On the Challenges of Self-Adaptation in Systems of Systems

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First International Workshop on Software Engineering Systems of Systems – SESoS 2013

Montpellier, 2nd July 2013

Linnæus University

Setting

Guaranteeing runtime qualities of SoS **is complex** due **uncertainties** (systems detach at will, resources change, etc.)

Self-adaptation enables a system to adapt itself to achieve particular quality goals in face of uncertainty and change

State of the art self-adaptation **centralized and hierarchical solutions**, which are not applicable to SoS

Proposal

3 architectural styles for self-adaptation in SoS

- Decentralized control with increasing levels of knowledge sharing and collaboration
- Challenge of guaranteeing properties that span multiple systems of SoS

Overview

- SoS
- Self-Adaptation

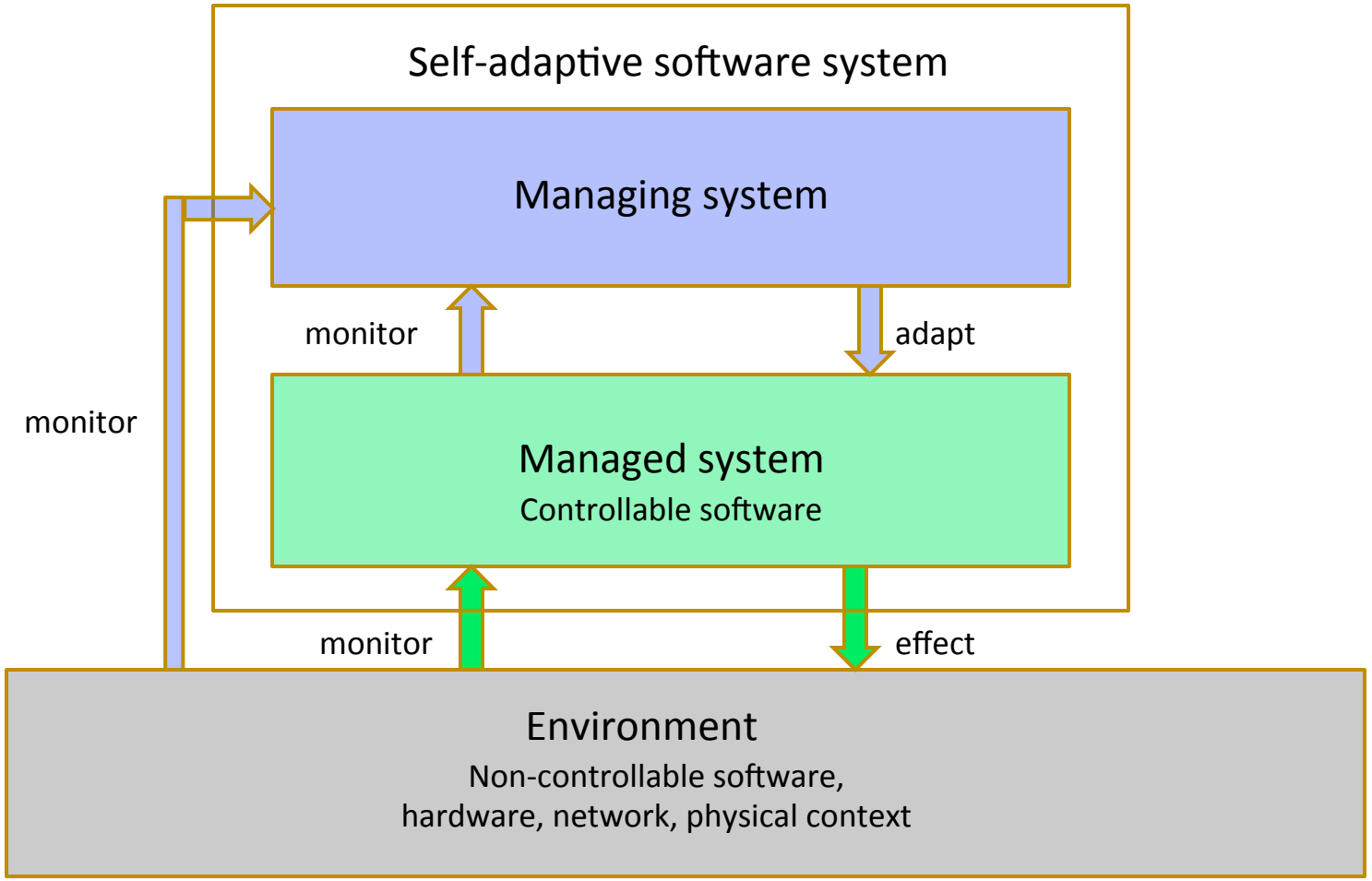
- Local adaptations
- Regional monitoring – local adaptations
- Collaborative adaptations

