Mastering PostgreSQL Administration

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

 http://momjian.us/presentations

Last updated: May, 2016

Outline

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

Installation

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

Initialization (initdb)

```
$ initdb
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".


fixing permissions on existing directory /u/pgsql/data ... ok
creating subdirectories ... ok
selecting default max_connections ... 100
selecting default shared_buffers ... 32MB
creating configuration files ... ok
creating template1 database in /u/pgsql/data/base/1 ... ok
initializing pg_authid ... ok
initializing dependencies ... ok
creating system views ... ok
loading system objects' descriptions ... ok
creating collations ... ok
creating conversions ... ok
creating dictionaries ... ok
setting privileges on built-in objects ... ok
creating information schema ... ok
loading PL/pgSQL server-side language ... ok
vacuuming database template1 ... ok
copying template1 to template0 ... ok
copying template1 to postgres ... ok
```

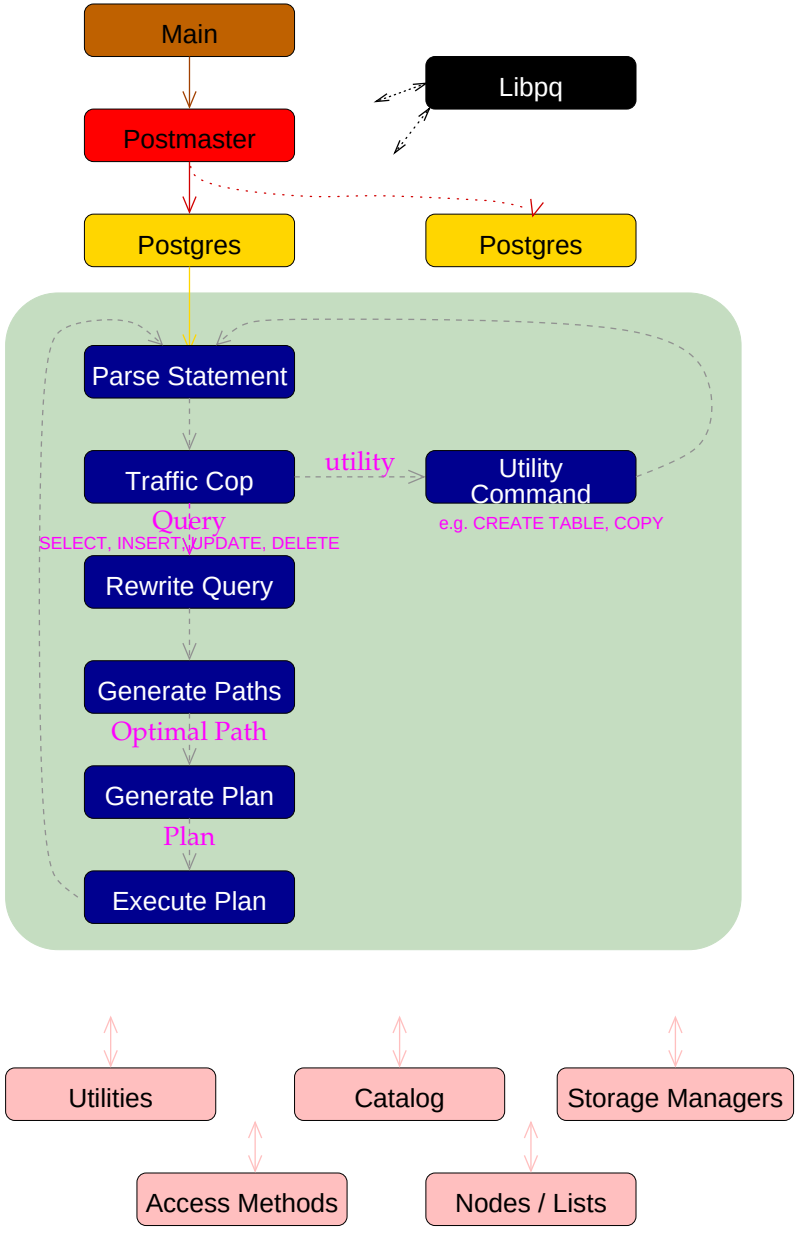
Initialization (continued)

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


Success. You can now start the database server using:


    /u/pgsql/bin/postgres -D /u/pgsql/data
or
    /u/pgsql/bin/pg_ctl -D /u/pgsql/data -l logfile start
```

pg_controldata

```
$ pg_controldata
pg_control version number:            903
Catalog version number:               201105231
Database system identifier:           5701206621592472575
Database cluster state:               in production
pg_control last modified:             Tue 24 Jan 2012 09:33:32 AM EST
Latest checkpoint location:           0/16BD258
Prior checkpoint location:            0/16BD1D0
Latest checkpoint's REDO location:    0/16BD258
Latest checkpoint's TimeLineID:       1
Latest checkpoint's NextXID:          0/679
Latest checkpoint's NextOID:          24576
Latest checkpoint's NextMultiXactId:  1
Latest checkpoint's NextMultiOffset:  0
Latest checkpoint's oldestXID:        668
Latest checkpoint's oldestXID's DB:   1
Latest checkpoint's oldestActiveXID:  0
Time of latest checkpoint:            Tue 24 Jan 2012 09:33:32 AM EST
Minimum recovery ending location:     0/0
Backup start location:                0/0
Current wal_level setting:            minimal
Current max_connections setting:      100
Current max_prepared_xacts setting:   0
Current max_locks_per_xact setting:   64
Maximum data alignment:               8
Database block size:                  8192
Blocks per segment of large relation: 131072
WAL block size:                       8192
Bytes per WAL segment:                16777216
Maximum length of identifiers:        64
Maximum columns in an index:          32
Maximum size of a TOAST chunk:        1996
Date/time type storage:               64-bit integers
Float4 argument passing:              by value
```

System Architecture



Starting Postmaster

```
LOG:  database system was shut down at 2012-01-24 09:33:29 EST
LOG:  database system is ready to accept connections
LOG:  autovacuum launcher started
```

- manually
- pg_ctl start
- on boot

Stopping Postmaster

```
LOG:  received smart shutdown request
LOG:  autovacuum launcher shutting down
LOG:  shutting down
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
  - 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          md5
# 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               md5
```

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_stat_tmp/   PG_VERSION
global/       pg_multixact/   pg_subtrans/   pg_xlog/
pg_clog/      pg_notify/      pg_tblspc/     postgresql.conf
pg_hba.conf   pg_serial/      pg_twophase/   postmaster.opts
```

