Pluggable Table Storage in PostgreSQL

Andres Freund

PostgreSQL Developer & Committer

Email: andres@anarazel.de
Email: andres.freund@enterprisedb.com
Twitter: @AndresFreundTec

anarazel.de/talks/2019-06-25-pgvision-pluggable-table-storage/pluggable.pdf

Pluggable Table Storage / tableam

CREATE TABLE …(...) USING heap;

In collaboration with:

- Haribabu Kommi
- Alvaro Herrera
- Ashutosh Bapat
- Alexander Korotkov
- Amit Khandekar
- Dmitry Dolgov

What do you mean: table storage

- Contents of a `TABLE / MATERIALIZED VIEW`
- **NOT** contents of indexes
- Not just / necessarily a change of IO layer

What do you mean: pluggable

```
CREATE EXTENSION magic_storage;
CREATE TABLE something (…) USING magic_storage;
SET default_table_access_method = ‘magic_storage’;
CREATE TABLE else (…); -- still uses magic_storage
```

Why?

Why?

PostgreSQL is not yet perfect

PostgreSQL Row Store Problems

Why row store: Best for most OLTP

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- per row overhead
- complexity around row-locking

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Hard to solve:

- binary compatibility important, not realistically in-place upgradable
- **lots** of existing data
- stability extremely important
- other approaches have different tradeoffs

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Potential new approach: ZHeap

- UNDO based storage, to address bloat and write amplification problems
- smaller per row overhead

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- Row store data density too low (compression)
- Row store doesn’t allow for effective vectorization

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- Column stores aren’t good for many other workloads
- Current PG table format can’t be developed into a column store

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Solution: PG needs both a Row and a Column Store

Zedstore AM is being developed

Why not?

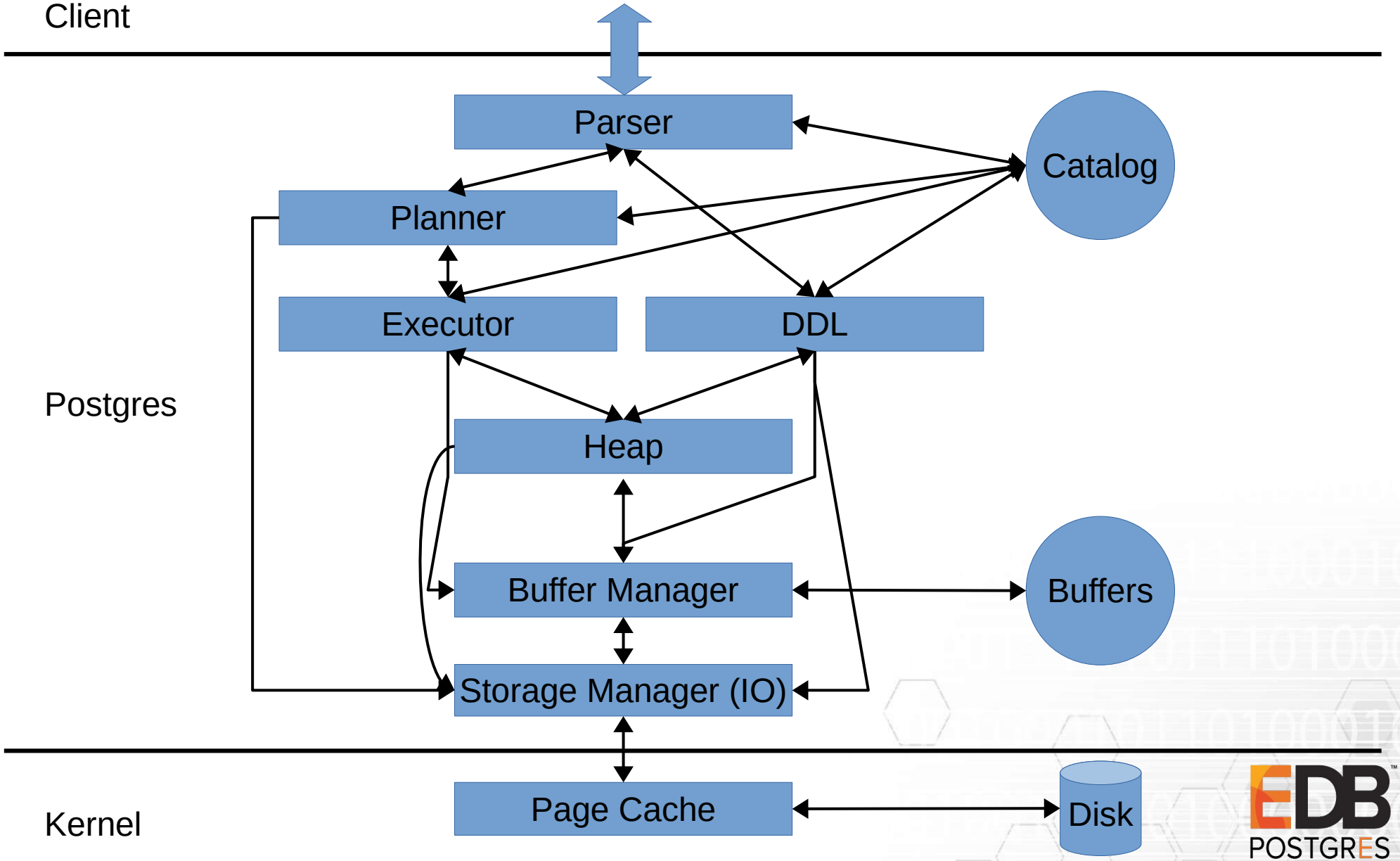
- Architectural impact
- Differing behavior between AMs making it harder to target PostgreSQL
- Proliferation of half-baked and extremely special-case storage engines, rather than one three good ones
- Proliferation of closed & commercial storage engines

