Hewlett Packard
Enterprise

May 22, 2017

PostgreSQL 10 New Features

With Examples

Hewlett-Packard Enterprise Japan Co, Ltd.
Noriyoshi Shinoda

Hewlett Packard
Enterprise

Index

Hewlett Packard
Enterprise

1. About This Document

1.1 Purpose

The purpose of this document is to provide information of the major new features of PostgreSQL 10, the Beta 1 version being published.

1.2 Audience

This document is written for engineers who already have knowledge of PostgreSQL, such as installation, basic management, etc.

1.3 Scope

This document describes the major difference between PostgreSQL 9.6 and PostgreSQL 10 Beta 1. As a general rule, this document examines the functions that users can see when they see changes. It does not describe and verify all new features. In particular, the following new functions are not included.

- Bug fix
- Performance improvement by changing internal behavior
- Improvement of regression test
- Operability improvement by psql command tab input
- Improvement of pgbench command (partly described)
- Improve documentation, modify typo in the sources

1.4 Software Version

This document is being verified for the following versions and platforms.

Table 1 Version

Software	Versions
PostgreSQL	PostgreSQL 9.6.3 (for comparison) PostgreSQL 10 Beta 1 (May 15, 2017 21:27:43)
Operating System	Red Hat Enterprise Linux 7 Update 1 (x86-64)

1.5 Question, Comment, and Responsibility

The contents of this document are not an official opinion of the Hewlett-Packard Enterprise Japan Co, Ltd. The author and affiliation company do not take any responsibility about the problem caused by the mistake of contents. If you have any comments for this document, please contact to Noriyoshi Shinoda (noriyoshi.shinoda@hpe.com) Hewlett-Packard Enterprise Japan Co, Ltd.

1.6 Notation

This document contains examples of the execution of the command or SQL statement. Execution examples are described according to the following rules:

Table 2 Examples notation

Notation	Description
#	Shell prompt for Linux root user
$	Shell prompt for Linux general user
bold	User input string
postgres=#	psql command prompt for PostgreSQL administrator
postgres=>	psql command prompt for PostgreSQL general user
underline	Important output items

The syntax is described in the following rules:

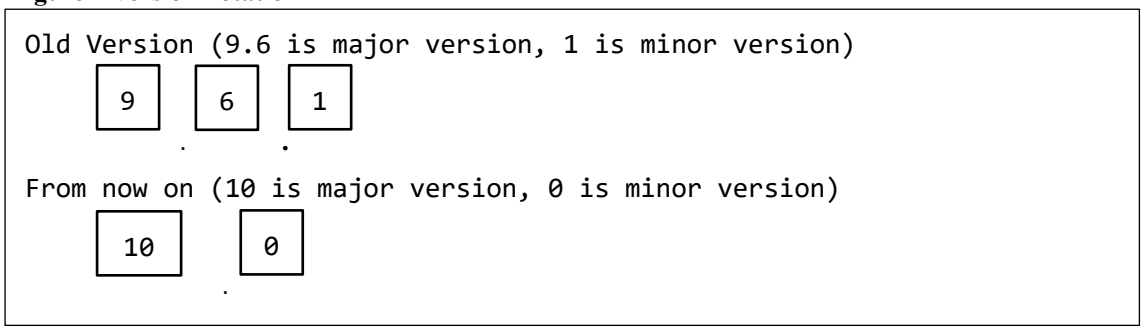
Table 3 Syntax rules

Notation	Description
Italic	Replaced by the name of the object which users use, or the other syntax
[ABC]	Indicate that it can be omitted
{ A | B }	Indicate that it is possible to select A or B
…	General syntax, it is the same as the previous version

2. Version notation

The notation of major version and minor version is changed from PostgreSQL 10. In the past, the first two numbers indicated major versions, but only the first number will indicate the major version in the future.

Figure 1 Version notation



3. New Features

3.1 Overview

More than 100 new features have been added to PostgreSQL 10. Here are some typical new features and benefits.

3.1.1 For large amount data

□ Native Partition Table

Native Partition Table is provided as a method of physically partitioning a large scale table. Unlike table partitioning using conventional inheritance table, performance during data insertion has been greatly improved. Providing the Native Partition Table makes building a large database easier.

□ Logical Replication

With the Logical Replication feature, it is possible to replicate only some tables between multiple instances. In traditional streaming replication, slave side instances were read-only, but tables synchronized by Logical Replication are updatable. Therefore, it is possible to create an index for analysis query to the slave side instance. Details are described in "3.3 Logical Replication".

□ Enhancement of Parallel Query

In PostgreSQL 9.6, a parallel query feature was provided to improve the query performance for large tables. Parallel query was used only in "Seq Scan" in PostgreSQL 9.6, but parallel queries are now available in many situations such as "Index Scan", "Merge Join", "Bitmap Join" and so on. It is expected to improve query performance for large amount tables. Details are described in "3.4 Extended Parallel Query".

3.1.2 For reliability improvement

Quorum-based synchronous replication for arbitrarily selecting instances for synchronous replication is now available (3.7 Quorum-base synchronous replication). Hash index that did not output WAL before PostgreSQL 9.6 now output WAL. For this reason, hash index is also available in replication environments (3.5.7 Hash index WAL).

3.1.3 For maintenance task

Wait events that are output in the pg_stat_activity catalog has been increased significantly. Information of all backend processes can now be referred (3.5.2 catalog change). A dedicated role to check the system load has been added (3.5.8 Addition of role).

3.1.4 Incompatibility

Unfortunately, some features of PostgreSQL 10 are incompatible with previous versions.

□ Change name

All the name XLOG was unified to WAL. For this reason, directory names in the database cluster, utility command names, function names, parameter names, and error messages named XLOG have been changed. For example, the pg_xlog directory in the database cluster has been changed to the pg_wal directory. The pg_receivexlog command has been changed to the pg_receivewal command. The default value of the directory where the log file is output has been changed from pg_log to log. Details are described in "3.5.4 Change from XLOG to WALL".

□ Default behavior of pg_basebackup utility

By default WAL streaming is used in PostgreSQL 10. Also, the -x parameter has been deprecated. Details are described in "3.11.3 pg_basebackup".

□ Wait mode of pg_ctl utility

By default, the behavior has been changed to wait for processing to complete on all operations. In the previous version, pg_ctl command did not wait for the completion of processing in instance startup processing etc. Details are described in "3.11.2 pg_ctl".

□ Deprecated of plain password store

It is no longer possible to save the password without encrypting it. This will improve security. Details are described in "3.9.12 CREATE USER statement" and "3.10.2 Changed parameters".

□ Deprecated parameters

The parameter min_parallel_relation_size has been changed to min_parallel_table_scan_size. The parameter sql_inheritance has been deprecated. Details are described in "3.10.4 Obsolete parameters".

□ Functions behavior changed

The to_date and to_timestamp functions have changed behavior. As a result of strict checking of the numerics of each element part of the date/time, errors will occur with values that were not problematic in the previous version. Also, the make_date function can now specify a date in BC. Details are described in "3.9.13 Function".

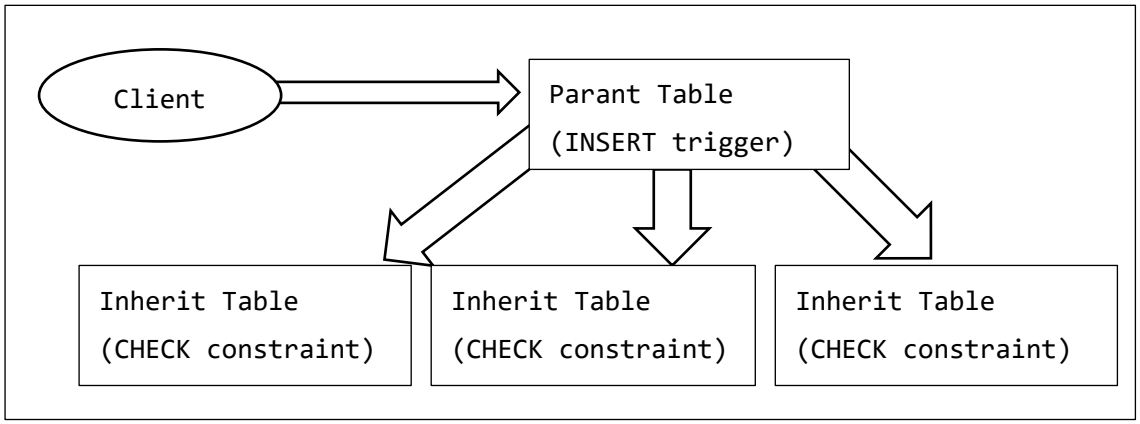
3.2 Native Partition Table

3.2.1 Overview

Traditional PostgreSQL used the function of the inheritance table as a method of physically partitioning a large table. The inheritance table creates multiple child tables for the parent table and maintains the consistency of data by CHECK constraints and triggers. The application can access the parent table and transparently use the data of the child table. However, this method had the following disadvantages.

- Data consistency depends on the CHECK constraint specified individually in the child table
- INSERT statements for the parent table need to redirect to child tables by triggers so that it is slower

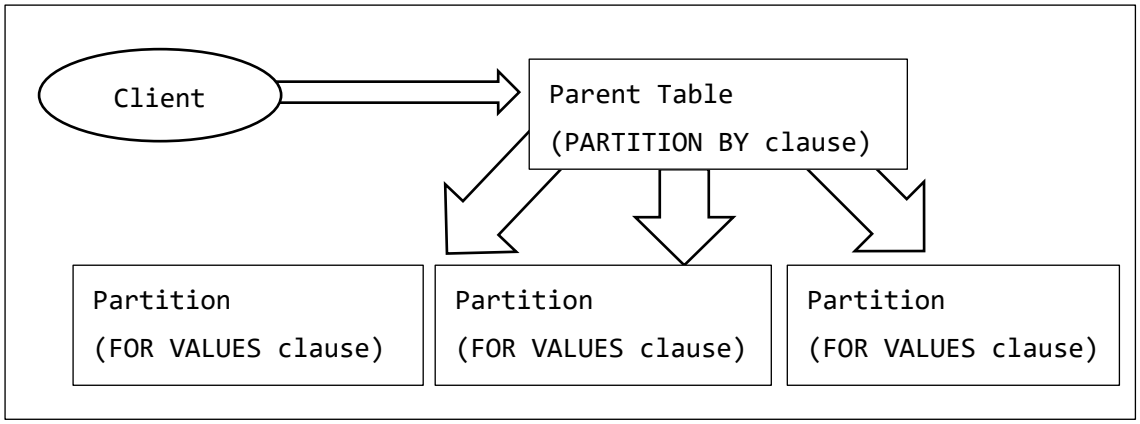
Figure 2 Structure of table partition using inheritance table



In PostgreSQL 10, partition table feature uses a more sophisticated table distribution method. It is the same as the conventional inheritance table that the partition table consists of child tables having the same structure as the parent table accessed by the application. However, INHERIT specification, CHECK constraint, trigger are unnecessary, so that addition or deletion of the child table can be done easily.

In PostgreSQL 10, the column (or calculated value) to be specified for partitioning table. RANGE partitions that specify the range of values to be stored and LIST partitions that specify only specific values are available. The type of the partition is determined when creating the parent table.

Figure 3 Partitioning table structure



3.2.2 List Partition Table

The LSIT partition table is a way to group multiple partitions that can only store certain values. To create a list partition table, first create a parent table accessed by the application, specifying the PARTITION BY LIST clause in the CREATE TABLE statement. In the LIST clause, specify the column name (or calculated value) to be partitioned. Only one column name can be specified. At this point the INSERT statement for the table fails. For tables created with PARTITION BY clause, the value of the "relkind" column in the pg_class catalog is 'p'.

Example 1 Create LIST partition table

```
postgres=> CREATE TABLE plist1(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY
LIST (c1) ;
CREATE TABLE
```

Next, create a child table (partition) where data is actually stored. In doing so, specify the parent table using the PARTITION OF clause and specify the value to include in the partition column using the FOR VALUES IN clause. Multiple values can be specified, separated by commas (,).

Example 2 Create child table

```
postgres=> CREATE TABLE plist1_v100 PARTITION OF plist1 FOR VALUES IN (100) ;
CREATE TABLE
postgres=> CREATE TABLE plist1_v200 PARTITION OF plist1 FOR VALUES IN (200) ;
CREATE TABLE
```

In the following example, refer to the definition of the partition table which has been created.

Example 3 Reference table definition

```
postgres=> \d+ plist1
                                        Table "public.plist1"
 Column |        Type         | Collation | Nullable | Default | Storage  | …
--------+---------------------+-----------+----------+---------+----------+…
 c1     | numeric             |           |          |         | main     |…
 c2     | character varying(10) |           |          |         | extended |…
Partition key: LIST (c1)
Partitions: plist1_v100 FOR VALUES IN ('100'),
            plist1_v200 FOR VALUES IN ('200')

postgres=> \d+ plist1_v100
                                     Table "public.plist1_v100"
 Column |        Type         | Collation | Nullable | Default | …
--------+---------------------+-----------+----------+---------+ …
 c1     | numeric             |           |          |         | …
 c2     | character varying(10) |           |          |         | …
Partition of: plist1 FOR VALUES IN ('100')
Partition constraint: ((c1 IS NOT NULL) AND (c1 = ANY (ARRAY['100'::numeric])))
```

The INSERT statement for the parent table is automatically distributed to the partitioned child table. An INSERT statement of data not included in the partition will result in an error.

Example 4 Execution of INSERT statement on parent table

```
postgres=> INSERT INTO plist1 VALUES (100, 'data1') ;
INSERT 0 1
postgres=> INSERT INTO plist1 VALUES (200, 'data2') ;
INSERT 0 1
postgres=> INSERT INTO plist1 VALUES (300, 'data3') ;
ERROR:  no partition of relation "plist1" found for row
DETAIL:  Partition key of the failing row contains (c1) = (300).
```

Partitioned child tables are also directly accessible. However, values other than the values specified in the partition target column cannot be stored.

□ Obtaining partition information

The pg_get_partkeydef function can be used to obtain the partition method and column information. Restrictions on each partition can be obtained with the pg_get_partition_constraintdef function.

Example 5 Obtain partition information

```
postgres=> SELECT pg_get_partkeydef('plist1'::regclass) ;
 pg_get_partkeydef
-------------------
 LIST (c1)
(1 row)

postgres=> SELECT pg_get_partition_constraintdef('plist1_v100'::regclass) ;
             pg_get_partition_constraintdef
------------------------------------------------------------
 ((c1 IS NOT NULL) AND (c1 = ANY (ARRAY['100'::numeric])))
(1 row)
```

3.2.3 Range Partition Table

The RANGE partition table is a way to group multiple partitions that can store a range of specific values. To create a range partition table, first create a parent table accessed by the application. Specify the PARTITION BY RANGE clause in the CREATE TABLE statement. In the RANGE clause, specify the column name (or calculated value) to be partitioned. Multiple column names can be specified by separating them with a comma (,). A NOT NULL constraint is automatically set for the partitioned columns (except for calculated values). At this point the INSERT statement for the table fails.

Example 6 Create RANGE Partition Table

```
postgres=> CREATE TABLE prange1(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY
RANGE (c1) ;
CREATE TABLE
```

Next, create a child table (partition) where data is actually stored. Use the PARTITION OF clause to specify the parent table and use the FOR VALUES FROM TO clause to specify the range of values to include in the partition. Only the value of "FROM <= value < TO" can be stored in the partition.