Database Directories

```
$ ls -CF global/
11669      11802      11808      11813      11819      11825  11917
11669_fsm  11804      11809      11815      11820      11826  pg_control
11669_vm   11805      11810      11816      11821      11911  pg_filenode.map
11671      11806      11810_fsm  11817      11821_fsm  11913  pg_internal.init
11672      11806_fsm  11810_vm   11817_fsm  11821_vm   11915  pgstat.stat
11800      11806_vm   11812      11817_vm   11823      11916

$ ls -CF base/
1/  11910/  11918/  16384/

$ ls -CF base/16384
11655      11695_vm   11731      11768      11836      11875_vm
11655_fsm  11697      11732      11768_fsm  11837      11877
11655_vm   11699      11733      11768_vm   11838      11879
11657      11700      11733_fsm  11770      11838_fsm  11880
11657_fsm  11701      11733_vm   11771      11838_vm   11880_fsm
11657_vm   11702      11735      11772      11840      11880_vm

...
```

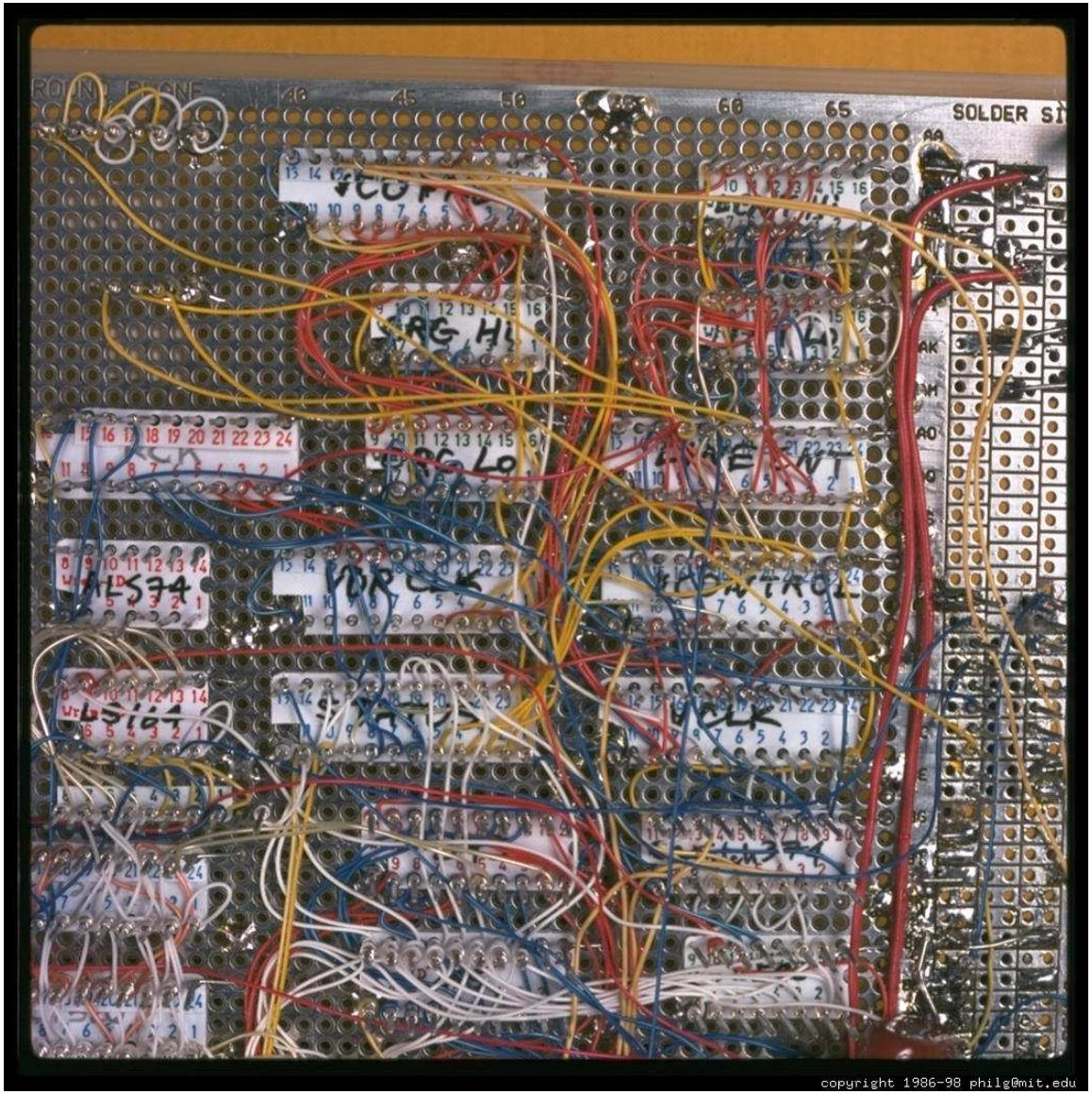
Transaction/WAL Directories

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

$ ls -CF pg_clog/
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/
```

Configuration of postgresql.conf



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, or use "pg_ctl reload".  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
#                                                   h   = hours
```

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 = '(none)'           # 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', '*' = all
                                        # (change requires restart)
#port = 5432                            # (change requires restart)
max_connections = 100                   # (change requires restart)
# Note:  Increasing max_connections costs ~400 bytes of shared memory per
# connection slot, plus lock space (see max_locks_per_transaction).
#superuser_reserved_connections = 3     # (change requires restart)
#unix_socket_directory = ''             # (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                              # (change requires restart)
#ssl_ciphers = 'ALL:!ADH:!LOW:!EXP:!MD5:@STRENGTH'      # allowed SSL ciphers
                                        # (change requires restart)
#ssl_renegotiation_limit = 512MB        # amount of data between renegotiations
#password_encryption = on

