Mastering PostgreSQL Administration

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PostgreSQL is an open-source, full-featured relational database. This presentation covers advanced administration topics.

https://momjian.us/presentations

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Outline

1. Installation
2. Configuration
3. Maintenance
4. Monitoring
5. Recovery

1. Installation

- Click-through Installers
  - MS Windows
  - OS X
- Ports
  - RPM
  - DEB
  - PKG
  - other packages
- Source
  - obtaining
  - build options
  - installing

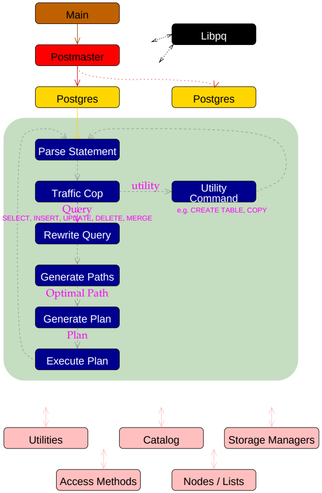
Initialization (initdb)

```
$ initdb /u/pgsql/data
The files belonging to this database system will be owned by user "postgres".
This user must also own the server process.

The database cluster will be initialized with locale "en_US.UTF-8".
The default database encoding has accordingly been set to "UTF8".
The default text search configuration will be set to "english".

Data page checksums are disabled.

fixing permissions on existing directory /u/pgsql/data ... ok
creating subdirectories ... ok
selecting default max_connections ... 100
selecting default shared_buffers ... 128MB
selecting dynamic shared memory implementation ... posix
creating configuration files ... ok
running bootstrap script ... ok
performing post-bootstrap initialization ... ok
syncing data to disk ... ok

WARNING: enabling "trust" authentication for local connections
You can change this by editing pg_hba.conf or using the option -A, or
--auth-local and --auth-host, the next time you run initdb.

Success. You can now start the database server using:

   pg_ctl -D /u/pgsql/data -l logfile start
```

pg_controldata

```
$ pg_controldata
pg_control version number:            1002
Catalog version number:               201707211
Database system identifier:           6544633619067825437
Database cluster state:               shut down
pg_control last modified:             Sun 15 Apr 2018 07:20:58 AM EDT
Latest checkpoint location:           0/15C09E0
Prior checkpoint location:            0/15C0708
Latest checkpoint's REDO location:    0/15C09E0
Latest checkpoint's REDO WAL file:    000000010000000000000001
Latest checkpoint's TimeLineID:       1
Latest checkpoint's PrevTimeLineID:   1
Latest checkpoint's full_page_writes: on
Latest checkpoint's NextXID:          0:555
Latest checkpoint's NextOID:          12296
Latest checkpoint's NextMultiXactId:  1
Latest checkpoint's NextMultiOffset:  0
Latest checkpoint's oldestXID:        548
Latest checkpoint's oldestXID's DB:   1
Latest checkpoint's oldestActiveXID:  0
Latest checkpoint's oldestMultiXid:   1
Latest checkpoint's oldestMulti's DB: 1
Latest checkpoint's oldestCommitTsXid:0
Latest checkpoint's newestCommitTsXid:0
Time of latest checkpoint:            Sun 15 Apr 2018 07:20:58 AM EDT
Fake LSN counter for unlogged rels:   0/1
Minimum recovery ending location:     0/0
Min recovery ending loc's timeline:   0
Backup start location:                0/0
Backup end location:                  0/0
…
```

System Architecture



Main

Libpq

Postmaster

Postgres

Postgres

Parse Statement

Traffic Cop

utility

Utility Command

e.g. CREATE TABLE, COPY

Query

SELECT, INSERT, UPDATE, DELETE, MERGE

Rewrite Query

Generate Paths

Optimal Path

Generate Plan

Plan

Execute Plan

Utilities

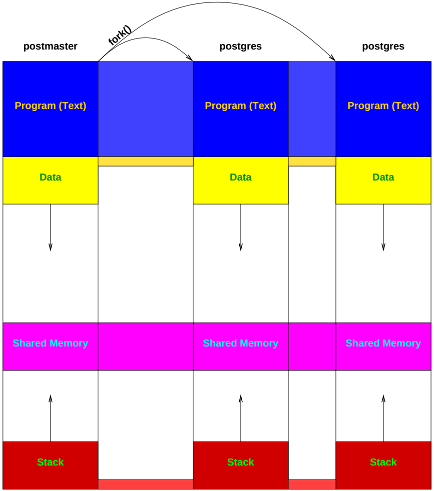
Catalog

Storage Managers

Access Methods

Nodes / Lists

Session Creation



Starting Postmaster

```
2018-04-15 07:23:18.172 EDT [12055] LOG:  listening on IPv4 address "127.0.0.1", port 5432
2018-04-15 07:23:18.173 EDT [12055] LOG:  listening on Unix socket "/tmp/.s.PGSQL.5432"
2018-04-15 07:23:18.185 EDT [12056] LOG:  database system was shut down at 2018-04-15 07:22:54 EDT
2018-04-15 07:23:18.188 EDT [12055] LOG:  database system is ready to accept connections
```

- manually
- pg_ctl start
- on boot

Stopping Postmaster

```
2018-04-15 07:23:47.317 EDT [12055] LOG:  received fast shutdown request
2018-04-15 07:23:47.318 EDT [12055] LOG:  aborting any active transactions
2018-04-15 07:23:47.318 EDT [12055] LOG:  worker process: logical replication launcher (PID 12062) exited with exit code 1
2018-04-15 07:23:47.319 EDT [12057] LOG:  shutting down
2018-04-15 07:23:47.327 EDT [12055] LOG:  database system is shut down
```

- manually
- pg_ctl stop
- on shutdown

Connections

- local — unix domain socket
- host — TCP/IP, both SSL or non-SSL
- hostssl — only SSL
- hostnossl — never SSL

Authentication

- trust
- reject
- passwords
  - scram-sha-256
  - md5
  - password (cleartext)
- local authentication
  - socket permissions
  - ’peer’ socket user name passing
  - host ident using local identd

Authentication (continued)

- remote authentication
  - host ident using pg_ident.conf
  - kerberos
    - gss
    - sspi
  - pam
  - ldap
  - radius
  - cert

Access

- hostname and network mask
- database name
- role name (user or group)
- filename or list of databases, role
- IPv6

pg_hba.conf Default

```
# TYPE  DATABASE        USER            ADDRESS                 METHOD

# "local" is for Unix domain socket connections only
local   all             all                                     trust
# IPv4 local connections:
host    all             all             127.0.0.1/32            trust
# IPv6 local connections:
host    all             all             ::1/128                 trust
# Allow replication connections from localhost, by a user with the
# replication privilege.
#local   replication     postgres                                trust
#host    replication     postgres        127.0.0.1/32            trust
#host    replication     postgres        ::1/128                 trust
```

pg_hba.conf Example

```
# TYPE  DATABASE        USER            ADDRESS                 METHOD

# "local" is for Unix domain socket connections only
local   all             all                                     trust
# IPv4 local connections:
host    all             all             127.0.0.1/32            trust
# IPv6 local connections:
host    all             all             ::1/128                 trust

# disable connections from the gateway machine
host    all             all             192.168.1.254/32        reject
# enable local network
host    all             all             192.168.1.0/24          scram-sha-256
# require SSL for external connections, but do not allow the superuser
hostssl all             postgres        0.0.0.0/0               reject
hostssl all             all             0.0.0.0/0               scram-sha-256
```

Permissions

- Host connection permissions
- Role permissions
  - create roles
  - create databases
  - table permissions
- Database management
  - template1 customization
  - system tables
  - disk space computations

