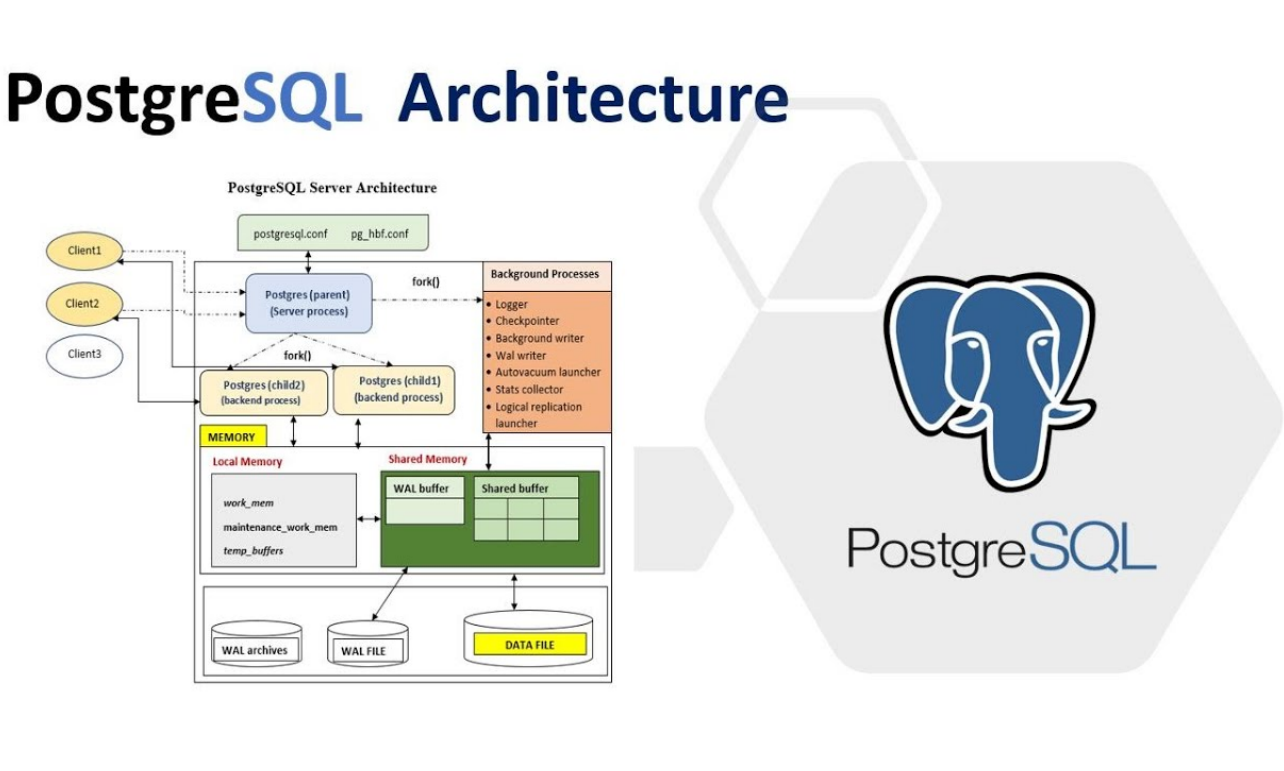
PostgreSQl Architectural fundametals



PostgreSQL operates on a `client-server` model.

- `A server process`, which manages the databse files, accepts connections to the database from the client applications, and performs database connections on behalf of the clients. the database server program is called `postgres`.
- The user's `client (frontend)` application that wants to perform database operations.
    - Custome Application (Written in language such as `Python, Java, C++ and Node`).
    - Web Framework (`Django, Rails, etc.`).
    - SQL tools like `psql`, GUI clients, or ORMs (Object Relational Mappers).

The `client` and the `server` can be on different `hosts`. In that case they communicate over a `TCP/IP` network connection.

The `PostgreSQL` server can handle multiple concurrent connections from clients. To achieve this it starts `(“forks”)` a new process for each connection.

- Client Application.
- PostgreSQL Client Library(`libpq`).
- PostgreSQL Server Process.
- PostgreSQL BackgroundProcesses.
- Shared Memory and Buffer Cache.
- Disk Storage.

`Client Application:`

These are the external applications that interact with the PostgreSQL server to perform optrations like `querying, inserting, updating and deleting data`.

- Custome Application (Written in language such as `Python, Java, C++ and Node`).
- Web Framework (`Django, Rails, etc.`).
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`PostgreSQL client library (libpq):`

This is the low-level `C library` that provide communication between `client application` and the `PostgreSQL server`.

