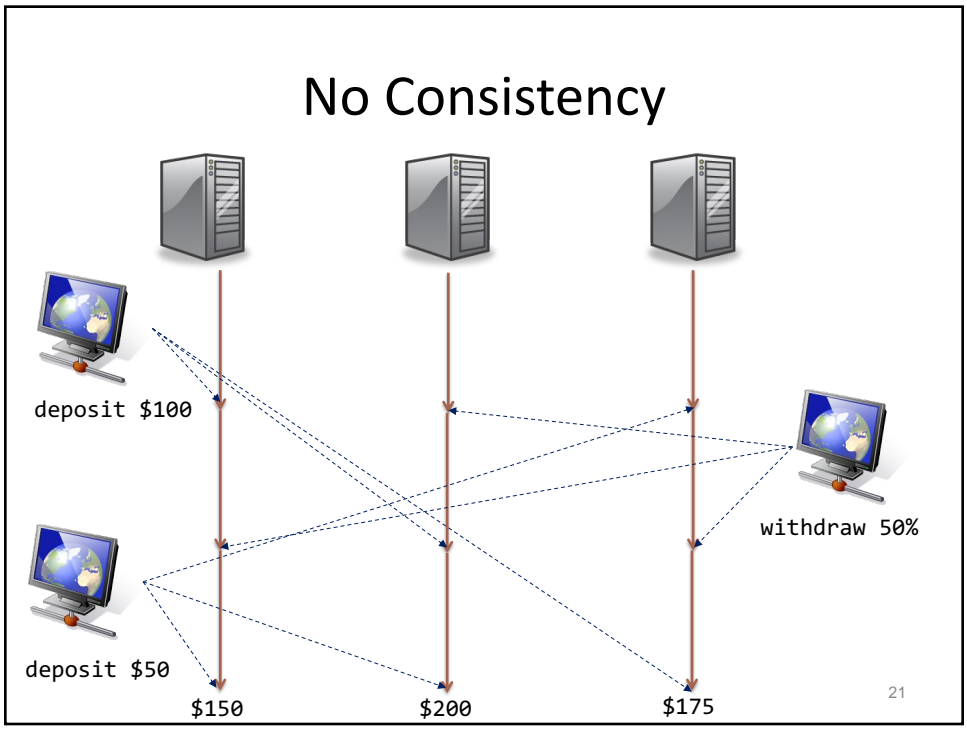
EVENTUAL CONSISTENCY

Strong Consistency

- As soon as one client successfully completes a write, all clients reading from the database must be able to see the value just written (*Recency*)
- Replicated database
- Must not read stale copy of data


No Consistency
deposit $100
withdraw 50%
deposit $50
$150
$200
$175
21

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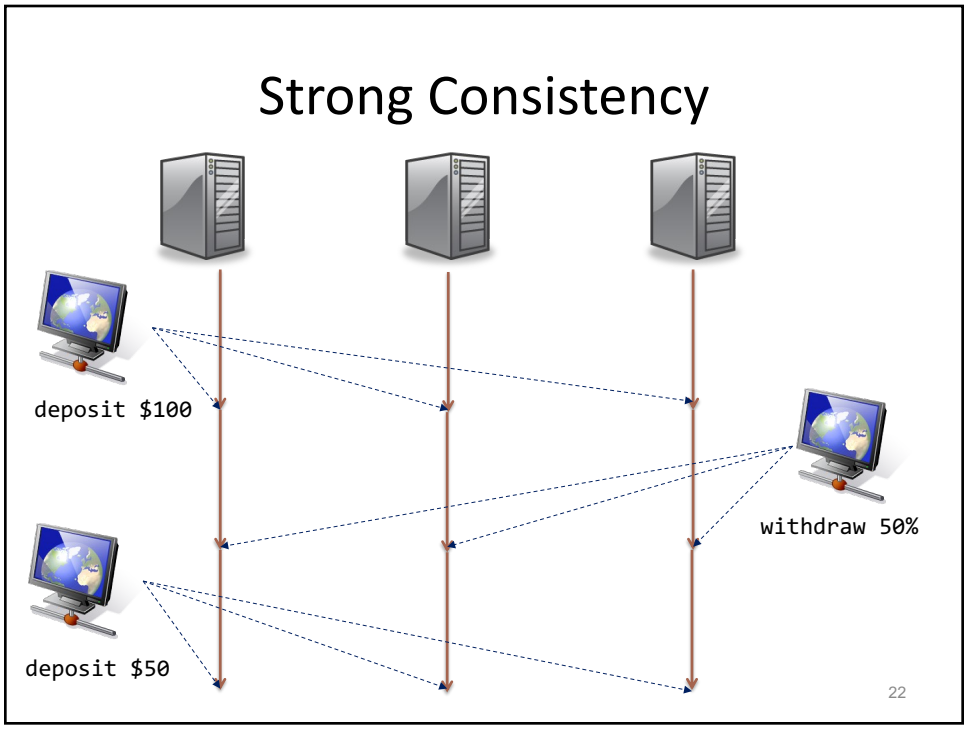
Strong Consistency
deposit $100
withdraw 50%
deposit $50
22

