Integrating BDI Reasoning into Agent Based Modelling and Simulation

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Outline

1. Motivation
2. Belief Desire Intention (BDI) Agents
3. Framework
4. Interaction and Synchronisation
5. Conclusion

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Policy and Planning

Many policy and planning tasks benefit from exploration via simulation.

Modelling of Human Behaviour

Need to model the behaviour of different people/roles.

- Humans are reactive - but not entirely.
- They typically have goals and plans that extend over a period of time.
- They make and adjust decisions based on the unfolding situation.
- They know what they have been doing and why - this is part of what they do next.
- The BDI agent paradigm captures these aspects well.

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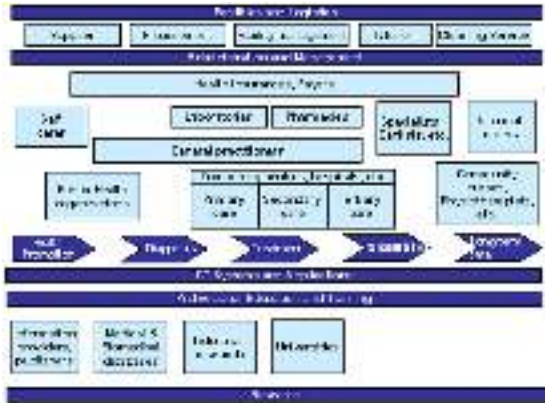
BDI Agent Systems Useful in Many Applications

Unmanned (Aerial) Vehicles

Logistics



E-Health

Trading Agents

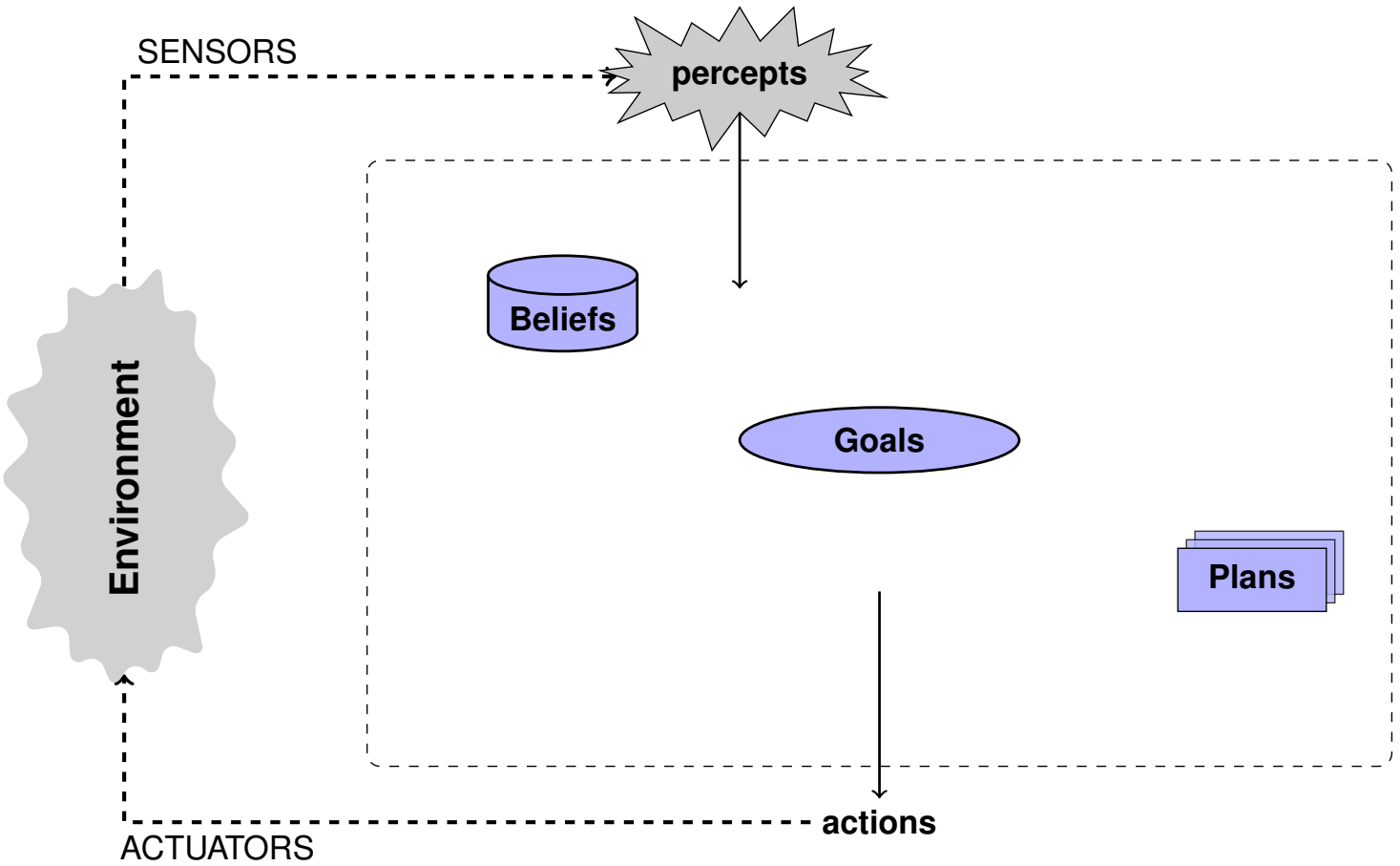
Air Traffic Control

BDI (Belief Desire Intention) agents have been used in many successful applications in complex environments.

BDI Agent Oriented Programming

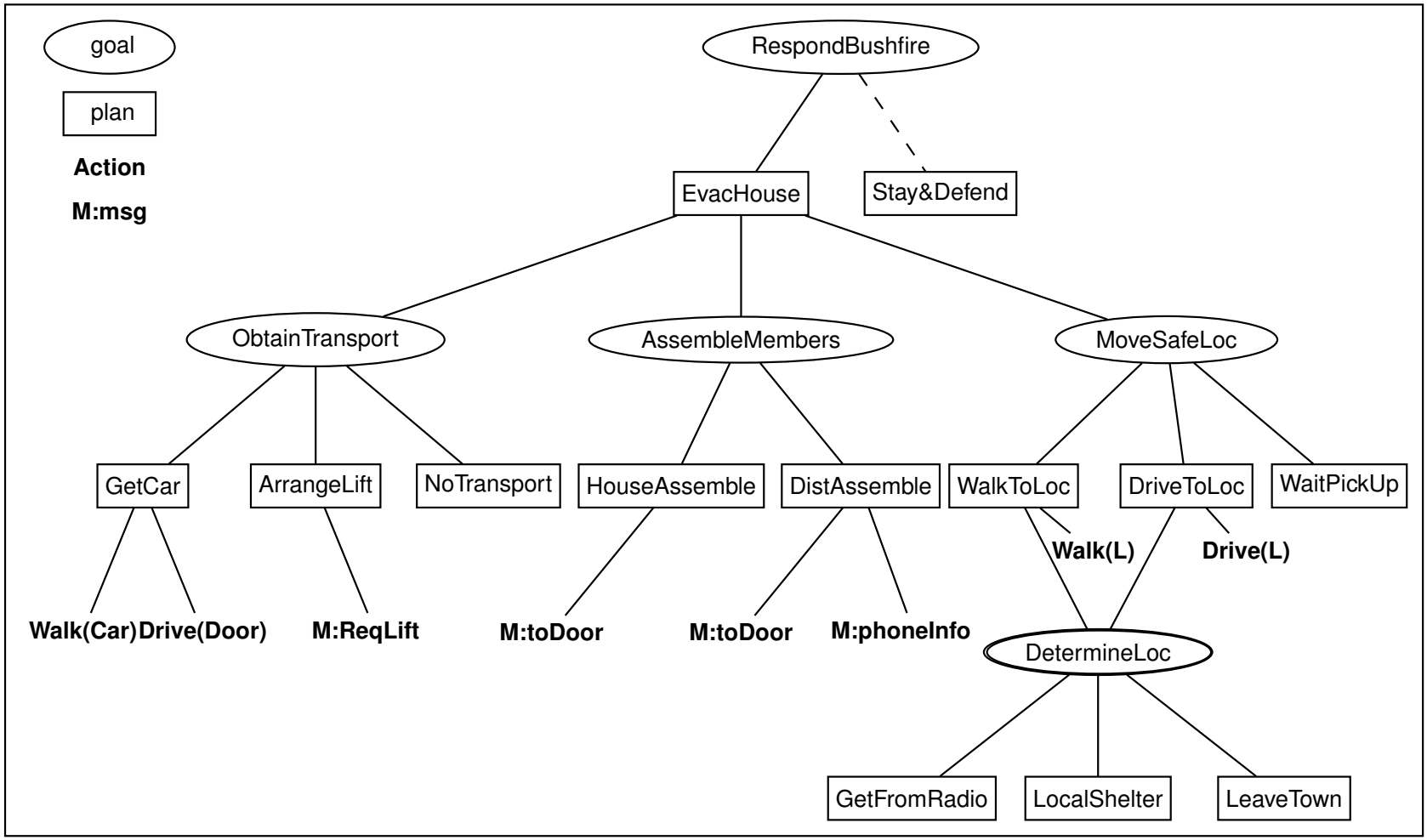
- BDI Agent-Oriented Programming provides abstraction at the level of mental attitudes to explain the operation of a system. Beliefs, Desires, Intentions.
- The modularity of plans makes it easy to develop complexity incrementally.
- The goal oriented approach makes it suitable for use in dynamic environments.
- Many efficient and powerful development environments available. JACK, Jadex, Jason, PRS, 2APL, ...
- BDI agent programs are fast to develop. A 2006 study showed:
  - Gain compared to Java programming 500%.

Belief-Desire-Intention (BDI) Agent Architecture



Percepts in, actions out. Internally, beliefs, goals and plans.

Example Plan Structure



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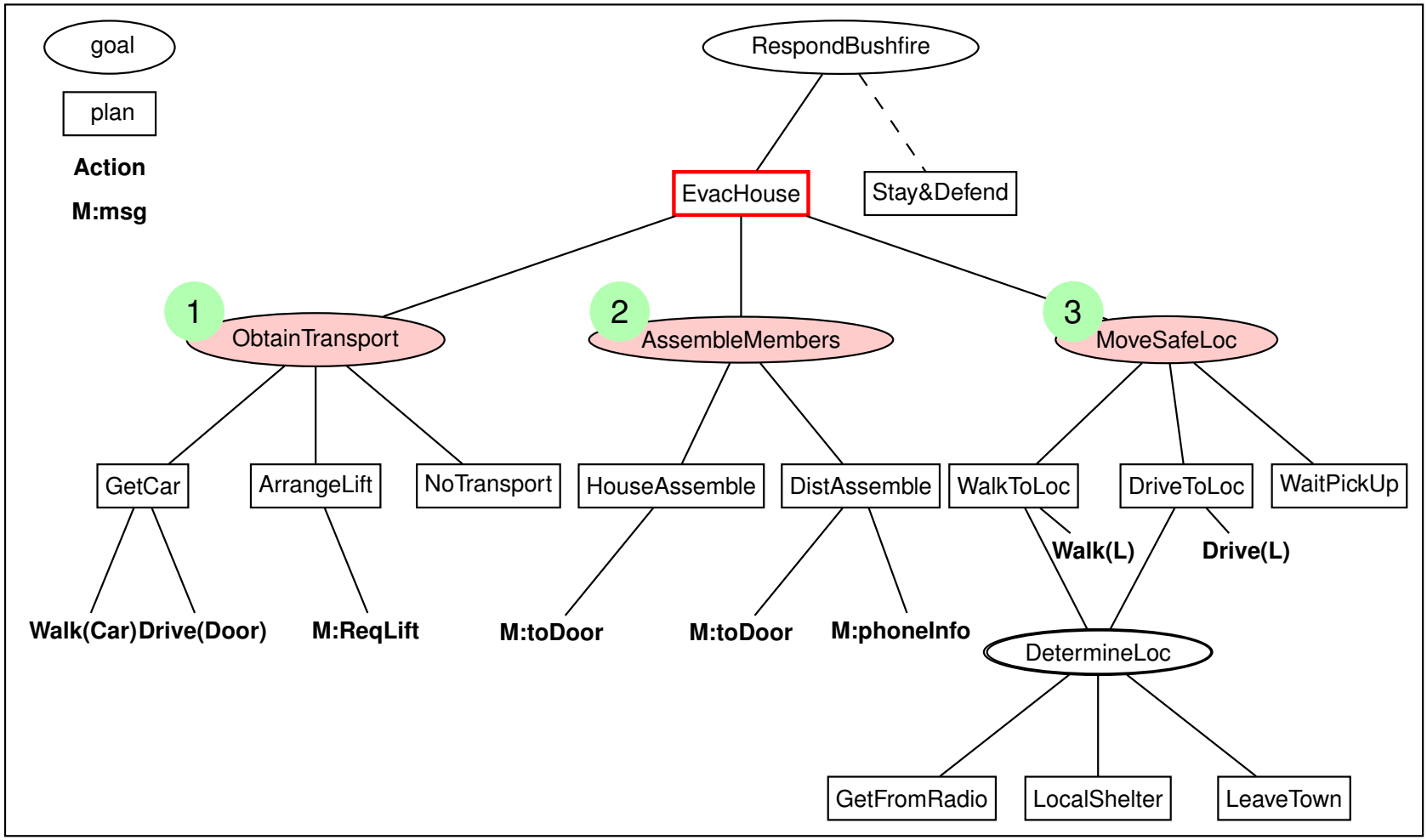
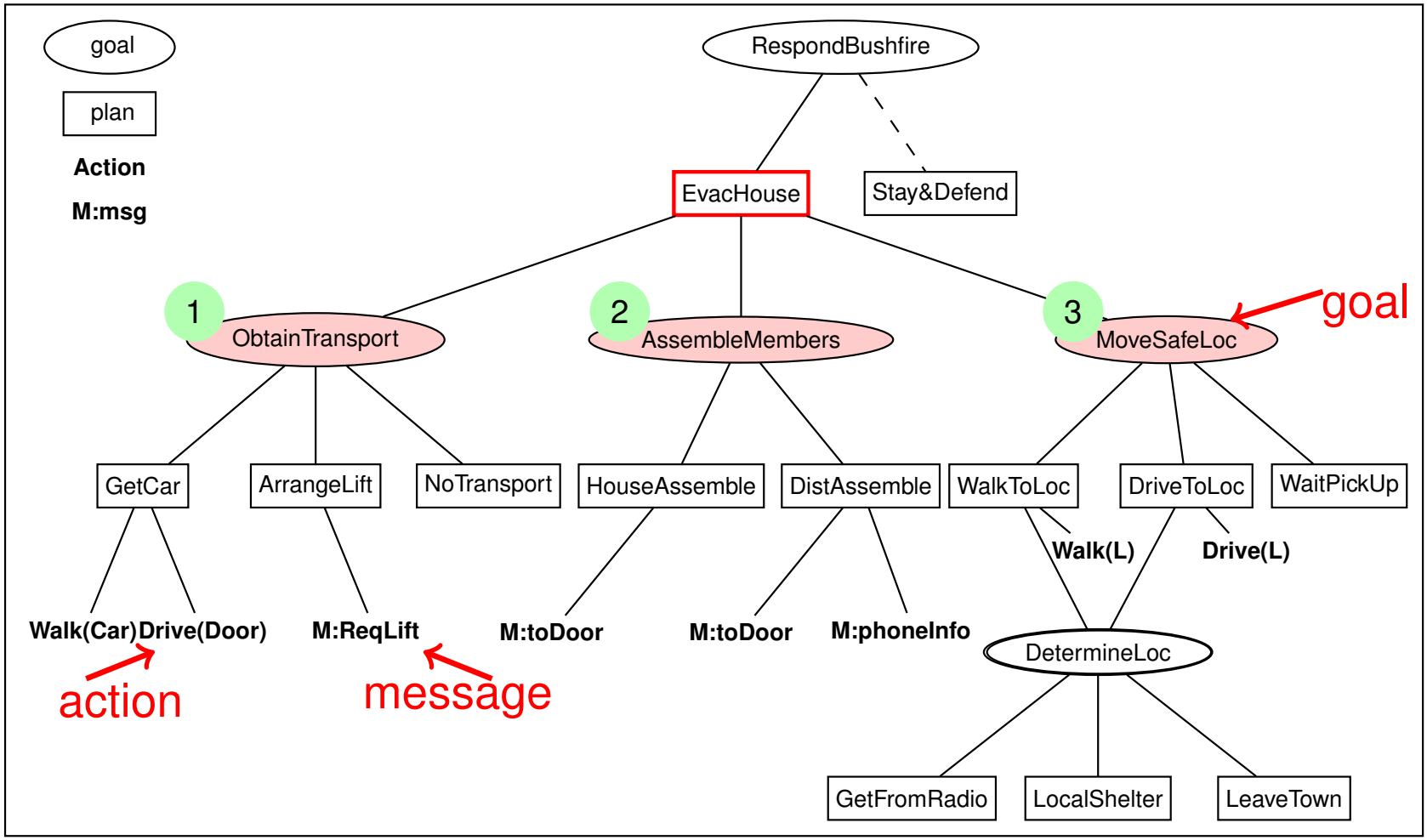