- Wrap up

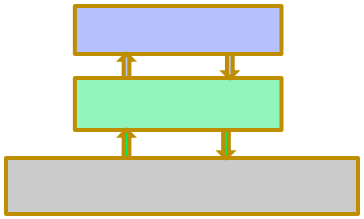
SoS

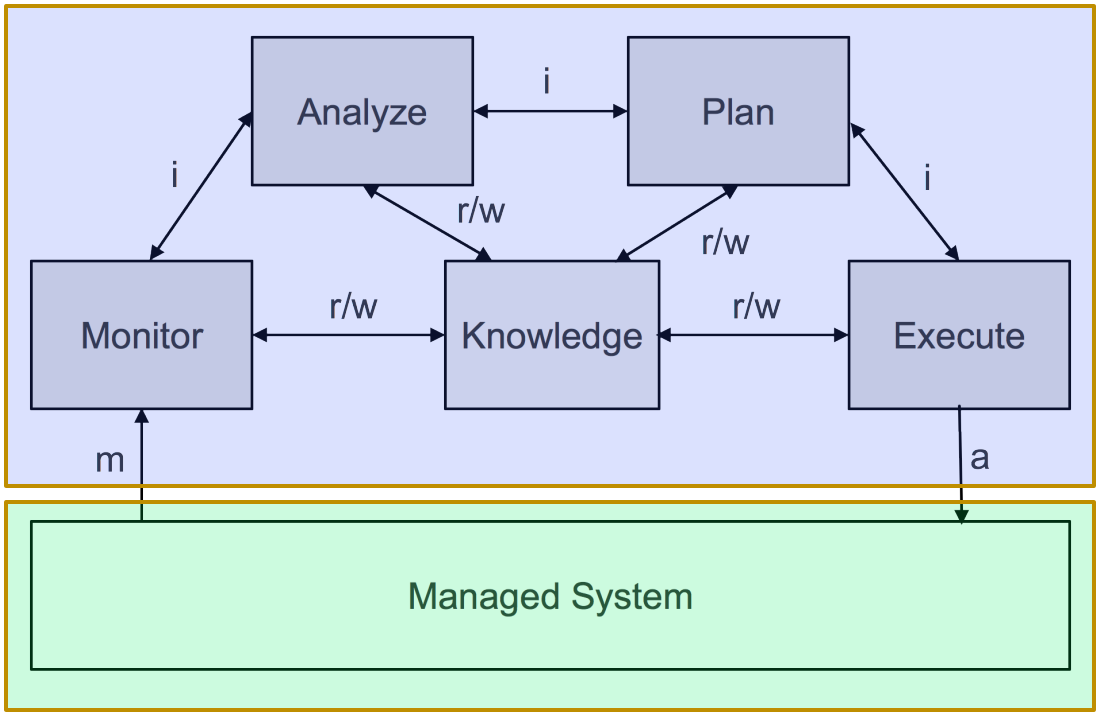
- An assembly of components which individually may be regarded as systems [Maier ‘98]
- Two key characteristics
  - Operational independence
  - Managerial independence

