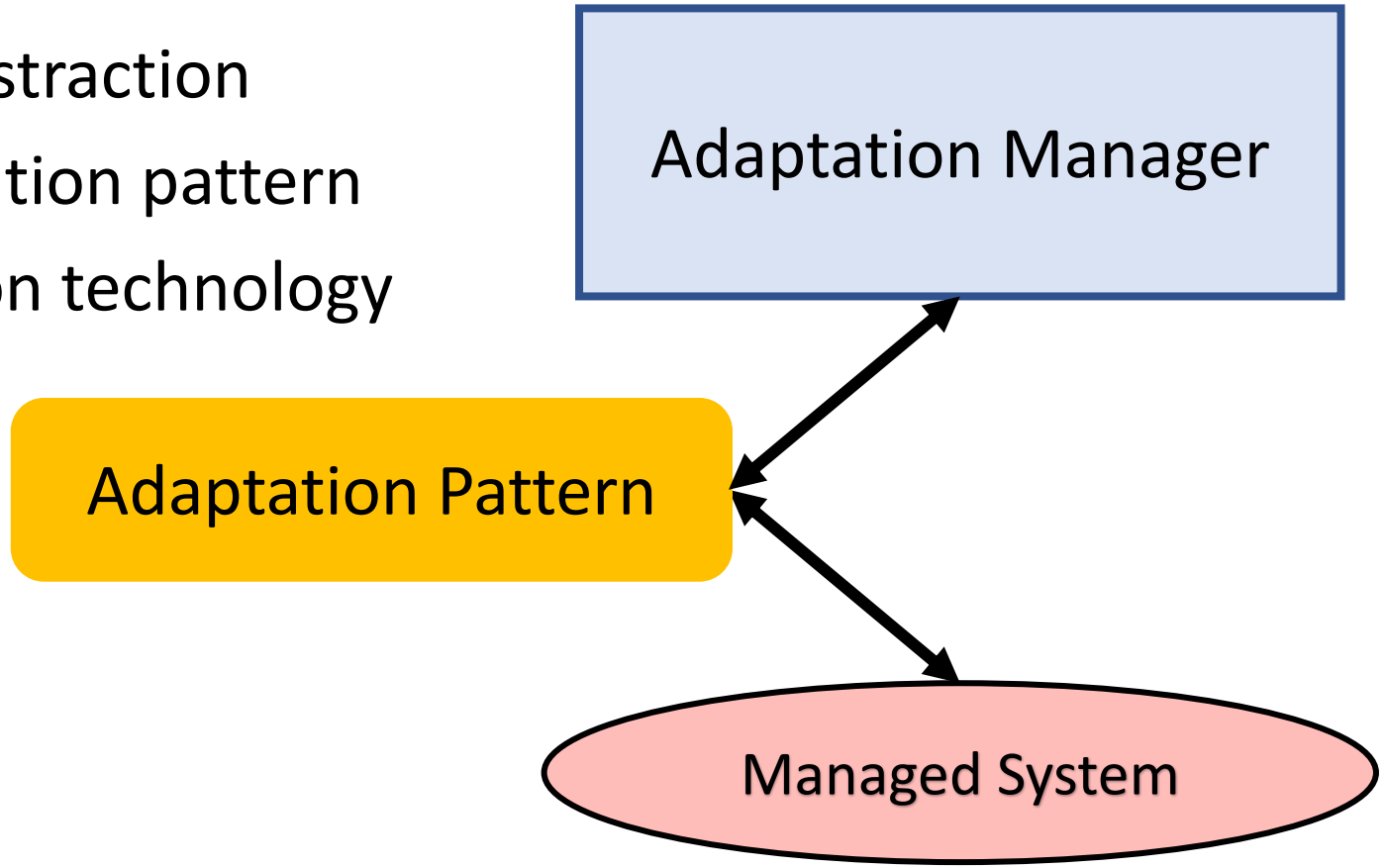
- Time-based, event-based, history-based…

- Important (for correctness)
- Necessary (for implementation)