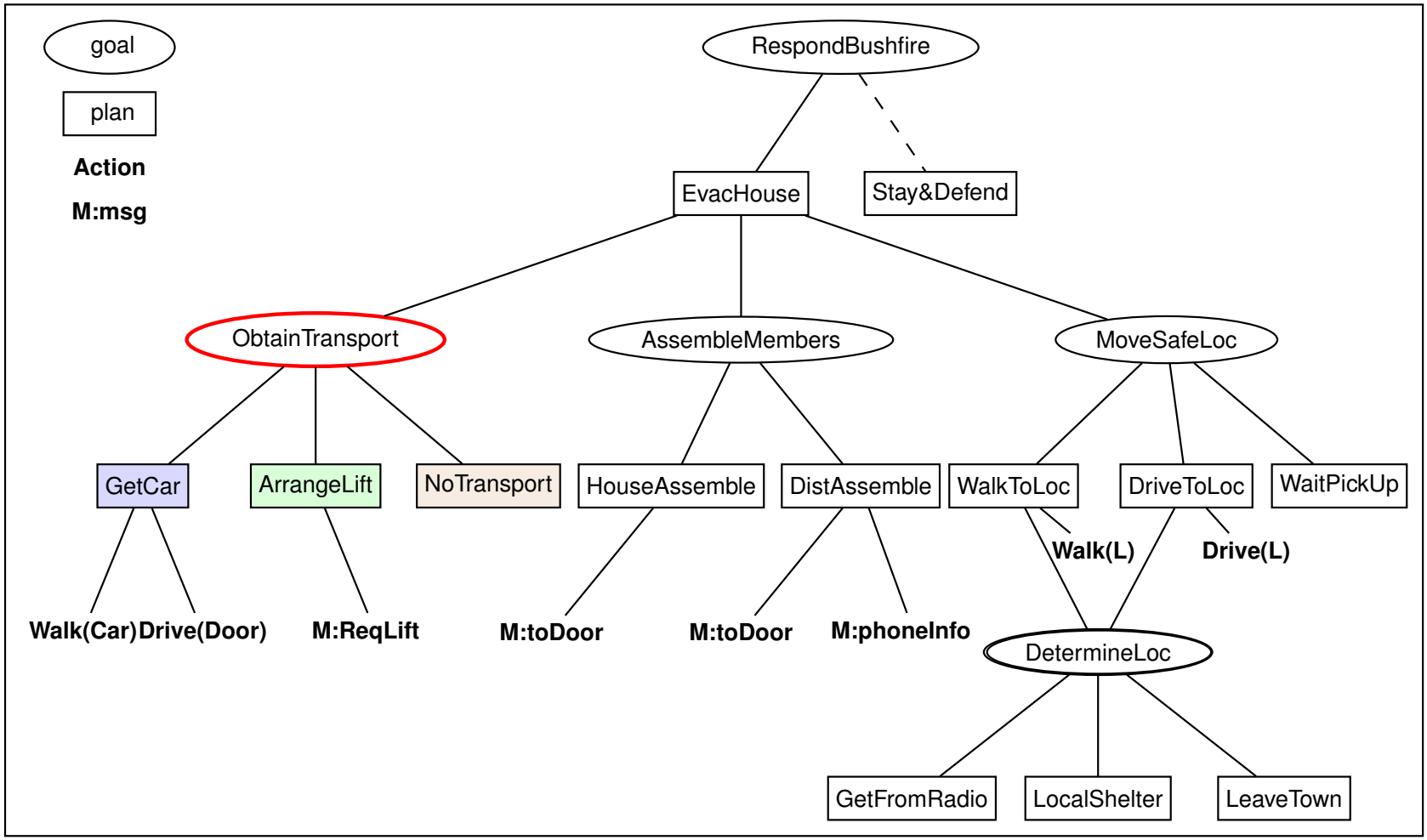
A plan is a sequence of steps

Example Plan Structure



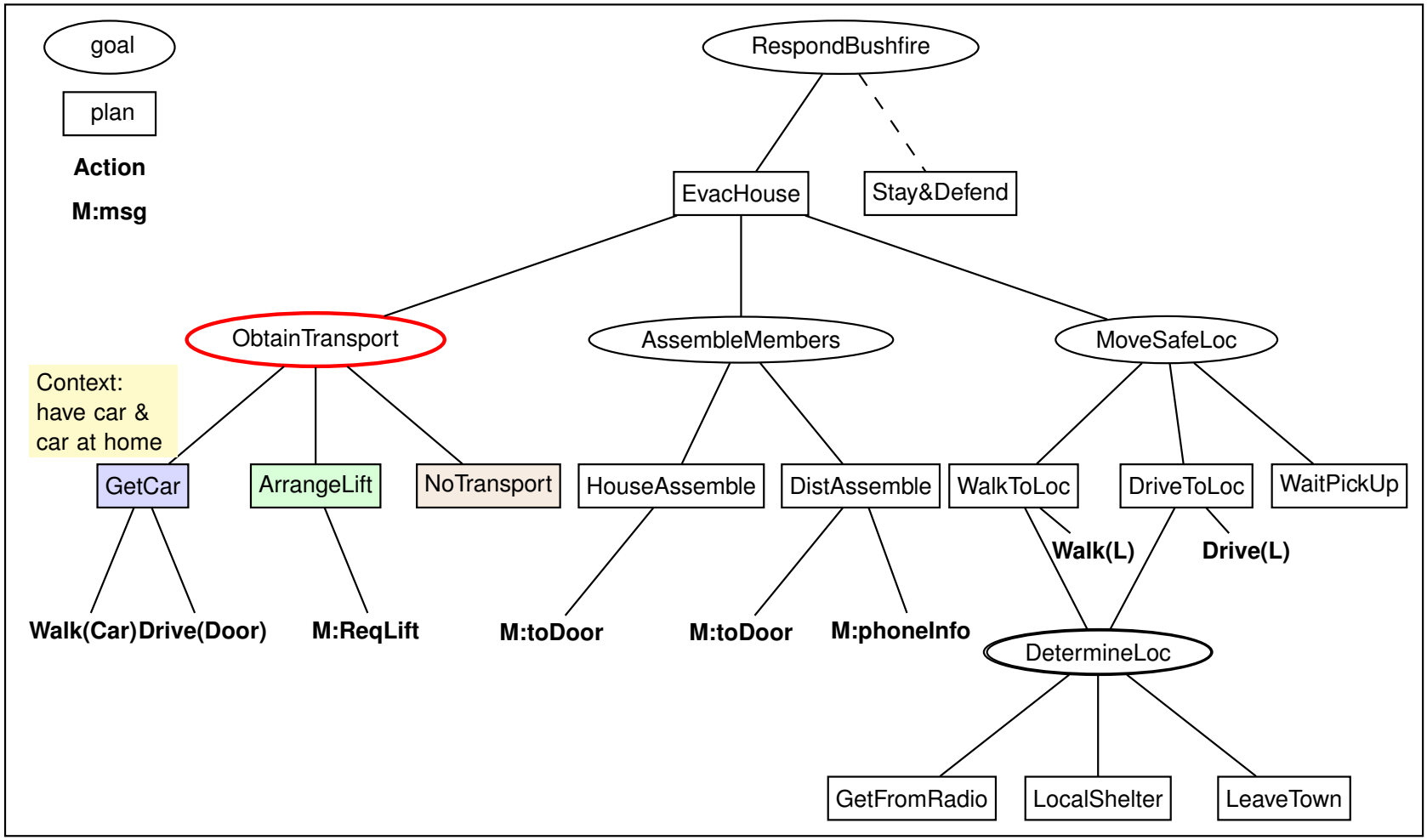
A step can be a goal, an action, a message to another agent, or some computation.

Example Plan Structure



A goal may have different plans, for achieving it in different situations.

Example Plan Structure



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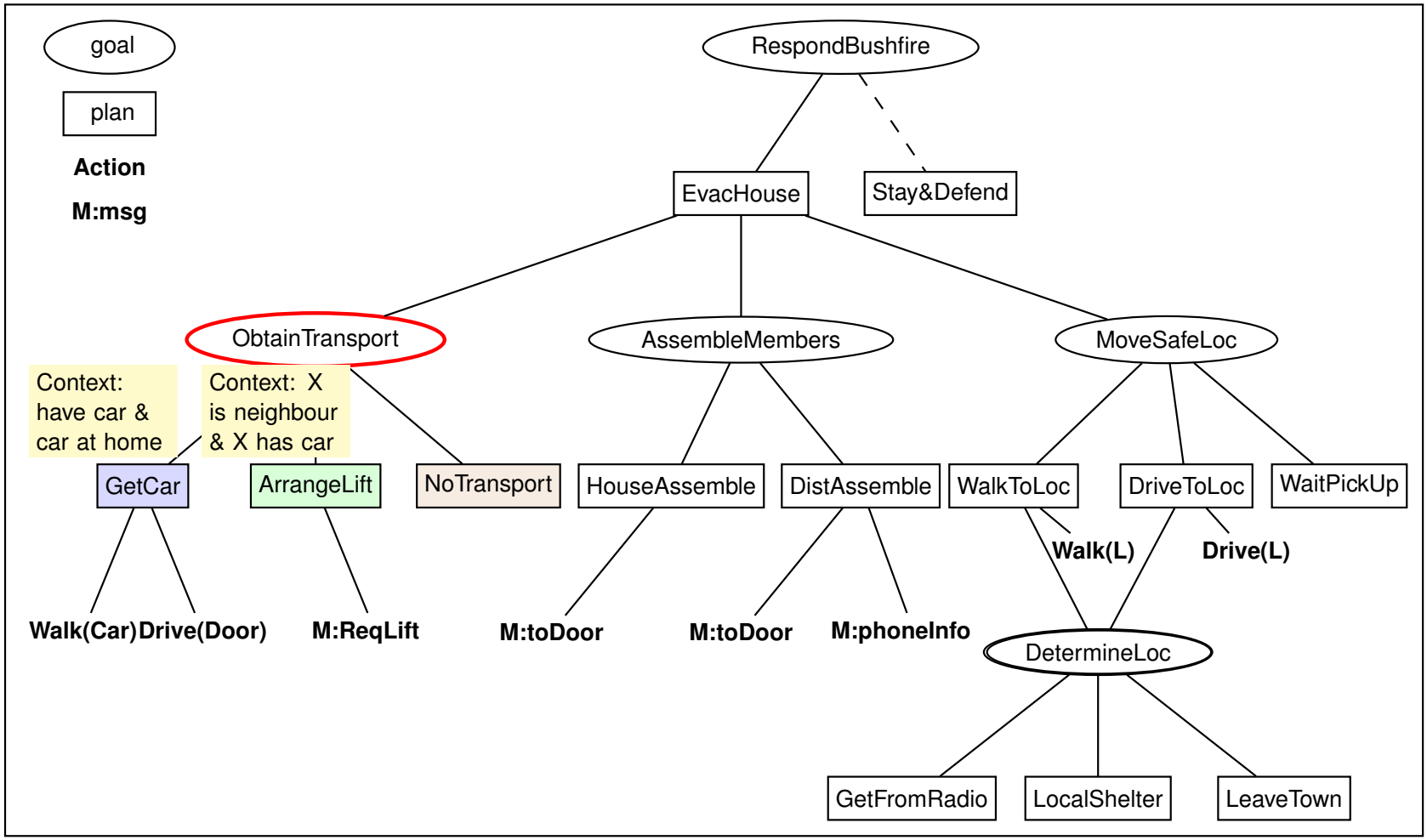

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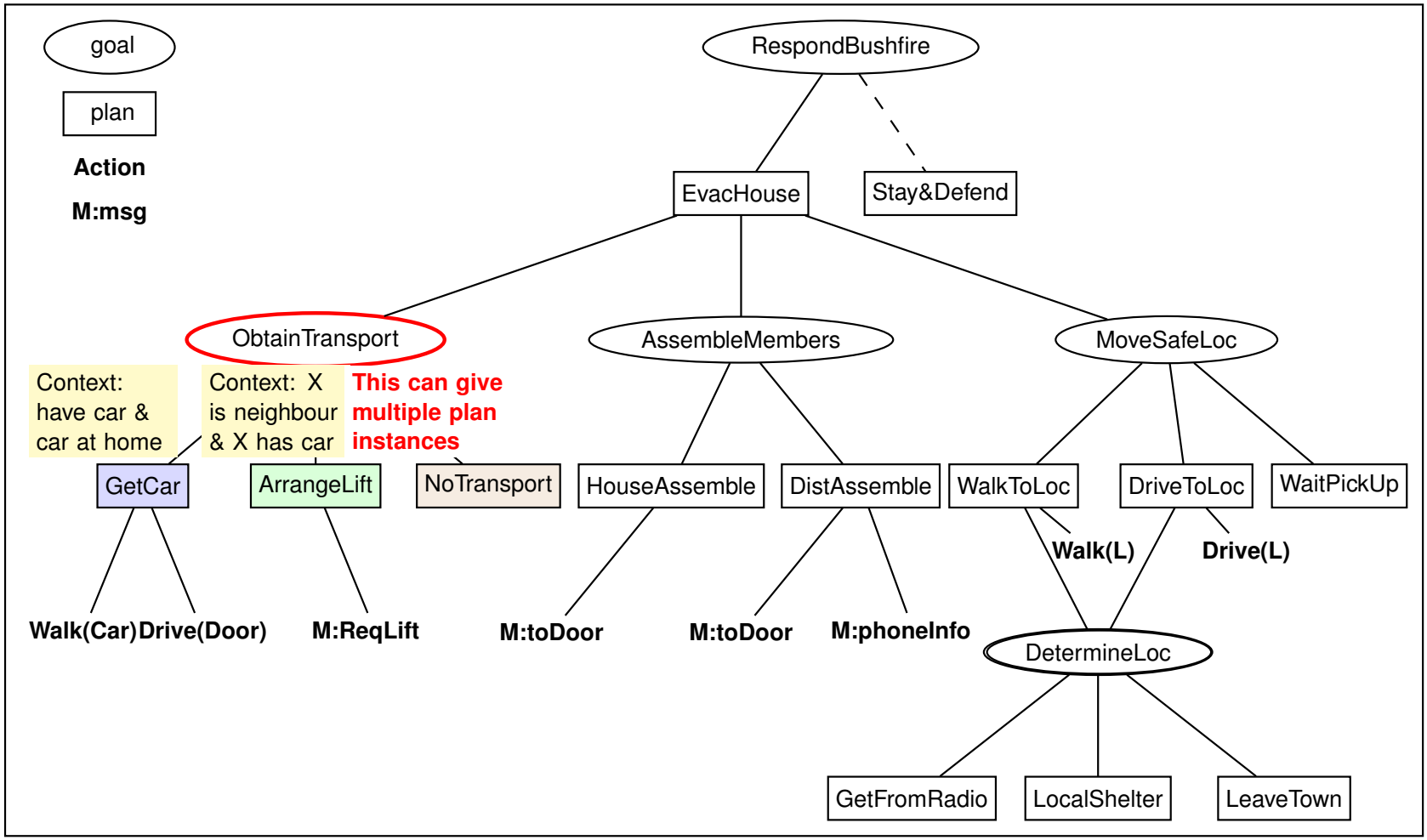