Self-adaptive software system

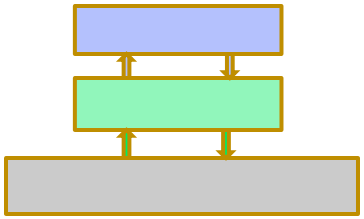


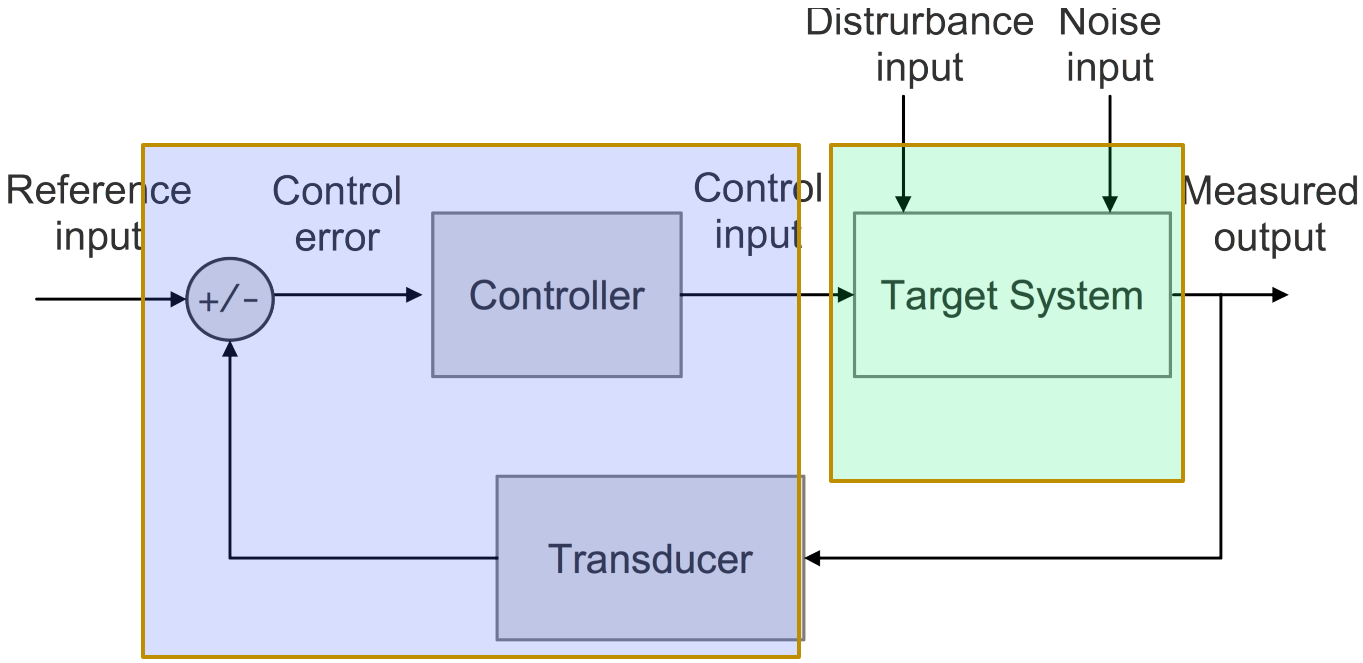
MAPE-K approach





Control-based approach





SoS as a managed system

- No single entity with knowledge/ authority to adapt systems of SoS
- Adaptation is decentralized

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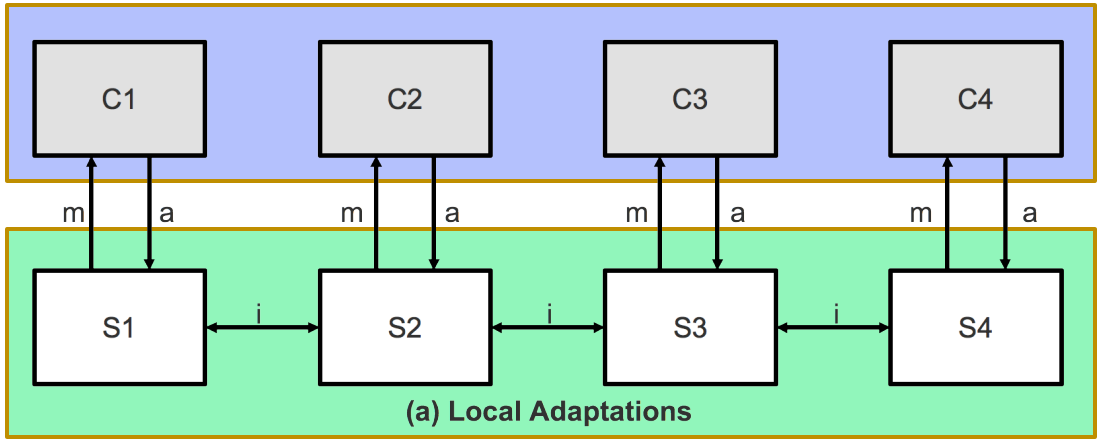
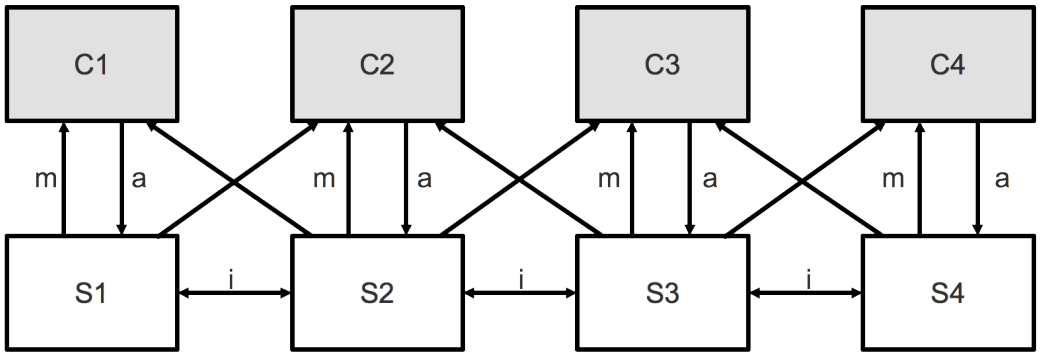
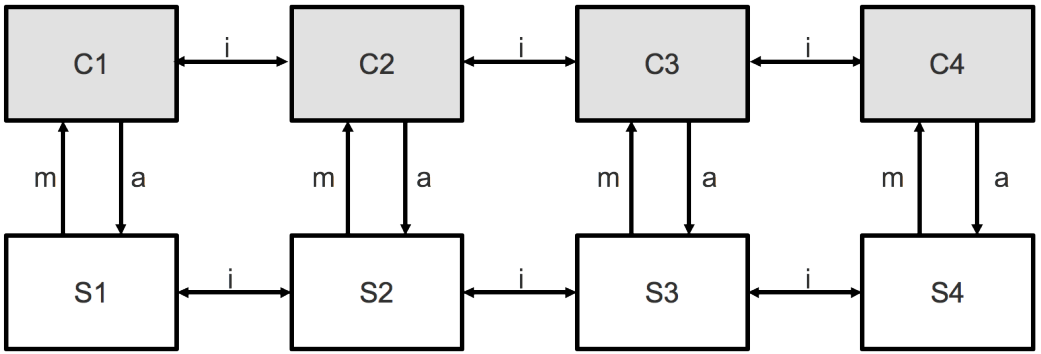
Local Adaptations



