

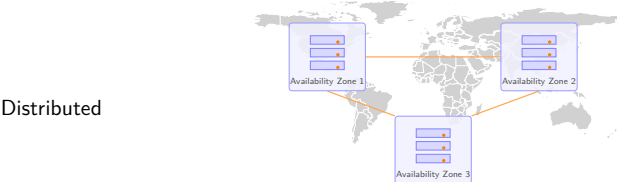
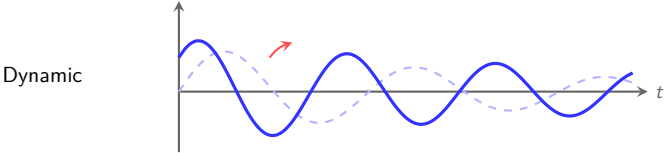
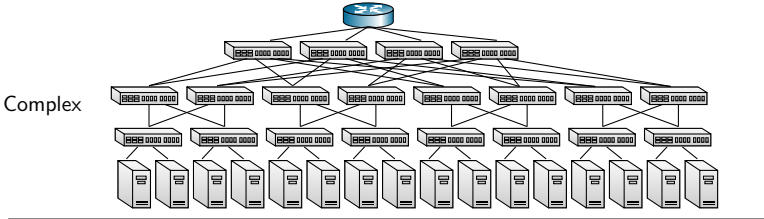
CSLE: A Reinforcement Learning Platform for Autonomous Security Management

Ninth Annual Conference on Machine Learning and Systems (MLSys)
Bellevue, WA, USA, *May 19, 2026*

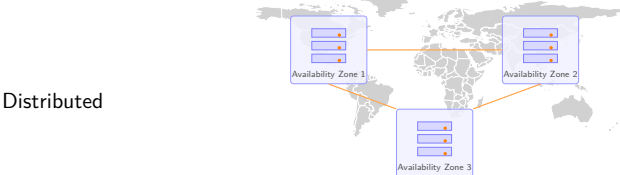
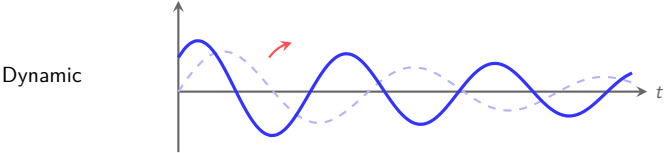
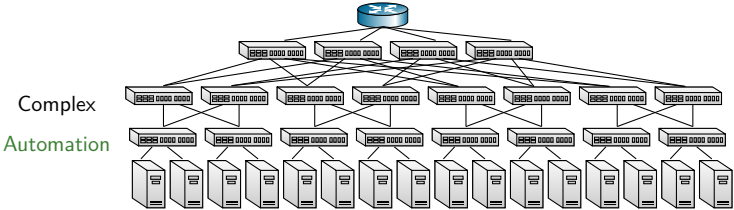
Kim Hammar
kimham@kth.se



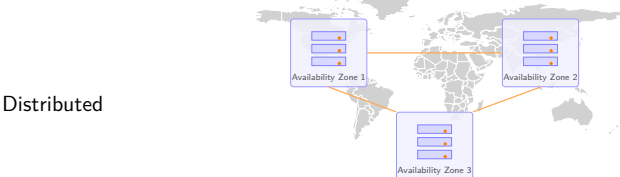
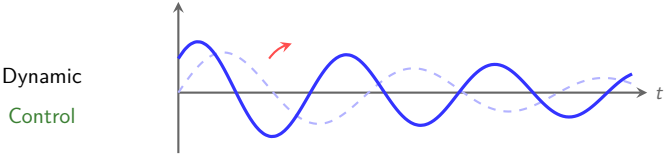
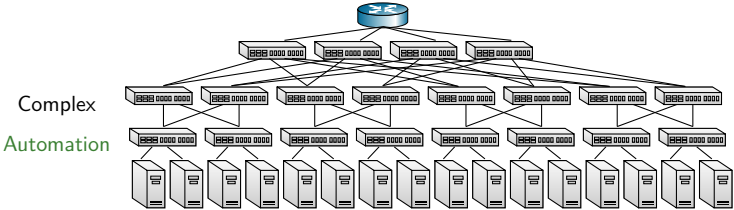
Networked Systems