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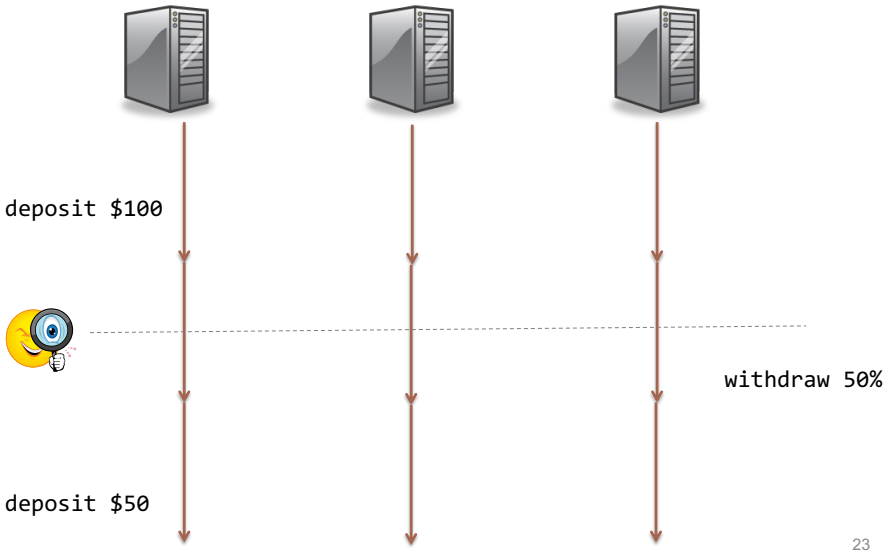
Strong Consistency



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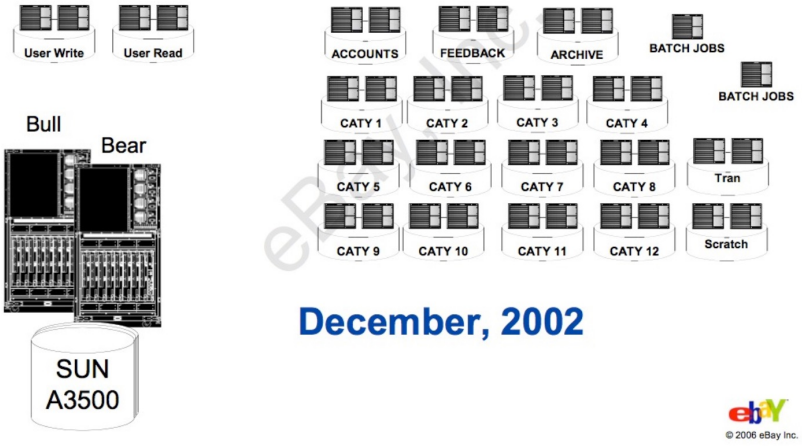

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BASE: Basically Available, Soft-state, Eventually consistent

- "BASE is diametrically opposed to ACID. Where ACID is pessimistic and forces consistency at the end of every operation, BASE is optimistic and accepts that the database consistency will be in a state of flux. Although this sounds impossible to cope with, in reality it is quite manageable and leads be obtained with ACID."
  - "BASE: An Acid Alternative," Dan Pritchett, eBay

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Relaxed Consistency

- Best effort consistency
  - Ex: Grapevine email transport
  - Replicas may unintentionally fail to converge
  - Ex: Update operations are not deterministic
  - Ex: Updates performed in different orders on replicas

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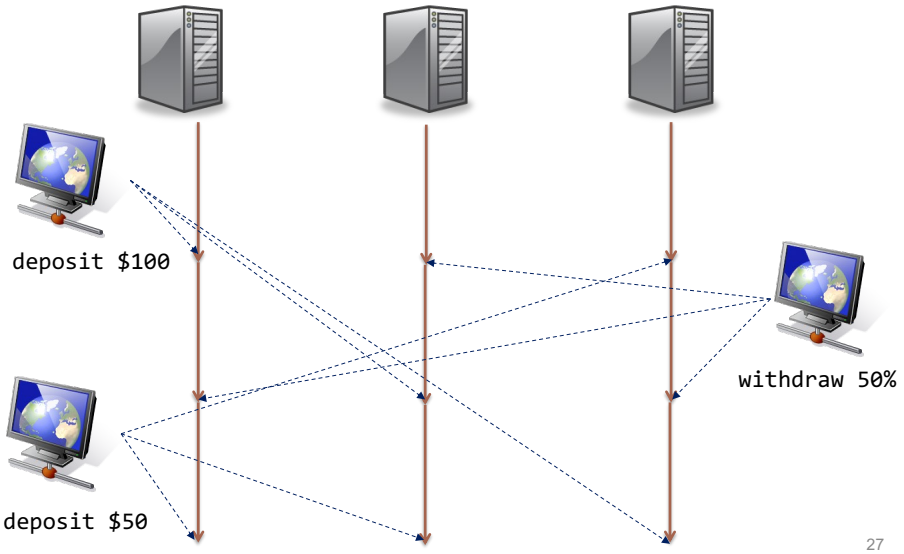
Relaxed Consistency