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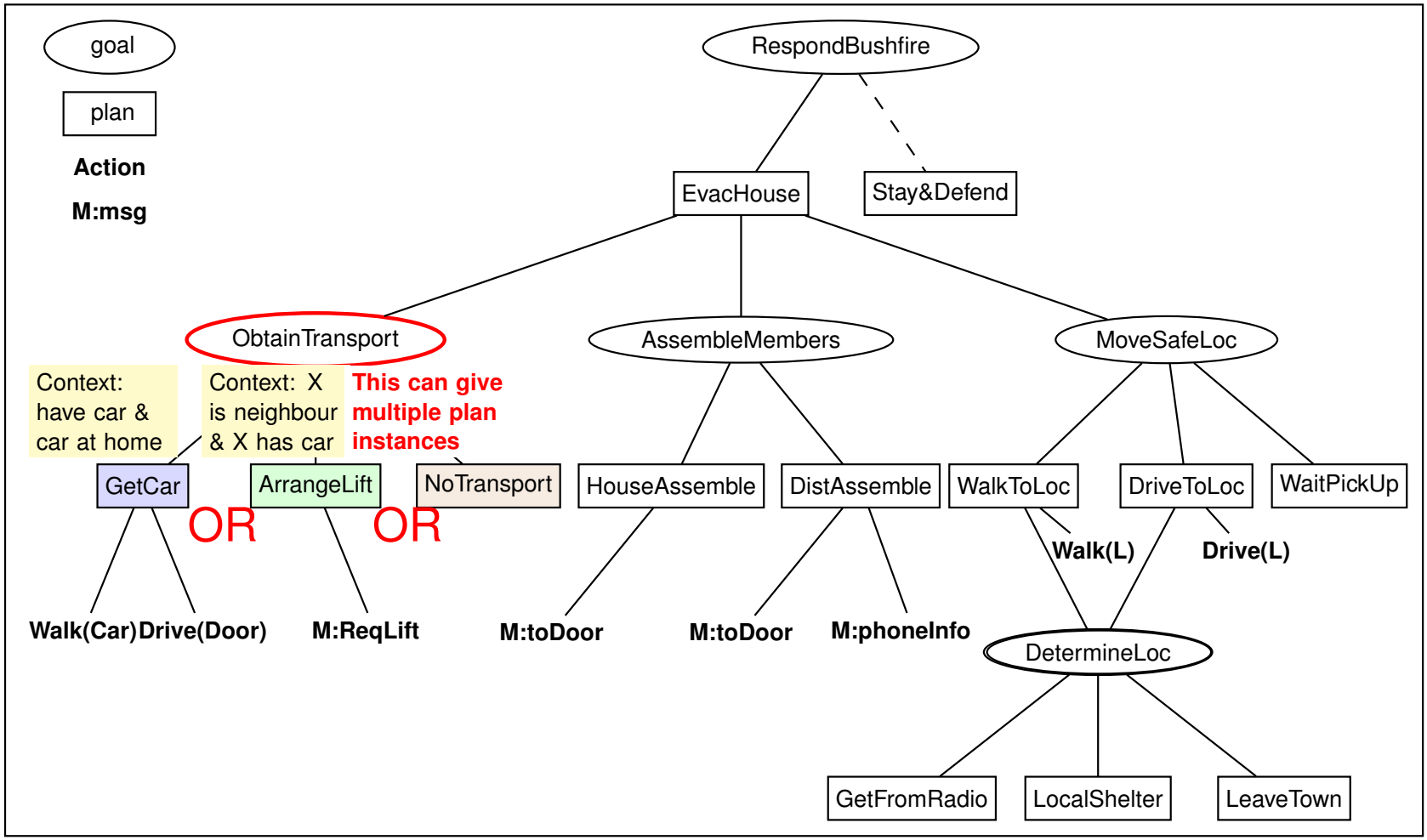
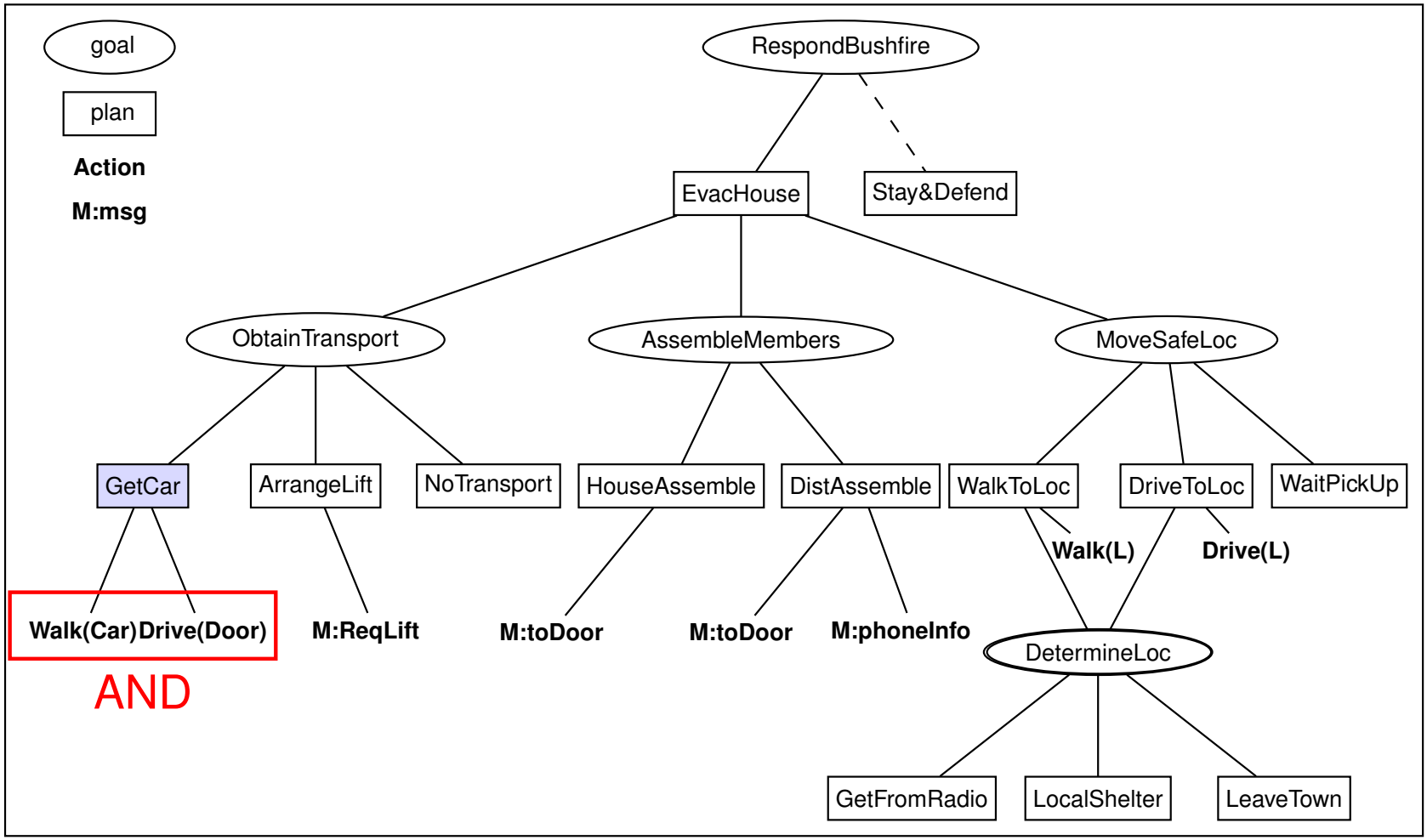


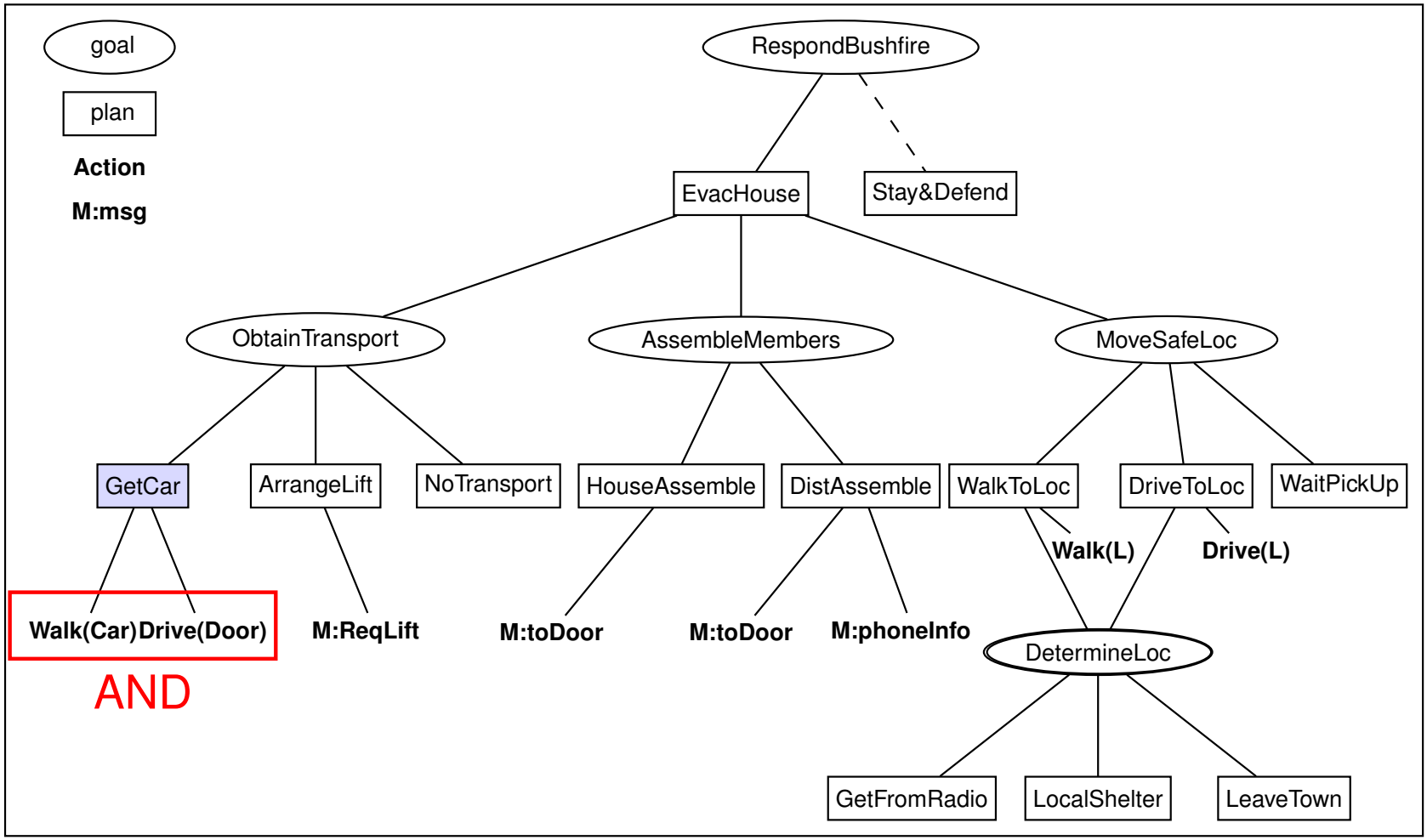
For a goal to succeed one of the plans must succeed. If one fails try another.

Example Plan Structure



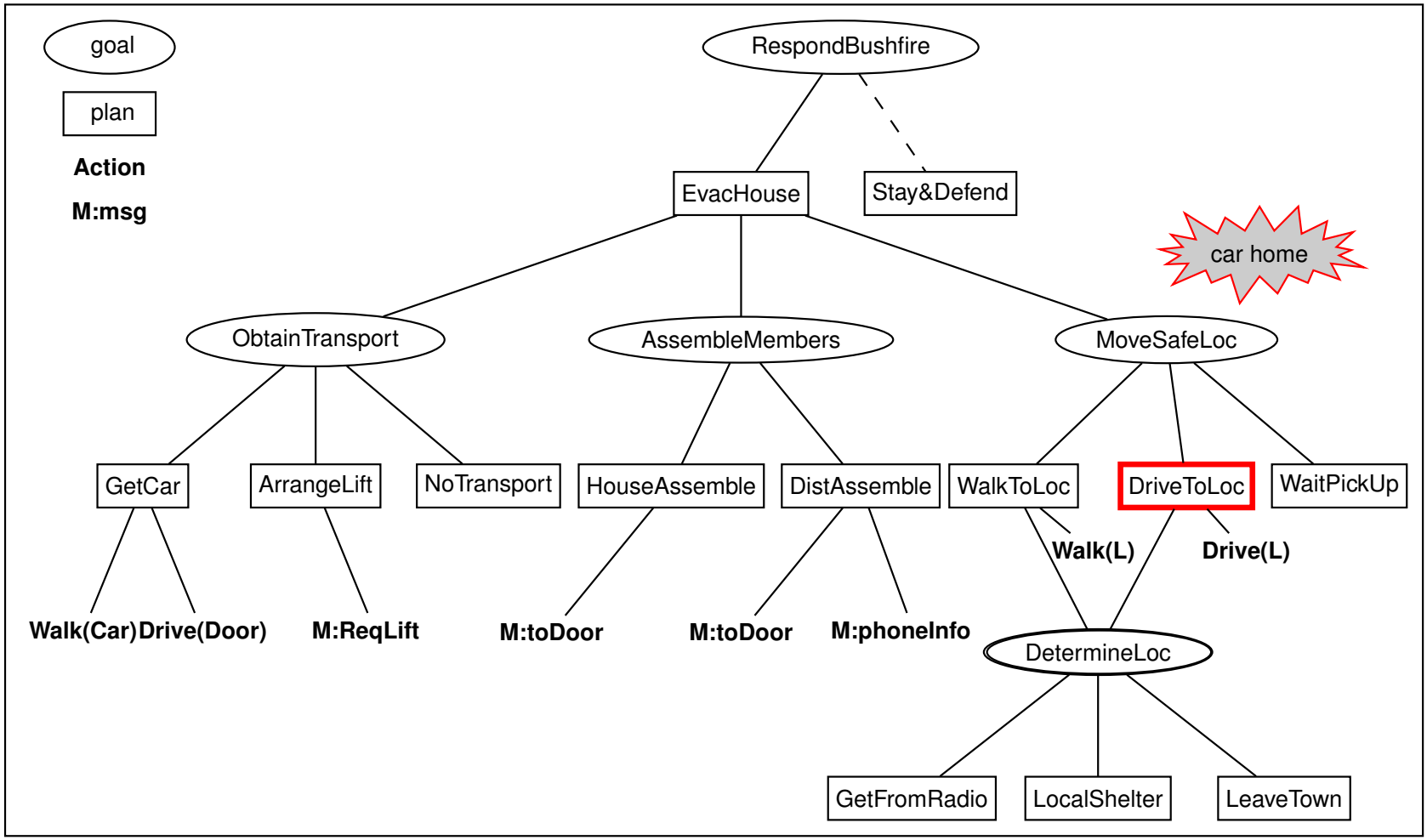
For a plan to succeed, all steps must succeed.

Example Plan Structure



If things fail, recovery happens as locally as possible

Example Plan Structure



Plan selection responsive to changing environment.

Advantages

- Intuitive representation
- Late selection: situation aware...
- Plan failure - retry new plan. Committed to choices, like humans.
- Agent is responsive to environmental changes.
- Huge number of options possible - over 2 million for modest tree. (Subgoal steps 4, Choices 2, Depth 3)

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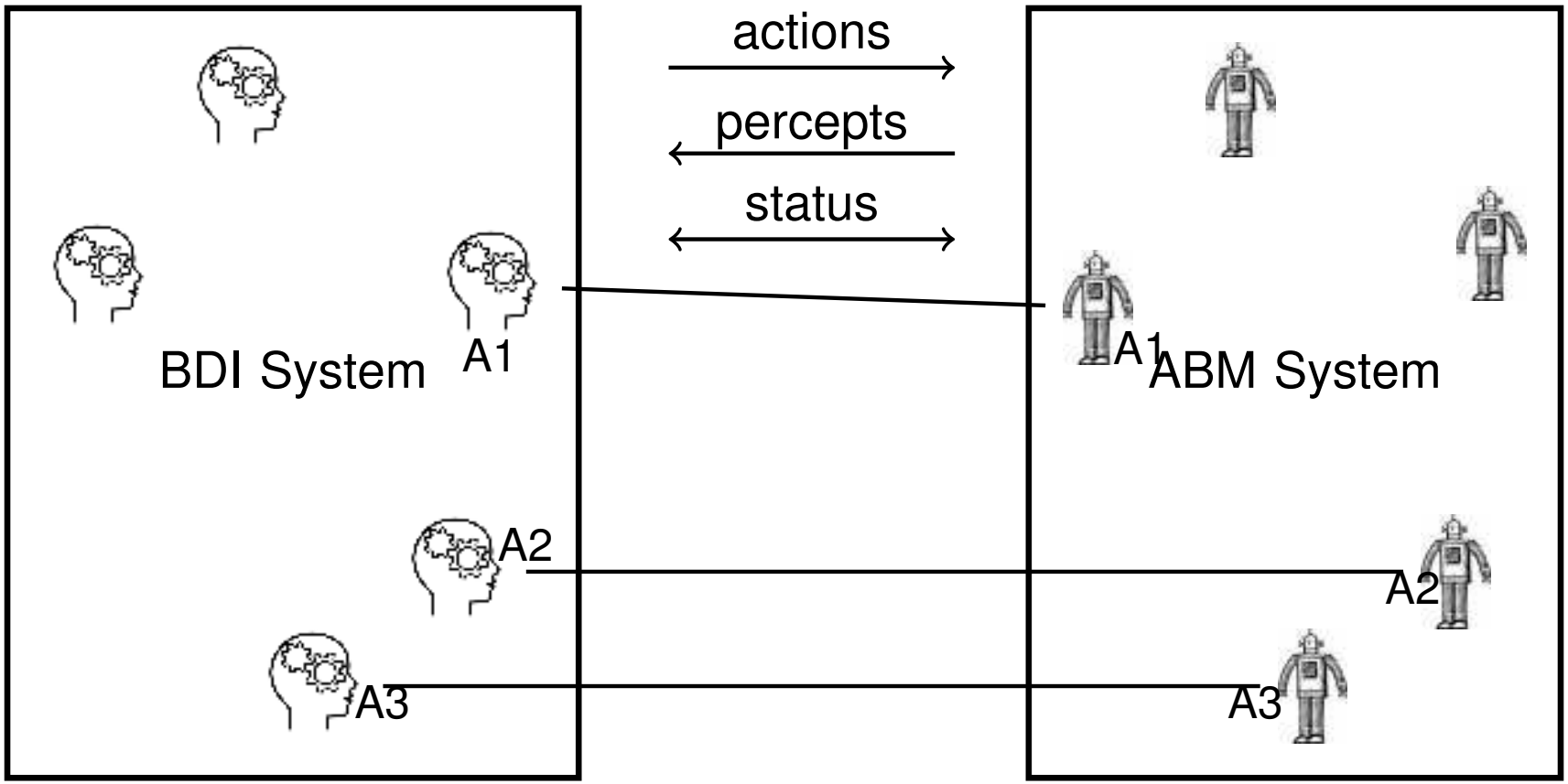
Framework Overview