#db_user_namespace = off


# Kerberos and GSSAPI
#krb_server_keyfile = ''
#krb_srvname = 'postgres'               # (Kerberos only)
#krb_caseins_users = off
```

TCP/IP Control

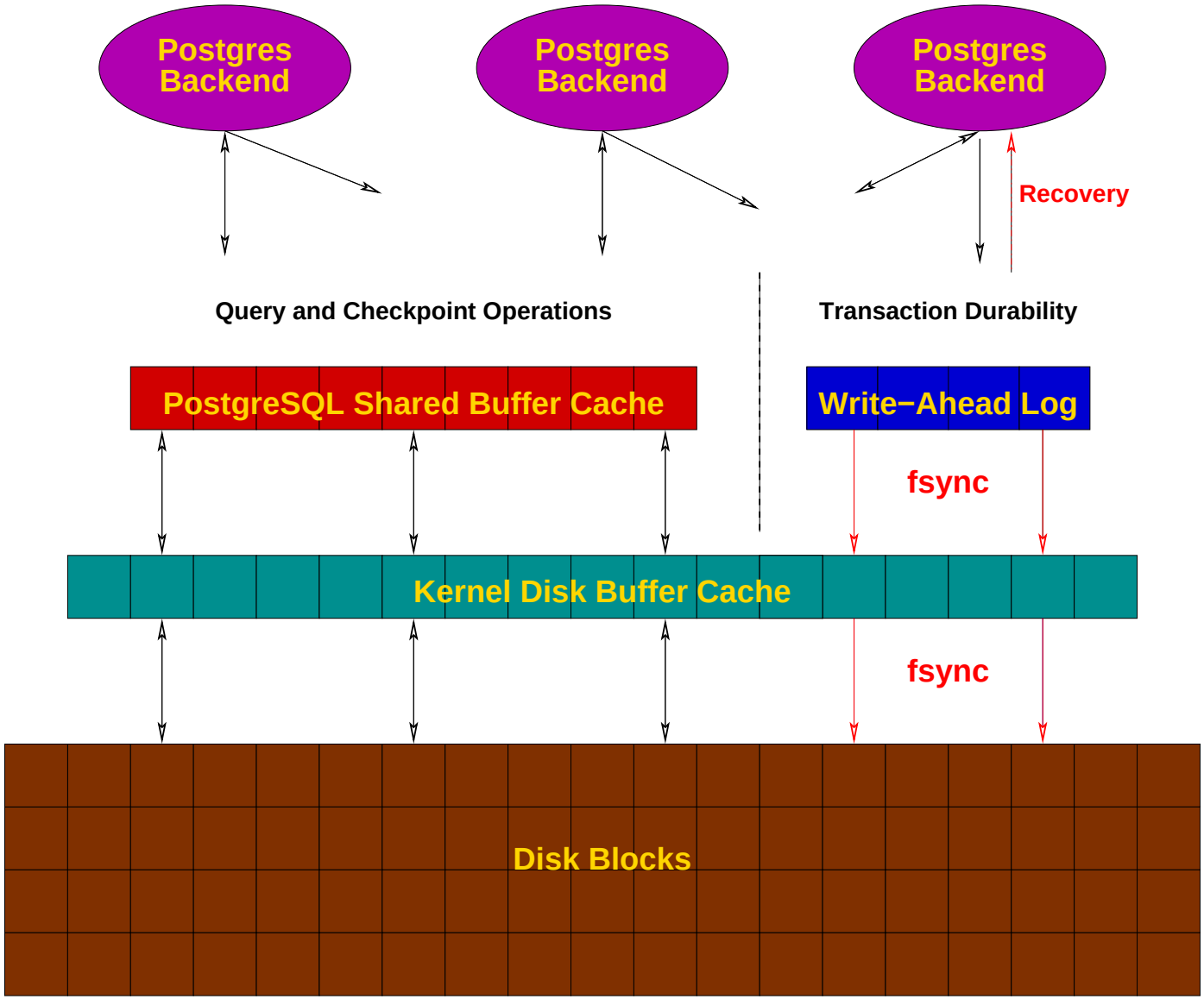
```
# see "man 7 tcp" for details

#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;
                                        # 0 selects the system default
```

Memory Usage

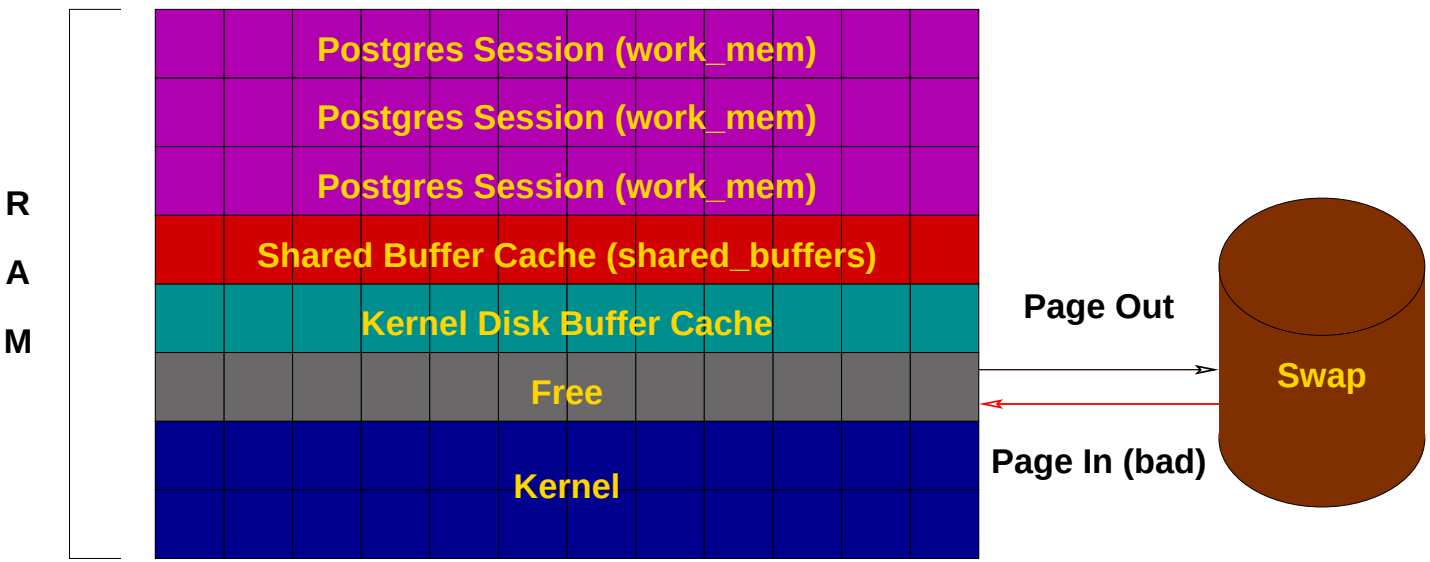
```
shared_buffers = 32MB                   # min 128kB
                                        # (change requires restart)
#temp_buffers = 8MB                     # min 800kB
#max_prepared_transactions = 0          # zero disables the feature
                                        # (change requires restart)
# Note:  Increasing max_prepared_transactions costs ~600 bytes of shared memory
# per transaction slot, plus lock space (see max_locks_per_transaction).
# It is not advisable to set max_prepared_transactions nonzero unless you
# actively intend to use prepared transactions.
#work_mem = 1MB                         # min 64kB
#maintenance_work_mem = 16MB            # min 1MB