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Strong and Eventual Consistency

- **Strong Consistency:** Effect of an update is visible by any operation that follows it
  - No stale reads
- **Eventual Consistency:**
  - **Consistent ordering:** Updates are done in same order on all replicas
  - **Total propagation:** Updates are performed on all replicas *eventually*

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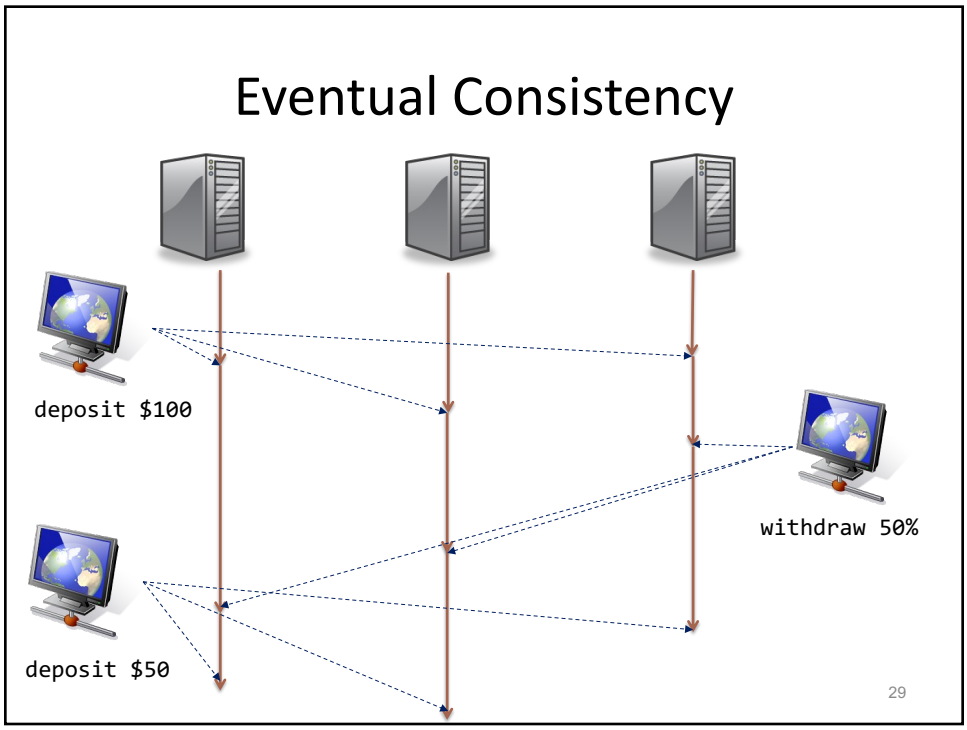
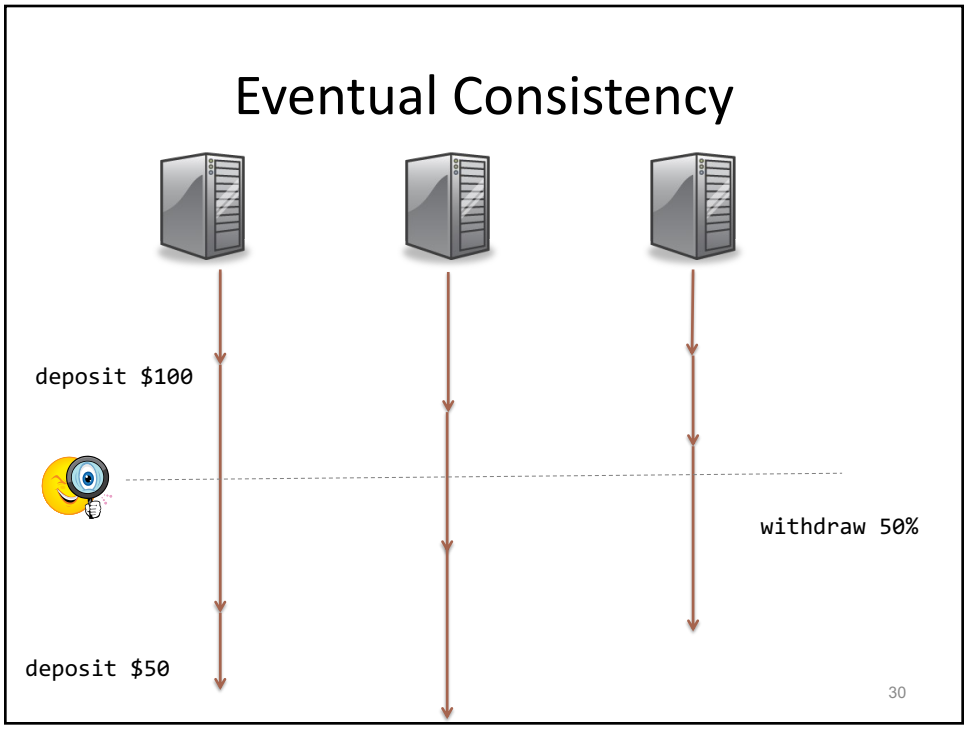