Agent	Action	Status
A1	act2	initiate
A2	act3	initiate
A3	act1	initiate

Agent	Action	Status
A2		
A3	act1	



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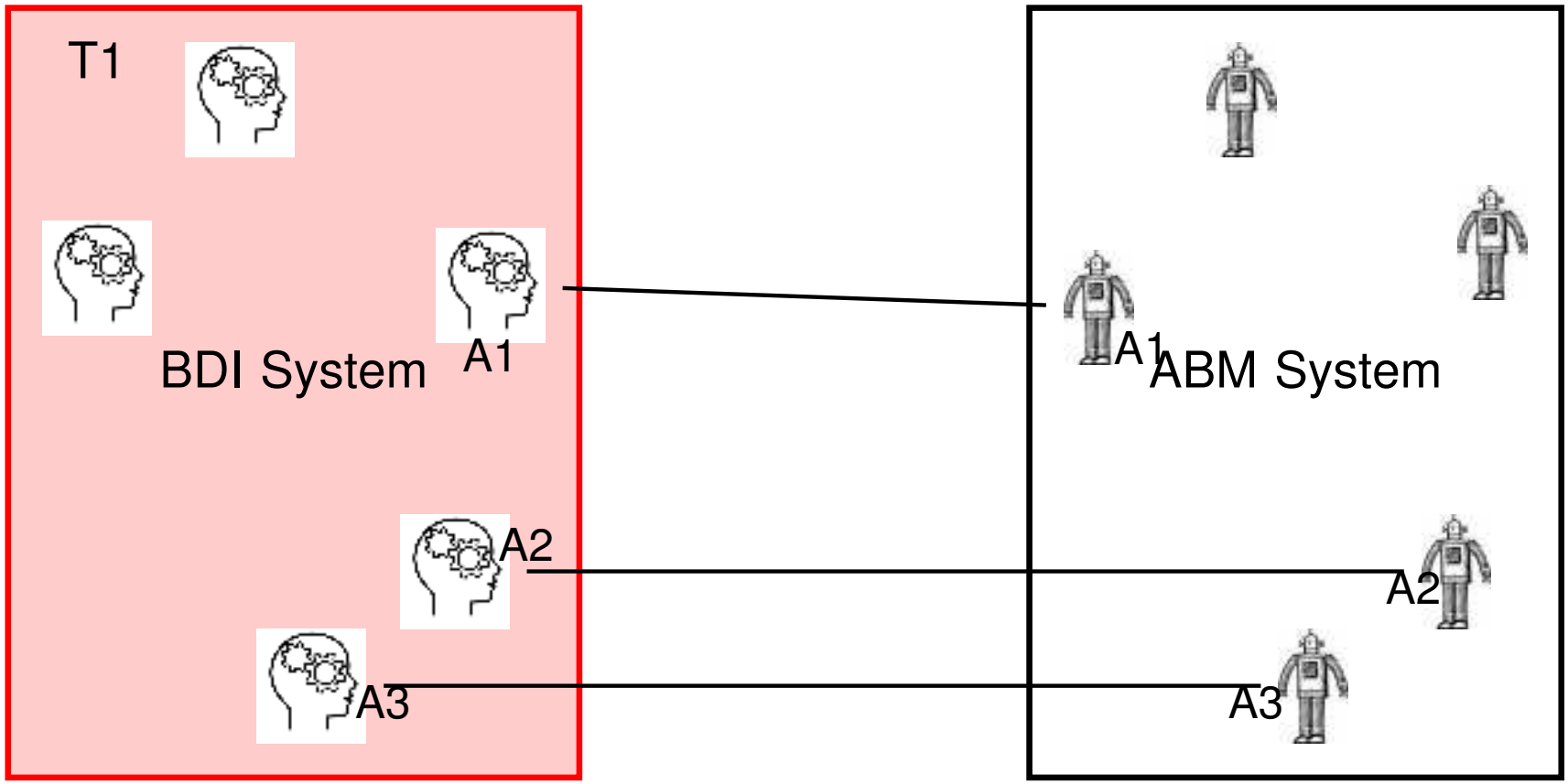

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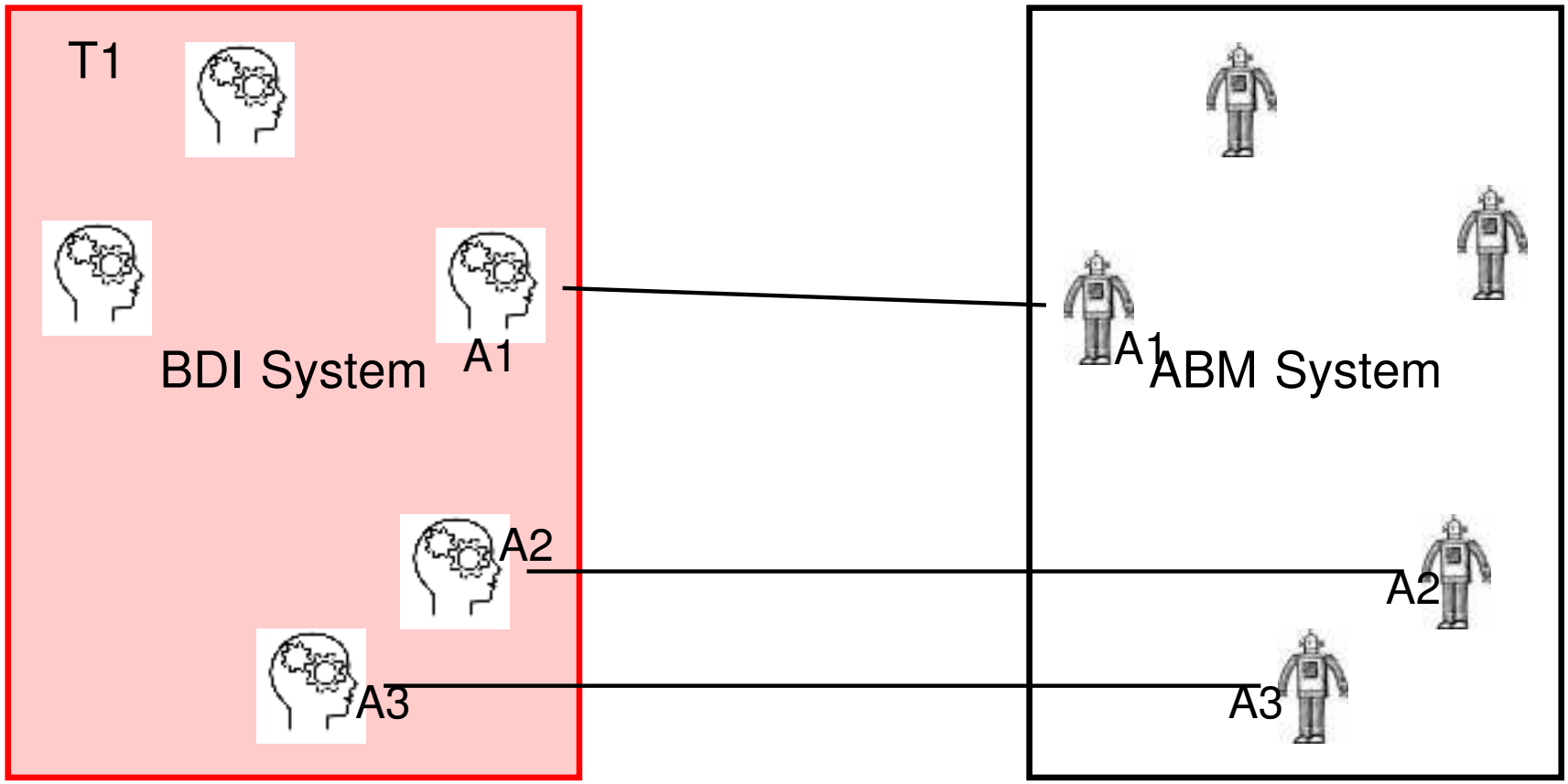
A3	act1	initiate



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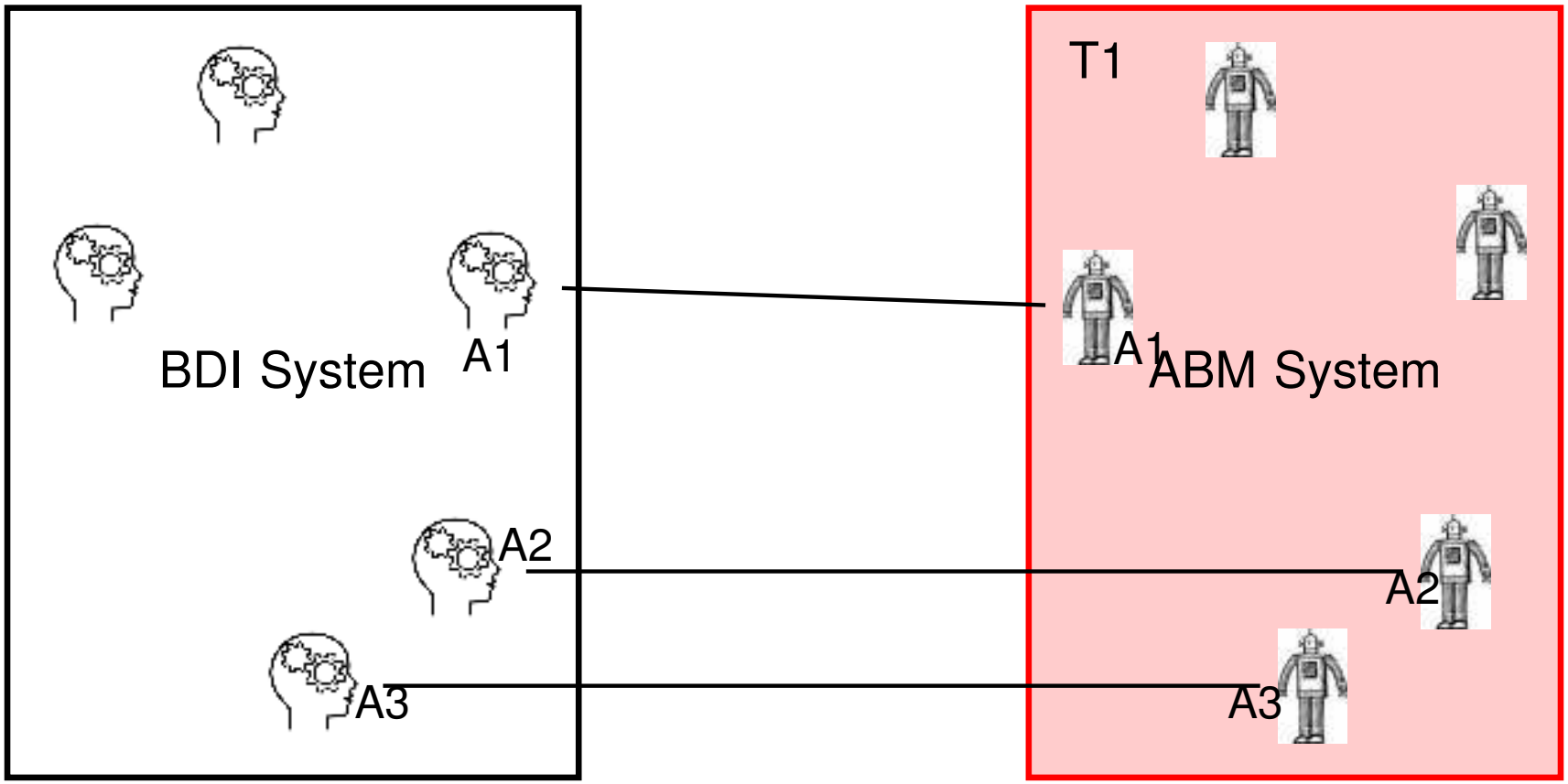
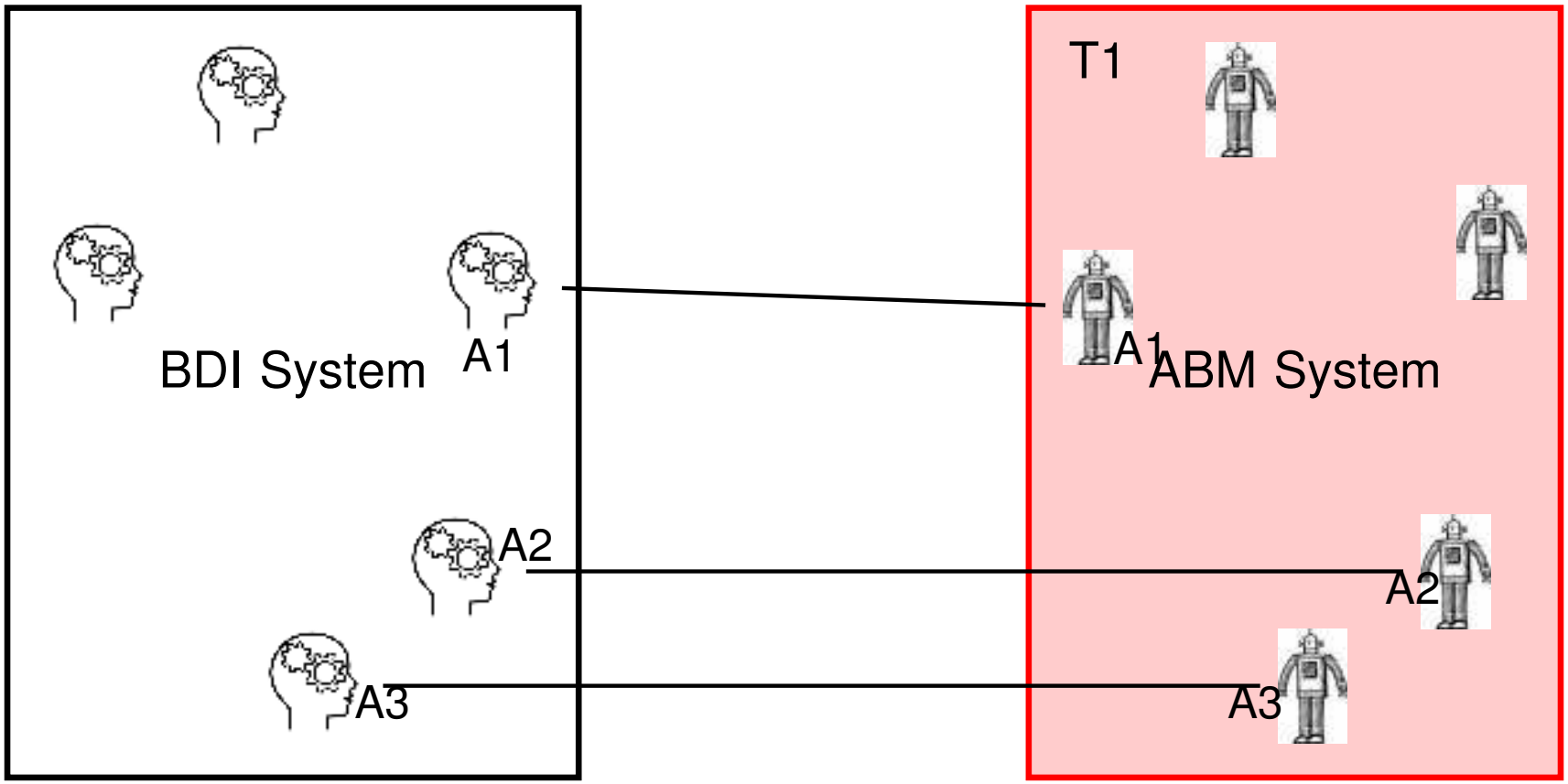