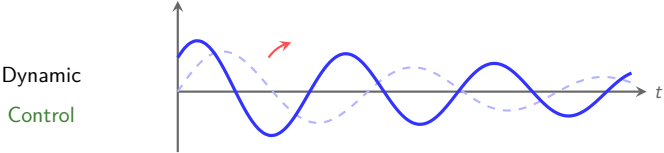
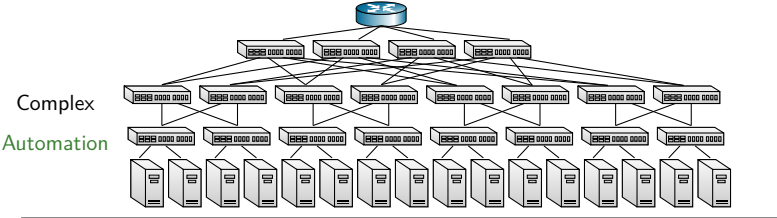
Networked Systems



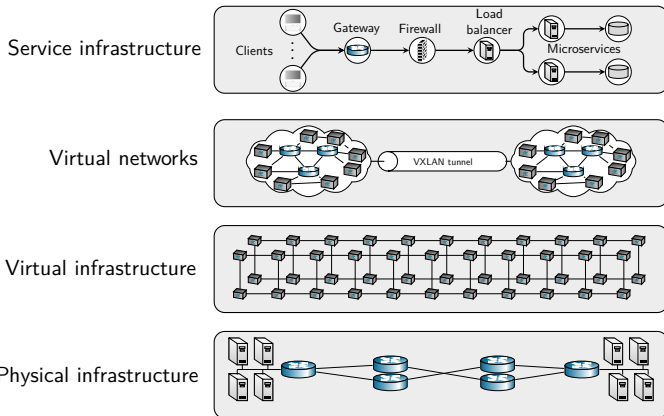
Networked Systems



Networked Systems

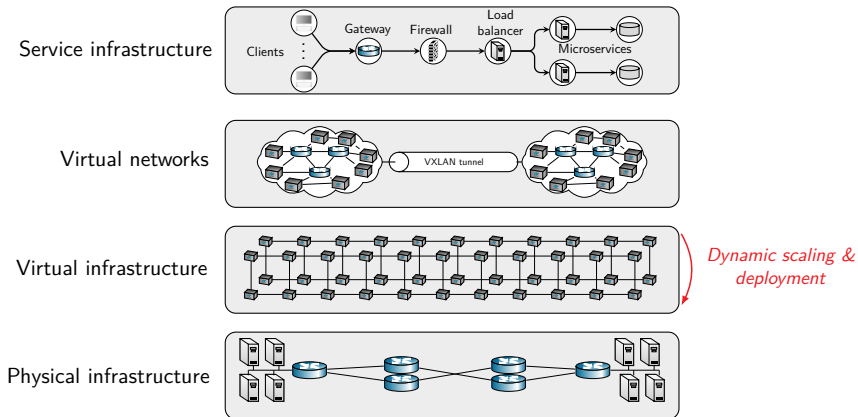


From Manual Configuration to Automatic Control



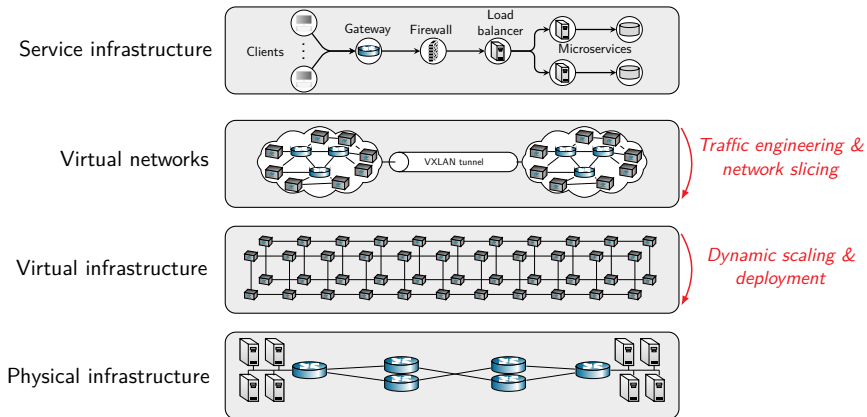
- ▶ Networked systems have undergone a shift from hardware-defined architectures to **software-defined** stacks.

