Pluggable Storage in PostgreSQL

Andres Freund

PostgreSQL Developer & Committer

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

anarazel.de/talks/2019-02-11-bangalore-edb-office-pluggable/pluggable.pdf

Pluggable Storage

CREATE TABLE …(...) USING heap;

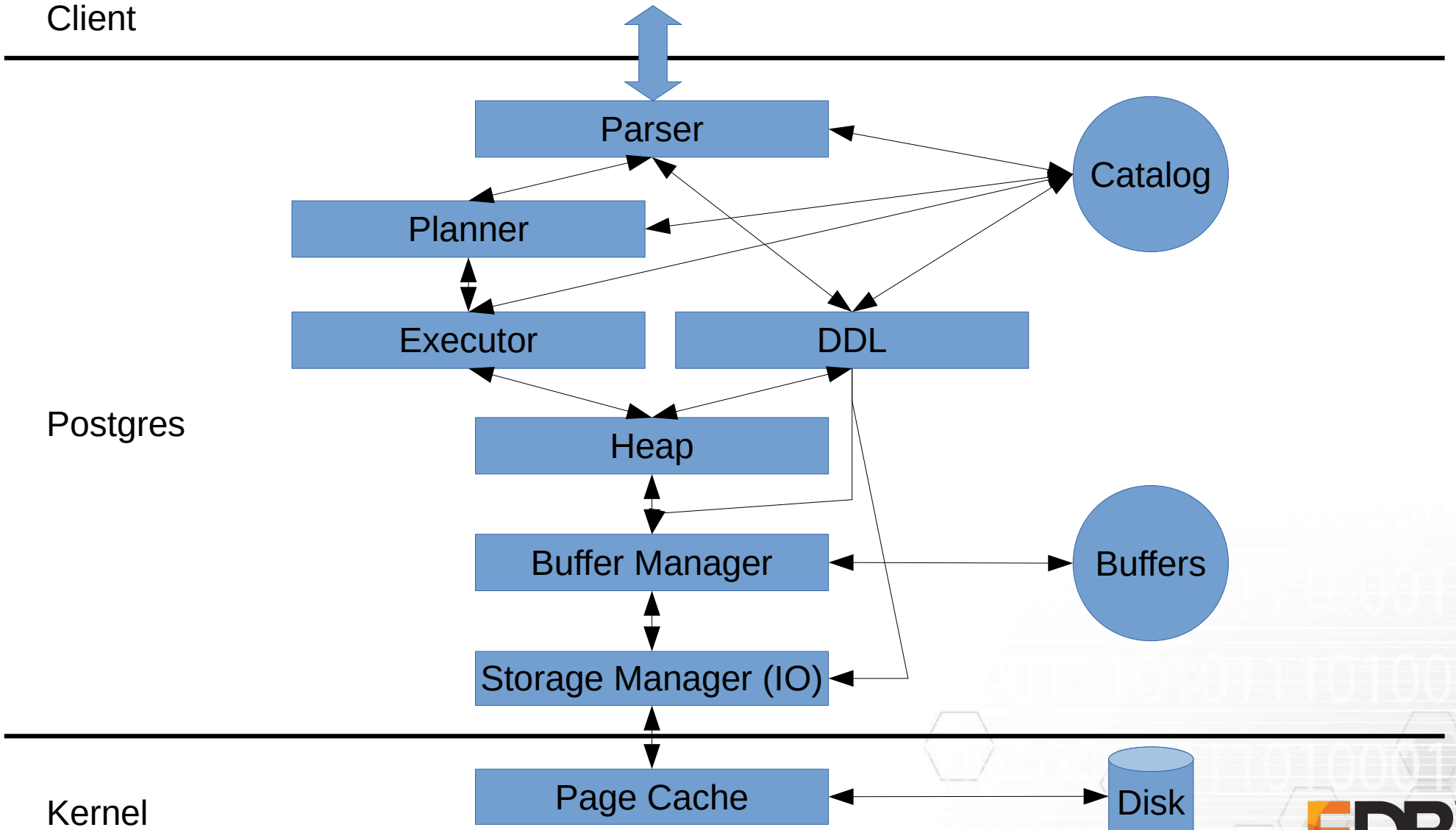
Work by:

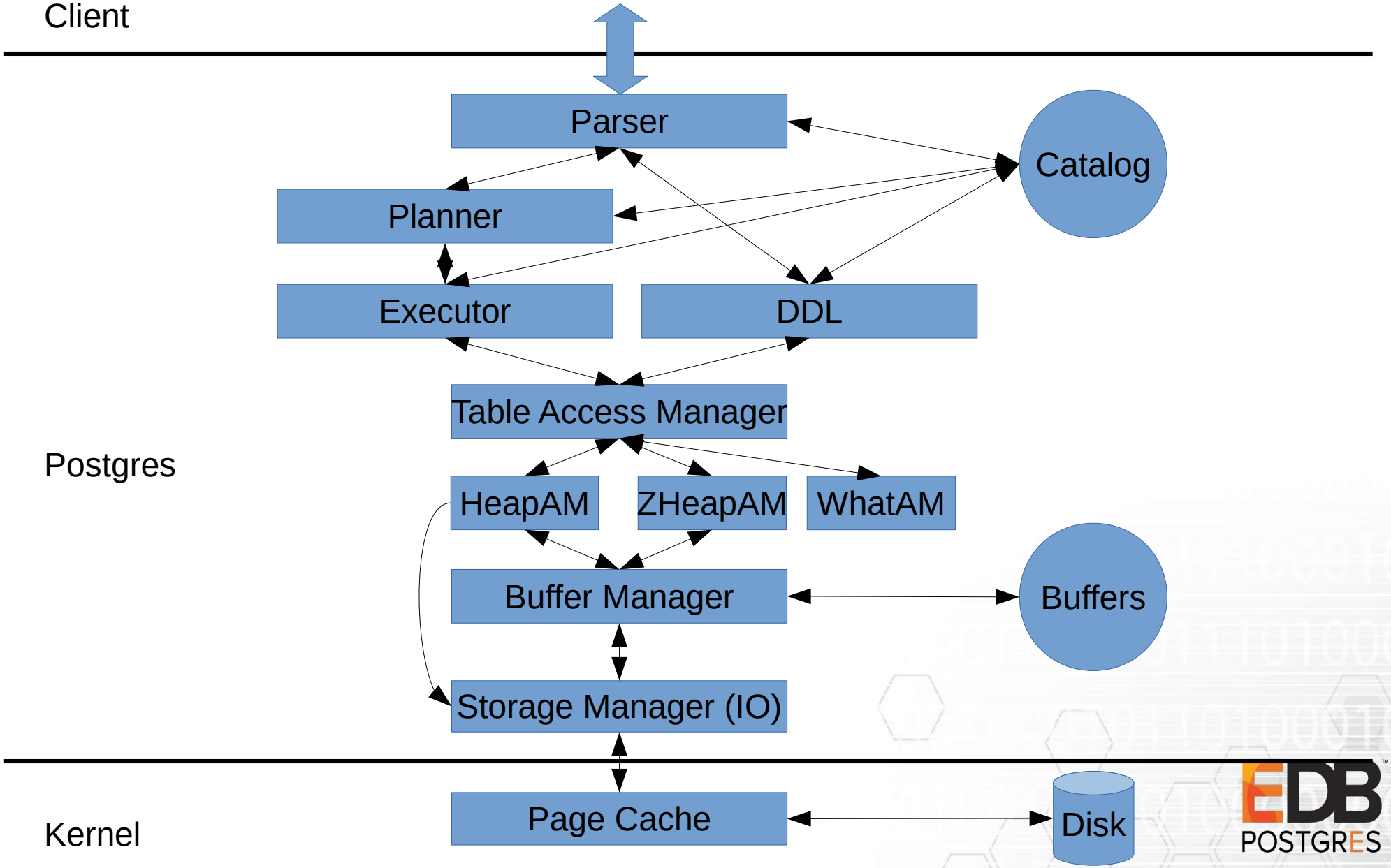
- Haribabu Kommi
- Alvaro Herrera
- Alexander Korotkov
- Ashutosh Bapat
- Amit Khandekar

EDB POSTGRES

What do you mean: storage

- Contents of a `TABLE / MATERIALIZED VIEW`
- **NOT** contents of indexes
- Not purely a change of IO layer
- => Code name: ‘tableam’ - table access method


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


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

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?

- ZHeap – UNDO based storage, address bloat and write amplification problems
- Columnar Storage
- Experiments

Why not?