Framework Overview

Agent	Action	Status
A1	act2	initiate
A2	act3	initiate
A3	act1	initiate

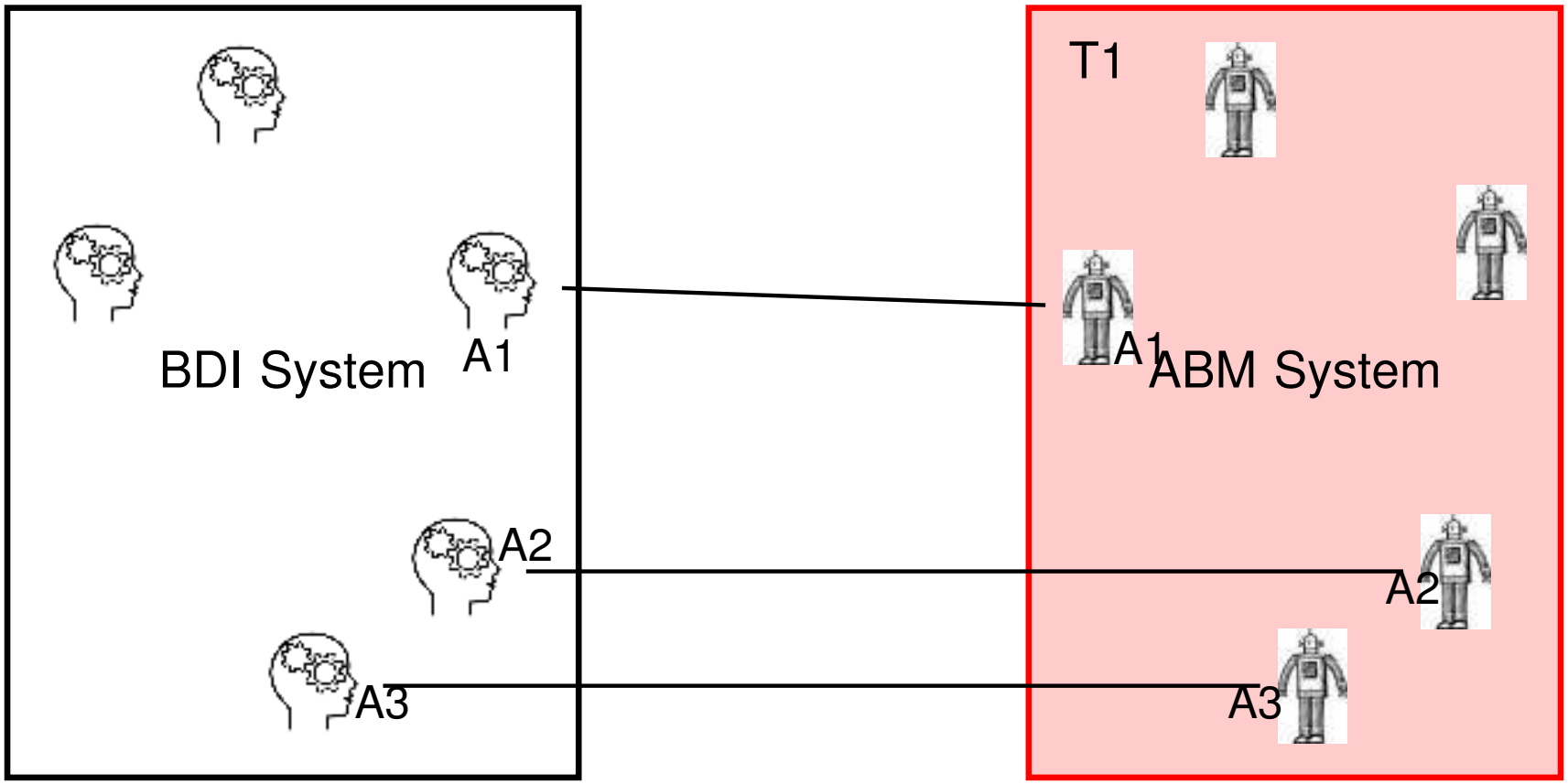
Agent	Action	Status
A1	act2	running
A2	act3	running
A3	act1	running



Framework Overview

Agent	Action	Status
A1	act2	initiate
A2	act3	initiate
A3	act1	initiate

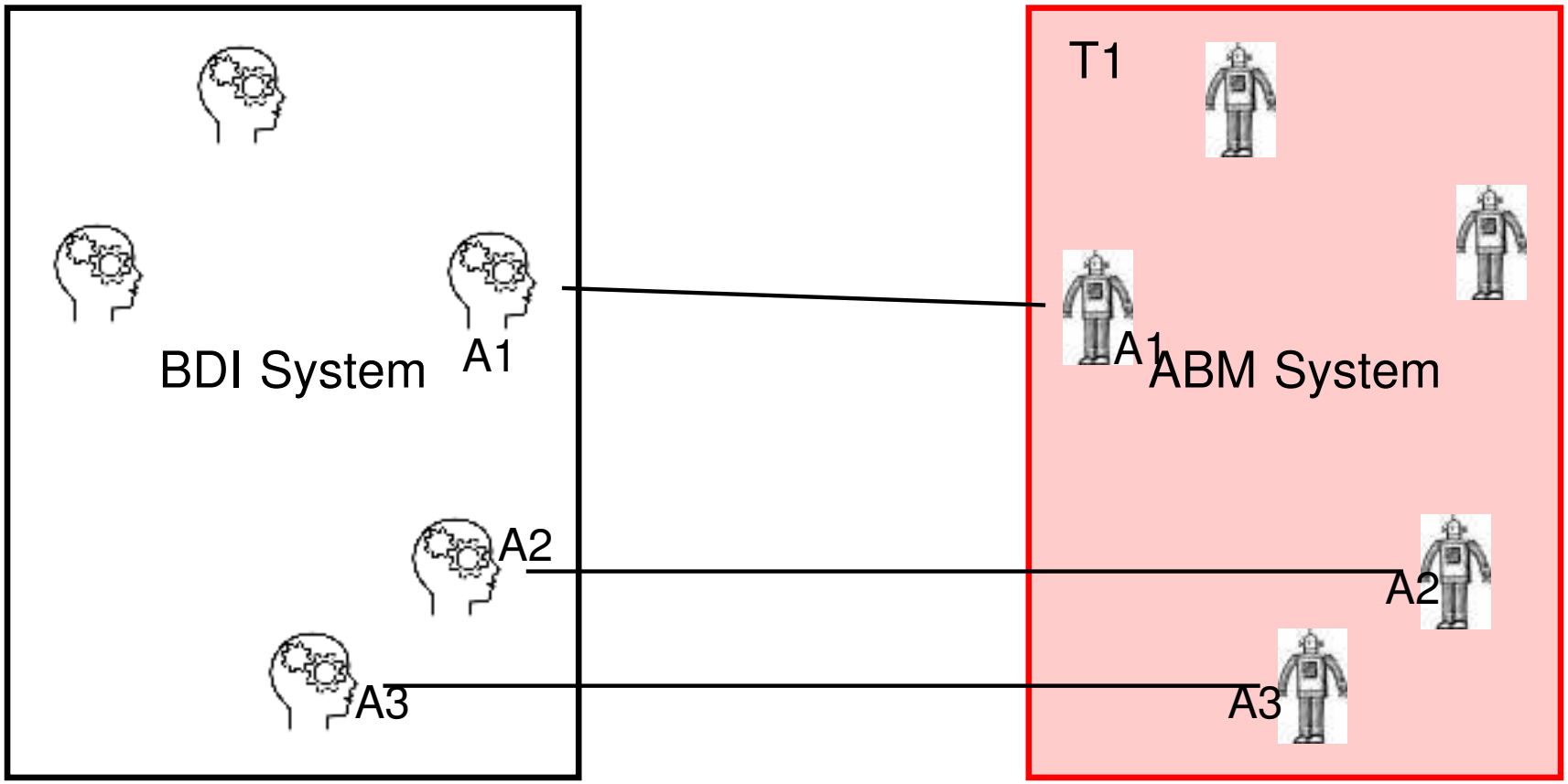
Agent	Action	Status
A1	act2	pass
A2	act3	running
A3	act1	running



Framework Overview

Agent	Action	Status
A1	act2	initiate
A2	act3	initiate
A3	act1	initiate

Agent	Action	Status
A1	act2	pass
A2	act3	fail
A3	act1	running



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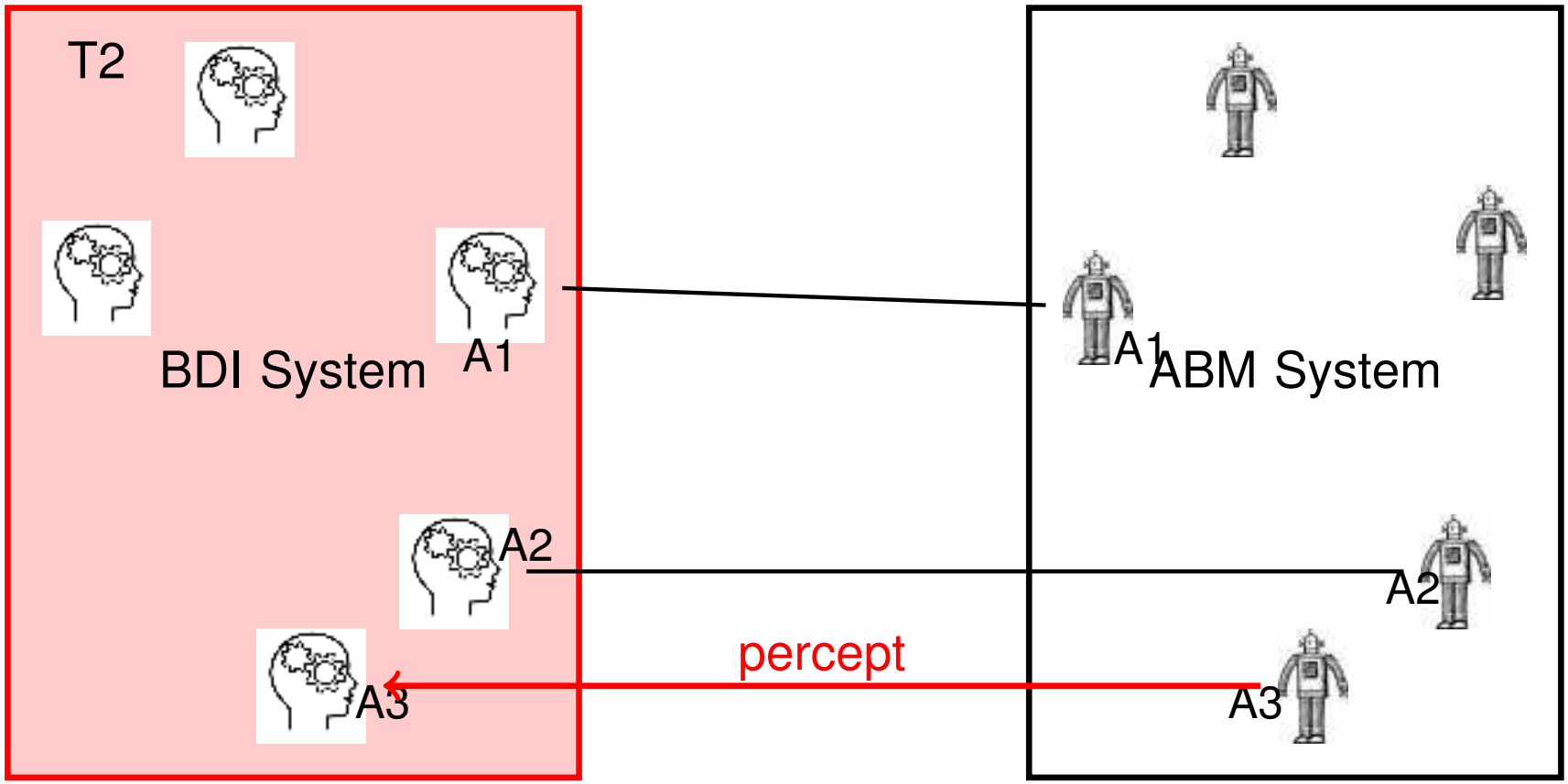
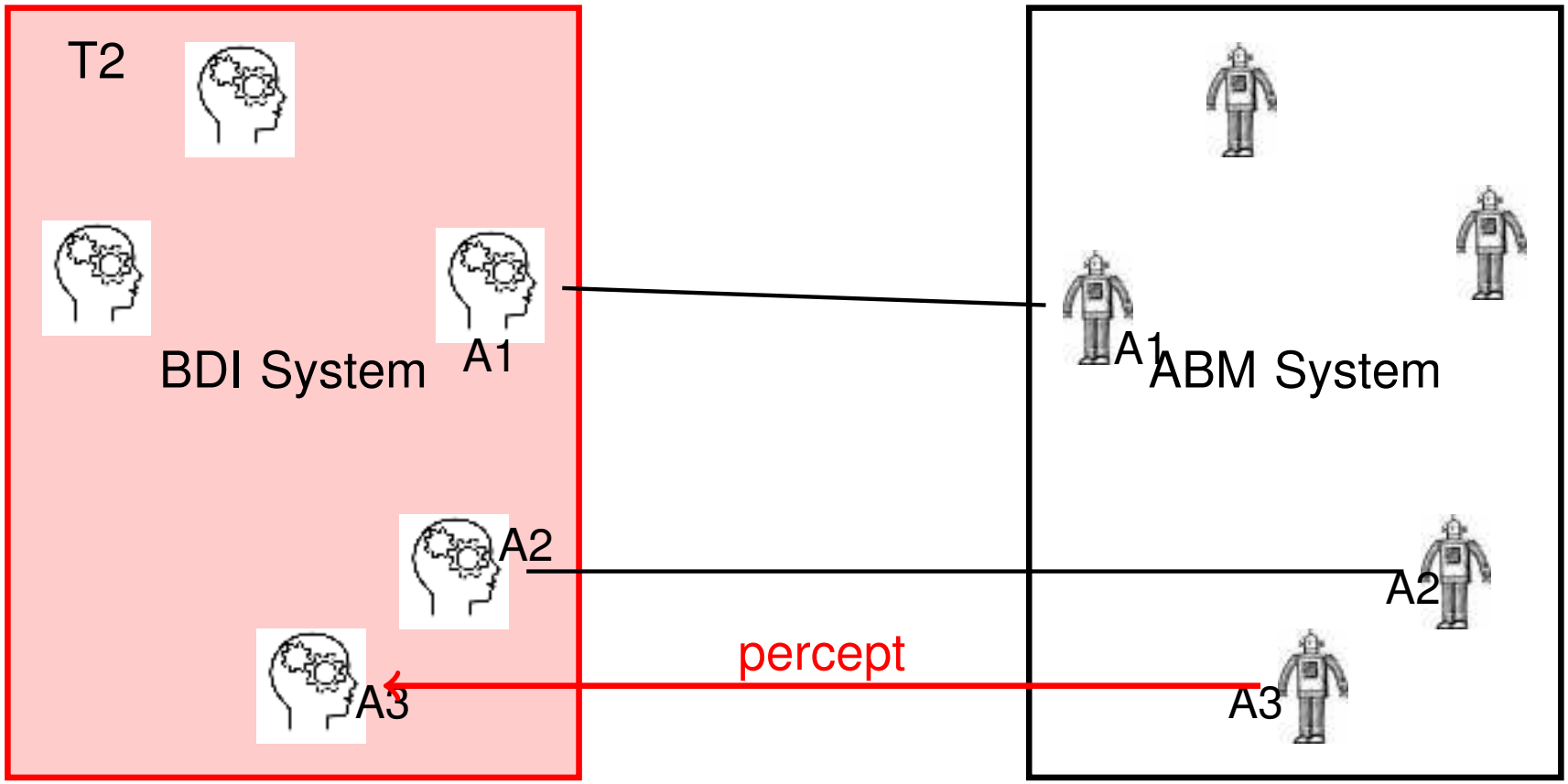


Framework Overview

Agent	Action	Status
A2	act3	fail
A3	act1	running

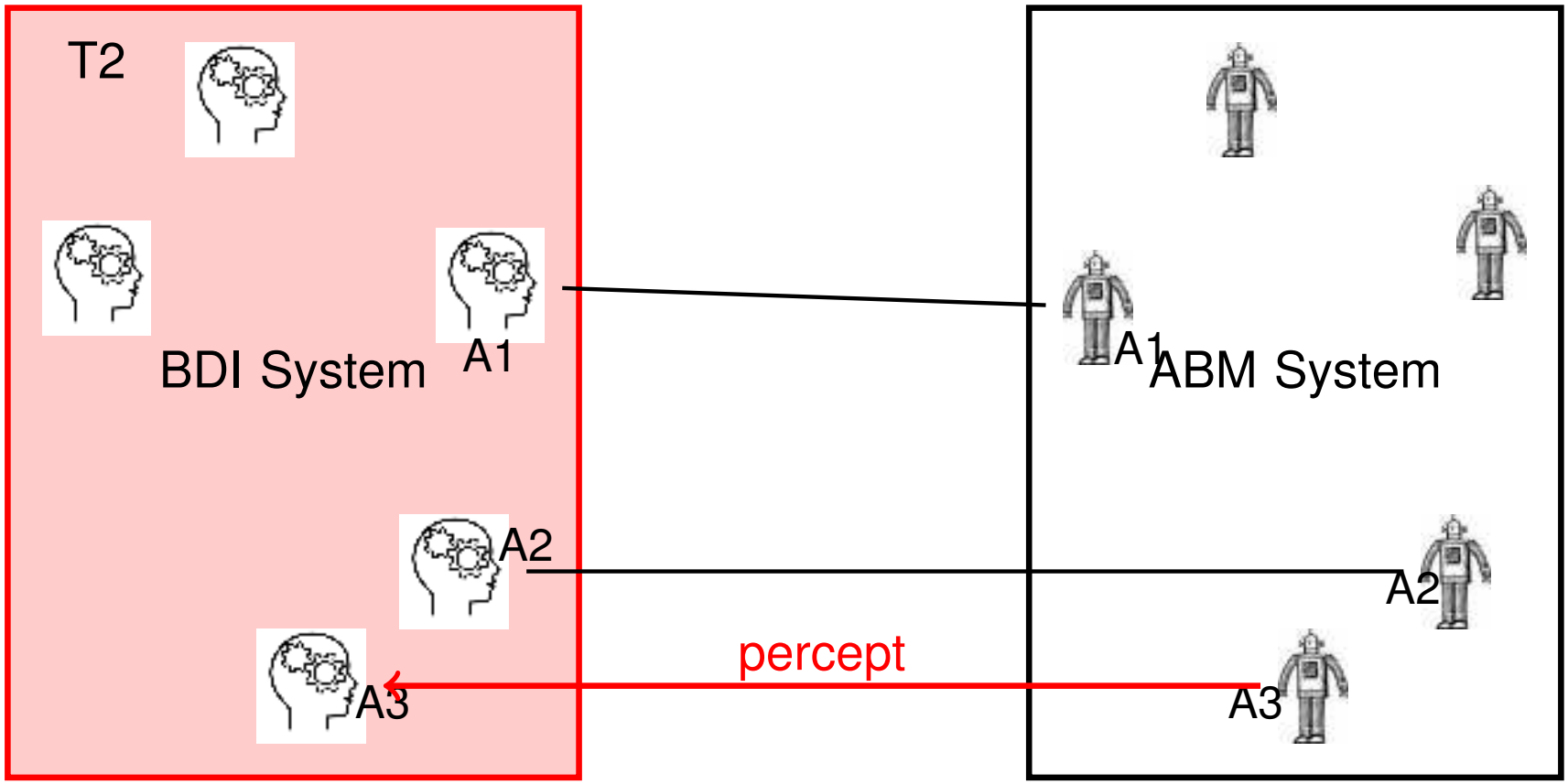
Agent	Action	Status
A1	act2	pass
A2	act3	fail
A3	act1	running