Eventual Consistency
deposit $100
withdraw 50%
deposit $50
29

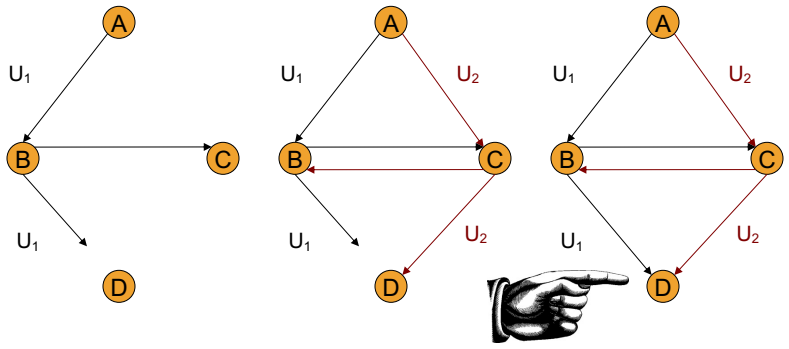
29


Eventual Consistency
deposit $100
withdraw 50%
deposit $50
30

30

Eventual Consistency

- Eventual consistency
  - Ordering of updates important



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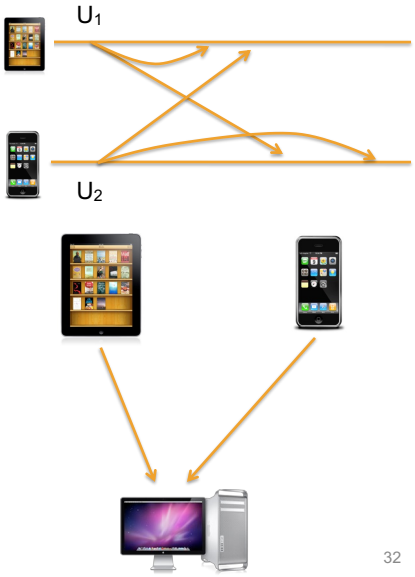
Out-of-order updates?

- Delay delivery
  - Ordered multicast
  - Delay even for local replica!
  - Not practical for disconnected
- Tentative update
  - Resolve with other updates later
    - Undo, perform missing updates, redo
  - Information about non-conflicting updates
    - API to specify



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Causal Consistency

- Strong & Eventual Consistency:
  - **Total order** on all updates
  - Causal: Weaken the required ordering
- What if two updates unrelated?
  - E.g. different DB records, or …
  - No **causal** relationship
- Advantage: No need to order "concurrent" updates
  - Unless application **requires** total order

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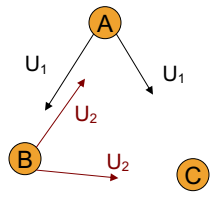
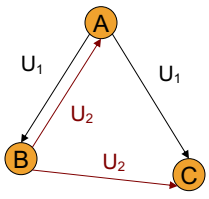
Causal Consistency



$U_1 \parallel U_2$



$U_1 \parallel U_2$

Does order of delivery matter at C?
Strong consistency: ✓
Causal consistency: ✗

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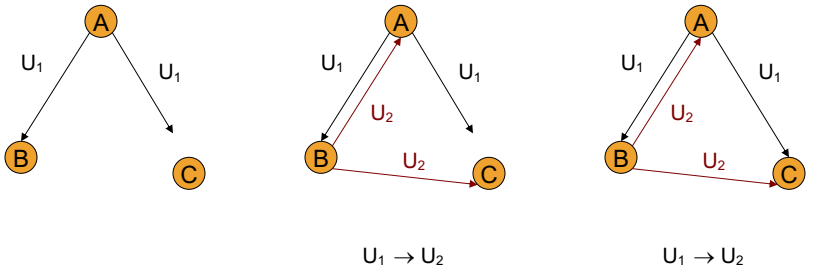
Causal Consistency



