# Postgres-2: Write-Scalable PostgreSQL Cluster

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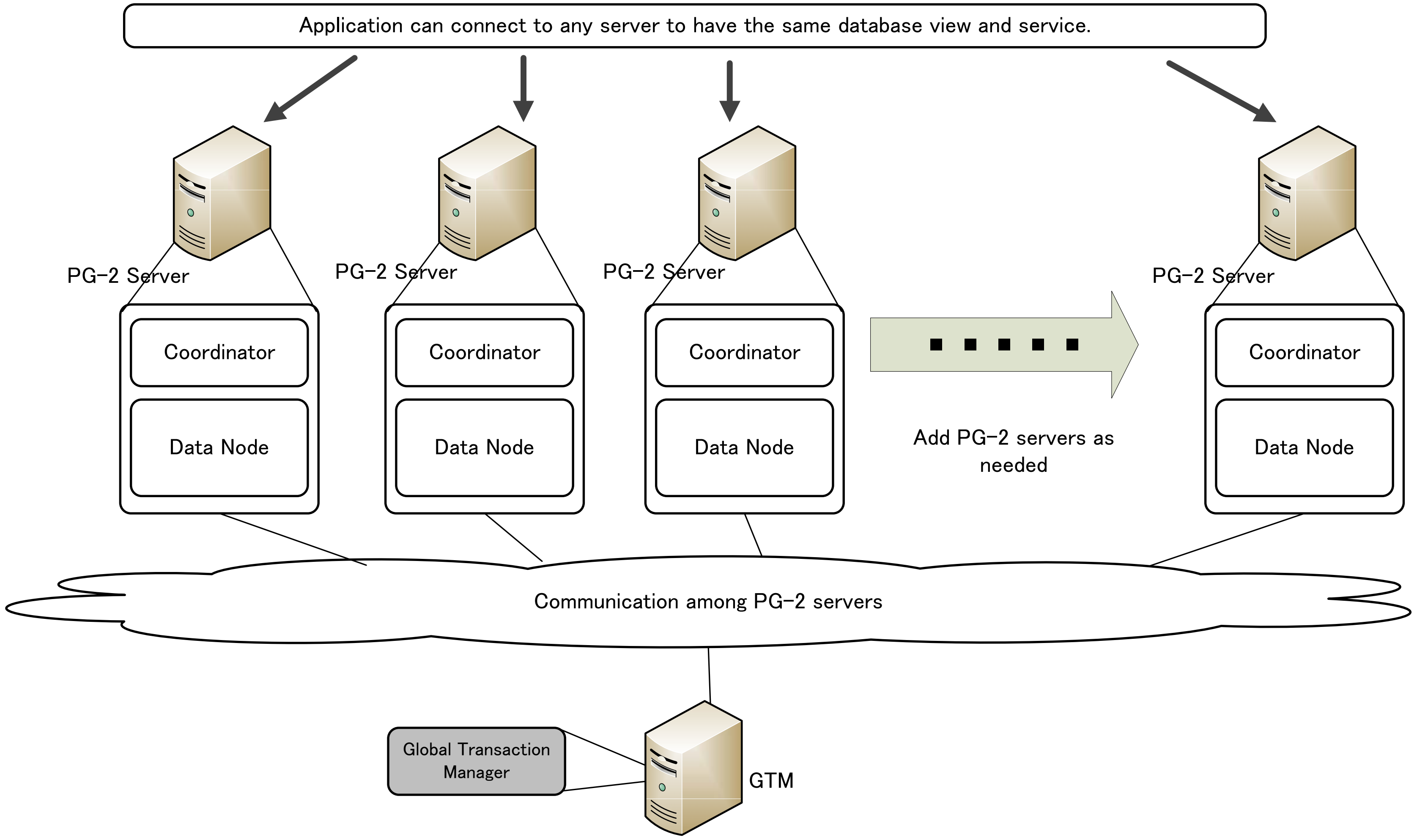
## What is Postgres-2 (or PG-2)?

