Extracting More Concurrency from Distributed Transactions

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Introduction

- Everyone wants their system to scale while supporting transactions

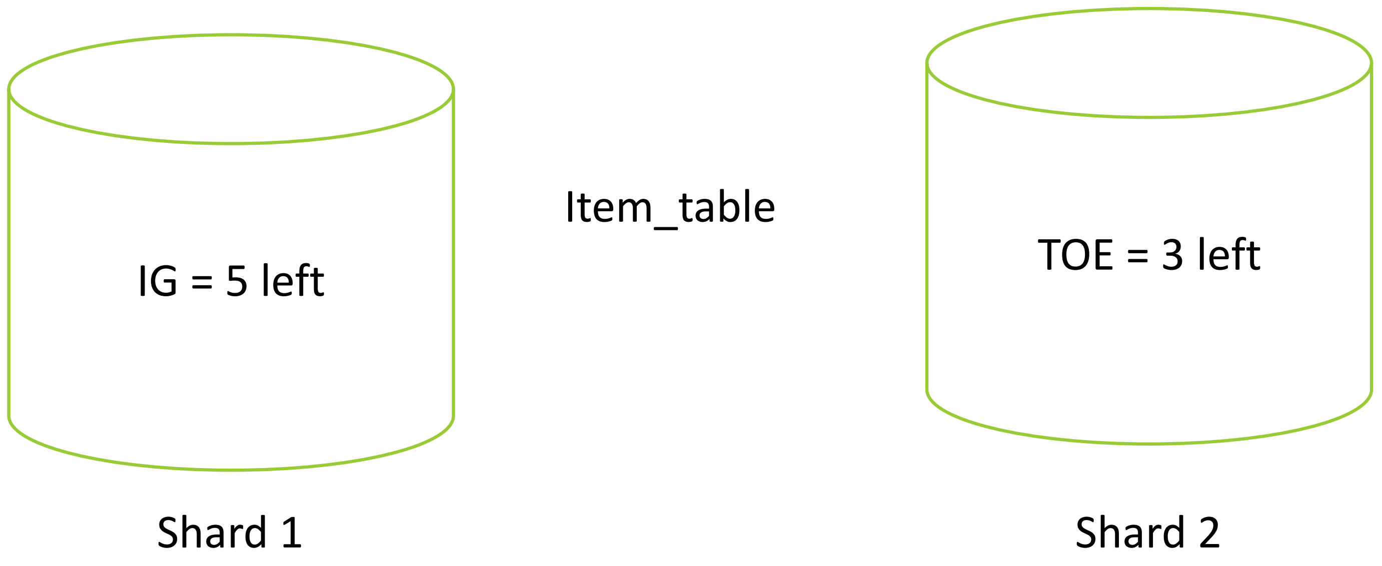
Transactions require strict serializability
  - Guaranteed by concurrency control

- What if there were no concurrency control in a system, like say shopping at Amazon?
  - Amazon might charge you twice
  - Amazon might deliver the same item twice for the price of one

- Popular protocols providing concurrency control:
  - Two Phase Locking (2PL)
  - Optimistic Concurrency Control (OCC)

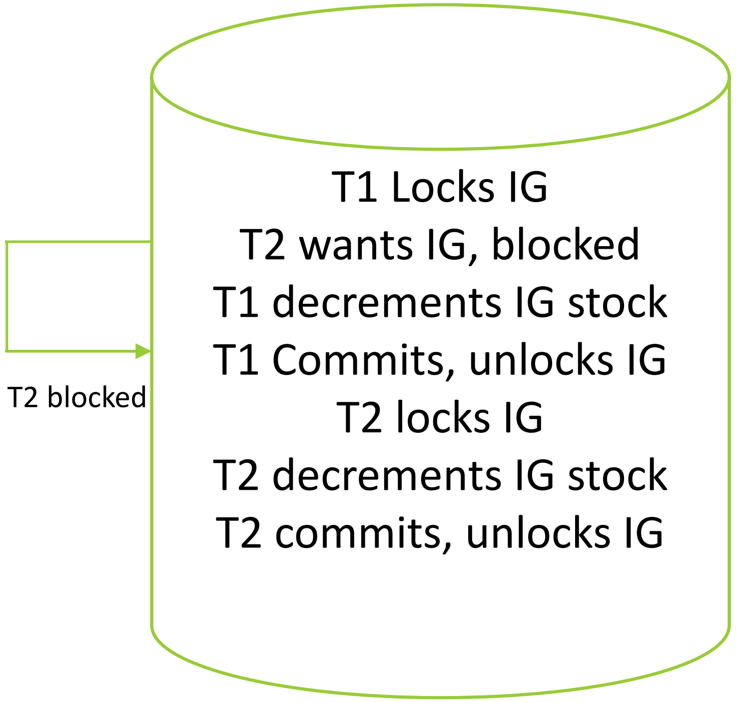
Use Case

- Combo offer for “Imitation Game” and “Theory of Everything”
- Stock for Imitation Game in Shard 1, Stock for Theory of Everything in Shard 2
- Two users buying both at same time

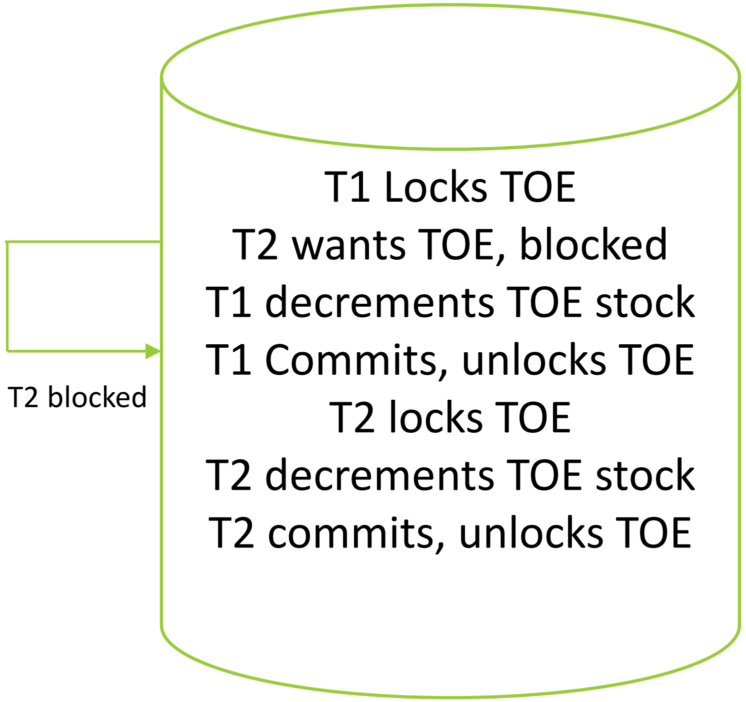


Two Phase Locking

SHARD 1



SHARD 2



Optimistic Concurrency Control

SHARD 1

T1 arrives, records timestamp

T2 arrives, records timestamp

T1 modifies value

T2 modifies value

T1 validates, inconsistency found, ABORT

T2 validates, inconsistency found, ABORT

SHARD 2

T1 arrives, records timestamp

T2 arrives, records timestamp

T1 modifies value

T2 modifies value

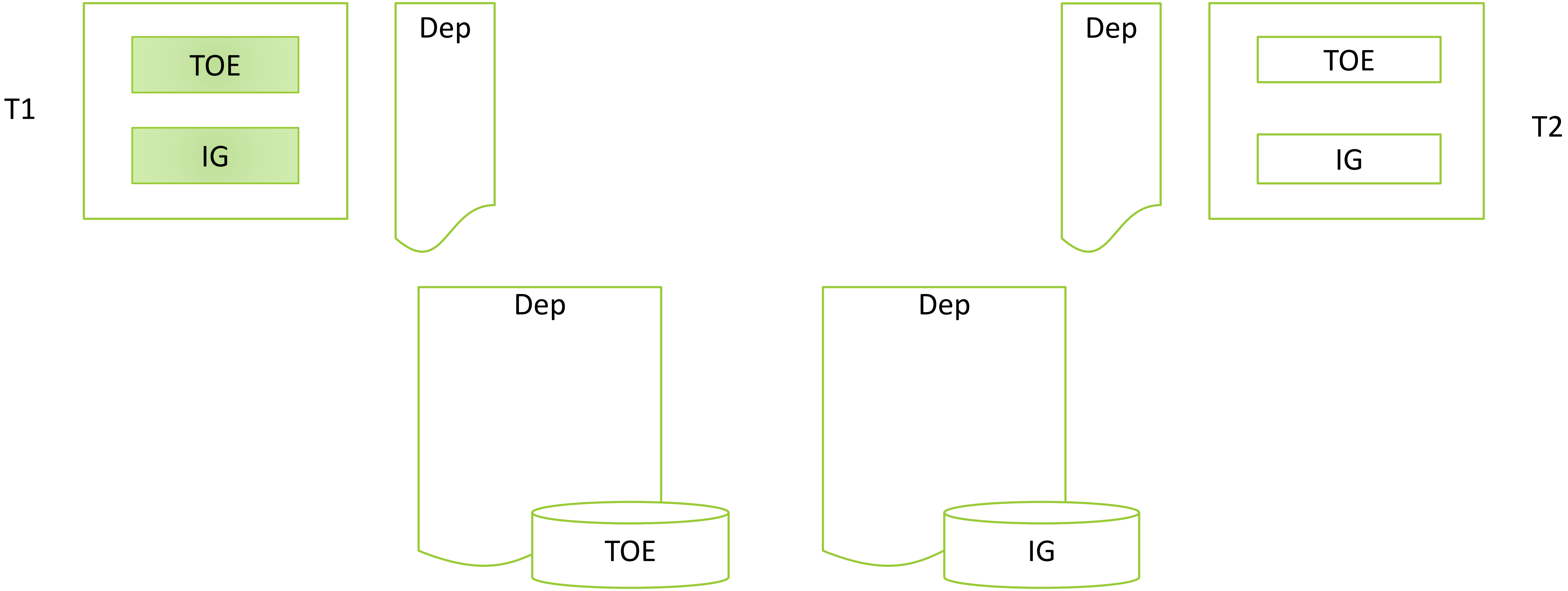
T1 validates, inconsistency found, ABORT

