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FDWs – how to use and write
Tutorial @ PGCon 2016

postgres_fdw demo

Create Server options

- All libpq connection options except
  - User, password – user mapping options
  - client_encoding – set to local server's encoding
- Some relevant options
  - host/hostaddr: name/location of foreign server
  - port: port number
  - dbname: database name to connect to
  - sslmode and other SSL related options

Create server options

- Planner cost options
  - fdw_startup_cost: represents the cost of establishing connection, parsing and planning query
  - fdw_tuple_cost: represents the cost of transferring data per tuple
  - use_remote_estimate: use EXPLAIN to get the cost of executing query on the foreign server
- fetch_size: number of tuples to get in each fetch operation
- extensions: list of matching extensions available on the foreign server

Create user mapping options

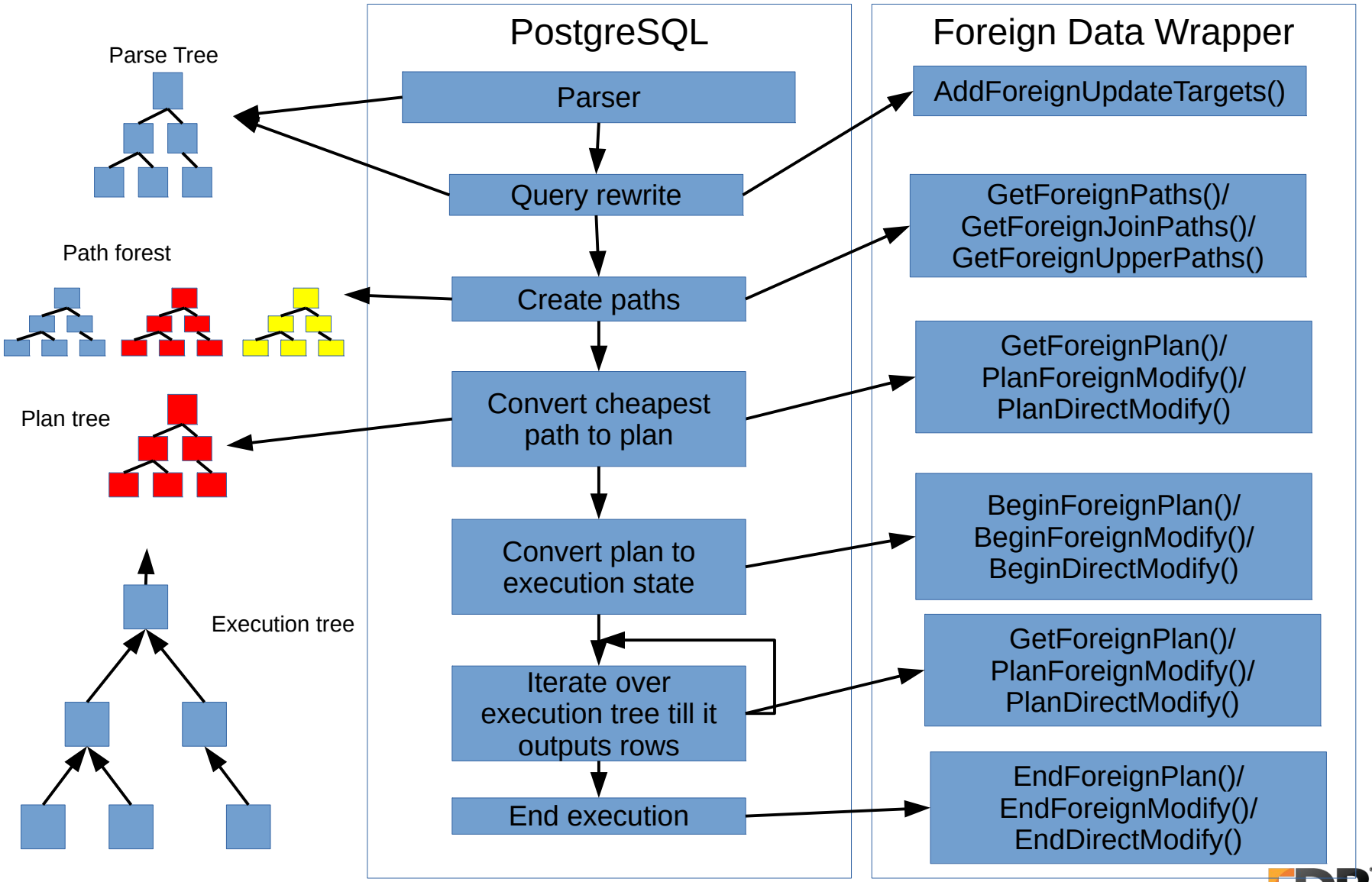
- user: foreign server user name to connect as
- password: password to be used for the user