- Write-scalable PostgreSQL cluster
  - More than 3.4 performance scalability with five servers, compared with pure PostgreSQL (DBT-1)
- Synchronous multi-master configuration
  - Any update to any master is visible from other masters immediately.
- Table location transparent
  - Can continue to use the same applications.
  - No change in transaction handling.
- Based upon PostgreSQL
- Same API to Apps. as PostgreSQL

## Why write-scalability?

- Many application could be write-traffic bottleneck such as –
  - Access log in BLOG/SNS
  - Mission critical systems like internet shopping site, telephone customer billing, call information and securities trade
- Now application has to deal with such write-bottleneck using multi-database.
  - Not distribution-transparent.
- As applications grow
  - It is desirable to make database distribution transparent for write operations too.

# Postgres-2 Architecture Outline


Application can connect to any server to have the same database view and service.
PG−2 Server
PG−2 Server
PG−2 Server
PG−2 Server
Coordinator
Data Node
Coordinator
Data Node
Coordinator
Data Node
Coordinator
Data Node
Add PG−2 servers as needed
Communication among PG−2 servers
Global Transaction Manager
GTM

# Postgres-2 Architecture

- Shared-nothing architecture
  - No shared disk
  - No shared memory
  - Only communication infrastructure
- Three Components
  - GTM (Global Transaction Manager)
    - Provide global transaction information to each transaction
      - Transaction ID
      - Snapshot
    - Provide other global data to statements
      - Sequence
      - Time/Sysdate (under plan)
  - Coordinator
    - Parse statements and determine location of involved data
    - Transfer statements for each data node (if needed)
    - Application I/F
  - Data Node
    - Store actual data
    - Execute statements from Coordinators

Postgres-2 also has Pooler to reuse coordinator and data node connections.

## What Applications?

- Short transaction applications (DBT-1/2 etc.)
  - Transactions can be executed in parallel in multiple data nodes.
- Complicated data warehouse (DBT-3 etc.)
  - Statement can be divided into several pieces which can be executed in parallel in multiple data nodes.
    - (Statement handling not available yet.)

## How to distribute tables?

- Tables can be partitioned or replicated over PG-2 servers according to application needs.
  - Can select partitioning key.
  - Rows will be partitioned according to the key value.
    - Hash
    - Range (future)
    - Others (future)
  - Transaction tables may be partitioned so that each transaction can be executed in limited number of data nodes.
  - Master tables may be replicated so that each transaction can read row values locally.
  - Table partitioning/replication is defined in the global catalog maintained by the coordinator.

## GTM: A Key Component

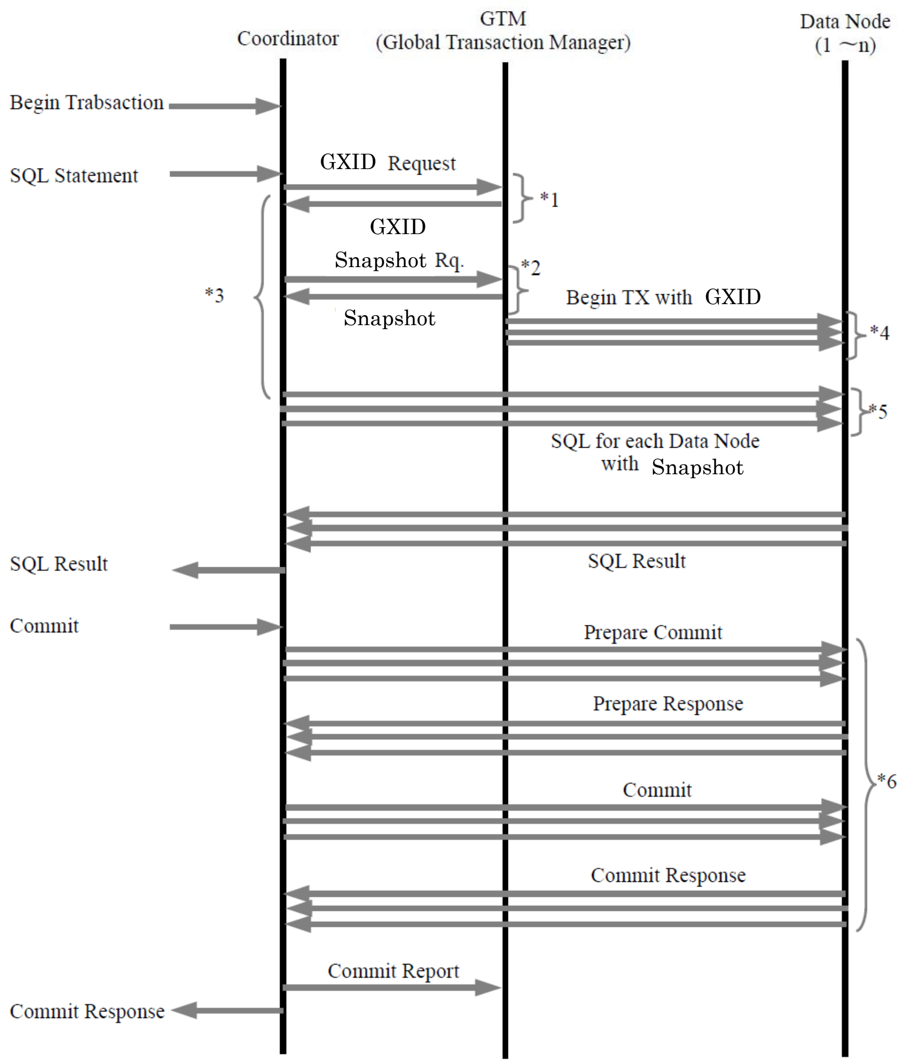
- Extracted essential of transaction management feature of PostgreSQL
  - Unique Transaction ID (GXID, Global Transaction ID) assignment,
  - Gather transaction status from all the coordinators and maintain snapshot data,
  - Provide snapshot data to each transaction/statement.
- Extract global value providing feature such as
  - Sequence
  - Time/sysdate