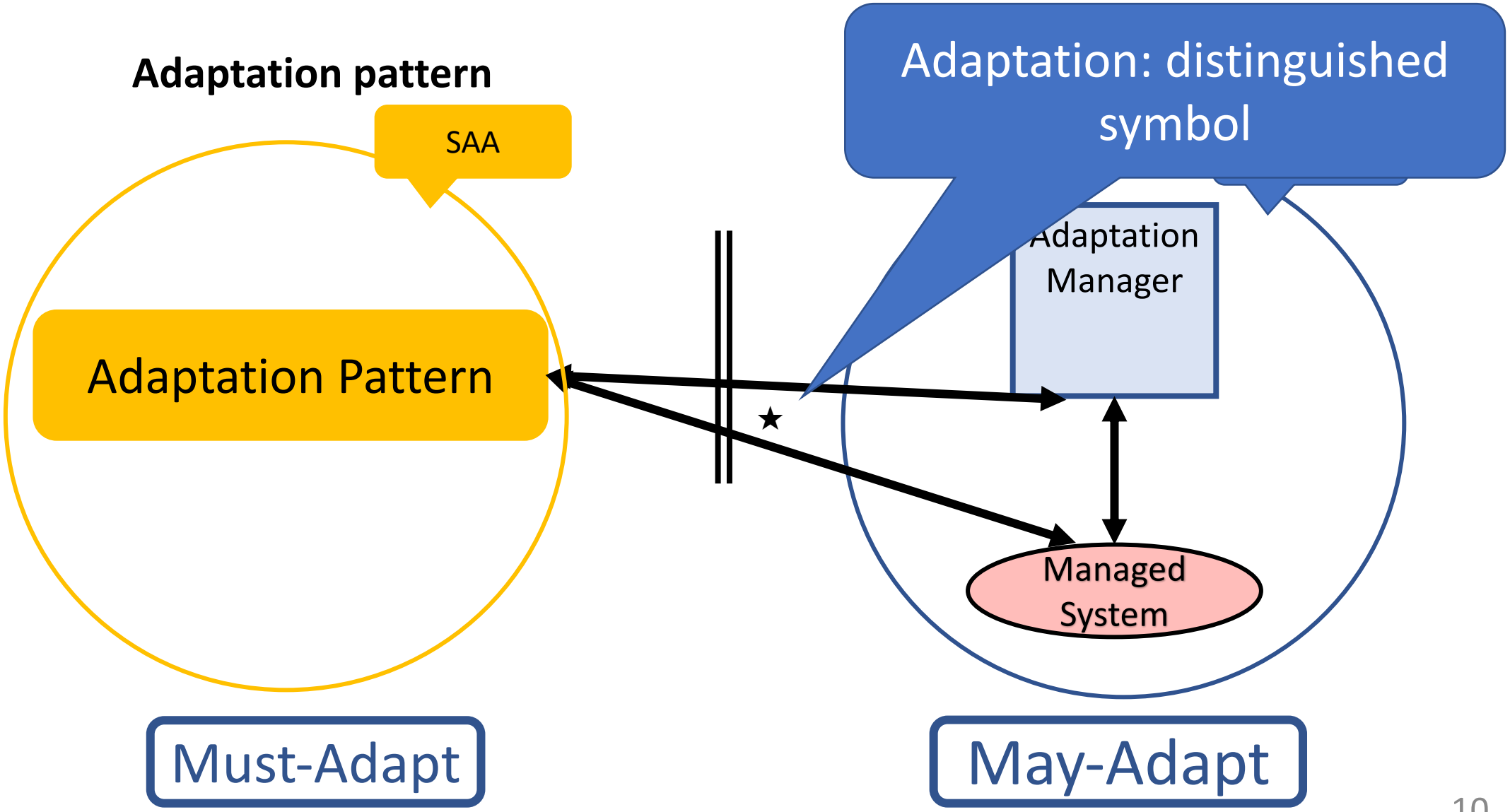


Goal: Enable Experimentation and Verification of Adaptation Patterns

- Model at a **high-level** of abstraction
- **Modularity**: localise adaptation pattern
- Leverage existing verification technology



Our Model: Self-Adaptive Automata (SAA)



Our Model: Self-Adaptive Automata (SAA)

SAA $\stackrel{\text{def}}{=} \langle Q,\ \Sigma,\ \Delta, q_0,\ \delta_0,\ \Pi \rangle$

