Cooperative Update: A New Model for Dependable Live Update

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Outline

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High-Availability systems

Characteristics

- Need for 24/7/365 operation.
- Disruption of service and loss of transient state is ill-affordable.
- Examples: business systems, mission/safety critical systems.

Consequences of downtime

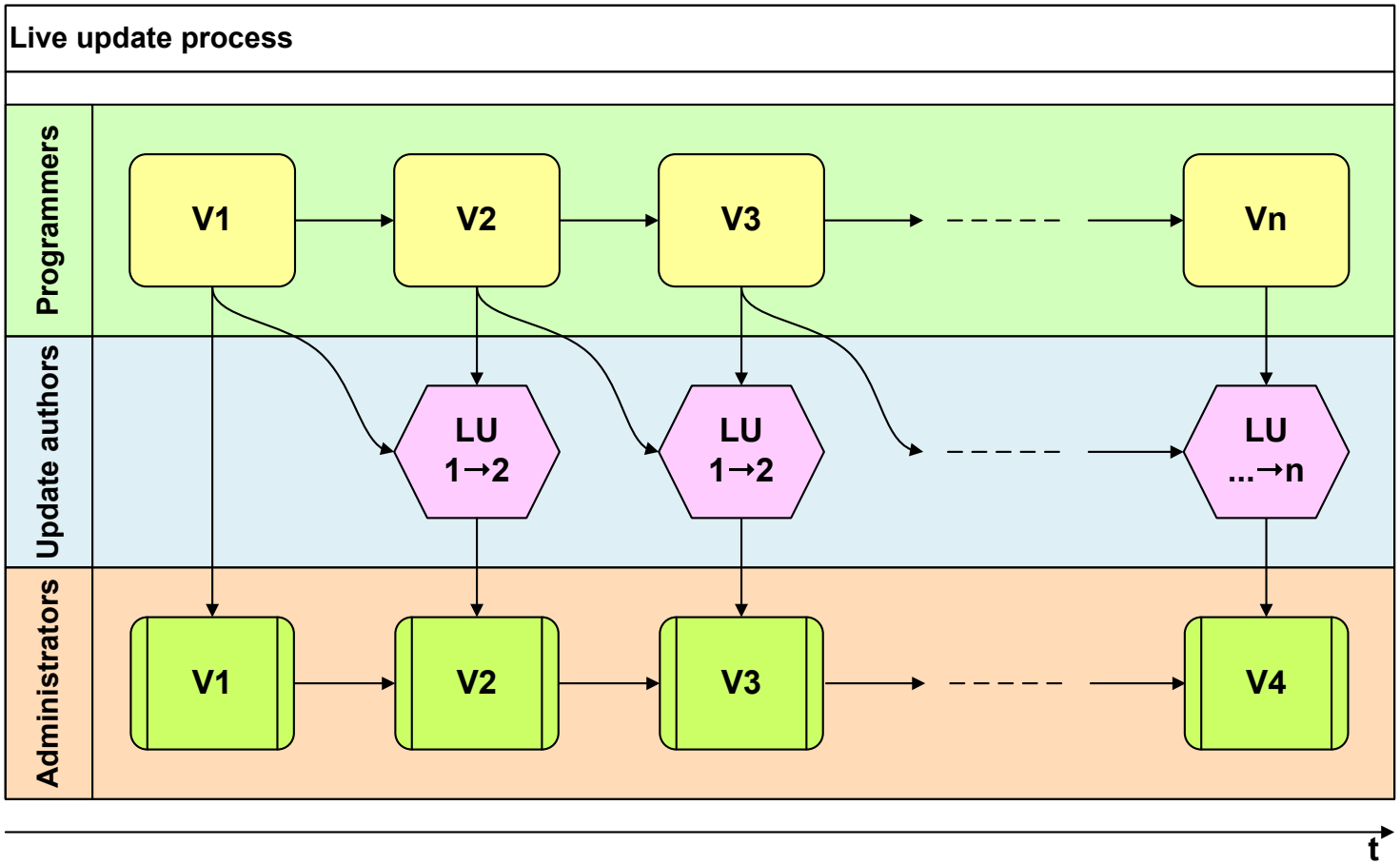
- eBay lost $5 million in 1999.
- Blackout affected 50 million people in U.S. and Canada in 2004.
- 26 American soldiers died during the Gulf War.

Live update

- A solution to support evolution in high-availability environments.
- Updates are generally perceived as a possible reliability threat.
- At high-availability sites, average time-to-update is **30** days.
- Live updates cannot afford weaker reliability guarantees.
- This motivates our focus on reliability.

Outline

Software-based live update



Interrupt model

A push model

1. The system is interrupted at an arbitrary point in time.
2. The update is glued into the running system and state transfered.
3. Execution is redirected to the new version.

Properties

- Suitable for binary backward compatibility.
- Safety constraints checked at runtime.
- Usually limited to type-safety enforced eagerly or lazily.

Invoke model

A pull model

1. The system reaches a valid update point and notifies the live update infrastructure (other variants are possible).
2. If an update is available, it is installed and state is transfered.
3. Execution is redirected to the new version.

Properties

- Suitable for source backward compatibility.
- Safety checks rely on predefined update points.
- Static/dynamic analysis can provide better safety guarantees.

Transparency

The upsides

- Separation of concerns is good.
- Need to integrate into existing software systems.

The downsides

- OSS projects doubling in number and size every $\approx$**14** months.
- Can we scale to large systems and complex updates?

Outline

Scalability threats: State transfer

- Complexity grows with the complexity of the update.
- This is a fundamental problem.
- But different models can handle this challenge in different ways.
- Note: state transfer is not only to handle datatype changes.
- See the paper for examples and more details.

Scalability threats: Detection of safe update time

- Chances of endless wait grow with the complexity of the update.
- A nontrivial update process may not complete in bounded time.
- Can affect both the interrupt and the invoke model.
- Problem arises when safety constraints are enforced eagerly.
- Problem worsens with stronger safety constraints.

Scalability threats: Ensuring correctness of execution

- Manual inspection effort grows with the complexity of the update.
- Verify update compliance with any of the possible system states.
- Affects in different ways the interrupt model and the invoke model.
- For complex systems, the number of states may be very large.
- Number of states grows exponentially with the number of threads.

For complex systems and updates...

Dependability problems

- State transfer and manual inspection are error-prone.
- Indefinite wait at update time is bad.
- Trading safety for flexibility is painful.

Most limiting assumptions

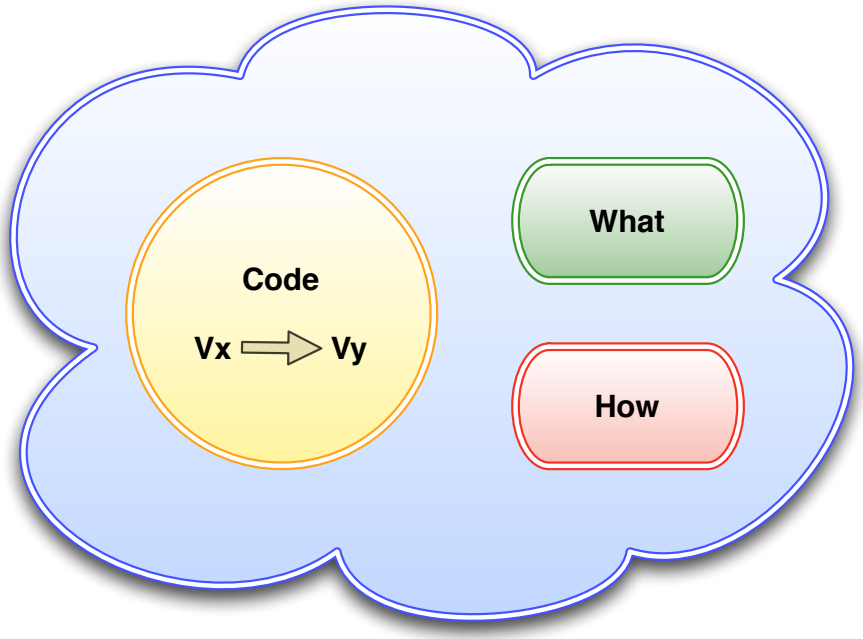
- The system is a hostile environment.
- The nature of the update is ignored.
- Assumptions derived from the transparency model.

Outline

Towards cooperative update

- Focus on dependability.
- No transparency or backward compatibility.
- The system cooperates in the update process.
- Live update integrated as part of the development cycle.
- The nature of the update characterizes the update process.

Live update packages



- Updates are made self-describing with enclosed metadata.
- Developers' specifications can simplify the update process.

System support

- The system is receptive to changes.
- An update manager processes the update package.
- Specifications are translated into an update protocol.
- The update protocol drives the system into the target state.
- Live update is only performed after then.