#max_stack_depth = 2MB                  # min 100kB
```

Kernel changes often required.

Memory Usage (Continued)



Sizing Shared Memory



Kernel Resources

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

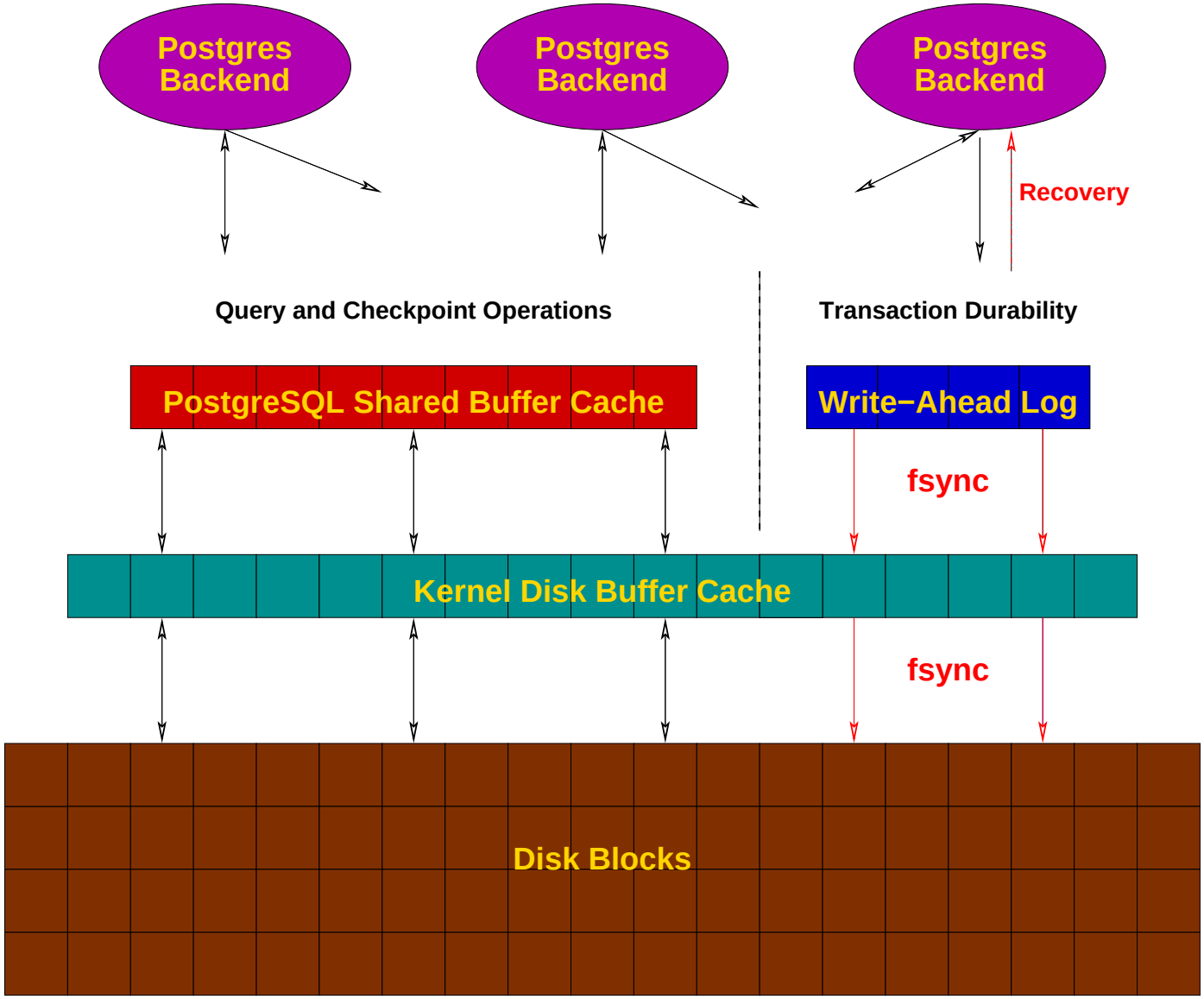
Vacuum and Background Writer

```
# - Cost-Based Vacuum Delay -

#vacuum_cost_delay = 0ms                # 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 multipler on buffers scanned/round

# - Asynchronous Behavior -

#effective_io_concurrency = 1           # 1-1000. 0 disables prefetching
```

Write-Ahead Log (WAL)

```
#wal_level = minimal                    # minimal, archive, or hot_standby
                                        # (change requires restart)
#fsync = on                             # turns forced synchronization on or off
#synchronous_commit = on                # synchronization level; on, off, or local
#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
#full_page_writes = on                  # recover from partial page writes
#wal_buffers = -1                       # min 32kB, -1 sets based on shared_buffers
                                        # (change requires restart)
#wal_writer_delay = 200ms               # 1-10000 milliseconds
#commit_delay = 0                       # range 0-100000, in microseconds
#commit_siblings = 5                    # range 1-1000
```

Write-Ahead Logging (Continued)



Checkpoints and Archiving

```
# - Checkpoints -

#checkpoint_segments = 3                # in logfile segments, min 1, 16MB each
#checkpoint_timeout = 5min              # range 30s-1h
#checkpoint_completion_target = 0.5     # checkpoint target duration, 0.0 - 1.0
#checkpoint_warning = 30s               # 0 disables


# - Archiving -

#archive_mode = off             # allows archiving to be done
                                # (change requires restart)
#archive_command = ''           # command to use to archive a logfile segment
#archive_timeout = 0            # force a logfile segment switch after this
                                # number of seconds; 0 disables
```

Master Replication Server

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


#max_wal_senders = 0             # max number of walsender processes
                                 # (change requires restart)
#wal_sender_delay = 1s           # walsender cycle time, 1-10000 milliseconds
#wal_keep_segments = 0           # in logfile segments, 16MB each; 0 disables
#vacuum_defer_cleanup_age = 0    # number of xacts by which cleanup is delayed
#replication_timeout = 60s       # in milliseconds; 0 disables
#synchronous_standby_names = '' # standby servers that provide sync rep
                                 # comma-separated list of application_name
                                 # from standby(s); '*' = all
```

Standby Replication Server

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

#hot_standby = off                      # "on" allows queries during recovery
                                        # (change requires restart)
#max_standby_archive_delay = 30s        # max delay before canceling queries
                                        # when reading WAL from archive;
                                        # -1 allows indefinite delay
#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
```

Planner Method Tuning

```
#enable_bitmapscan = on
#enable_hashagg = on
#enable_hashjoin = on
#enable_indexscan = 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
#effective_cache_size = 128MB
```

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
```

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 = 'pg_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)

```
# These are relevant when logging to syslog:
#syslog_facility = 'LOCAL0'
#syslog_ident = 'postgres'
#silent_mode = off                          # Run server silently.
                                            # DO NOT USE without syslog or
                                            # logging_collector
                                            # (change requires restart)
```

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 = ''

# 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
#   %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
#   %% = '%'
```

What to Log (Continued)

```
#log_lock_waits = off                   # log lock waits >= deadlock_timeout
#log_statement = 'none'                 # none, ddl, mod, all
#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 = '(defaults to server environment setting)'
```

Runtime Statistics

```
# - Query/Index Statistics Collector -

#track_activities = on
#track_counts = on
#track_functions = none                 # none, pl, all
#track_activity_query_size = 1024       # (change requires restart)
#update_process_title = on
#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_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_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
#vacuum_freeze_min_age = 50000000
#vacuum_freeze_table_age = 150000000
#bytea_output = 'hex'                    # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
```

Locale and Formatting

```
datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
#timezone = '(defaults to server environment setting)'
#timezone_abbreviations = 'Default'     # Select the set of available time zone
                                        # abbreviations.  Currently, there are
                                        #   Default
                                        #   Australia
                                        #   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 messages
                                                # 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'
```

Full Text Search