Data Directory

```
$ ls -CF
base/          pg_ident.conf  pg_serial/     pg_tblspc/    postgresql.auto.conf
global/        pg_logical/    pg_snapshots/  pg_twophase/  postgresql.conf
pg_commit_ts/  pg_multixact/  pg_stat/       PG_VERSION    postmaster.opts
pg_dynshmem/   pg_notify/     pg_stat_tmp/   pg_wal/
pg_hba.conf    pg_replslot/   pg_subtrans/   pg_xact/
```

Database Directories

```
$ ls -CF global/
1136      1214_fsm  1261_vm   2671  2846     2967     6000_vm
1136_fsm  1214_vm   1262      2672  2846_vm  3592     6001
1136_vm   1232      1262_fsm  2676  2847     3592_vm  6002
1137      1233      1262_vm   2677  2964     3593     pg_control
1213      1260      2396      2694  2964_vm  4060     pg_filenode.map
1213_fsm  1260_fsm  2396_fsm  2695  2965     4060_vm  pg_internal.init
1213_vm   1260_vm   2396_vm   2697  2966     4061
1214      1261      2397      2698  2966_vm  6000

$ ls -CF base/
1/  12406/  12407/  16384/

$ ls -CF base/16384
112        1249_fsm  2606_vm   2652  2699      3081      3598_vm
113        1249_vm   2607      2653  2701      3085      3599
12242      1255      2607_fsm  2654  2702      3118      3600
12242_fsm  1255_fsm  2607_vm   2655  2703      3118_vm   3600_fsm
12242_vm   1255_vm   2608      2656  2704      3119      3600_vm
12244      1259      2608_fsm  2657  2753      3164      3601
12246      1259_fsm  2608_vm   2658  2753_fsm  3256      3601_fsm

…
```

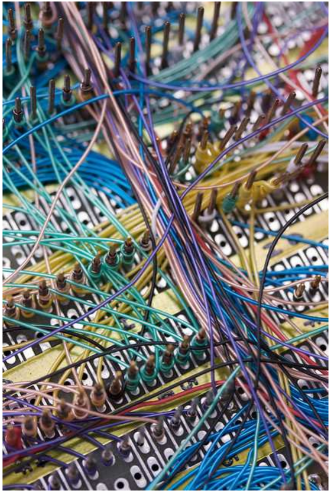
Transaction/WAL Directories

```
$ ls -CF pg_wal/
000000010000000000000001  archive_status/

$ ls -CF pg_xact/
0000
```

Configuration Directories

```
$ ls -CF share/
conversion_create.sql    postgres.bki              snowball_create.sql
extension/               postgres.description      sql_features.txt
information_schema.sql   postgresql.conf.sample    system_views.sql
pg_hba.conf.sample       postgres.shdescription    timezone/
pg_ident.conf.sample     psqlrc.sample             timezonesets/
pg_service.conf.sample   recovery.conf.sample      tsearch_data/
```

2. Configuration



https://www.flickr.com/photos/mwichary/

postgresql.conf

```
# -----------------------------
# PostgreSQL configuration file
# -----------------------------
#
# This file consists of lines of the form:
#
#   name = value
#
# (The "=" is optional.)  Whitespace may be used.  Comments are introduced with
# "#" anywhere on a line.  The complete list of parameter names and allowed
# values can be found in the PostgreSQL documentation.
#
# The commented-out settings shown in this file represent the default values.
# Re-commenting a setting is NOT sufficient to revert it to the default value;
# you need to reload the server.
```

postgresql.conf (Continued)

```
# This file is read on server startup and when the server receives a SIGHUP
# signal.  If you edit the file on a running system, you have to SIGHUP the
# server for the changes to take effect, run "pg_ctl reload", or execute
# "SELECT pg_reload_conf()".  Some parameters, which are marked below,
# require a server shutdown and restart to take effect.
#
# Any parameter can also be given as a command-line option to the server, e.g.,
# "postgres -c log_connections=on".  Some parameters can be changed at run time
# with the "SET" SQL command.
#
# Memory units:  kB = kilobytes        Time units:  ms  = milliseconds
#                MB = megabytes                     s   = seconds
#                GB = gigabytes                     min = minutes
#                TB = terabytes                     h   = hours
#                                                   d   = days
```

Configuration File Location

```
# The default values of these variables are driven from the -D command-line
# option or PGDATA environment variable, represented here as ConfigDir.

#data_directory = 'ConfigDir'           # use data in another directory
                                        # (change requires restart)
#hba_file = 'ConfigDir/pg_hba.conf'     # host-based authentication file
                                        # (change requires restart)
#ident_file = 'ConfigDir/pg_ident.conf' # ident configuration file
                                        # (change requires restart)

# If external_pid_file is not explicitly set, no extra PID file is written.
#external_pid_file = ''                 # write an extra PID file
                                        # (change requires restart)
```

Connections and Authentication

```
#listen_addresses = 'localhost'         # what IP address(es) to listen on;
                                        # comma-separated list of addresses;
                                        # defaults to 'localhost'; use '*' for all
                                        # (change requires restart)
#port = 5432                            # (change requires restart)
max_connections = 100                   # (change requires restart)
#superuser_reserved_connections = 3     # (change requires restart)
#unix_socket_directories = '/tmp'       # comma-separated list of directories
                                        # (change requires restart)
#unix_socket_group = ''                 # (change requires restart)
#unix_socket_permissions = 0777         # begin with 0 to use octal notation
                                        # (change requires restart)
#bonjour = off                          # advertise server via Bonjour
                                        # (change requires restart)
#bonjour_name = ''                      # defaults to the computer name
                                        # (change requires restart)
```

Security and Authentication

```
#authentication_timeout = 1min          # 1s-600s
#ssl = off
#ssl_ciphers = 'HIGH:MEDIUM:+3DES:!aNULL' # allowed SSL ciphers
#ssl_prefer_server_ciphers = on
#ssl_ecdh_curve = 'prime256v1'
#ssl_dh_params_file = ''
#ssl_cert_file = 'server.crt'
#ssl_key_file = 'server.key'
#ssl_ca_file = ''
#ssl_crl_file = ''
#password_encryption = md5              # md5 or scram-sha-256
#db_user_namespace = off
#row_security = on

# GSSAPI using Kerberos
#krb_server_keyfile = ''
#krb_caseins_users = off
```

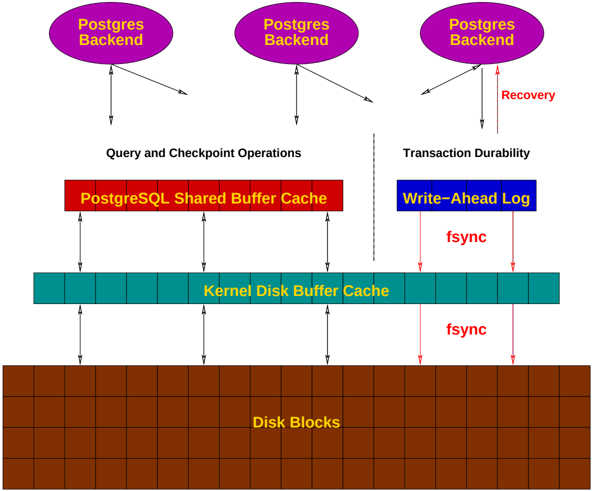
TCP/IP Control

```
#tcp_keepalives_idle = 0                # TCP_KEEPIDLE, in seconds;
                                        # 0 selects the system default
#tcp_keepalives_interval = 0            # TCP_KEEPINTVL, in seconds;
                                        # 0 selects the system default
#tcp_keepalives_count = 0               # TCP_KEEPCNT;
```