The live update process

1. Initialization.
2. Notification.
3. Preparation.
4. State checking.
5. State transfer.
6. Replacement.

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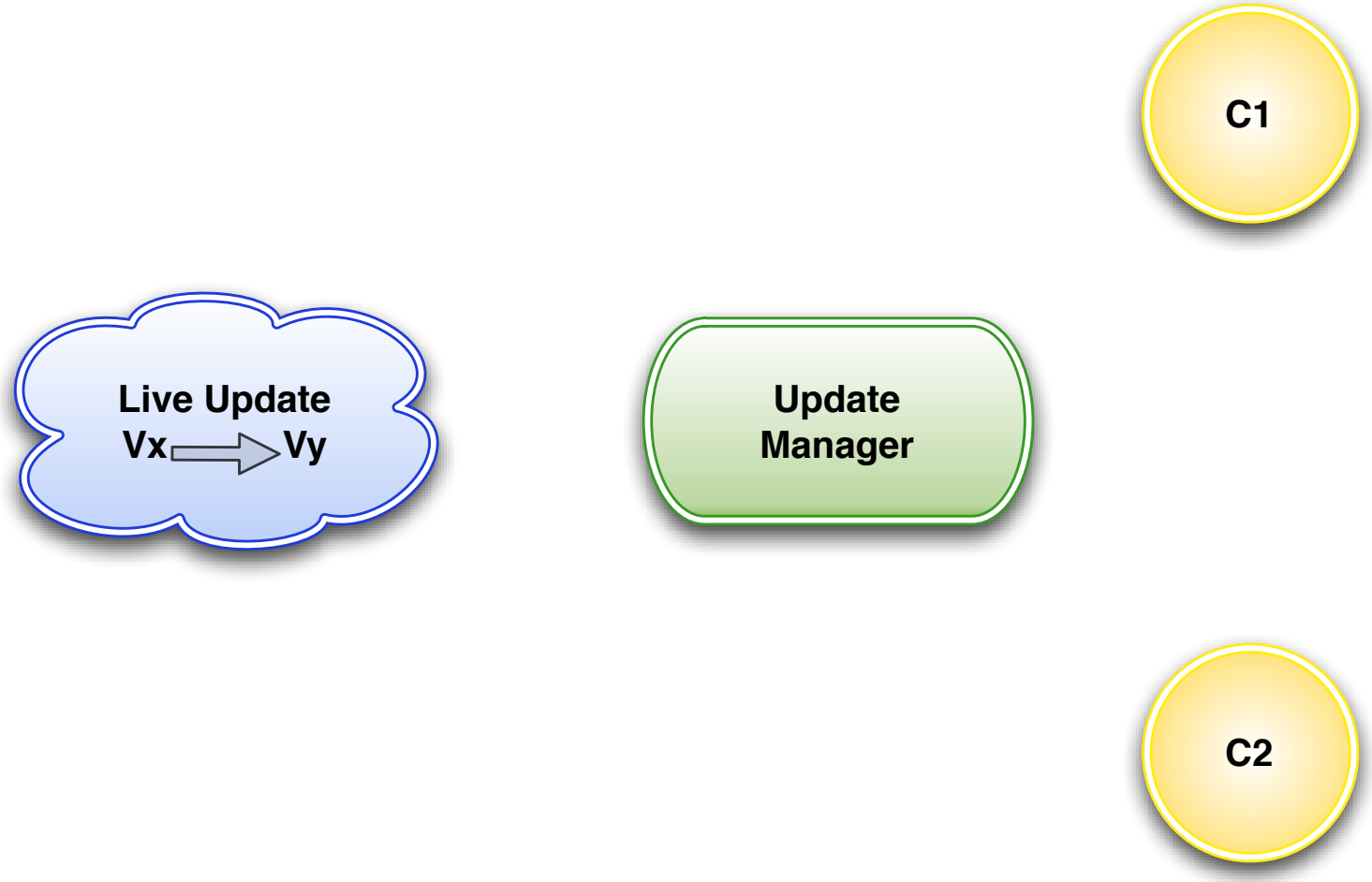

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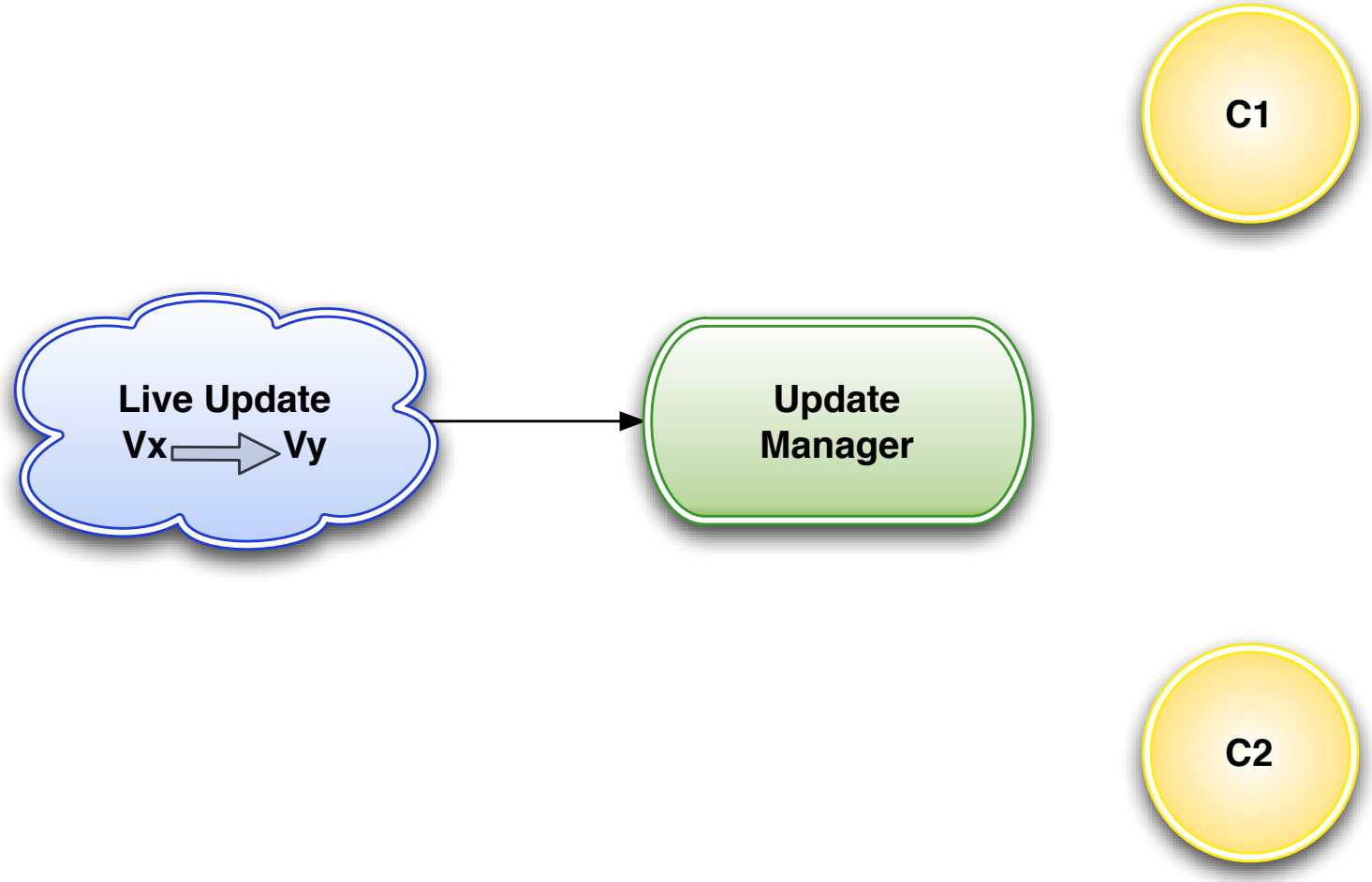