Example 7 Create child table

```
postgres=> CREATE TABLE prange1_a1 PARTITION OF prange1 FOR VALUES FROM
(100) TO (200) ;
CREATE TABLE
postgres=> CREATE TABLE prange1_a2 PARTITION OF prange1 FOR VALUES FROM
(200) TO (300) ;
CREATE TABLE
```

In the following example, refer to the definition of the partition table which has been created.

Example 8 Reference table definition

```
postgres=> \d+ prange1
                                    Table "public.prange1"
 Column |         Type          | Collation | Nullable | Default | …
--------+-----------------------+-----------+----------+---------+ …
 c1     | numeric               |           | not null |         | …
 c2     | character varying(10) |           |          |         | …
Partition key: RANGE (c1)
Partitions: prange1_a1 FOR VALUES FROM ('100') TO ('200'),
            prange1_a2 FOR VALUES FROM ('200') TO ('300')

postgres=> \d+ prange1_a1
                                   Table "public.prange1_a1"
 Column |         Type          | Collation | Nullable | Default | …
--------+-----------------------+-----------+----------+---------+ …
 c1     | numeric               |           | not null |         | …
 c2     | character varying(10) |           |          |         | …
Partition of: prange1 FOR VALUES FROM ('100') TO ('200')
Partition constraint: ((c1 >= '100'::numeric) AND (c1 < '200'::numeric))
```

The INSERT statement for the parent table is automatically distributed to the partitioned child table. An INSERT statement of data not included in the partition will result in an error.

Example 9 Execution of INSERT statement on parent table

```
postgres=> INSERT INTO prange1 VALUES (100, 'data1') ;
INSERT 0 1
postgres=> INSERT INTO prange1 VALUES (200, 'data2') ;
INSERT 0 1
postgres=> INSERT INTO prange1 VALUES (300, 'data3') ;
ERROR:  no partition of relation "prange1" found for row
DETAIL:  Partition key of the failing row contains (c1) = (300).
```

Partitioned child tables are also directly accessible. However, values other than the values specified in the partition target column cannot be stored.

Example 10 Access to child table

```
postgres=> SELECT * FROM prange1_a1 ;
 c1  |  c2
-----+-------
 100 | data1
(1 row)
postgres=> INSERT INTO prange1_a1 VALUES (200, 'data2') ;
ERROR:  new row for relation "prange1_a1" violates partition constraint
DETAIL:  Failing row contains (200, data2).
```

□ UNBOUNDED specification of range

UNBOUNDED can be specified in the FROM clause or TO clause of the RANGE partition in addition to concrete values. This designation can create partitions that do not limit the lower limit (FROM) or upper limit (TO) range. In the example below, two tables are specified with a value less than 100 and a value of 100 or more as the partition of the prange1 table.

Example 11 UNBOUNDED designation

```
postgres=> CREATE TABLE prange1_1 PARTITION OF prange1 FOR VALUES FROM
(UNBOUNDED) TO (100) ;
CREATE TABLE
postgres=> CREATE TABLE prange1_2 PARTITION OF prange1 FOR VALUES FROM
(100) TO (UNBOUNDED) ;
CREATE TABLE
```

A partition that specifies "a value to divide a partition containing an existing UNBOUNDED value" can not be added.

Example 12 Split UNBOUNDED partition

```
postgres=> CREATE TABLE prange1_3 PARTITION OF prange1 FOR VALUES FROM
(200) TO (300) ;
ERROR:  partition "prange1_3" would overlap partition "prange1_2"
```

3.2.4 Existing tables and partitions

Validation of how to register an existing table in the partition table and remove it from the partition table.

□ ATTACH of child table

An existing table can be attached as a partition (child table) in a parent table. The child table must be created in the same column configuration as the parent table. Also, it is possible to detach a table registered as a partition into a normal table.

Example 13 Create a table with the same structure as the parent table

```
postgres=> CREATE TABLE plist1_v100 (LIKE plist1) ;
CREATE TABLE
postgres=> CREATE TABLE plist1_v200 (LIKE plist1) ;
CREATE TABLE
```

Attach the created table as a partition of the parent table. Use the ALTER TABLE ATTACH PARTITION statement. At the same time, specify the value of the partitioning column. In the example below, a plist1_v100 table storing data of LIST partition c1=100 and a plist1_v200 table storing data of c1=200 are registered.

Example 14 Attach a partition

```
postgres=> ALTER TABLE plist1 ATTACH PARTITION plist1_v100 FOR VALUES IN (100) ;
ALTER TABLE
postgres=> ALTER TABLE plist1 ATTACH PARTITION plist1_v200 FOR VALUES IN (200) ;
ALTER TABLE
```

Objects that can be registered as partitions are limited to tables or FOREIGN TABLE.

□ DETACH of child table

To remove the partitioned child table from the parent table, execute the ALTER TABLE DETACH statement

Example 15 Detach a partition

```
postgres=> ALTER TABLE plist1 DETACH PARTITION plist1_v100 ;
ALTER TABLE
```

3.2.5 Operation on partition table

Validation of the behavior when executing DDL or COPY statement for the parent table or child table.

□ TRUNCATE for parent table

Execution of the TRUNCATE statement for the parent table propagates to all partitions.

Example 16 TRUNCATE for parent table

```
postgres=> TRUNCATE TABLE part1 ;
TRUNCATE TABLE
postgres=> SELECT COUNT(*) FROM part1_v1 ;
 count
-------
     0
(1 row)
```

□ COPY for parent table

The COPY statement for the parent table propagates to the child table.

Example 17 COPY for parent table

```
postgres=# COPY part1 FROM '/home/postgres/part1.csv' WITH (FORMAT text) ;
COPY 10000
postgres=# SELECT COUNT(*) FROM part1_v1 ;
 count
-------
 10000
(1 row)
```

□ DROP parent table

Dropping the parent table also drops all child tables. The DROP TABLE statement for the child table drops only the child table.

□ Add / delete columns to the parent table

When adding / deleting a column to / from the parent table, the child table is changed in the same way. However, columns that are partition keys cannot be deleted. Also, if the partition is FOREIGN TABLE, column addition is not done automatically.

Example 18 Adding and deleting columns from the parent table

```
postgres=> \d part1
                    Table "public.part1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          |
 c2     | character varying(10) |           |          |
Partition key: LIST (c1)
Number of partitions: 2 (Use \d+ to list them.)

postgres=> ALTER TABLE part1 ADD c3 NUMERIC ;
ALTER TABLE
postgres=> \d part1_v1
                    Table "public.part1_v1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          |
 c2     | character varying(10) |           |          |
 c3     | numeric               |           |          |
Partition of: part1 FOR VALUES IN ('100')

postgres=> ALTER TABLE part1 DROP c1 ;
ERROR:  cannot drop column named in partition key
```

□ TEMPORARY table

A TEMPORARY table can be used for both parent table and partitioned child table. However, if the parent table is a temporary table, the partition table must also be a temporary table.

□ UNLOGGED table

An UNLOGGED table can be used for parent table or partition table.

□ Hierarchical structure

By partitioning different columns, hierarchical partition table can be created. In the example below, a table partitioned by column c2 is added under the table partitioned by column c1.

Example 19 Hierarchical partition

```
postgres=> CREATE TABLE part2 (c1 NUMERIC, c2 NUMERIC, c3 VARCHAR(10)) PARTITION
BY LIST (c1) ;
CREATE TABLE
postgres=> CREATE TABLE part2_v1 PARTITION OF part2 FOR VALUES IN (100) PARTITION
BY LIST (c2) ;
CREATE TABLE
postgres=> CREATE TABLE part2_v1_v2 PARTITION OF part2_v1 FOR VALUES IN (200) ;
CREATE TABLE
```

3.2.6 Execution Plan

If there is a condition to specify the partition to be accessed in the WHERE clause, an execution plan that accesses only specific partitions is created.

Example 20 Partition-identifiable SQL and execution plan

```
postgres=> EXPLAIN SELECT * FROM plist1 WHERE c1 = 100 ;
                          QUERY PLAN
-----------------------------------------------------------------------
 Append  (cost=0.00..20.38 rows=4 width=70)
   ->  Seq Scan on plist1_v100  (cost=0.00..20.38 rows=4 width=70)
         Filter: (c1 = '100'::numeric)
(3 rows)
```

However, when the partition cannot be specified (ex. left side of the WHERE clause is a formula), an execution plan that access all partitions is created.

Example 21 Partition-unspecified SQL and execution plan

```
postgres=> EXPLAIN SELECT * FROM plist1 WHERE c1 + 1 = 101 ;
                          QUERY PLAN
-----------------------------------------------------------------------
 Append  (cost=0.00..44.90 rows=8 width=70)
   ->  Seq Scan on plist1_v100  (cost=0.00..22.45 rows=4 width=70)
         Filter: ((c1 + '1'::numeric) = '101'::numeric)
   ->  Seq Scan on plist1_v200  (cost=0.00..22.45 rows=4 width=70)
         Filter: ((c1 + '1'::numeric) = '101'::numeric)
(5 rows)
```

3.2.7 Catalog

Information on the partitioned parent table can be checked in the pg_partitioned_table catalog. Below is the table information of which name part1, LIST partition (partstrat = 'l'), attached table number 2 (partnatts = 2).

Example 22 Information of the parent table

```
postgres=> SELECT partrelid::regclass, * FROM pg_partitioned_table ;
-[ RECORD 1 ]-+------
partrelid     | part1
partrelid     | 16444
partstrat     | l
partnatts     | 2
partattrs     | 1
partclass     | 3125
partcollation | 0
partexprs     |
```

The table of which the relispartition column in the pg_class catalog is "true" is a child table. When the table is child table, the partition boundary information is stored in the relpartbound column in the pg_class catalog. Information on this column can be converted easily by pg_get_expr function.

Example 23 Information of child table

```
postgres=> SELECT relname, relispartition, relpartbound FROM pg_class WHERE
relname = 'prange1_v1' ;
-[ RECORD 1 ]--+-----------------------------------------------------------
relname       | prange1_v1
relispartition | t
relpartbound    | {PARTITIONBOUND :strategy r :listdatums <> :lowerdatums
({PARTRANGEDATUM :infinite false :value {CONST :consttype 1700 :consttypmod
-1   :constcollid   0   :constlen   -1   :constbyval   false   :constisnull
false :location -1 :constvalue 8 [ 32 0 0 0 0 -128 100 0 ]}}) :upperdatums
({PARTRANGEDATUM :infinite false :value {CONST :consttype 1700 :consttypmod
-1   :constcollid   0   :constlen   -1   :constbyval   false   :constisnull
false :location -1 :constvalue 8 [ 32 0 0 0 0 -128 -56 0 ]}})}

postgres=> SELECT relname, relispartition, pg_get_expr(relpartbound, oid)
FROM pg_class WHERE relname = 'prange1_v1' ;
-[ RECORD 1 ]--+----------------------------------
relname       | prange1_v1
relispartition | t
pg_get_expr    | FOR VALUES FROM ('100') TO ('200')
```

3.2.8 Restriction

The partition table has the following restrictions.

□ Number of partitioning columns

Only one column can be specified in the PARTITION BY LIST clause of the CREATE TABLE statement. In the column name part, it is possible to specify a calculation expression enclosed in functions and parentheses.

Example 24 Partition using function

```
postgres=> CREATE TABLE plist2(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY
LIST (upper(c2)) ;
CREATE TABLE
```

□ NULL for partitioning column

Null values cannot be stored in partitioned columns of RANGE partitions. For a list partition, it can be stored by creating a partition containing NULL values.

Example 25 RANGE partition and NULL value

```
postgres=> CREATE TABLE partnl(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY
RANGE (c1) ;
CREATE TABLE
postgres=> CREATE TABLE partnlv PARTITION OF partnl FOR VALUES FROM
(UNBOUNDED) TO (UNBOUNDED) ;
CREATE TABLE
postgres=> INSERT INTO partnl VALUES (NULL, 'null value') ;
ERROR:  range partition key of row contains null
```

□ Restriction of child table

The child table must have the same structure as the parent table. Excess and deficiency or data type mismatch of column are not allowed.

Example 26 Partition with different structure child table

```
postgres=> CREATE TABLE plist3(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY LIST
(c1) ;
CREATE TABLE
postgres=> CREATE TABLE plist3_v100 (c1 NUMERIC, c2 VARCHAR(10), c3 NUMERIC) ;
CREATE TABLE
postgres=> ALTER TABLE plist3 ATTACH PARTITION plist3_v100 FOR VALUES IN (100) ;
ERROR:  table "plist3_v100" contains column "c3" not found in parent "plist3"
DETAIL:  New partition should contain only the columns present in parent.
postgres=> CREATE TABLE plist3_v200 (c1 NUMERIC);
CREATE TABLE
postgres=> ALTER TABLE plist3 ATTACH PARTITION plist3_v200 FOR VALUES IN (200) ;
ERROR:  child table is missing column "c2"
```

□ Primary Key Constraint / Unique Constraint / Check Constraint

Primary key constraint (or unique constraint) cannot be specified in the parent table. The uniqueness

of the entire partition table depends on the primary key setting of the child table. CHECK constraints on the parent table can be specified. When creating a child table, the CHECK constraint is automatically added to the child table.

Example 27 Add primary key to parent table

```
postgres=> ALTER TABLE plist1 ADD CONSTRAINT pl_plist1 PRIMARY KEY (c1) ;
ERROR:  primary key constraints are not supported on partitioned tables
LINE 1: ALTER TABLE plist1 ADD CONSTRAINT pl_plist1 PRIMARY KEY (c1)...
                                ^
```

□ INSERT ON CONFLICT statement

The INSERT ON CONFLICT statement for the parent table cannot be executed.

□ UPDATE of partitioning column

When updating the value of a partitioned column, it can be updated only to the value contained in the FOR VALUES clause of the child table. It cannot be updated to a value that cannot be included in the child table.

Example 28 Update partitioned column

```
postgres=> UPDATE plist1 SET c1 = 200 WHERE c1 = 100;
ERROR:  new row for relation "plist1_v100" violates partition constraint
DETAIL:  Failing row contains (200, data1).
```

Since the above error occurs, data movement between child tables cannot be realized by UPDATE statement (use DELETE RETURNING INSERT statement).

□ ATTACHing of already stored data table

ATTACHing a child table that stores data already to the parent table is possible. However, in that case, all tuples are checked whether they can be included in the partition.

Example 29 ATTACH of the partition containing the tuple

```
postgres=> CREATE TABLE plist2 (c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY LIST
(c1) ;
CREATE TABLE
postgres=> CREATE TABLE plist2_v100 (LIKE plist2) ;
CREATE TABLE
postgres=> INSERT INTO plist2_v100 VALUES (100, 'data1') ;
INSERT 0 1
postgres=> INSERT INTO plist2_v100 VALUES (200, 'data2') ;
INSERT 0 1
postgres=> ALTER TABLE plist2 ATTACH PARTITION plist2_v100 FOR VALUES IN (100) ;
ERROR:  partition constraint is violated by some row
```

□ Partition where column values overlap

RANGE partitions with overlapping ranges and LIST partitions with the same value cannot be created. In the example below, an attempt is made to attach partitions with column values 100 to 200 and 150 to 300 partitions, but it occurs an error.

Example 30 Partition where column values overlap

```
postgres=> ALTER TABLE prange2 ATTACH PARTITION prange2_v1 FOR VALUES
FROM (100) TO (200) ;
ALTER TABLE
postgres=> ALTER TABLE prange2 ATTACH PARTITION prange2_v2 FOR VALUES
FROM (150) TO (300) ;
ERROR:  partition "prange2_v2" would overlap partition "prange2_v1"
```

□ Specify FOREIGN TABLE as a child table

FOREIGN TABLE can be specified as child table. However, in this case, aggregation push-downis not executed.