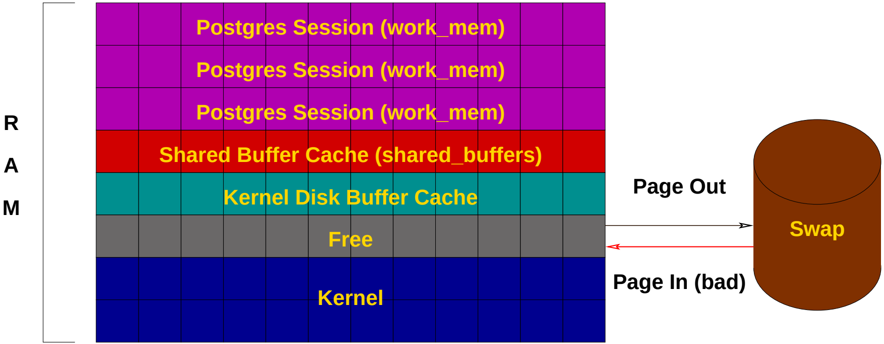
Memory Usage

```
shared_buffers = 128MB                  # min 128kB
                                        # (change requires restart)
#huge_pages = try                       # on, off, or try
                                        # (change requires restart)
#temp_buffers = 8MB                     # min 800kB
#max_prepared_transactions = 0          # zero disables the feature
                                        # (change requires restart)
# Caution: it is not advisable to set max_prepared_transactions nonzero unless
# you actively intend to use prepared transactions.
#work_mem = 4MB                         # min 64kB
#maintenance_work_mem = 64MB            # min 1MB
#replacement_sort_tuples = 150000       # limits use of replacement selection sort
#autovacuum_work_mem = -1               # min 1MB, or -1 to use maintenance_work_mem
#max_stack_depth = 2MB                  # min 100kB
dynamic_shared_memory_type = posix      # the default is the first option
                                        # supported by the operating system:
                                        #   posix
                                        #   sysv
                                        #   windows
                                        #   mmap
                                        # use none to disable dynamic shared memory
                                        # (change requires restart)
```

Memory Usage (Continued)



Sizing Shared Memory


R
A
M
Postgres Session (work_mem)
Postgres Session (work_mem)
Postgres Session (work_mem)
Shared Buffer Cache (shared_buffers)
Kernel Disk Buffer Cache
Free
Kernel
Page Out
Page In (bad)
Swap

Disk and Kernel Resources

```
# - Disk -

#temp_file_limit = -1                   # limits per-process temp file space
                                        # in kB, or -1 for no limit

# - Kernel Resource Usage -

#max_files_per_process = 1000           # min 25
                                        # (change requires restart)
#shared_preload_libraries = ''          # (change requires restart)
```

Vacuum and Background Writer

```
# - Cost-Based Vacuum Delay -

#vacuum_cost_delay = 0                  # 0-100 milliseconds
#vacuum_cost_page_hit = 1               # 0-10000 credits
#vacuum_cost_page_miss = 10             # 0-10000 credits
#vacuum_cost_page_dirty = 20            # 0-10000 credits
#vacuum_cost_limit = 200                # 1-10000 credits

# - Background Writer -

#bgwriter_delay = 200ms                 # 10-10000ms between rounds
#bgwriter_lru_maxpages = 100            # 0-1000 max buffers written/round
#bgwriter_lru_multiplier = 2.0          # 0-10.0 multiplier on buffers scanned/round
#bgwriter_flush_after = 512kB           # measured in pages, 0 disables
```

Asynchronous Behavior

```
# - Asynchronous Behavior -

#effective_io_concurrency = 1           # 1-1000; 0 disables prefetching
#max_worker_processes = 8               # (change requires restart)
#max_parallel_workers_per_gather = 2    # taken from max_parallel_workers
#max_parallel_workers = 8               # maximum number of max_worker_processes that
                                        # can be used in parallel queries
#old_snapshot_threshold = -1            # 1min-60d; -1 disables; 0 is immediate
                                        # (change requires restart)
#backend_flush_after = 0                # measured in pages, 0 disables
```

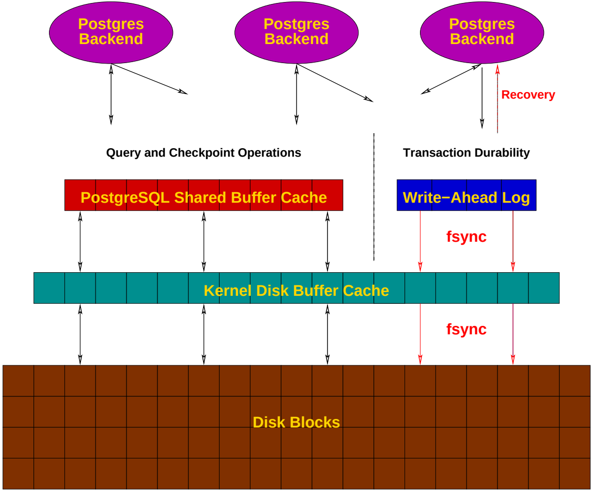
Write-Ahead Log (WAL)

```
#wal_level = replica                    # minimal, replica, or logical
                                        # (change requires restart)
#fsync = on                             # flush data to disk for crash safety
                                        # (turning this off can cause
                                        # unrecoverable data corruption)
#synchronous_commit = on                # synchronization level;
                                        # off, local, remote_write, remote_apply, or on
#wal_sync_method = fsync                # the default is the first option
                                        # supported by the operating system:
                                        #   open_datasync
                                        #   fdatasync (default on Linux)
                                        #   fsync
                                        #   fsync_writethrough
                                        #   open_sync
```

Write-Ahead Log (WAL)

```
#full_page_writes = on                  # recover from partial page writes
#wal_compression = off                  # enable compression of full-page writes
#wal_log_hints = off                    # also do full page writes of non-critical updates
                                        # (change requires restart)
#wal_buffers = -1                       # min 32kB, -1 sets based on shared_buffers
                                        # (change requires restart)
#wal_writer_delay = 200ms               # 1-10000 milliseconds
#wal_writer_flush_after = 1MB           # measured in pages, 0 disables

#commit_delay = 0                       # range 0-100000, in microseconds
#commit_siblings = 5                    # range 1-1000
```

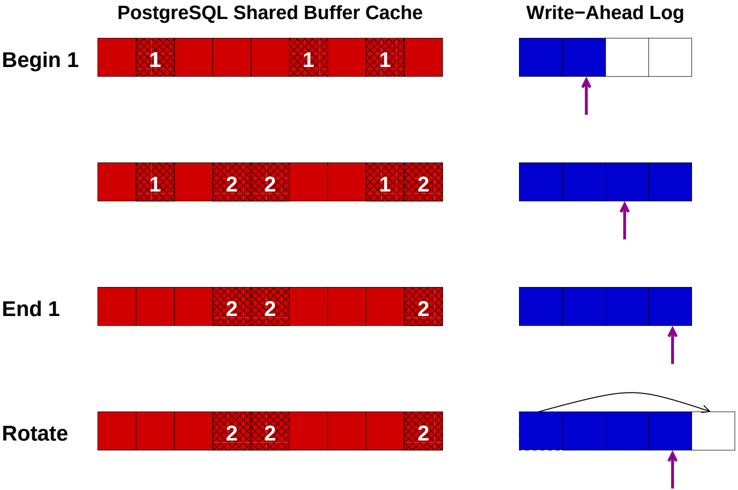
Write-Ahead Logging (Continued)



Checkpoints and Archiving

```
#checkpoint_timeout = 5min              # range 30s-1d
#max_wal_size = 1GB
#min_wal_size = 80MB
#checkpoint_completion_target = 0.5     # checkpoint target duration, 0.0 - 1.0
#checkpoint_flush_after = 256kB         # measured in pages, 0 disables
#checkpoint_warning = 30s               # 0 disables

# - Archiving -

#archive_mode = off             # enables archiving; off, on, or always
                                # (change requires restart)
#archive_command = ''           # command to use to archive a logfile segment
                                # placeholders: %p = path of file to archive
                                #               %f = file name only
                                # e.g., 'test ! -f /mnt/server/archivedir/%f && cp %p …
#archive_timeout = 0            # force a logfile segment switch after this
                                # number of seconds; 0 disables
```

Write-Ahead Logging (Continued)