Create foreign table options

- schema_name: schema on the foreign server in which foreign table is located
- table_name: name of the table on the foreign server
- column_name: name of the column on the foreign server
- use_remote_estimate, fetch_size: similar to the foreign server

Query processing in PostgreSQL

FDW and query execution



Node

- Basic block of any tree structure in PostgreSQL
- Broad types
  - Parse nodes – appear in parse trees
  - Expression nodes – appear everywhere to represent various expressions
  - Plan nodes – appear in plan tree
  - Execution state nodes – appear in execution tree, hold the current execution state of node

Path and path cost

- Each operation in a query can be realized in multiple ways
  - Joins: hash, merge, nested loop
- Each method is represented as a path
- Path
  - A light-weight plan
  - Estimated cost of path models execution time
  - Startup cost: cost expended before fetching any tuples
  - Total cost: startup cost + cost for fetching all tuples

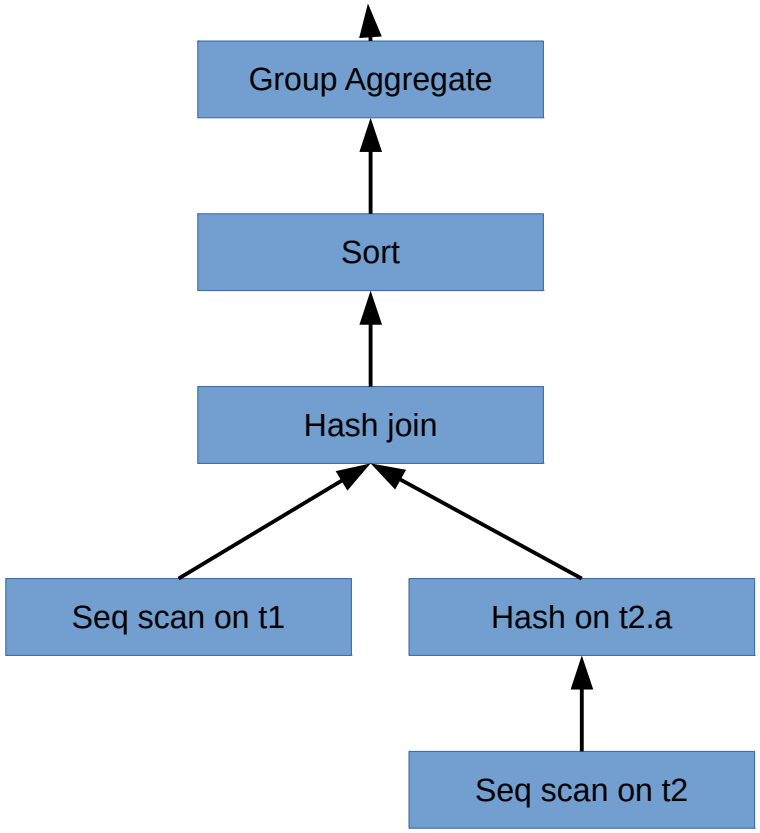
Relations: unit of query result

- Query: ordered set of (SQL) operations
- Relation: result of each operation
  - Result of scanning a table
  - Result of joins, grouping, limit etc.
- RelOptInfo
  - Represents results of various operations in query
  - Represents result of a node in plan/execution tree.
  - Holds all the paths for realizing that result
  - fdw_private member for FDW specific information
    - E.g. file_fdw stores path of file on the disk