T2 validates, inconsistency found, ABORT

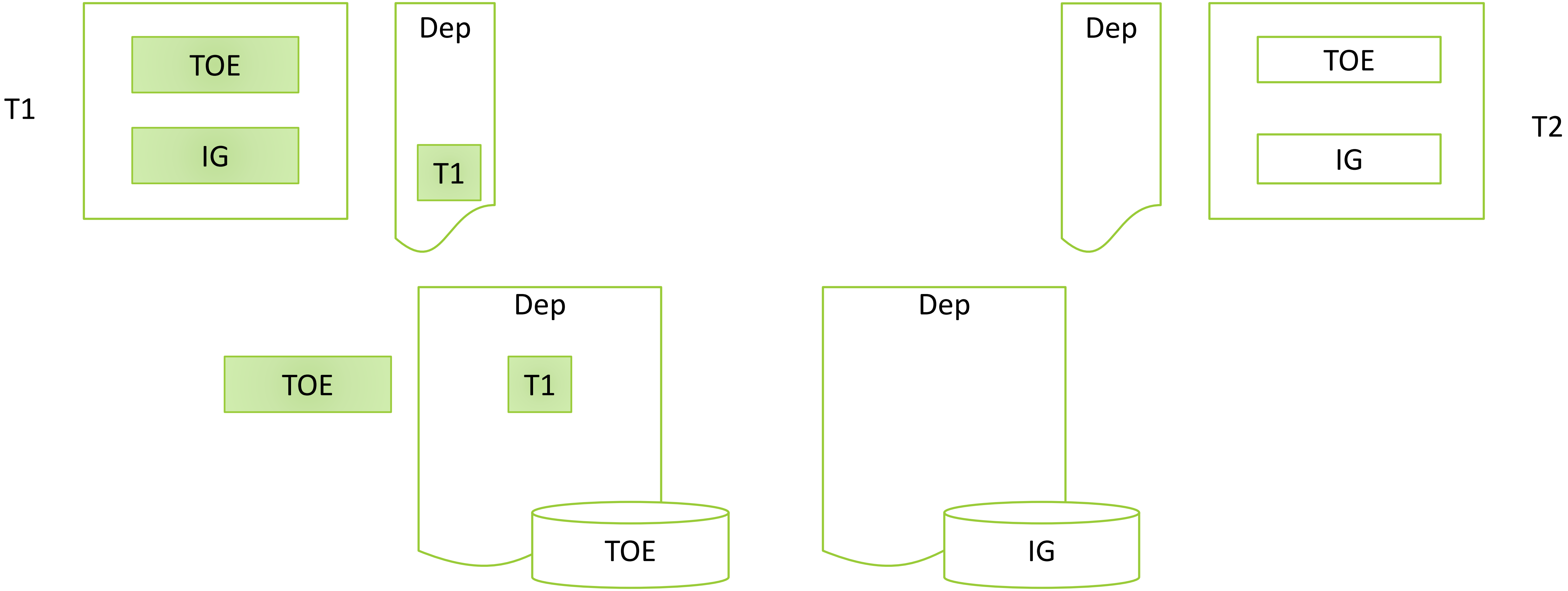
Introducing ROCOCO

- ROCOCO - Reordering Conflicts for Concurrency
- Aims to extract more concurrency during contention
  - Without aborting (unlike OCC)
  - Without blocking (unlike 2PC)
- Basic Idea:
  - Break transactions into atomic pieces
  - Identify dependencies of various transaction pieces across different servers
  - Reorder the pieces deterministically and then execute