Sending Server

```
# Set these on the master and on any standby that will send replication data.

#max_wal_senders = 10           # max number of walsender processes
                                # (change requires restart)
#wal_keep_segments = 0          # in logfile segments, 16MB each; 0 disables
#wal_sender_timeout = 60s       # in milliseconds; 0 disables

#max_replication_slots = 10     # max number of replication slots
                                # (change requires restart)
#track_commit_timestamp = off   # collect timestamp of transaction commit
                                # (change requires restart)
```

Primary Replication Server

```
# These settings are ignored on a standby server.

#synchronous_standby_names = '' # standby servers that provide sync rep
                                # method to choose sync standbys, number of sync standbys,
                                # and comma-separated list of application_name
                                # from standby(s); '*' = all
#vacuum_defer_cleanup_age = 0   # number of xacts by which cleanup is delayed
```

Standby Replication Server

```
# These settings are ignored on a master server.

#hot_standby = on                       # "off" disallows queries during recovery
                                        # (change requires restart)
#max_standby_archive_delay = 30s        # max delay before canceling queries#wal_level = replica
                                        # (change requires restart)
#fsync = on                             # flush data to disk for crash safety
                                        # (turning this off can cause
                                        # unrecoverable data corruption)
#synchronous_commit = on                # synchronization level;
                                        # off, local, remote_write, remote_apply, or on
#wal_sync_method = fsync                # the default is the first option
                                        # supported by the operating system:
                                        #   open_datasync
                                        #   fdatasync (default on Linux)
                                        #   fsync
                                        #   fsync_writethrough
                                        #   open_sync
                                        # when reading WAL from archive;
                                        # -1 allows indefinite delay
```

Standby Replication Server

```
#max_standby_streaming_delay = 30s      # max delay before canceling queries
                                        # when reading streaming WAL;
                                        # -1 allows indefinite delay
#wal_receiver_status_interval = 10s     # send replies at least this often
                                        # 0 disables
#hot_standby_feedback = off             # send info from standby to prevent
                                        # query conflicts
#wal_receiver_timeout = 60s             # time that receiver waits for
                                        # communication from master
                                        # in milliseconds; 0 disables
#wal_retrieve_retry_interval = 5s       # time to wait before retrying to
                                        # retrieve WAL after a failed attempt
```

Subscriber Server

```
# These settings are ignored on a publisher.

#max_logical_replication_workers = 4    # taken from max_worker_processes
                                        # (change requires restart)
#max_sync_workers_per_subscription = 2  # taken from max_logical_replication_workers
```

Planner Method Tuning

```
#enable_bitmapscan = on
#enable_hashagg = on
#enable_hashjoin = on
#enable_indexscan = on
#enable_indexonlyscan = on
#enable_material = on
#enable_mergejoin = on
#enable_nestloop = on
#enable_seqscan = on
#enable_sort = on
#enable_tidscan = on
```

Planner Constants

```
#seq_page_cost = 1.0                    # measured on an arbitrary scale
#random_page_cost = 4.0                 # same scale as above
#cpu_tuple_cost = 0.01                  # same scale as above
#cpu_index_tuple_cost = 0.005           # same scale as above
#cpu_operator_cost = 0.0025             # same scale as above
#parallel_tuple_cost = 0.1              # same scale as above
#parallel_setup_cost = 1000.0   # same scale as above
#min_parallel_table_scan_size = 8MB
#min_parallel_index_scan_size = 512kB
#effective_cache_size = 4GB
```

Planner GEQO

```
#geqo = on
#geqo_threshold = 12
#geqo_effort = 5                        # range 1-10
#geqo_pool_size = 0                     # selects default based on effort
#geqo_generations = 0                   # selects default based on effort
#geqo_selection_bias = 2.0              # range 1.5-2.0
#geqo_seed = 0.0                        # range 0.0-1.0
```

Miscellaneous Planner Options

```
#default_statistics_target = 100        # range 1-10000
#constraint_exclusion = partition       # on, off, or partition
#cursor_tuple_fraction = 0.1            # range 0.0-1.0
#from_collapse_limit = 8
#join_collapse_limit = 8                # 1 disables collapsing of explicit
                                        # JOIN clauses

#force_parallel_mode = off
```

Where To Log

```
#log_destination = 'stderr'             # Valid values are combinations of
                                        # stderr, csvlog, syslog, and eventlog,
                                        # depending on platform.  csvlog
                                        # requires logging_collector to be on.

# This is used when logging to stderr:
#logging_collector = off                # Enable capturing of stderr and csvlog
                                        # into log files. Required to be on for
                                        # csvlogs.
                                        # (change requires restart)

# These are only used if logging_collector is on:
#log_directory = 'log'                  # directory where log files are written,
                                        # can be absolute or relative to PGDATA
#log_filename = 'postgresql-%Y-%m-%d_%H%M%S.log'         # log file name pattern,
                                        # can include strftime() escapes
#log_file_mode = 0600                   # creation mode for log files,
                                        # begin with 0 to use octal notation
```

Where To Log (rotation)

```
#log_truncate_on_rotation = off         # If on, an existing log file with the
                                        # same name as the new log file will be
                                        # truncated rather than appended to.
                                        # But such truncation only occurs on
                                        # time-driven rotation, not on restarts
                                        # or size-driven rotation.  Default is
                                        # off, meaning append to existing files
                                        # in all cases.
#log_rotation_age = 1d                  # Automatic rotation of logfiles will
                                        # happen after that time.  0 disables.
#log_rotation_size = 10MB               # Automatic rotation of logfiles will
                                        # happen after that much log output.
                                        # 0 disables.
```

Where to Log (syslog)

```
#syslog_facility = 'LOCAL0'
#syslog_ident = 'postgres'
#syslog_sequence_numbers = on
#syslog_split_messages = on

# This is only relevant when logging to eventlog (win32):
# (change requires restart)
#event_source = 'PostgreSQL'
```

When to Log

```
#client_min_messages = notice           # values in order of decreasing detail:
                                        #   debug5
                                        #   debug4
                                        #   debug3
                                        #   debug2
                                        #   debug1
                                        #   log
                                        #   notice
                                        #   warning
                                        #   error
#log_min_messages = warning             # values in order of decreasing detail:
                                        #   debug5
                                        #   debug4
                                        #   debug3
                                        #   debug2
                                        #   debug1
                                        #   info
                                        #   notice
                                        #   warning
                                        #   error
                                        #   log
                                        #   fatal
                                        #   panic
```

When to Log (Continued)

```
#log_min_error_statement = error        # values in order of decreasing detail:
                                        #   debug5
                                        #   debug4
                                        #   debug3
                                        #   debug2
                                        #   debug1
                                        #   info
                                        #   notice
                                        #   warning
                                        #   error
                                        #   log
                                        #   fatal
                                        #   panic (effectively off)

#log_min_duration_statement = -1        # -1 is disabled, 0 logs all statements
                                        # and their durations, > 0 logs only
                                        # statements running at least this number
                                        # of milliseconds
```

What to Log

```
#debug_print_parse = off
#debug_print_rewritten = off
#debug_print_plan = off
#debug_pretty_print = on
#log_checkpoints = off
#log_connections = off
#log_disconnections = off
#log_duration = off
#log_error_verbosity = default          # terse, default, or verbose messages
#log_hostname = off
```

What To Log: log_line_prefix

```
#log_line_prefix = '%m [%p] '
```

```
# special values:
#   %a = application name
#   %u = user name
#   %d = database name
#   %r = remote host and port
#   %h = remote host
#   %p = process ID
#   %t = timestamp without milliseconds
#   %m = timestamp with milliseconds
#   %n = timestamp with milliseconds (as a Unix epoch)
#   %i = command tag
#   %e = SQL state
#   %c = session ID
#   %l = session line number
#   %s = session start timestamp
#   %v = virtual transaction ID
#   %x = transaction ID (0 if none)
#   %q = stop here in non-session
#        processes
#   %% = '%'
# e.g., '<%u%%%d> '
```