Example

explain verbose select count(*), t1.a from t1, t2 where t1.a = t2.a group by t1.a, t1.b + t2.b order by t1.b + t2.b;

```
QUERY PLAN
------------------------------------------------------------------------------
----------
 GroupAggregate  (cost=45.13..46.66 rows=68
width=16)
   Output: count(*), t1.a, ((t1.b + t2.b))
   Group Key: ((t1.b + t2.b)), t1.a
   ->  Sort  (cost=45.13..45.30 rows=68 width=8)
         Output: t1.a, ((t1.b + t2.b))
         Sort Key: ((t1.b + t2.b)), t1.a
         ->  Hash Join  (cost=1.14..43.06 rows=68 width=8)
               Output: t1.a, (t1.b + t2.b)
               Hash Cond: (t1.a = t2.a)
               ->  Seq Scan on frgn_schema.t1
(cost=0.00..32.60 rows=2260 width=8)
                     Output: t1.a, t1.b
               ->  Hash  (cost=1.06..1.06 rows=6 width=8)
                     Output: t2.b, t2.a
                     ->  Seq Scan on frgn_schema.t2
(cost=0.00..1.06 rows=6 width=8)
                           Output: t2.b, t2.a
```



Writing a foreign data wrapper

blackhole_fdw – a great way to start

- Accepts everything and returns nothing
- Skeleton template for writing a new FDW
- Available at https://bitbucket.org/adunstan/blackhole_fdw/src
- Heavily annotated code
  - Author doesn't need to refer to documentation
  - Ready to use extension files

FDW handler and validator

- Handler function
  - Returns a structure of function pointers
  - Function pointers implement FDW APIs
- Validator function
  - Validates options given to CREATE/ALTER commands
  - Input: array of options with values, type of object (server, table, user mapping)
  - Returns nothing, should throw error on encountering an invalid option