From Manual Configuration to Automatic Control



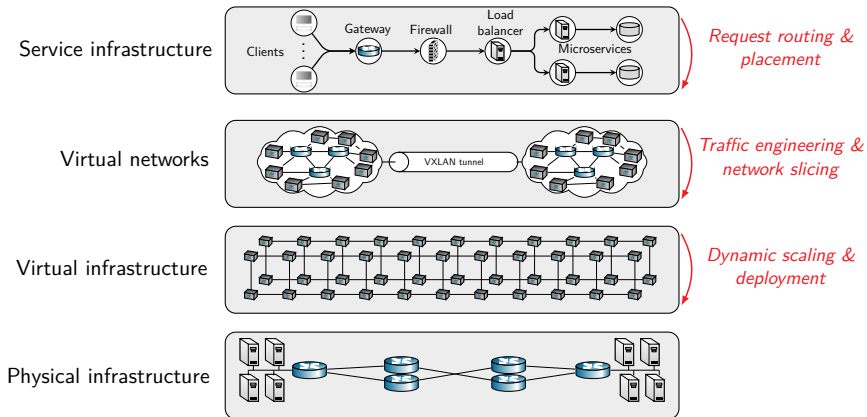
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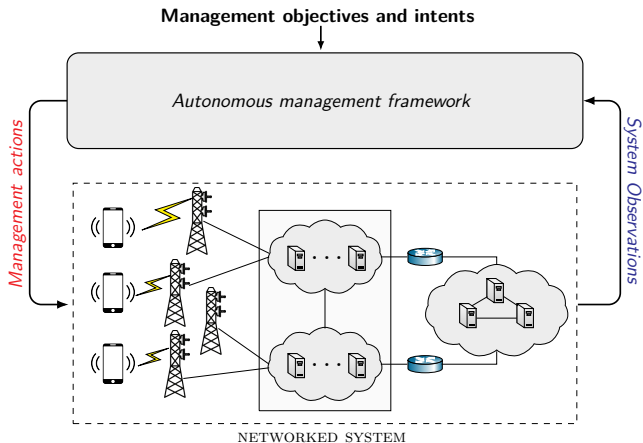
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From Manual Configuration to Automatic Control



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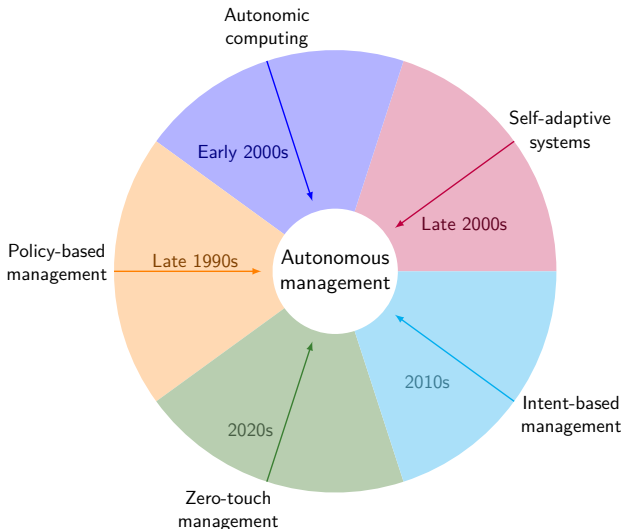
Autonomous Security Management of Networked Systems



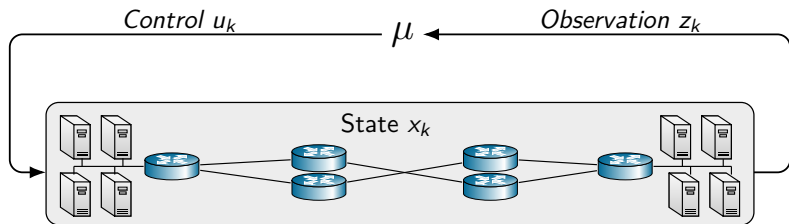
- ▶ Autonomous security management is needed to cope with the **increasing complexity and dynamism of networked systems**.
- ▶ The programmability and controllability of network and system functions is a prerequisite for autonomous management.

Prior Research

- ▶ Efforts towards automating the security management of networks and IT systems have been undertaken over the last 30 years.