(a) Local Adaptations

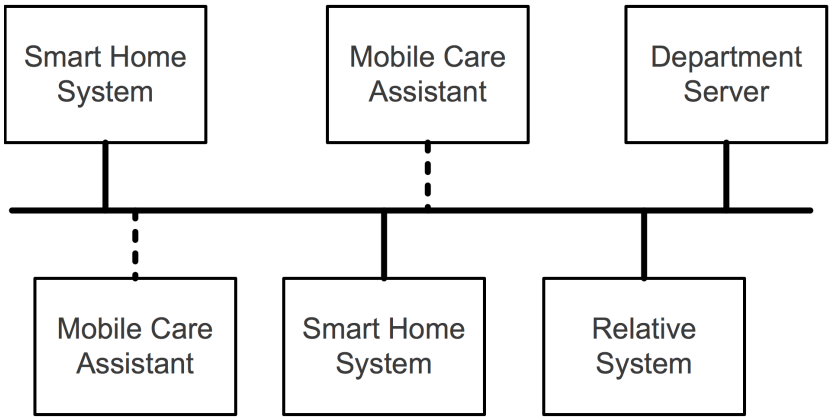


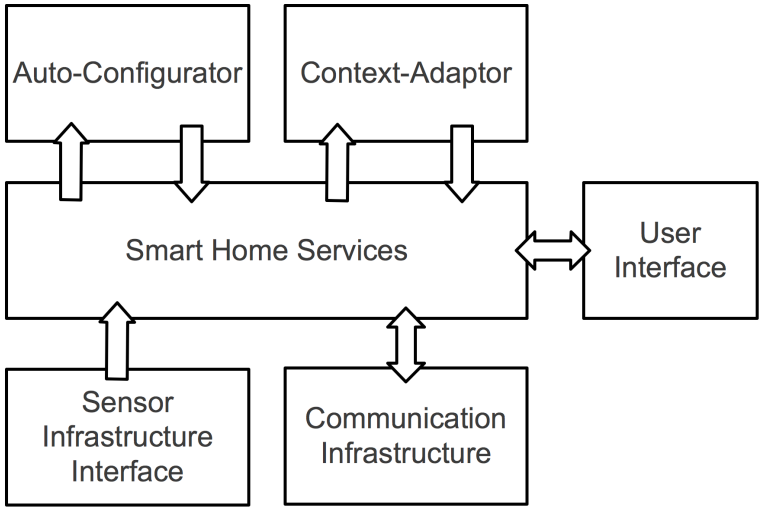
(b) Regional Monitoring - Local Adaptations