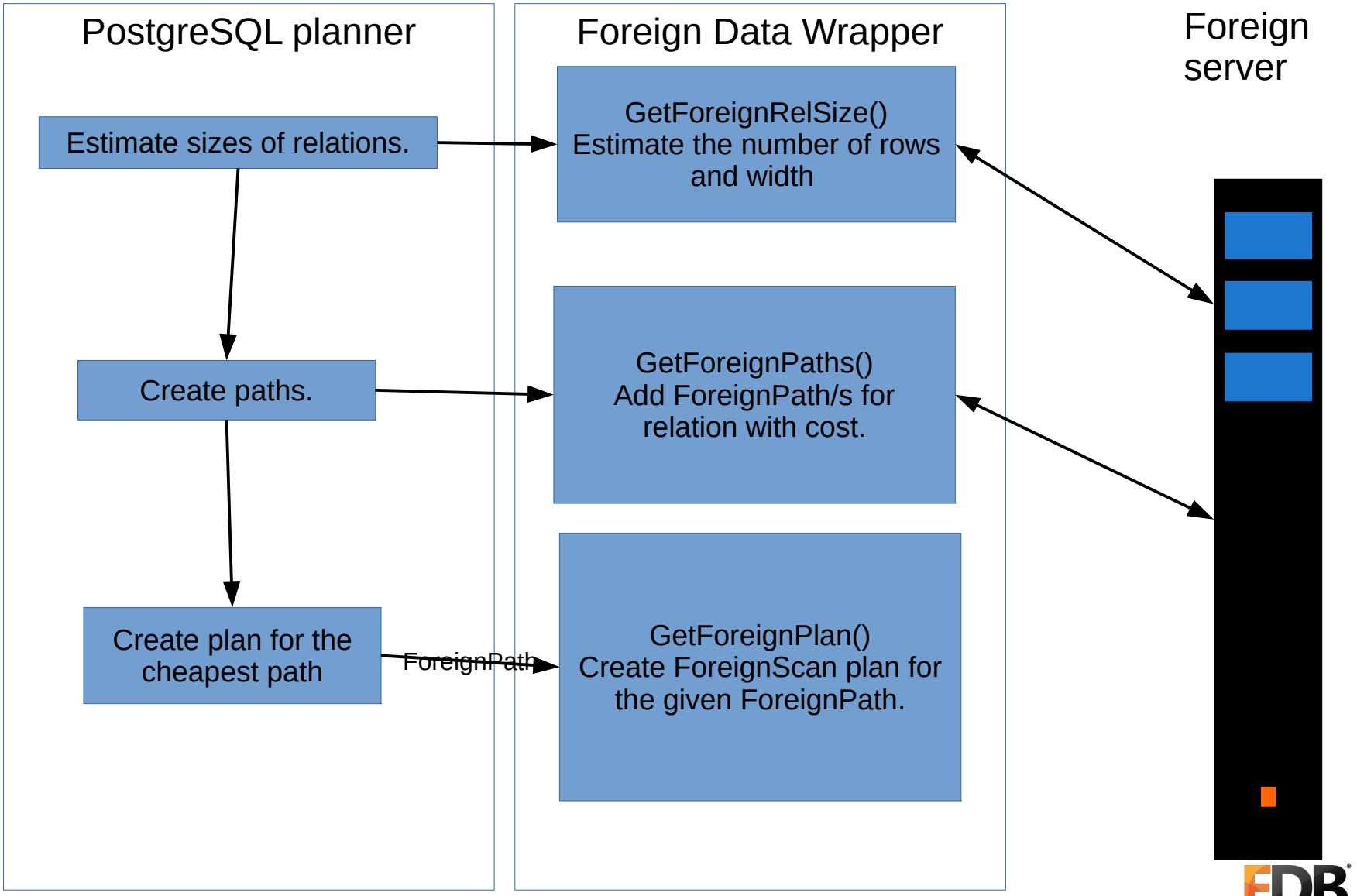
Pushing down operations

- FDWs aim at delegating or pushing down operations to the foreign server
- What can be pushed down (as of 9.6)
  - Expressions in SELECT clause
  - Conditions in WHERE, ON, HAVING clauses
  - Joins
  - Sorting
  - aggregates, grouping
  - Limit

