## Interval-based Trace Format Guideline

To perform isolation level verification in a black-box mode, we log the *interval-based trace* (trace for short) of each operation in a workload. In this document, we introduce the format of logging traces in detail. Generally speaking, as an example shown in Figure 1, the trace of an operation consists of :

- 1. **threadID** The thread identification of the operation.
- 2. **transactionID** The transaction identification of the operation.
- 3. **operationID** The operation identification.
- 4. **operationTraceType** The operation type.
- 5. **startTimestamp** The timestamp before the operation executed.
- 6. **finishTimestamp** The timestamp after the operation executed.
- 7. **predicateLock** The predicate lock acquired by the operation. It is decided by the type of the test DBMS and the operation type. The details have been described in Section 4.
- 8. **traceLockMode** The lock mode of the operation.
- 9. **readMode** The read mode of the operation. Both lock mode and read mode are decided by the type of the test DBMS and the operation type. The details have been described in Section 2 and 3.
- 10. Read/Write Tuple List The data accessed by the operation. Specifically, for a read (resp. write) operation, we log its read (resp. write) tuple list. Each tuple list consists of the tuple identification and value.

```
{
  "threadID": "0-0-0",
 "transactionID": "0-0-0,0",
  "operationID": "0-0-0,0,1",
 "operationTraceType": "UPDATE",
  "startTimestamp": 1663798322622208619,
  "finishTimestamp": 1663798322632200949,
  "predicateLock": null,
  "traceLockMode": "EXCLUSIVE_LOCK",
  "readMode": "LOCKING_READ",
  "writeTupleList": [
     "table": "0",
      "primaryKey": "0",
      "valueMap": {
        "v": 1
      }
},
```

Figure 1: Interval-based Trace Example

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# 1. Three Types of Lock Modes

- NON\_LOCK
  - An operation accesses data without acquiring lock.
- SHARE\_LOCK
  - An operation accesses data before acquiring shared lock.
- EXCLUSIVE\_LOCK
  - An operation accesses data before acquiring exclusive lock.

#### InnoDB

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_LO	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
Uncomm	CK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
itted						
Read	NON_LO	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
Committ	CK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
ed						
Repeata	NON_LO	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
ble Read	CK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
Serializa	SHARE_L	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
ble	OCK	OCK	_LOCK	_LOCK	_LOCK	_LOCK

#### PostgreSQL

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Uncomm	OCK	OCK	LOCK	LOCK	LOCK	LOCK
itted						
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Committ	OCK	OCK	LOCK	LOCK	LOCK	LOCK
ed						
Repeata	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
ble Read	OCK	OCK	LOCK	LOCK	LOCK	LOCK

Serializa	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
ble	OCK	OCK	LOCK	LOCK	LOCK	LOCK

## Oceanbase

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Uncomm	OCK	OCK	LOCK	LOCK	LOCK	LOCK
itted						
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Committ	OCK	OCK	LOCK	LOCK	LOCK	LOCK
ed						
Repeata	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
ble Read	OCK	OCK	LOCK	LOCK	LOCK	LOCK
Serializa	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
ble	OCK	OCK	LOCK	LOCK	LOCK	LOCK

## TiDB Pessimistic Transaction

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Commi	OCK	OCK	LOCK	LOCK	LOCK	LOCK
tted						
Repeat	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
able	OCK	OCK	LOCK	LOCK	LOCK	LOCK
Read						

## Oracle

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
Commi	OCK	OCK	LOCK	LOCK	LOCK	LOCK
tted						

Repeat	NON_L	SHARE_L	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_	EXCLUSIVE_
able	OCK	OCK	LOCK	LOCK	LOCK	LOCK
Read						

# Derby

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_LO	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
Uncomm	CK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
itted						
Read	SHARE_L	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
Committ	OCK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
ed						
Repeata	SHARE_L	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
ble Read	OCK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
Serializa	SHARE_L	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
ble	OCK	OCK	_LOCK	_LOCK	_LOCK	_LOCK