(c) Collaborative Adaptations

Local adaptations style

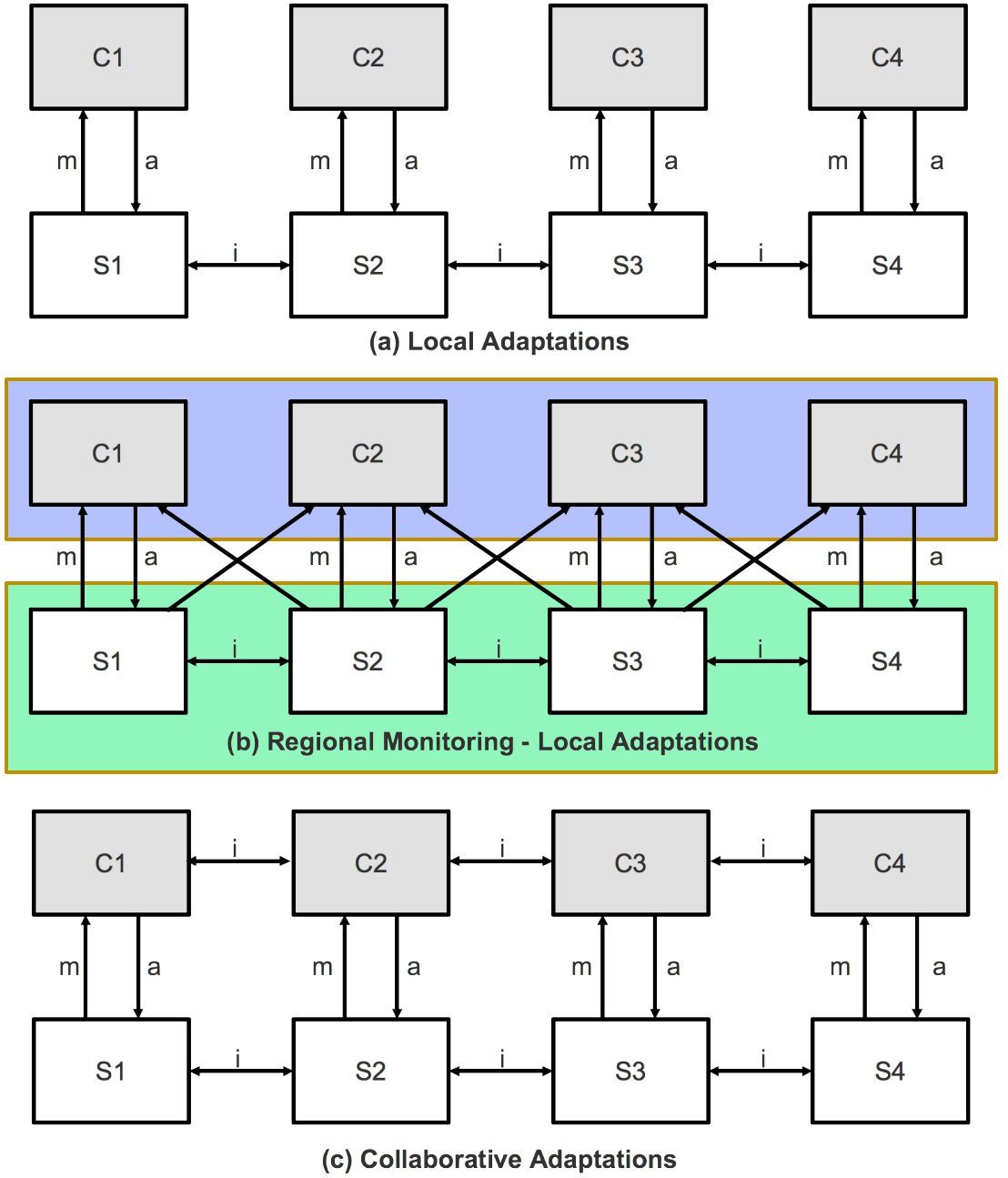




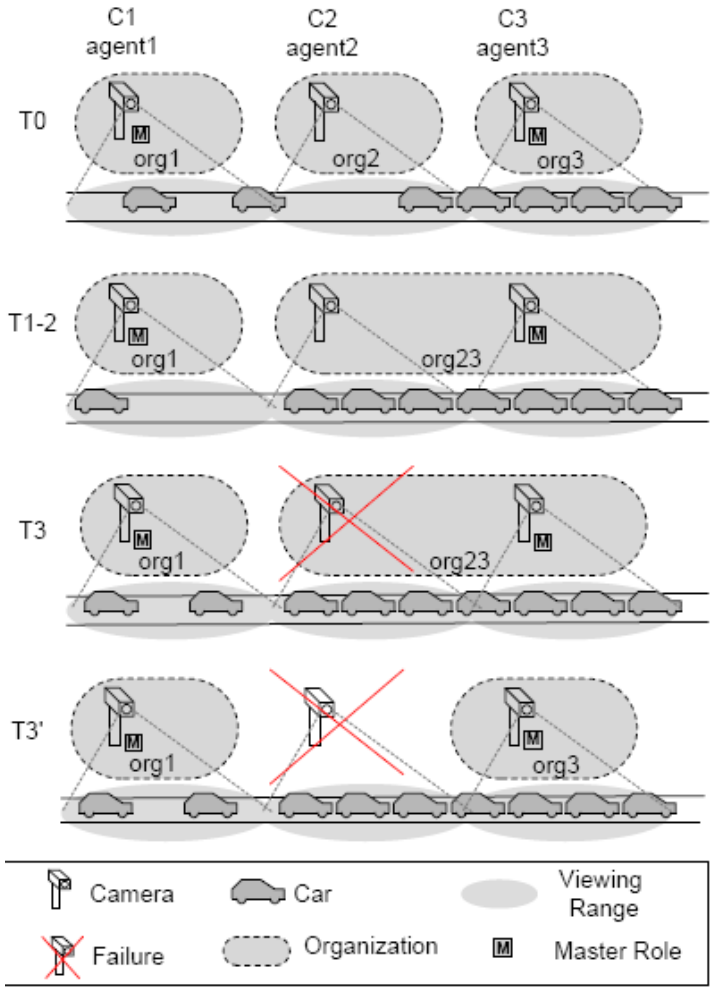
Local adaptations style