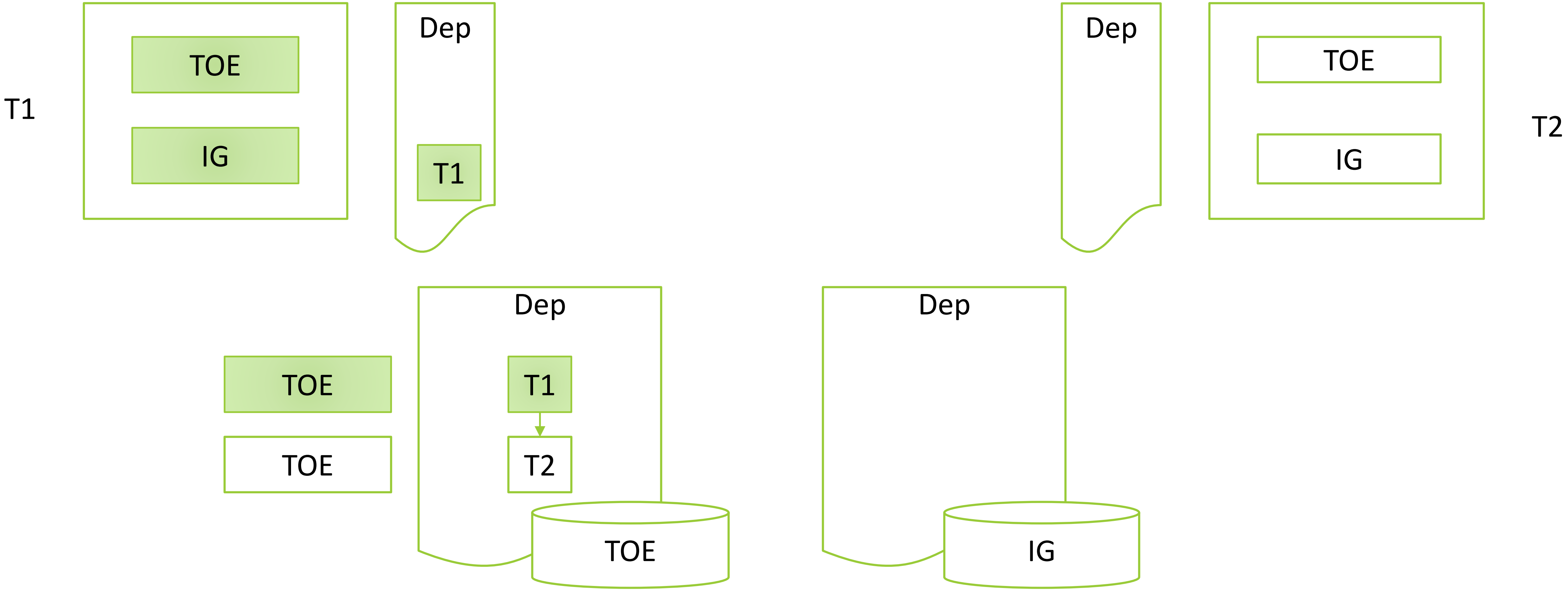
Introduction to ROCOCO



Start Phase



Start Phase



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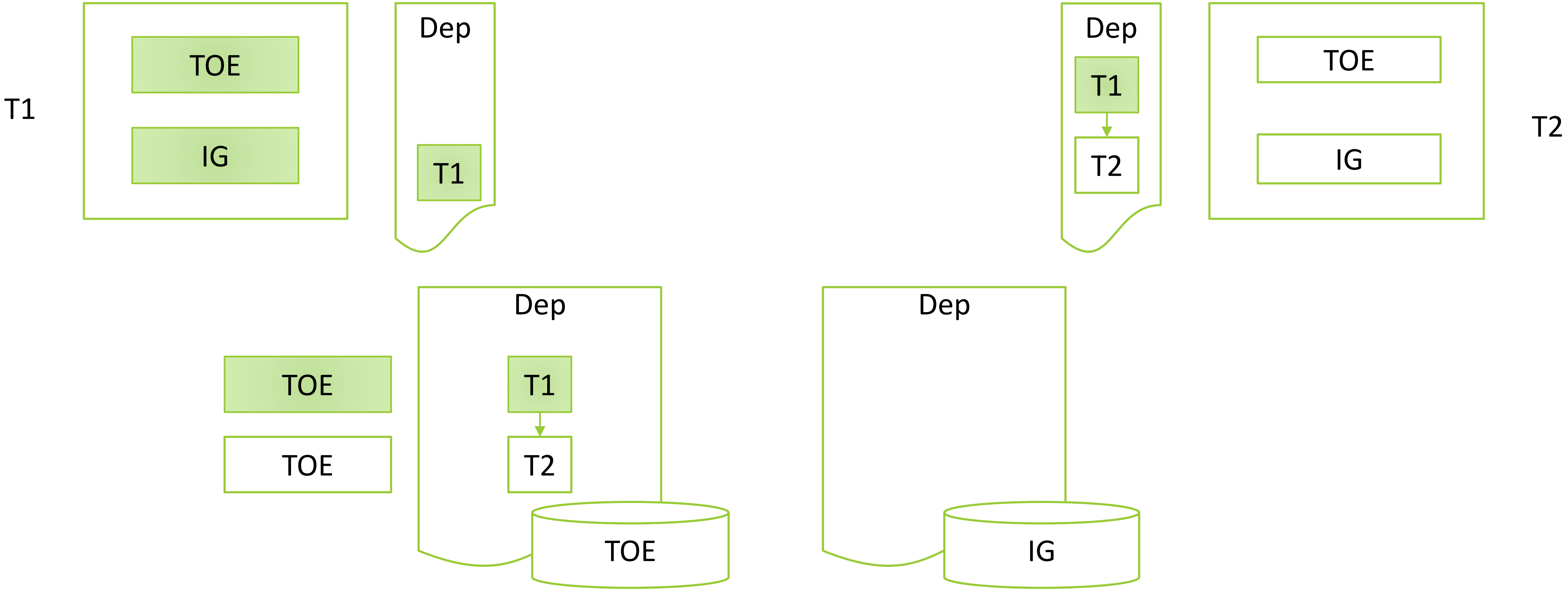
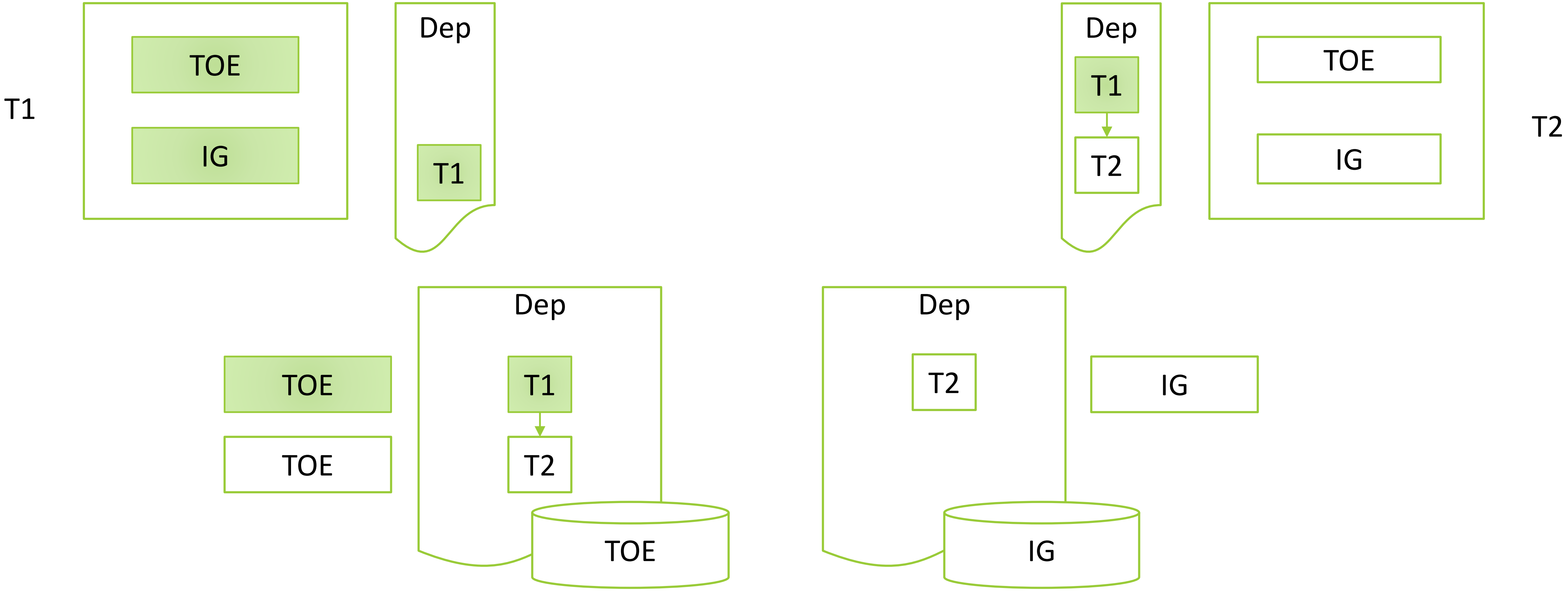


Start Phase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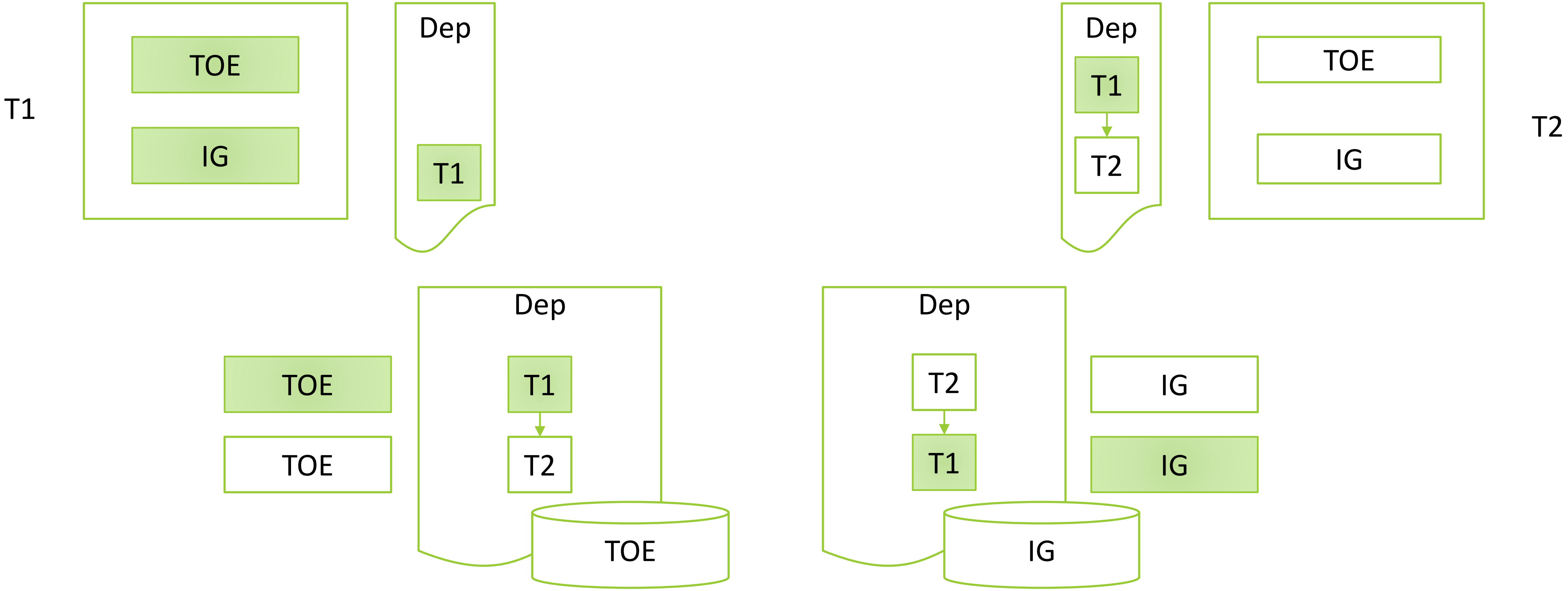
Start phase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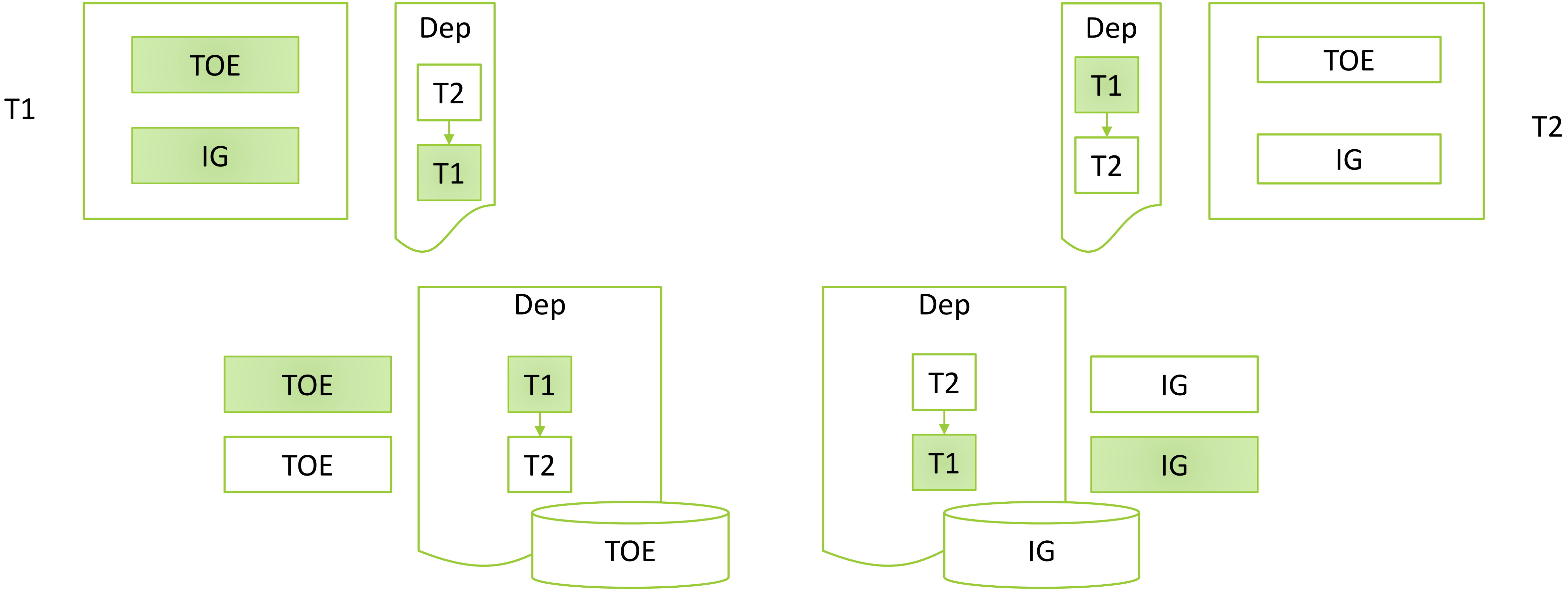
Start phase