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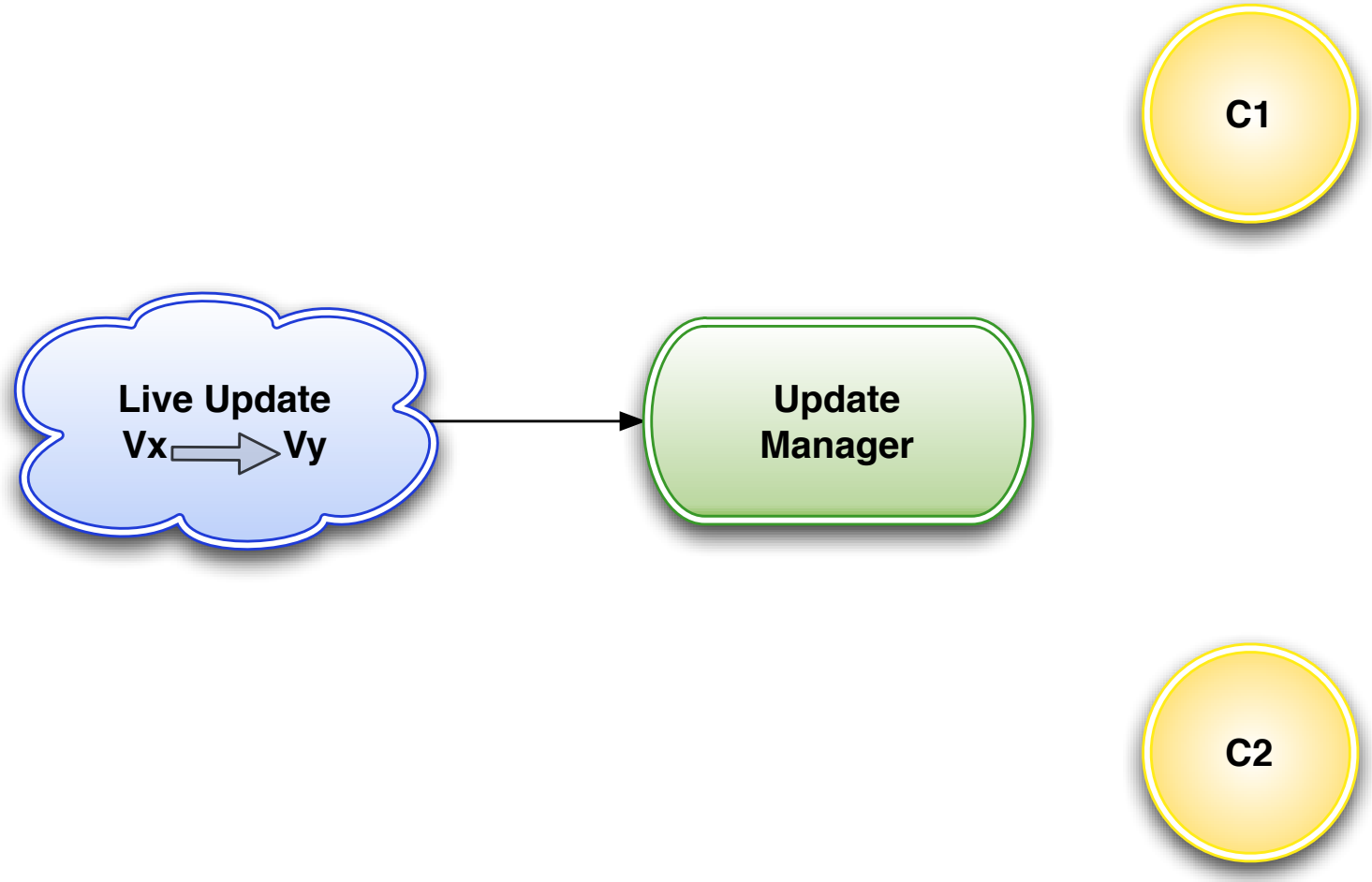

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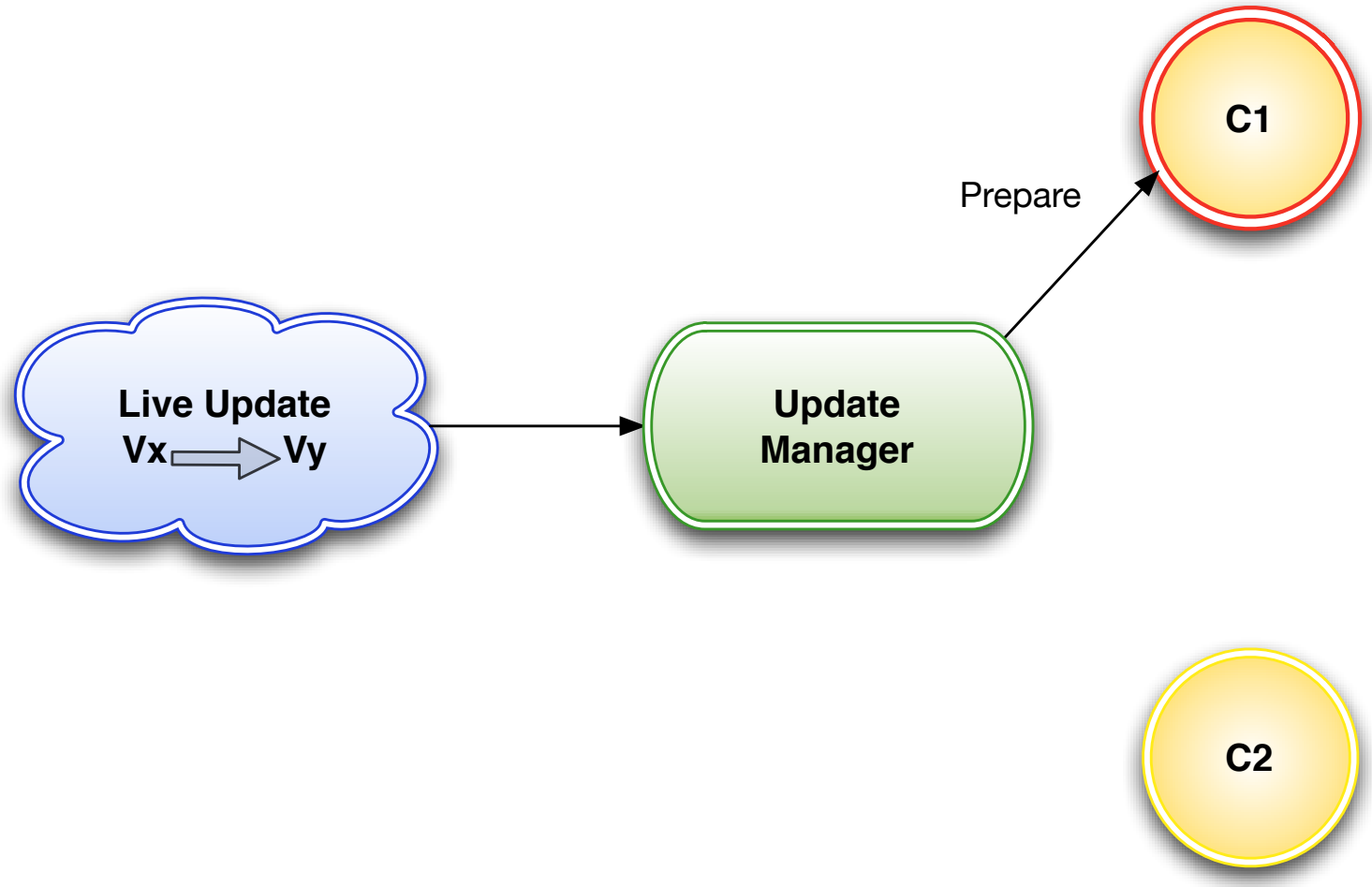

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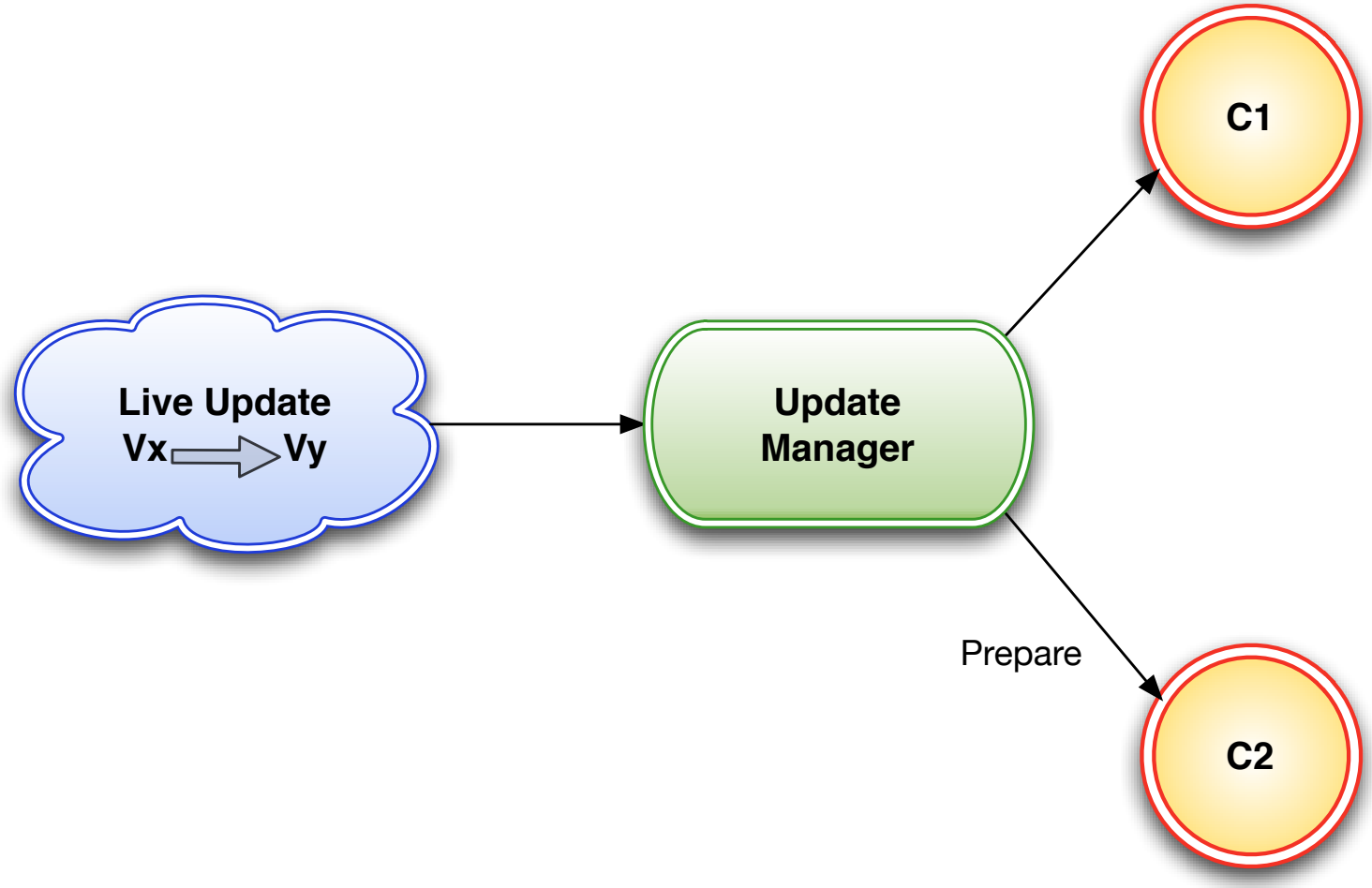