```
# default configuration for text search
default_text_search_config = 'pg_catalog.english'
```

Other Defaults

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

Lock Management

```
#deadlock_timeout = 1s
#max_locks_per_transaction = 64         # min 10
                                        # (change requires restart)
# Note:  Each lock table slot uses ~270 bytes of shared memory, and there are
# max_locks_per_transaction * (max_connections + max_prepared_transactions)
# lock table slots.
#max_pred_locks_per_transaction = 64    # min 10
                                        # (change requires restart)
```

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
#quote_all_identifiers = off
#sql_inheritance = on
#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?
```

Custom Variables

```
#custom_variable_classes = ''          # list of custom variable class names
```

Interfaces

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

Include Files

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

Library Files

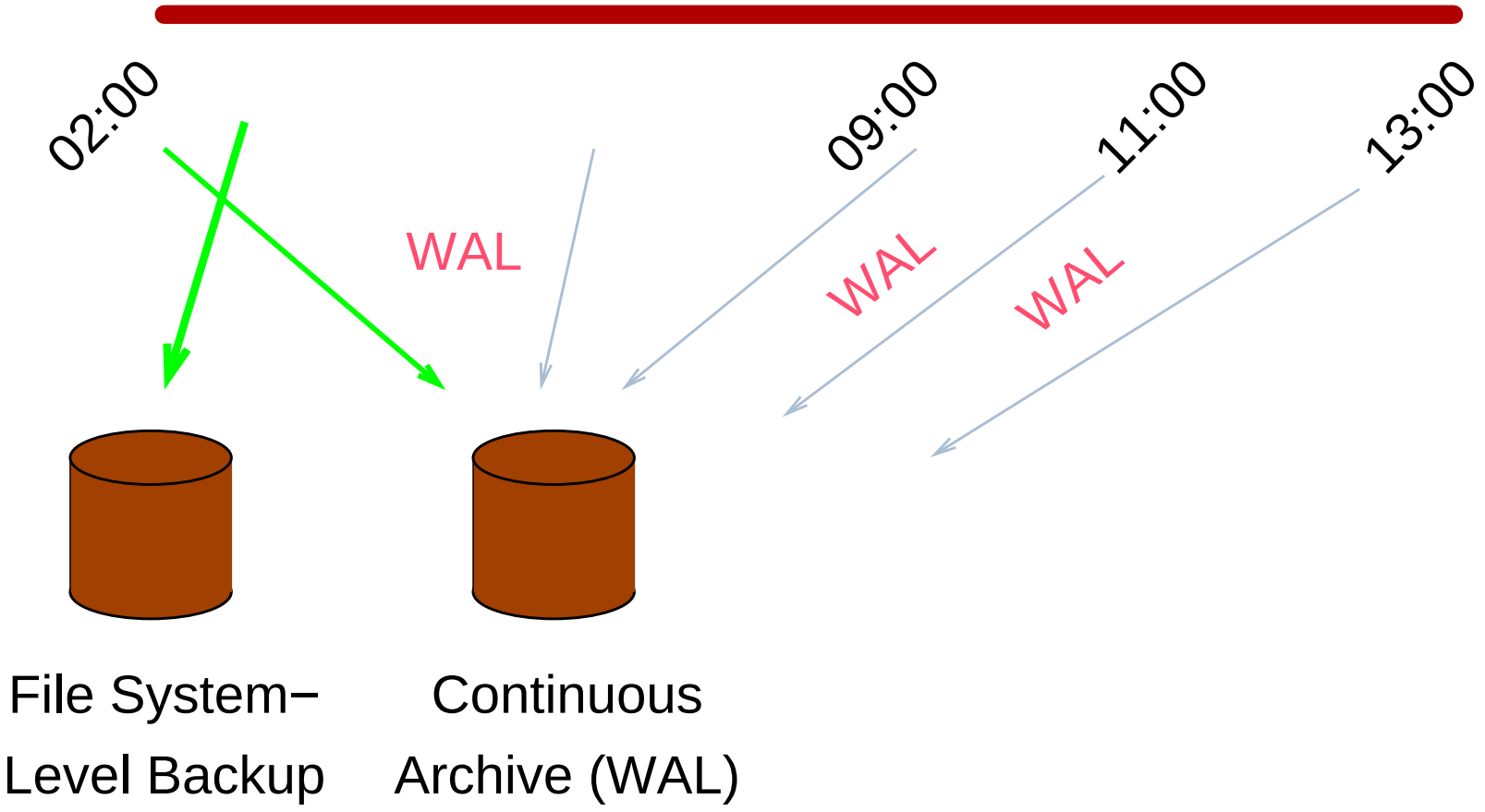
```
$ ls -CF lib/
ascii_and_mic.so*       libecpg.so.6.3*       utf8_and_cyrillic.so*
cyrillic_and_mic.so*    libpgport.a           utf8_and_euc2004.so*
dict_snowball.so*       libpgtypes.a          utf8_and_euc_cn.so*
euc2004_sjis2004.so*    libpgtypes.so@        utf8_and_euc_jp.so*
euc_cn_and_mic.so*      libpgtypes.so.3@      utf8_and_euc_kr.so*
euc_jp_and_sjis.so*     libpgtypes.so.3.2*    utf8_and_euc_tw.so*
euc_kr_and_mic.so*      libpq.a               utf8_and_gb18030.so*
euc_tw_and_big5.so*     libpq.so@             utf8_and_gbk.so*
latin2_and_win1250.so*  libpq.so.5@           utf8_and_iso8859_1.so*
latin_and_mic.so*       libpq.so.5.4*         utf8_and_iso8859.so*
libecpg.a               libpqwalreceiver.so*  utf8_and_johab.so*
libecpg_compat.a        pgxs/                 utf8_and_sjis2004.so*
libecpg_compat.so@      plperl.so*            utf8_and_sjis.so*
libecpg_compat.so.3@    plpgsql.so*           utf8_and_uhc.so*
libecpg_compat.so.3.3*  plpython2.so*         utf8_and_win.so*
libecpg.so@             utf8_and_ascii.so*
libecpg.so.6@           utf8_and_big5.so*
```

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)