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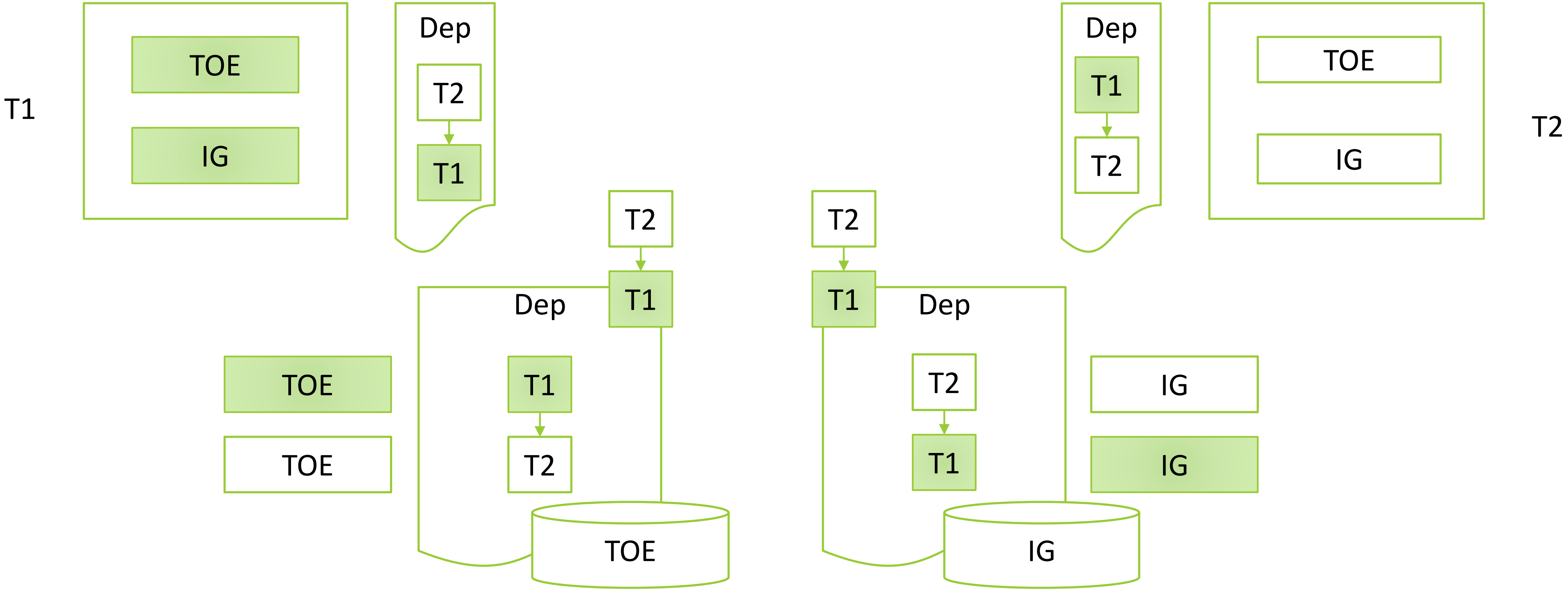
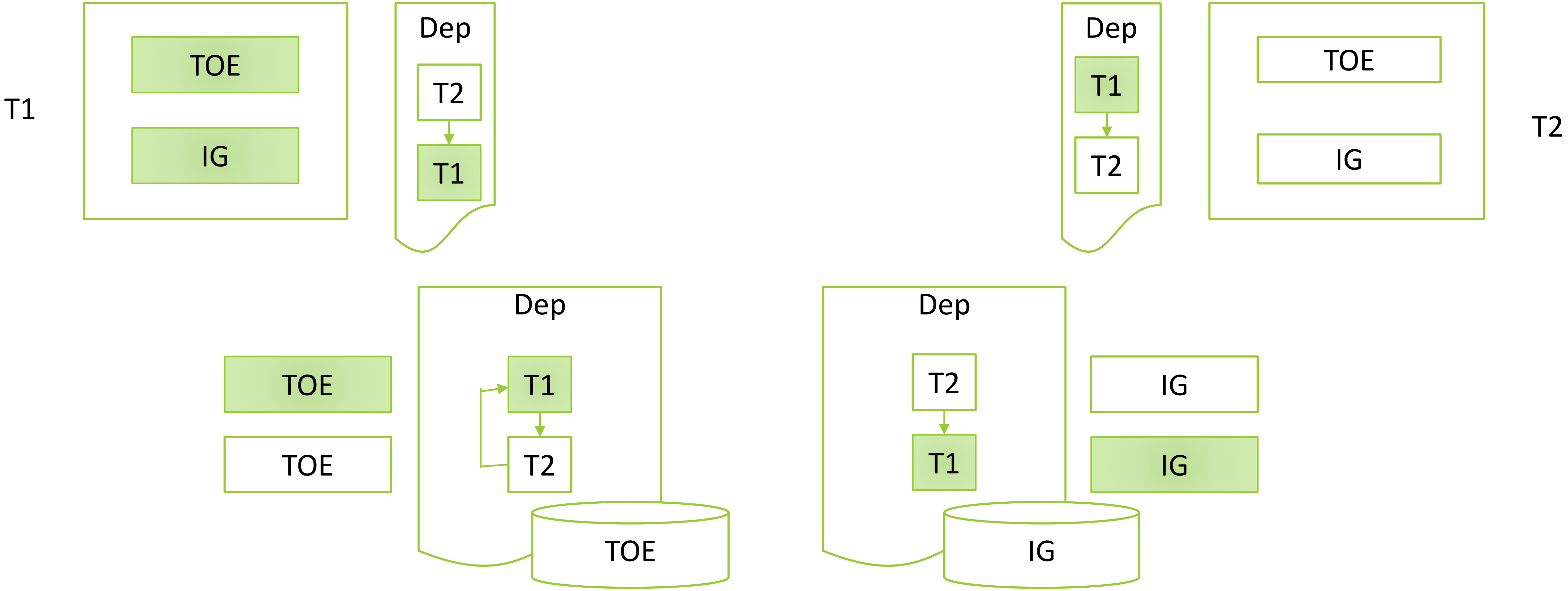
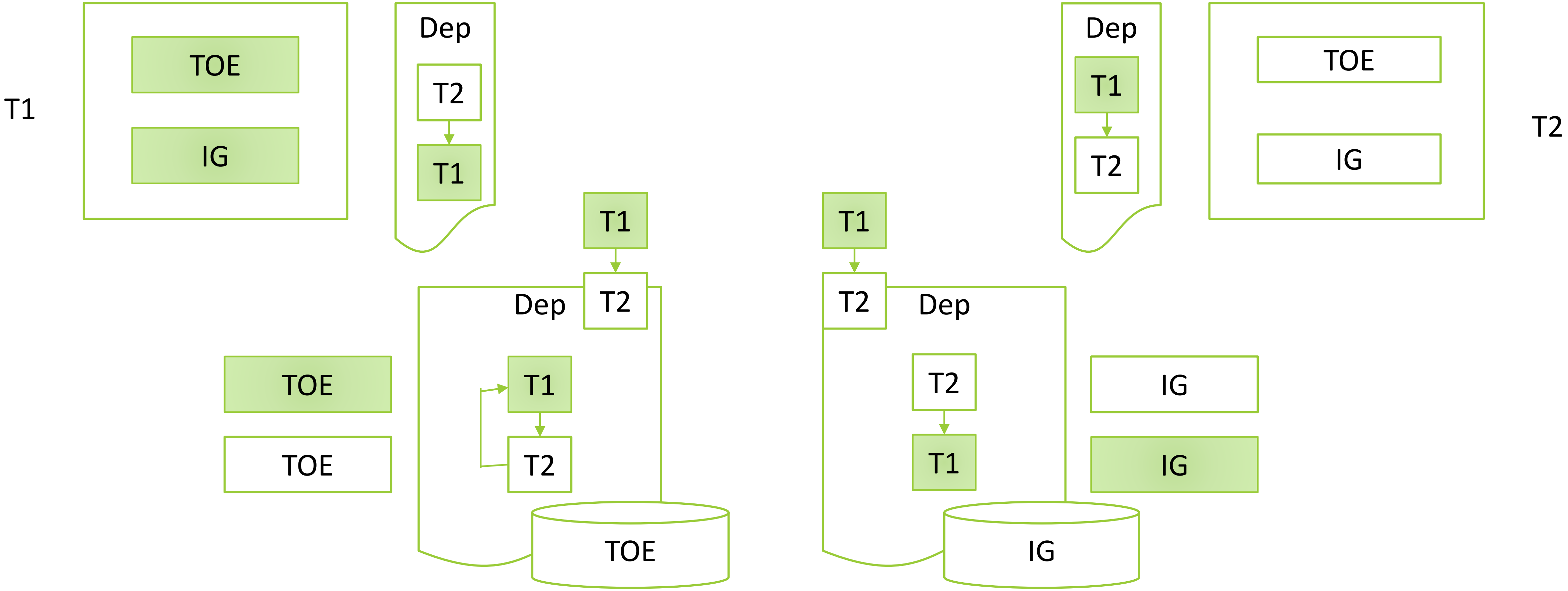
Commit phase