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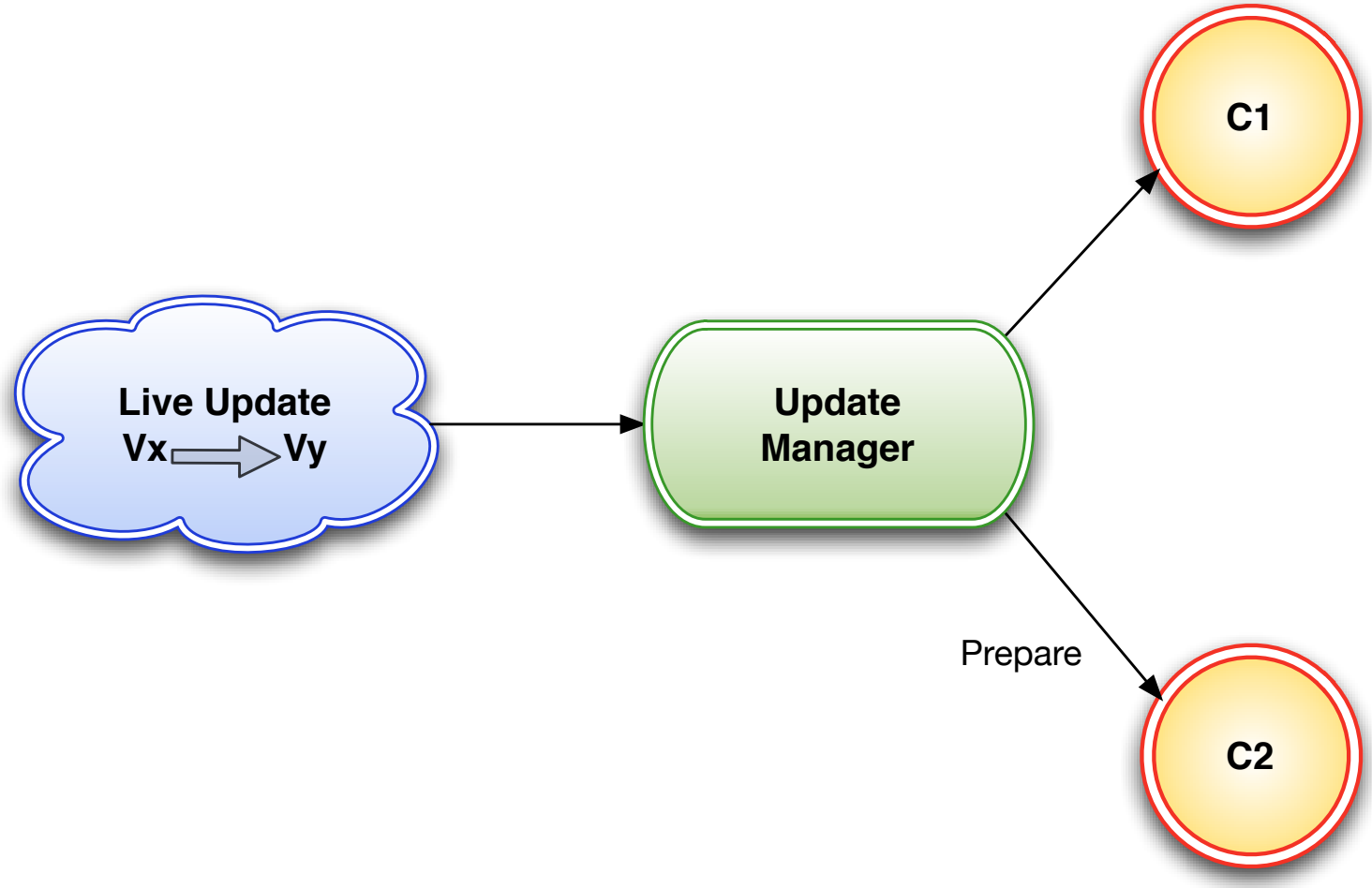

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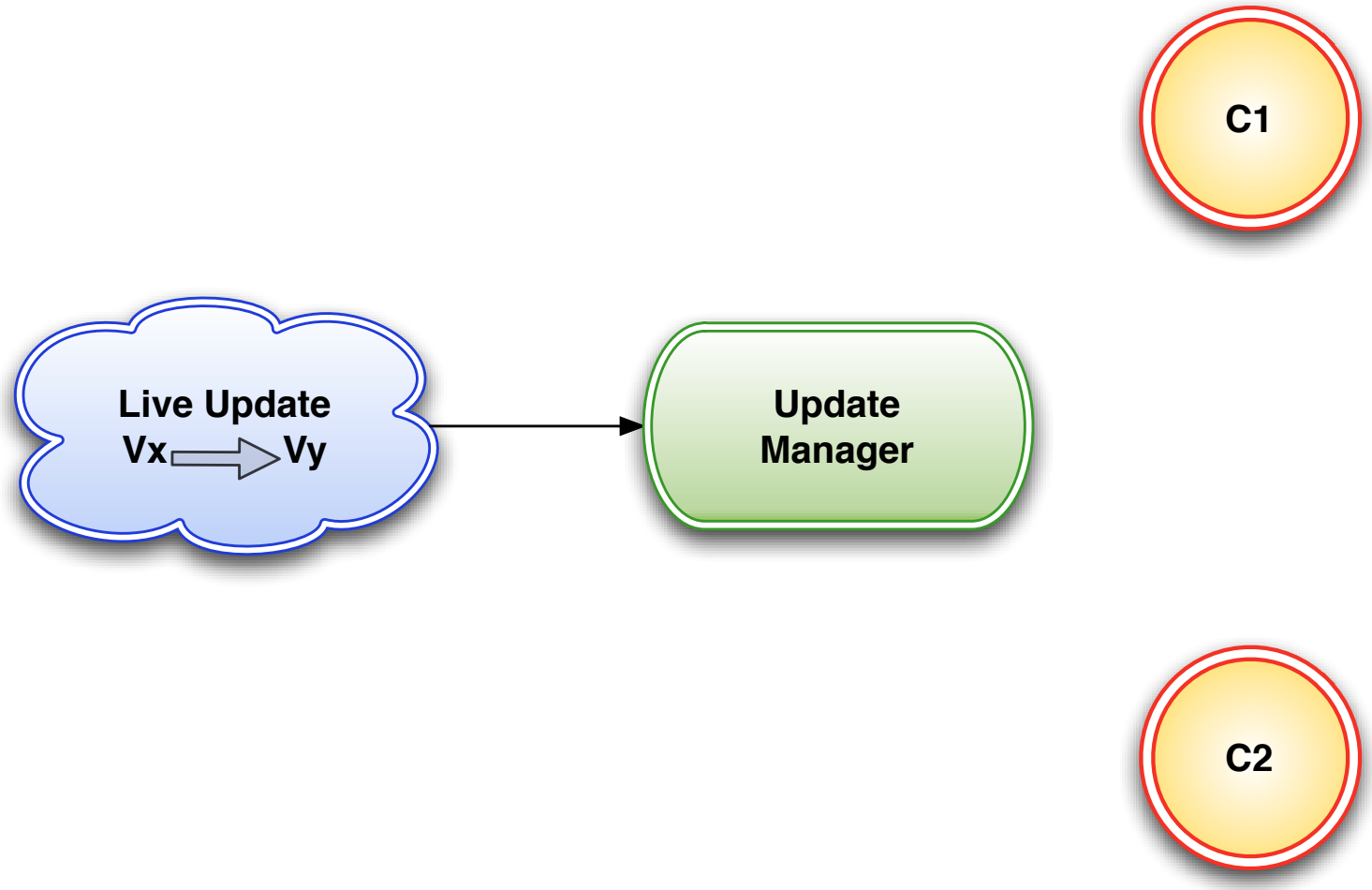