Example 31 ATTACH for FOREIGN TABLE

```
postgres=# CREATE FOREIGN TABLE datar2(c1 NUMERIC, c2 VARCHAR(10)) SERVER
remote1 ;
CREATE FOREIGN TABLE
postgres=# ALTER TABLE pfor1 ATTACH PARTITION datar2 FOR VALUES IN ('data2') ;
ALTER TABLE
postgres=# SELECT COUNT(*) FROM pfor1 WHERE c2='data2' ;
```

Example 32 SQL executed on the remote instance

```
statement: START TRANSACTION ISOLATION LEVEL REPEATABLE READ
execute <unnamed>: DECLARE c1 CURSOR FOR
        SELECT NULL FROM public.datar2
statement: FETCH 100 FROM c1
statement: CLOSE c1
statement: COMMIT TRANSACTION
```

The INSERT statement fails if the child table is FOREIGN TABLE.

Example 33 fail of INSERT statement

```
postgres=# INSERT INTO pfor1 VALUES (100, 'data1') ;
ERROR:  cannot route inserted tuples to a foreign table
```

□ Index

It is necessary to create an index for each child table. Indexes cannot be created on the parent table.

Example 34 Index creation failure

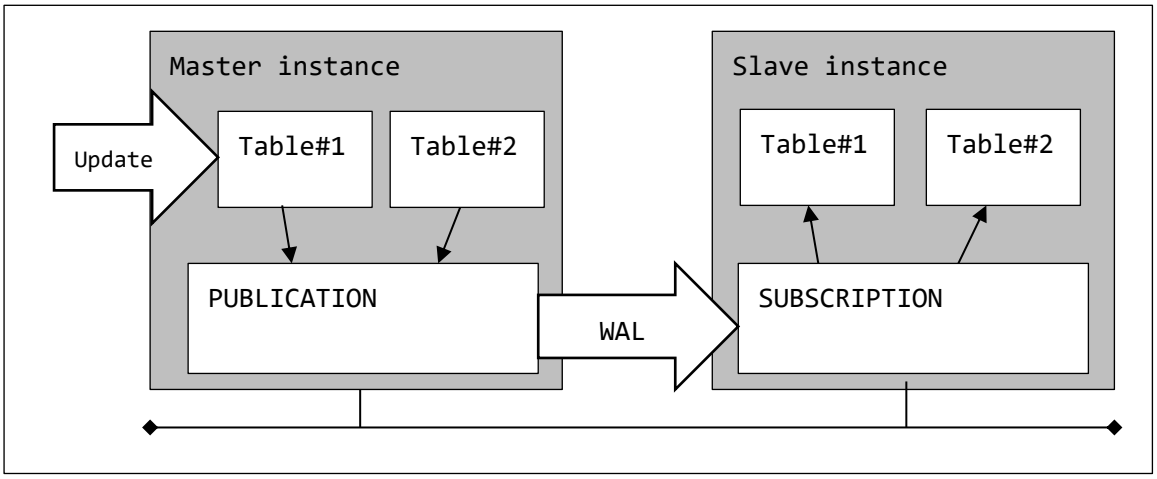
```
postgres=> CREATE TABLE part1(c1 NUMERIC, c2 VARCHAR(10)) PARTITION BY
LIST (c1) ;
CREATE TABLE
postgres=> CREATE INDEX idx1_part1 ON part1(c1) ;
ERROR:  cannot create index on partitioned table "part1"
```

3.3 Logical Replication

3.3.1 Overview

Logical Replication is a function to perform replication between instances for each table. In PostgreSQL 10, in order to realize the Logical Replication function, PUBLICATION object managing the master table and UBSCRIPTION object created in the slave instance are constructed. Replication is performed between tables of the same name including the schema name on the master side and the slave side. Slony-I is existing software with equivalent functions, but it differs in that Logical Replication does not use triggers and the slave side table is also updatable.

Figure 4 Object structure



Logical Replication is implemented by the standard replication plug-in pgoutput based on the basis of Logical Decoding implemented in PostgreSQL 9.4.

□ PUBLICATION object

PUBLICATION is an object created in the master instance. In the PUBLICATION object, register the table to be replicated. Multiple tables can be targeted for replication with a single PUBLICATION object. It is possible to select operations (INSERT / DELETE / UPDATE) to perform replication for each PUBLICATION. By default, all operations (DML) are applied on the slave side. PUBLICATION objects can be created by users with CREATE privilege on the database. In the psql command, a list is displayed with the \dRp command.

Syntax 1 Create PUBLICATION object

```
CREATE PUBLICATION name
[ FOR TABLE [ ONLY ] table_name [*] [, … ] | FOR ALL TABLES ]
[ WITH ( options [ = value] [, …] ) ]
```

The FOR TABLE clause specifies the table to be replicated. It is also possible to specify multiple tables separated by commas (,).In the WITH clause, specify the target DML statement. When omitted, all DML are targeted. The "publish" option by specifying separate the DML name with a comma (,), it is possible to specify the DML of interest. If the ONLY clause is omitted, inherited child tables are also subject to replication.

When FOR ALL TABLES is specified, all tables in the database are subject to replication. When a table is added on PUBLICATION side, it is automatically registered as replication target.

To alter PUBLICATION, execute the ALTER PUBLICATION statement. The replication target table can be added to the PUBLICATION object by specifying the ADD TABLE clause. The DROP TABLE clause deletes replication targets. The SET TABLE clause limits the tables contained in PUBLICATION to the specified table only. To change the DML to be replicated, execute the ALTER PUBLICATION SET statement.

Syntax 2 Alter PUBLICATION object

```
ALTER PUBLICATION name ADD TABLE [ ONLY ] table_name [, table_name … ]
ALTER PUBLICATION name SET TABLE [ ONLY ] table_name [, table_name … ]
ALTER PUBLICATION name DROP TABLE [ ONLY ] table_name [, table_name … ]
ALTER PUBLICATION name SET ( option [ = value ] [ , … ] )
ALTER PUBLICATION name OWNER TO { owner | CURRENT_USER | SESSION_USER }
ALTER PUBLICATION name RENAME TO new_name
```

To delete the PUBLICATION object Execute the DROP PUBLICATION statement.

Syntax 3 Drop PUBLICATION object

```
DROP PUBLICATION [IF EXISTS] name [ , … ] [ { CASCADE | RESTRICT } ]
```

A PUBLICATION object can receive replication requests from multiple SUBSCRIPTION. In addition, the table can belong to more than one PUBLICATION at the same time.

□ SUBSCRIPTION object

SUBSCRIPTION is an object that connects to the PUBLICATION object and updates the table based on the WAL information received via the wal sender process. The table to be updated is a table with the same name (including the schema name) as the table managed by the connection target PUBLICATION object.

To create a SUBSCRIPTION object, execute the CREATE SUBSCRIPTION statement. In the CONNECTION clause, specify the connection string for the instance where the PUBLICATION is created. Specify the name of the database where the PUBLICATION object is created in the dbname parameter. As with streaming replication, it is necessary to connect by users with REPLICATION privilege. It may be necessary to edit the pg_hba.conf file on PUBLICATION side. In the PUBLICATION clause, specify the name of the PUBLICATION object that manages the replication target table. Multiple PUBLICATION objects can be specified. SUPERUSER privilege is required to create SUBSCRIPTION object. In the psql command, a list is displayed with the \dRs command.

Syntax 4 Create SUBSCRIPTION object

```
CREATE SUBSCRIPTION name CONNECTION 'conn_info' PUBLICATION
 publication_name [, publication_name … ]
 [ WITH ( option [ = value ] , … ) ]
```

Table 4 option specification

Syntax	Description	Note
enabled	Enable SUBSCRIPTION	Default
create_slot	Create Replication Slot	Default
slot_name = *name* | NONE	Name of the Replication Slot	Default is SUBSCRIPTION name
copy_data	Copy of the initial data	Default
connect	Connect to PUBLICATION	Default
synchronous_commit	Overrides configuration parameter	Default "off"

By default, Logical Replication Slot with the same name as SUBSCRIPTION is created in the PUBLICATION instance. It is not checked whether the PUBLICATION object specified in the CREATE SUBSCRIPTION statement actually exists.

Syntax 5 Alter SUBSCRIPTION object

```
ALTER SUBSCRIPTION name CONNECTION 'connection'
ALTER SUBSCRIPTION SET PUBLICATION publication_name [, publication_name …]
        { REFRESH [ WITH ( option [ = value ] ) | SKIP REFRESH }
ALTER SUBSCRIPTION name REFRESH PUBLICATION WITH ( option [, option … ] )
ALTER SUBSCRIPTION name { ENABLE | DISABLE }
ALTER SUBSCRIPTION SET ( option [ = value ] [ , … ] )
ALTER SUBSCRIPTION name OWNER TO owner | CURRENT_USER | SESSION_USER
ALTER SUBSCRIPTION name RENAME TO new_name
```

To change the SUBSCRIPTION object, execute the ALTER SUBSCRIPTION statement. The same value as the CREATE SUBSCRIPTION statement can be specified in the option clause. Execution of the ALTER SUBSCRIPTION REFRESH PUBLICATION statement is required when adding a table to the PUBLICATION object.

To drop the SUBSCRIPTION object, use the DROP SUBSCRIPTION statement. By default, it also deletes the replication slots created on the PUBLICATION side. If the instance on the PUBLICATION side is stopped, execute the DROP SUBSCRIPTION statement after releasing the replication slot with the ALTER SUBSCRIPTION DISABLE statement and the ALTER SUBSCRIPTION SET (slot_name = NONE) statement.

Syntax 6 Drop SUBSCRIPTION object

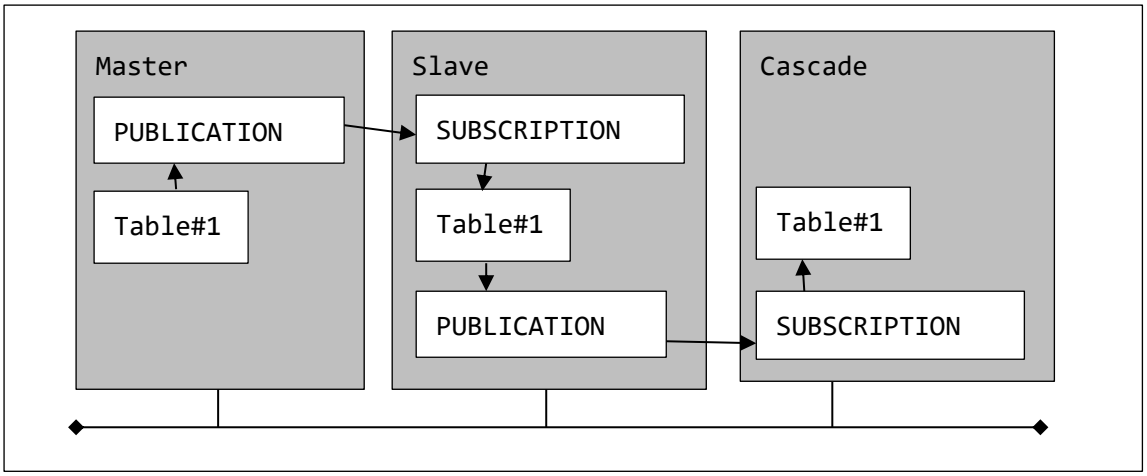
```
DROP SUBSCRIPTION [IF EXISTS] name [ { CASCADE | RESTRICT } ]
```

Since new objects have been added, PUBLICATION and SUBSCRIPTION can now be specified in COMMENT ON and SECURITY LABEL statements.

□ Cascade replication

It was confirmed that the replication environment can be cascaded.

Figure 5 Cascade replication



3.3.2 Related resources

This section describes the objects that constitute Logical Replication and related parameters.

□ Processes

Ordinarily, the process "bgworker: logical replication launcher" is running. The worker process "bgworker: logical replication worker for subscription" is invoked for each SUBSCRIPTION in the instance where the SUBSCRIPTION object is created. The SUBSCRIPTION worker process connects to the master instance. In order to forward the WAL to the SUBSCRIPTION, the wal sender process is started on the master instance.

□ Catalogs

The following catalog has been newly added.

Table 5 Added catalog

Catalog name	Contents	Instance
pg_publication	PUBLICATION information	Master
pg_publication_rel	Table information of WAL transfer target	Master
pg_publication_tables	Table information of WAL transfer target	Master
pg_stat_subscription	WAL information received in SUBSCRIPTION	Slave
pg_subscription	SUBSCRIPTION information	Slave
pg_subscription_rel	Replication table information	Slave

Records are also added to the pg_stat_replication catalog and pg_replication_slots catalog. In the instance where the SUBSCRIPTION object is created, the status of Logical Replication can be checked using the pg_stat_subscription catalog. Users without superuser privilege can view this catalog.

Example 35 Search pg_stat_subscription catalog

```
postgres=> SELECT * FROM pg_stat_subscription ;
-[ RECORD 1 ]---------+-----------------------------
subid                 | 16396
subname               | sub1
pid                   | 23275
relid                 |
received_lsn          | 0/1650C68
last_msg_send_time    | 2017-05-18 23:22:56.654912+09
last_msg_receipt_time | 2017-05-18 23:22:56.654939+09
latest_end_lsn        | 0/1650C68
latest_end_time       | 2017-05-18 23:22:56.654912+09
```

□ Parameters

The following configuration parameters are related to the Logical Replication settings.

Table 6 Related configuration parameters

Parameter name	Instance	Description
max_replication_slots	Master	Maximum number of replication slots
max_wal_senders	Master	Maximum number of wal senders process
max_logical_replication_workers	Slave (new)	Maximum number of logical replication worker processes
wal_level	Master	It must be specified as 'logical'
max_worker_processes	Master / Slave	Maximum number of worker processes
max_sync_workers_per_subscription	Slave (new)	Parallel degree setting when copying initial data

□ Replication Slots

The CREATE SUBSCRIPTION statement creates a replication slot with the same name as SUBSCRIPTION in the PUBLICATION instance (by default). If a replication slot with the same name

already exists, the CREATE SUBSCRIPTION statement will fail.

Example 36 Replication Slot status

```
postgres=> SELECT * FROM pg_replication_slots ;
-[ RECORD 1 ]-------+-----------
slot_name           | sub1
plugin              | pgoutput
slot_type           | logical
datoid              | 16385
database            | postgres
temporary           | f
active              | t
active_pid          | 12140
xmin                |
catalog_xmin        | 606
restart_lsn         | 0/535A1AF0
confirmed_flush_lsn | 0/535A1B28
```

3.3.3 Examples

In the example below, the table schema1.data1 is created for replication. Next, the PUBLICATION object is created and the schema1.data1 table is registered in the PUBLICATION object.

Example 37 Create replication target table (master / slave instance)

```
postgres=> CREATE TABLE schema1.data1(c1 NUMERIC PRIMARY KEY, c2 VARCHAR(10)) ;
CREATE TABLE
```

The PUBLICATION object is created and the schema1.table1 table is added.

Example 38 PUBLICATION object creation (master instance)

```
postgres=> CREATE PUBLICATION pub1 ;
CREATE PUBLICATION
postgres=> ALTER PUBLICATION pub1 ADD TABLE schema1.data1 ;
ALTER PUBLICATION
```

The SUBSCRIPTION object is created. When the SUBSCRIPTION object is created, a replication slot with the same name is created in the PUBLICATION instance. SUPERUSER privilege is required to create SUBSCRIPTION object.