What?

- Multiple table AMs should be able to exist at compile time
- new table AMs can be added at runtime (`i.e. CREATE EXTENSION new_am;`)
- Indexes: Should work across different table AMs
- Planner: Should work largely unmodified against different AMs
- NOT: stable API for near-term future
- NOT: Fully extensible WAL logging
- NOT: non-heap catalog tables
- NOT: Executor/Planner magic to make every storage method super fast

Contrast to Foreign Data Wrapper API

- FDWs basically hook in at the planner level
- FDWs not intended to locally store data
- Transactional Integration
- FDWs do not really support DDL
- Foreign Keys not supported (and it doesn't really make sense to support)
- Different goals, but some overlap exists


Client
Parser
Catalog
Planner
Executor
DDL
Postgres
Heap
Buffer Manager
Buffers
Storage Manager (IO)
Page Cache
Disk
Kernel

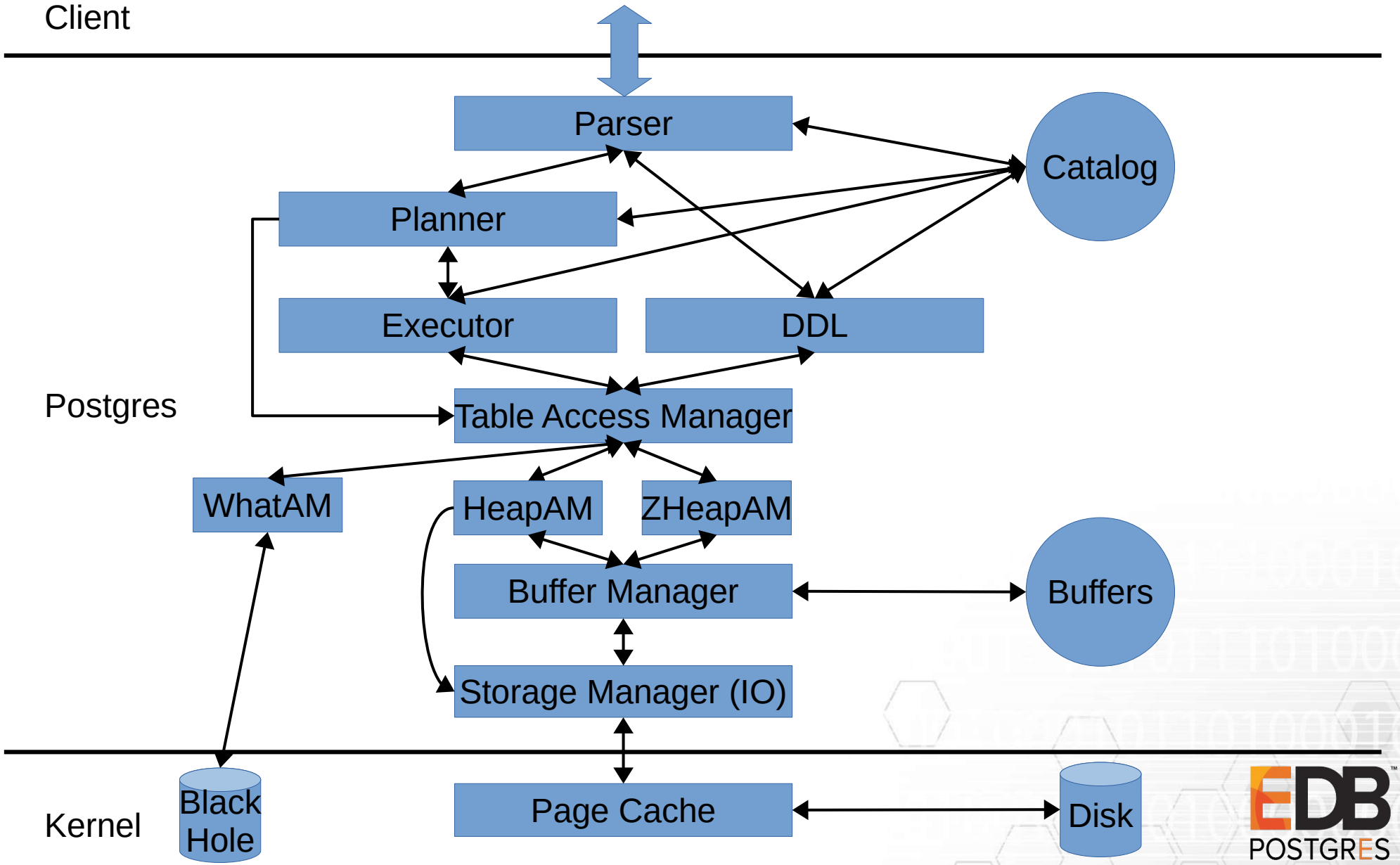

Client
Parser
Catalog
Planner
Executor
DDL
Postgres
Table Access Manager
WhatAM
HeapAM
ZHeapAM
Buffer Manager
Buffers
Storage Manager (IO)
Black Hole
Page Cache
Disk
Kernel

Table AM Handlers

```
postgres[28850][1]=# SELECT * FROM pg_am WHERE amtype = 't';
```

amname	amhandler	amtype
heap	heap_tableam_handler	t

(1 row)

```
postgres[28850][1]=# \df heap_tableam_handler
                                  List of functions
```