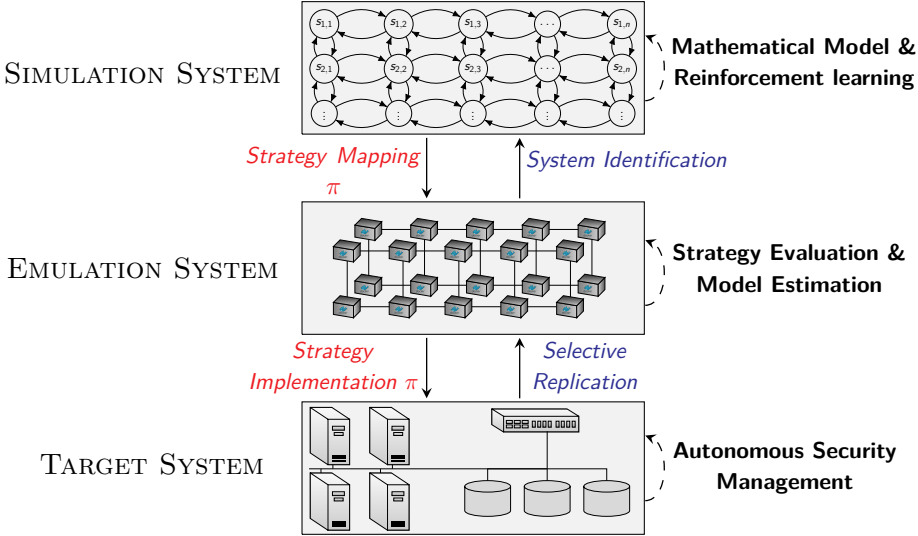


Autonomous Security Management as a Control Problem

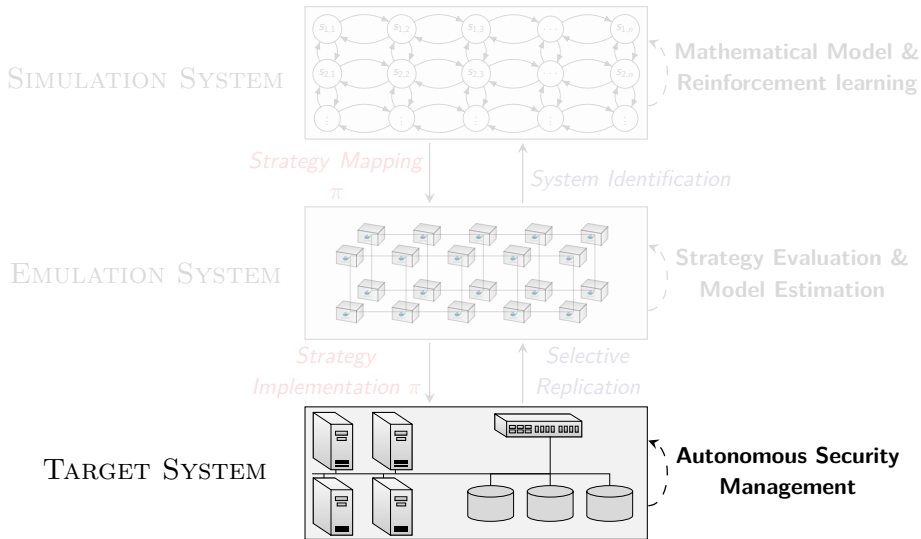


- ▶ State x_k (e.g., security status and system configuration).
- ▶ Observation z_k (e.g., log files and security alerts).
- ▶ Control u_k (e.g., network segmentation and access control).
- ▶ **Goal:** find a strategy μ that meets security objectives.

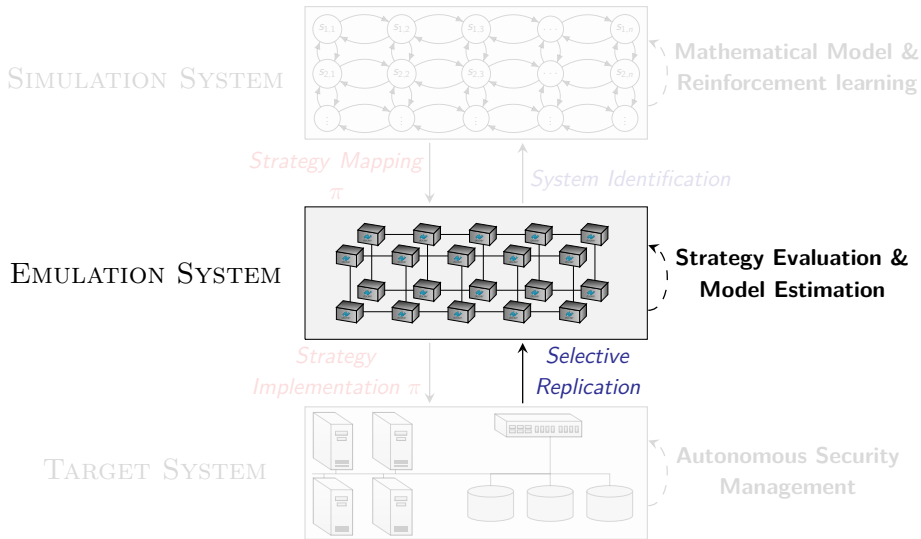
Methodology for Building Autonomous Security Systems