Example 39 Create SUBSCRIPTION object (slave instance)

```
postgres=# CREATE SUBSCRIPTION sub1 CONNECTION 'host=master1 port=5432
user=postgres dbname=postgres' PUBLICATION pub1 ;
NOTICE:  synchronized table states
NOTICE:  created replication slot "sub1" on publisher
CREATE SUBSCRIPTION
```

3.3.4 Collision and inconsistency

Both on the PUBLICATION instance and the SUBSCRIPTION instance, the replication target table is updatable. Therefore, there is a possibility that WAL sent from PUBLICATION cannot be applied on SUBSCRIPTION side. If problems such as data collision occur, the subscription worker process stops and restarts at 5 second intervals. The following example is a log when a primary key violation occurs (on the SUBSCRIPTION side). The constraints (PRIMARY KEY, UNIQUE, CHECK) set in the SUBSCRIPTION side table are checked against the data transferred from the PUBLICATION side.

Example 40 Log that detected primary key violation on SUBSCRIPTION side

```
ERROR:  duplicate key value violates unique constraint "data1_pkey"
DETAIL:  Key (c1)=(14) already exists.
LOG:  worker process: logical replication worker for subscription 16399
(PID 3626) exited with exit code 1
```

Example 41 Worker restart log

```
LOG:  starting logical replication worker for subscription "sub1"
LOG:  logical replication sync for subscription sub1, table data1 started
LOG:  logical replication synchronization worker finished processing
```

On the PUBLICATION side, the wal sender process detects disconnection of the session and the following log is output.

Example 42 Session disconnection log

```
LOG:  unexpected EOF on client connection with an open transaction
```

□ Updating multiple tables with a single transaction

When multiple tables are updated within a transaction, they are also updated on a SUBSCRIPTION side by transaction basis. For this reason, transaction consistency is maintained on SUBSCRIPTION side as well. In order to resolve the conflict, update the problem tuple on SUBSCRIPTION side. Although there is also a method of referring to the pg_replication_origin_status catalog and a conflict resolution method using the pg_replication_origin_advance function, the author has not tested it. Also, if the table is locked on the SUBSCRIPTION side (ex. LOCK TABLE statement), replication also stops.

□ DELETE / UPDATE target tuple does not exist

If on the PUBLICATION UPDATE or DELETE statement is executed and a target tuple does not exist on the SUBSCRIPTION side, no error occurs.

Table 7 Behavior at mismatch occurrence

Master operation	Mismatch / Collision	Behavior
INSERT	Constraint violation on slave	Replication stopped
	Different column definitions (compatible)	Processing continues / No log
	Different column definitions (no compatibility)	Replication stopped
UPDATE	No target tuple in slave	Processing continues / No log
	Constraint violation on slave	Replication stopped
DELETE	No target tuple in slave	Processing continues / No log
TRUNCATE	Do not propagate	Processing continues / No log
ALTER TABLE	Do not propagate	Processing continues / No log

3.3.5 Restriction

Logical Replication has the following restrictions.

□ Execute permission

The SUPERUSER privilege is required to execute the CREATE PUBLICATION FOR ALL TABLES statement. A PUBLICATION object corresponding to an individual table can also be created by a general user.

□ Initial data

When replicating the table in which data is already stored, existing data is transferred to the SUBSCRIPTION side by default. At that time, existing data on SUBSCRIPTION side will not be deleted. Initial data transfer is done asynchronously using temporary replication slots. The CREATE SUBSCRIPTION statement finish without waiting for the completion of the initial data transfer.

□ Primary key or unique key

Primary key (PRIMARY KEY) constraint or unique key (UNIQUE) and NOT NULL constraint are required on the target table to propagate UPDATE or DELETE statement to be replicated. Also, to propagate UPDATE or DELETE statement in the table where the unique key is set, following statements need to be executed. On the PUBLICATION side, ALTER TABLE REPLICA IDENTITY FULL statement or ALTER TABLE REPLICA IDENTITY USING INDEX statement, on the SUBSCRIPTION side, ALTER TABLE REPLICA IDENTITY USING INDEX statement.

□ DDL statement

The ALTER TABLE and TRUNCATE statements do not propagate to the SUBSCRIPTION side. The DDL statement can be executed the table of either side.

□ Character encoding

Replication can be executed between databases with different character encoding. Character encoding are converted automatically.

□ Auditing

Data update processed by SUBSCRIPTION is not recorded even if parameter log_statement parameter is set to 'all'.

□ Combination with partition table

Partition parent table cannot be added to PUBLICATION. To replicate partitioned table, it is necessary to add child tables to the PUBLICATION.

Example 43 Partition tables and replication

```
postgres=> ALTER PUBLICATION pub1 ADD TABLE range1 ;
ERROR:  "range1" is a partitioned table
DETAIL:  Adding partitioned tables to publications is not supported.
HINT:  You can add the table partitions individually.
```

□ In-Instance Replication

When executing the CREATE SUBSCRIPTION statement, the CREATE SUBSCRIPTION statement hangs by specifying the same instance as the PUBLICATION object in the CONNECTION clause. By creating a Replication Slot in advance and specifying the WITH (create_slot = false) clause in the CREATE SUBSCRIPTION statement, it is possible to create an in-instance replication environment.

□ Mutual replication

It is not possible to create mutually updated table structure(multimaster replication) using PUBLICATION and SUBSCRIPTION. Although the CREATE PUBLICATION / CREATE SUBSCRIPTION statements succeed, when executed the replication, the WAL applied to the slave side will return to the master side, so that WAL application error will occur.

□ Trigger execution

Triggers on the SUBSCRIPTION side table are not executed by update processing of Logical Replication.

3.4 Enhancement of Parallel Query

In PostgreSQL 10, the processing that can use parallel queries has been expanded.

3.4.1 PREPARE / EXECUTE statement

Parallel queries can now be executed even in search processing using PREPARE and EXECUTE statements. Parallel processing was not executed in that process in PostgreSQL 9.6.

Example 44 Parallel query with PREPARE and EXECUTE statements

```
postgres=> EXPLAIN SELECT COUNT(*) FROM large1 ;
                                    QUERY PLAN
-------------------------------------------------------------------------------
 Finalize Aggregate  (cost=11614.55..11614.56 rows=1 width=8)
   ->  Gather  (cost=11614.33..11614.54 rows=2 width=8)
         Workers Planned: 2
         ->  Partial Aggregate  (cost=10614.33..10614.34 rows=1 width=8)
               ->  Parallel Seq Scan on large1  (cost=0.00..9572.67 rows=416667
width=0)
(5 rows)

postgres=> PREPARE p1 AS SELECT COUNT(*) FROM large1 ;
PREPARE
postgres=> EXPLAIN EXECUTE p1 ;
                                    QUERY PLAN
-------------------------------------------------------------------------------
 Finalize Aggregate  (cost=11614.55..11614.56 rows=1 width=8)
   ->  Gather  (cost=11614.33..11614.54 rows=2 width=8)
         Workers Planned: 2
         ->  Partial Aggregate  (cost=10614.33..10614.34 rows=1 width=8)
               ->  Parallel Seq Scan on large1  (cost=0.00..9572.67 rows=416667
width=0)
(5 rows)
```

3.4.2 Parallel Index Scan

Parallel queries are now also used for Index Scan and Index Only Scan.

Example 45 Parallel Index Scan

```
postgres=> EXPLAIN SELECT * FROM large1 WHERE c1 BETWEEN 10000 AND 20000000 ;
                              QUERY PLAN
-----------------------------------------------------------------------------
 Gather  (cost=0.43..369912.83 rows=7917410 width=12)
   Workers Planned: 2
   ->  Parallel Index Scan using idx1_large1 on large1
                (cost=0.43..369912.83 rows=3298921 width=12)
         Index Cond: ((c1 >= '10000'::numeric) AND (c1 <= '20000000'::numeric))
(4 rows)
```

Example 46 Parallel Index Only Scan

```
postgres=> EXPLAIN SELECT COUNT(c1) FROM large1 WHERE c1 BETWEEN 1000 AND
10000000 ;
                           QUERY PLAN
-----------------------------------------------------------------------------
Finalize Aggregate  (cost=316802.38..316802.39 rows=1 width=8)
   ->  Gather  (cost=316802.17..316802.38 rows=2 width=8)
         Workers Planned: 2
         ->  Partial Aggregate  (cost=315802.17..315802.18 rows=1 width=8)
               ->  Parallel Index Only Scan using idx1_large1 on
                        large1  (cost=0.43..305386.50 rows=4166267 width=6)
                     Index   Cond:   ((c1   >=   '1000'::numeric)   AND   (c1   <=
'10000000'::numeric))
(6 rows)
```

3.4.3 SubPlan

Parallel queries can now be used with SELECT statements that has SubPlan.

Example 47 SubPlan and parallel query

```
postgres=>  EXPLAIN SELECT * FROM large1 l1 WHERE l1.c1 NOT IN (SELECT l2.c1
        FROM large2 l2 WHERE l2.c1 in (1000,2000,3000)) ;
                                QUERY PLAN
-------------------------------------------------------------------------------
 Seq Scan on large1 l1  (cost=23269.95..59080.95 rows=1000000 width=11)
   Filter: (NOT (hashed SubPlan 1))
   SubPlan 1
     ->  Gather  (cost=1000.00..23269.93 rows=6 width=6)
           Workers Planned: 2
           ->    Parallel  Seq  Scan  on  large2  l2    (cost=0.00..22269.33  rows=2
width=6)
                 Filter: (c1 = ANY ('{1000,2000,3000}'::numeric[]))
(7 rows)
```

3.4.4 Parallel Merge Join / Gather Merge

Parallel queries are now available even when Merge Join is chosen. Gather Merge which gathers results while Merge by parallel processing is now available.

Example 48 Parallel Merge Join

```
postgres=> EXPLAIN SELECT COUNT(*) FROM large1 INNER JOIN large2 ON large1.c1 =
large2.c1 ;
                                        QUERY PLAN
------------------------------------------------------------------------------
Finalize Aggregate  (cost=447792.07..447792.08 rows=1 width=8)
   ->  Gather  (cost=447791.86..447792.07 rows=2 width=8)
         Workers Planned: 2
         ->  Partial Aggregate  (cost=446791.86..446791.87 rows=1 width=8)
               ->  Merge Join  (cost=407305.94..442727.96 rows=1625561 width=0)
                     Merge Cond: (large2.c1 = large1.c1)
                     ->  Sort  (cost=112492.52..114575.86 rows=833333 width=6)
                           Sort Key: large2.c1
                           ->  Parallel Seq Scan on large2  (cost=0.00..19144.33
 rows=833333 width=6)
                     ->  Materialize  (cost=294813.42..304813.25 rows=1999965 wi
…
```

3.4.5 Parallel bitmap heap scan

Bitmap Heap Scan has supported parallel query.

Example 49 Parallel Bitmap Heap Scan

```
postgres=> EXPLAIN SELECT COUNT(c1) FROM large1 WHERE c1 BETWEEN 100000 AND 200000 ;
                                        QUERY PLAN
------------------------------------------------------------------------------
 Finalize Aggregate  (cost=18500.74..18500.75 rows=1 width=8)
   ->  Gather  (cost=18500.52..18500.73 rows=2 width=8)
         Workers Planned: 2
         ->  Partial Aggregate  (cost=17500.52..17500.53 rows=1 width=8)
               ->  Parallel Bitmap Heap Scan on large1  …
                     Recheck Cond: ((c1 >= '100000'::numeric) …
                     ->  Bitmap Index Scan on idx1_large1 …
                           Index Cond: ((c1 >= '100000'::numeric) …
(8 rows)
```

3.5 Architecture

3.5.1 Added Catalogs

With the additional features, the following system catalogs have been added.

Table 8 Added system catalog list

Catalog name	Description
pg_hba_file_rules	Referencing pg_hba.conf file
pg_partitioned_table	Partitioning table information
pg_publication	PUBLICATION object for Logical Replication
pg_publication_rel	Target table list for Logical Replication
pg_publication_tables	Target table list for Logical Replication
pg_sequence	SEQUENCE object list
pg_sequences	SEQUENCE object list
pg_stat_subscription	Status for Logical Replication
pg_statistic_ext	Extended statistics view
pg_subscription	SUBSCRIPTION object for Logical Replication
pg_subscription_rel	Target table list for Logical Replication

□ pg_hba_file_rules catalog

The pg_hba_file_rules catalog can refer to the contents of the pg_hba.conf file. When changing the file, the contents of the view are reflected immediately. Comment only lines are not included.

Table 9 pg_hba_file_rules catalog

Column name	Data type	Description
line_number	integer	Line number in the file
type	text	Connection type of local, host, etc
database	text[]	Target database or all, replication
user_name	text[]	Username or all
address	text	TCP/IP address
netmask	text	Net mask
auth_method	text	Authentication method
options	text[]	Options
error	text	Error messages

□ pg_partitioned_table catalog

The pg_partitioned_table catalog stores information on the parent table on partitioning table.

Table 10 pg_partitioned_table catalog

Column name	Data type	Description
partrelid	oid	OID for the table
partstrat	char	Partitioning method (list = 'l', range = 'r')
partnatts	smallint	Number of attached partitions
partattrs	int2vector	Array of partition column values
partclass	oidvector	The data type of the partition key.
partcollation	oidvector	Collation information of partition-key columns
partexprs	pg_node_tree	Information on partitioning columns

□ pg_publication catalog

The pg_publication catalog stores information on PUBLICATION objects used in Logical Replication.

Table 11 pg_publication catalog

Column name	Data type	Description
pubname	name	Name of the PUBLICATION
pubowner	oid	Owner of the PUBLICATION object
puballtables	boolean	If true, this publication automatically includes all tables in the database
pubinsert	boolean	If true, INSERT operations are replicated for tables
pubupdate	boolean	If true, UPDATE operations are replicated for tables
pubdelete	boolean	If true, UPDATE operations are replicated for tables

□ pg_publication_rel catalog

The pg_publication_rel catalog stores the information of the replication target table contained in the PUBLICATION object.

Table 12 pg_publication_rel catalog

Column name	Data type	Description
prpubid	oid	OID of the PUBLICATION object
prrelid	oid	OID of the target table

□ pg_publication_tables catalog

The pg_publication_tables catalog stores the information of the replication target table contained in the PUBLICATION object.

Table 13 pg_publication_tables catalog

Column name	Data type	Description
pubname	name	Name of the PUBLICATION object
schemaname	name	Name of the schema
tablename	name	Name of the target table

□ pg_sequence catalog

The pg_sequence catalog that provides a list of SEQUENCE objects has been added. This catalog can be searched by general users.

Table 14 pg_sequence catalog

Column name	Data type	Description
seqrelid	oid	OID of the object
seqtypid	oid	Data type of the SEQUENCE
seqstart	bigint	Start value
seqincrement	bigint	Incremental value
seqmax	bigint	Maximum sequence value
seqmin	bigint	Minimum sequence value
seqcache	bigint	Number of caches
seqcycle	boolean	Indicate whether to cyclic

□ pg_sequences catalog

The pg_sequences catalog that provides a list of SEQUENCE object has been added. Although this catalog can be searched by general users, the last_value column is NULL if the nextval function has not been executed yet or if the search user does not have USAGE or SELECT privilege on that SEQUENCE.

Table 15 pg_sequences catalog

Column name	Data type	Description
schemaname	name	Name of the schema
sequencename	name	Name of the SEQUENCE object
sequenceowner	name	Name of the owner
data_type	regtype	Data type of the SEQUENCE
start_value	bigint	Start value
min_value	bigint	Minimum value
max_value	bigint	Maximum value
increment_by	bigint	Incremental value
cycle	boolean	Indicate whether to cyclic
cache_size	bigint	Number of caches
last_value	bigint	Last sequence value or NULL

Example 50 Reference pg_sequences catalog

```
postgres=> \x
Expanded display is on.
postgres=> SELECT * FROM pg_sequences ;
-[ RECORD 1 ]-+--------------------
schemaname    | public
sequencename  | seq1
sequenceowner | postgres
data_type     | bigint
start_value   | 1
min_value     | 1
max_value     | 9223372036854775807
increment_by  | 1
cycle         | f
cache_size    | 1
last_value    |
```

The result of the SELECT statement for the sequence has changed due to the addition of the pg_sequences catalog.