What to Log (Continued)

```
#log_lock_waits = off                   # log lock waits >= deadlock_timeout
#log_statement = 'none'                 # none, ddl, mod, all
#log_replication_commands = off
#log_temp_files = -1                    # log temporary files equal or larger
                                        # than the specified size in kilobytes;
                                        # -1 disables, 0 logs all temp files
log_timezone = 'US/Eastern'

# - Process Title -

#cluster_name = ''                      # added to process titles if nonempty
                                        # (change requires restart)
#update_process_title = on
```

Runtime Statistics

```
# - Query/Index Statistics Collector -

#track_activities = on
#track_counts = on
#track_io_timing = off
#track_functions = none                 # none, pl, all
#track_activity_query_size = 1024       # (change requires restart)
#stats_temp_directory = 'pg_stat_tmp'

# - Statistics Monitoring -

#log_parser_stats = off
#log_planner_stats = off
#log_executor_stats = off
#log_statement_stats = off
```

Autovacuum

```
#autovacuum = on                        # Enable autovacuum subprocess?  'on'
                                        # requires track_counts to also be on.
#log_autovacuum_min_duration = -1       # -1 disables, 0 logs all actions and
                                        # their durations, > 0 logs only
                                        # actions running at least this number
                                        # of milliseconds.
#autovacuum_max_workers = 3             # max number of autovacuum subprocesses
                                        # (change requires restart)
#autovacuum_naptime = 1min              # time between autovacuum runs
#autovacuum_vacuum_threshold = 50       # min number of row updates before
                                        # vacuum
#autovacuum_analyze_threshold = 50      # min number of row updates before
                                        # analyze
```

Autovacuum

```
#autovacuum_vacuum_scale_factor = 0.2   # fraction of table size before vacuum
#autovacuum_analyze_scale_factor = 0.1  # fraction of table size before analyze
#autovacuum_freeze_max_age = 200000000  # maximum XID age before forced vacuum
                                        # (change requires restart)
#autovacuum_multixact_freeze_max_age = 400000000        # maximum multixact age
                                        # before forced vacuum
                                        # (change requires restart)
#autovacuum_vacuum_cost_delay = 20ms    # default vacuum cost delay for
                                        # autovacuum, in milliseconds;
                                        # -1 means use vacuum_cost_delay
#autovacuum_vacuum_cost_limit = -1      # default vacuum cost limit for
                                        # autovacuum, -1 means use
                                        # vacuum_cost_limit
```

Statement Behavior

```
#search_path = '"$user", public'        # schema names
#default_tablespace = ''                # a tablespace name, '' uses the default
#temp_tablespaces = ''                  # a list of tablespace names, '' uses
                                        # only default tablespace
#check_function_bodies = on
#default_transaction_isolation = 'read committed'
#default_transaction_read_only = off
#default_transaction_deferrable = off
#session_replication_role = 'origin'
#statement_timeout = 0                  # in milliseconds, 0 is disabled
#lock_timeout = 0                       # in milliseconds, 0 is disabled
#idle_in_transaction_session_timeout = 0        # in milliseconds, 0 is disabled
#vacuum_freeze_min_age = 50000000
#vacuum_freeze_table_age = 150000000
#vacuum_multixact_freeze_min_age = 5000000
#vacuum_multixact_freeze_table_age = 150000000
#bytea_output = 'hex'                   # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
#gin_fuzzy_search_limit = 0
#gin_pending_list_limit = 4MB
```

Locale, Formatting, and Full Text Search

```
datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
timezone = 'US/Eastern'
#timezone_abbreviations = 'Default'     # Select the set of available time zone
                                        # abbreviations.  Currently, there are
                                        #   Default
                                        #   Australia (historical usage)
                                        #   India
                                        # You can create your own file in
                                        # share/timezonesets/.
#extra_float_digits = 0                 # min -15, max 3
#client_encoding = sql_ascii            # actually, defaults to database
                                        # encoding

# These settings are initialized by initdb, but they can be changed.
lc_messages = 'en_US.UTF-8'                     # locale for system error message
                                        # strings
lc_monetary = 'en_US.UTF-8'                     # locale for monetary formatting
lc_numeric = 'en_US.UTF-8'                      # locale for number formatting
lc_time = 'en_US.UTF-8'                         # locale for time formatting
# default configuration for text search
default_text_search_config = 'pg_catalog.english'
```

Other Defaults

```
#dynamic_library_path = '$libdir'
#local_preload_libraries = ''
#session_preload_libraries = ''
```

Lock Management

```
#deadlock_timeout = 1s
#max_locks_per_transaction = 64         # min 10
                                        # (change requires restart)
#max_pred_locks_per_transaction = 64    # min 10
                                        # (change requires restart)
#max_pred_locks_per_relation = -2       # negative values mean
                                        # (max_pred_locks_per_transaction
                                        #  / -max_pred_locks_per_relation) - 1
#max_pred_locks_per_page = 2            # min 0
```

Version/Platform Compatibility

```
# - Previous PostgreSQL Versions -

#array_nulls = on
#backslash_quote = safe_encoding        # on, off, or safe_encoding
#default_with_oids = off
#escape_string_warning = on
#lo_compat_privileges = off
#operator_precedence_warning = off
#quote_all_identifiers = off
#standard_conforming_strings = on
#synchronize_seqscans = on

# - Other Platforms and Clients -

#transform_null_equals = off
```

Error Handling

```
#exit_on_error = off                    # terminate session on any error?
#restart_after_crash = on               # reinitialize after backend crash?
```

Config File Includes

```
#include_dir = 'conf.d'                 # include files ending in '.conf' from
                                        # directory 'conf.d'
#include_if_exists = 'exists.conf'      # include file only if it exists
#include = 'special.conf'               # include file
```

Interfaces

- Installing
  - Compiled Languages (C, ecpg)
  - Scripting Language (Perl, Python, PHP)
  - SPI
- Connection Pooling

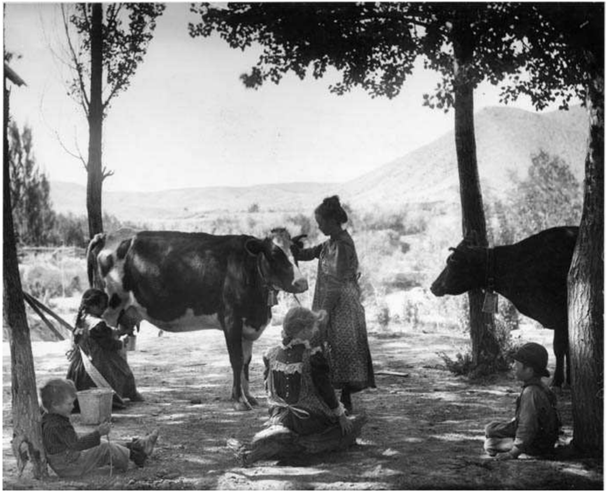
Include Files

```
$ ls -CF include/
ecpg_config.h    libpq/              pgtypes_date.h       sql3types.h
ecpgerrno.h      libpq-events.h      pgtypes_error.h      sqlca.h
ecpg_informix.h  libpq-fe.h          pgtypes_interval.h   sqlda-compat.h
ecpglib.h        pg_config_ext.h     pgtypes_numeric.h    sqlda.h
ecpgtype.h       pg_config.h         pgtypes_timestamp.h  sqlda-native.h
informix/        pg_config_manual.h  postgres_ext.h
internal/        pg_config_os.h      server/
```

