Self-stabilization and eventual consistency in replicated real-time databases

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Presentation outline

- Replication in DeeDS
- Conflict detection and resolution
- Convergence and stabilization
- Challenges and ongoing work

Fundamental questions

- What does self-healing mean to us?
  - Error processing part of fault tolerance
    - Self-inflicted “errors”
    - Restoring global consistency
- What part of the self-healing problem?
  - Detecting and resolving inconsistencies
  - Proving system convergence

Fundamental questions, cont.

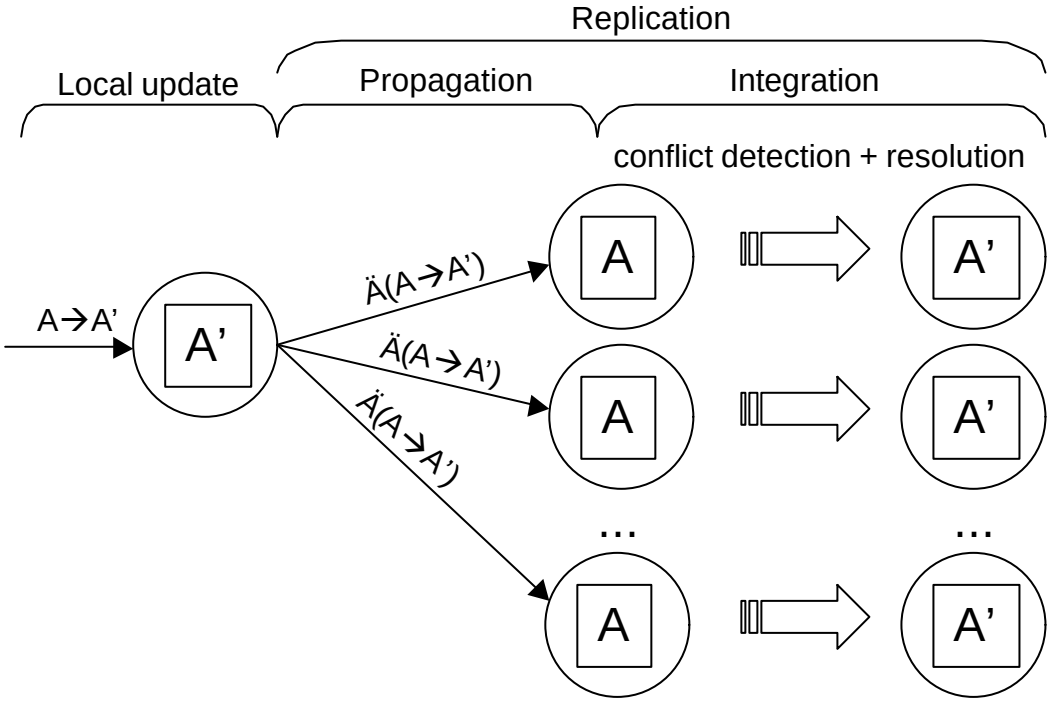
- What applications are we targeting?
  - Embedded, distributed real-time systems
- What are our main ideas?
  - Applying self-stabilization theory to a new area
  - Framework for resolving conflicts and proving convergence

DeeDS: Distributed Active Real-time Database System

- Embedded & distributed real-time systems
  - Predictable resource requirements
  - Fault tolerance
  - Example application: unmanned helicopters (WITAS)
- Full data replication
  - Central for communication, fault tolerance, availability
  - *Eventual* rather than immediate (mutual) consistency
    - Local predictability

DeeDS: replication protocol

- Supertransaction: consistent; relaxed isolation
- Subtransactions: single node; relaxed global consistency