Commit phase



Commit phase



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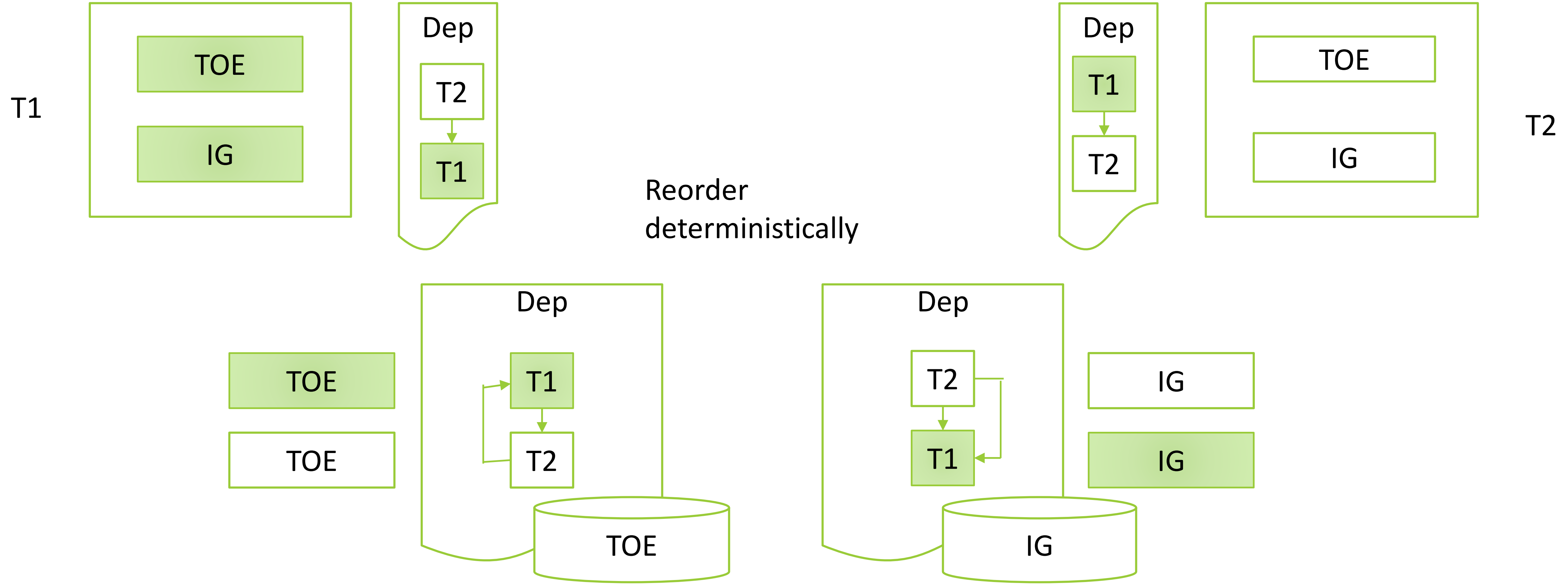
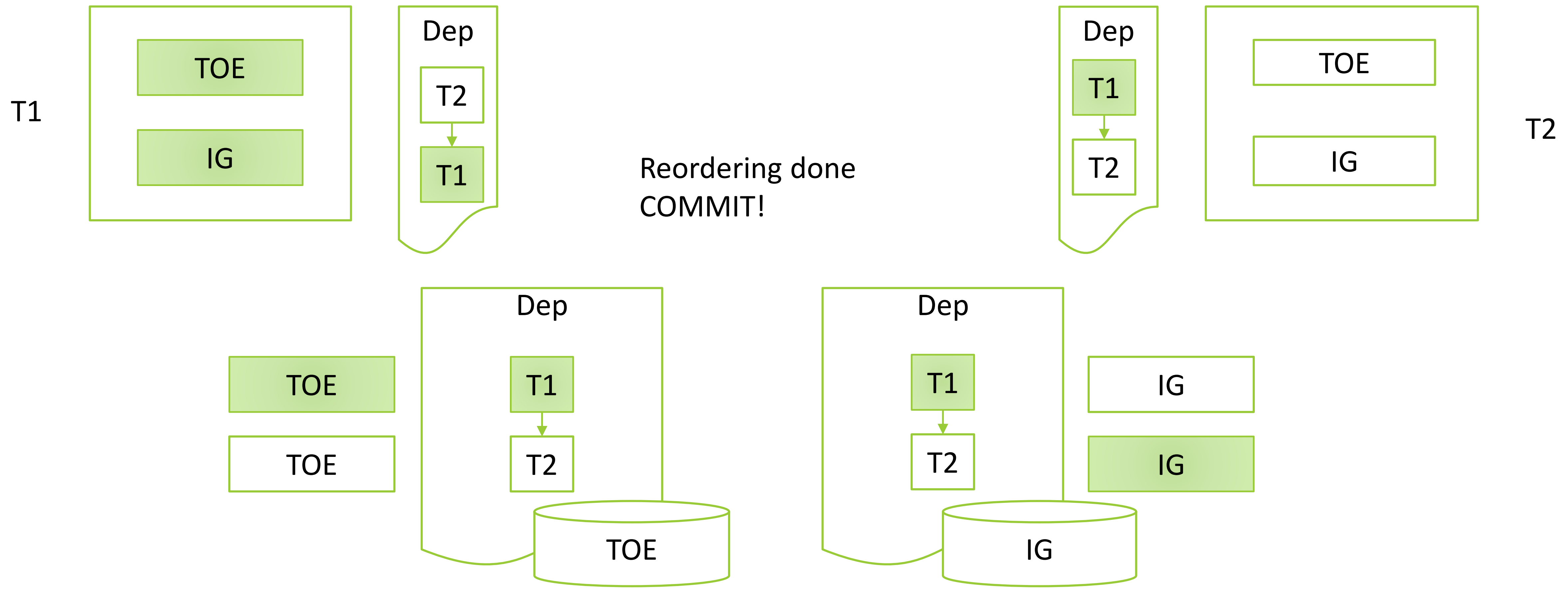