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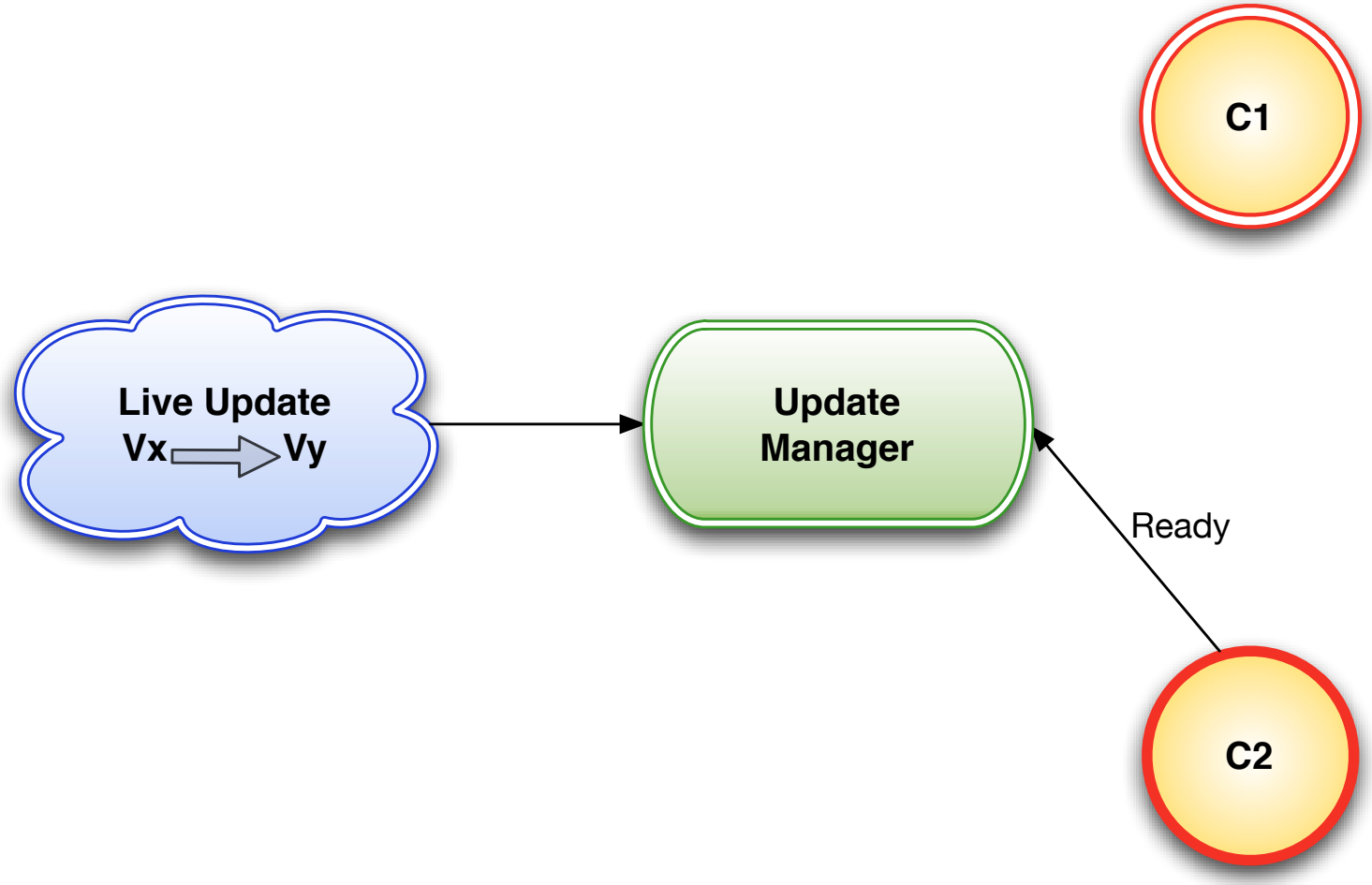

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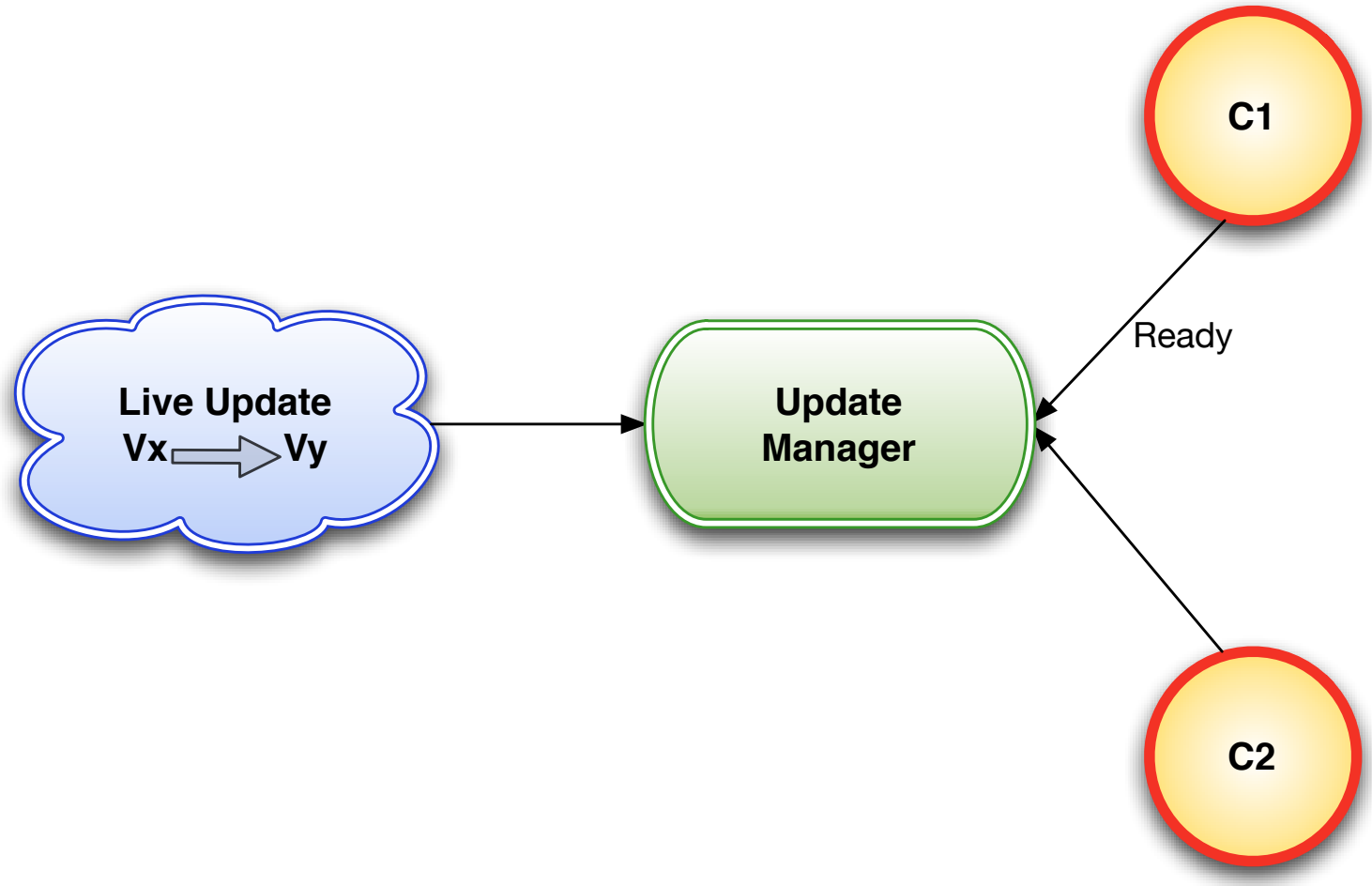