Example 51 Search for a sequence (PostgreSQL 9.6)

```
postgres=> CREATE SEQUENCE seq1 ;
CREATE SEQUENCE
postgres=> SELECT * FROM seq1 ;
-[ RECORD 1 ]-+--------------------
sequence_name | seq1
last_value    | 1
start_value   | 1
increment_by  | 1
max_value     | 9223372036854775807
min_value     | 1
cache_value   | 1
log_cnt       | 0
is_cycled     | f
is_called     | f
```

Example 52 Search for a sequence (PostgreSQL 10)

```
postgres=> CREATE SEQUENCE seq1 ;
CREATE SEQUENCE
postgres=> SELECT * FROM seq1 ;
-[ RECORD 1 ]-----
last_value | 1
log_cnt    | 0
is_called  | f
```

□ pg_stat_subscription catalog

The pg_stat_subscription catalog stores WAL information received by the SUBSCRIPTION object. This catalog can refer to data only while the replication process is running.

Table 16 pg_stat_subscription catalog

Column name	Data type	Description
subid	oid	OID of the SUBSCRIPTION
subname	name	Name of the SUBSCRIPTION
pid	integer	Process id of the logical replication worker
relid	oid	OID of the table
received_lsn	pg_lsn	Received LSN
last_msg_send_time	timestamp with time zone	Message send time
last_msg_receipt_time	timestamp with time zone	Message receive time
latest_end_lsn	pg_lsn	Latest end LSN
latest_end_time	timestamp with time zone	Latest end timestamp

□ pg_statistic_ext catalog

The pg_statistic_ext catalog stores information on extended statistics created with the CREATE STATISTICS statement.

Table 17 pg_statistic_ext catalog

Column name	Data type	Description
stxrelid	oid	OID of the statistics acquisition table
stxname	name	Name of the extended statistics
stxnamespace	oid	OID of the namespace
stxowner	oid	Owner of extended statistics
stxkeys	int2vector	Array of column numbers from which extended statistics were obtained
stxkind	"char"[]	Types of the statistics activated
stxndistinct	pg_ndistinct	Serialized N-distinct value
stxdependencies	pg_dependencies	Column dependencies

□ pg_subscription catalog

The pg_subscription catalog stores information on the SUBSCRIPTION object used by Logical Replication. This catalog can only be viewed by users with SUPERUSER privilege.

Table 18 pg_subscription catalog

Column name	Data type	Description
subdbid	oid	OID of database constituting SUBSCRIPTION
subname	name	Name of the SUBSCRIPTION object
subowner	oid	Owner's OID
subenabled	boolean	Is the object valid?
subconninfo	text	Connection information to PUBLICATION instance
subslotname	name	Name of the replication slot
subsynccommit	text	Synchronous COMMIT setting value
subpublications	text[]	Array of PUBLICATION names

□ pg_subscription_rel catalog

The pg_subscription_rel catalog stores the information on table targeted by the SUBSCRIPTION object used in Logical Replication.

Table 19 pg_subscription_rel catalog

Column name	Data type	Description
srsubid	oid	OID of SUBSCRIPTION object
srrelid	oid	OID of target table
srsubstate	"char"	Status i = initializing, d = data transferring, s = synchronizing, r = normal
srsublsn	pg_lsn	The last LSN of the s or r state of srsubstate column

3.5.2 Modified catalogs

The following catalogs have been changed.

Table 20 System catalog with columns added

Catalog name	Added column	Data Type	Description
pg_class	relispartition	boolean	Partition parent table
	relpartbound	pg_node_tree	Partitioning information
pg_replication_slots	temporary	boolean	Indicate a temporary slot
pg_policy	polpermissive	boolean	PERMISSIVE mode
pg_policies	permissive	text	PERMISSIVE mode
pg_stat_replication	write_lag	interval	Write lag
	flush_lag	interval	Flush lag
	replay_lag	interval	Replay lag
pg_collation	collprovider	char	Provider information
	collversion	text	Version information
pg_stat_activity	backend_type	text	Type of process
pg_attribute	attidentity	char	GENERATED column

□ pg_stat_activity catalog

The statuses of all backend processes except the postmaster process are now displayed in the pg_stat_activity catalog. The type of backend process can be confirmed by backend_type column.

Example 53 Referencing pg_stat_activity catalog

```
postgres=# SELECT pid,wait_event, backend_type FROM pg_stat_activity ;
  pid  |     wait_event      |    backend_type
-------+---------------------+---------------------
 12251 | AutoVacuumMain      | autovacuum launcher
 12253 | LogicalLauncherMain | background worker
 12269 |                     | client backend
 12249 | BgWriterHibernate   | background writer
 12248 | CheckpointerMain    | checkpointer
 12250 | WalWriterMain       | walwriter
(6 rows)
```

3.5.3 Enhancement of libpq library

The following enhancements have been added to the PostgreSQL Client library libpq.

□ Multi-instance specification

Settings for connecting to multiple instances which are already supported in the JDBC Driver are also implemented in the libpq library. As described below, multiple host names and port numbers can be described in comma-separated form.

Syntax 7 Multi-instance specification

```
host=host1,host2
host=host1,host2 port=port1,port2
postgresql://host1,host2/
postgresql://host1:port2,host2:port2/
```

Multiple values can be specified with the comma (,) separator in the environment variables PGHOST and PGPORT. Along with this, it is now possible to specify multiple values for the --host and --port parameters of the psql and pg_basebackup commands

□ Added target_session_attrs attribute

Target_session_attrs has been added as a new connection attribute. This parameter can be specified as "any" if the instance to be connected can be hot standby, or "read-write" if the instance is writable. A similar specification can be specified for the environment variable PGTARGETSESSIONATTRS. Internally, it seems to be use the SHOW transaction_read_only statement to determine the connection

destination.

□ Added passfile attribute

"passfile" has been added as a new connection attribute. In the past, it was specified with the environment variable PGPASSFILE etc.

3.5.4 Change from XLOG to WAL

The name of XLOG used in the function, directory name, and utility was unified in WAL. Also, the pg_clog directory has been changed to the pg_xact directory. The default output directory name of the log file has been changed due to the effect of changing the default value of the parameter log_directory. The name "location" indicating the location of WAL has been changed to "lsn".

Table 21 Changed name

Category	Before change	After changing
Directories	pg_xlog	pg_wal
	pg_clog	pg_xact
	pg_log	log
Utilities	pg_receivexlog	pg_receivewal
	pg_resetxlog	pg_resetwal
	pg_xlogdump	pg_waldump
	pg_basebackup --xlog-method	pg_basebackup --wal-method
	pg_basebackup --xlogdir	pg_basebackup --waldir
	initdb --xlogdir	initdb --waldir
Functions	pg_xlog_location_diff	pg_wal_location_diff
	pg_switch_xlog	pg_switch_wal
	pg_current_xlog_*	pg_current_wal_*
	pg_xlogfile*	pg_walfile*
	pg_is_xlog_replay_replay_paused	pg_is_wal_replay_replay_paused
	pg_last_xlog_*	pg_last_wal_*
	pg_*location*	pg_*lsn*
Catalog	pg_stat_replication Catalog	pg_stat_replication Catalog
	- sent_location	- sent_lsn
	- write_location	- write_lsn
	- flush_location	- flush_lsn
	- replay_location	- replay_lsn

At the same time, the string XLOG included in the error message has also been changed to WAL. It has been changed to the following message.

- Failed while allocating a WAL reading processor.
- could not read two-phase state from WAL at …
- expected two-phase state data is not present in WAL at …
- Failed while allocating a WAL reading processor.
- WAL redo at %X/%X for %s
- Forces a switch to the next WAL file if a new file has not been started within N seconds.

The description of the parameter archive_timeout has been changed as follows.

- Forces a switch to the next WAL file if a new file has not been started within N seconds.

3.5.5 Temporary replication slot

Replication slots can be used for building a streaming replication environment or for the pg_basebackup command. In PostgreSQL 10, temporary replication slots can now be created. A temporary replication slot is the same as a normal replication slot except that it is automatically deleted by session termination. To create a temporary replication slot, specify true for the third parameter of the pg_create_physical_replication_slot function or pg_create_logical_replication_slot function. Along with this, "temporary" column has been added to the pg_replication_slots catalog.

Example 54 Create temporary replication slot

```
postgres=# SELECT pg_create_physical_replication_slot('temp1', true, true) ;
 pg_create_physical_replication_slot
-------------------------------------
 (temp1,0/30000370)
(1 row)

postgres=# SELECT slot_name, temporary FROM pg_replication_slots ;
 slot_name | temporary
-----------+-----------
 temp1     | t
(1 row)
```

3.5.6 Change instance startup log

The listen address and port number are now output to the instance startup log.

Example 55 Instance start log (partially omitted)

```
$ pg_ctl -D data start
waiting for server to start....
LOG:  listening on IPv4 address "0.0.0.0", port 5432
LOG:  listening on IPv6 address "::", port 5432
LOG:  listening on Unix socket "/tmp/.s.PGSQL.5432"
LOG:  redirecting log output to logging collector process
HINT:  Future log output will appear in directory "log".
 done
server started
```

3.5.7 WAL of hash index

Hash index of previous versions did not generate WAL on update. In PostgreSQL 10, it now generate WAL, so it can now be used in streaming replication environments. The warnings outputted in the CREATE INDEX USING HASH statement are no longer output.

Example 56 Create hash index (PostgreSQL 10)

```
postgres=> CREATE INDEX idx1_hash1 ON hash1 USING hash (c1) ;
CREATE INDEX
```

Example 57 Create hash index (PostgreSQL 9.6)

```
postgres=> CREATE INDEX Idx1_hash1 ON hash1 USING hash (c1) ;
WARNING:  hash indexes are not WAL-logged and their use is discouraged
CREATE INDEX
```

3.5.8 Added roles

The following roles have been added. All roles do not have "login" privilege.

Table 22 Added role

Role	Description
pg_read_all_settings	All configuration parameters can be referred.
pg_read_all_stats	All pg_stat_ * views can be referred.
pg_stat_scan_tables	Execute the monitoring function to take AccessShareLock lock
pg_monitor	All of the above 3 roles have authority

Registering the following Contrib modules, execute permissions for function are automatically granted to the roles above.

- pg_buffercache
- pg_freespacemap
- pg_stat_statements
- pg_visibility
- pgstattuple

3.5.9 Custom Scan Callback

A new callback called at the end of the parallel query has been added. It is explained in the manual "58.3. Executing Custom Scans" as follows.

Example 58 Custom Scan Callback

```
Initialize a parallel worker's custom state based on the shared state set
up in the leader by InitializeDSMCustomScan. This callback is optional,
and needs only be supplied if this custom path supports parallel execution.

void (*ShutdownCustomScan) (CustomScanState *node);
```

3.5.10 Size of WAL file

The choice of WAL file size determined by the --with-wal-segsize option of the "configure" command has increased. 128, 256, 512, 1024 can be used in addition to the conventional 1 to 64.

3.5.11 ICU

ICU can be used for locale function. Specify --with-icu when executing "configure" command. When building in Linux environment, installation of libicu package and libicu-devel package is necessary.

3.5.12 EUI-64 data type

The data type macaddr8 indicating the EUI-64 address is now available.

3.5.13 Unique Join

When joining tables, the execution plan that performs a join using a unique index can be planned.

In the execution plan displayed by EXPLAIN VERBOSE statement, it will appear as "Inner Unique: true".

Example 59 Inner Unique Join

```
postgres=> CREATE TABLE unique1(c1 INTEGER PRIMARY KEY, c2 VARCHAR(10)) ;
CREATE TABLE
postgres=> CREATE TABLE unique2(c1 INTEGER PRIMARY KEY, c2 VARCHAR(10)) ;
CREATE TABLE
…
postgres=> EXPLAIN VERBOSE SELECT * FROM unique1 u1 INNER JOIN unique2 u2 ON u1.c1 =
u2.c1 ;
                                QUERY PLAN
------------------------------------------------------------------------------
 Hash Join  (cost=280.00..561.24 rows=10000 width=18)
   Output: u1.c1, u1.c2, u2.c1, u2.c2
   Inner Unique: true
   Hash Cond: (u1.c1 = u2.c1)
   ->  Seq Scan on public.unique1 u1  (cost=0.00..155.00 rows=10000 width=9)
         Output: u1.c1, u1.c2
   ->  Hash  (cost=155.00..155.00 rows=10000 width=9)
         Output: u2.c1, u2.c2
         ->  Seq Scan on public.unique2 u2  (cost=0.00..155.00 rows=10000 width=9)
               Output: u2.c1, u2.c2
(10 rows)
```

3.5.14 Shared Memory Address

When the EXEC_BACKEND macro is defined and installed, the environment variable PG_SHMEM_ADDR can be used. Specify the start address of System V shared memory used as part of the cache. Internally it is digitized with the strtoul function and used as the second parameter of the shmat system call.

3.6 Monitoring

3.6.1 Monitor wait events

Wait events that are shown in the wait_event_type and wait_event columns of the pg_stat_activity catalog have been added. LWLockNamed and LWLockTranche that were output in the wait_event_type column in PostgreSQL 9.6 have been renamed to LWLock.

Table 23 Value to be output to the wait_event_type column

wait_event_type column	Description	Change
LWLock	Light weight lock wait	Renamed
Lock	Lock wait	
BufferPin	Waiting for buffer	
Activity	Waiting for processing acceptance of background processes	Added
Client	A state in which the client is waiting for processing	Added
Extension	Wait for background worker	Added
IPC	A state waiting for processing from another process	Added
Timeout	Waiting for timeout	Added
IO	Waiting for I / O	Added

3.6.2 EXPLAIN SUMMARY statement

A SUMMARY clause has been added to the EXPLAIN statement to output only the execution plan generation time.

Example 60 EXPLAIN SUMMARY

```
postgres=> EXPLAIN (SUMMARY) SELECT * FROM data1 ;
                          QUERY PLAN
---------------------------------------------------------------
 Seq Scan on data1  (cost=0.00..15406.00 rows=1000000 width=11)
 Planning time: 0.072 ms
(2 rows)
```

3.6.3 VACUUM VERBOSE statement

Oldest xmin and frozen pages are now output as the output of the VACUUM VERBOSE statement.

Example 61 Execute VACUUM VERBOSE statement

```
postgres=> VACUUM VERBOSE data1 ;
NFO:  vacuuming "public.data1"
…
DETAIL:  0 dead row versions cannot be removed yet, oldest xmin: 587
There were 0 unused item pointers.
Skipped 0 pages due to buffer pins, 0 frozen pages.
0 pages are entirely empty.
…
```

3.7 Quorum-based synchronous replication

In PostgreSQL 9.5 and earlier, only one instance was available for synchronous replication. In PostgreSQL 9.6, synchronous replication can be performed on multiple instances.

PostgreSQL 10 implements Quorum-based synchronous replication, which arbitrarily selects an instance to perform synchronous replication. The synchronous replication environment is set by the synchronous_standby_names configuration parameter as before.