Schema	Name	Result data type	Argument data types	Type
pg_catalog	heap_tableam_handler	table_am_handler	internal	func

(1 row)

Table AM Handlers

```
Datum
heap_tableam_handler(PG_FUNCTION_ARGS)
{
    PG_RETURN_POINTER(&heapam_methods);
}

static const TableAmRoutine heapam_methods = {
    .type = T_TableAmRoutine,

    .slot_callbacks = heapam_slot_callbacks,
…
};
```

Table AM API – DML & DDL

```
/
 * API struct for a table AM.  Note this must be allocated in a
 * server-lifetime manner, typically as a static const struct, which then gets
 * returned by FormData_pg_am.amhandler.
…
typedef struct TableAmRoutine
{
…
    void    (*tuple_insert) (Relation rel, TupleTableSlot *slot,
                             CommandId cid, int options,
                             struct BulkInsertStateData *bistate);
…
    void    (*relation_set_new_filenode) (Relation rel,
                                          const RelFileNode *newrnode,
                                          char persistence,
                                          TransactionId *freezeXid,
                                          MultiXactId *minmulti);
    void    (*relation_vacuum) (Relation onerel,
                                struct VacuumParams *params,
                                BufferAccessStrategy bstrategy);
…
    double  (*index_build_range_scan) (…);
…
}           TableAmRoutine;
```

