



Uncertainty Reduction in Self-Adaptive Systems

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Uncertainty in self-adaptive systems

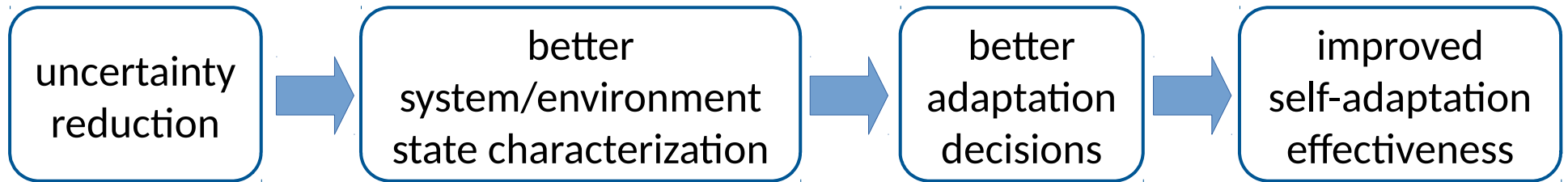
When deciding how to adapt, a self-adaptive system usually faces uncertainty.

For example:

- uncertainty about whether a service not recently used is still available
- uncertainty about the state of the environment, perhaps only known with a wide confidence interval

Existing self-adaptation approaches can reason about uncertainty, but do not consider ways to reduce it. *This is a missed opportunity to improve.*

Uncertainty reduction



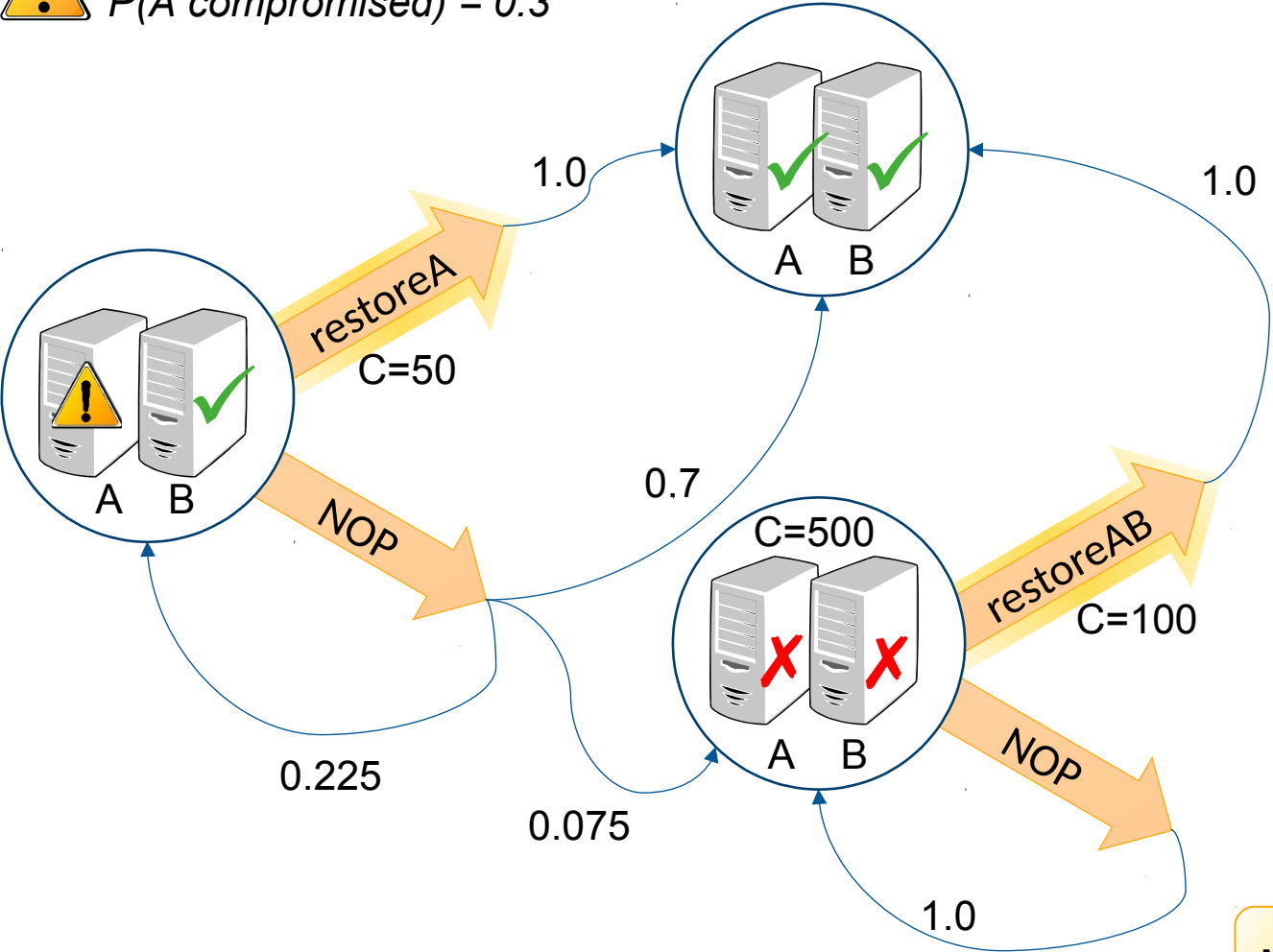
However, reducing uncertainty has a cost:

- resource consumption
- user annoyance







A principled decision-making approach that considers this trade-off is needed to **decide at run time when and how to reduce uncertainty.**

Example of adaptation decision under uncertainty

 Intrusion Detection System alert:
 $P(A \text{ compromised}) = 0.3$



Key

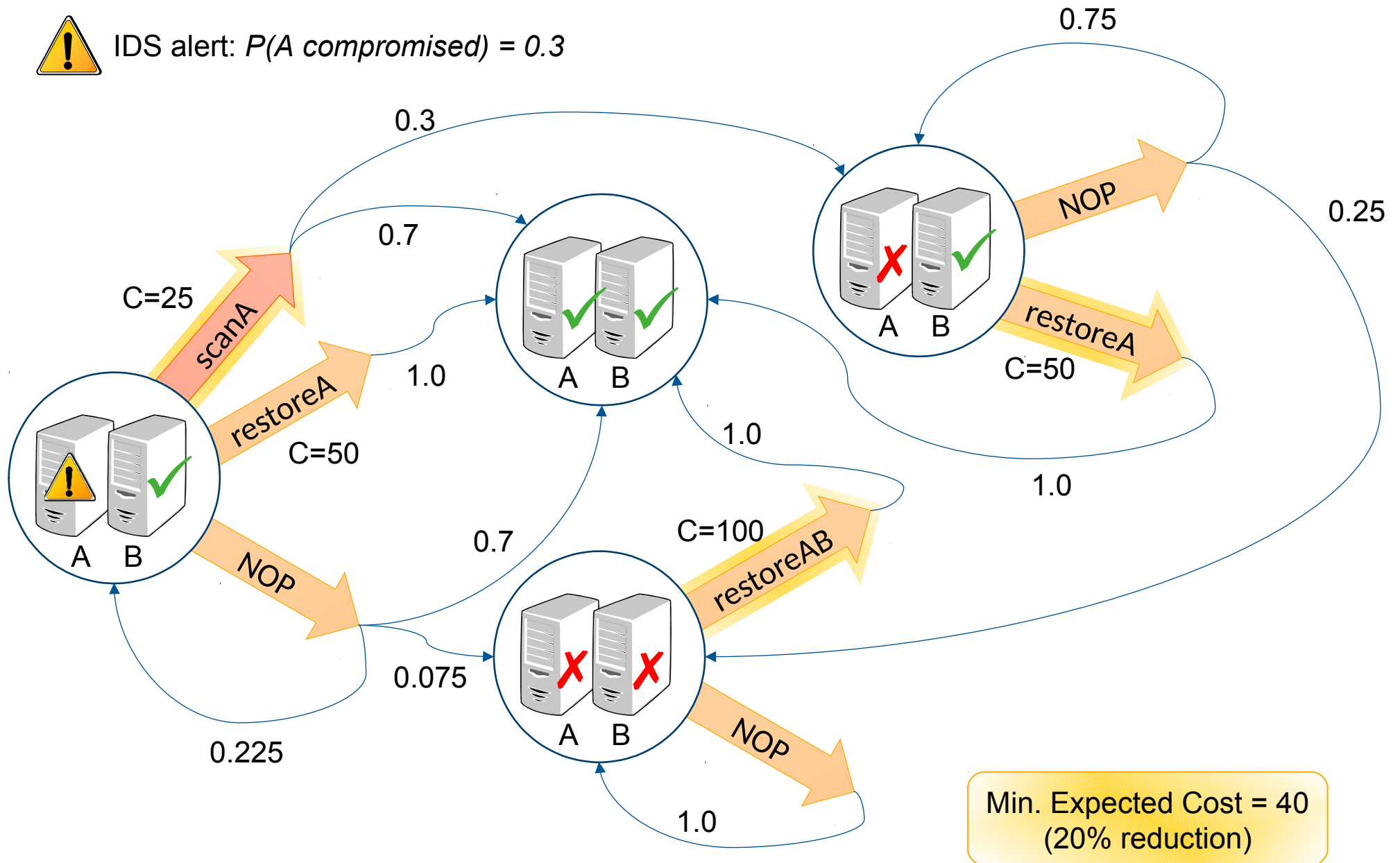
-  state
-  tactic
- p  transition with probability p
- C cost (negative reward)
-  clean
-  with IDS alert
-  compromised

