Rare but extremely challenging PostgreSQL Performance Problems

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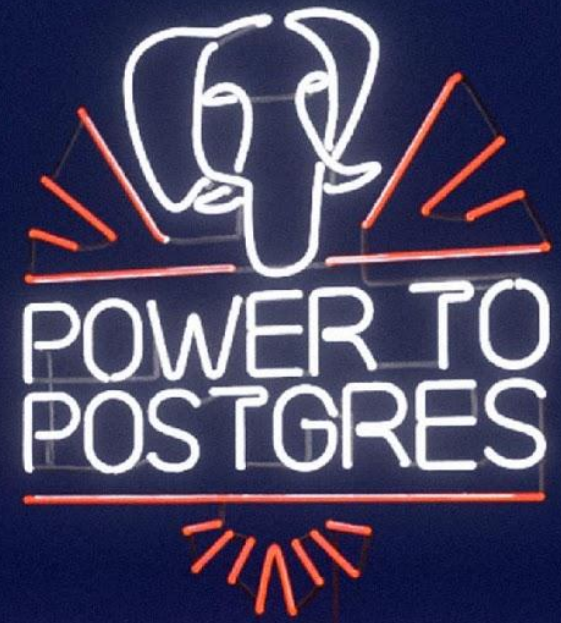

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Agenda:

- Problem introduction - 1
- Snapshot
- PG_SUBTRANS SLRU
- Visibility check
- Subtransaction cache overflow
- Presence of long running transactions
- Problem introduction - 2
- Row locking
- Multixact
- Summary
- Q&A

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Problem Introduction - 1

SETUP

scale factor: 300
shared_buffers=8GB
checkpoint_timeout=40min
max_wal_size=20GB
max_connections=200
maintenance_work_mem=1GB&
./pgbench -c 64 -j 64 -T 1800 -P5 -M prepared postgres

86595	LWLock	SubtransSLRU
14619	LWLock	SubtransBuffer
2574	Client	ClientRead
1876	Activity	WalWriterMain
1799	Lock	transactionid
1717	Timeout	PgSleep
1093	Activity	BgWriterMain
404	IO	SLRURead

RESULT

progress: 5.0 s, 30008.0 tps, lat 2.117 ms stddev 1.390, 0 failed

progress: 10.0 s, 30134.3 tps, lat 2.123 ms stddev 1.280, 0 failed

progress: 530.0 s, 28612.6 tps, lat 2.236 ms stddev 1.272, 0 failed

——-> create subtransaction overflow <——----------

progress: 545.0 s, 15876.0 tps, lat 4.011 ms stddev 2.604, 0 failed

progress: 705.0 s, 16366.2 tps, lat 3.909 ms stddev 3.292, 0 failed

——-> start a long running idle transaction<——----------

progress: 710.0 s, 15762.8 tps, lat 4.060 ms stddev 3.236, 0 failed

progress: 715.0 s, 5604.2 tps, lat 11.399 ms stddev 6.955, 0 failed

….

progress: 1790.0 s, 227.4 tps, lat 268.356 ms stddev 368.967, 0 failed

progress: 1795.0 s, 264.6 tps, lat 250.147 ms stddev 359.489, 0 failed

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Snapshot

- We need a snapshot for getting a consistent view of the data (ACID)
- All running (sub)transaction ids are kept in snapshot's xip/subxip array
- Snapshot is bounded with xmin and xmax
- Snapshot is prepared by reading xid and subxid information from each backend
- Each backend can cache 64 subxids

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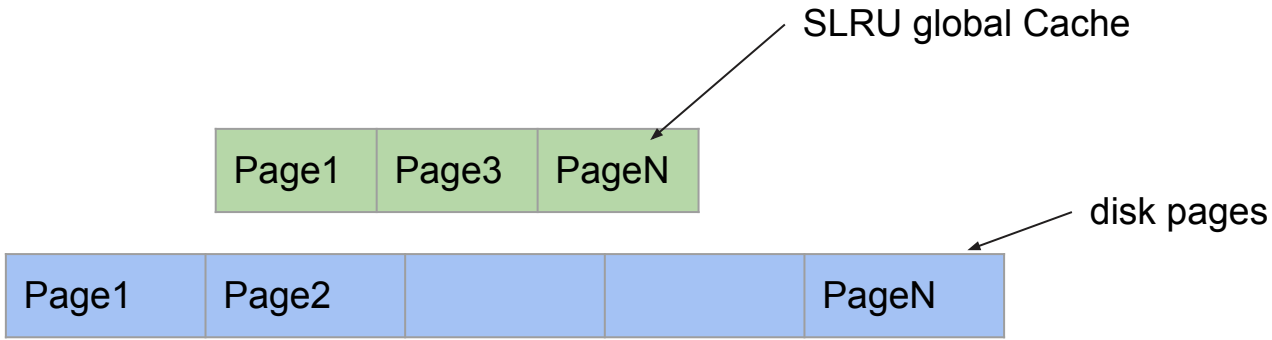
PG_SUBTRANS SLRU