Q: Set of States

Σ : Set of Events

Δ : Set of Transition Functions

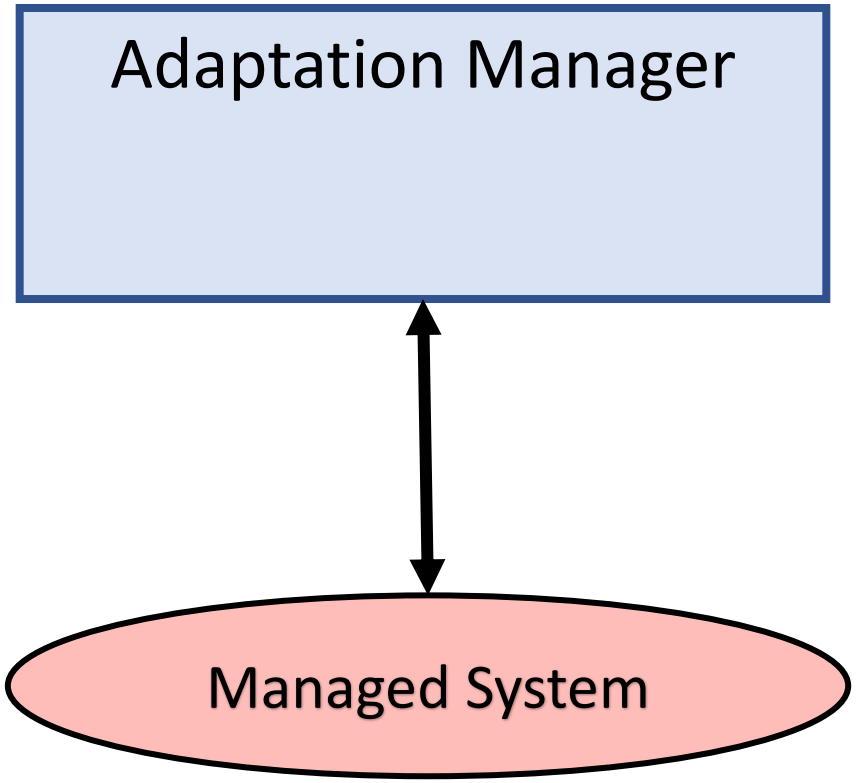
q_0 : Initial State

δ_0 : Initial Transition Function

$Q \times \Sigma \rightharpoonup Q$

Π : Adaptation Function

$Q \rightharpoonup Q \times \Delta$



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Π : Adaptation Function

$Q \rightharpoonup Q \times \Delta$

Operational semantics

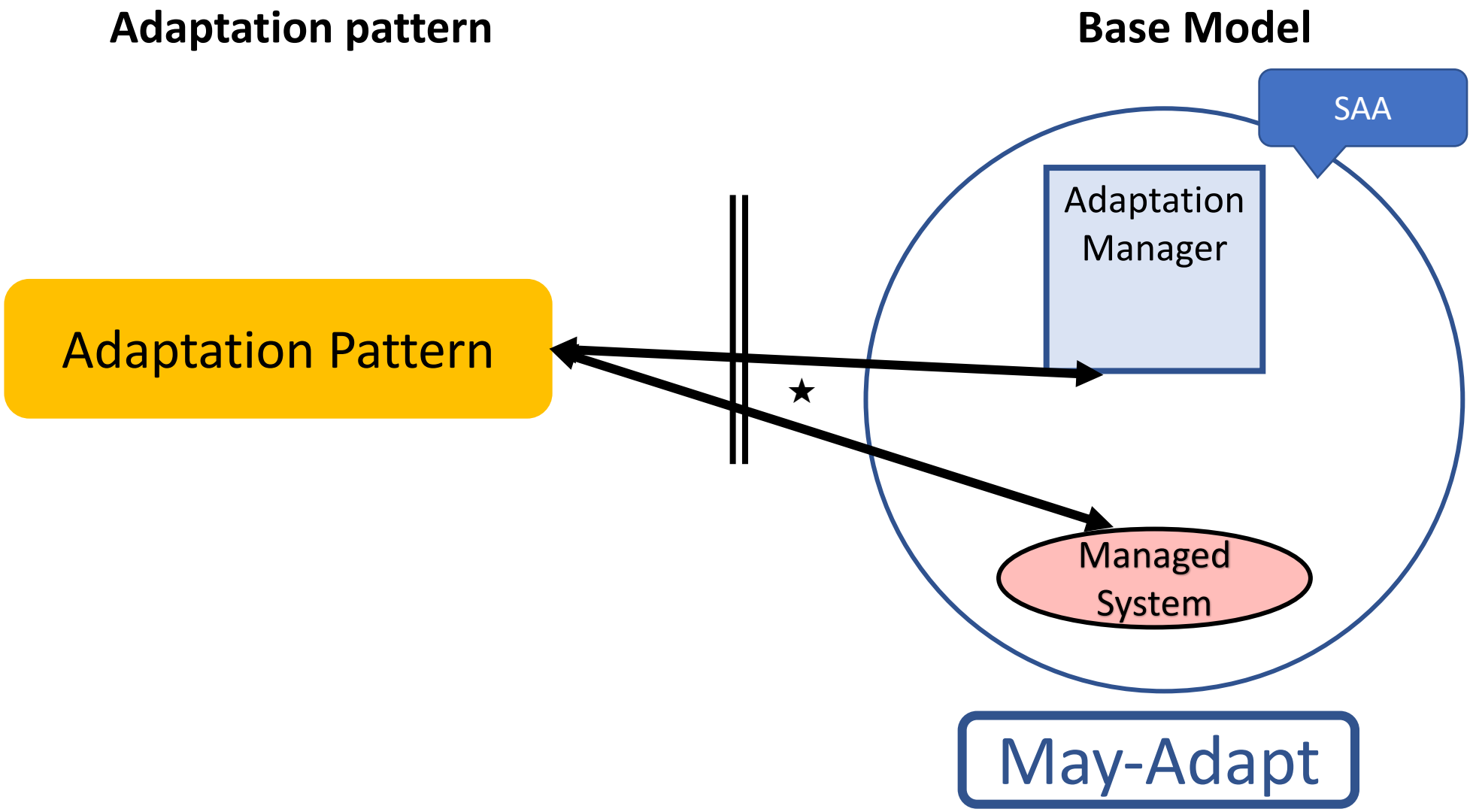
$<q,\delta> \xrightarrow{a} <q',\delta>$