Framework Overview

Agent	Action	Status
A2	act7	initiate
A3	act1	running

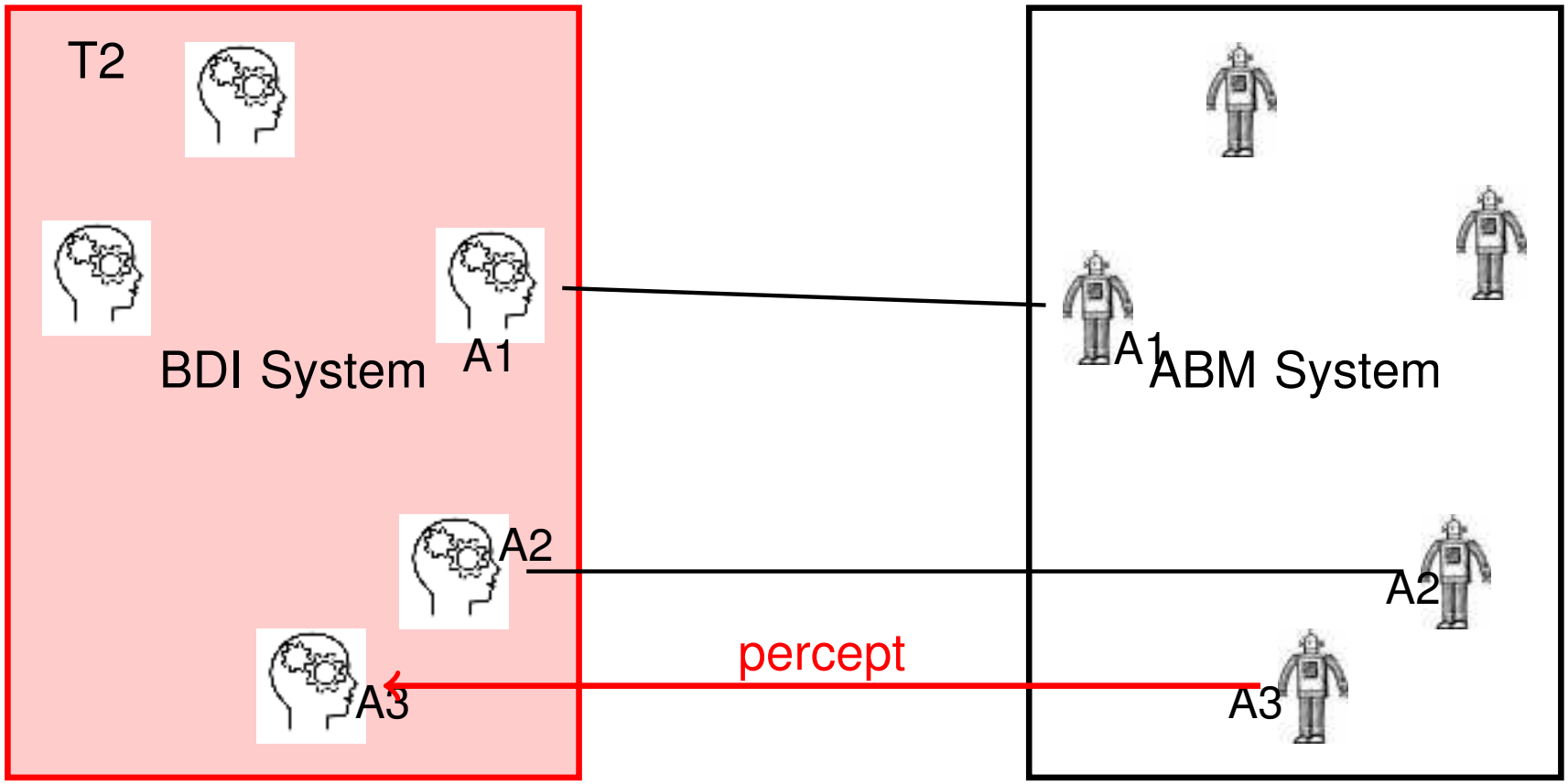
Agent	Action	Status
A1	act2	pass
A2	act3	fail
A3	act1	running



Framework Overview

Agent	Action	Status
A2	act7	initiate
A3	act1	dropped

Agent	Action	Status
A1	act2	pass
A2	act3	fail
A3	act1	running



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Agent	Action	Status
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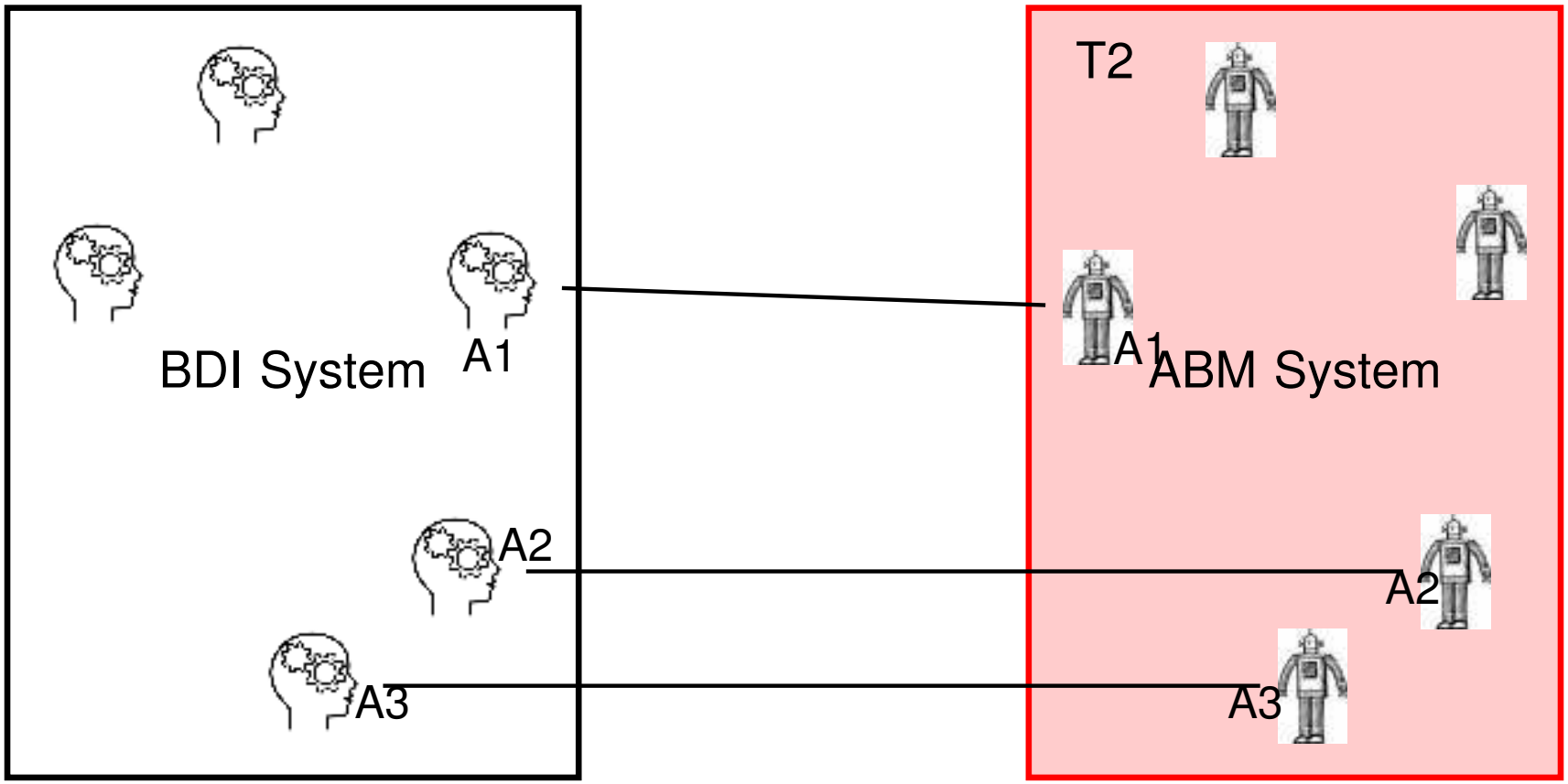

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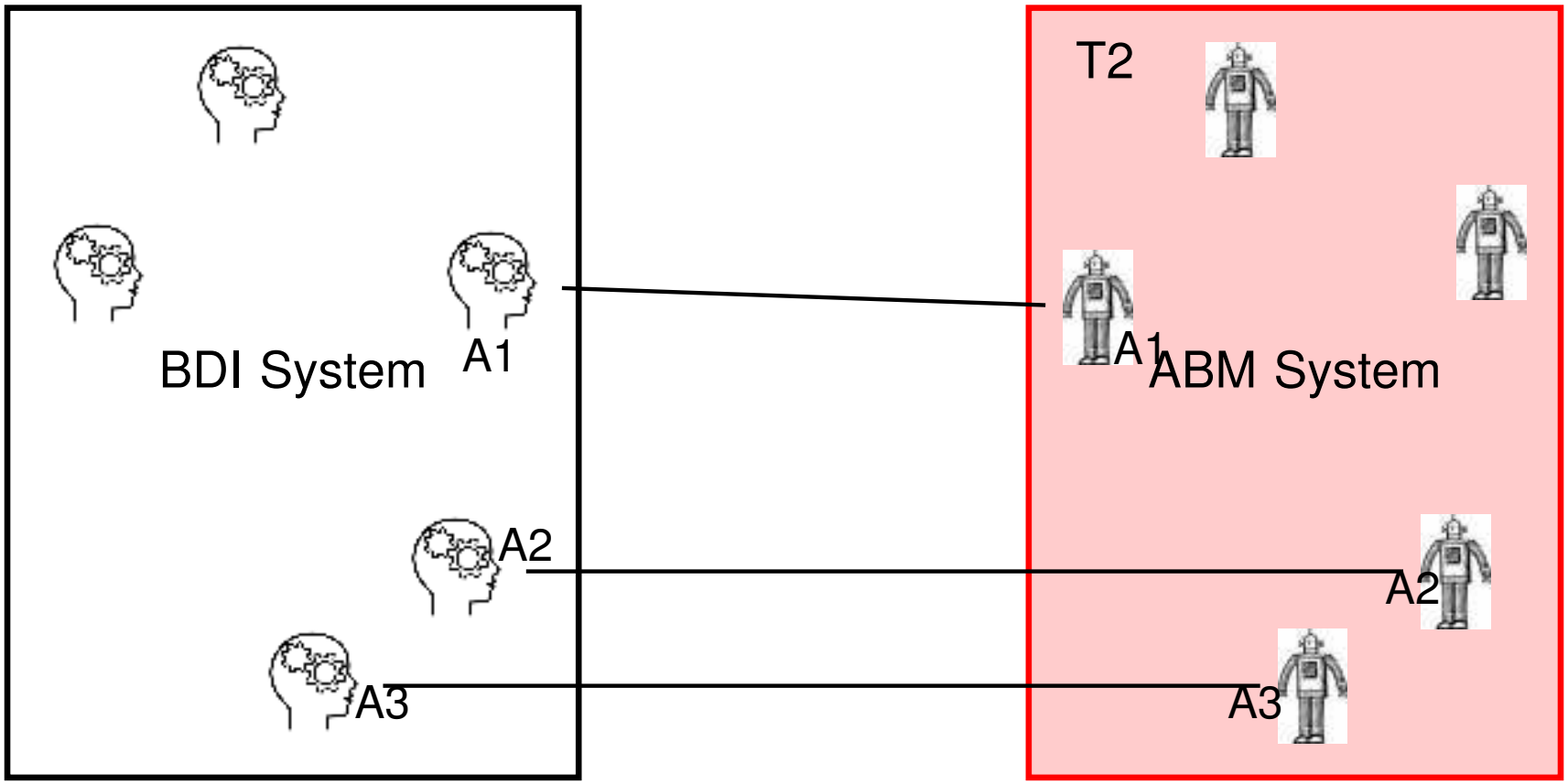

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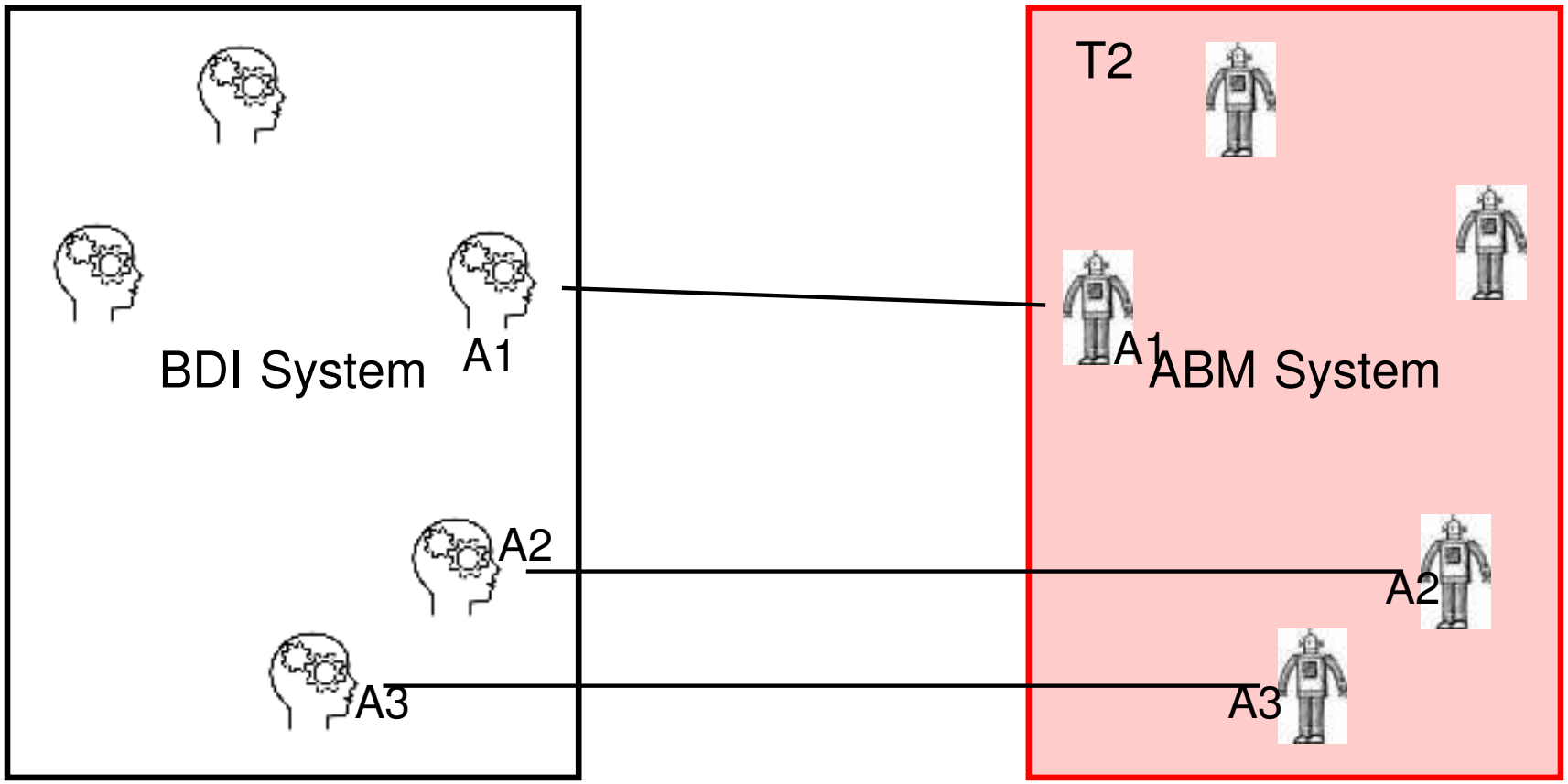
Agent	Action	Status
A2	act7	running



