Preserving Reciprocal Consistency in Distributed Graph Databases

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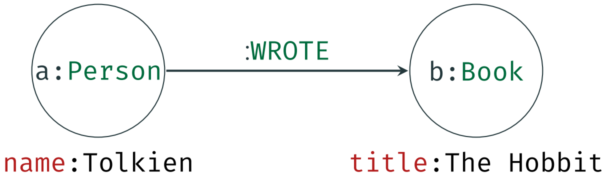

Figure 1: Vertices connected by an edge

Storage Layer Representation

- In the storage layer,
  - edge directionality does **not** exist
  - connected vertices store information about each other

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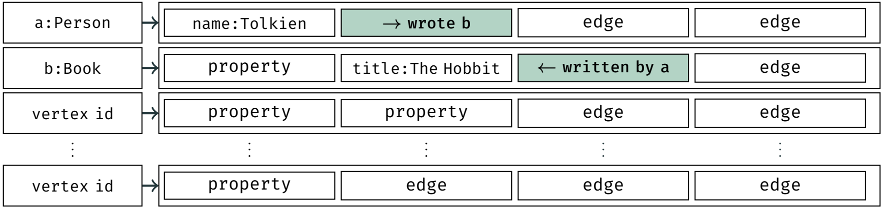


Figure 2: Edge storage layer representation

Reciprocal Consistency

When the adjacency list edge pointers for a given edge refer to each other in a complementary manner, that edge is ***reciprocally consistent***

Partition graph across machines in a cluster

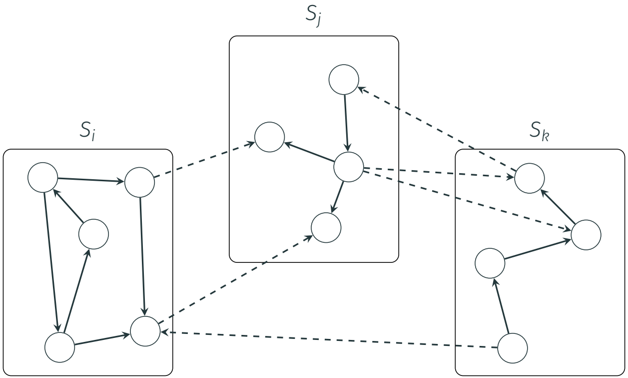


Figure 3: Partitioned graph

Distributed Graph Databases

A degree of concurrency control is needed for ensuring reciprocal consistency of distributed edges

Reciprocal Inconsistency

Distributed edge *ab* indicates `Tolkien` wrote `The Hobbit`

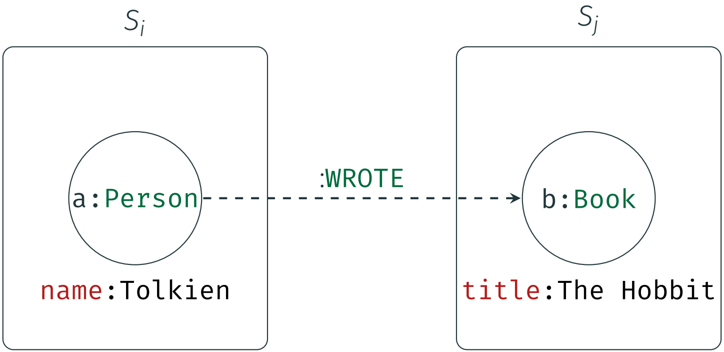
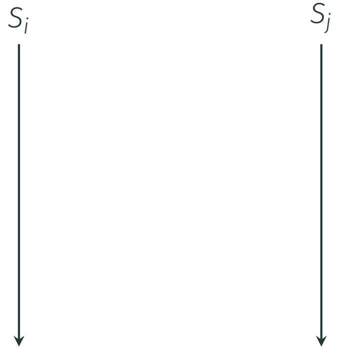