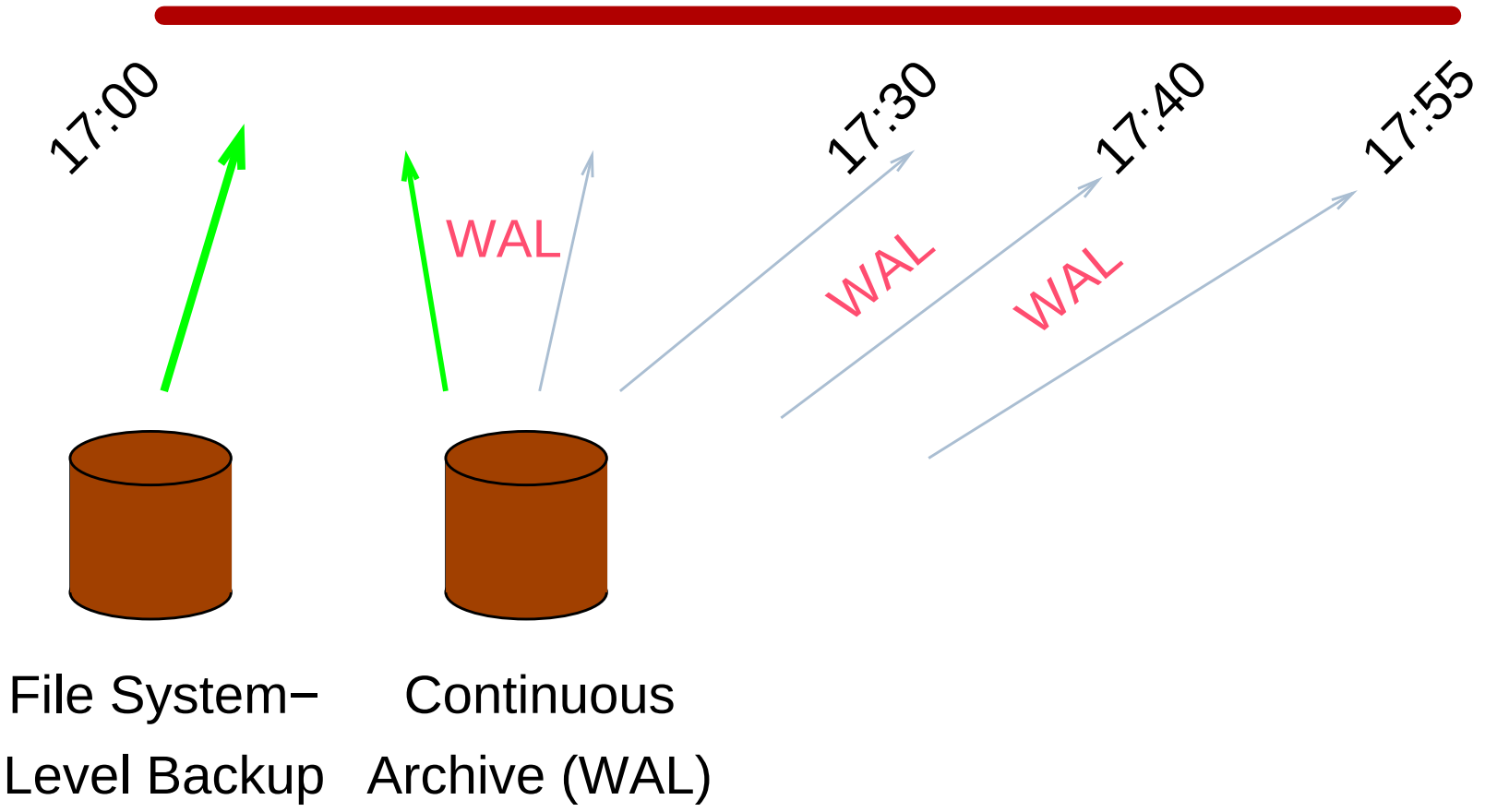


PITR Backup Procedures

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 and can be run on version 9.2+ standbys.

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

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

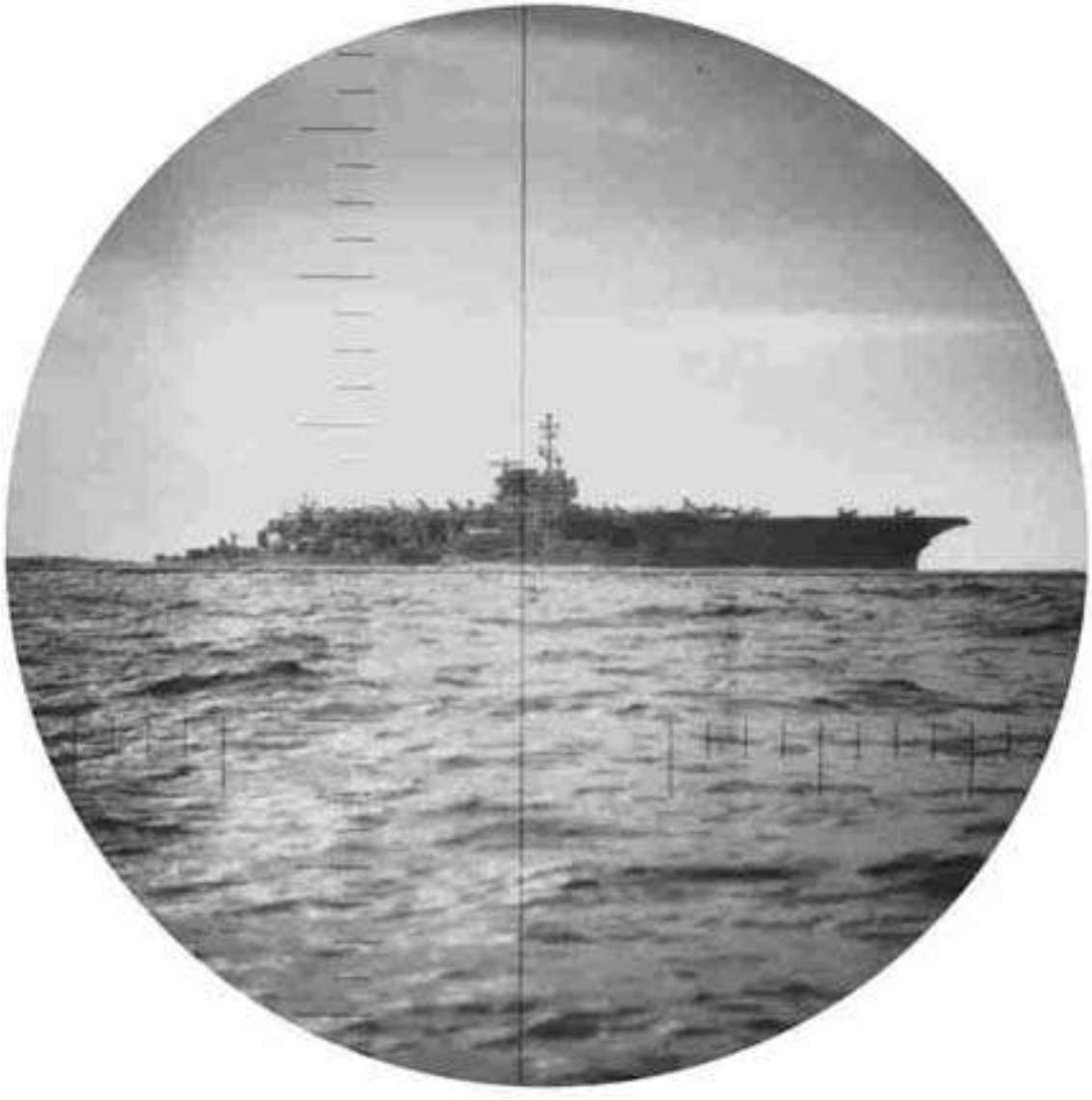
Automating Tasks

Autovacuum handles vacuum and analyze tasks automatically.