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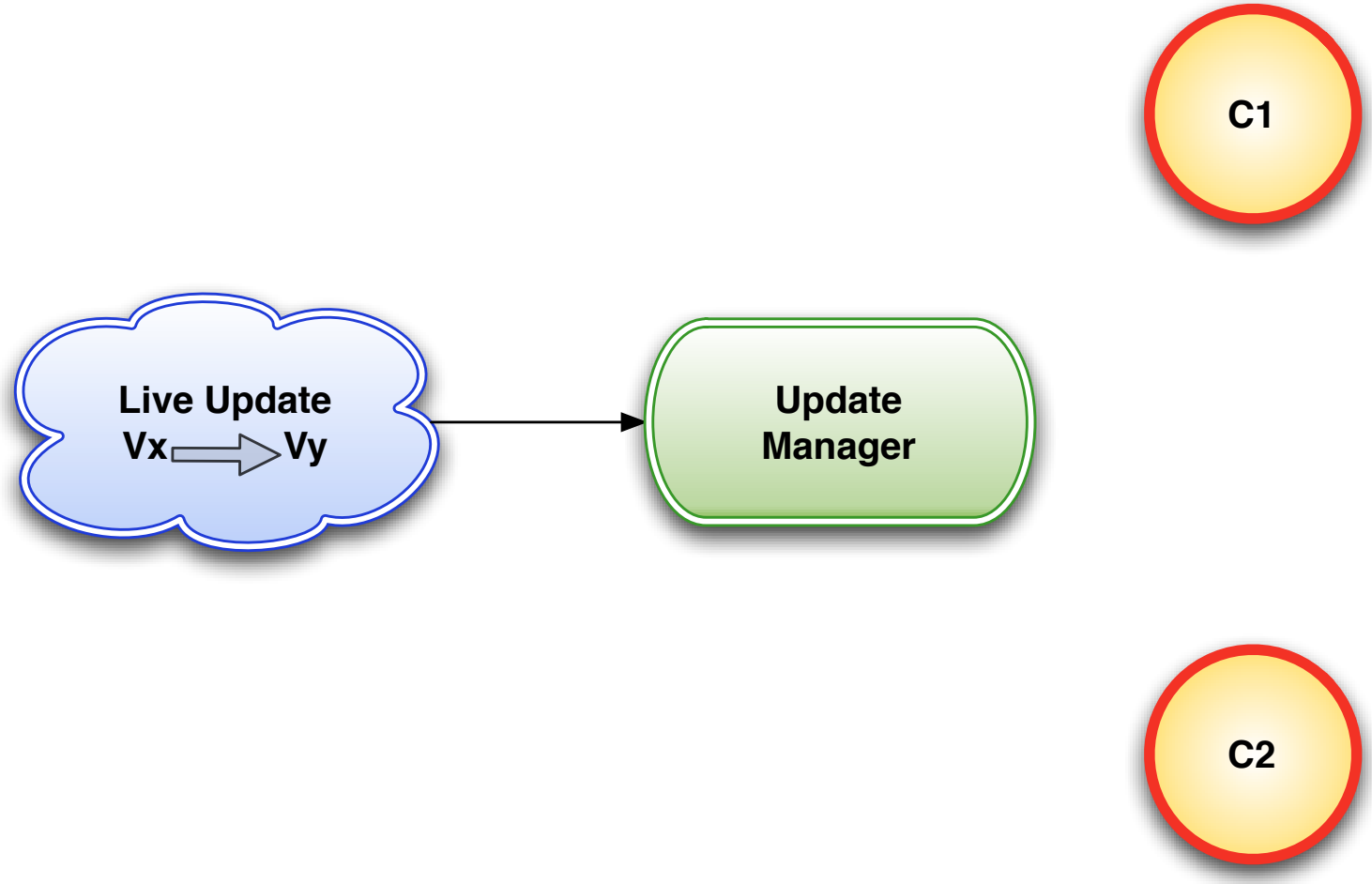

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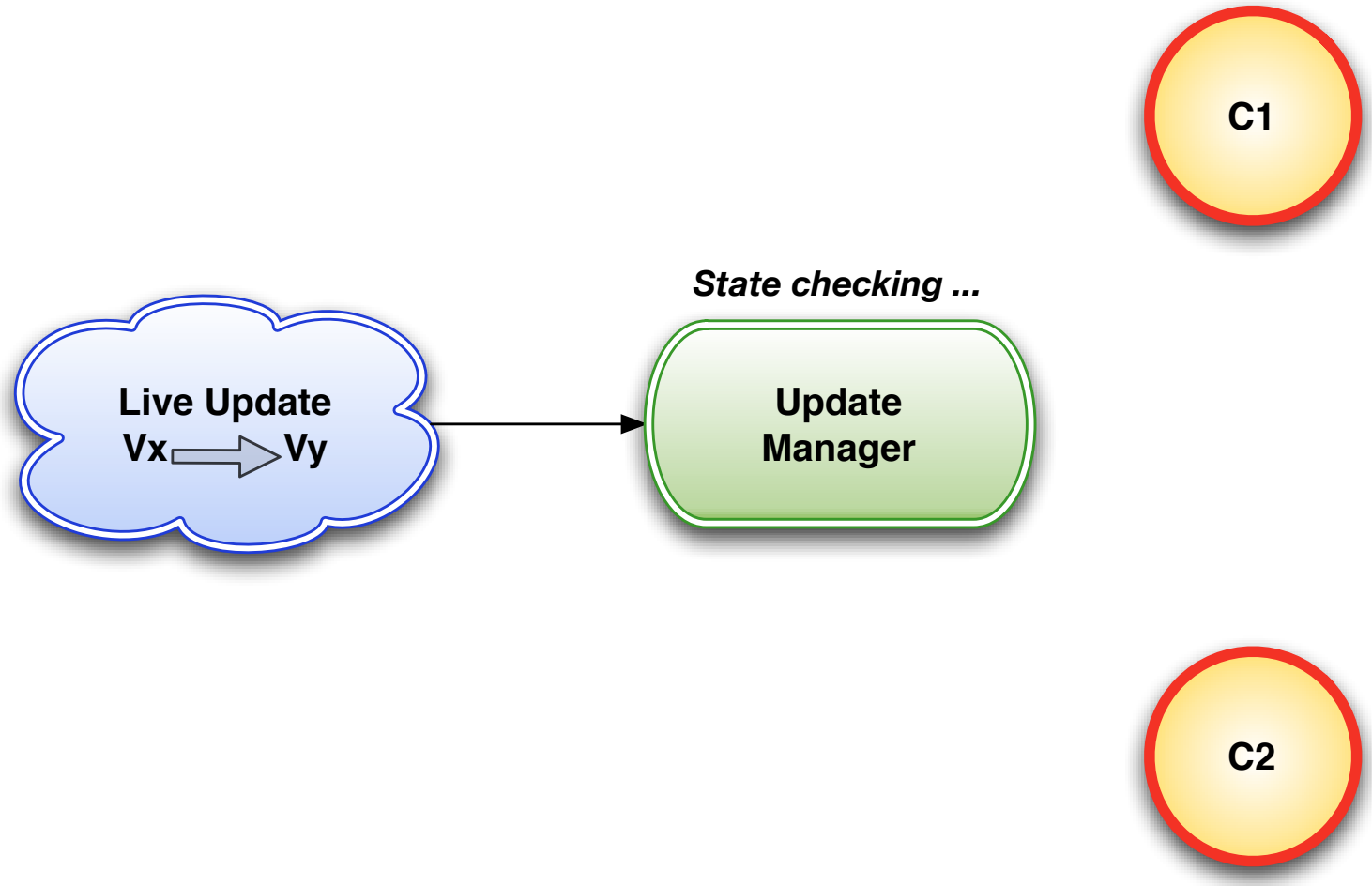

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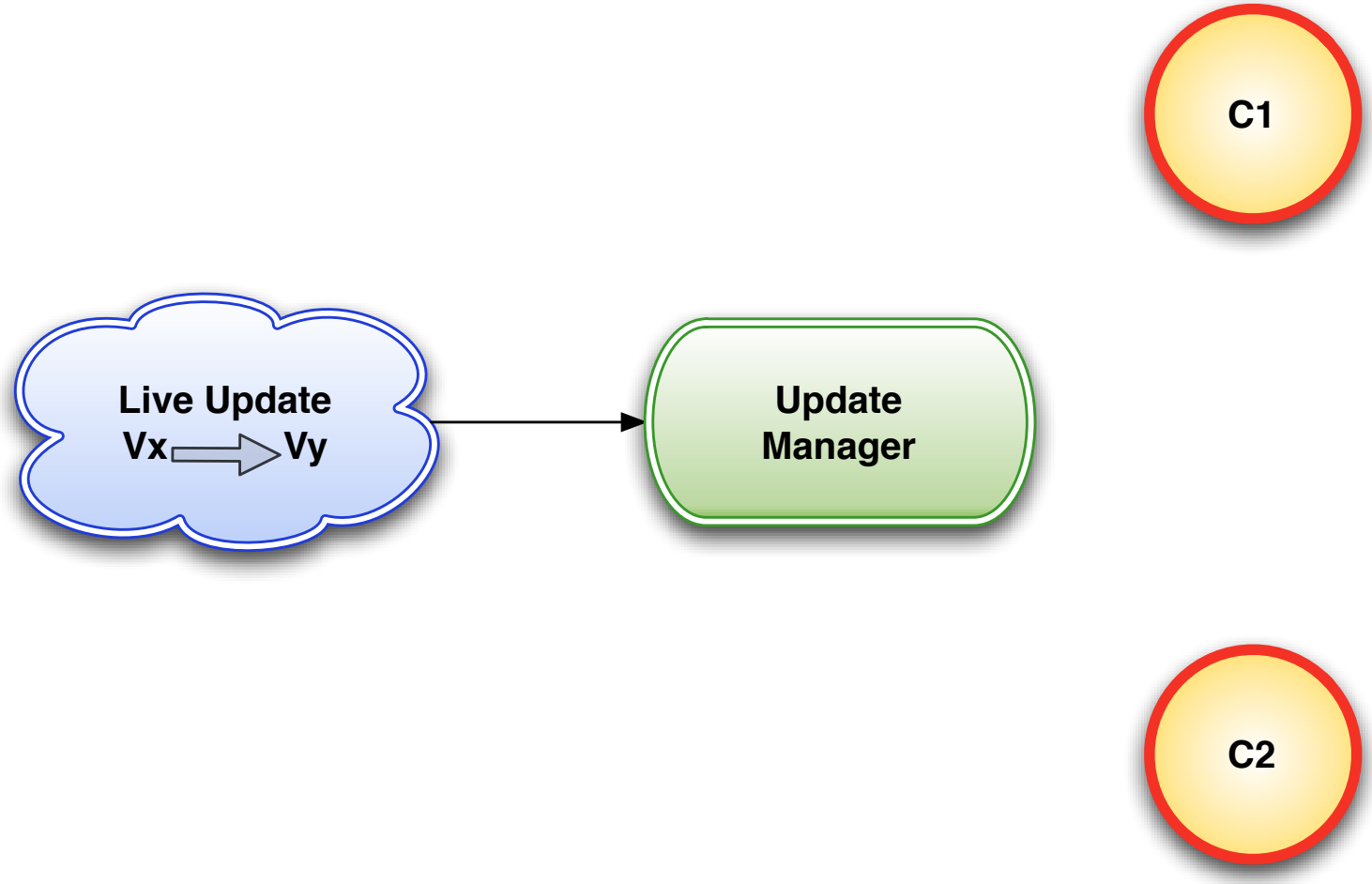