Framework Overview

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A2	act7	running

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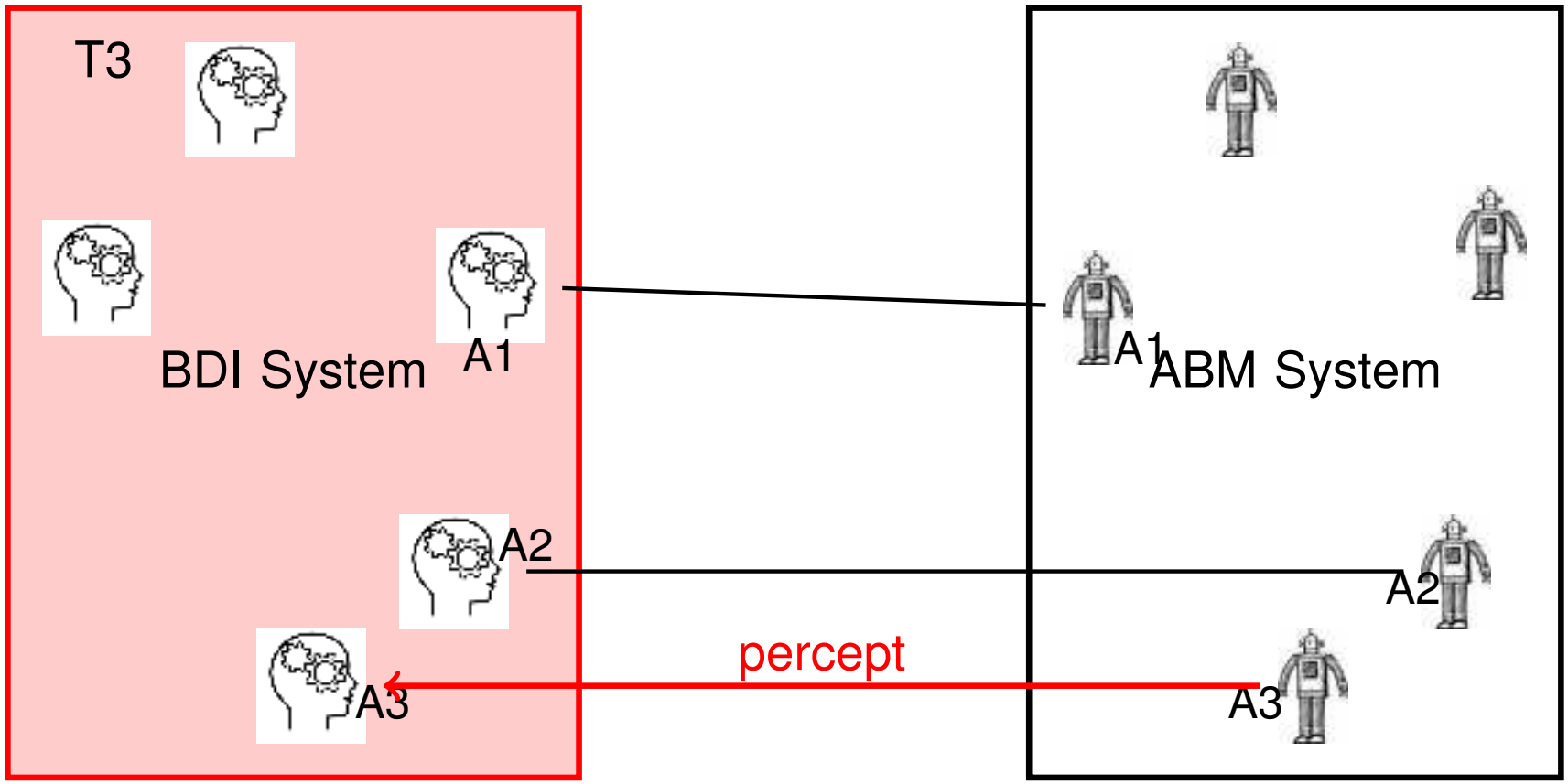
A2	act7	running



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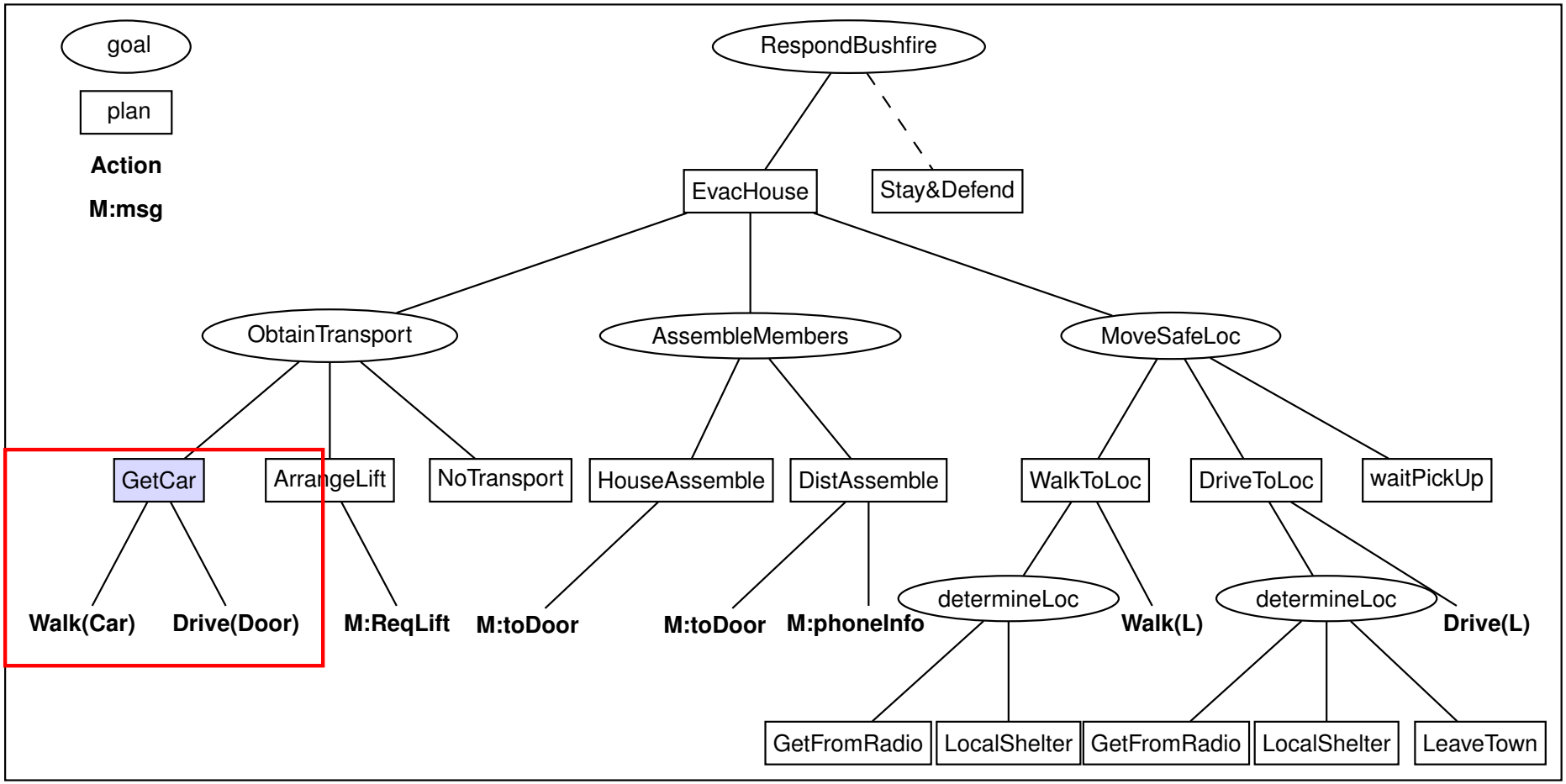
The Interface

- Actions: $< id, parameters, status >$
- Percepts: $< type, value >$ (value may be a complex object)
- BDI sensing actions.
  - While processing BDI can request information from ABM counterpart.
  - No effect on environment, but may include computation.
  - (E.g. get current location.)
- Anything that changes the environment must be a BDI action.

Generic Action Plan



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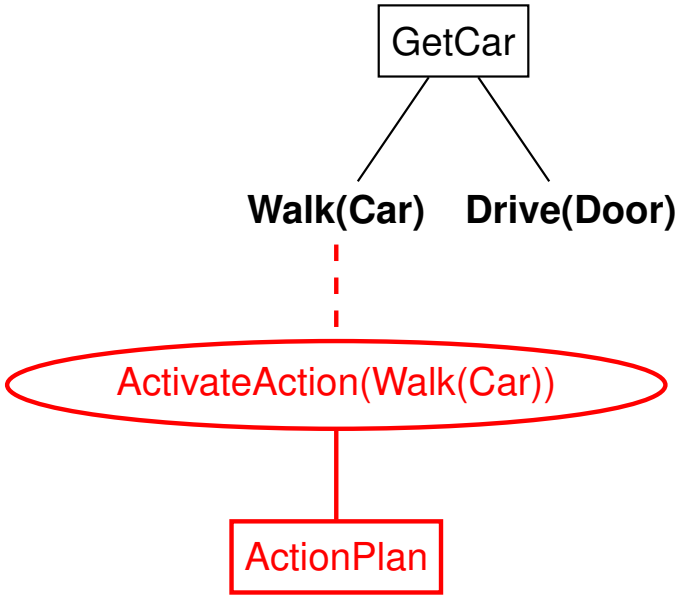

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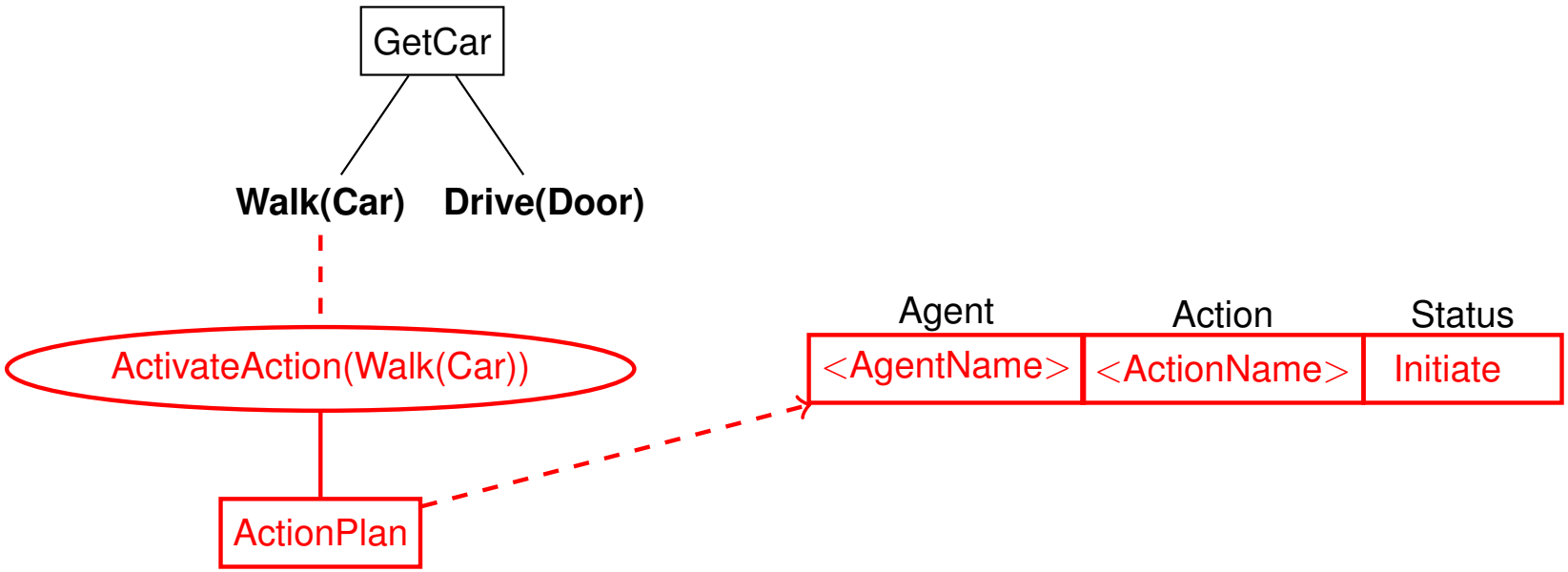
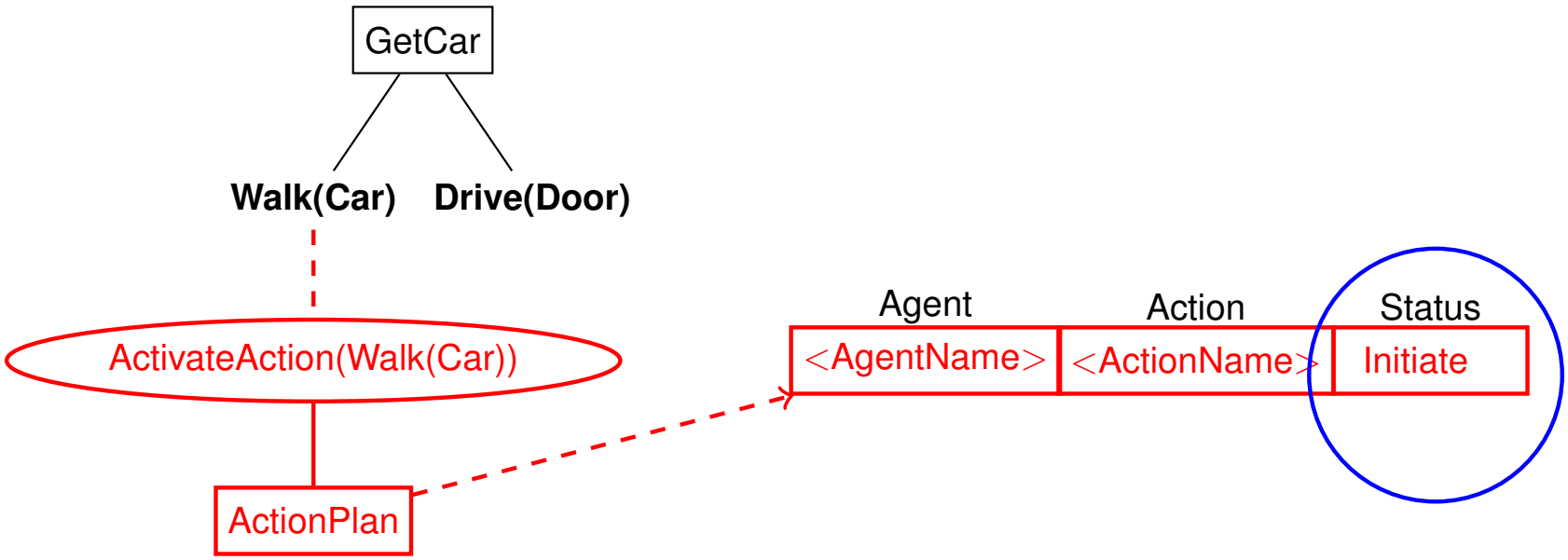