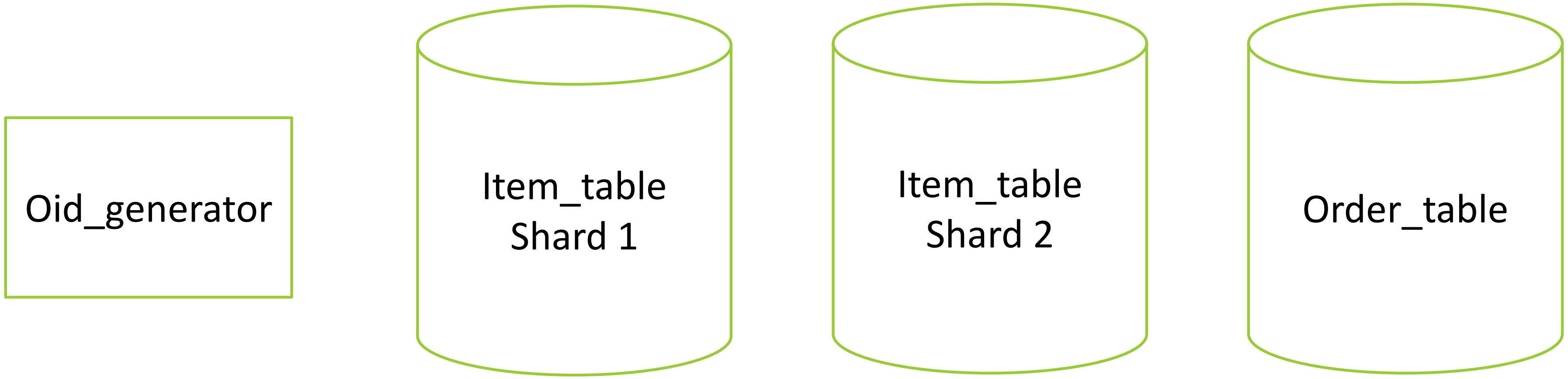
Commit phase



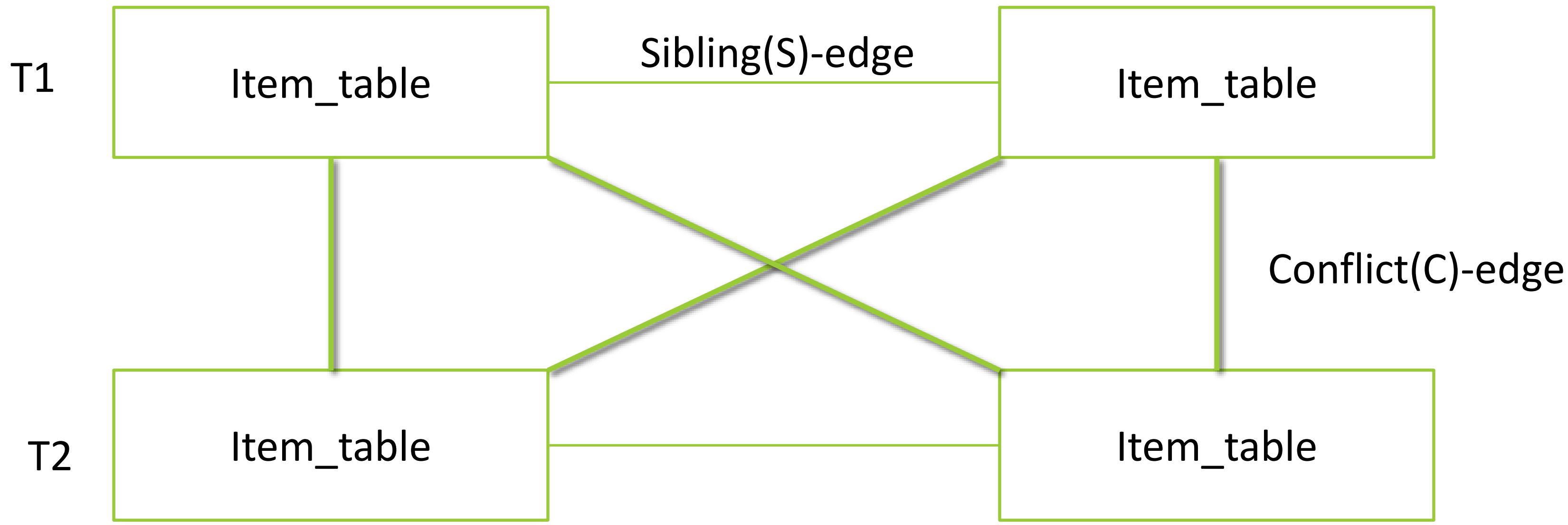
Introduction to ROCOCO

- Some transactions cannot be reordered
- What if the output of one piece acts as an input to another piece?
- These pieces need to be executed immediately!
- We need to determine which pieces are immediate and which can be deferred
- This is done by a component called the “Offline Checker”

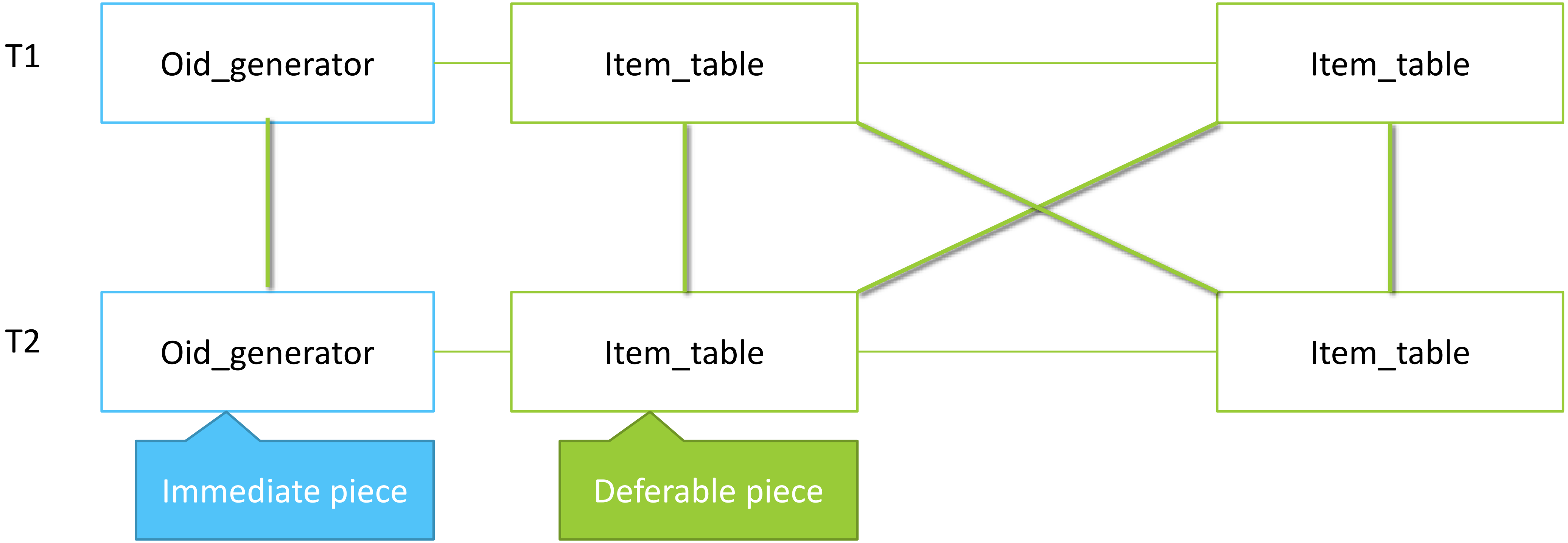
Unreorderable transactions



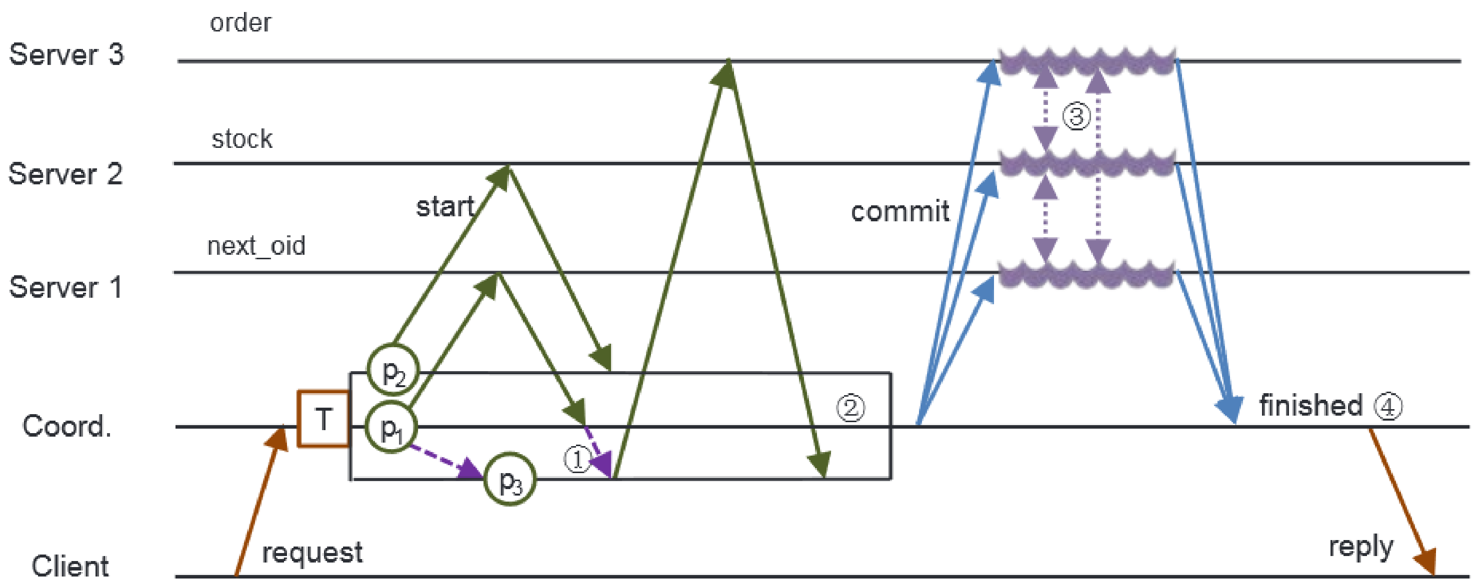
Offline Checker : S/C Cycles



Offline Checker : Immediate/Deferrable pieces



Typical ROCOCO workflow



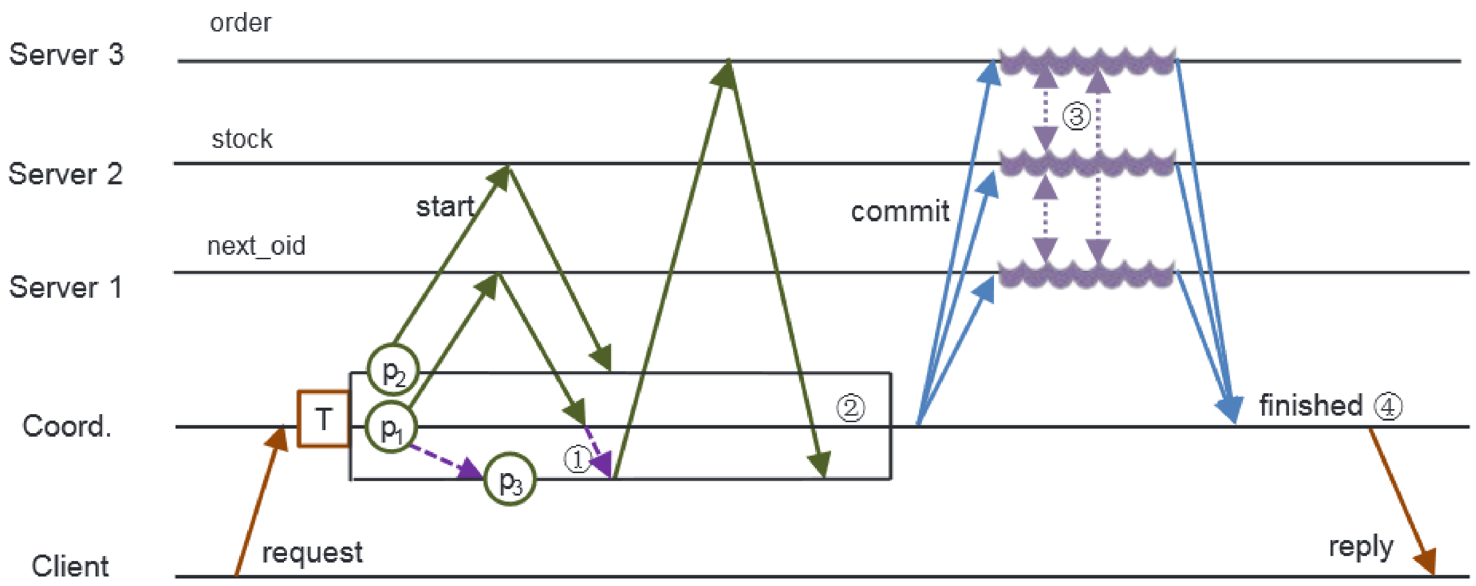
① the output of p_1 contains the input of p_3