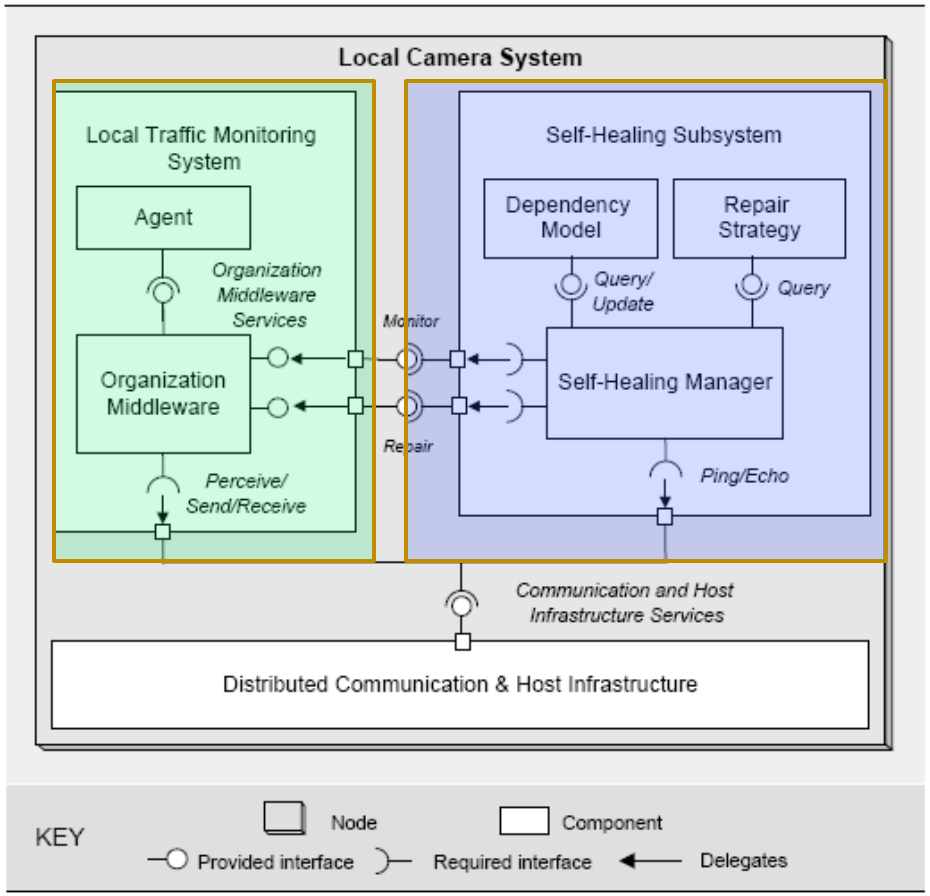
- Design local feedback loops
- Feedback loops interact indirectly
  - Sensitive to side effects/emergent behavior