# GXID and Global Snapshot

- GXID
  - Unique Transaction ID in the system
- Global Snapshot
  - Includes snapshot information of transactions in other coordinators.

- Data node can handle transactions from different coordinators without consistency problem.
- Visibility is maintained as standalone PostgreSQL.

# Typical transaction handling flow



*1 Requests GXID only when Coordinator receives updating statement.

*2 When isolation level is serializable, snapshot is obtained only once and reused throughout the transaction.

*3 Mapping from global table to local tables are done referring to the global catalog stored in the coordinator.

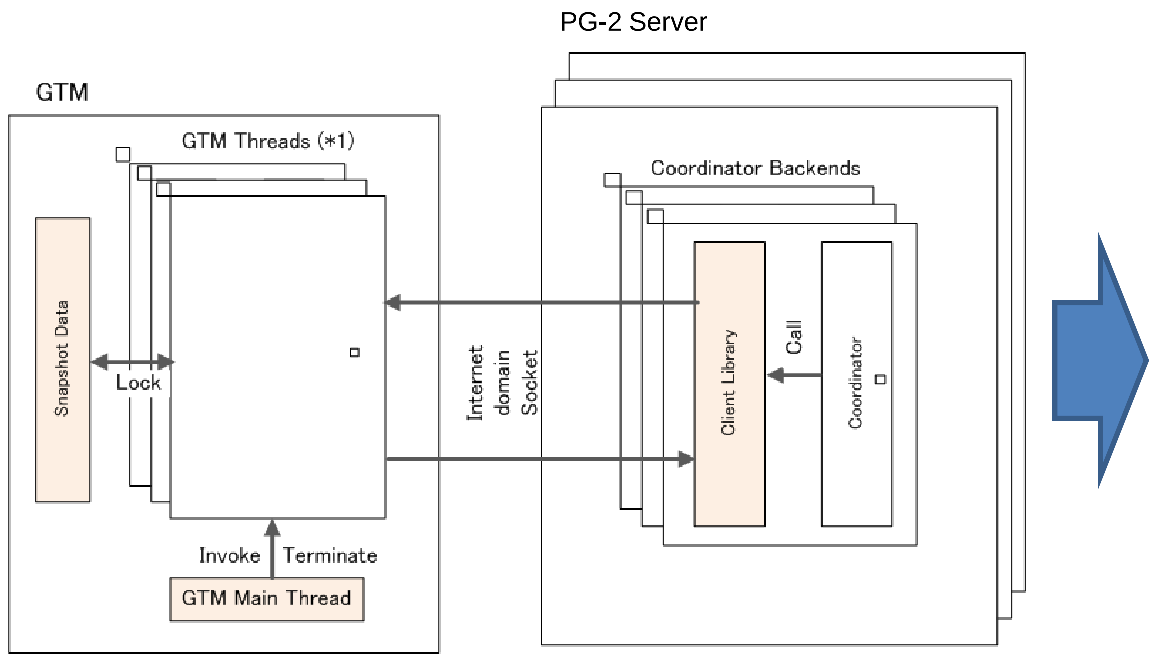
*4 GXID is associated when an updating statement is received.