such that $\delta(q, a) = q'$

$<q,\delta> \xrightarrow{\star} <q',\delta'>$

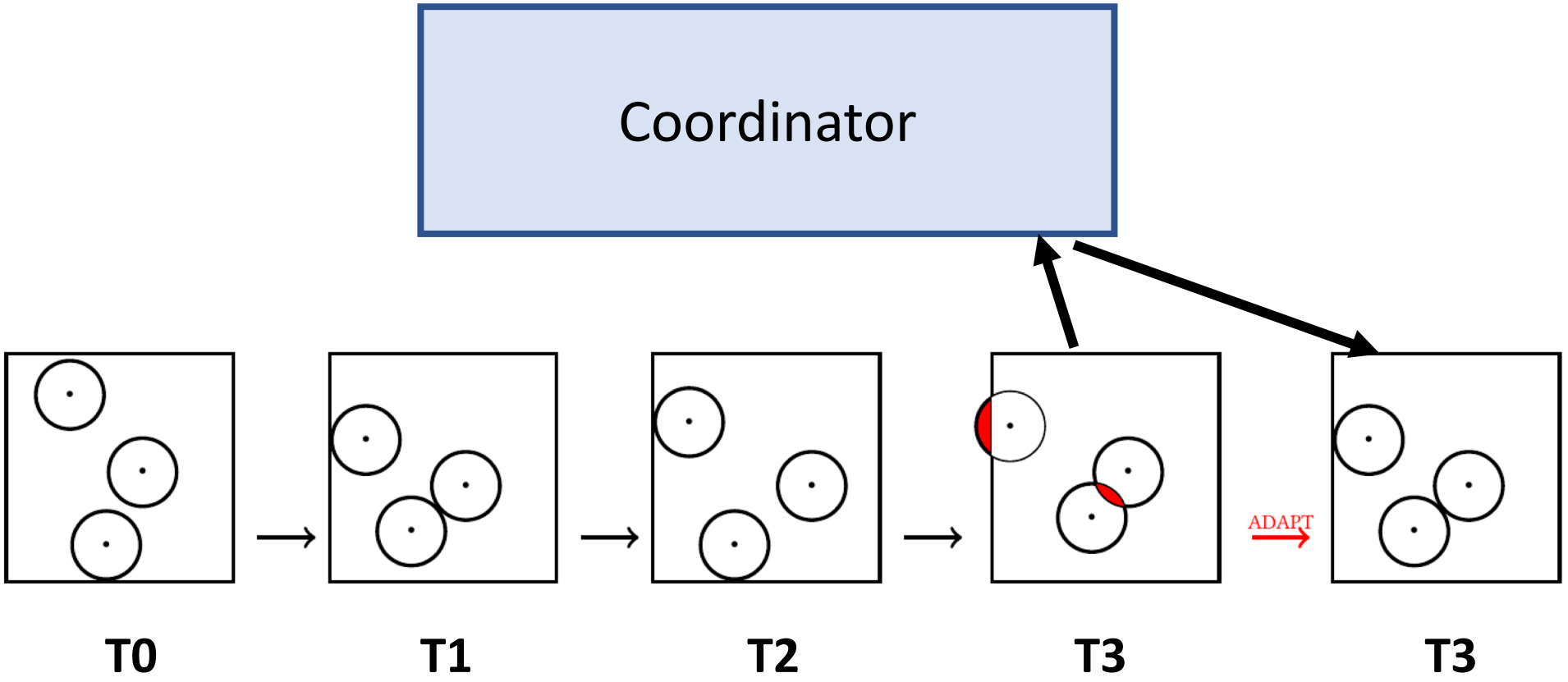
such that $\Pi(q) = <q',\delta'>$

Modelling the **Adaptation Pattern** with SAA



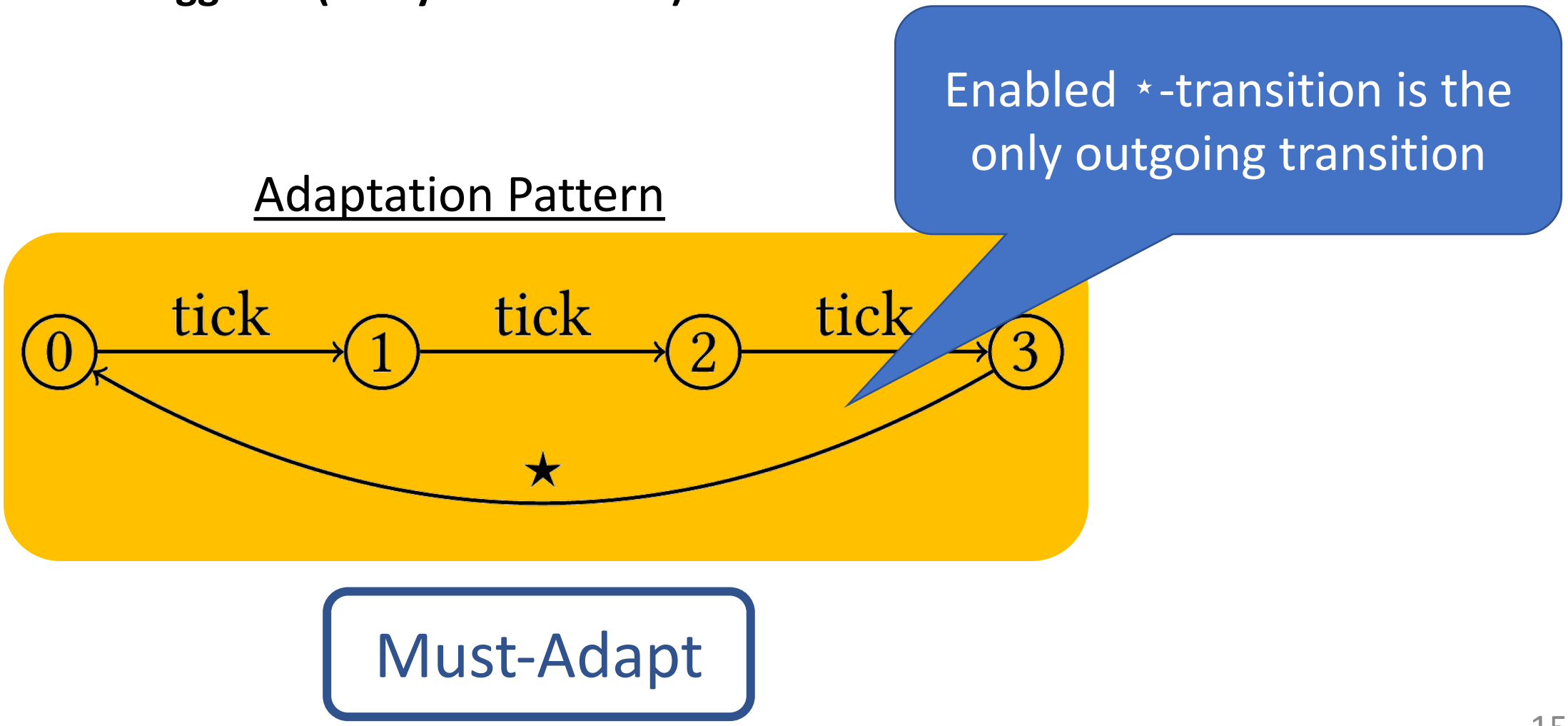
Implementing the **Adaptation Pattern** with SAA

Time-Triggered (every 3 time units)