Syntax 8 Up to PostgreSQL 9.5

```
synchronous_standby_names = application_name, application_name, …
```

Syntax 9 PostgreSQL 9.6

```
synchronous_standby_names = num_sync (application_name,
application_name, …)
```

Syntax 10 PostgreSQL 10

```
synchronous_standby_names = FIRST | ANY num_sync (application_name,
application_name, …)
```

Specifying FIRST or omitting it will have the same behavior as PostgreSQL 9.6. Priorities are determined in the order described in the parameter application_name, and synchronous replication is performed for the number of instances specified by num_sync.

If ANY is specified, it will not depend on the order of the instances specified in parameter application_name, and will determine the completion of synchronous replication when WAL is transferred to the slave instance specified by num_sync. If ANY is specified for the configuration parameter synchronous_standby_names, "quorum" is output in the sync_state column of the pg_stat_replication catalog.

Example 62 Quorum-based synchronous replication

```
postgres=> SHOW synchronous_standby_names ;
        synchronous_standby_names
-------------------------------------
 any 2 (standby1, standby2, standby3)
(1 row)

postgres=> SELECT application_name,sync_state, sync_priority
               FROM pg_stat_replication ;
 application_name | sync_state | sync_priority
------------------+------------+---------------
 standby1         | quorum     |             1
 standby2         | quorum     |             1
 standby3         | quorum     |             1
(3 rows)
```

3.8 Enhancement of Row Level Security

3.8.1 Overview

When multiple policies were set for a table, policies were determined by OR condition in PostgreSQL 9.6 and earlier. In PostgreSQL 10 it is possible to specify a policy with an AND condition. The AS PERMISSIVE clause and the AS RESTRICTIVE clause can now be specified in the CREATE POLICY statement that create the policy. When specifying the AS PERMISSIVE clause, the restriction becomes loose (OR), and if AS RESTRICTIVE is specified, the limit becomes strict (AND). When designation is omitted, it becomes the same as in the previous version. Along with this, a column indicating condition specification has been added to the pg_policy catalog and the pg_policies catalog.

Table 24 Added column (pg_policy catalog)

Column name	Data type	Description
polpermissive	boolean	POLICY mode (PERMISSIVE in the case of true)

Table 25 Added column (pg_policies catalog)

Column name	Data type	Description
permissive	text	POLICY mode (PERMISSIVE or RESTRICTIVE)

Syntax 11 CREATE POLICY statement

```
CREATE POLICY policy_name ON table_name
 [ AS { PERMISSIVE | RESTRICTIVE } ]
 [ FOR { ALL | SELECT | INSERT | UPDATE | DELETE } ]
 [ TO { role_name | PUBLIC | CURRENT_USER | SESSION_USER } [, ...] ]
 [ USING ( using_expression ) ]
```

3.8.2 Validation of multiple POLICY setting

The author set multiple POLICY for the table and verified the effect. POLICY pol1 in PERMISSIVE mode and POLICY pol2, pol3 in RESTRICTIVE mode were prepared for the table poltbl1 and veryfied by combining them.

Example 63 Creating tables and POLICY (PERMISSIVE + RESTRICTIVE)

```
postgres=> CREATE TABLE poltbl1 (c1 NUMERIC, c2 VARCHAR(10), uname VARCHAR(10)) ;
CREATE TABLE
postgres=> ALTER TABLE poltbl1 ENABLE ROW LEVEL SECURITY ;
ALTER TABLE
postgres=> CREATE POLICY pol1 ON poltbl1 FOR ALL USING (uname = current_user) ;
CREATE POLICY
postgres=> CREATE POLICY pol2 ON poltbl1 AS RESTRICTIVE FOR ALL USING (c2 =
'data') ;
CREATE POLICY
postgres=> SELECT polname, polpermissive FROM pg_policy ;
 polname | polpermissive
---------+---------------
 pol1    | t
 pol2    | f
(2 rows)
postgres=> SELECT tablename, policyname, permissive FROM pg_policies ;
 tablename | policyname | permissive
-----------+------------+-------------
 poltbl1   | pol1       | PERMISSIVE
 poltbl1   | pol2       | RESTRICTIVE
(2 rows)
postgres=> \d poltbl1
                   Table "public.poltbl1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          |
 c2     | character varying(10) |           |          |
 uname  | character varying(10) |           |          |
Policies:
    POLICY "pol1"
      USING (((uname)::name = CURRENT_USER))
    POLICY "pol2" AS RESTRICTIVE
      USING (((c2)::text = 'data'::text))
```

In the above example, the setting of the table poltbl1 shows that POLICY pol2 is RESTRICTIVE.

Example 64 Confirmation of execution plan (PERMISSIVE + RESTRICTIVE)

```
postgres=> EXPLAIN SELECT * FROM poltbl1 ;
                              QUERY PLAN
------------------------------------------------------------------------
 Seq Scan on poltbl1  (cost=0.00..20.50 rows=1 width=108)
   Filter: (((c2)::text = 'data'::text) AND ((uname)::name = CURRENT_USER))
(2 rows)
```

It can be seen that the two conditions are combined by "AND". Next, delete POLICY pol1 and create a table applying POLICY pol3 in RESTRICTIVE mode.

Example 65 Create POLICIES in RESTRICTIVE mode

```
postgres=> CREATE POLICY pol3 ON poltbl1 AS RESTRICTIVE FOR ALL USING
(c1 > 1000) ;
CREATE POLICY
postgres=> \d poltbl1
                  Table "public.poltbl1"
 Column |        Type         | Collation | Nullable | Default
--------+---------------------+-----------+----------+---------
 c1     | numeric             |           |          |
 c2     | character varying(10) |           |          |
 uname  | character varying(10) |           |          |
Policies:
    POLICY "pol2" AS RESTRICTIVE
      USING (((c2)::text = 'data'::text))
    POLICY "pol3" AS RESTRICTIVE
      USING ((c1 > (1000)::numeric))
```

Example 66 Confirmation of execution plan (RESTRICTIVE + RESTRICTIVE)

```
postgres=> EXPLAIN SELECT * FROM poltbl1 ;
                QUERY PLAN
-------------------------------------------
 Result  (cost=0.00..0.00 rows=0 width=108)
   One-Time Filter: false
(2 rows)
```

If all policies are in RESTRICTIVE mode, the execution plan does not seem to be displayed.

3.9 Enhancement of SQL statement

This section explains enhancement of SQL statements.

3.9.1 UPDATE statement and ROW keyword

The ROW keyword can be used for UPDATE statement.

Example 67 UPDATE statement with ROW keyword

```
postgres=> UPDATE pgbench_tellers SET (bid, tbalance) = ROW (2, 1) WHERE
tid = 10;
UPDATE 1
```

3.9.2 CREATE STATISTICS statement

With the CREATE STATISTICS statement, it is now possible to gather statistical information on multiple column correlations. The timing at which the statistical values are actually collected is when the ANALYZE statement is executed.

Syntax 12 CREATE STATISTICS statement

```
CREATE STATISTICS [ IF NOT EXISTS ] stat_name [ ( stat_type [ , … ] ) ]
ON col1, col2 [, ... ] FROM table_name
```

For stat_name, specify the name of the extended statistics. It can also be qualified with a schema name. At least two columns must be specified. For stat_type, "dependencies", "ndistinct" can be specified. If omitted, both are assumed to be specified.

To alter the extended statistics, execute the ALTER STATISTICS statement.

Syntax 13 ALTER STATISTICS statement

```
ALTER STATISTICS stat_name OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER STATISTICS stat_name RENAME TO new_name
ALTER STATISTICS stat_name SET SCHEMA new_schema
```

To drop extended extensions, execute the DROP STATISTICS statement.

Syntax 14 DROP STATISTICS statement

```
DROP STATISTICS [ IF EXISTS ] name [, ...]
```

Example 68 Creating extended statistics with the CREATE STATISTICS statement

```
postgres=> CREATE TABLE stat1(c1 NUMERIC, c2 NUMERIC, c3 VARCHAR(10)) ;
CREATE TABLE
postgres=> INSERT INTO stat1 VALUES(generate_series(1, 100000) / 5,
              generate_series(1, 100000) / 10, 'init') ;
INSERT 0 100000
postgres=> CREATE STATISTICS stat1_stat1 ON c1, c2 FROM stat1 ;
CREATE STATISTICS
```

Example 69 Confirm the information of the table that created the extended statistics

```
postgres=> \d stat1
                    Table "public.stat1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          |
 c2     | numeric               |           |          |
 c3     | character varying(10) |           |          |
Statistics objects:
    "public"."stat1_stat1" (ndistinct, dependencies) ON c1, c2 FROM stat1
```

Information of the extended statistics can be checked in the pg_statistic_ext catalog.

Example 70 Confirm extended statistics

```
postgres=> SELECT * FROM pg_statistic_ext ;
-[ RECORD 1 ]---+----------------------------------------
stxrelid        | 16575
stxname         | stat1_stat1
stxnamespace    | 2200
stxowner        | 16454
stxkeys         | 1 2
stxkind         | {d,f}
stxndistinct    | {"1, 2": 19982}
stxdependencies | {"1 => 2": 1.000000, "2 => 1": 0.170467}
```

3.9.3 GENERATED AS IDENTITY column

The GENERATED AS IDENTITY constraint has been added to the CREATE TABLE statement to automatically assign a unique value to a column. It is almost the same function as the "serial" type which can be used in the conventional version, but some specifications are different. The GENERATED AS IDENTITY constraint can be added to more than one column. Both the serial type and the GENERATED AS IDENTITY constraint internally use the SEQUENCE object.

Syntax 15 CREATE TABLE statement (column definition)

```
column_name type GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
[ ( sequence_option ) ]
```

SMALLINT, INT, BIGINT can be used for the data type (type). When creating a table using the LIKE clause, the GENERATED constraint is not inherited. Only the NOT NULL constraint is inherited.

To add a GENERATED AS IDENTITY constraint to an existing column, execute the ALTER TABLE statement. A NOT NULL constraint is required for the specified column.

Syntax 16 ALTER TABLE statement (add constraint)

```
ALTER TABLE table_name ALTER COLUMN column_name ADD GENERATED { ALWAYS |
BY DEFAUT } AS IDENTITY { ( sequence_option ) }
```

Syntax 17 ALTER TABLE statement (drop constraint)

```
ALTER TABLE table_name ALTER COLUMN column_name DROP IDENTITY [ IF EXISTS ]
```

Syntax 18 ALTER TABLE statement (update constraint)

```
ALTER TABLE table_name ALTER COLUMN column_name { SET GENERATED { ALWAYS
| BY DEFAULT } | SET sequence_option | RESTART [ [ WITH ] restart ] }
```

Information on the columns created with the above syntax is stored in the "columns" table of the information_schema schema. In the past, the is_identity column was "NO", and the other information was NULL.

□ GENERATED ALWAYS

Columns specified with GENERATED ALWAYS are prohibited from setting column values from the application by the INSERT statement or updating to values other than the DEFAULT value by the

UPDATE statement.

Example 71 GENERATED ALWAYS

```
postgres=> CREATE TABLE ident1 (c1 bigint GENERATED ALWAYS AS IDENTITY, c2 VARCHAR(10)) ;
CREATE TABLE
demodb=> \d ident1
                            Table "public.ident1"
 Column |         Type          | Collation | Nullable |          Default
--------+-----------------------+-----------+----------+-----------------------------
 c1     | bigint                |           | not null | generated always as identity
 c2     | character varying(10) |           |          |

postgres=> INSERT INTO ident1(c1, c2) VALUES (1, 'data1') ;
ERROR:  cannot insert into column "c1"
DETAIL:  Column "c1" is an identity column defined as GENERATED ALWAYS.
HINT:  Use OVERRIDING SYSTEM VALUE to override.
postgres=> INSERT INTO ident1(c2) VALUES ('data1') ;
INSERT 0 1
postgres=> UPDATE ident1 SET c1=2 WHERE c1=1 ;
ERROR:  column "c1" can only be updated to DEFAULT
DETAIL:  Column "c1" is an identity column defined as GENERATED ALWAYS.
postgres=> UPDATE ident1 SET c1=DEFAULT WHERE c1=1 ;
UPDATE 1
```

Any value can be stored on GENERATED column by specifying the OVERRIDING SYSTEM VALUE clause in the INSERT statement.

Example 72 OVERRIDING SYSTEM VALUE clause

```
postgres=> INSERT INTO ident1 OVERRIDING SYSTEM VALUE VALUES (100, 'data1') ;
INSERT 0 1
```

□ GENERATED BY DEFAULT

When GENERATED BY DEFAULT clause is specified, the automatic numbering column is updatable. It has the same behavior as the "serial" type column.

Example 73 GENERATED BY DEFAULT

```
postgres=> CREATE TABLE ident2 (c1 bigint GENERATED BY DEFAULT AS
IDENTITY, c2 VARCHAR(10)) ;
CREATE TABLE
postgres=> INSERT INTO ident2 VALUES (1, 'data1') ;
INSERT 0 1
postgres=> INSERT INTO ident2(c2) VALUES ('data2') ;
INSERT 0 1
postgres=> UPDATE ident2 SET c1=2 WHERE c2='data2' ;
UPDATE 1
```

3.9.4 ALTER TYPE statement

It is possible to change the name of the ENUM type by using the ALTER TYPE statement.

Syntax 19 ALTER TYPE RENAME VALUE statement

```
ALTER TYPE type_name RENAME VALUE existing_val TO replace_val
```

Example 74 Change of ENUM type by ALTER TYPE statement

```
postgres=> CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy') ;
CREATE TYPE
postgres=> ALTER TYPE mood RENAME VALUE 'ok' TO 'good' ;
ALTER TYPE
```

3.9.5 CREATE SEQUENCE statement

The data type can be specified in the CREATE SEQUENCE statement. The data types that can be specified are SMALLINT, INTEGER, and BIGINT (default). The range of sequence values is limited to the range of data types.

Syntax 20 CREATE SEQUENCE statement

```
CREATE SEQUENCE sequence_name [ AS type ] [ INCREMENT … ]
```

Example 75 Specify SMALLINT type in CREATE SEQUENCE statement

```
postgres=> CREATE SEQUENCE seq1 AS SMALLINT ;
CREATE SEQUENCE
```

It is also possible to change the data type with the ALTER SEQUENCE AS statement. If the data type is changed, the maximum value of SEQUENCE will also be updated. However, changes to reduce the current sequence value are not allowed.

3.9.6 COPY statement

A COPY statement can now be executed on a simple view with the INSTEAD OF INSERT trigger.

Example 76 COPY statement for VIEW

```
postgres=> CREATE TABLE instead1(c1 NUMERIC, c2 VARCHAR(10)) ;
CREATE TABLE
postgres=> CREATE VIEW insteadv1 AS SELECT c1, c2 FROM instead1 ;
CREATE VIEW
postgres=> CREATE OR REPLACE FUNCTION view_insert_row1() RETURNS trigger AS
         $$
         BEGIN
            INSERT INTO instead1 VALUES (new.c1, new.c2);
            RETURN new;
         END;
         $$
         LANGUAGE plpgsql ;
CREATE FUNCTION
postgres=> CREATE TRIGGER insteadv1_insert
         INSTEAD OF INSERT ON insteadv1 FOR EACH ROW
         EXECUTE PROCEDURE view_insert_row1() ;
CREATE TRIGGER
postgres=# COPY insteadv1 FROM '/home/postgres/instead.csv' ;
COPY 2
```

3.9.7 CREATE INDEX statement

"autosummarize" can now be specified in the WITH clause of the CREATE INDEX statement that creates a BRIN index. When this is specified, it specifies that summarization is performed on the

previous page when data is inserted in the page.