Library Files

```
$ ls -CF lib/
ascii_and_mic.so*        libpgcommon.a         utf8_and_ascii.so*
cyrillic_and_mic.so*     libpgfeutils.a        utf8_and_big5.so*
dict_snowball.so*        libpgport.a           utf8_and_cyrillic.so*
euc2004_sjis2004.so*     libpgtypes.a          utf8_and_euc2004.so*
euc_cn_and_mic.so*       libpgtypes.so@        utf8_and_euc_cn.so*
euc_jp_and_sjis.so*      libpgtypes.so.3@      utf8_and_euc_jp.so*
euc_kr_and_mic.so*       libpgtypes.so.3.10*   utf8_and_euc_kr.so*
euc_tw_and_big5.so*      libpq.a               utf8_and_euc_tw.so*
latin2_and_win1250.so*   libpq.so@             utf8_and_gb18030.so*
latin_and_mic.so*        libpq.so.5@           utf8_and_gbk.so*
libecpg.a                libpq.so.5.10*        utf8_and_iso8859_1.so*
libecpg_compat.a         libpqwalreceiver.so*  utf8_and_iso8859.so*
libecpg_compat.so@       pgoutput.so*          utf8_and_johab.so*
libecpg_compat.so.3@     pgxs/                 utf8_and_sjis2004.so*
libecpg_compat.so.3.10*  pkgconfig/            utf8_and_sjis.so*
libecpg.so@              plperl.so*            utf8_and_uhc.so*
libecpg.so.6@            plpgsql.so*           utf8_and_win.so*
libecpg.so.6.10*         plpython2.so*
```

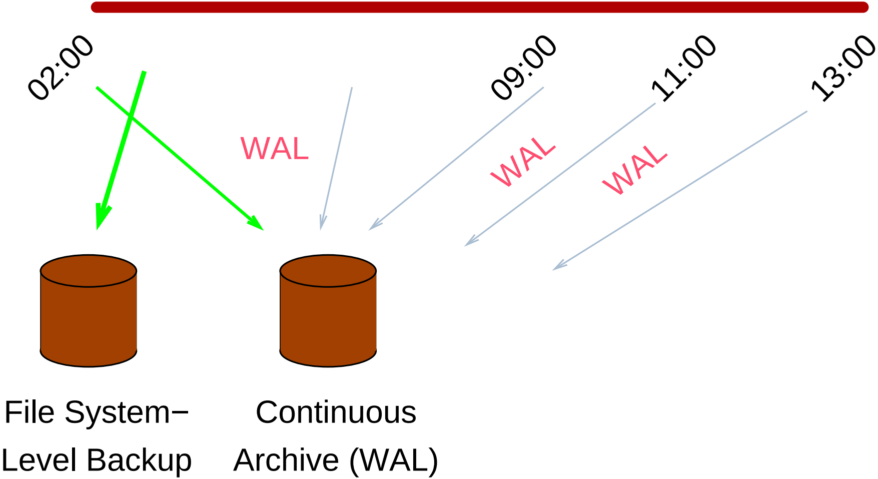
3. Maintenance



Backup

- File system-level (physical)
  - tar, cpio while shutdown
  - file system snapshot
  - rsync, shutdown, rsync, restart
- pg_dump/pg_dumpall (logical)
- Restore/pg_restore with custom format

Continuous Archiving / Point-In-Time Recovery (PITR)

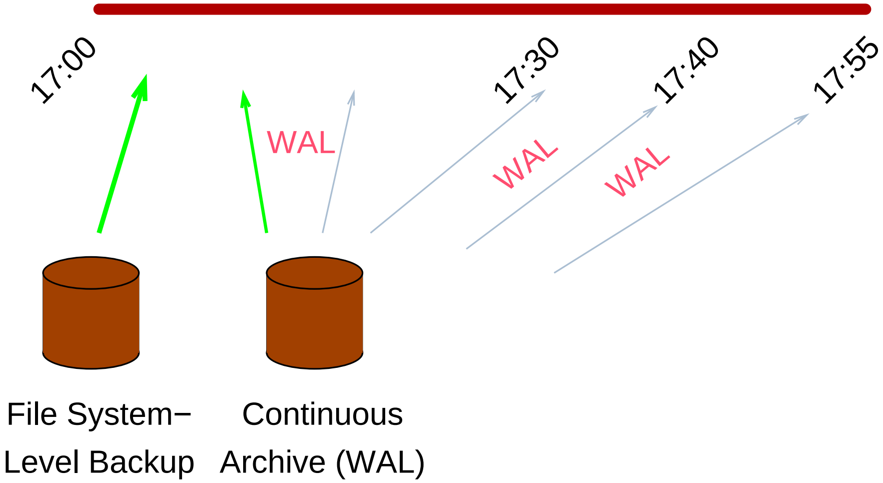


PITR Backup Procedures

1. `archive_mode = on`
2. `wal_level = archive`
3. `archive_command = 'cp -i %p /mnt/server/pgsql/%f < /dev/null'`
4. `SELECT pg_start_backup('label');`
5. Perform file system-level backup (can be inconsistent)
6. `SELECT pg_stop_backup();`

pg_basebackup does this automatically.

PITR Recovery



PITR Recovery Procecdures

1. Stop postmaster
2. Restore file system-level backup
3. Make adjustments as outlined in the documentation
4. Create recovery.conf
5. `restore_command = 'cp /mnt/server/pgsql/%f %p'`
6. Start the postmaster

Continuous Archive Management

Simplify backups and WAL archive file management with:

- *pgBackRest*
- *barman*

Data Maintenance

- VACUUM (nonblocking) records free space into .fsm (free space map) files
- ANALYZE collects optimizer statistics
- VACUUM FULL (blocking) shrinks the size of database disk files

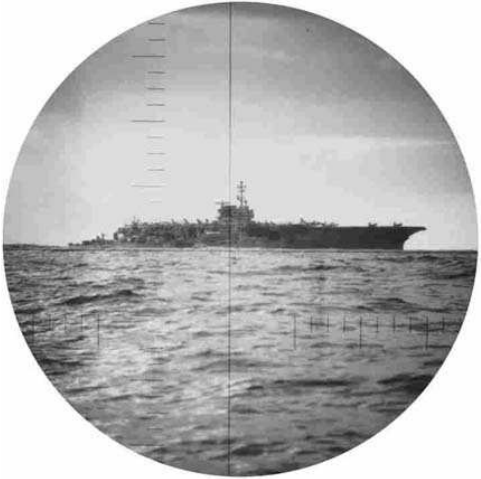
Automating Tasks

Autovacuum handles vacuum and analyze tasks automatically.

Checkpoints

- Write all dirty shared buffers
- Sync all dirty kernel buffers
- Recycle WAL files
- Controlled by *checkpoint_timeout* and *max_wal_size*

4. Monitoring



ps

```
$ ps -f -Upostgres
postgres   825     1  0 Tue12AM  ??         0:06.57 /u/pgsql/bin/postmaster -i
postgres   829   825  0 Tue12AM  ??         0:35.03 writer process    (postmaster)
postgres   830   825  0 Tue12AM  ??         0:16.07 wal writer process    (postmaster)
postgres   831   825  0 Tue12AM  ??         0:11.34 autovacuum launcher process    (postmaster)
postgres   832   825  0 Tue12AM  ??         0:07.63 stats collector process    (postmaster)
postgres 13003   825  0  3:44PM  ??         0:00.01 postgres test [local] idle (postmaster)
postgres 13002 12997  0  3:44PM  ttyq1      0:00.03 /u/pgsql/bin/psql test
```

top

```
$ top -c
top - 10:29:47 up 23 days, 18:53,  6 users,  load average: 1.73, 1.49, 0.81
Tasks: 387 total,   2 running, 385 sleeping,   0 stopped,   0 zombie
%Cpu(s):  5.9 us,  0.5 sy,  0.0 ni, 93.7 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
KiB Mem:  24734444 total, 19187724 used,  5546720 free,   532280 buffers
KiB Swap:  6369276 total,   168292 used,  6200984 free. 16936936 cached Mem

 PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM    TIME+ COMMAND
32037 postgres  20   0  190980  27940  21420 R 100.0  0.1  0:09.74 postgres: postgres test [local] INSERT
32061 root      20   0   26056   3240   2444 R   0.7  0.0  0:00.09 top -c
```