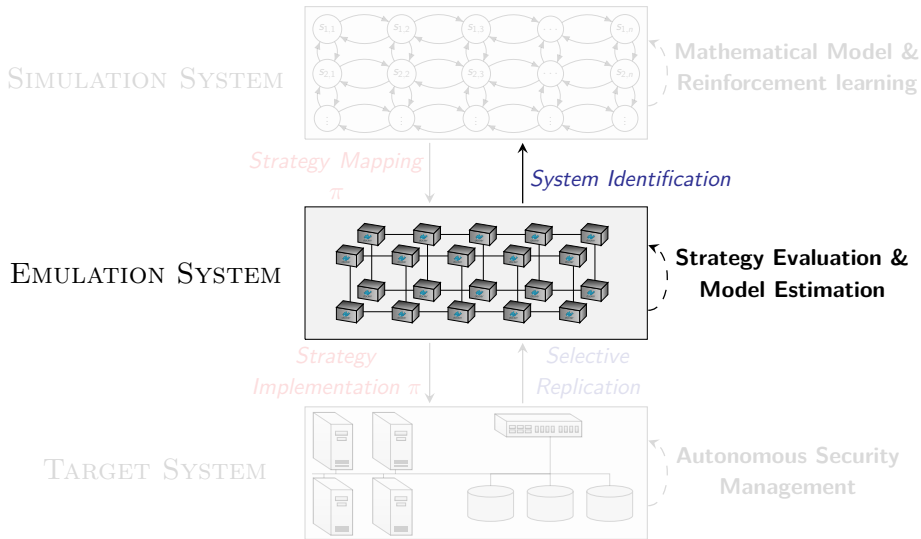
Methodology for Building Autonomous Security Systems



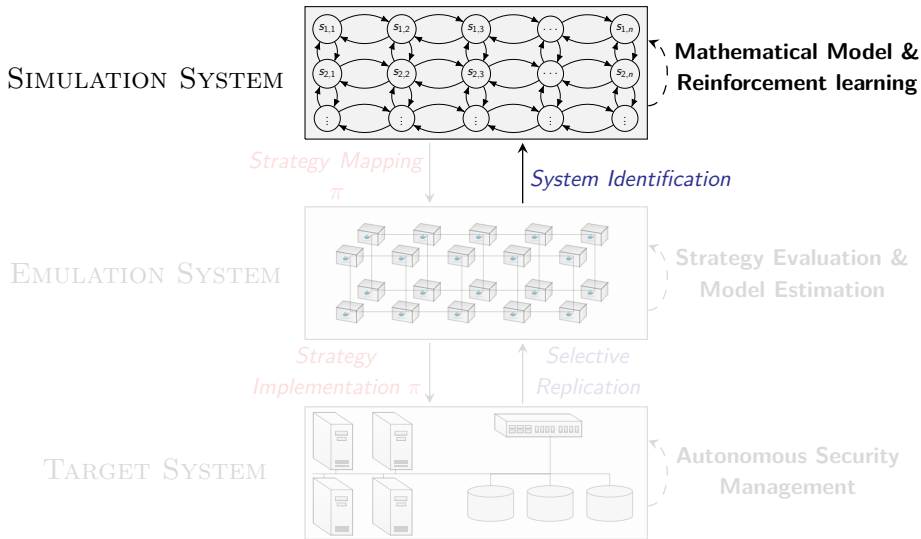
Methodology for Building Autonomous Security Systems