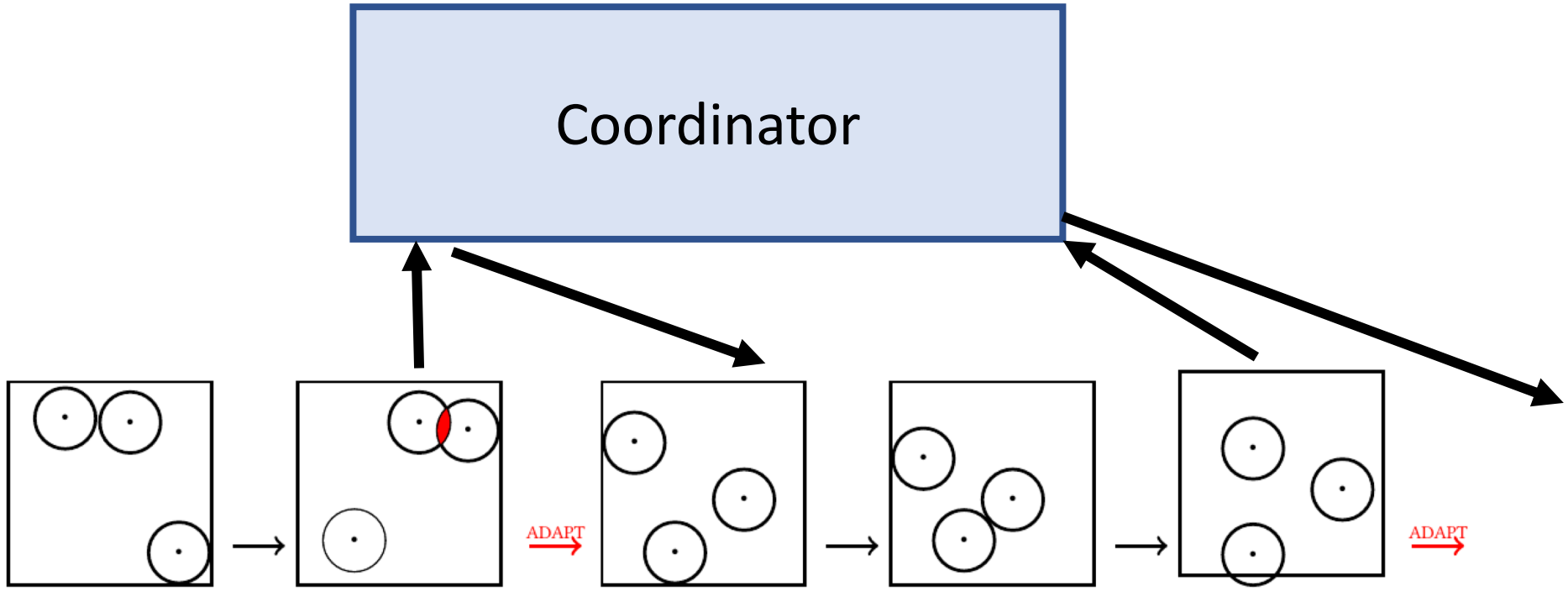
Modelling the **Adaptation Pattern** with SAA

Time-Triggered (every 3 time units)



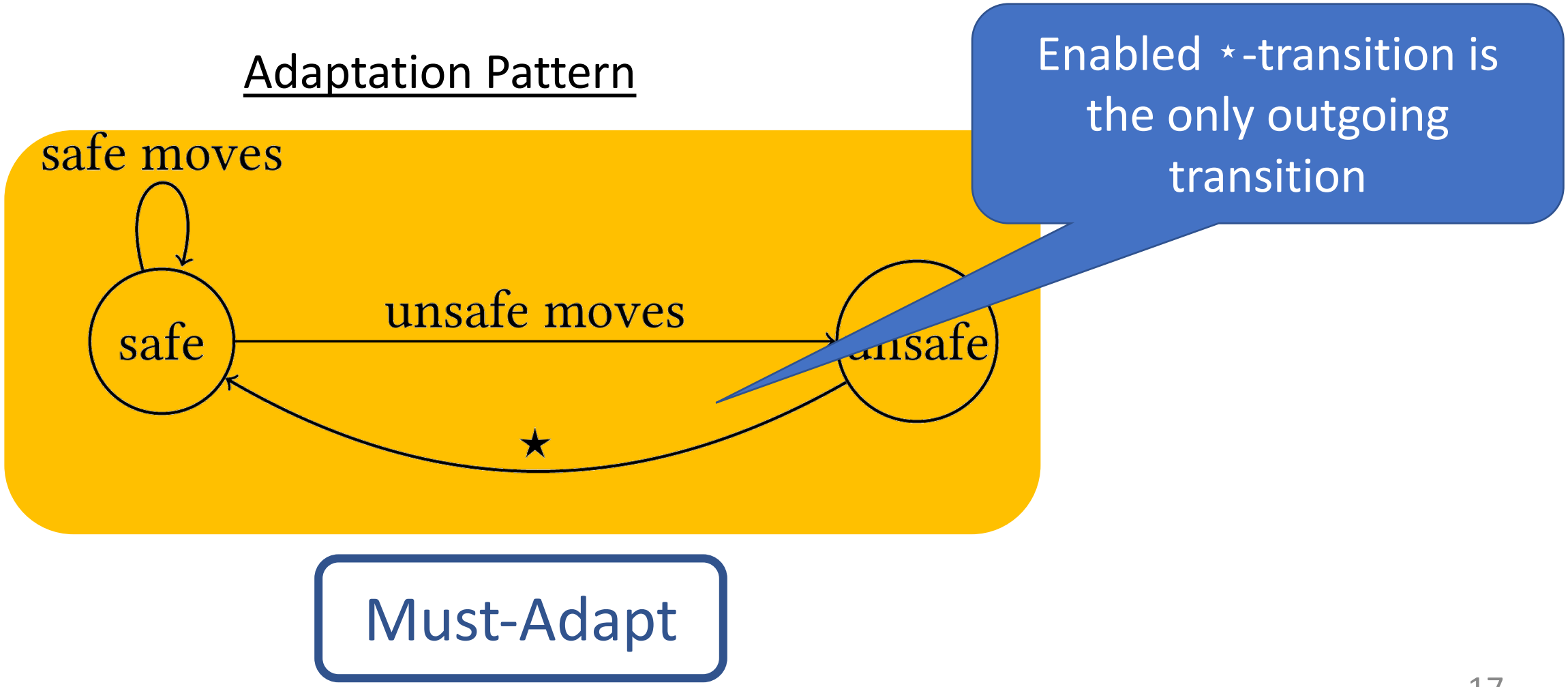
Modelling the **Adaptation Pattern** with SAA