Query Monitoring

```
test=> SELECT * FROM pg_stat_activity;
…
datid            | 16384
datname          | test
pid              | 16382
usesysid         | 10
usename          | postgres
application_name | psql
client_addr      |
client_hostname  |
client_port      | -1
backend_start    | 2018-04-15 09:00:26.467813-04
xact_start       | 2018-04-15 09:00:48.028667-04
query_start      | 2018-04-15 09:00:48.028667-04
state_change     | 2018-04-15 09:00:48.028671-04
wait_event_type  |
wait_event       |
state            | active
backend_xid      |
backend_xmin     | 556
query            | SELECT * FROM pg_stat_activity;
backend_type     | client backend
```

Access Statistics

```
pg_stat_all_indexes      | view     | postgres
pg_stat_all_tables       | view     | postgres
pg_stat_database         | view     | postgres
pg_stat_sys_indexes      | view     | postgres
pg_stat_sys_tables       | view     | postgres
pg_stat_user_indexes     | view     | postgres
pg_stat_user_tables      | view     | postgres
pg_statio_all_indexes    | view     | postgres
pg_statio_all_sequences  | view     | postgres
pg_statio_all_tables     | view     | postgres
pg_statio_sys_indexes    | view     | postgres
pg_statio_sys_sequences  | view     | postgres
pg_statio_sys_tables     | view     | postgres
pg_statio_user_indexes   | view     | postgres
pg_statio_user_sequences | view     | postgres
pg_statio_user_tables    | view     | postgres
```

Database Statistics

```
test=> SELECT * FROM pg_stat_database;
...
-[ RECORD 4 ]-+----------
datid         | 16384
datname       | test
numbackends   | 1
xact_commit   | 188
xact_rollback | 0
blks_read     | 95
blks_hit      | 11832
tup_returned  | 64389
tup_fetched   | 2938
tup_inserted  | 0
tup_updated   | 0
tup_deleted   | 0
```

Table Activity

```
test=> SELECT * FROM pg_stat_all_tables;
-[ RECORD 10 ]---+-------------------------
relid            | 2616
schemaname       | pg_catalog
relname          | pg_opclass
seq_scan         | 2
seq_tup_read     | 2
idx_scan         | 99
idx_tup_fetch    | 99
n_tup_ins        | 0
n_tup_upd        | 0
n_tup_del        | 0
n_tup_hot_upd    | 0
n_live_tup       | 0
n_dead_tup       | 0
last_vacuum      |
last_autovacuum  |
last_analyze     |
last_autoanalyze |
```

Table Block Activity

```
test=> SELECT * FROM pg_statio_all_tables;
-[ RECORD 50 ]--+------------------------
relid           | 2602
schemaname      | pg_catalog
relname         | pg_amop
heap_blks_read  | 3
heap_blks_hit   | 114
idx_blks_read   | 5
idx_blks_hit    | 303
toast_blks_read |
toast_blks_hit  |
tidx_blks_read  |
tidx_blks_hit   |
```

Analyzing Activity

- Heavily used tables
- Unnecessary indexes
- Additional indexes
- Index usage
- TOAST usage

CPU

```
$ vmstat 5
 procs     memory      page                     disks      faults      cpu
 r  b w    avm    fre  flt  re  pi  po  fr  sr  s0  s0   in   sy  cs us sy  id
 1  0 0 501820  48520 1234  86   2   0   0   3   5   0  263 2881 599 10  4  86
 3  0 0 512796  46812 1422 201  12   0   0   0   3   0  259 6483 827  4  7  88
 3  0 0 542260  44356  788 137   6   0   0   0   8   0  286 5698 741  2  5  94
 4  0 0 539708  41868  576  65  13   0   0   0   4   0  273 5721 819 16  4  80
 4  0 0 547200  32964  454   0   0   0   0   0   5   0  253 5736 948 50  4  46
 4  0 0 556140  23884  461   0   0   0   0   0   2   0  249 5917 959 52  3  44
 1  0 0 535136  46280 1056 141  25   0   0   0   2   0  261 6417 890 24  6  70
```

I/O

```
$ iostat 5
      tty             sd0             sd1             sd2                % cpu
 tin tout   sps  tps msps   sps  tps msps   sps  tps msps  usr nic sys int idl
   7  119   244   11  6.1     0    0 27.3     0    0 18.1    9   1   4   0  86
   0   86    20    1  1.4     0    0  0.0     0    0  0.0    2   0   2   0  96
   0   82    61    4  3.6     0    0  0.0     0    0  0.0    2   0   2   0  97
   0   65     6    0  0.0     0    0  0.0     0    0  0.0    1   0   2   0  97
  12   90    31    2  5.4     0    0  0.0     0    0  0.0    4   0   3   0  93
  24  173     6    0  4.9     0    0  0.0     0    0  0.0   48   0   3   0  49
   0   91  3594   63  4.6     0    0  0.0     0    0  0.0   11   0   4   0  85
```

Disk Usage

```
test=> \df *size*
                                   List of functions
   Schema   |          Name          | Result data type | Argument data types |  Type
------------+------------------------+------------------+---------------------+--------
 pg_catalog | pg_column_size         | integer          | "any"               | normal
 pg_catalog | pg_database_size       | bigint           | name                | normal
 pg_catalog | pg_database_size       | bigint           | oid                 | normal
 pg_catalog | pg_indexes_size        | bigint           | regclass            | normal
 pg_catalog | pg_relation_size       | bigint           | regclass            | normal
 pg_catalog | pg_relation_size       | bigint           | regclass, text      | normal
 pg_catalog | pg_size_pretty         | text             | bigint              | normal
 pg_catalog | pg_table_size          | bigint           | regclass            | normal
 pg_catalog | pg_tablespace_size     | bigint           | name                | normal
 pg_catalog | pg_tablespace_size     | bigint           | oid                 | normal
 pg_catalog | pg_total_relation_size | bigint           | regclass            | normal
```

Database File Mapping - oid2name

```
$ oid2name
All databases:
---------------------------------
18720  = test1
1      = template1
18719  = template0
18721  = test
18735  = postgres
18736  = cssi
```

Table File Mapping

```
$ cd /usr/local/pgsql/data/base
$ oid2name
All databases:
---------------------------------
16817  = test2
16578  = x
16756  = test
1      = template1
16569  = template0
16818  = test3
16811  = floattest

$ cd 16756
$ ls 1873*
18730   18731   18732   18735   18736   18737   18738   18739
```

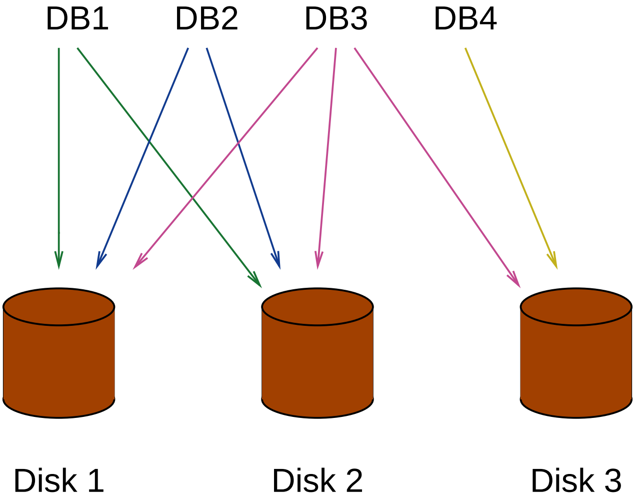
Table File Mapping

```
$ oid2name -d test -o 18737
Tablename of oid 18737 from database "test":
---------------------------------
18737  = ips

$ oid2name -d test -t ips
Oid of table ips from database "test":
---------------------------------
18737  = ips

$ # show disk usage per database
$ cd /usr/local/pgsql/data/base
$ du -s * |
> while read SIZE OID
> do
>       echo "$SIZE      `oid2name -q | grep ^$OID' '`"
> done |
> sort -rn
2256        18721  = test
2135        18735  = postgres
```