Checkpoints

- Write all dirty shared buffers
- Sync all dirty kernel buffers
- Recycle WAL files
- Check for server messages indicating too-frequent checkpoints
- If so, increase *checkpoint_segments*

Monitoring Active Sessions



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
load averages:  0.56,  0.39,  0.36                                    18:25:58
138 processes: 5 running, 130 sleeping, 3 zombie
CPU states: 50.0% user,  0.0% nice,  0.0% system,  0.0% interrupt, 50.0% idle
Memory: Real: 96M/133M Virt: 535M/1267M Free: 76M

  PID USERNAME PRI NICE  SIZE   RES STATE   TIME   WCPU    CPU COMMAND
23785 postgres  57    0   11M 5336K run/0   0:07 30.75% 30.66% postmaster
23784 postgres   2    0   10M   11M sleep   0:00  2.25%  2.25% psql
```

Query Monitoring

```
test=> SELECT * FROM pg_stat_activity;
-[ RECORD 1 ]----+---------------------------------
datid            | 16384
datname          | test
procpid          | 29964
usesysid         | 10
usename          | postgres
application_name | psql
client_addr      |
client_port      | -1
backend_start    | 2011-04-04 08:27:33.089199-04
xact_start       | 2011-04-04 08:27:47.901121-04
query_start      | 2011-04-04 08:27:47.901121-04
waiting          | f
current_query    | SELECT * FROM pg_stat_activity;
```

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
(11 rows)
```

Database File Mapping - oid2name

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

Table File Mapping

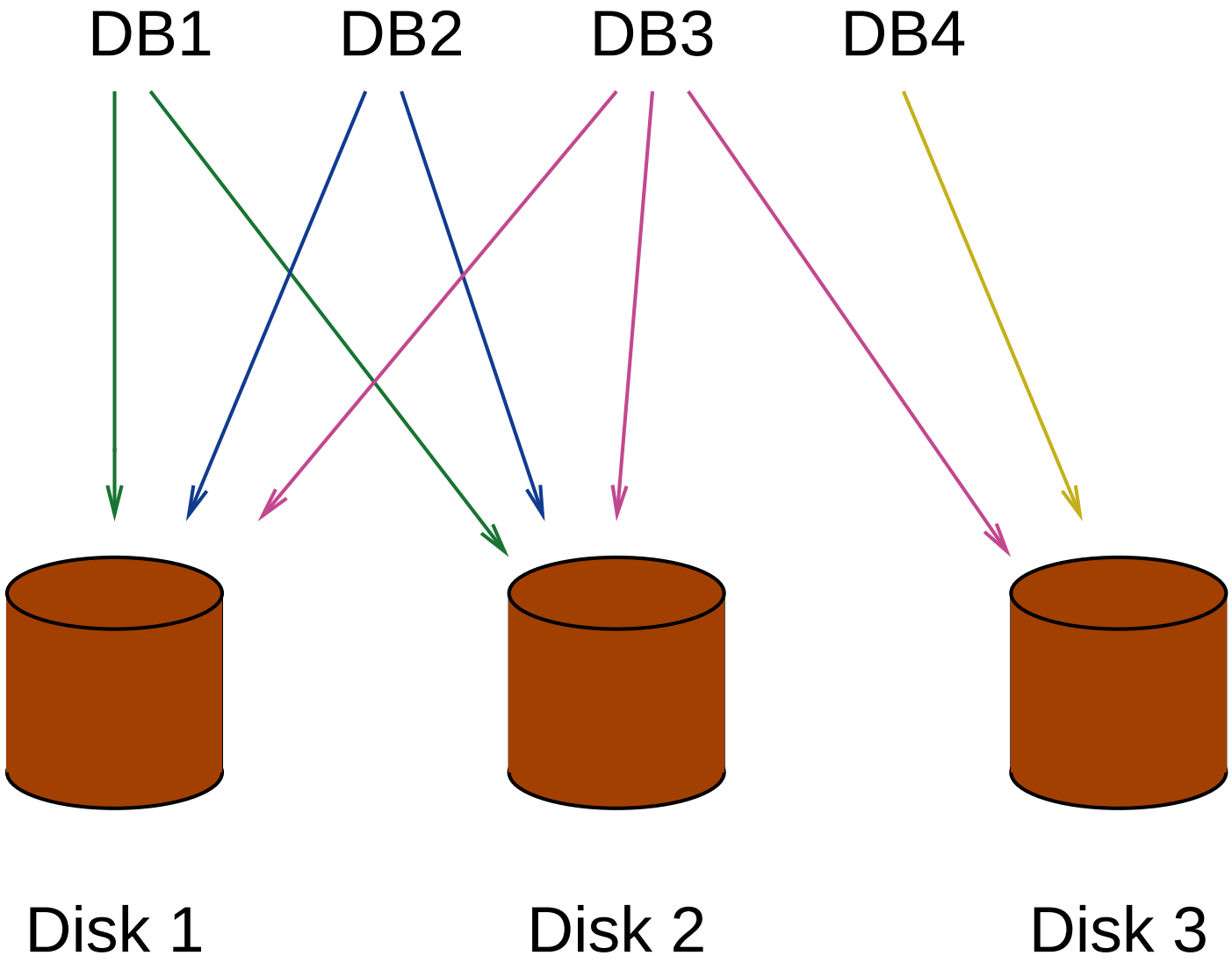
```
$ cd /usr/local/pgsql/data/base
$ oid2name
All databases:
----------------------------------
16817  = test2
16578  = x
16756  = test
1      = template1
16569  = template0
16818  = test3
16811  = floattest

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