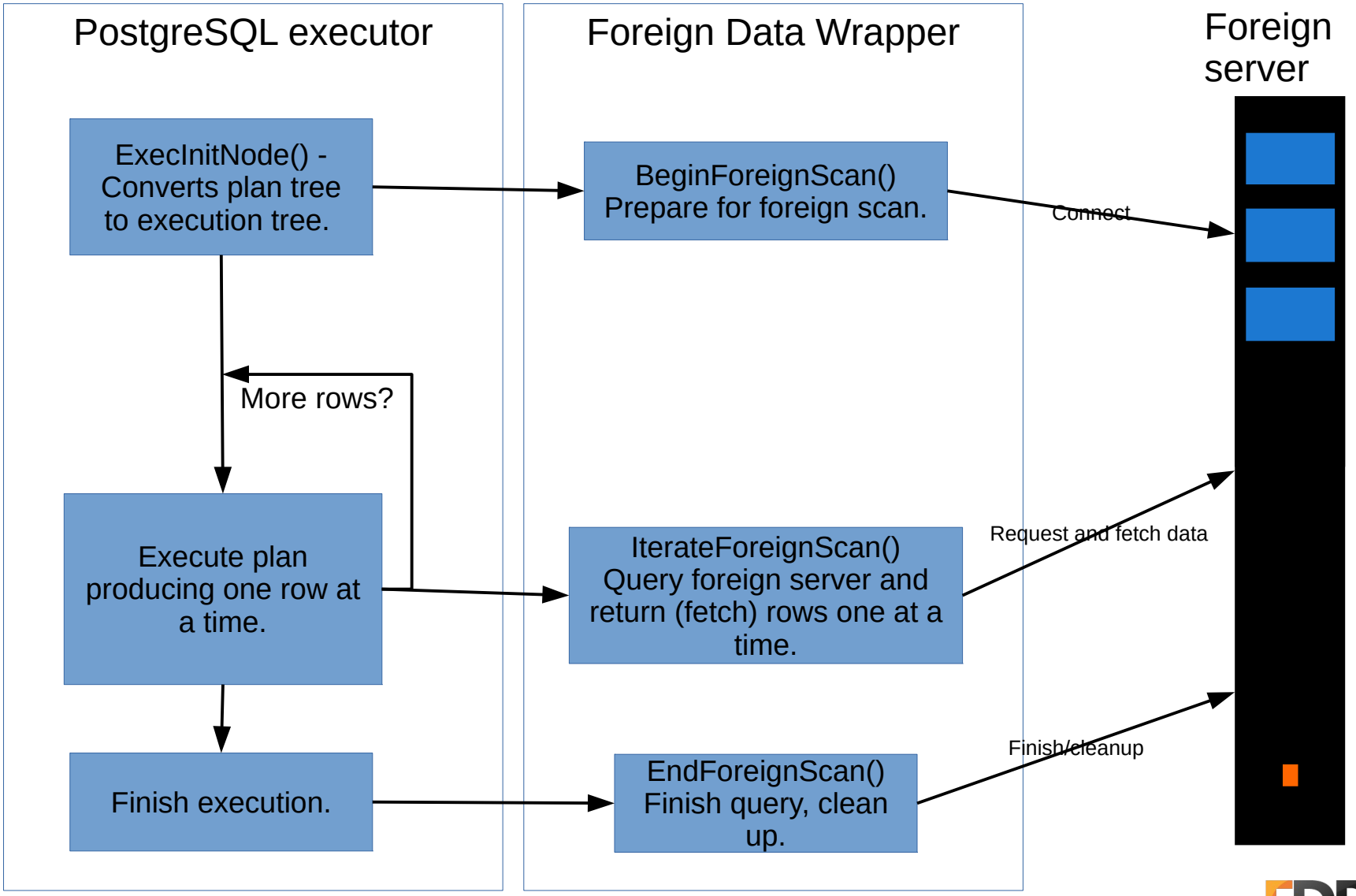
Push-down consideration

- Push-down safety
  - Can foreign server evaluate a construct?
    - Joins may not be evaluated by file_fdw
  - Evaluating construct on the foreign server should produce same result as local server
    - now(): unsafe
    - arithmetic, logical operations on integers: safe
- Pushdown efficiency
  - Is evaluation at foreign server going to improve performance?

Writing simple table scanner: planning



Writing simple table scanner: execution



Writing simple table scanner

- GetForeignPaths()
  - Calculate the cost of scanning the relation
  - Startup cost: cost for connecting to foreign server, querying etc.
  - Total cost: cost of fetching all the tuples from the foreign server
  - Create path using create_foreignscan_path()
  - Store the path using add_path()

Writing simple table scanner

- GetForeignPlan()
  - Inputs: previously created path, targetlist, restriction clauses etc.
  - Segregate the restriction clauses, target list entries into shippable, non-shippable items
  - Construct query/code to fetch the required data from the foreign server
  - Create ForeignScan node using make_foreignscan().

file_fdw executor using COPY protocol

- fileBeginForeignScan()
  - Calls BeginCopyFrom() with filename and foreign table options
  - Opens file, reads header if any
  - Sets up data type input functions
- fileEndForeignScan()
  - Calls EndCopyFrom()
  - Closes file
- fileRescanForeignScan()
  - EndCopyFrom(); BeginCopyFrom()

file_fdw: per row data conversion

- fileIterateForeignScan()
  - Calls NextCopyFrom()
  - Reads next record from file
  - Separates data column-wise using deliminator
  - For every column, converts input data to PostgreSQL data format using data type input functions
    - e.g. date_in() for text or date_receive() for binary

mongo_fdw in nutshell

```
CREATE FOREIGN TABLE warehouse(
        _id NAME,
        warehouse_id int,
         warehouse_name text,
        warehouse_created timestamptz))
SERVER mongo_server
        OPTIONS (database 'db', collection 'warehouse');

SELECT * FROM warehouse WHERE warehouse_id = 1;
```

Mongodb query: db.warehouse.find({"warehouse_id" : 1})

```
db.warehouse.find({"warehouse_id" : 1}).pretty()
{
    "_id" : ObjectId("53720b1904864dc1f5a571a0"),
    "warehouse_id" : 1,
    "warehouse_name" : "UPS",
    "warehouse_created" : ISODate("2014-12-12T07:12:10Z")
}
```

```
           _id           | warehouse_id | warehouse_name |     warehouse_created
-------------------------+--------------+----------------+---------------------------
53720b1904864dc1f5a571a0|            1 | UPS            | 12-DEC-14 12:12:10 +05:00
```

mongo_fdw: scanning a simple table

- MongoBeginForeignScan
  - Open connection to mongodb - MongoConnect()
  - Create mongo cursor – MongoCursorCreate()
- MongoRescanForeignScan
  - Close running cursor: MongoCursorDestroy()
  - Reopen it – MongoCursorCreate()
- MongoEndForeignScan
  - Close running cursor: MongoCursorDestroy().