# SQLite

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NON_LO	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
Uncomm	CK	OCK	_LOCK	_LOCK	_LOCK	_LOCK
itted						
Serializa	SHARE_L	SHARE_L	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE	EXCLUSIVE
ble	OCK	OCK	_LOCK	_LOCK	_LOCK	_LOCK

## CockroachDB

	Select	Select for update	Insert	update	delete
Serializable	NON_LOCK	EXCLUSIVE_LOCK	NON_LOCK	NON_LOCK	NON_LOCK

### YugabyteDB

	Select	Select for	Insert	update	delete
		update			
Serializable	NON_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK
Repeatable	NON_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK
Read					
Read	NON_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK	EXCLUSIVE_LOCK
Committed					

# 2. Three Types of Read Modes

- UNCOMMITTED\_READ
  - An operation sees a uncommitted data.
- CONSISTENT\_READ
  - An operation performs a consistent read on the snapshot of database.
- LOCKING\_READ
  - An operation access data before acquiring lock.

#### InnoDB

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	UNCOMMITT	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
Uncom	ED_READ	_READ	_READ	_READ	_READ	_READ
mitted						
Read	CONSISTENT_	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
Committ	READ	_READ	_READ	_READ	_READ	_READ
ed						
Repeata	CONSISTENT_	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
ble Read	READ	_READ	_READ	_READ	_READ	_READ
Serializa	LOCKING_REA	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
ble	D	_READ	_READ	_READ	_READ	_READ

#### PostgreSQL

Select	Select lock	Select for	Insert	update	delete
--------	-------------	------------	--------	--------	--------

		in share	update			
		mode				
Read	CONSISTE	CONSISTE	CONSISTE	LOCKIN	CONSISTE	CONSISTE
Uncom	NT_READ	NT_READ	NT_READ	G_READ	NT_READ	NT_READ
mitted						
Read	CONSISTE	CONSISTE	CONSISTE	LOCKIN	CONSISTE	CONSISTE
Commit	NT_READ	NT_READ	NT_READ	G_READ	NT_READ	NT_READ
ted						
Repeat	CONSISTE	CONSISTE	CONSISTE	LOCKIN	CONSISTE	CONSISTE
able	NT_READ	NT_READ	NT_READ	G_READ	NT_READ	NT_READ
Read						
Serializ	CONSISTE	CONSISTE	CONSISTE	LOCKIN	CONSISTE	CONSISTE
able	NT_READ	NT_READ	NT_READ	G_READ	NT_READ	NT_READ

## Oceanbase

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	UNCOMMIT	CONSISTE	CONSISTE	CONSISTE	CONSISTE	CONSISTE
Uncom	TED_READ	NT_READ	NT_READ	NT_READ	NT_READ	NT_READ
mitted						
Read	CONSISTEN	CONSISTE	CONSISTE	CONSISTE	CONSISTE	CONSISTE
Commi	T_READ	NT_READ	NT_READ	NT_READ	NT_READ	NT_READ
tted						
Repeat	CONSISTEN	CONSISTE	CONSISTE	CONSISTE	CONSISTE	CONSISTE
able	T_READ	NT_READ	NT_READ	NT_READ	NT_READ	NT_READ
Read						
Serializ	CONSISTEN	CONSISTE	CONSISTE	CONSISTE	CONSISTE	CONSISTE
able	T_READ	NT_READ	NT_READ	NT_READ	NT_READ	NT_READ

## TiDB Pessimistic Transaction

	Select	Select lock in share mode	Select for update	Insert	update	delete
Read	CONSISTENT	LOCKING_	LOCKING_	LOCKING_	LOCKING_	LOCKING_
Commi	_READ	READ	READ	READ	READ	READ
tted						
Repeat	CONSISTENT	LOCKING_	LOCKING_	LOCKING_	LOCKING_	LOCKING_

able	_READ	READ	READ	READ	READ	READ
Read						

## Oracle

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	CONSISTE	LOCKING	CONSISTE	CONSISTE	CONSISTE	CONSISTE
Comm	NT_READ	_READ	NT_READ	NT_READ	NT_READ	NT_READ
itted						
Repea	CONSISTE	LOCKING	CONSISTE	CONSISTE	CONSISTE	CONSISTE
table	NT_READ	_READ	NT_READ	NT_READ	NT_READ	NT_READ
Read						