② receive replies to start requests of all pieces

③ the servers may exchange dependencies to reach a deterministic serializable order

④ all pieces have finished executing and all outputs are ready

Typical ROCOCO workflow



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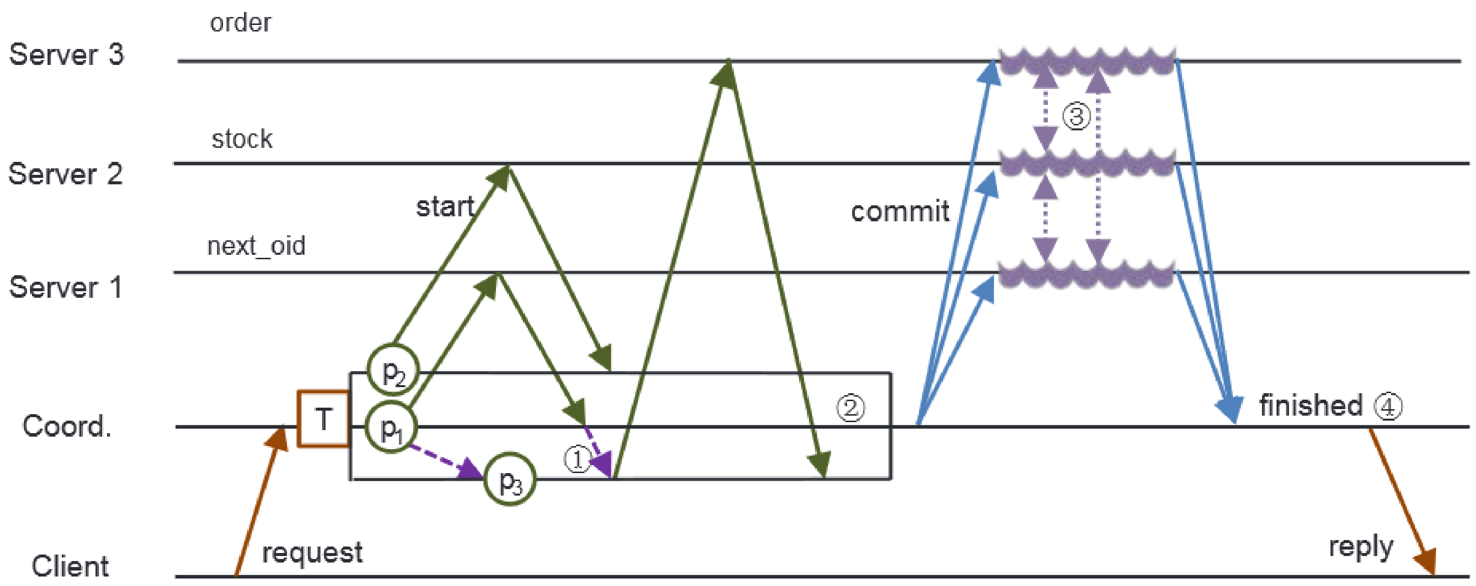

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Protocol : Start phase

- Coordinator sends requests for pieces to appropriate servers
- If piece is immediate, server executes piece and returns output; else buffers for later execution
- Server creates and maintains dependency graph:
  - Vertices : transactions and their status (started, committing or decided)
  - Edges : Conflicting pieces between two transactions. Labelled by {immediate, deferrable} depending on type of piece
- Server returns updated dependency graph and immediate pieces' execution outputs

Protocol : Commit Phase

- Begins after coordinator sends commit requests containing aggregated dependency graph of all servers
- Updates status of transaction in graph to “committing” if status is “started”. Aggregates coordinators dependency graph to its own
- Waits for all ancestors of transaction in graph to become committed
- Calculates SCC of transaction, sets all transactions within SCC to “decided” state
- Waits for all ancestors of SCC to be decided
- Server sorts transactions in SCC according to the “I”-edges, executes them in the order given by the sort
- Returns results to coordinator

Optimizations and Fault Tolerance

Optimizations

- Track only one-hop dependencies instead of entire-graph dependencies
  - One technique is to only add the most recent conflicts for each piece to server's dependency graph instead of all previous ones
- In start phase, instead of entire dependency graph, server provides only subgraph of transaction's ancestors which are not yet "decided"

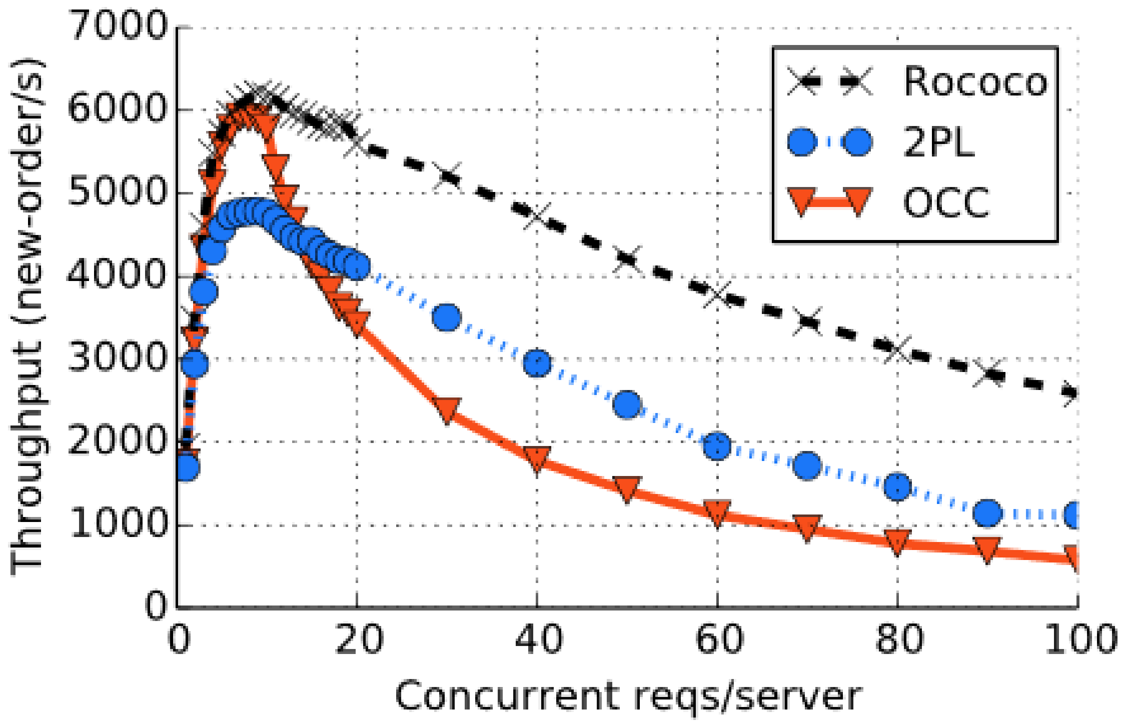
Fault tolerance

- Transaction logs persisted to disk; replicated using paxos-like systems
- Coordinator logs every transaction request
- Server logs every start request