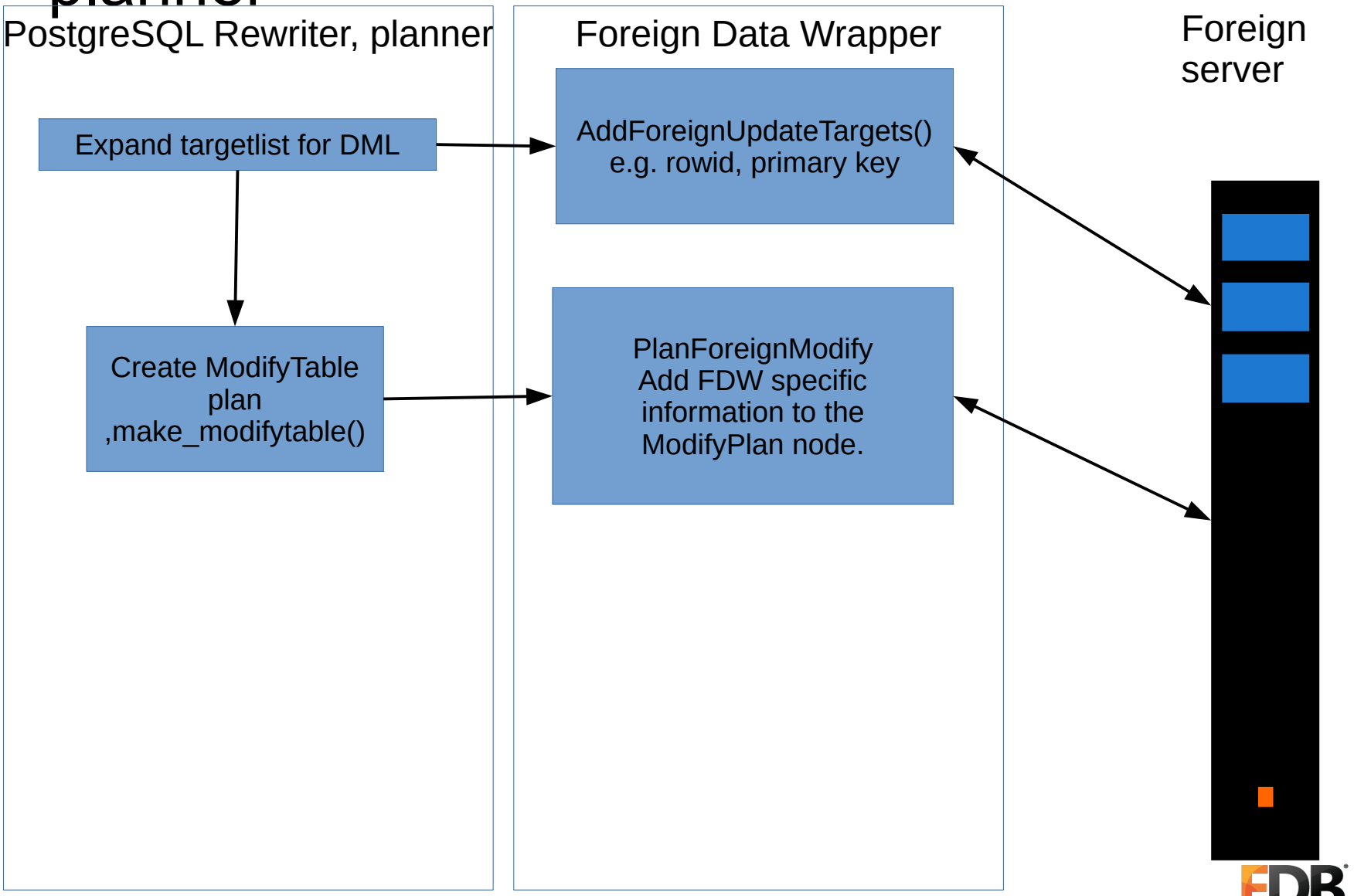
mongo_fdw: scanning a simple table

- MongoIterateForeignScan
  - Fetch next record – MongoCursorNext()
  - Fetch columns from record by iterating over the contents of record using MongoCursorBson(), BsonIterInit(), BsonIterNext().
  - Fetch column value using BsonIter<Type>
    - e.g. BsonIterInt(), BsonIterDouble(),
  - Convert to PostgreSQL using <Type>GetDatum() calls
    - e.g. Int32GetDatum(), Float4GetDatum()