```
$ 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
```

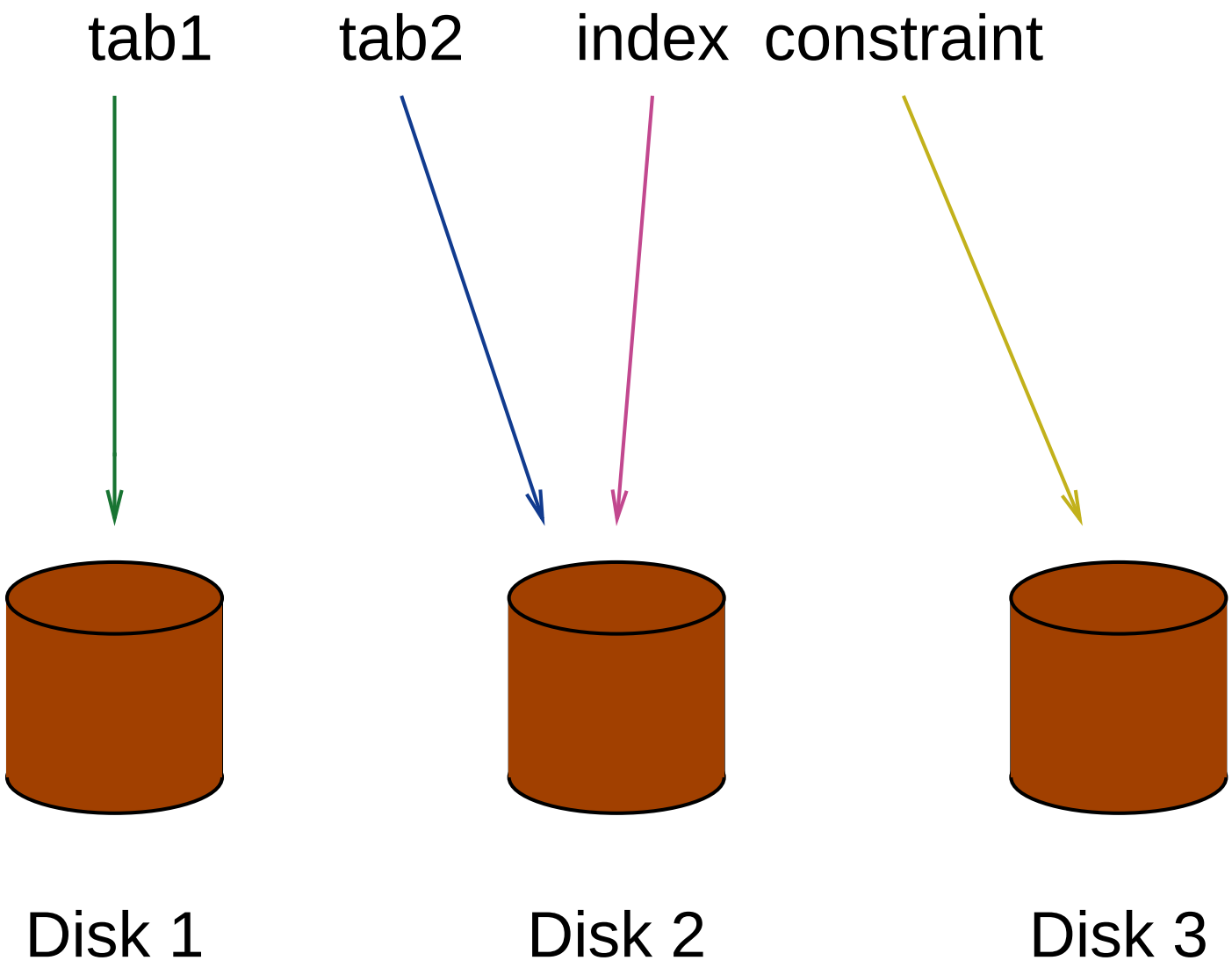
Disk Balancing

- Move pg_xlog 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
(9 rows)
```

Miscellaneous Tasks

- Log file rotation, syslog
- Upgrading
  - pg_dump, restore
  - pg_upgrade
  - Slony
- Migration

Administration Tools

- pgadmin
- phppgadmin

External Monitoring Tools

- Alerting: check_postgres, tail_n_mail, Nagios
- Analysis: Munin, Cacti, Zabbix, Nagios, MRTG
- Queries: pgbadger, pgFouine
- Commercial: Circonus (or open-source Reconnoiter), Postgres Enterprise Manager (PEM), Hyperic

Recovery

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

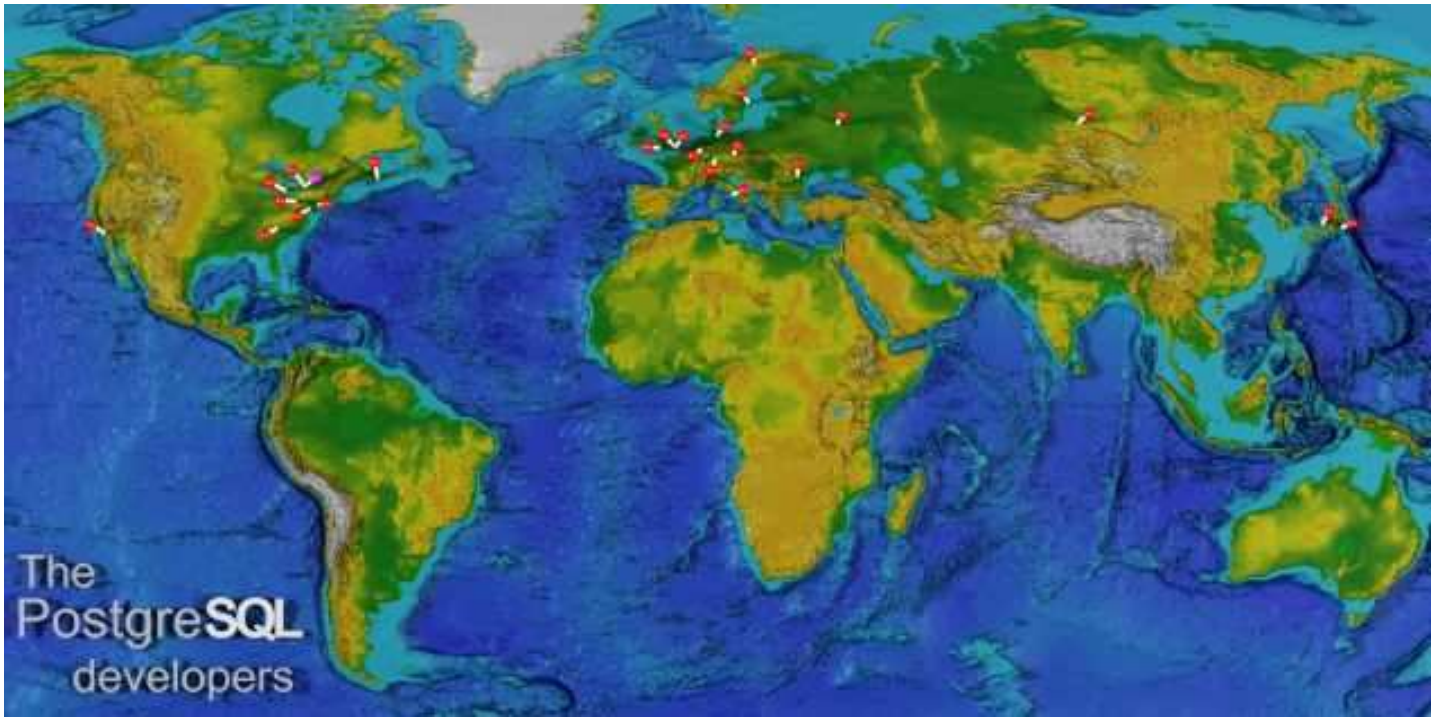
Index Corruption

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 http://sources.redhat.com/rhdb/tools.html to analyze the internal structure of the table.

Conclusion



http://momjian.us/presentations