*5 We have many options how to divide a statement. Here, we used SQL statement to command Data Node.

*6 2PC protocol is used only when multiple data nodes are involved in updating

# Could GTM be a bottleneck?

- Depending on implementation
  - Current Implementation

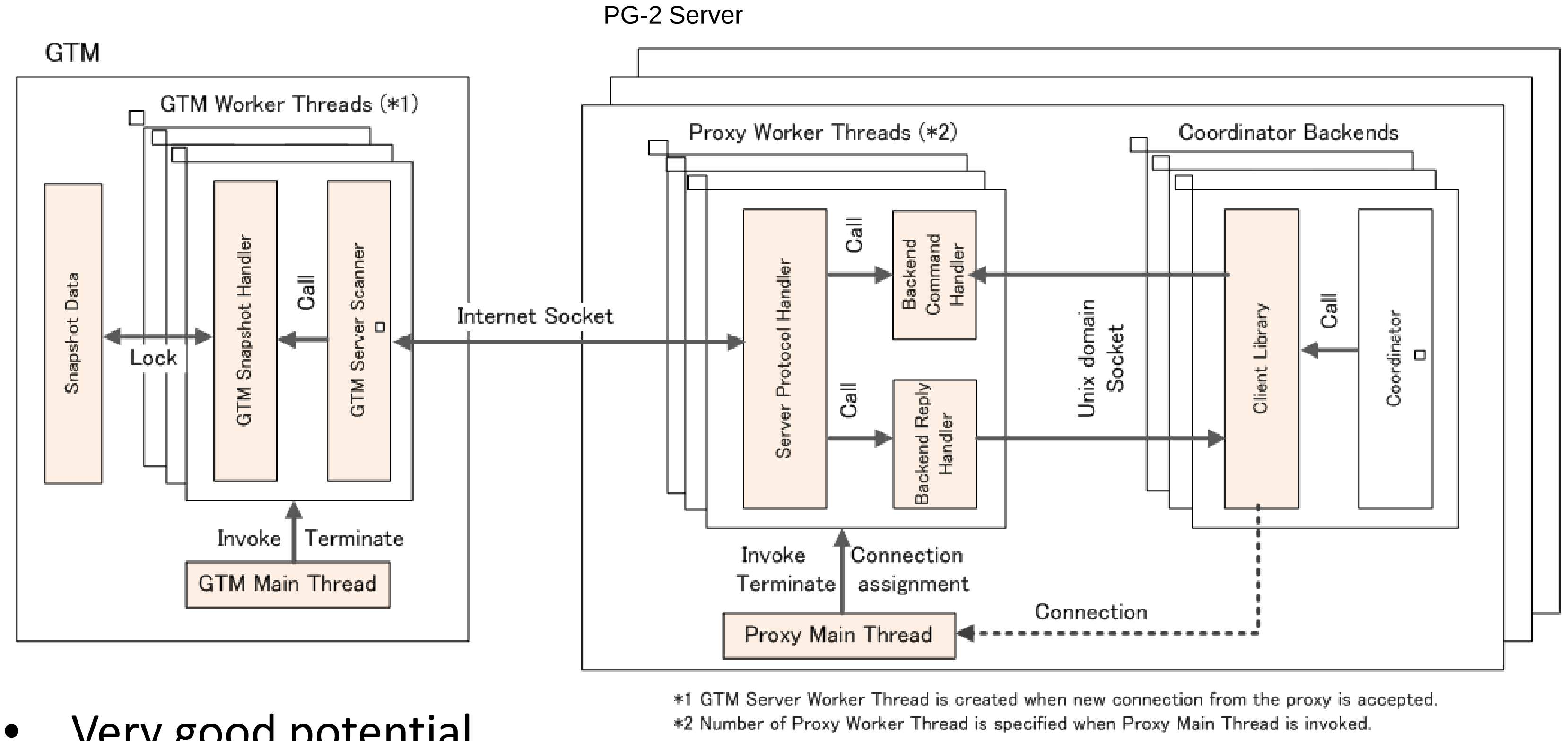


Applicable up to five PG-2 servers (DBT-1)

  - Large snapshot size and number
  - Too many interaction between GTM and Coordinators