Example 77 Enhancement of BRIN index

```
postgres=> CREATE INDEX idx1_brin1 ON brin1 USING brin (c1) WITH
(autosummarize) ;
CREATE INDEX
postgres=> \d brin1
                    Table "public.brin1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          |
 c2     | character varying(10) |           |          |
Indexes:
    "idx1_brin1" brin (c1) WITH (autosummarize='true')
```

3.9.8 CREATE TRIGGER statement

The REFERENCING clause can be used in the CREATE TRIGGER statement. It became possible to specify the table name to store the update difference. This setting can be set only for AFTER trigger.

Syntax 21 CREATE TRIGGER statement

```
CREATE [ CONSTRAINT ] TRIGGER name { BEFORE | AFTER | INSTEAD OF } …
[ NOT DEFERRABLE | [ DEFERRABLE ] [ INITIALLY IMMEDIATE | INITIALLY
DEFERRED ] ]
[ REFERENCING { { OLD | NEW } TABLE [ AS ] transition_relation_name }
[ ... ] ]
[ FOR [ EACH ] { ROW | STATEMENT } ]
…
```

3.9.9 DROP FUNCTION statement

More than one FUNCTION can now be specified in the DROP FUNCTION statement. To specify multiple FUNCTIONs, separate them with a comma (,).

3.9.10 ALTER DEFAULT PRIVILEGE statement

The ON SCHEMAS clause can now be specified in the GRANT and REVOKE clauses of the ALTER DEFAULT PRIVILEGE statement. In the conventional version, it was ON FUNCTIONS, ON SEQUENCES, ON TABLES, and ON TYPES only.

3.9.11 CREATE SERVER statement

The IF NOT EXISTS clause is now available in CREATE SERVER and CREATE USER MAPPING statements.

3.9.12 CREATE USER statement

The UNENCRYPTED clause can no longer be used in CREATE USER, CREATE ROLE, and ALTER USER statements. Passwords are no longer stored in the pg_shadow catalog without being converted.

Example 78 UNENCRYPTED clause

```
postgres=# CREATE USER user1 UNENCRYPTED PASSWORD 'user1' ;
ERROR:  UNENCRYPTED PASSWORD is no longer supported
LINE 1: CREATE USER user1 UNENCRYPTED PASSWORD 'user1' ;
                          ^
HINT:  Remove UNENCRYPTED to store the password in encrypted form instead.
```

3.9.13 Functions

The following functions have been added or enhanced.

□ Delete element from JSONB array

Elements can be deleted from the JSONB array.

Example 79 Delete element from JSONB array

```
postgres=> SELECT '{"a":1 , "b":2, "c":3}'::jsonb - '{a,c}'::text[] ;
 ?column?
----------
 {"b": 2}
(1 row)
```

□ pg_current_logfile

The pg_current_logfile function returns the path of the output log file. Path including configuration parameter log_directory can be acquired. NULL is returned if the configuration parameter log_destination is set to "syslog" or the configuration parameter logging_collector is set to "off". SUPERUSER privilege is required to execute this function.

Example 80 pg_current_logfile function

```
postgres=# SELECT pg_current_logfile() ;
          pg_current_logfile
----------------------------------------
 log/postgresql-2017-05-20_092939.log
(1 row)
```

□ xmltable

An xmltable function is provided that obtains tabular output from XML data. In order to use this function, it is necessary to specify --with-libxml as a parameter of the "configure" command at the time of installation. Also, in order to build the binary with the --with-libxml parameter, the following packages need to be installed (For Red Hat Enterprise Linux 7).

- libxml2 (version >= 2.6.23)
- libxml2-devel
- xz-devel

Example 81 xmltable function

```
postgres=> SELECT xmltable.*
postgres->   FROM xmldata,
postgres->        XMLTABLE('//ROWS/ROW'
postgres(>                 PASSING data
postgres(>                 COLUMNS id int PATH '@id',
postgres(>                         ordinality FOR ORDINALITY,
postgres(>                         "COUNTRY_NAME" text,
postgres(>                         country_id text PATH 'COUNTRY_ID',
postgres(>                         size_sq_km float PATH 'SIZE[@unit = "sq_km"]',
postgres(>                         size_other text PATH
postgres(>                  'concat(SIZE[@unit!="sq_km"], " ", SIZE[@unit!="sq_km"]/@unit)',
postgres(>                   premier_name text PATH 'PREMIER_NAME' DEFAULT 'not specified') ;
 id | ordinality | COUNTRY_NAME | country_id | size_sq_km |  size_other  | premier_name
----+------------+--------------+------------+------------+--------------+--------------
  1 |          1 | Australia    | AU         |            |              | not specified
  5 |          2 | Thailand     | TH         |            |              | Prayuth Chan
  6 |          3 | Singapore    | SG         |        697 |              | not specified
(3 rows)
```

□ regexp_match

The regexp_match function to perform pattern matching has been added. Unlike conventional regexp_matches, it returns an array of text type. The citext Contrib module also has a regexp_match function corresponding to the citext type.

Example 82 regexp_match function

```
postgres=> \dfS regexp_match
                              List of functions
   Schema   |     Name     | Result data type | Argument data types |  Type
------------+--------------+------------------+---------------------+--------
 pg_catalog | regexp_match | text[]           | text, text          | normal
 pg_catalog | regexp_match | text[]           | text, text, text    | normal
(2 rows)
```

□ pg_ls_logdir / pg_ls_waldir

These functions return the name, size, update date and time of the log file list and WAL file list. Execution of these functions requires SUPERUSER privilege.

Example 83 pg_ls_logdir / pg_ls_waldir functions

```
postgres=# SELECT * FROM pg_ls_logdir() ;
             name              | size |      modification
-------------------------------+------+------------------------
 postgresql-2017-05-20_092939.log |  5220 | 2017-05-20 21:44:21+09
(1 row)

postgres=# SELECT * FROM pg_ls_waldir() ;
          name           |   size   |      modification
-------------------------+----------+------------------------
 000000010000000000000002E | 16777216 | 2017-05-19 22:55:33+09
(1 row)
```

□ txid_status

The txid_status function has been added to check the status of transactions. By specifying the transaction ID, the status of the corresponding transaction is returned.

Example 84 txid_status function

```
postgres=> BEGIN ;
BEGIN
postgres=> SELECT txid_current() ;
 txid_current
--------------
          578
(1 row)

postgres=> SELECT txid_status(578) ;
 txid_status
-------------
 in progress
(1 row)

postgres=> COMMIT ;
COMMIT
postgres=> SELECT txid_status(578) ;
 txid_status
-------------
 committed
(1 row)

postgres=> SELECT txid_status(1000) ;
ERROR:  transaction ID 1000 is in the future
```

□ JSON / JSONB type

The following functions correspond to JSON type and JSONB type.

- to_tsvector
- ts_headline

□ pg_stop_backup

The pg_stop_backup function has added a parameter wait_for_archive, which specifies to wait for WAL's archive. By default (true), it waits for WAL archive as before.

□ pg_import_system_collations

The pg_import_system_collations function imports information into the PostgreSQL instance when a new Collation is installed in the OS. SUPERUSER privilege is required to execute this function.

Syntax 22 pg_import_system_collations

```
pg_import_system_collations(if_not_exists boolean, schema regnamespace)
```

□ to_date / to_timestamp

The to_date function and to_timestamp functions are now strictly checked for the input values of each field. For PostgreSQL 10, the value automatically calculated in the conventional version is an error.

Example 85 to_date (PostgreSQL 9.6)

```
postgres=> SELECT to_date('2017-04-40', 'YYYY-MM-DD') ;
  to_date
------------
 2017-05-10
(1 row)
```

Example 86 to_date (PostgreSQL 10)

```
postgres=> SELECT to_date('2017-04-40', 'YYYY-MM-DD') ;
ERROR:  date/time field value out of range: "2017-04-40"
```

□ make_date

Negative values (BC) can now be specified for parameters specifying years.

Example 87 make_date (PostgreSQL 9.6)

```
postgres=> SELECT make_date(-2000, 4, 30) ;
ERROR:  date field value out of range: -2000-04-30
```

Example 88 make_date (PostgreSQL 10)

```
postgres=> SELECT make_date(-2000, 4, 30) ;
   make_date
---------------
 2000-04-30 BC
(1 row)
```

3.9.14 Procedural language

This section explains the enhancement of procedural language.

□ PL/Python

Plan.execute and plan.cursor statements have been added.

Example 89 execute method / cursor method

```
# plan.execute
plan = plpy.prepare("SELECT val FROM data1 WHERE key=$1", [ "NUMERIC" ])
result = plan.execute(key)

# plan.cursor
plan = plpy.prepare("SELECT val FROM data1 WHERE key=$1", [ "NUMERIC" ])
rows = plan.cursor([2])
```

□ PL/Tcl

Transactions with "subtransaction" syntax can now be executed.

Example 90 subtransaction syntax

```
CREATE FUNCTION transfer_funds2() RETURNS void AS $$
if [catch {
    subtransaction {
        spi_exec "UPDATE accounts SET balance = balance - 100 WHERE account_name = 'joe'"
        spi_exec "UPDATE accounts SET balance = balance + 100 WHERE account_name = 'mary'"
   }
} errormsg] {
     set result [format "error transferring funds: %s" $errormsg]
} else {
     set result "funds transferred correctly"
}
    set plan  [spi_prepare "INSERT INTO operations (result) VALUES ($1)"]
    spi_execp $plan, [list $result]
$$ LANGUAGE pltclu;
```

Pltcl.start_proc and pltclu.start_proc which are GUC which specifies initialization procedure name have been added.

3.10 Change of configuration parameters

In PostgreSQL 10 the following parameters have been changed.

3.10.1 Added parameters

The following parameters have been added.

Table 26 Added parameters

Parameter name	Description (context)	Default
enable_gathermerge	Enable execution plan Gather Merge (user)	on
max_parallel_workers	Maximum number of parallel worker process (user)	8
max_sync_workers_per_subscription	Maximum number of synchronous workers for SUBSCRIPTION (sighup)	2
wal_consistency_checking	Check the consistency of WAL on the standby instance (superuser)	-
max_logical_replication_workers	Maximum number of Logical Replication worker process (postmaster)	4
max_pred_locks_per_relation	Maximum number of pages that can be Predicate-Lock before locking the entire relation (sighup)	-2
max_pred_locks_per_page	Maximum number of records that can be Predicate-Lock before locking the entire page (sighup)	2
min_parallel_table_scan_size	Minimum table size at which Parallel table scan are considered (user)	8MB
min_parallel_index_scan_size	Minimum table size at which Parallel index scan are considered (user)	512kB

□ Parameter max_parallel_workers

Specifies the maximum number of parallel query worker processes that can run concurrently in the instances. The default value is 8. In the old version, the max_worker_processes parameter was the upper limit. If this value is set to 0, the parallel query is invalidated.

□ Parameter max_logical_replication_workers

Specifies the maximum value of the Logical Replication Worker processes to be started for each SUBSCRIPTION. Even if the value of this parameter is less than the required value, CREATE

SUBSCRIPTION statement will not fail. The following logs are periodically output when replication starts.

Example 91 Lack max_logical_replication_workers parameters

```
WARNING:  out of logical replication worker slots
HINT:  You might need to increase max_logical_replication_workers.
```

□ Parameter wal_consistency_checking

This parameter is used for bug checking of the WAL re-execution program in the replication environment. For the parameter, specify the object type to be checked with a comma (,) delimiter. The following values are available: all, hash, heap, heap 2, btree, gin, gist, sequence, spgist, brin, generic.

□ Parameter max_pred_locks_per_page

Specifies the maximum number of tuple locks to transition to page lock.

□ Parameter max_pred_locks_per_relation

Specifies the maximum number of page locks to transition to relation lock.

3.10.2 Changed parameters

The setting range and options were changed for the following configuration parameters.

Table 27 Changed configuration parameters (from pg_settings catalog)

Parameter name	Changes
ssl	The value of the context column has been changed to sighup
ssl_ca_file	The value of the context column has been changed to sighup
ssl_cert_file	The value of the context column has been changed to sighup
ssl_ciphers	The value of the context column has been changed to sighup
ssl_crl_file	The value of the context column has been changed to sighup
ssl_ecdh_curve	The value of the context column has been changed to sighup
ssl_key_file	The value of the context column has been changed to sighup
ssl_prefer_server_ciphers	The value of the context column has been changed to sighup
bgwriter_lru_maxpages	The value of max_val column was changed to INT_MAX / 2
archive_timeout	The value of the short_desc column has changed
server_version_num	The value of max_val / min_val column was changed to 100000
password_encryption	The value of the vartype was changed to enum. "md5" or "scram-sha-256" can specified. "on" is a alias for "md5"
max_wal_size	The value of the unit column has been changed to 1MB
min_wal_size	The value of the unit column has been changed to 1MB

3.10.3 Parameters with default values changed

The default values of the following configuration parameters have been changed.

Table 28 Parameters with default values changed

Parameter name	PostgreSQL 9.6	PostgreSQL 10
hot_standby	off	on
log_line_prefix	''	%m [%p]
max_parallel_workers_per_gather	0	2
max_replication_slots	0	10
max_wal_senders	0	10
password_encryption	on	md5
server_version	9.6.3	10beta1
server_version_num	90603	100000
wal_level	minimal	replica
log_directory	pg_log	log

□ Parameter log_line_prefix

The parameter default value has been changed.

Example 92 Parameter log_line_prefix default

```
postgres=# SHOW log_line_prefix ;
 log_line_prefix
-----------------
 %m [%p]
(1 row)

$ tail -1 data/log/postgresql-2017-05-20_093448.log
2017-05-20 09:34:48.617 JST [12187] LOG:  autovacuum launcher started
```

3.10.4 Deprecated parameters

The following parameters are deprecated.

Table 29 Deprecated parameters

Parameter name	Alternative value
min_parallel_relation_size	Changed to min_parallel_table_scan_size
sql_inheritance	None (same as 'on')

3.10.5 New function of authentication method

The following changes were made to the pg_hba.conf file.

□ Specify the RADIUS server

The specification of the RADIUS server necessary for RADIUS authentication changed from "radiusserver" to "radiusservers". Multiple servers separated by commas can be specified.

□ Added SCRAM authentication

Scram-sha-256 can be specified for the authentication method in pg_hba.conf. This is an implementation of SCRAM-SHA-256 as specified in RFC 5802 and 7677. Scram-sha-256 can also be specified for configuration parameter password_encryption.

3.10.6 Default value of authentication setting

The replication related default value contained in the pg_hba.conf file has been changed. By default, the local connection is set to the "trust" setting.

Example 93 Default setting of pg_hba.conf file

```
# Allow replication connections from localhost, by a user with the
# replication privilege.
local   replication     all                                     trust
host    replication     all             127.0.0.1/32            trust
host    replication     all             ::1/128                 trust
```

3.10.7 Other parameter change

The parameter recovery_target_lsn related to "Point In Time Recovery" has been added to the recovery.conf file. For this parameter, specify the recovery complete LSN.

3.11 Change of utility

This section explain the major function enhancement points of utility commands.

3.11.1 psql

The following functions have been added to the psql command.

□ \d command

The format of table information outputted by \d command has been changed. "Modifier" column that was conventionally used has been divided into Collation, Nullable, and Default.

Example 94 Display table information (PostgreSQL 9.6)

```
postgres=> \d data1
           Table "public.data1"
 Column |         Type          | Modifiers
--------+-----------------------+-----------
 c1     | numeric               | default 1
 c2     | character varying(10) | not null
```

Example 95 Display table information (PostgreSQL 10)

```
postgres=> \d data1
                    Table "public.data1"
 Column |         Type          | Collation | Nullable | Default
--------+-----------------------+-----------+----------+---------
 c1     | numeric               |           |          | 1
 c2     | character varying(10) |           | not null |
```

□ Additional information of the \timing command

The \timing command controls the output of the execution time of the SQL statement. In the new version, time format that is easy to understand has been added to the execution time output. When the SQL execution time is less than 1 second, it is outputted in the same format as the old version.