Regional Monitoring Local Adaptations



Regional monitoring – local adaptations

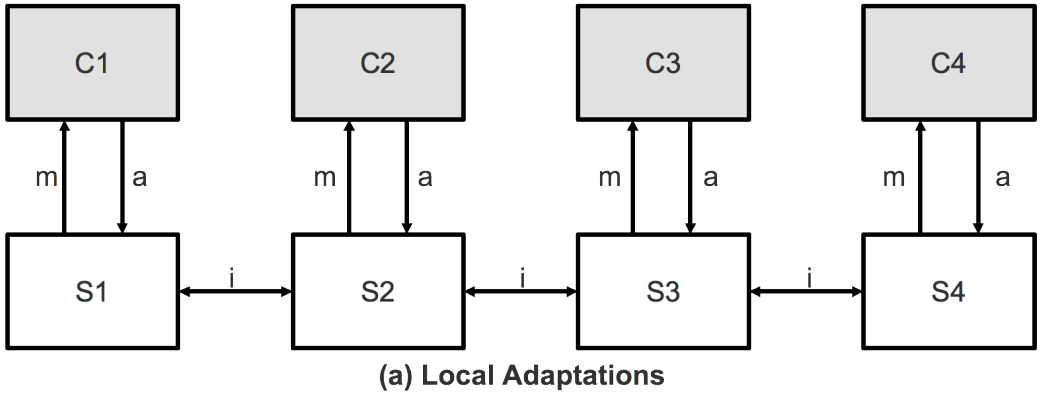




Regional monitoring – local adaptations

- Feedback loops share information loops
- Create dependencies

Collaborative Adaptations



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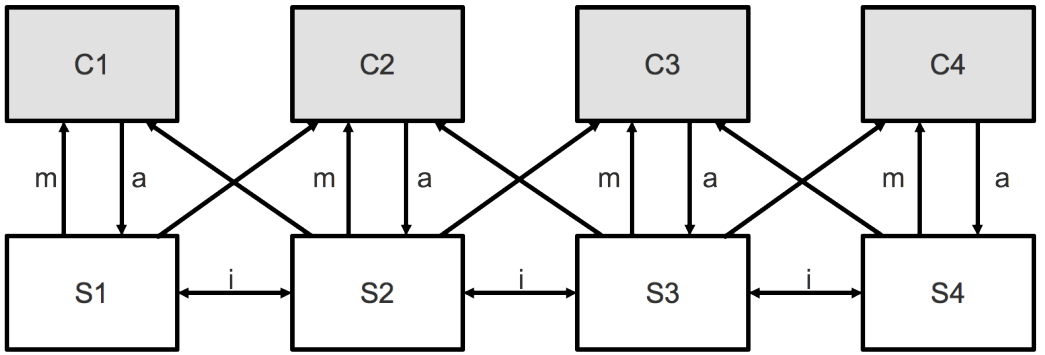