- PG_SUBTRANS maintains the parent xid of each subxid
- Need to update this information whenever we assign a subtransaction id
- Reader do not need to access this SLRU in normal cases
  - Snapshot should contains subtransaction information in subxip array



Visibility check

- Each tuple has xmin and xmax
  - it has different meaning than snapshot xmin and xmax

- Tuple xids (xmin/xmax) falling within the snapshot xmin/xmax range need to be looked into the snapshot’s subxip and xip array

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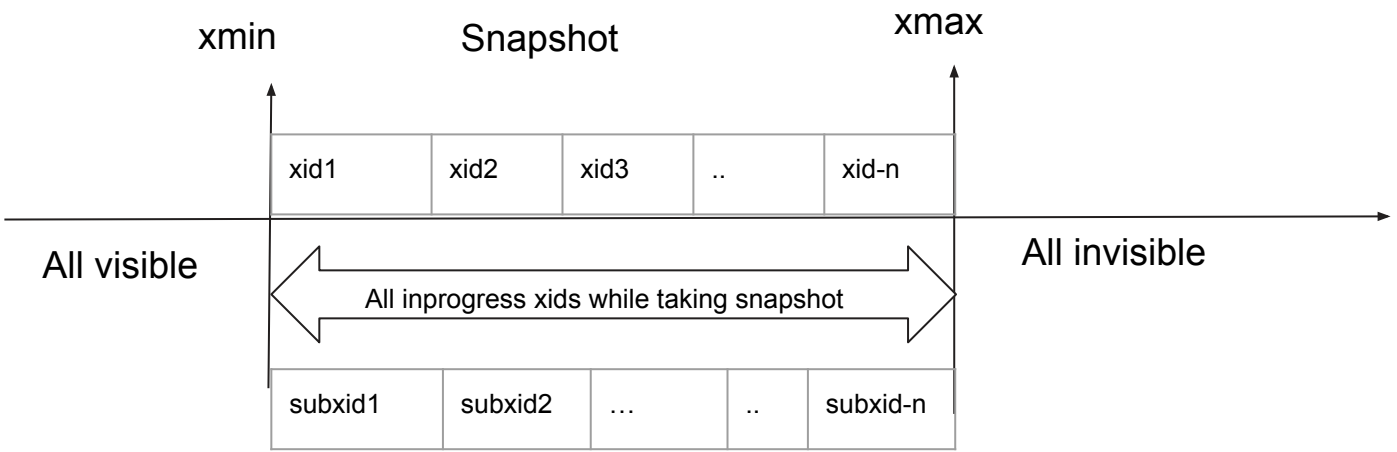
Visibility check



Xmin and xmax in Heap Page

xmin	xmax	tuple1
xmin	xmax	tuple2
xmin	xmax	tuple3

Subtransaction cache overflow

- Per backend there is cache to hold 64 subtransaction
  - If this limit cross we no longer maintain the subxid informations
  - Now snapshot->subxip is not complete
    - We can only rely on snapshot->xip array but not on snapshot->subxip array
    - We need to access the pg_subtrans SLRU to get parent xid and then look into xip array
- Problems in accessing pg_subtrans SLRU
  - This is accessed under LWLock
  - Reader and Writer conflict on Lock
  - Need to access disk if pages are not in SLRU buffer