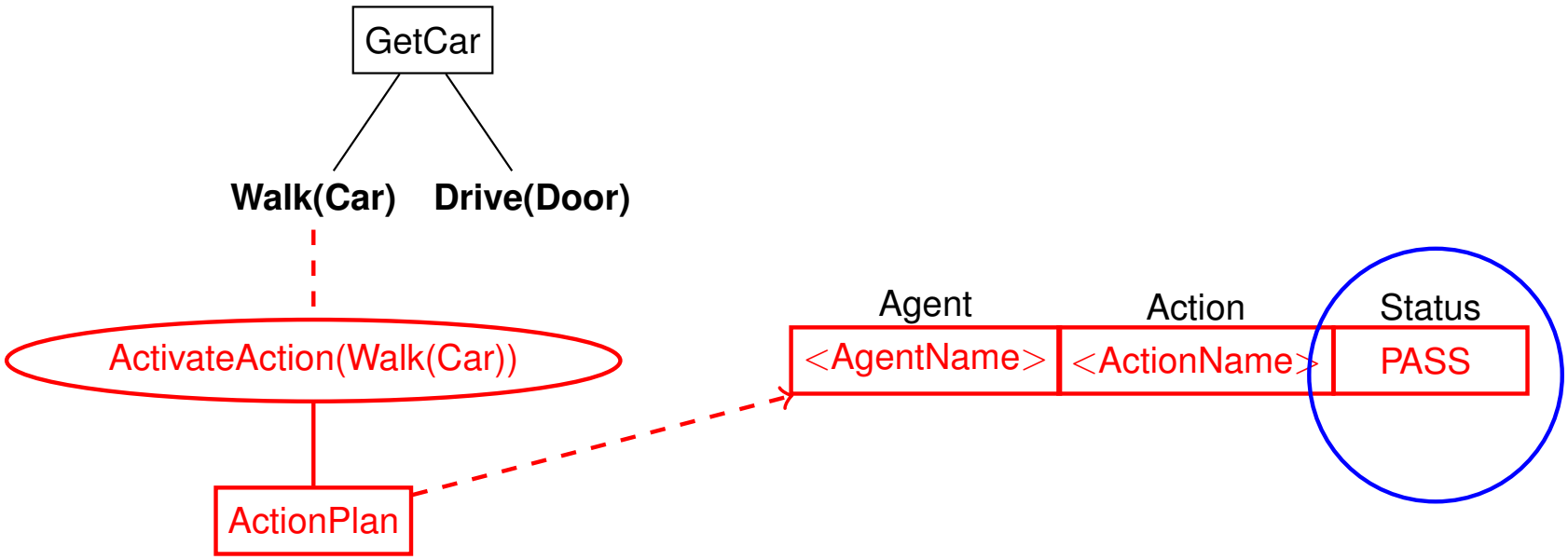
1) Write action info for sending to ABM

Generic Action Plan



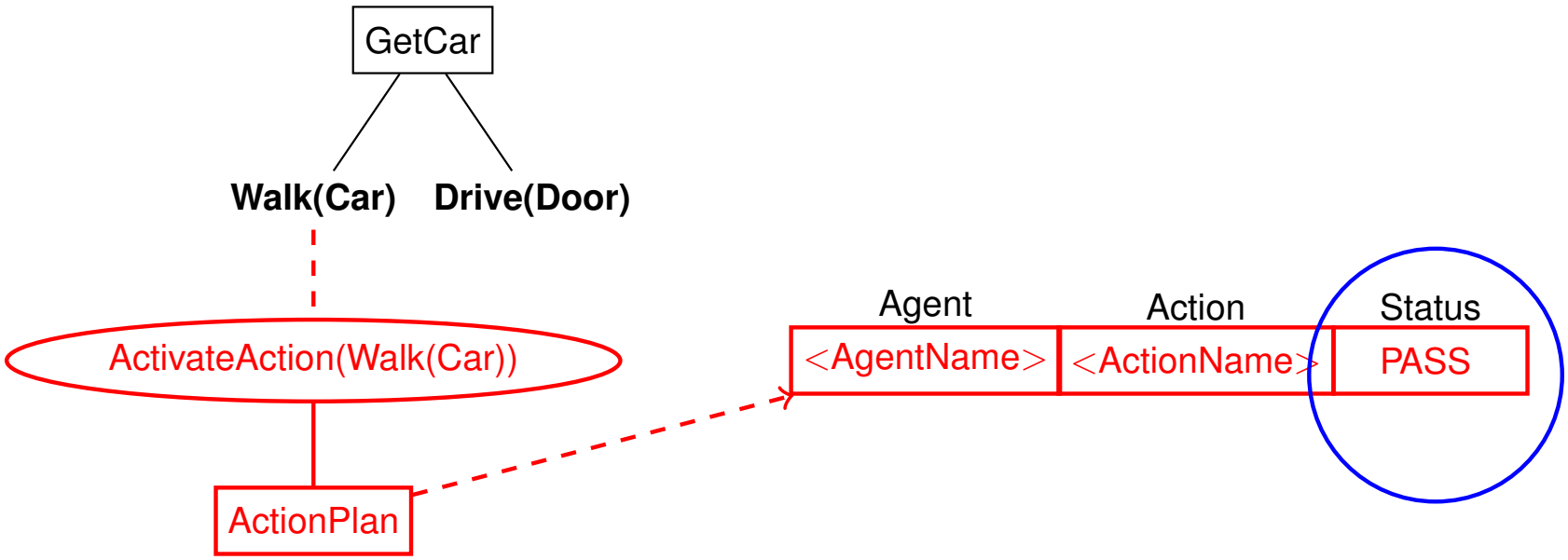
2) Monitor action status

Generic Action Plan



3) Respond to status

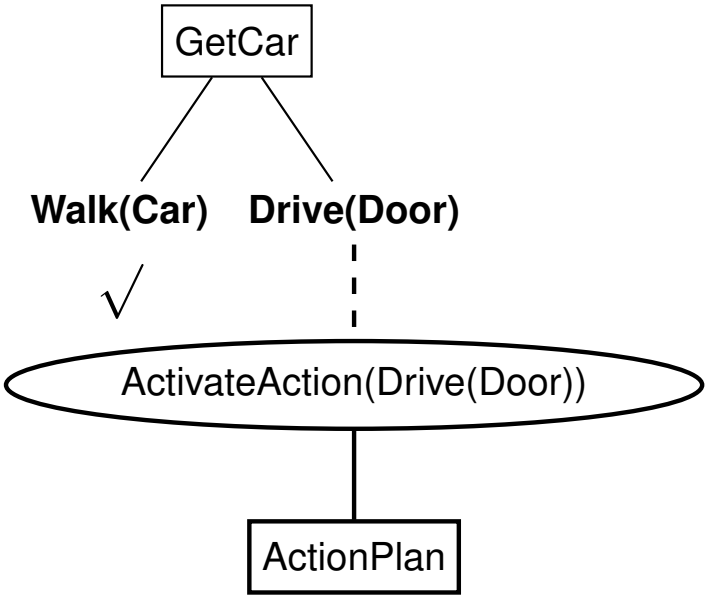
Generic Action Plan



3) Respond to status

Status = PASS, succeed plan which propagates up; Continue to next step.

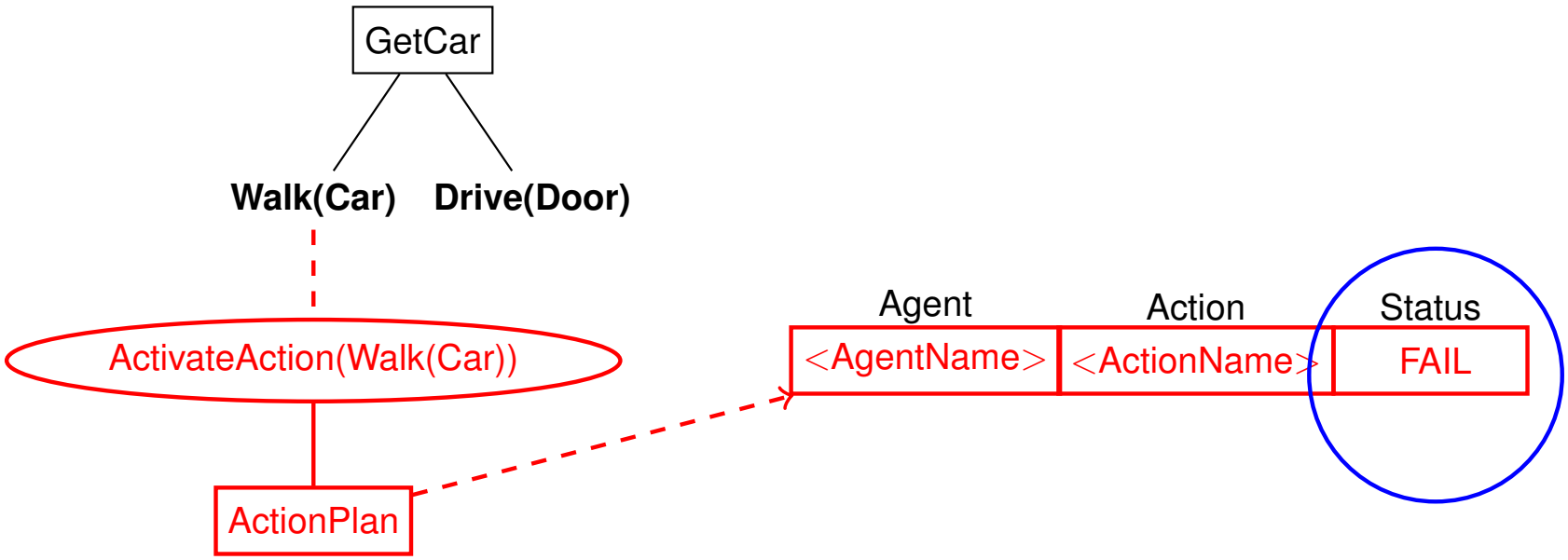
Generic Action Plan



3) Respond to status

Status = PASS, succeed plan which propagates up; Continue to next step.

Generic Action Plan



3) Respond to status

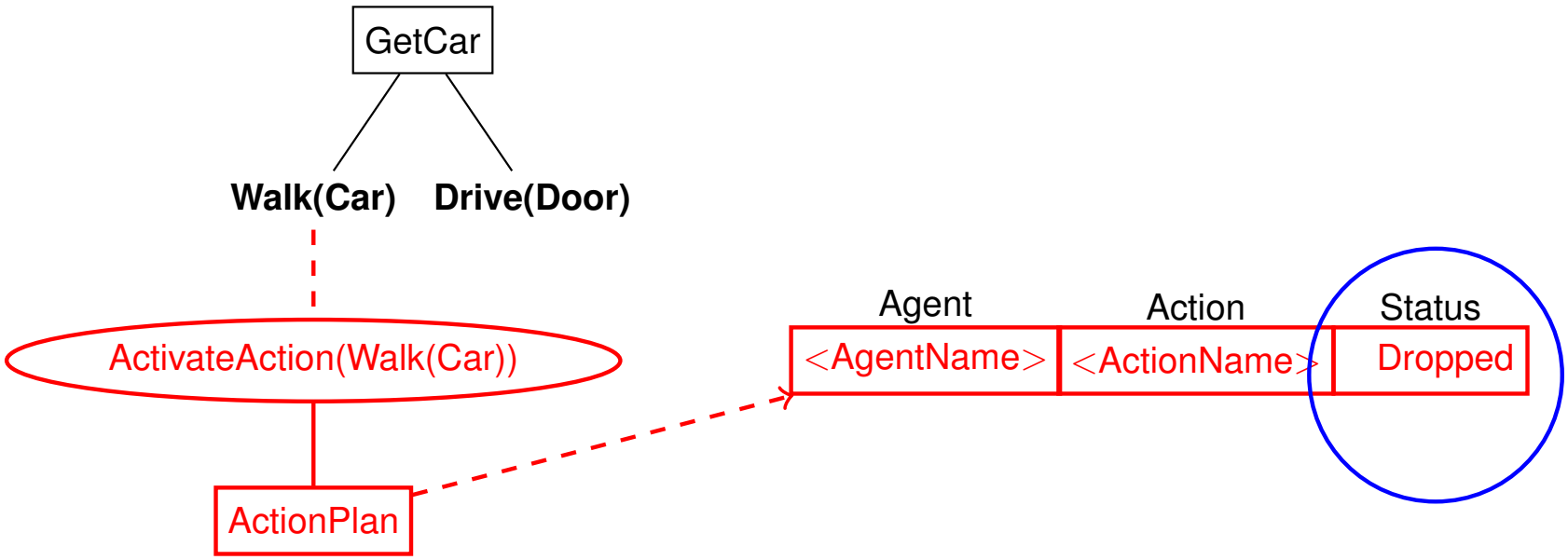
Status = FAIL, fail plan, propagates up; Plan fails.

Generic Action Plan

3) Respond to status

Status = FAIL, fail plan, propagates up; Plan fails.

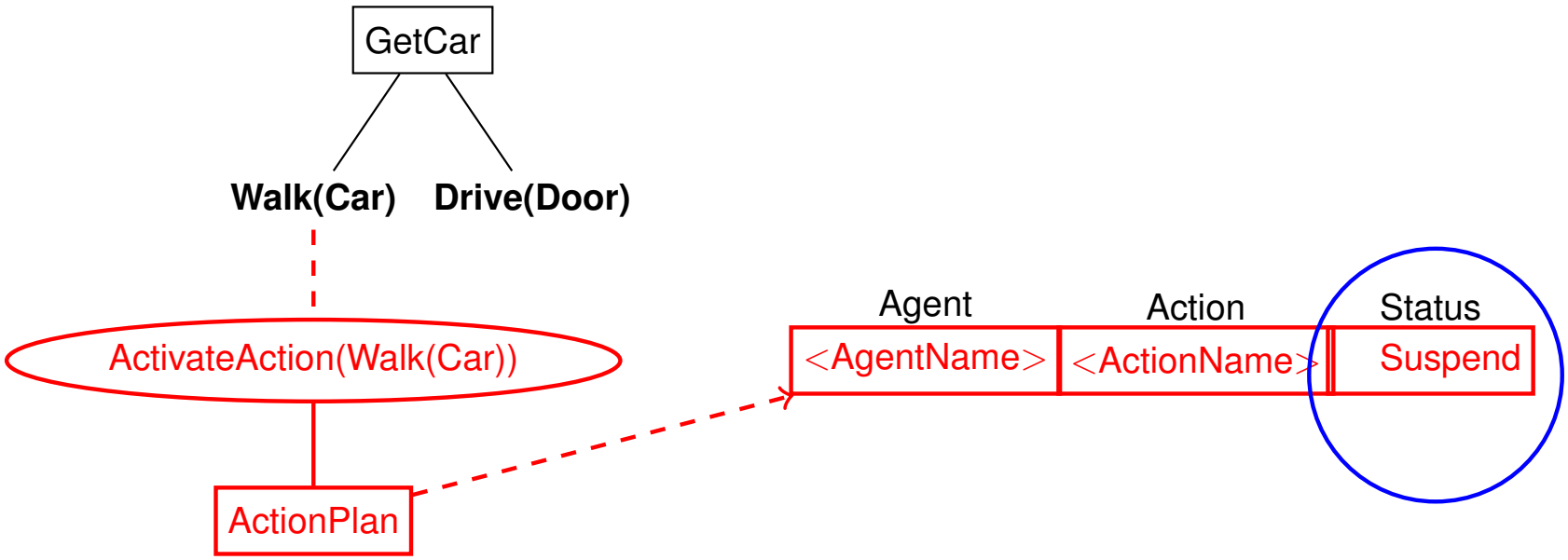
Generic Action Plan



3) Respond to status

Status = Dropped, Same as fail, but BDI initiated.

Generic Action Plan



3) Respond to status

Status = Suspend (also BDI initiated). No stepping on ABM side

Synchronisation Issues

- BDI and ABM take it in turn to run (BDI if needed)
  - System execution time should not affect conceptual model.
  - BDI runs only if action status change or percept generated.

- ABM systems generally use time-steps; BDI are generally event based, reacting to an external environment.
  - We use time-steps as basic model.
  - BDI system runs until each agent has finished its reasoning, possibly posting an action.
  - Depending on implementation platform, may require some care to detect end of BDI step.

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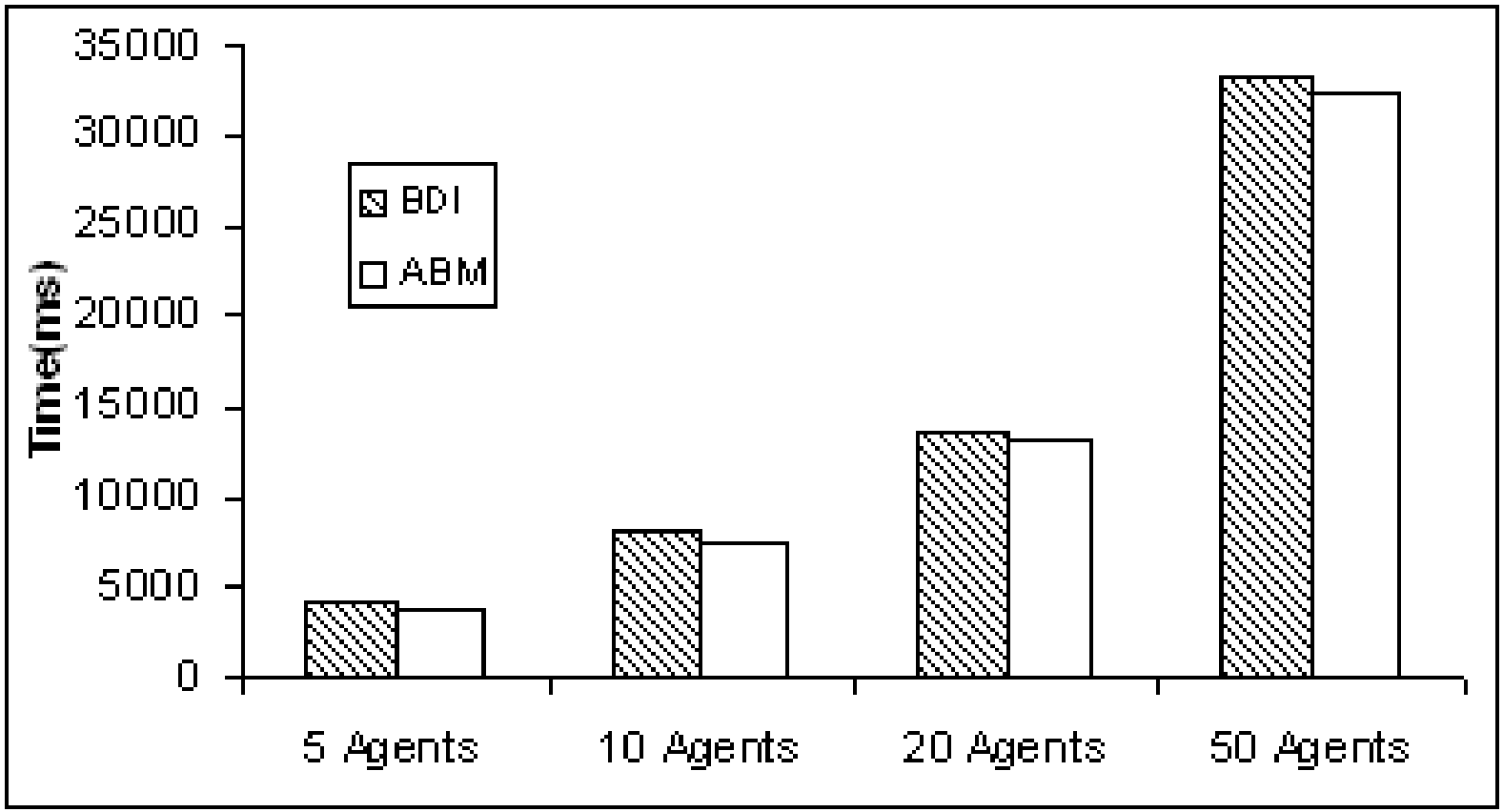
Efficiency Evaluation



Conclusion

- Successfully integrated existing BDI (JACK) and ABM (Repast) systems.
- Evaluation showed minimal efficiency cost.
- BDI representation supports easier specification of goal directed human behaviour over multiple time-steps.
- One next step is graphical interface for BDI specification.
- Also plan to work with social scientists to map SS models of human behavior to BDI style representations for richer simulation.

Questions