# Derby

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	UNCOMMITT	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
Uncom	ED_READ	_READ	_READ	_READ	_READ	_READ
mitted						
Read	LOCKING_REA	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
Committ	D	_READ	_READ	_READ	_READ	_READ
ed						
Repeata	LOCKING_REA	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
ble Read	D	_READ	_READ	_READ	_READ	_READ
Serializa	LOCKING_REA	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
ble	D	_READ	_READ	_READ	_READ	_READ

# SQLite

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	UNCOMMITT	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
Uncom	ED_READ	_READ	_READ	_READ	_READ	_READ
mitted						

Serializa	LOCKING_REA	LOCKING	LOCKING	LOCKING	LOCKING	LOCKING
ble	D	_ <i>READ</i>	_ <i>READ</i>	_READ	_READ	_READ

## CockroachDB

	Select	Select for update	Insert	update	delete
Serializable	CONSISTENT_R	LOCKIN	CONSISTEN	CONSISTEN	CONSISTEN
	EAD	G_READ	T_READ	T_READ	T_READ

## YugabyteDB

	Select	Select	Insert	update	delete
		for			
		update			
Serializable	CONSISTENT_R	LOCKIN	CONSISTEN	CONSISTEN	CONSISTEN
	EAD	G_READ	T_READ	T_READ	T_READ
Read	CONSISTENT_R	LOCKIN	CONSISTEN	CONSISTEN	CONSISTEN
Committed	EAD	G_READ	T_READ	T_READ	T_READ
Repeatable	CONSISTENT_R	LOCKIN	CONSISTEN	CONSISTEN	CONSISTEN
Read	EAD	G_READ	T_READ	T_READ	T_READ

# 3. Predicate Lock

### InnoDB

	Select	Select lock in share mode	Select for update	Insert	update	delete
Read	NO	NO	NO	NO	NO	NO
Uncommitted						
Read	NO	NO	NO	NO	NO	NO
Committed						
Repeatable	NO	YES	YES	NO	NO	NO
Read						
Serializable	YES	YES	YES	NO	NO	NO

# PostgreSQL

	Select	Select	Select for	Insert	update	delete
		lock in	update			
		share				
		mode				
Read	NO	NO	NO	NO	NO	NO
Uncommitted						
Read	NO	NO	NO	NO	NO	NO
Committed						
Repeatable	NO	NO	NO	NO	NO	NO
Read						
Serializable	YES	YES	YES	NO	NO	NO

## Oceanbase

No predicate lock required.

### TiDB

No predicate lock required.

#### Oracle

No predicate lock required.

## Derby

	Select	Select lock in share mode	Select for update	Insert	update	delete
Read	NO	NO	NO	NO	NO	NO
Uncommitted						
Read	NO	NO	NO	NO	NO	NO
Committed						
Repeatable	NO	NO	NO	NO	NO	NO
Read						
Serializable	YES	YES	YES	NO	NO	NO

## **SQLite**

No predicate lock required.

#### CockroachDB

No predicate lock required.

#### **Predicate Lock Rewrite Rules**

If there is no *Where* clause, add a table level lock for each table in the from clause, and connect the table level lock with *OR* operator. If there is no index on the attribute column in where clause, add table level lock; Otherwise, add range level lock.

#### **Table-level Lock Rewrite Rules**

tableName.table = 'tableName'

#### Range-level Lock Rewrite Rules

- predicate
  - **-**
    - =
  - **=** >
    - **♦** >
  - <
    - **♦** <
  - >=
    - **◆** >=
  - <=
    - **♦** <=
  - **■** !=
    - **♦** !=
  - Like
    - ◆ table-level lock
  - In
    - ♦ table-level lock
  - Between and
    - Between and
  - Is null
    - ♦ Is null
  - Not
    - **•** =
    - **\ldot** >
    - **A** /
    - **\lambda** >=

- **♦** <=
- Between and
- ♦ Is null
- **♦** !=
  - Not
- **♦** Like
  - table-level lock
- **♦** In
  - table-level lock
- And
  - **♦** And
- Or
  - ♦ Or