Event Triggered: Vehicles are dangerously close to each other

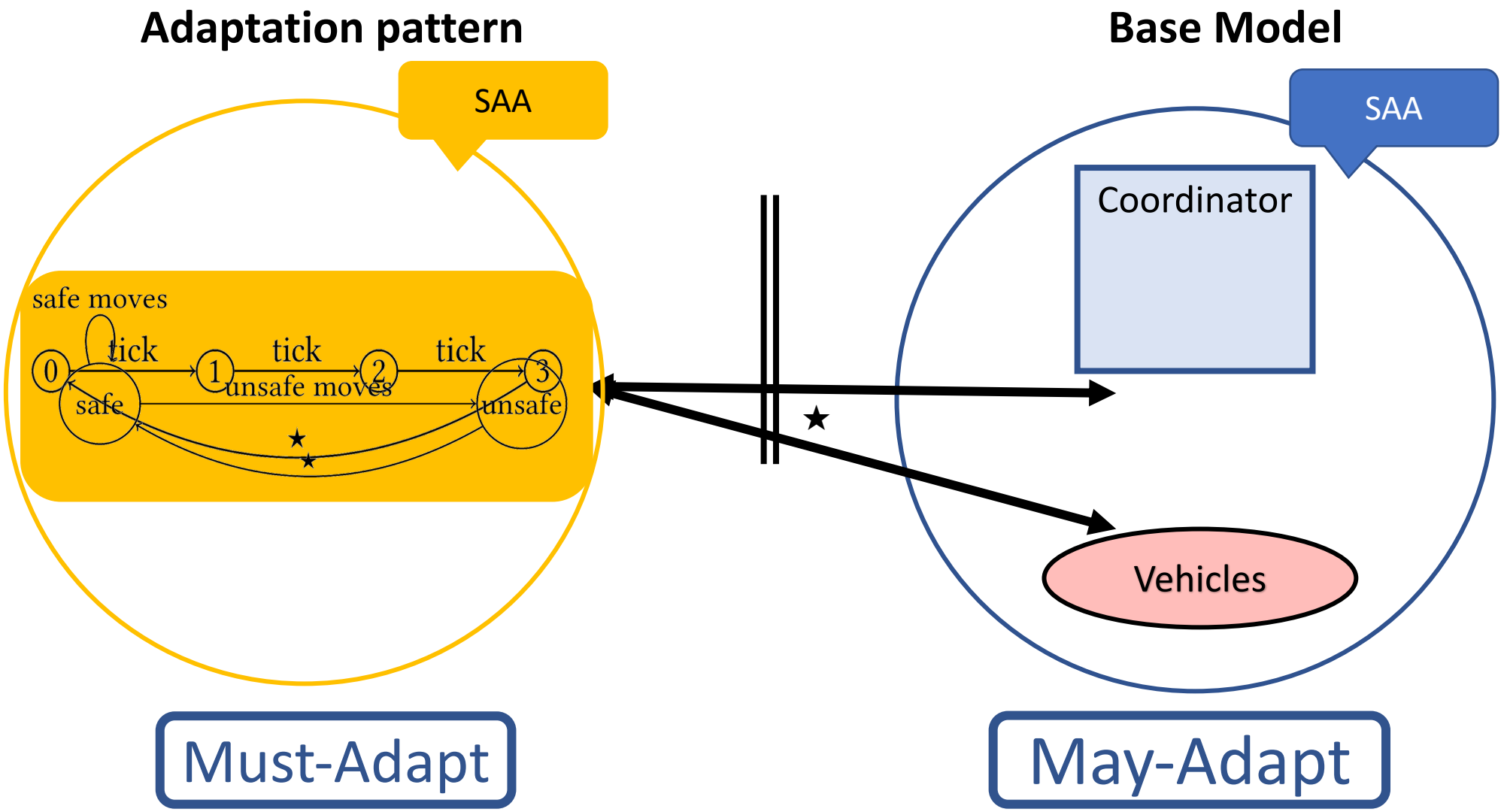


Modelling the **Adaptation Pattern** with SAA

Event Triggered: Vehicles are dangerously close to each other



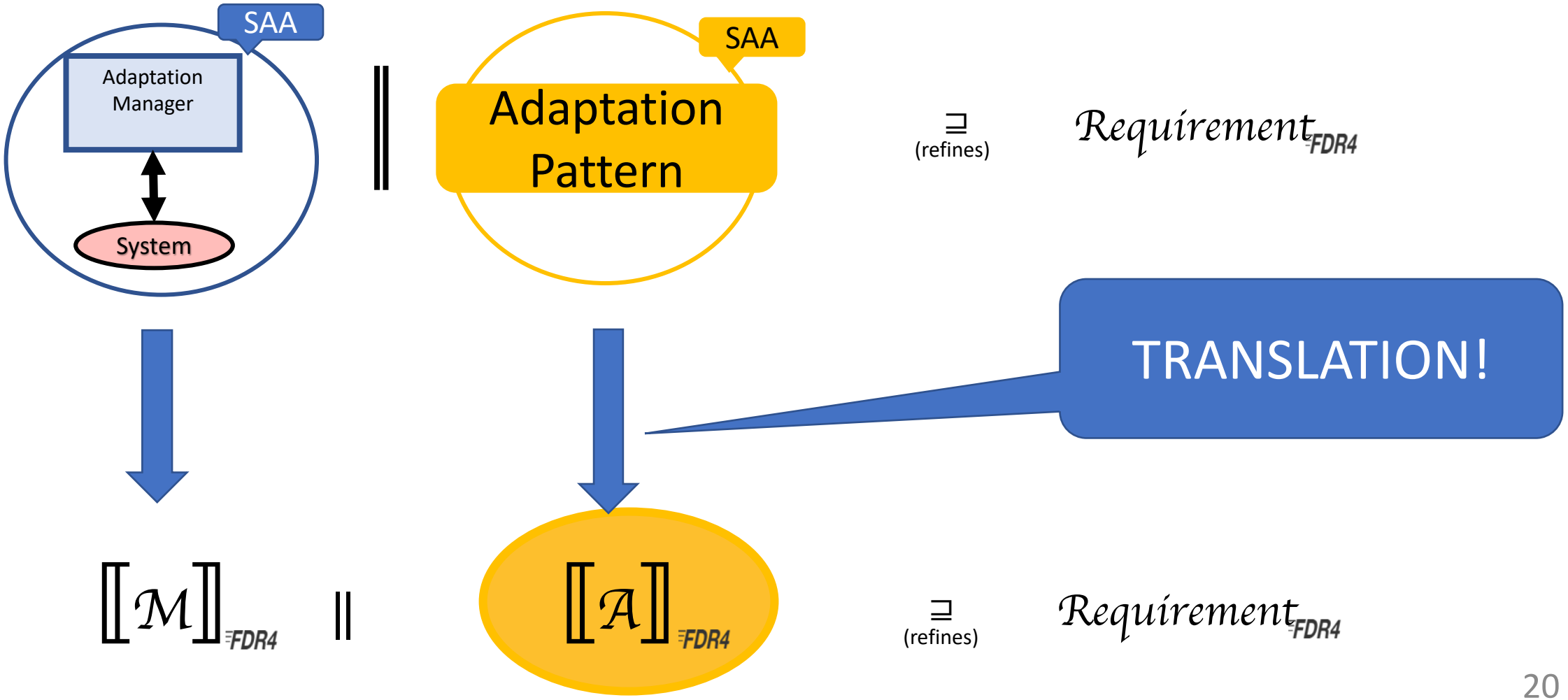
Self-Adaptive System



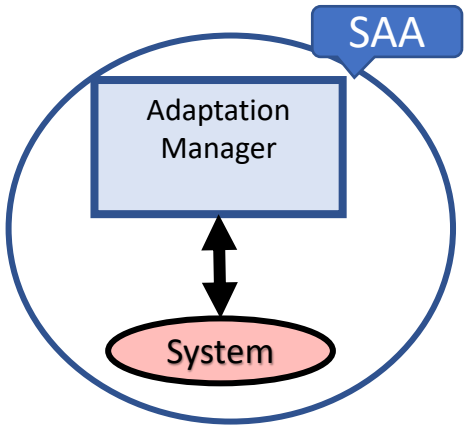