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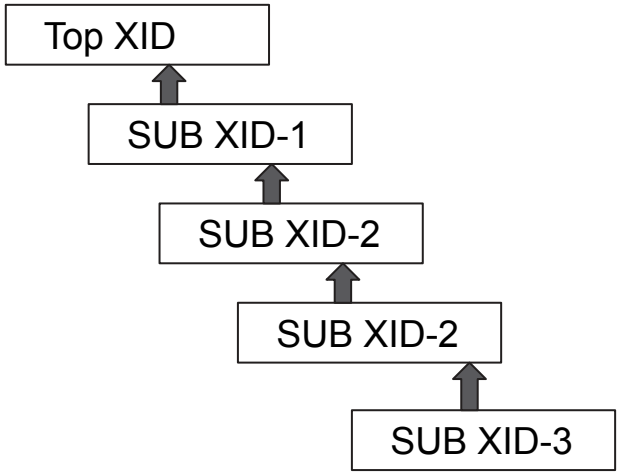
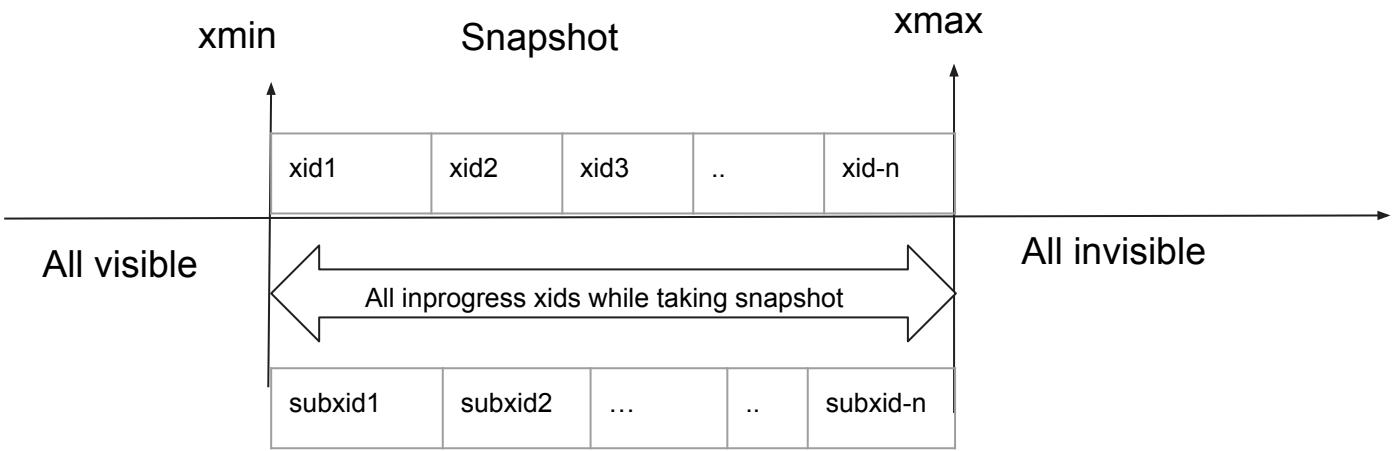
Subtransaction cache overflow

- Need to traverse the subtransaction tree in the pg_subtrans slru to get the top transaction id



Presence of long running transaction

- What is long running transaction
  - Assign xid and do not commit
- Impact on visibility
  - Snapshot has large range of xmin and xmax
    - More access to SLRU
  - Frequent SLRU cache miss



Release Savepoint vs Rollback To Savepoint

- Rollback to Savepoint
  - Revert the effect of partial transaction
  - Subxid is immediately marked aborted in PG_XACT
  - Now we can release the subxid slot from backend cache

- Release savepoint
  - Release the current active subtransaction from stack
    - Help reducing the depth of subxact tree
  - Subxid can not be considered committed until top xid is committed
  - Can not release the slot from the session cache

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Subtransaction cache overflow - Summary

- Frequent subtransaction overflow can create slow down due to SLRU lookup
- This become worst in presence of long running transaction(s)
  - Because that will force more xids to be looked up into the SLRU
  - Create contention on SLRU lock as well as frequent SLRU buffer replacement
- Use release savepoint whenever possible to reduce the subxact tree depth

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Problem Introduction - 2

```
BEGIN;
SELECT FROM pgbench_accounts WHERE aid = :aid FOR
UPDATE;
SAVEPOINT S1;
UPDATE pgbench_accounts SET abalance = abalance + :delta
WHERE aid = :aid;
SELECT abalance FROM pgbench_accounts WHERE aid =
:aid;
END;
```

```
16729  LWLock     | MultiXactOffsetSLRU
 7086  LWLock     | MultiXactOffsetBuffer
 1313  Client     | ClientRead
  443  Activity   | LogicalLauncherMain
  443  Activity   | CheckpointerMain
  443  Activity   | AutoVacuumMain
```

RESULT

```
progress: 5.0 s, 32610.6 tps, lat 1.949 ms stddev 0.612, 0 failed
progress: 10.0 s, 33412.6 tps, lat 1.915 ms stddev 0.625, 0 failed
progress: 15.0 s, 32396.0 tps, lat 1.974 ms stddev 0.745, 0 failed
.....
progress: 20.0 s, 32109.6 tps, lat 1.993 ms stddev 0.799, 0 failed
—--> start a long running idle transaction←—----------

progress: 100.0 s, 26762.9 tps, lat 2.390 ms stddev 2.685, 0 failed
progress: 105.0 s, 17583.5 tps, lat 3.636 ms stddev 2.907, 0 failed
progress: 110.0 s, 7990.4 tps, lat 7.993 ms stddev 9.713, 0 failed
progress: 115.0 s, 4305.4 tps, lat 14.837 ms stddev 20.893, 0 failed
....

progress: 745.0 s, 1375.4 tps, lat 46.531 ms stddev 22.377, 0 failed
progress: 750.0 s, 1359.8 tps, lat 46.982 ms stddev 22.115, 0 failed
progress: 755.0 s, 1352.2 tps, lat 47.423 ms stddev 22.168, 0 failed
```