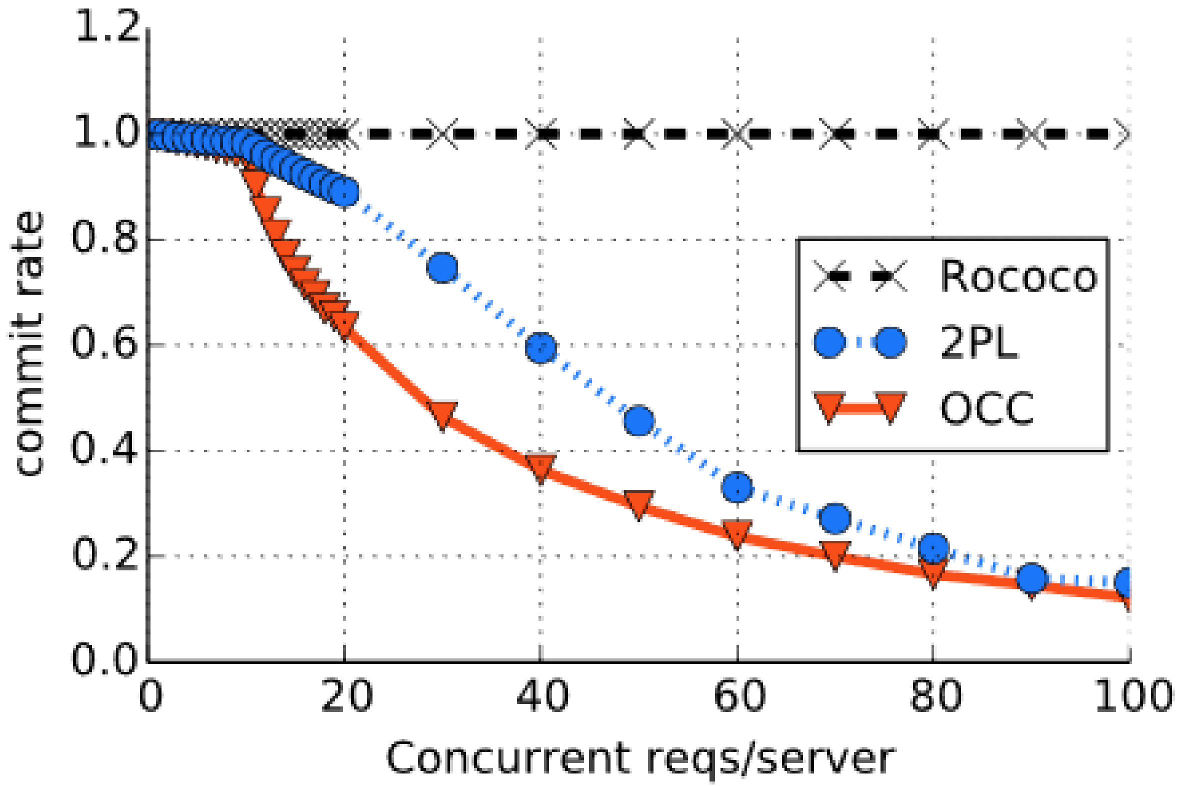
Evaluation : Setup and Workload

- Kodiak testbed; each machine having 1-core 2.6Ghz AMD Opteron 252 CPU, 8GB RAM, Gigabit Ethernet
- Each client running 1-30 single-threaded client processes, each server machine running one single-thread server process
- Logging turned off
- Partition strategy : Partition by warehouse, which in turn is partitioned by districts
- Ratio of customer, district and warehouse = 3M:1K:1

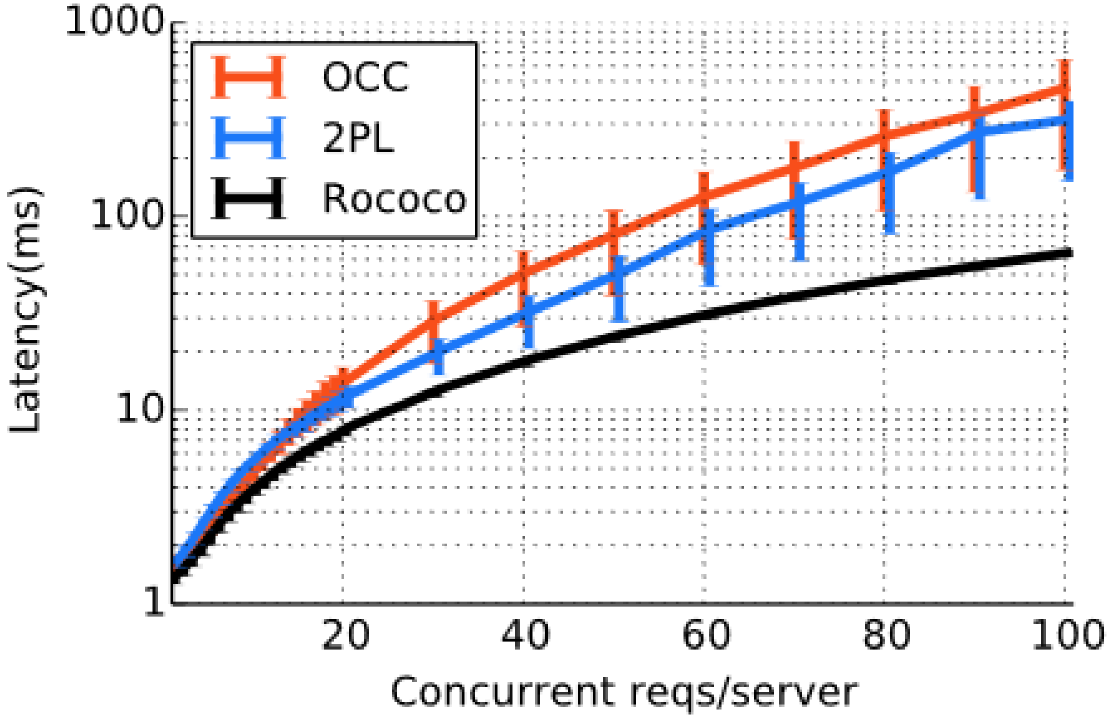
Evaluation : Throughput



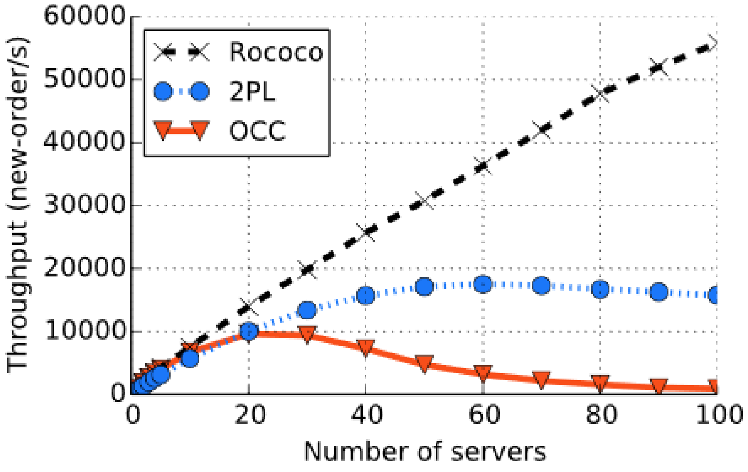
Evaluation : Commit Rates



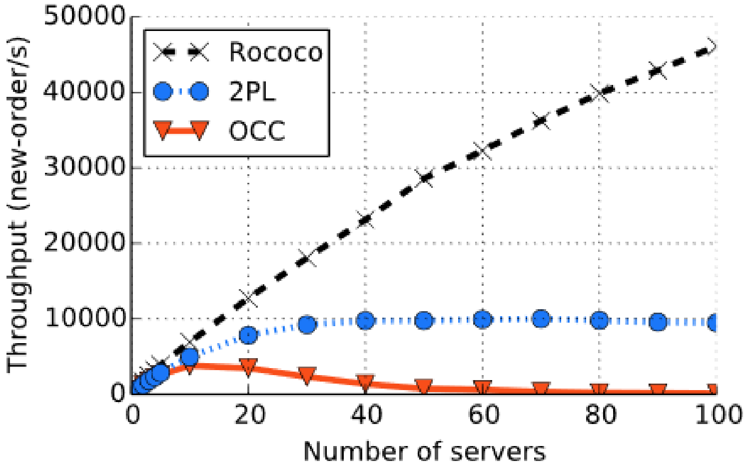
Evaluation : Latency



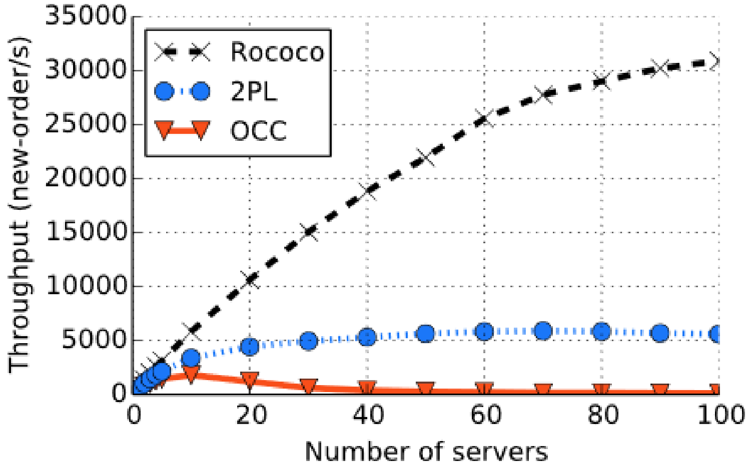
Evaluation : Scale



(a) 10 clients per server.



(b) 20 clients per server.



(c) 40 clients per server.

Related Work

- 2PL Forms and variations : Gamma, Bubba, R*, Spanner (replicated commit)
- OCC forms and variations : H-store, VoltDB, MDCC, Percolator, Adya
- Concurrency control with limited transactions : Megastore (serializable transactions only within a data partition), Granola, Calvin and Sinfonia (concurrency protocols for known read-write keys)
- Dependency and interference : Paxos variants, COPS/Eiger (tracks dependencies within operations), Warp
- Transaction Decomposition and Offline checking : Transaction Chopping theory by Shasha et al (utilized by ROCOCO offine checker), Lynx
- Geodistributed systems with weaker semantics: Dynamo, Cassandra, Walter, Gemini

Comments, Criticism and Questions

- No allowance for user-initiated aborts
- Any difference in performance for read-only and read-write transactions? Evaluations are combined for both types
- Breaking transactions to pieces: is this trivial for all OLTP systems?