Min. Expected Cost = 50

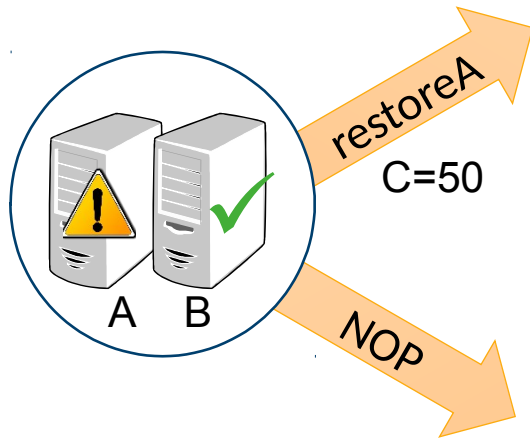
Introducing uncertainty reduction



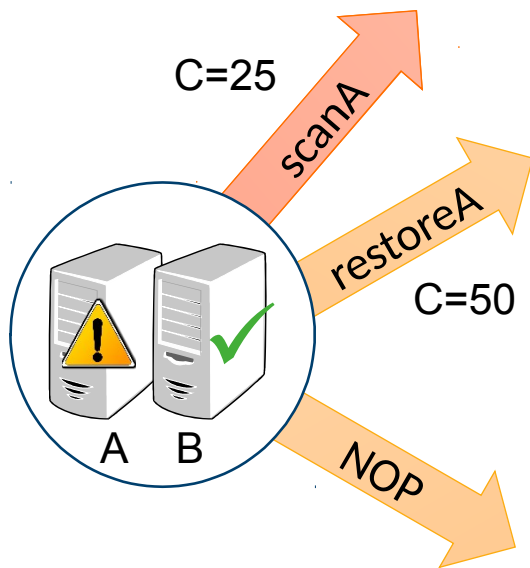
IDS alert: $P(A \text{ compromised}) = 0.3$



Without and with uncertainty reduction



$p = P(\text{A compromised})$	Tactic
$p \leq 0.267$	NOP
$p > 0.267$	restoreA



$p = P(\text{A compromised})$	Tactic
$p \leq 0.198$	NOP
$0.198 < p \leq 0.5$	scan
$p > 0.5$	restoreA

probabilistic
model-checking
results

Research challenges

Creating a catalog of uncertainty reduction tactics

- How to make it system-independent and useful simultaneously

Specifying the impact of uncertainty reduction tactics

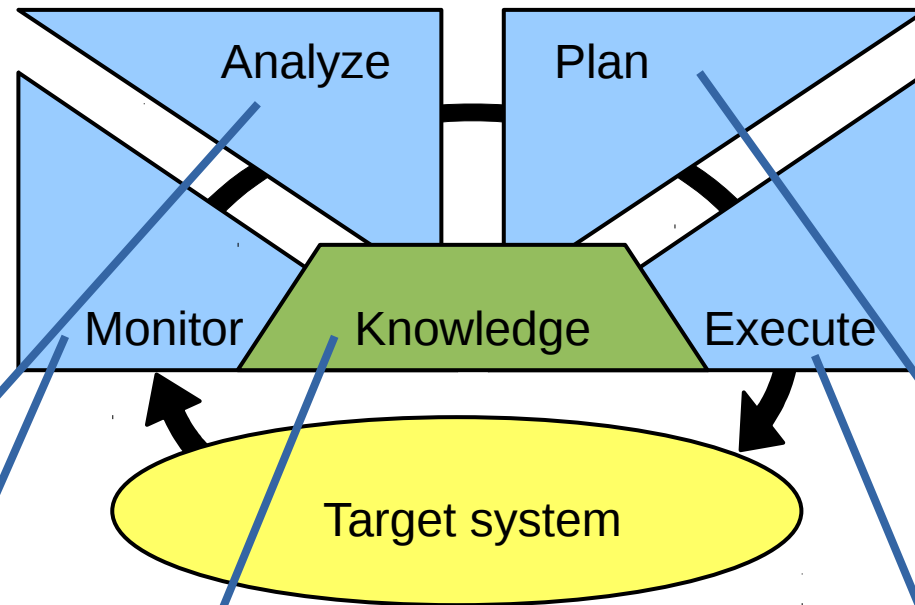
- How to specify the impact in a generic way
- How to consider partial uncertainty reduction

Developing decision procedures that integrate uncertainty reduction with normal adaptation

- How to avoid state space explosion to keep the decision time low enough for run-time decision

Additional Slides

Integrating uncertainty reduction in MAPE-K



- Determine whether UR would be beneficial
- Since UR affects subsequent adaptation, UR would likely have to be done iteratively

- Decide which uncertainty reduction tactics to use
- Since UR does not have a benefit by itself, the benefit is realized through the adaptation process

- Execute uncertainty reduction tactics
 - some change the target system (e.g., turn sensor on)
 - some change the knowledge base (e.g., sensor configuration)

- Models extended with uncertainty quantification

Examples of uncertainty reduction tactics

Source of uncertainty [Esfahani & Malek 2013]	Tactic	Purpose
due to simplifying assumptions	use analysis with higher fidelity	reduce the uncertainty in the analysis results
due to noise	change sampling rate	get narrower confidence interval
due to model drift	probe service/device not recently used	determine availability and response time
	turn probe/sensor on	obtain (previously unknown) value for model property
in the context	present a CAPTCHA	determine if requests are coming from humans or bots
due to human in the loop	poll humans for their state	determine availability and/or willingness to perform task
due to decentralization	query other systems	actively update other systems' state instead of waiting for information to propagate