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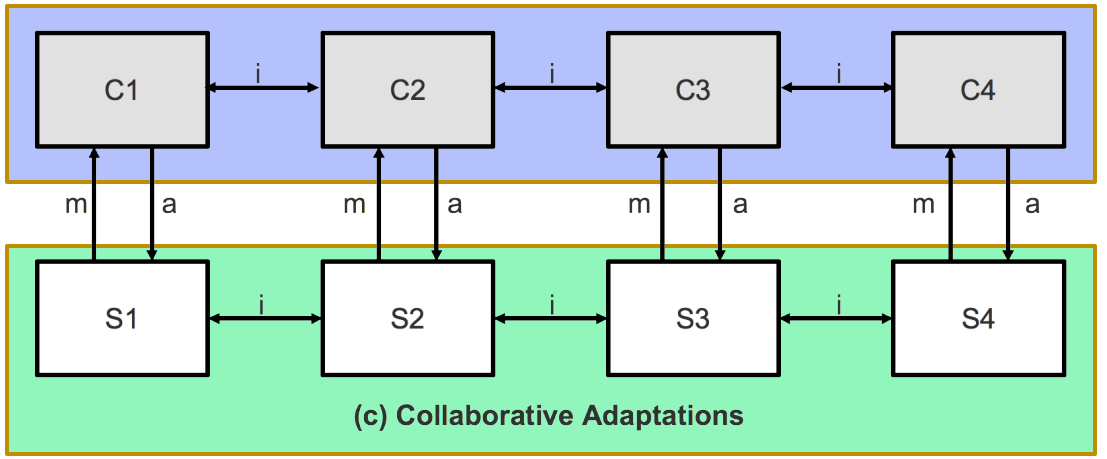
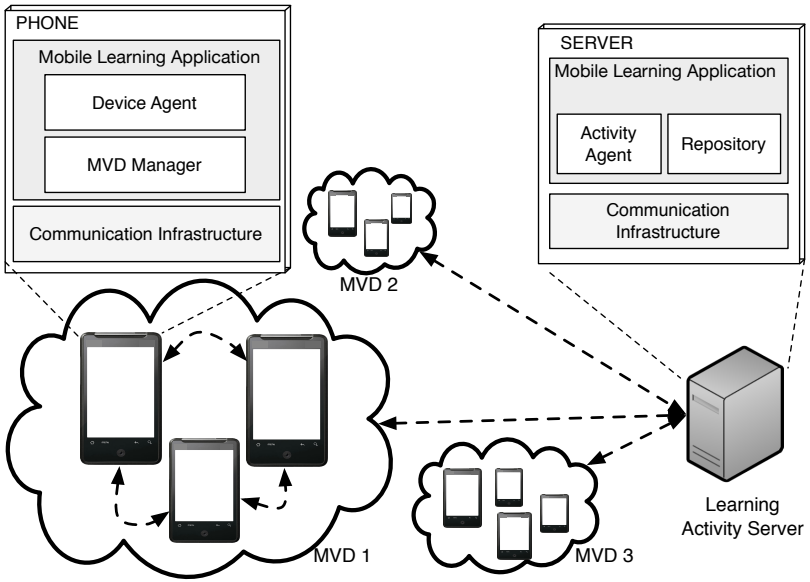
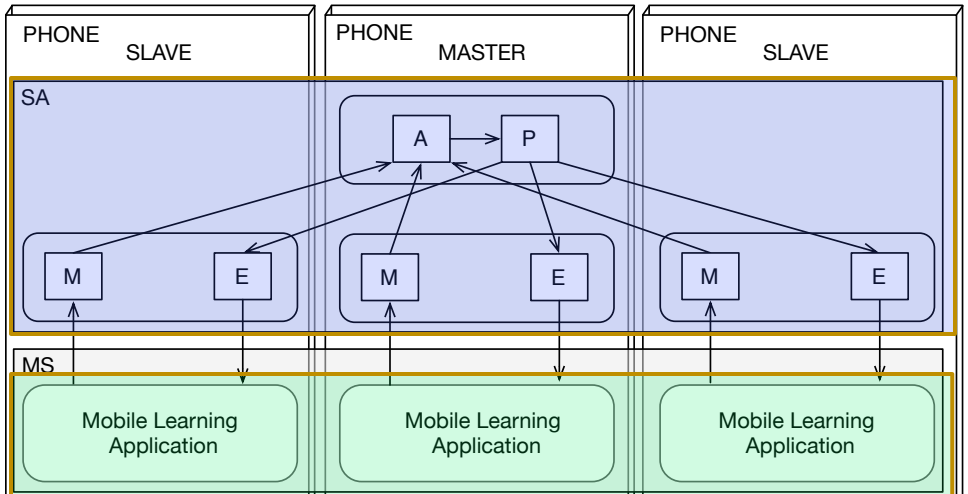


(c) Collaborative Adaptations

Collaborative adaptations style





Collaborative adaptations style

- Feedback loops adapt collaboratively
- Increased dependencies

A key challenge

- How to guarantee properties that span multiple systems of SoS?
  - Beyond correctness by construction
    - Runtime analysis & verification
    - Learning approaches
  - Control theory, e.g., stability analysis
    - Guarantees with arbitrary interactions = open problem
  - Complex systems theory, e.g., entropy
  - System architects versus SoS architect

Wrap up

- Self-adaptation as a means to separate concerns to mitigate uncertainty
- Three styles provide increasing degree of knowledge sharing and collaboration
- Design power vs. increased dependencies

- Key challenge: provide guarantees of properties that span multiple systems of SoS

References

- M. W. Maier. Architecting principles for systems- of-systems. Systems Engineering, 1(4):267–284, 1998.
- B. Cheng, et al. Software engineering for self-adaptive systems: A research roadmap. In Software Engineering for Self-Adaptive Systems, volume5525. Springer, 2009.
- R. Lemos,et al. Software engineering for self-adaptive systems: A second research roadmap. In Software Engineering for Self-Adaptive Systems II, volume 7475 of Lecture Notes in Computer Science. Springer, 2013.
- D. Weyns, S. Malek, and J. Andersson. Forms: Unifying reference model for formal specification of distributed self-adaptive systems. ACM Transactions on Autonomous and Adaptive Systems, 7(1), 2012.
- D. Weyns, B. Schmerl, V. Grassi, S. Malek, R. Mirandola, C. Prehofer, J. Wuttke, J. Andersson, H. Giese, and K. Goeschka. On patterns for decentralized control in self-adaptive systems. Lecture Notes in Computer Science vol. 7475, Springer, 2012.