$U_1 \rightarrow U_2$ $U_1 \rightarrow U_2$

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Consistent Prefix Reads

- Issue: Violation of causal dependency

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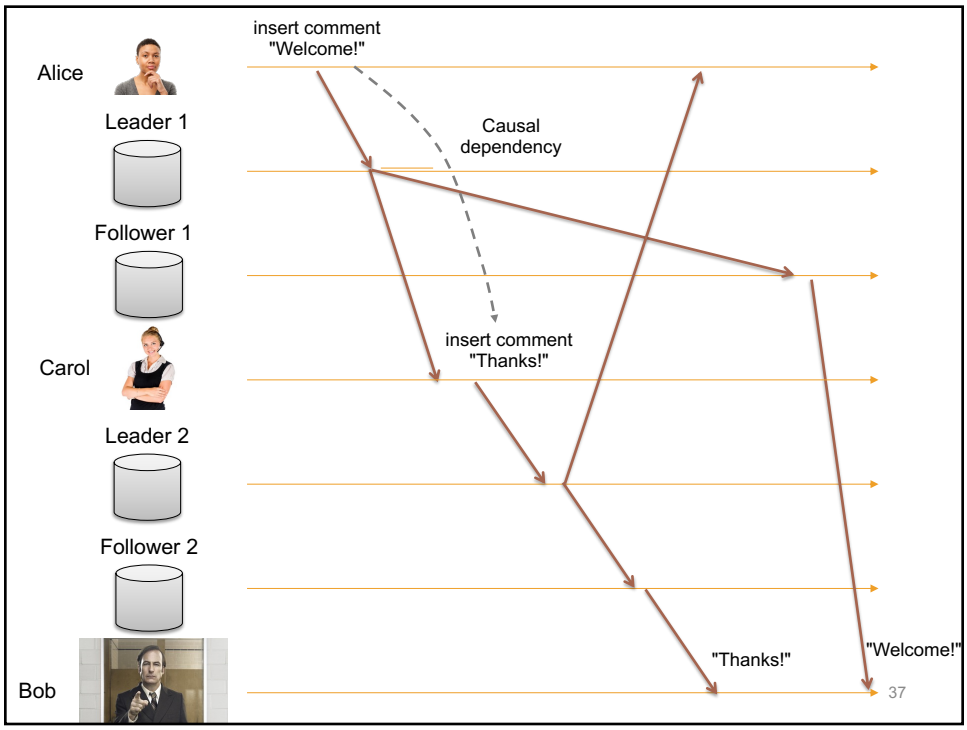

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Consistent Prefix Reads

- Issue: Violation of causal dependency
- CPR: Causally related writes are read in that order
  - "Welcome!" written before "Thanks!"
- Guarantee: Causally consistent version of DB
  - May not be current version of master...
  - …but it was a version *at some point*
  - …related to Snapshot Isolation

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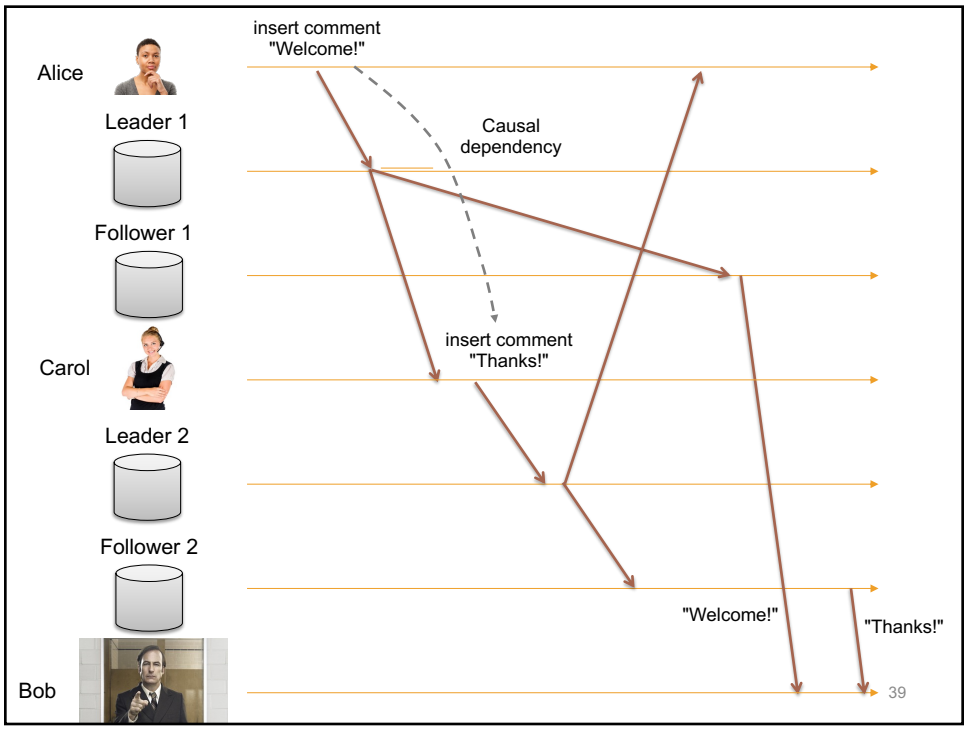