Verifying Adaptation Patterns

Translation to FDR (a refinement-based verification tool)

Refinement-based Verification



Refinement-based Verification



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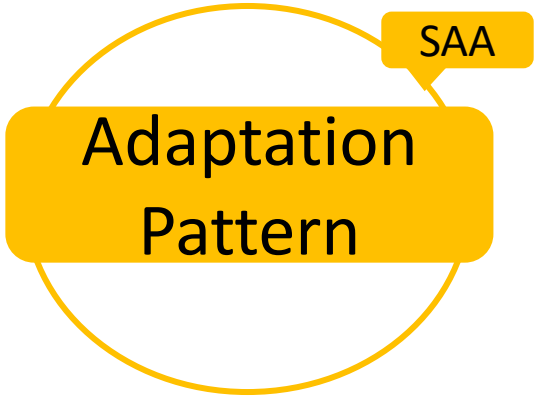
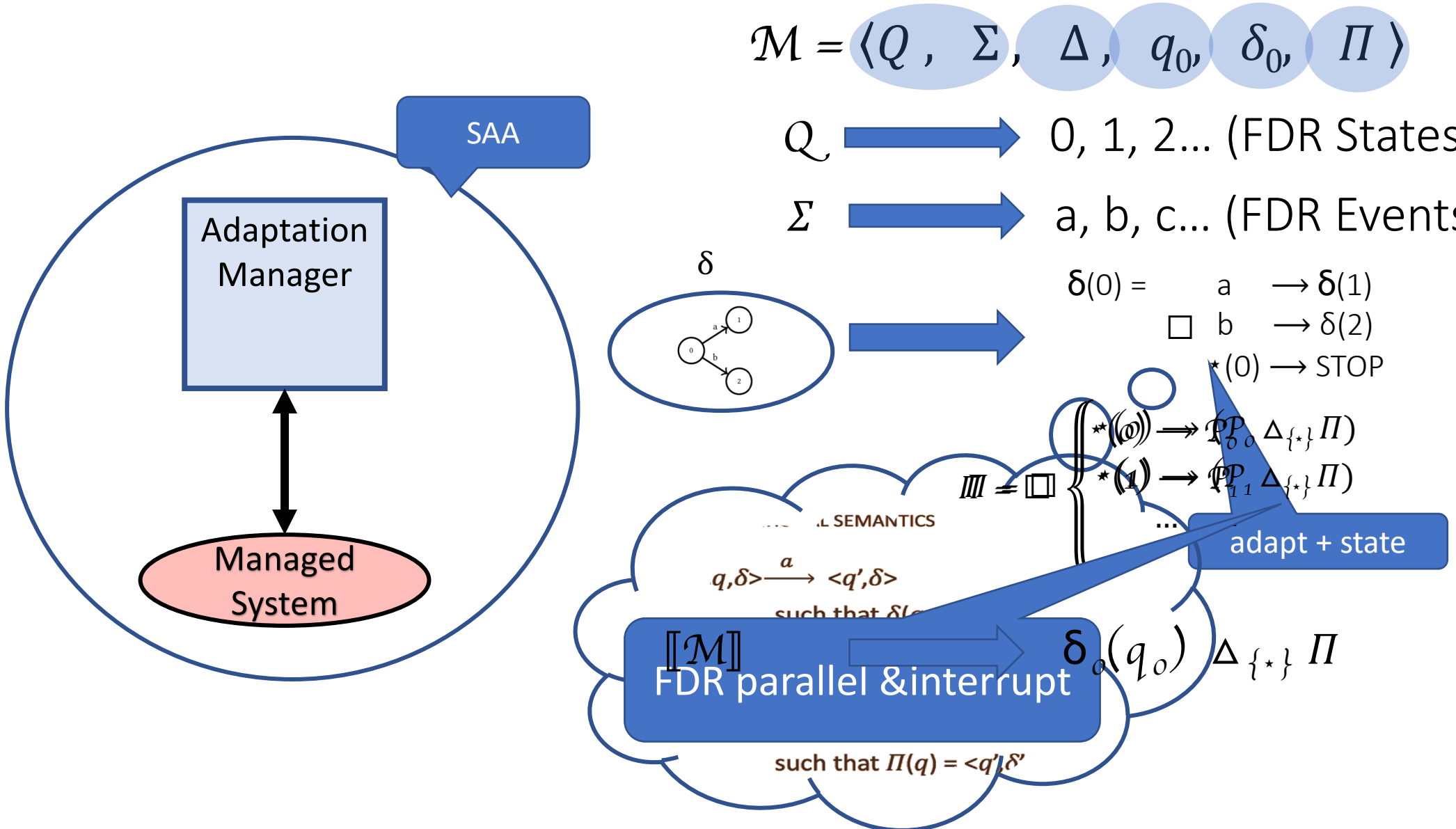