- Proliferation of half-baked storage engines, rather than one good one
- Proliferation of closed & commercial storage engines
- Architectural impact

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: non-heap catalog tables
- NOT: Fully extensible WAL logging
- 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
- DDL not really supported
- Local indexes not supported
- Foreign Keys not supported (and it doesn’t really make sense to support)
- Different goals, but some overlap exists

TupleTableSlots

- historic name, “Tuple Holder” more accurate
- Holds various forms of tuples, makes accesses to columns cheap(er)
- Made extensible:

```
typedef struct TupleTableSlotOps
{
    size_t       base_slot_size;
    void         (*init)(TupleTableSlot *slot);
    void         (*getsomeattrs)(TupleTableSlot *slot, int natts);
    HeapTuple    (*copy_heap_tuple)(TupleTableSlot *slot);
…
}
struct TupleTableSlot
{
    NodeTag      type;
    uint16       tts_flags;
    AttrNumber   tts_nvalid;
    const TupleTableSlotOps *const tts_cb;
    Datum       *tts_values;       /* current per-attribute values */
    bool        *tts_isnull;       /* current per-attribute isnull flags */
}
```

EDB POSTGRES

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,
…
};
```

TupleTableSlots #2

```
extern PGDLLIMPORT const TupleTableSlotOps TTSOpsVirtual;
extern PGDLLIMPORT const TupleTableSlotOps TTSOpsHeapTuple;
extern PGDLLIMPORT const TupleTableSlotOps TTSOpsMinimalTuple;
extern PGDLLIMPORT const TupleTableSlotOps TTSOpsBufferTuple;
...
extern TupleTableSlot *MakeTupleTableSlot(TupleDesc tupleDesc,
                    const TupleTableSlotOps *tts_ops);
extern TupleTableSlot *ExecAllocTableSlot(List **tupleTable, TupleDesc desc,
                    const TupleTableSlotOps *tts_ops);
extern TupleTableSlot *MakeSingleTupleTableSlot(TupleDesc tupdesc,
                          const TupleTableSlotOps *tts_ops);
...
```

Table AM API – DML & DDL

```
/*
 * API struct for a table AM.  Note instances of this this must be
 * allocated in a server-lifetime manner, typically as a static const struct.
 */
typedef struct TableAmRoutine
{
…
    void    (*tuple_insert) (Relation rel, TupleTableSlot *slot, CommandId cid,
                             int options, struct BulkInsertStateData *bistate);
…
    void    (*relation_set_new_filenode) (Relation rel, char persistence,
                                          TransactionId *freezeXid,
                                          MultiXactId *minmulti);
    void    (*relation_vacuum) (Relation onerel, int options,
                                struct VacuumParams *params, ...);
…
    double      (*index_build_range_scan) (Relation heap_rel, ...);

…
}           TableAmRoutine;
```

Table AM API – Scans

```
typedef struct TableAmRoutine
{
…
    TableScanDesc (*scan_begin) (Relation rel, Snapshot snapshot,
                                 int nkeys, struct ScanKeyData *key,
                                 ParallelTableScanDesc parallel_scan,...);
    TupleTableSlot *(*scan_getnextslot) (TableScanDesc scan,
                                         ScanDirection direction, TupleTableSlot *slot);
…
    bool    (*scan_bitmap_pagescan) (TableScanDesc scan,
                                     TBMIterateResult *tbmres);
    bool    (*scan_bitmap_pagescan_next) (TableScanDesc scan,
                                          TupleTableSlot *slot);

} TableAmRoutine;
```

Infrastructure Changes

- Lots of rote changes to using slots & new scan APIs
  - DDL
  - Many executor nodes
- More complex slot changes:
  - Triggers
  - EvalPlanQual
  - Fix discrepancies between “declared” type of slot, and actually returned slot types
  - Analyze
  - COPY
- More complex executor changes:
  - Bitmap Scan
  - Sample Scan
- Other changes
  - error checks in extensions like pageinspect

Problems

- Indexes only have space for 6byte tuple-identifier
  - good enough for now, probably needs to be generalized
- Planner / Executor improvements needed for efficiency for some storage types (columnar)
  - can be addressed via planner hooks + custom executor nodes
- Unnecessary conversions to/from HeapTuple
  - mainly when calling external triggers, but also MinimalTuple conversion slightly slower
- WAL logging not as extensible as desirable