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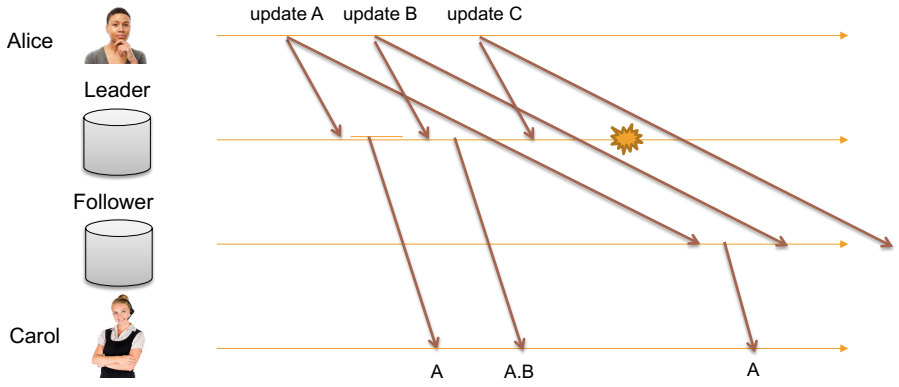
Consistent Prefix Reads



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Consistent Prefix Reads

- Issue: Violation of causal dependency
- CPR: Causally related writes are read in that order
  - "Welcome!" written before "Thanks!"
- Guarantee: Causally consistent version of DB
- No bound on staleness from any replica
- …only global ordering

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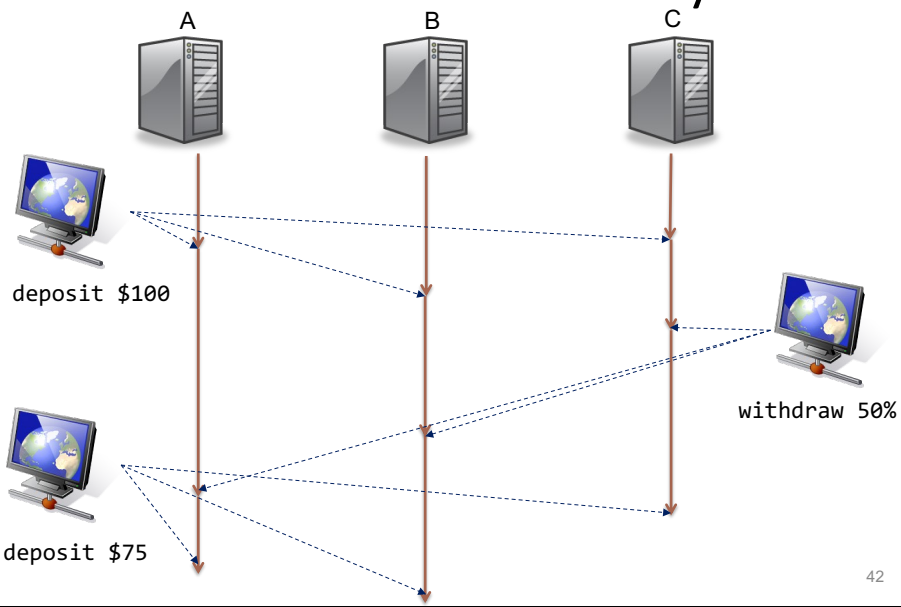
Eventual Consistency