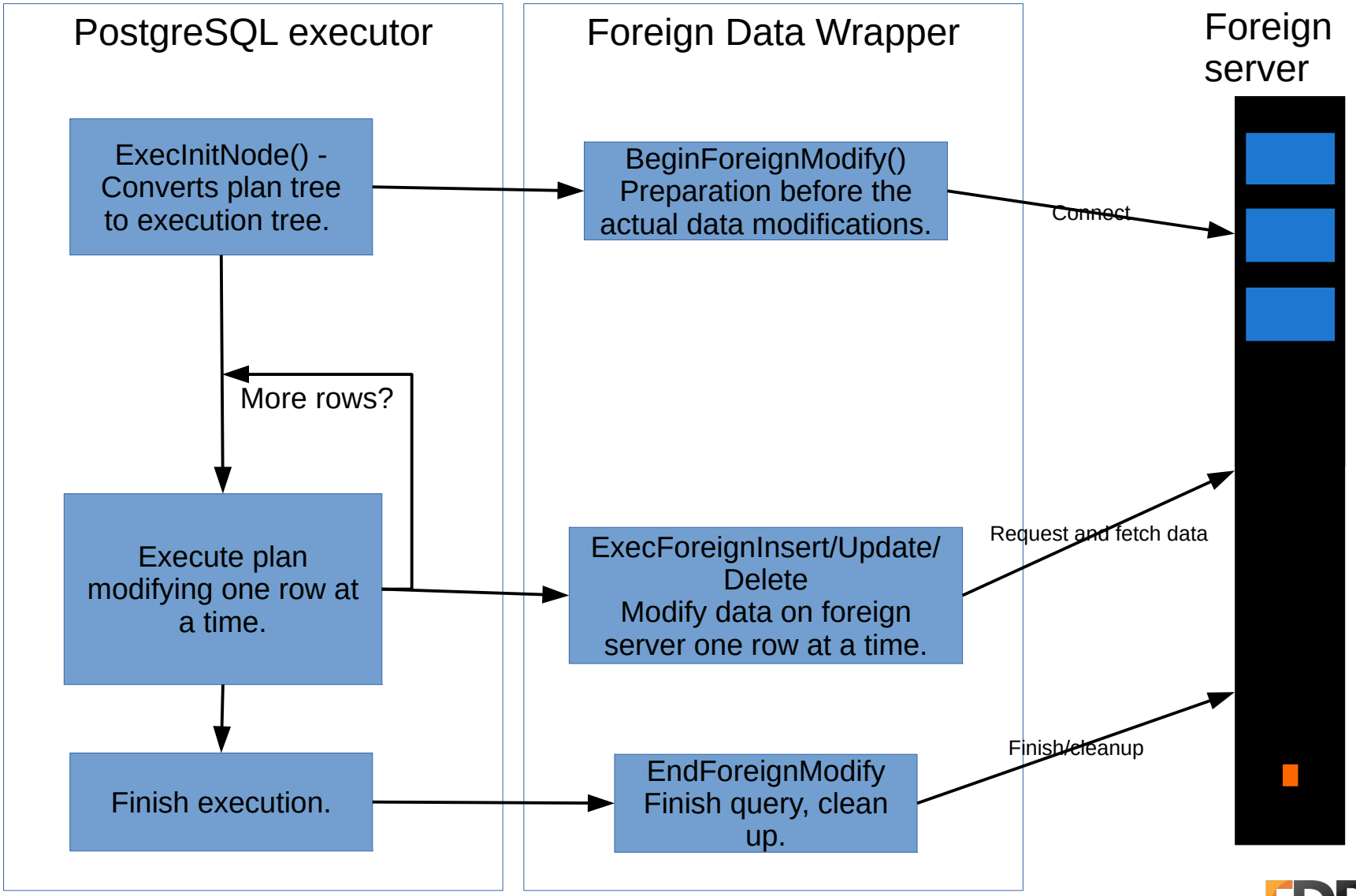
Join and post-join operation pushdown

- Use GetForeignJoinPaths() hook to add ForeignPaths for join between two foreign relations
  - Assess pushdown safety of join
- Use GetForeignUpperPaths() hook to add ForeignPaths for operations like grouping, aggregation, sort, limit etc.
- In GetForeignPlan() create a fdw_scan_tlist representing the result of join from the foreign server.