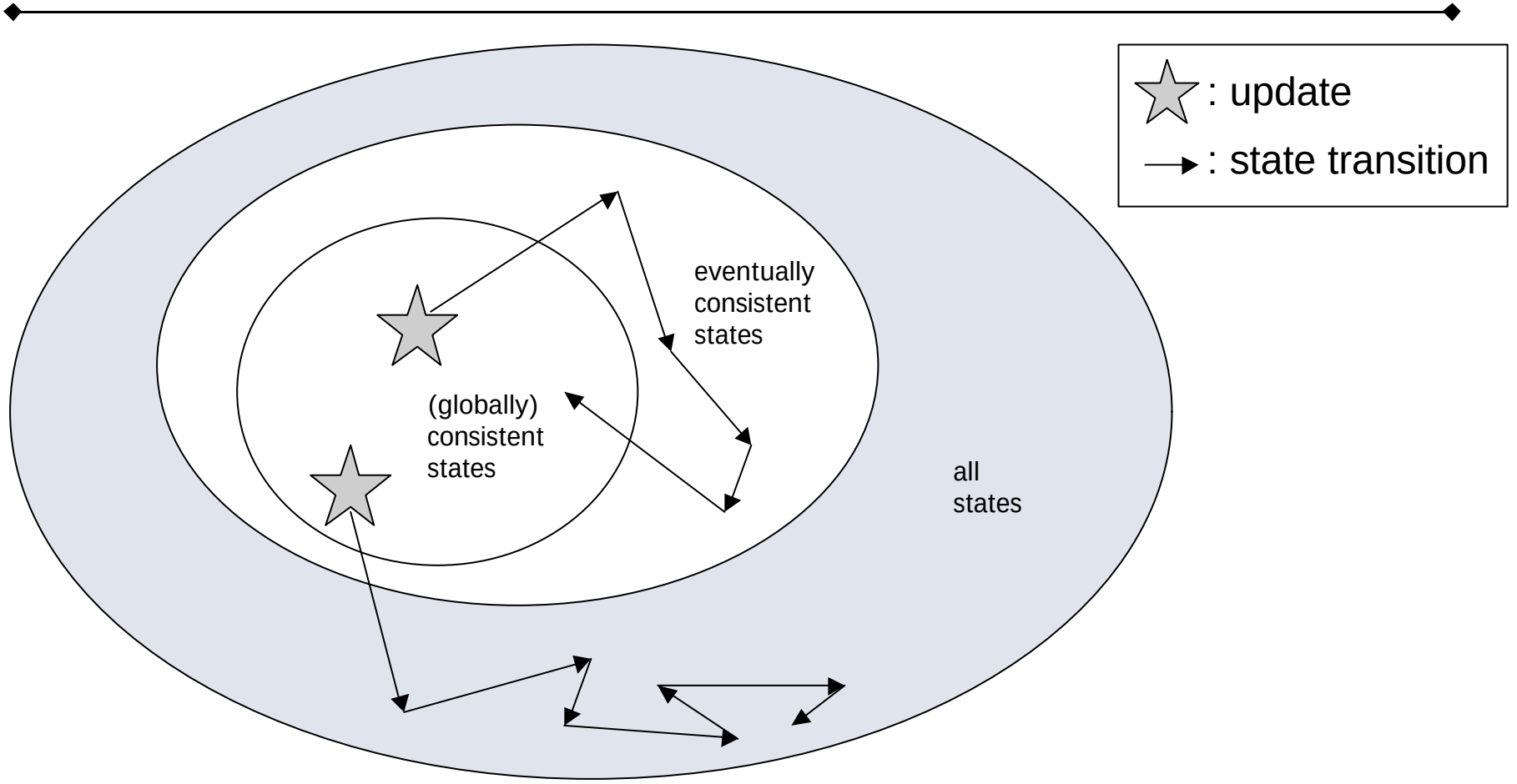
Conflict detection and resolution

- Conflict detection
  - E.g., double-booked flight seats
  - Performed using version vectors
- Conflict resolution
  - Requires a *policy* and a *mechanism*
  - The policy could be simple and generic ...
    - E.g., use value with lowest timestamp
  - ... or complex and application-specific
    - E.g., “Book one of the passengers on a later flight, and compensate her by giving her a free trip in the future.”

Convergence and stabilization

- Convergence: correctness criterion
  - Eventual consistency
    - A quiescent system eventually stabilizes
  - Tolerance of inconsistency
    - Applications must be aware of possible inconsistencies
  - Similar to self-stabilization
- Conflict resolution protocol must guarantee eventual consistency
  - Self-stabilization theory may help

Convergence and stabilization, cont.



Convergence and stabilization, cont.

- Conflict resolution protocol
  - Consists of a policy and a mechanism
- Requires that
  - The mechanism correctly implements the policy
  - The system stabilizes in a finite number of steps
    - In a quiescent system
    - The mechanism never takes the system to an inconsistent state

Challenges and differences

- Complexity
  - CR protocols are application-specific and complex
  - Is it still feasible to use self-stabilization theory?
- Conflict resolution is explicit; self-stabilization generally implicit in the algorithm
- Stabilizes from inconsistencies introduced by applications in normal operation rather than from faults

Ongoing work

- Application of self-stabilization theory to a new area: conflict resolution in eventually consistent databases
- A formal method for analysis of conflict resolution protocols
  - Specification of state spaces
  - Specification of conflict resolution policies
- Proofs for generic conflict resolution protocols