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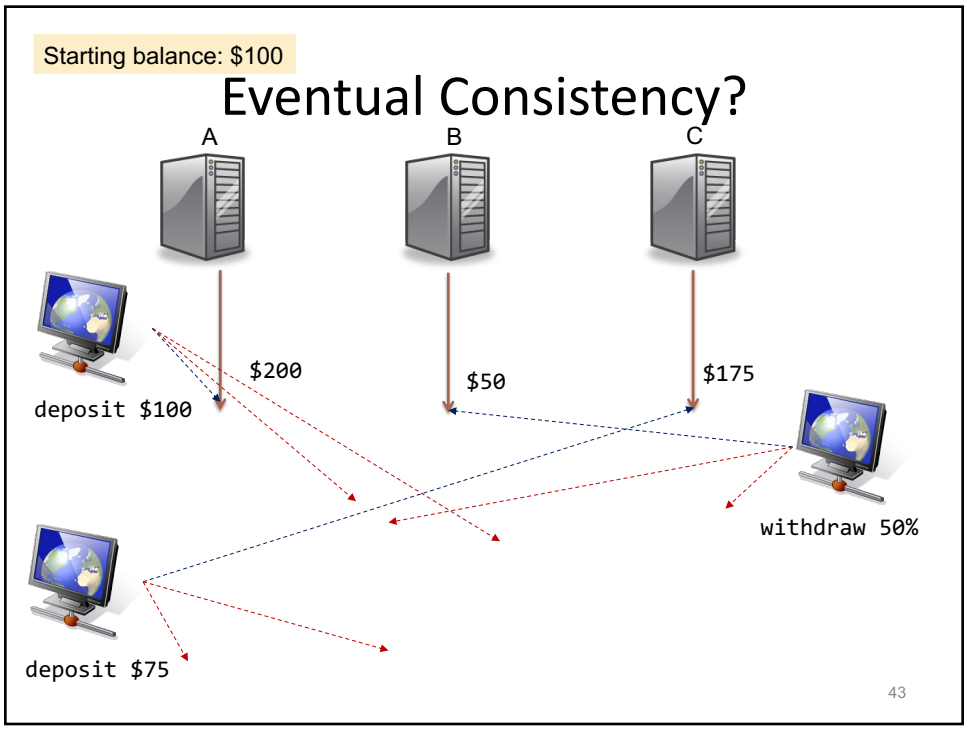
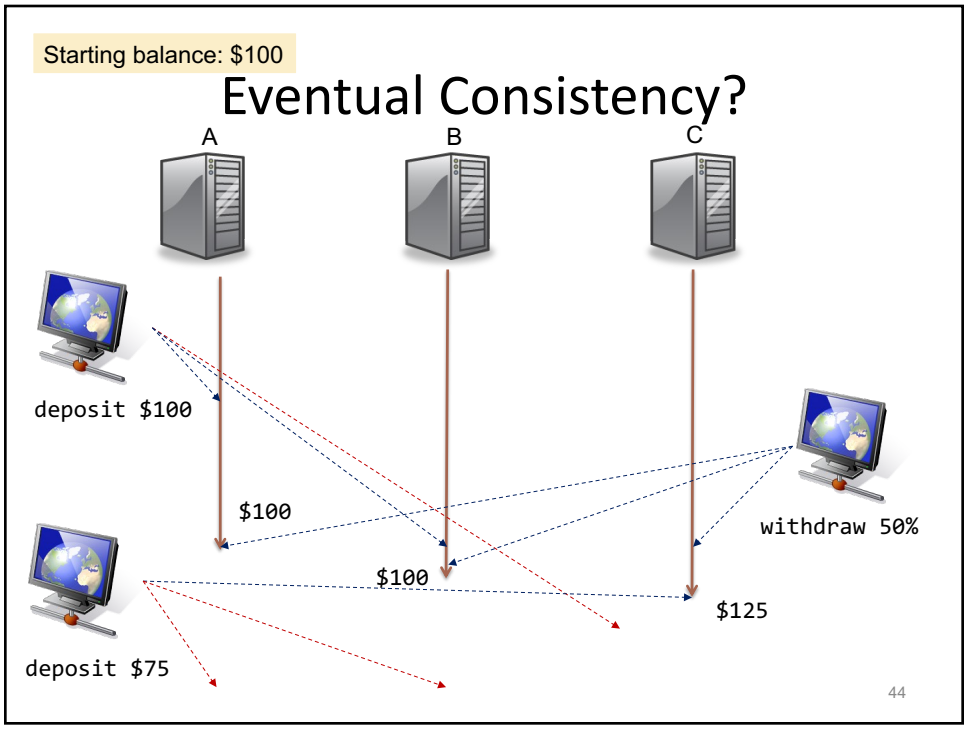
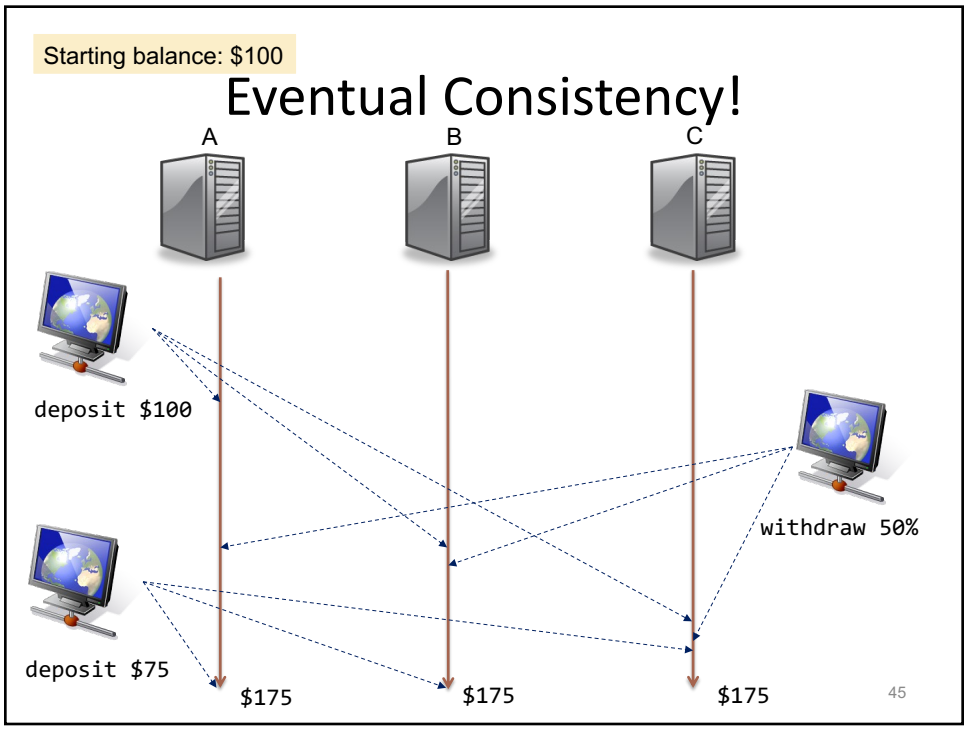