Modifying a foreign table: rewriter and planner



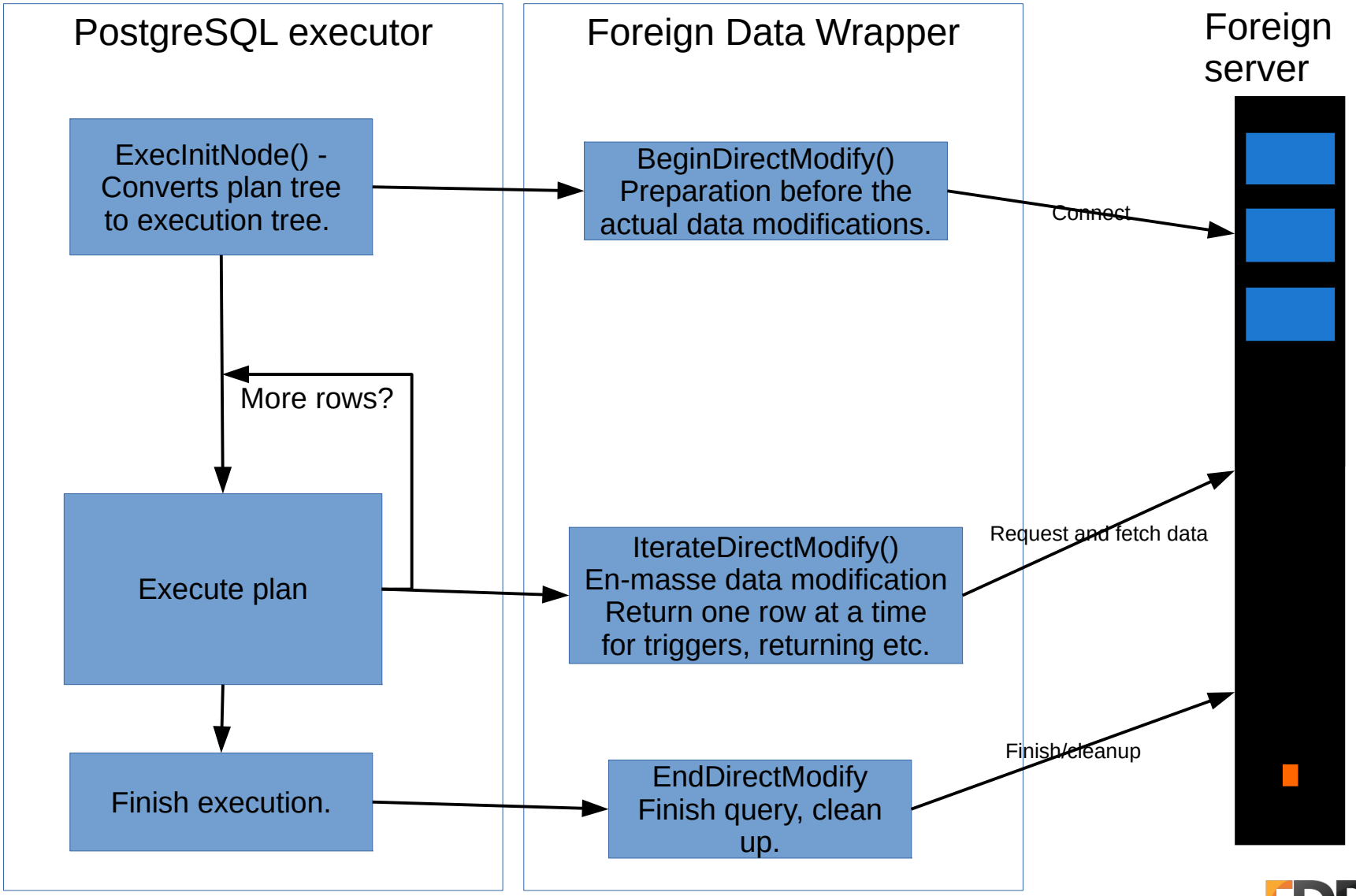
Modifying a foreign table: execution



Direct modification: planner

- PlanDirectModify()
  - Assess whether the DML is safe to be executed on the foreign server
  - Construct the query/code to execute the DML on the foreign server
  - Add ForeignScan plan as subplan to given ModifyTable plan

Direct Modification: execution



More APIs and further reading

- ExplainForeignScan, ExplainForeignModify
  - For adding FDW specific information in EXPLAIN output
- AnalyzeForeignTable
  - Scan foreign table to sample rows for collecting statistics
- ImportForeignSchema
  - Implementation hook for IMPORT FOREIGN SCHEMA command
- http://www.postgresql.org/docs/devel/static/fdwhandler.html

Multicorn

- Python based extension and FDW
- Makes it easy to write FDWs
- A “wrapper over wrapper”
- Good for quickies


THANK YOU
grazie
merci
spasiba
kam ouen
tak
gratzias
manana
mahalo
kitos
cheers
hvala
welalin
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