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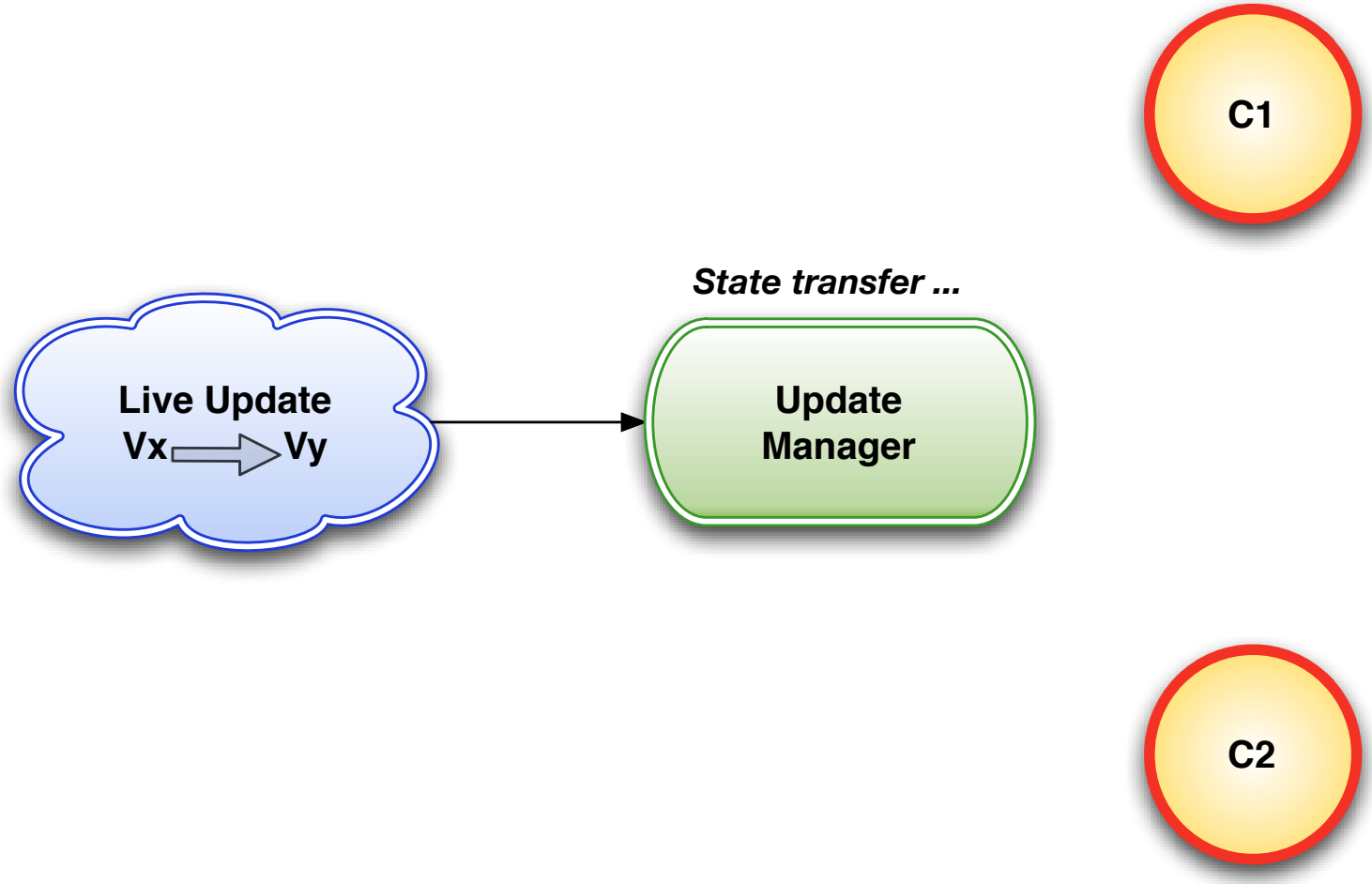

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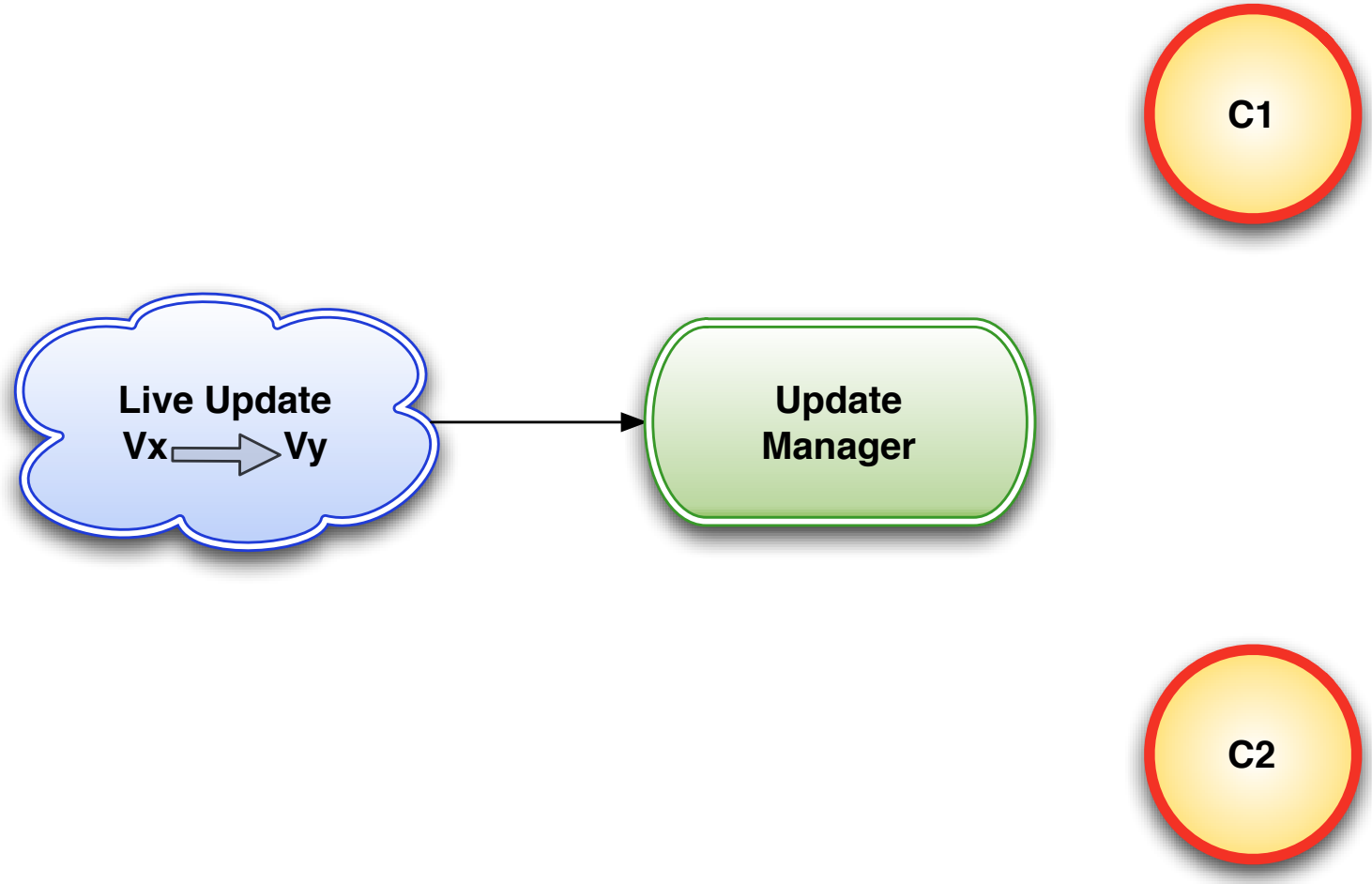