Table AM API – Scans

```
typedef struct TableAmRoutine
{
…
    TableScanDesc (*scan_begin) (Relation rel,
                                 Snapshot snapshot,
                                 int nkeys, struct ScanKeyData *key,
                                 ParallelTableScanDesc pscan,
                                 uint32 flags);
…
    bool    (*scan_getnextslot) (TableScanDesc scan,
                                 ScanDirection direction,
                                 TupleTableSlot *slot);
…
    bool    (*scan_bitmap_next_block) (TableScanDesc scan,
                                       struct TBMIterateResult *tbmres);
    bool    (*scan_bitmap_next_tuple) (TableScanDesc scan,
                                       struct TBMIterateResult *tbmres,
                                       TupleTableSlot *slot);
…
} TableAmRoutine;
```

EDB POSTGRES

Infrastructure Changes

- Remove WITH OIDs support
- Generalize tuple slots
  - different types of tuples have different storage requirements
  - lots of rote changes
  - More complex slot changes:
    - Triggers
    - EvalPlanQual
    - Fix discrepancies between “declared” type of slot, and actually returned slot types
    - COPY
- Non-trivial changes to route things through tableam:
  - Executor:
    - Bitmap Scan
    - Sample Scan
  - DDL
    - ALTER TABLE SET TABLESPACE
    - ANALYZE
    - CLUSTER / VACUUM FULL
    - VACUUM
- Other changes
  - error checks in extensions like pageinspect

Limit: WAL Logging

- introducing new WAL record types not possible without patching core code
- `access/generic_xlog.h` isn't fast / small / capable enough
- need proper extensible WAL
  - dynamic registry problem repeatedly debated, not easy
  - static registry in core?

Limit: TID Format

```
typedef struct ItemPointerData
{
    BlockIdData ip_blkid;  // 4 bytes
    OffsetNumber ip_posid; // 2 bytes
}
```

- limits table size
- limits type of storage (no index organized table)
- What's needed to fix:
  - Invent smart variable width encoding
  - Have space for wider TIDs in indexes
    - also helps global indexes and indirect indexes
  - Change lots of functions to accept variable width functions

Limit: Missing API conversions

- toast (lots of code duplication necessary)
- predicate locking (duplication)
- Index only & bitmap scan nodes access visibilitymap (fsm needs to have compatible addressing)
- pg_relation_size() looks at filesystem, rather than go through AM (usability)
- triggers (unnecessary conversions to/from HeapTuple)
- too many heap_ functions, that aren't accurately named anymore (but really weren't before either)
- some ambiguity in header file names
- …

Limit: Planner / Executor Integration

- Improvements particularly needed for efficiency for some storage types (columnar)
  - can partially be addressed via planner hooks + custom executor nodes
- Scans need to know the to-be-accessed columns
  - very important for columnar, but even interesting for heap
  - should be integrated with both AM and various slot types
- Costing improvements for individual AMs
  - can partially be “addressed” by skewing returned planner estimates

Limit: Relation Filenodes & Relation Forks

- relation forks not necessarily a good idea / set of forks not enough for all AMs
- only one relation fork for each pg_class entry
- to be integrated into base backups, files have to be in the traditional directories

Limit: Catalog on non-heap AM

- lots of rote code changes needed to not assume heap
- struct / table content mapping
- assumptions about precise transactional behavior (e.g. cache invalidation via xmin checks)

Limit: AMs assumed to be block based

- Planner cost estimates in blocks
- Analyze sampling is block based

Questions?

Email: andres@anarazel.de
Email: andres.freund@enterprisedb.com
Twitter: @AndresFreundTec
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