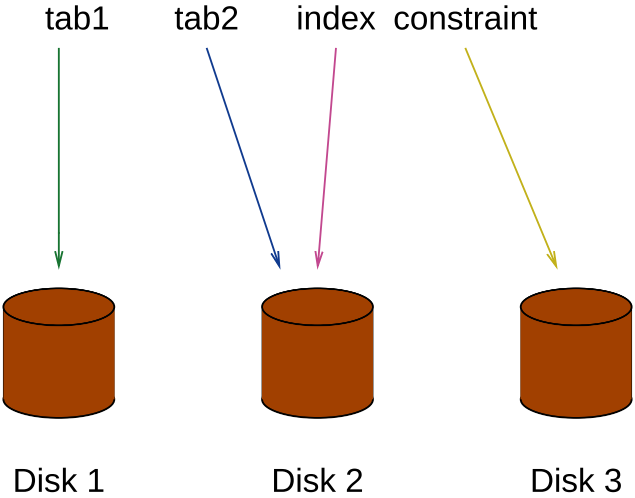
Disk Balancing

- Move pg_wal to another drive using symlinks
- Tablespaces

Per-Database Tablespaces



Per-Object Tablespaces



Analyzing Locking

```
$ ps -f -Upostgres
  PID  TT  STAT      TIME COMMAND
 9874  ??  I      0:00.07 postgres test [local] idle in transaction (postmaster)
 9835  ??  S      0:00.05 postgres test [local] UPDATE waiting (postmaster)
10295  ??  S      0:00.05 postgres test [local] DELETE waiting (postmaster)

test=> SELECT * FROM pg_locks;
 relation | database | transaction | pid  |       mode       | granted
----------+----------+-------------+------+------------------+---------
    17143 |    17142 |             | 9173 | AccessShareLock  | t
    17143 |    17142 |             | 9173 | RowExclusiveLock | t
          |          |         472 | 9380 | ExclusiveLock    | t
          |          |         468 | 9338 | ShareLock        | f
          |          |         470 | 9338 | ExclusiveLock    | t
    16759 |    17142 |             | 9380 | AccessShareLock  | t
    17143 |    17142 |             | 9338 | AccessShareLock  | t
    17143 |    17142 |             | 9338 | RowExclusiveLock | t
          |          |         468 | 9173 | ExclusiveLock    | t
```

Miscellaneous Tasks

- Log file rotation, syslog
- Major version upgrading
  - pg_dump, restore
  - pg_upgrade
  - logical replication
- Migration

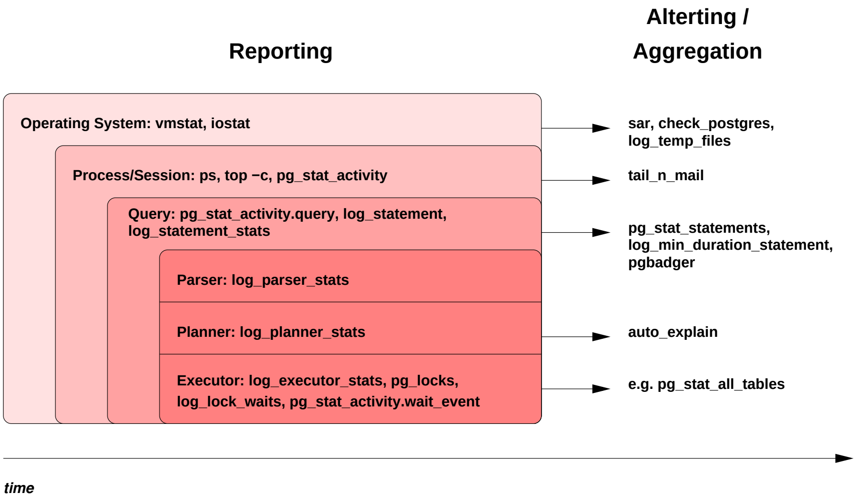
Administration Tools

- pgadmin
- phppgadmin

External Monitoring Tools

- Alerting: check_postgres, tail_n_mail, Nagios
- Server analysis: Munin, Cacti, Zabbix, Nagios, MRTG, Prometheus, Grafana
- Queries: pg_stat_statements, auto_explain, pgbadger
- Commercial: Postgres Enterprise Manager (PEM), Percona Monitoring and Management (PMM), Circonus, VividCortex

Monitoring Summary



Reporting

Alterting / Aggregation

Operating System: vmstat, iostat

Process/Session: ps, top −c, pg_stat_activity

Query: pg_stat_activity.query, log_statement, log_statement_stats

Parser: log_parser_stats

Planner: log_planner_stats

Executor: log_executor_stats, pg_locks, log_lock_waits, pg_stat_activity.wait_event

sar, check_postgres, log_temp_files

tail_n_mail

pg_stat_statements, log_min_duration_statement, pgbadger

auto_explain

e.g. pg_stat_all_tables

time

5. Recovery

https://www.flickr.com/photos/coastguardnews/

Client Application Crash

Nothing Required. Transactions in progress are rolled back.

Graceful Postgres Server Shutdown

Nothing Required. Transactions in progress are rolled back.

Abrupt Postgres Server Crash

Nothing Required. Transactions in progress are rolled back.

Operating System Crash

Nothing Required. Transactions in progress are rolled back. Partial page writes are repaired.

Disk Failure

Restore from previous backup or use PITR.

Accidental DELETE

Recover table from previous backup, perhaps using pg_restore. It is possible to modify the backend code to make deleted tuples visible, dump out the deleted table and restore the original code. All tuples in the table since the previous vacuum will be visible. It is possible to restrict that so only tuples deleted by a specific transaction are visible.

Write-Ahead Log (WAL) Corruption

See pg_resetwal. Review recent transactions and identify any damage, including partially committed transactions.

File Deletion

It may be necessary to create an empty file with the deleted file name so the object can be deleted, and then the object restored from backup.

Accidental Drop Table

Restore from previous backup.

Accidental Drop Index

Recreate index.

Accidental Drop Database

Restore from previous backup.

Non-Starting Installation

Restart problems are usually caused by write-ahead log problems. See pg_resetwal. Review recent transactions and identify any damage, including partially committed transactions.

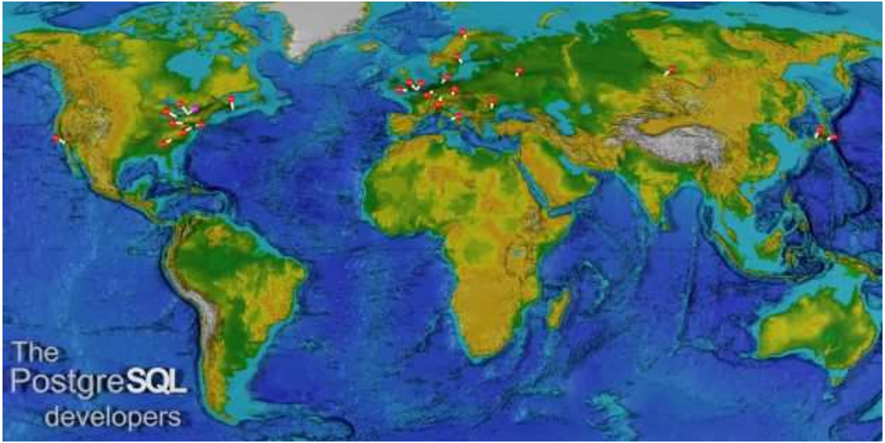
Index Corruption

Use REINDEX.

Table Corruption

Try reindexing the table. Try identifying the corrupt OID of the row and transfer the valid rows into another table using SELECT…INTO…WHERE oid != ###. Use *pageinspect* to analyze the internal structure of the table.

Conclusion



https://momjian.us/presentations