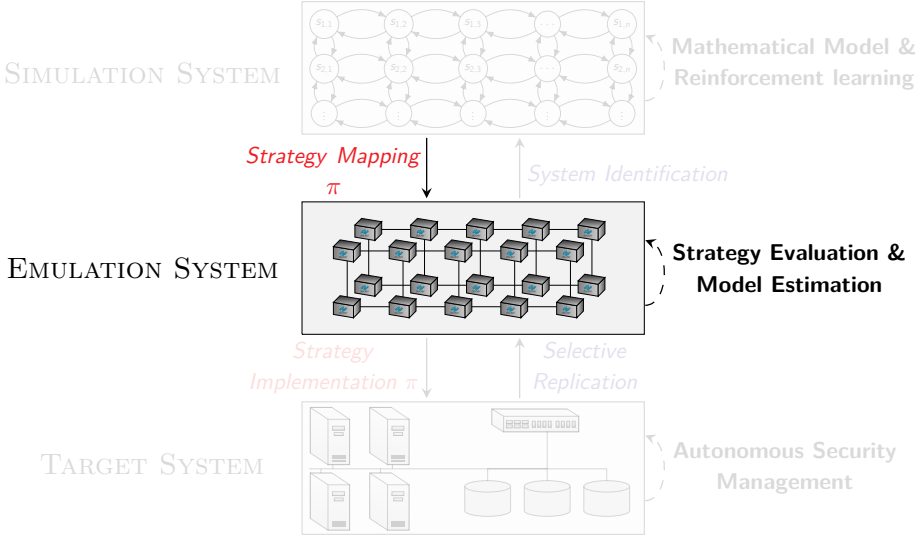
Methodology for Building Autonomous Security Systems



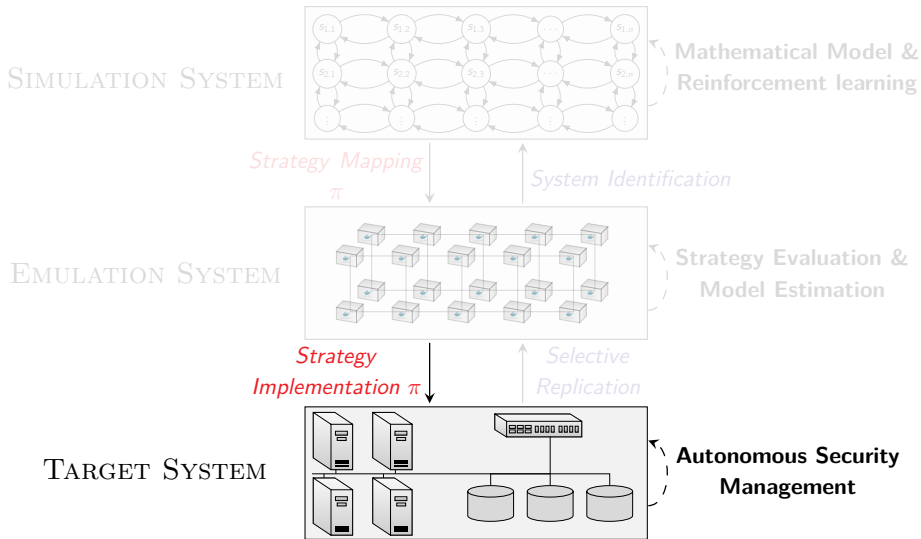
Methodology for Building Autonomous Security Systems



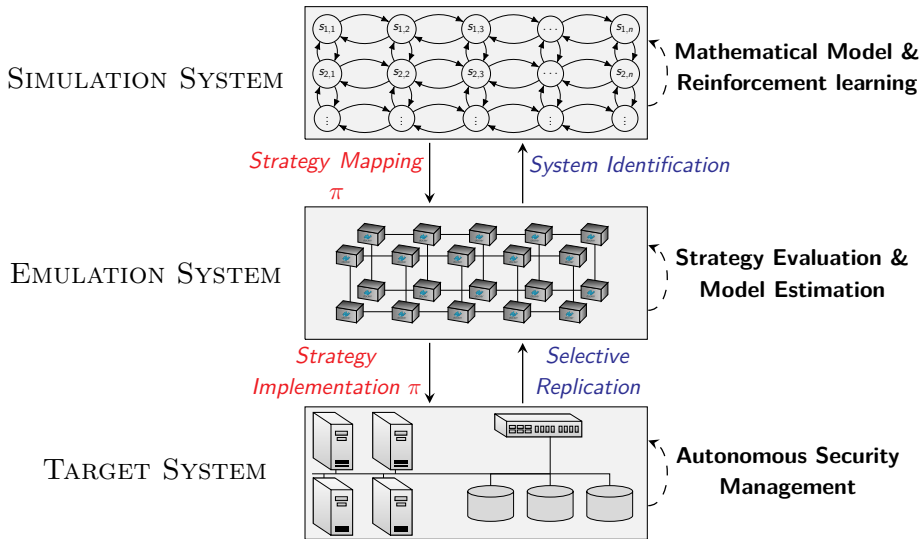
Methodology for Building Autonomous Security Systems