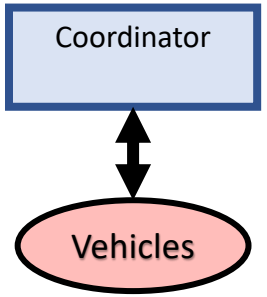
Translation is a bisimulation

$[\![\mathcal{M}]\!]_{FDR4}$ $\|$ $[\![\mathcal{A}]\!]_{FDR4}$ $\sqsupseteq$ (refines) $Requirement_{FDR4}$

Translation: SAA ⟶ FDR



Verifying different Adaptation Patterns



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	Event-Triggered	~~Time-Triggered (3 steps)~~	Time-Triggered (3 steps)
No Collision FDR4	😊	☹	😊
Vehicles Stay In Area FDR4	😊	☹	😊
Search All Area FDR4	😊	☹	😊

Expressivity of SAA

Model: Self-Adaptive Automata

SAA $\stackrel{\text{def}}{=} \langle Q, \Sigma, \Delta, q, \delta, \Pi \rangle$

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Π : Adaptation Function
$Q \rightharpoonup Q \times \Delta$

Operati

<q,δ

such that $\delta(q, a) = q'$

Sets of States Q and Transition Functions Δ are **fixed**

<q,δ> $\longrightarrow$ <q',δ'>

such that $\Pi(q)$ = <q',δ'>

SAA vs other self-modifying Models

SMFA [Schutt et al 1994]

+ Compact representation of dynamic behaviour
+ Add significant expressivity to base Model
- No verification tools

SAA

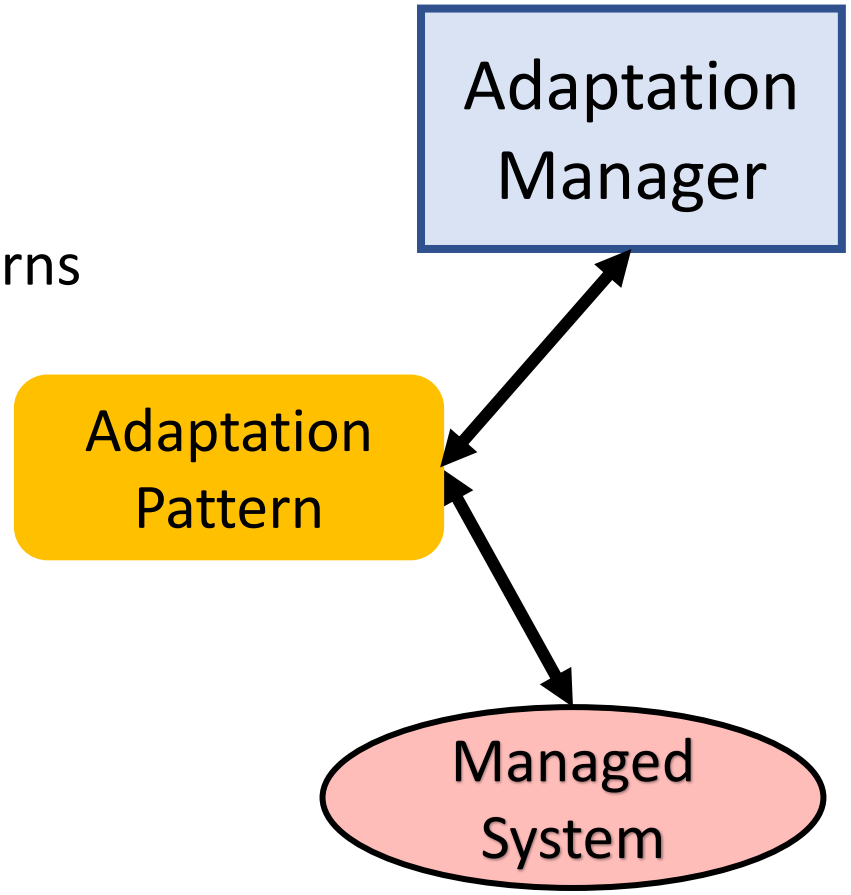
+ Compact representation of dynamic behaviour
- Does not add expressivity to base Model
+ Leverage existing verification tools

Proven through a bidirection Translation to Execution Monito (see paper)

Translation to FDR

Conclusion

- High-level Model for Self-Adaptive Systems
  - **Modularizes** Adaptation patterns
  - Enables **experimentation** with Adaptation Patterns



- Leverage existing verification technologies
  - Enables **verification** of Adaptation Patterns

- Future Work: improve usability, use other verification technologies

Thank you!

Questions?