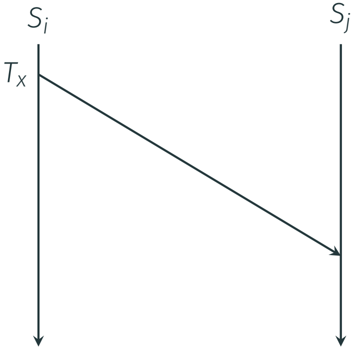
Figure 4: Distributed edge

Reciprocal Inconsistency



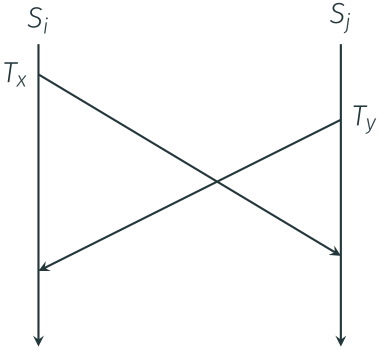
Reciprocal Inconsistency

- T_x deletes the edge



Reciprocal Inconsistency

- T_x deletes the edge
- T_y appends a property `{year:1937}`



The distributed edge is now *reciprocally inconsistent*

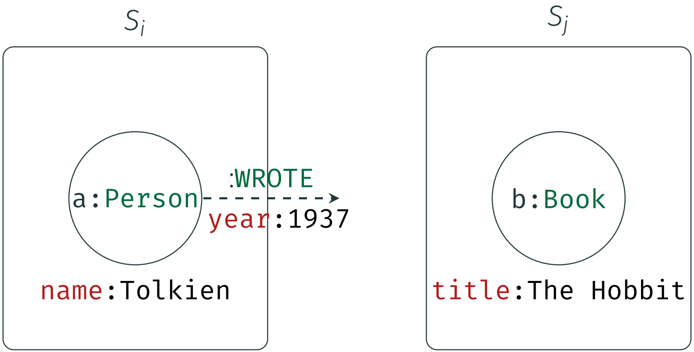


Figure 5: Reciprocally inconsistent distributed edge

Reciprocal Inconsistency

Storage layer consists of two inconsistent uni-directional edge pointers

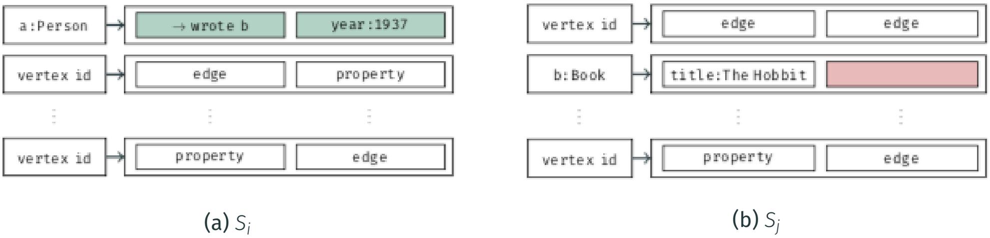


Figure 6: Edge storage layer representation

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- Semantic corruption spreads through the database
- **Motivated the design of a lightweight concurrency control protocol that preserves distributed edge reciprocal consistency**

Protocol Design Considerations

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Protocol must permit multiple updates on the same distributed edge provided they are *sufficiently* apart in time to ensure reciprocal consistency

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- **Parameter Selection:** Choose $\Delta > \delta$

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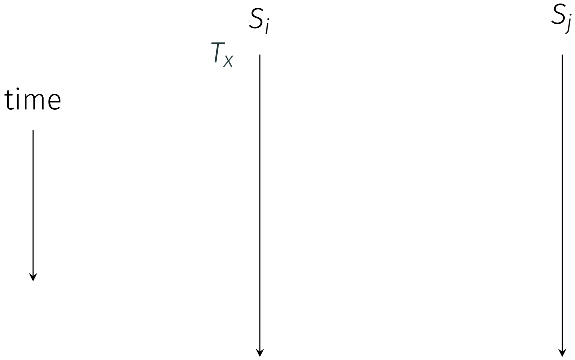

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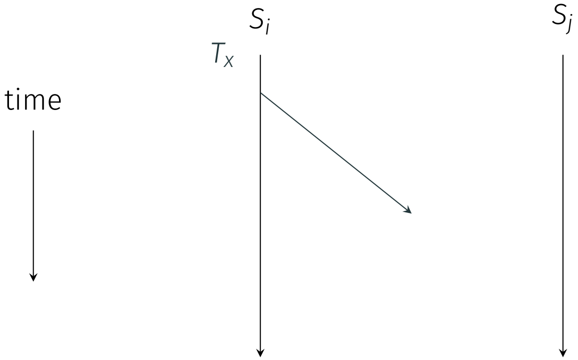

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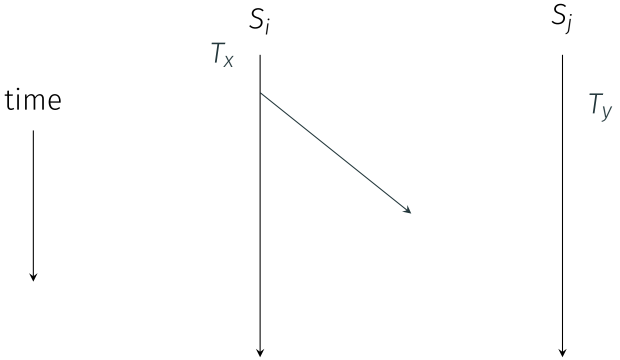

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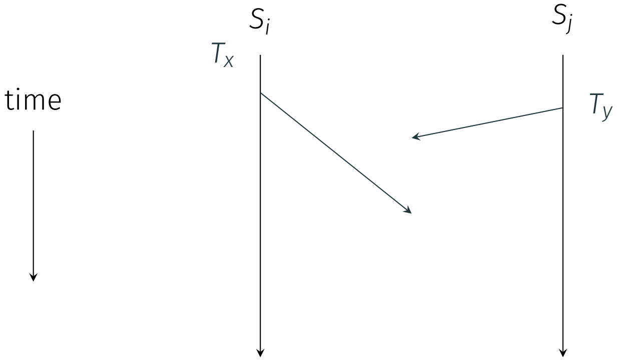