# Could GTM be a bottleneck (cont.)?

- Proxy Implementation

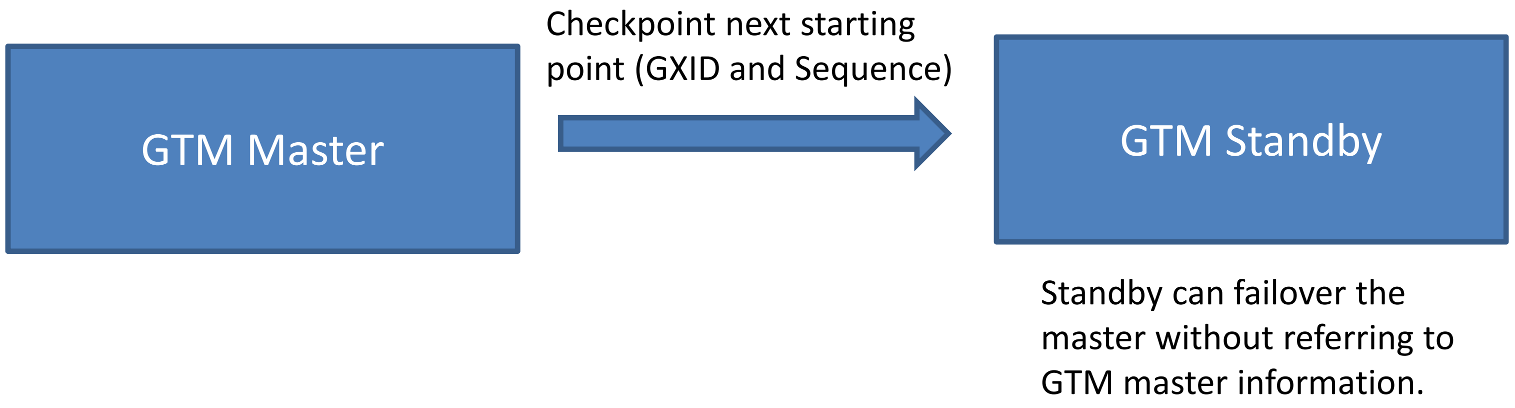


*1 GTM Server Worker Thread is created when new connection from the proxy is accepted.
*2 Number of Proxy Worker Thread is specified when Proxy Main Thread is invoked.

- Very good potential
  - Request/Response grouping
  - Single representative snapshot applied to multiple transactions
- Maybe applicable for more than ten PG-2 servers