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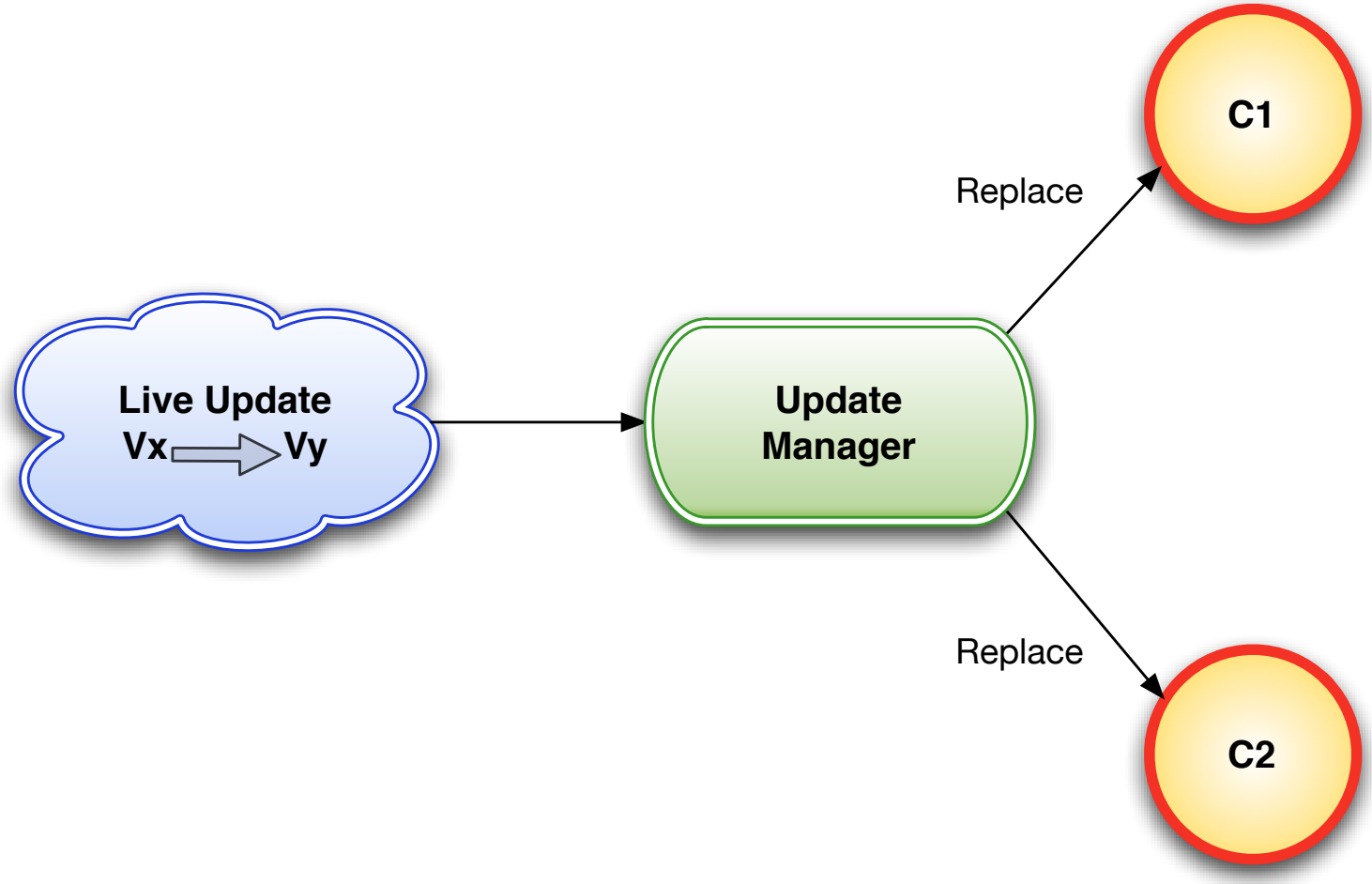

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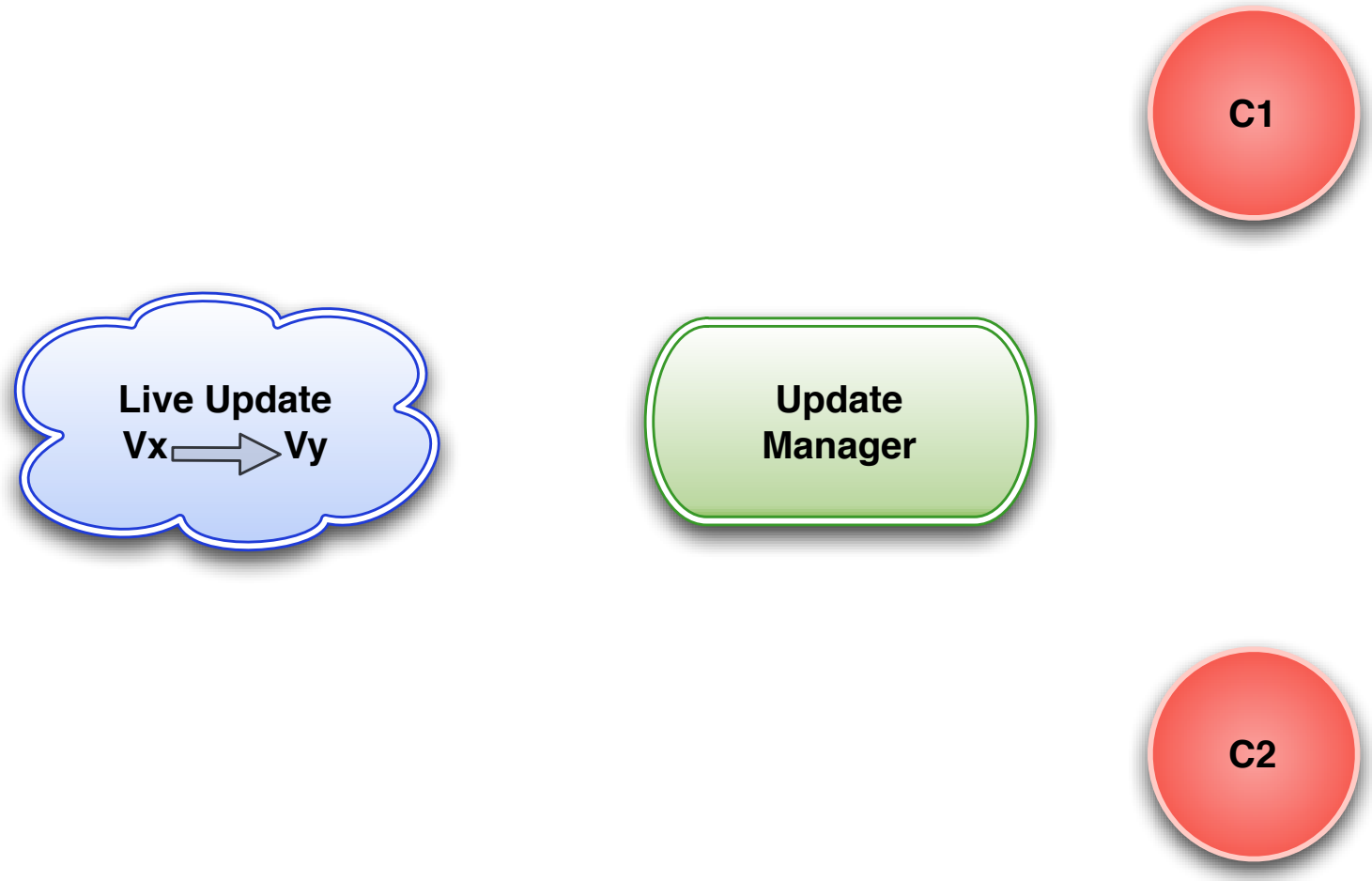

Cooperative update

Properties

- The live update process is deterministic and time-bounded.
- The update only occurs in a stable and known state.
- The feasibility of an update becomes a implementation problem.
- Flexibility to tune atomicity constraints at update time.

Dependability benefits

1. State transfer still required, but simpler.
2. Detection of safe update time at runtime is no longer an issue.
3. Ensuring correctness of execution at design time.

Implementation considerations

- Model effective with complex systems and a modular design.
- Components need a well-defined interface.
- Components need an appropriate level of isolation.
- A component could be a module, object, process, etc.
- Promotes a better system design and documentation of changes.

Outline

Summary

- A new cooperative model for dependable live update.
- Tailored to complex systems and a broad range of updates.
- System no longer assumed hostile and unaware of updates.
- Solves many recurring problems structurally.
- Sacrifices transparency for improved dependability and flexibility.

Thank You!


John Doe O.S.
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