Starting balance: $100
Eventual Consistency?
A
B
C
$200
$50
$175
deposit $100
withdraw 50%
deposit $75
43

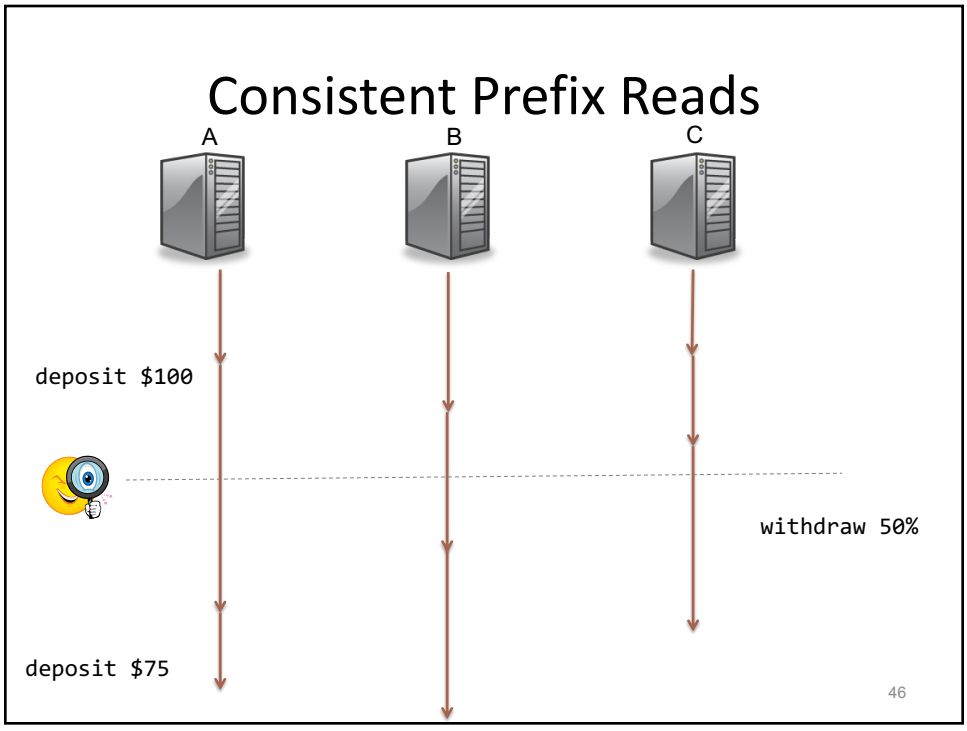
43


Starting balance: $100
Eventual Consistency?
A
B
C
deposit $100
$100
withdraw 50%
$100
$125
deposit $75
44

44


Starting balance: $100
Eventual Consistency!
A
B
C
deposit $100
withdraw 50%
deposit $75
$175
$175
$175
45

45


Consistent Prefix Reads
A
B
C
deposit $100
withdraw 50%
deposit $75
46

46