Methodology for Building Autonomous Security Systems

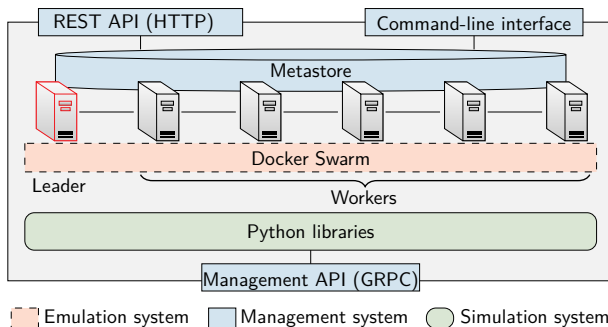


Methodology for Building Autonomous Security Systems



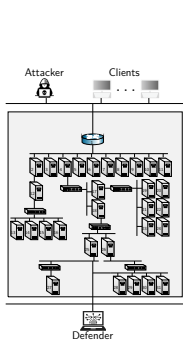
CSLE: A Platform that Supports the Methodology

- ▶ The Cyber Security Learning Environment (CSLE) enables experimentation with reinforcement learning for autonomous security management under realistic conditions.
- ▶ The implementation of CSLE consists of three systems:
 - ▶ An emulation system for creating digital twins.
 - ▶ A simulation system for reinforcement learning.
 - ▶ A management system for orchestration.

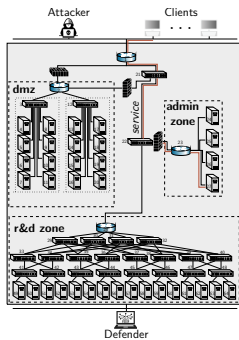


Example Use Cases for Experimental Evaluation

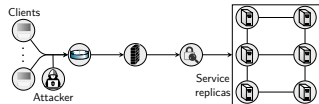
- ▶ We demonstrate CSLE by applying it to four use cases.
 - ▶ **Flow control:** block network flows to mitigate intrusions.
 - ▶ **Segmentation control:** direct network flows or create network zones to mitigate intrusions.
 - ▶ **Recovery control:** Decide when to recover components in a replicated system to maintain service availability.
 - ▶ **Replication control:** Select the number of replicas.



a) Target system for the flow control use case.



b) Target system for the segmentation use case.

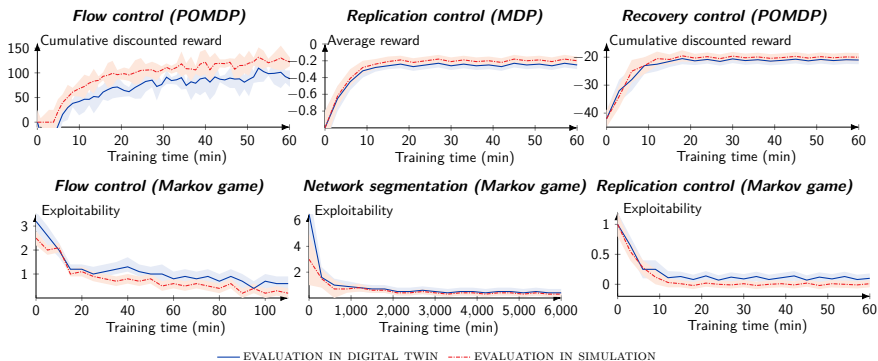


c) Target system for the replication and recovery use cases.

Experimental Evaluation

► Evaluation metrics:

- Reward for decision-theoretic models (\uparrow better).
- Exploitability for game-theoretic models. (\downarrow better).



💡 *Performance on the simulator transfers to the digital twin.*

Conclusion

- ▶ CSLE is a **platform for autonomous security management**.
 - ▶ Enables experimentation in realistic operating conditions.
 - ▶ We use CSLE to demonstrate simulation-to-emulation transfer.
 - ▶ Open source: <https://github.com/Kim-Hammar/csle>.