# Could GTM be a SPOF?

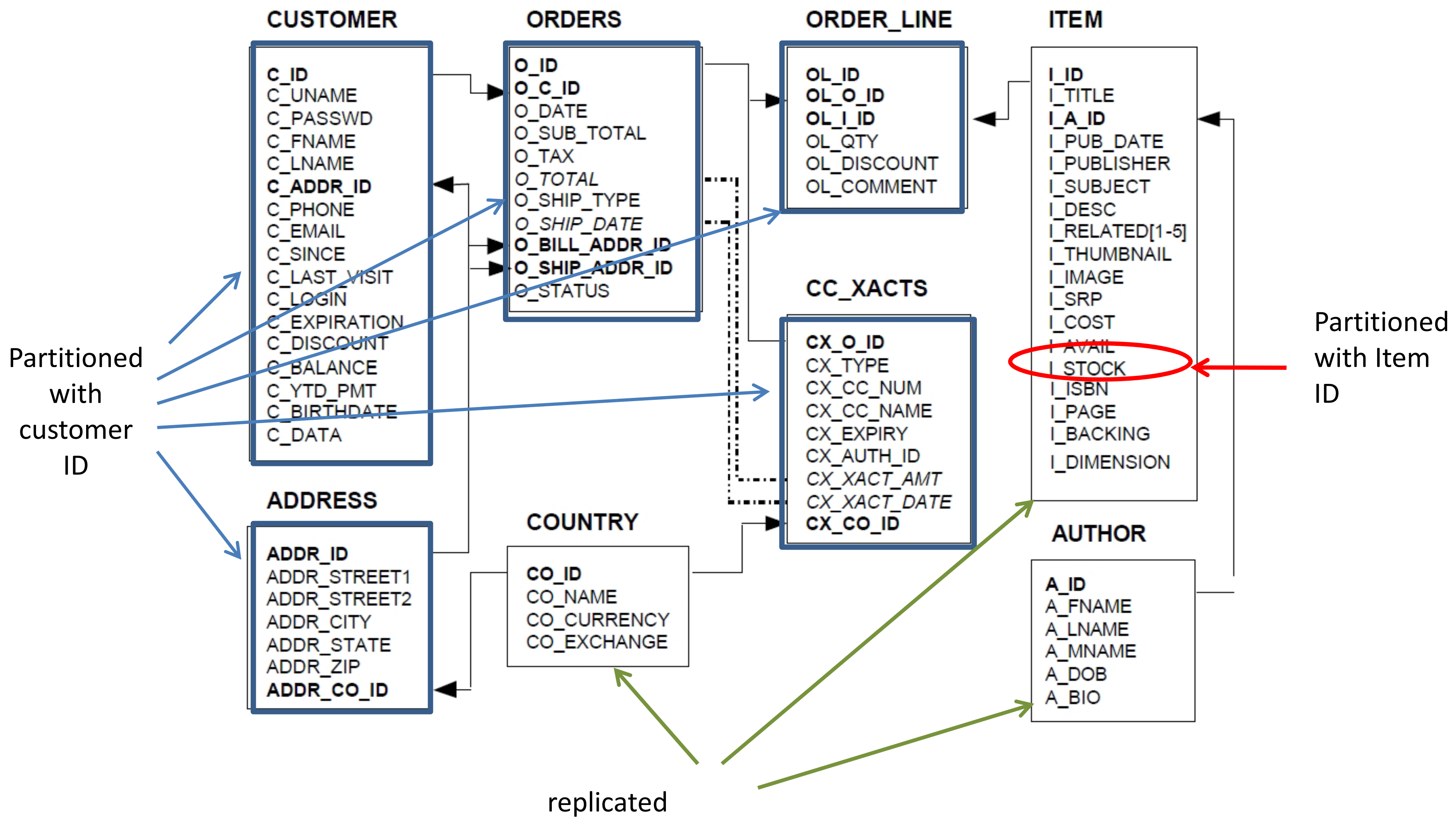
- Simple to implement GTM standby


GTM Master
Checkpoint next starting point (GXID and Sequence)
GTM Standby
Standby can failover the master without referring to GTM master information.

# DBT-1 Performance Benchmark

- DBT-1 schema change manually for partitioning
  - DDL not yet unavailable
  - Utilize key dependence
  - Added joins to WHERE clauses if needed
    - Could be handled automatically when DDL is supported
- Three replicated tables
- Seven partitioned tables
  - Three partitioning keys
- Item table is divided into item and inventory
  - As found in new TPC-W spec.