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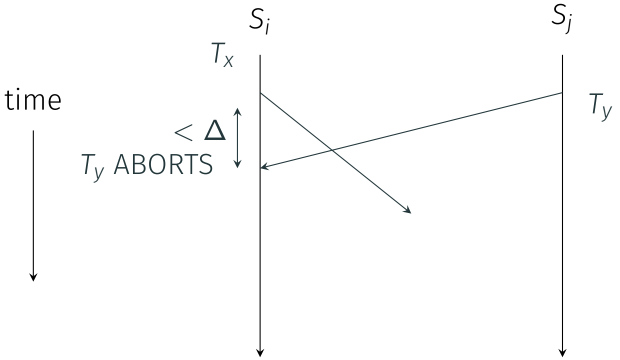

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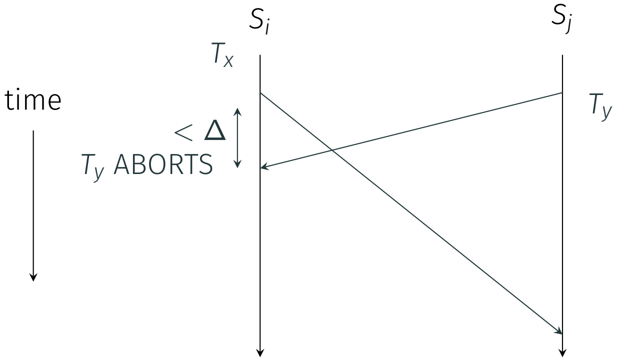

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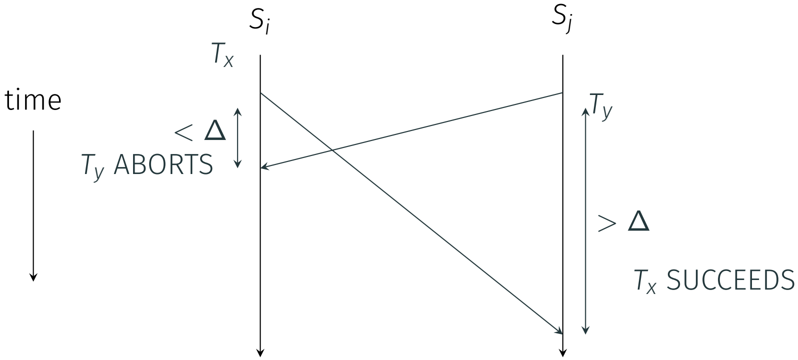

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- If Δ is exceeded then reciprocal inconsistency and hence semantic corruption can occur
- Setting a large Δ tends to preserve consistency but leads to more aborted transactions

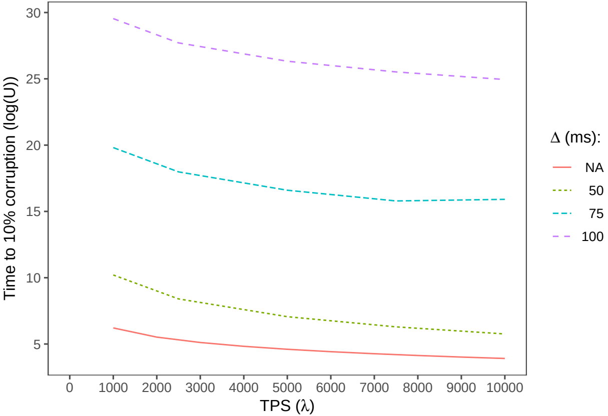
Performance Evaluation

Through simulations the following two metrics for various values of Δ were evaluated:

- Time taken for 10% of a large database to become semantically corrupt
- Fraction of transactions aborted per second

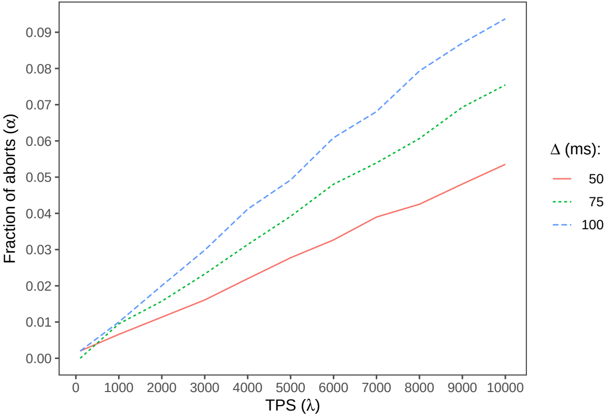
Time until 10% semantic corruption $log(U)$ vs Transaction Arrival Rate (λ)

For $\Delta = 50ms$, time taken for 10% of a large database to become semantically corrupt is between to 1-75 years



Fraction of Aborts (α) vs Transaction Arrival Rate (λ)

For $\Delta = 50ms$, the fraction of aborts is between 1 - 5%



Summary

- Lack of concurrency control in a distributed graph database can lead to reciprocally inconsistent distributed edges
- Resulting in the spread of semantic corruption
- Delta protocol prevents reciprocal inconsistency given Δ is not exceeded
- Delta protocol significantly reduces the spread of semantic corruption at the cost of a very small fraction of aborts