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Row Locking

- A regular select statement does not give you enough protection if you want to query data and make a change in the database related to it.
  - Other transactions can update or delete the data you just queried.
- With ROW Locking PostgreSQL offers additional select statements that lock on read and provide an extra layer of safety.
  - The *select for update* - acquire a exclusive lock on row(s)
    - Mainly require for selecting first and updating later
  - The *select for share* acquires a shared lock
    - Can lock a particular row in primary key table before inserting in foreign key table

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Row Locking

- PostgreSQL maintains the xid of an inserter in xmin and xid of an deleter/updater in xmax field of the tuple
- Xid of the locker is also maintained in the xmax field
- Now we are allowed to acquire multiple concurrent row shared lock
  - So how to store multiple xid in one xmax field?

MultiXact

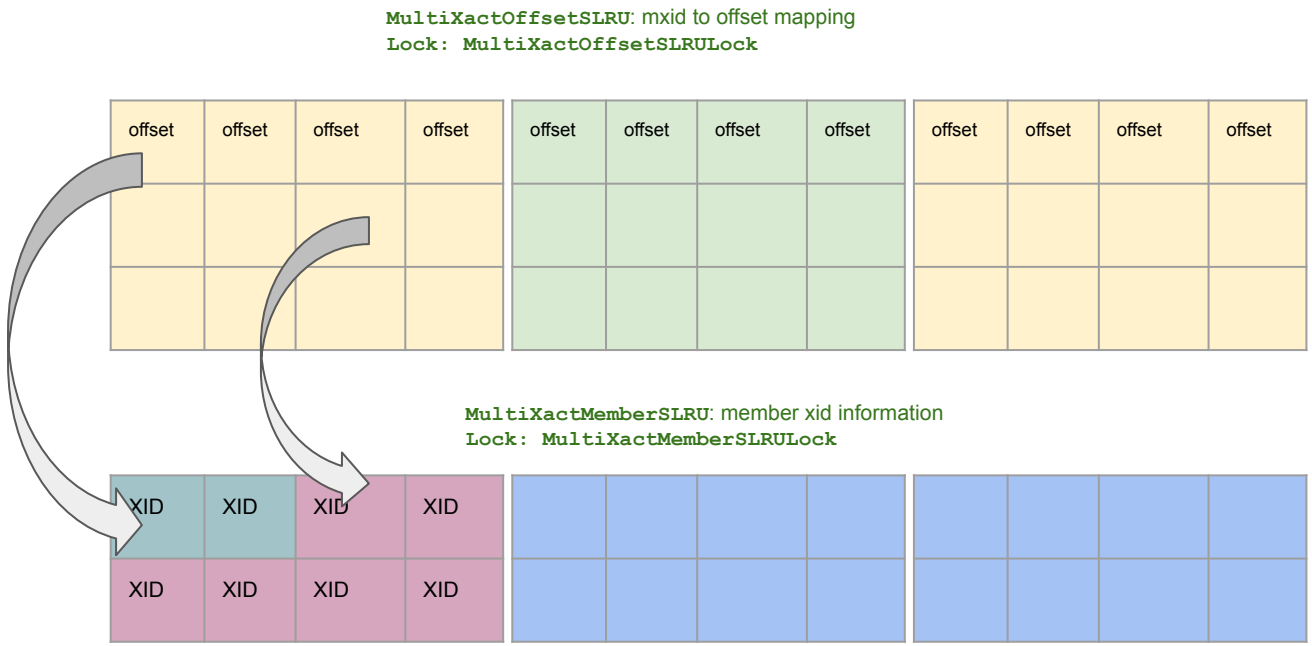
- Multixact provide a way to create a new kind of xid called multi-xact id
  - Under the hood it is a mapping from a new xid called multi-xact id to a list of xids and their locking status

- The pg_multixact manager stores an array of MultiXactMember for each MultiXactId.

MultiXact

- Number of member xid for the multixact-id is variable so we can not map to a fixed offset
- For handling this we use two SLRU
  - One for storing the offsets at which the data starts for each MultiXactId
  - And in other one we store variable length of transaction ids

MultiXact



MultiXact

- When MultiXact ID is created
  - Generally it required a share locker
    - SELECT for SHARE
    - SELECT for NO KEY UPDATE
    - SELECT for KEY SHARE
  - Special case when it is created by single transaction with a subtransaction
    - Special Case

```
BEGIN

SELECT … FOR UPDATE;

SAVEPOINT s1;

UPDATE
```

MultiXact Summary

- Generally share lockers create multixact id
- Long running can block cleanup of hot chains
    - This will create more contention on the MultiXact SLRU

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Q & A

Thank You