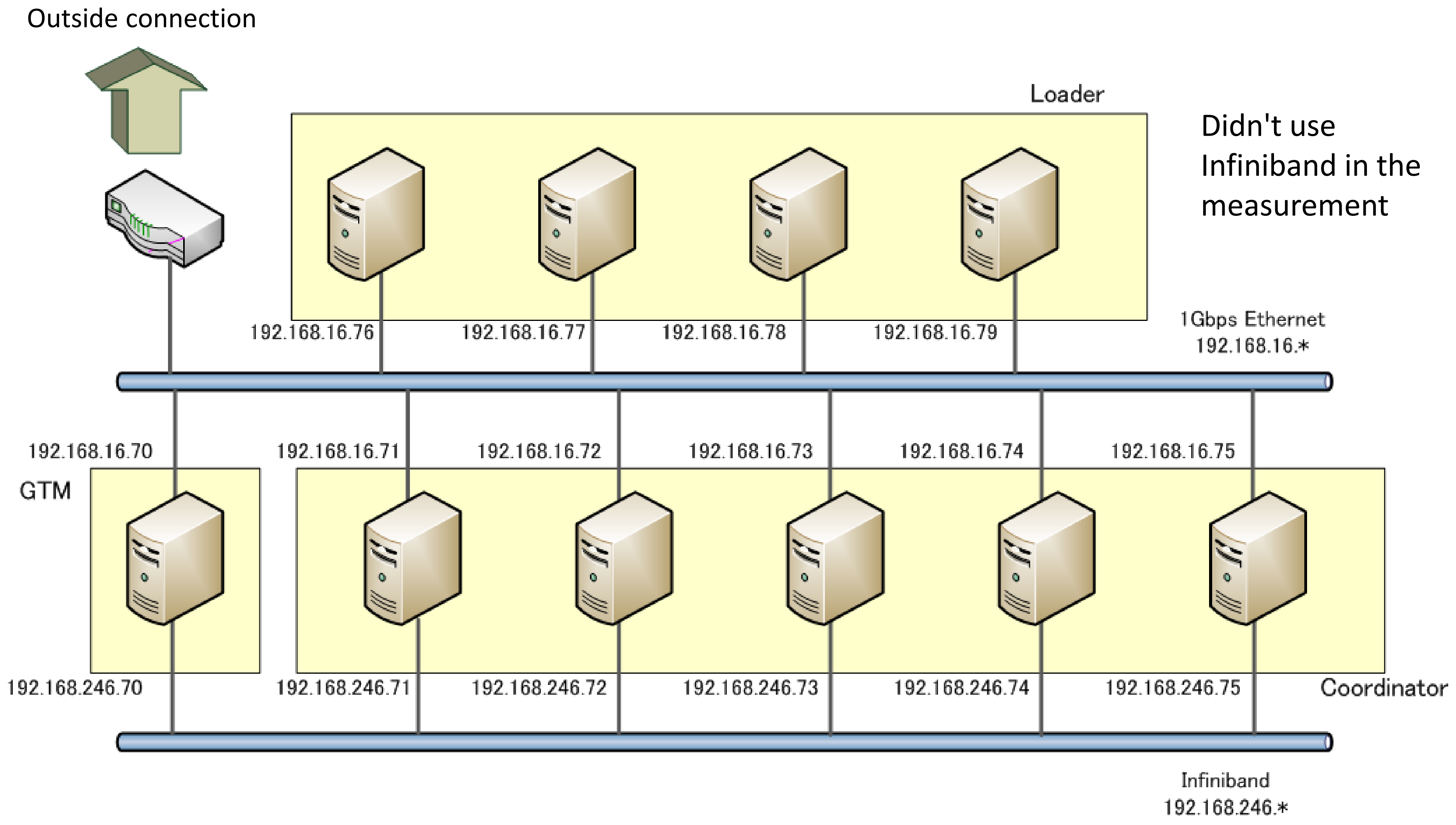
# DBT-1 Performance Benchmark (cont.1)



## DBT-1 Performance Benchmark (cont.2)

- Shopping cart and Shopping cart line
  - Partitioned using shopping cart ID

# Performance Measurement Environment



Didn't use Infiniband in the measurement

# Throughput

| Configuration | Performance | Relative to PostgreSQL | Relative to single node PG-2 |
|---|---|---|---|
| Pure PostgreSQL | 1900 TPS | 1 | 1.32 or worse* |
| Single Node PG-2 | 1740 TPS | 0.76 or better* | 1 |
| Five Node PG-2 | 8140 TPS | 4.4 or better* | 3.4 or better* |

- Very good performance
- Scale factor is excellent
  - May scale up to ten nodes.
- No significant performance drop in single node PG-2.
- Does not scale linearly from single node to five nodes
  - Additional communication among PG-2 servers
  - Additional overhead by 2PC (maybe very small)

*Above score is the worst one, when original PostgreSQL setting consumes almost 100% CPU. If original setting consumes less, scalability is better.

# Current Implementation

- Minimum feature to run DBT-1
  - No backup/recovery
  - Minimum error handling
  - Use timeout to detect cross-node deadlocks
  - Minimum SQL feature
    - No DDL
      - Global catalog setup manually
      - Manual table creation in each node
    - Hash partitioning only
      - Range partitioning not available yet
    - No cross-node join (not necessary in DBT-1)
    - No aggregate functions
    - No "copy"
    - Partitioning keys cannot be updated
      - Need to relocate tuples.
    - No consistent update of replicated tables
      - DBT-1 does not update replicated tables
      - Pgpool-II methodology can be applied.
  - 2PC improvement
    - Saved writes to state files
      - Writes to state files occur if a transaction is left prepared and not committed or aborted at checkpoints.

# Future issues

- Stabilize the code
  - Continue to run with full load for days/weeks
- Coordinator enhancement
- Open the code
  - Can GTM be used in other projects to harmonize multi-master synchronously?
- Integration with future PostgreSQL releases
  - APIs?
  - Hooks?
  - Can reuse PostgreSQL binaries?