Example 96 Added output of \timing command

```
postgres=> \timing
Timing is on.
postgres=> INSERT INTO data1 values (generate_series(1, 10000000)) ;
INSERT 0 10000000
Time: 61086.012 ms (01:01.086)
```

□ \gx command

The \gx command reruns the most recently executed SQL statement in the extended format.

Example 97 \gx command

```
postgres=> SELECT * FROM data1 ;
 c1 |  c2
----+------
  1 | data
(1 row)

postgres=> \gx
-[ RECORD 1 ]
c1 | 1
c2 | data
```

□ \set command

More parameters have been displayed by the \set command.

Example 98 \set command

```
postgres=> \set
AUTOCOMMIT = 'on'
COMP_KEYWORD_CASE = 'preserve-upper'
DBNAME = 'demodb'
ECHO = 'none'
…
```

□ \if, \elif, \else, \endif command

It is now possible to perform conditional branching within the psql command. Conditional branching can be performed between \if, \else, and \endif, and the commands there between are treated as a block. For \If command and \elif command, the parameters that can determined True or False must be specified. It is also possible to nest conditional statements.

Example 99 \if command

```
SELECT
    EXISTS(SELECT 1 FROM customer WHERE customer_id=123) AS is_customer,
    EXISTS(SELECT 1 FROM employee WHERE employee_id=456) AS is_employee ;
\gset
\if :is_customer
     SELECT * FROM customer WHERE customer_id = 123 ;
\elif :is_employee
     SELECT * FROM employee WHERE employee_id = 456 ;
\endif
```

3.11.2 pg_ctl

The following functions have been added to the pg_ctl command.

□ Wait for promotion

The pg_ctl command can specify an option '-w' to wait for the standby instance to be promoted. In the past, it was necessary to refer to the trigger file to confirm completion of promotion.

□ Added aliases for options

"--wait" and "--no-wait " can be used as aliases for option "-w" and "-W ". Also, "--options" can be used for "-o" to specify options.

□ Wait for startup (-w) to default

By default, all operations have become to wait for operation completion (--wait). In the past, the default behavior of instance startup and promotion processing did not wait for operation completion.

3.11.3 pg_basebackup

The following changes have been added to the pg_basebackup command.

□ Change default mode

The default WAL transfer mode is now Stream. For this reason, connections to multiple wal sender processes are used by default.

□ Discontinue the -x option

The -x option (--xlog option) has been deprecated.

□ Change the -X option

For -X option, value "none" which means that transaction log does not included in the backup can be specified now. Also, the long option name has been changed from "--xlog-method" to "--wal-method".

□ Change the --xlogdir option

The option name has been changed from "--xlogdir" to "--waldir".

□ -Ft option and -Xstream option combination

The option to output backup data to tar file -Ft and the -Xstream option can now be used at the same time. In this case, the pg_wal.tar file in which transaction logs are stored in the directory specified by the -D option is output.

Example 100 -Ft option and -Xstream option

```
$ pg_basebackup -D back1 -v -Ft -Xstream
pg_basebackup: initiating base backup, waiting for checkpoint to complete
pg_basebackup: checkpoint completed
…
pg_basebackup: waiting for background process to finish streaming ...
pg_basebackup: base backup completed
$ ls back1/
base.tar  pg_wal.tar
$ tar tvf back1/pg_wal.tar
-rw------- postgres/postgres 16777216 2017-05-20 16:36 000000100000000000000002F
-rw------- postgres/postgres       0 2017-05-20 16:36
archive_status/000000100000000000000002F.done
$
```

□ Using temporary replication slots

When the slot name (-S) is not specified (and --no-slot is not specified), temporary replication slot is

used. Below is the log when log_replication_commands parameter is set to "on". Temporary slots with names starting with pg_basebackup_ have been created.

Example 101 Temporary replication slot creation log.

```
LOG:  received replication command: IDENTIFY_SYSTEM
LOG:  received replication command: BASE_BACKUP LABEL 'pg_basebackup
base backup'    NOWAIT
LOG:  received replication command: IDENTIFY_SYSTEM
LOG:  received replication command: CREATE_REPLICATION_SLOT
"pg_basebackup_12889" TEMPORARY PHYSICAL RESERVE_WAL
LOG:  received replication command: START_REPLICATION SLOT
"pg_basebackup_12889" 0/49000000 TIMELINE 1
```

If the replication slot is full, creating replication slot fails so that pg_basebackup command fails. Please check that the parameter max_replication_slots has free space.

Example 102 Error when there is no margin in the number of replication slots

```
$ pg_basebackup -D back
pg_basebackup: could not connect to server: FATAL:  number of requested
standby connections exceeds max_wal_senders (currently 0)
pg_basebackup: removing contents of data directory "back"
$ echo $?
1
```

□ Cleanup on error

When an error occurs during the pg_basebackup command or when a signal received, the file in the directory specified by the -D parameter will be deleted. If you do not want the delete operation, you can specify the parameter --no-clean (or -n).

□ --verbose mode output

More detailed information is displayed when parameter --verbose (or -v) is specified.

Example 103 Output in --verbose mode

```
$ pg_basebackup  -D back --verbose
pg_basebackup: initiating base backup, waiting for checkpoint to complete
pg_basebackup: checkpoint completed
pg_basebackup: write-ahead log start point: 0/35000028 on timeline 1
pg_basebackup: starting background WAL receiver
pg_basebackup: write-ahead log end point: 0/35000130
pg_basebackup: waiting for background process to finish streaming ...
pg_basebackup: base backup completed
$
```

3.11.4 pg_dump

The following options have been added.

- -B (--no-blobs)
  Exclude large objects
- --no-subscriptions
  Exclude SUBSCRIPTION objects used for Logical Replication
- --no-publications
  Exclude PUBLICATION objects used for Logical Replication
- --no-sync
  Does not execute sync system call after writing file. By default, the sync call is executed to ensure a reliable write operation.

3.11.5 pg_dumpall

The following options have been added.

- --no-sync
  Does not execute sync system call after writing file. By default, the sync call is executed to ensure a reliable write operation.
- --no-role-passwords
  Does not dump role's password.
- --no-subscriptions
  Exclude SUBSCRIPTION objects used for Logical Replication
- --no-publications

Exclude PUBLICATION objects used for Logical Replication

3.11.6 pg_recvlogical

The -E option (--endpos option) to terminate the program after receiving the specified LSN has been added

3.11.7 pgbench

"--log-prefix" parameter to change the prefix string of the log file has been added. The default value is "pgbench_log" as in the previous version. In addition to the above, some new functions were provided to the pgbench command, but no verification has been done.

3.11.8 initdb

"--noclean" and "--nosync" options have been changed to "--no-clean" and "--no-sync" option.

3.11.9 pg_receivexlog

The name of the command was changed to pg_receivewal. The --compress parameter can now be specified to compress the output WAL file. Compression ratio can be specified from 0 to 9. In order to use this function it is necessary to build in the environment where the libz library is installed.

3.11.10 pg_restore

The following options have been added.

- -N (--exclude-schema)
  To specify the name of the schema not to be restored has been added.
- --no-subscriptions
  Exclude SUBSCRIPTION objects used for Logical Replication
- --no-publications
  Exclude PUBLICATION objects used for Logical Replication

3.11.11 pg_upgrade

Internally it treats tables and sequences as separate objects.

3.11.12 createuser

"--unencrypted" option (-N option) has been deprecated.

3.11.13 createlang / droplang

The createlang command, droplang command has been deprecated.

3.12 Contrib modules

This section describes the new features of the Contrib module.

3.12.1 postgres_fdw

The following enhancements have been added to the postgres_fdw module.

□ Push-down of aggregation processing

It is now possible to push down of FULL JOIN between remote tables.

Example 104 SQL for local execution

```
postgres=# SELECT COUNT(*), AVG(c1), SUM(c1) FROM datar1 ;
count |        avg         |  sum
-------+--------------------+--------
  1000 | 500.5000000000000000 | 500500
(1 row)
```

The above SQL statement is converted to the following SQL statement at FOREIGN SERVER.

Example 105 Remote execution SQL (from log_statement = 'all' log)

```
statement: START TRANSACTION ISOLATION LEVEL REPEATABLE READ
execute <unnamed>: DECLARE c1 CURSOR FOR
       SELECT count(*), avg(c1), sum(c1) FROM public.datar1
statement: FETCH 100 FROM c1
statement: CLOSE c1
statement: COMMIT TRANSACTION
```

□ Push down of FULL JOIN

Pushdown is now done when doing FULL JOIN between remote tables.

Example 106 FULL JOIN between remote tables

```
postgres=> EXPLAIN (VERBOSE, COSTS OFF) SELECT * FROM (SELECT * FROM remote1 WHERE
c1 < 10000) r1 FULL JOIN (SELECT * FROM remote2 WHERE c1 < 10000) r2 ON (TRUE) LIMIT
10 ;

                          QUERY PLAN
------------------------------------------------------------------------------
 Limit
   Output: remote1.c1, remote1.c2, remote2.c1, remote2.c2
   ->  Foreign Scan
         Output: remote1.c1, remote1.c2, remote2.c1, remote2.c2
         Relations: (public.remote1) FULL JOIN (public.remote2)
         Remote SQL: SELECT s4.c1, s4.c2, s5.c1, s5.c2 FROM ((SELECT c1, c2 FROM
public.remote1 WHERE ((c1 < 10000::numeric))) s4(c1, c2) FULL JOIN (SELECT c1, c2
FROM public.remote2 WHERE ((c1 < 10000::numeric))) s5(c1, c2) ON (TRUE))
(6 rows)
```

3.12.2 file_fdw

A "program" option to run the application has been added. The program option is specified instead of the filename option indicating the file name. When the SELECT statement for FOREIGN TABLE is executed, the specified program is automatically executed. The content that the executed program outputs to the standard output is returned to the application as tuples.

Example 107 Program specified file_fdw module

```
postgres=# CREATE EXTENSION file_fdw ;
CREATE EXTENSION
postgres=# CREATE SERVER fs FOREIGN DATA WRAPPER file_fdw ;
CREATE SERVER
postgres=# CREATE FOREIGN TABLE tfile1 (id NUMERIC, val VARCHAR(10)) SERVER fs
    OPTIONS (program '/home/postgres/bin/file_fdw.py', delimiter ',') ;
CREATE FOREIGN TABLE
postgres=# SELECT * FROM tfile1 ;
```

In the above example, when FOREIGN TABLE tfile1 is searched, the program file_fdw.py is executed. The program uses standard output as follows.

Example 108 Examples of programs executed

```
#!/bin/python
for x in range(1000):
    print x,",test"
```

The end of the program is regarded as the end of the SELECT statement. Internally, the program is passed to popen(3) function and executed (OpenPipeStream function in src/backend/storage/file/fd.c file).

3.12.3 amcheck

The amcheck module to check the consistency of the BTree index has been added to the Contrib module. The following functions have been added to this module.

- bt_index_check(index regclass)
  Checks the integrity of the specified BTree index
- bt_index_parent_check(index regclass)
  Checks the consistency of parent-child index

In the example below, the bt_index_check function is executed for the index (idx1_check1) where some data is corrupted.

Example 109 Execution of bt_index_check function

```
postgres=# CREATE EXTENSION amcheck ;
CREATE EXTENSION
postgres=# SELECT bt_index_check('idx1_check1') ;
ERROR:  item order invariant violated for index "idx1_check1"
DETAIL:  Lower index tid=(1,2) (points to heap tid=(0,2)) higher index
tid=(1,3) (points to heap tid=(0,3)) page lsn=0/7EFE4638.
```

3.12.4 pageinspect

The following functions corresponding to Hash Index have been added.

- hash_page_type
- hash_page_stats
- hash_page_items
- hash_metapage_info
- page_checksum
- bt_page_items(IN page bytea)

3.12.5 pgstattuple

The following functions have been added.

- pgstathashindex

Provides information on Hash Index.

Example 110 pgstathashindex function

```
postgres=# SELECT * FROM pgstathashindex('idx1_hash1') ;
-[ RECORD 1 ]--+----------------
version        | 3
bucket_pages   | 33
overflow_pages | 15
bitmap_pages   | 1
unused_pages   | 32
live_items     | 13588
dead_items     | 0
free_percent   | 58.329244357213
```

3.12.6 btree_gist / btree_gin

GiST indexes can now be created in UUID type columns and ENUM type columns. GIN index can be created in ENUM type columns.

Example 111 GiST index creation for columns of UUID type and ENUM type

```
postgres=# CREATE EXTENSION btree_gist ;
CREATE EXTENSION

postgres=> CREATE TYPE type1 AS ENUM ('typ1', 'typ2', 'typ3') ;
CREATE TYPE
postgres=> CREATE TABLE gist1(c1 UUID, c2 type1) ;
CREATE TABLE
postgres=> CREATE INDEX idx1_gist1 ON gist1 USING gist (c1) ;
CREATE INDEX
postgres=> CREATE INDEX idx2_gist1 ON gist1 USING gist (c2) ;
CREATE INDEX
```

3.12.7 pg_stat_statements

The format of the SQL statement stored in the query column of the pg_stat_statements view has been changed. The literal value of the WHERE clause was conventionally output as a question mark (?), but it has been changed to $ {N} (N = 1, 2, ...).

Example 112 pg_stat_statements view

```
postgres=> SELECT query FROM pg_stat_statements WHERE query LIKE '%part1%' ;
                    query
-------------------------------------------------
SELECT COUNT(*) FROM part1 WHERE c1=$1
SELECT COUNT(*) FROM part1 WHERE c1=$1 AND c2=$2
(2 rows)
```

3.12.8 tsearch2

The tsearch2 module has been deleted.

Hewlett Packard
Enterprise

URL list

The following web sites are the references to create this material.

- Release Notes
  https://www.postgresql.org/docs/devel/static/release-10.html
- Commitfests
  https://commitfest.postgresql.org/
- PostgreSQL 10 Beta Manual
  https://www.postgresql.org/docs/devel/static/index.html
- GitHub
  https://github.com/postgres/postgres
- Open source developer based in Japan (Michael Paquier)
  http://paquier.xyz/
- Hibino Kiroku Bekkan (Nuko@Yokohama)
  http://d.hatena.ne.jp/nuko_yokohama/
- Qiita (Nuko@Yokohama)
  http://qiita.com/nuko_yokohama
- pgsql-hackers Mailing list
  https://www.postgresql.org/list/pgsql-hackers/
- Announce of PostgreSQL 10 Beta 1
  https://www.postgresql.org/about/news/1749/
- PostgreSQL 10 Roadmap
  https://blog.2ndquadrant.com/postgresql-10-roadmap/
- PostgreSQL10 Roadmap
  https://wiki.postgresql.org/wiki/PostgreSQL10_Roadmap
- Slack - postgresql-jp
  https://postgresql-jp.slack.com/

Hewlett Packard
Enterprise

Change history

Change history

Version	Date	Author	Description
0.1	Apr 4, 2017	Noriyoshi Shinoda	Create internal review version Reviewers: Satoshi Nagayasu (Uptime Technologies, LCC.) Tomoo Takahashi (HPE)
0.9	May 21, 2017	Noriyoshi Shinoda	Recheck completed to respond to for PostgreSQL 10 Beta 1
1.0	May 22, 2017	Noriyoshi Shinoda	Create a public version

Hewlett Packard
Enterprise