`libpq` is responsible for handling the `client-server communication`, packaging SQL commands into messages and seding/receiving responses.

`libpq` manages the following:

- Establishes a connection to the PostgreSQL server.
- Sends SQL queries from the client application to the server.
- Receives and processes responses (query results, error messages, etc).
- Manages connection pooling (if needed).

`Shared Memory:`

Shared memory refers to the memory reserved for the `database caching` and `transaction log caching`.

The most important elements in shared memory are

- Shared Buffer
- WAL buffers

`Shared Buffers:`

The purpose of `Shared Buffer` is to minimize `DISK IO`.

- You need to access very large (tens, hundreds of gigabytes) buffers quickly.
- You should minimize contention when many users access it at the same time.
- Frequently used blocks must be in the buffer for as long as possible.

Shared buffers play a crucial role i the performance and efficiency of PostgreSQL. The shared buffer cache is a portion of memory allocated by PostgreSQL to cache blocks of data read from the disk. This caching is esseential for sevaral reasons:

- Reduce Disk I/O.
- Improve Performance.
- Support for Concurrent Access.
- Data Consistency and Integrity.
- Efficient Use of System Resources.

`WAL Buffer:`

The `WAL buffer` is a buffer that temporarily stores changes to the database. the contents stored in the `WAL buffer` are written to the `WAL file` at a predetermined point in time. From a backup and recovery point of view, WAL buffers and WAL files are very important.

`PostgreSQL Process Types:`

PostgreSQL has four process types:

- Postmaster (Daemon) process.
- Background process.
- Backend process.
- Client process.

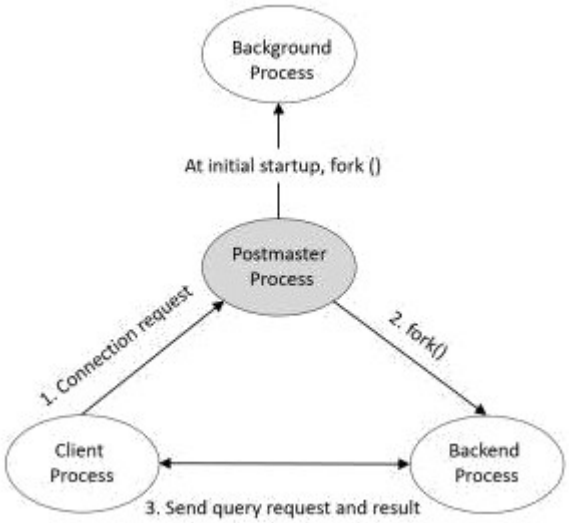
`Postmaster Process (Main Server Process):`

Also known as `database server process` is the central process that starts when `PostgreSQL` is launched. It listens for incoming client connection on a specific IP address or Unix socket. this is the entry point for all client connections.

- The postmaster will listen on a TCP/IP socket or a Unix domain socket (if the connection is local).
- When a client connects, the postmaster spawns a new backend process to handle the request. The postmaster itself doesn't execute SQL queries directly but manages connections, authentication, and spawning of worker processes.
- The `Postmaster` process is the first process started when you start `PostgreSQL`. At startup, performs `recovery`, initialize `shared memory`, and run `background processes`.

  It also creates a `backend process` when there is a connection request from the `client process`.

  - It listens for incomming connection



`Background Process:`

The list of background processes required for PostgreSQL operation are.

Process	Role

Process	Role
logger	Write the error message to the log file
checkpointer	When a checkpoint occurs, the dirty buffer is written to the file
writer	Periodically writes the dirty buffer to a file
wal writer	Write the WAL buffer to the WAL file
Autovacuum launcher	Fork autovacuum worker when autovacuum is enabled. It is the responsibility of the autovacuum daemon to carry vacuum operations on loated tables on demand.
archiver	When in Archive.log mode, copy the WAL file to the specified directory.
stats collector	DBMS usage statistics such as session execution information (pg_stat_activity) and table usage statistical information (pg_stat_all_tables) are collected.

Performance Metrics and Benchmarks:

`Maximum database size`: PostgreSQL can handle extremely large databases. The theoretical maximum database size is `32 TB` per database (with 64 bit systems), but practical limits are usually constrained by available hardware and storage.

- Maximum table size: 32 TB per table.
- Maximum row size: 1.6 TB per row.
- Maximum index size: 32 TB per index.
- Maximum number of columns per table: 1,600 columns.
- Maximum number of tables per schema: 4 billion tables (limited by OIDs, which are 32-bit identifiers).