Row-Level Security sucks. Can we make it usable?

SCaLE 22x

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About me

- Systems & Database Architect
- Based in Edinburgh, Scotland
- Open Source user & contributor (25+ years)
- PostgreSQL exclusively (16+ years)
- Author, PostgreSQL Mistakes and How to Avoid Them
- Co-author, PostgreSQL 16 Administration Cookbook
- **`pg_statviz`** PostgreSQL extension

Contents

- What is RLS?
- When to use it
- How it works
- How to use it
- What's wrong with it
- What to do about it
- More things to try

Motivation, etc.

- Customer wanted application users to not see each other's data
- Duh? But:
- Customer was used to application being badly coded
- REST URLs like `/user/1234/data`

What is Row-Level Security (RLS)?

- Fine-grained control over which rows are visible to which users
- Provides additional security beyond table or column level privileges
- It's a type of Access Control List (ACL)
- Saves you application-side security filtering

When would you use RLS?

- Confidential data
  - Restrict access to sensitive records
- Role / department separation
  - e.g. only HR sees HR-related content
- Multi-tenant systems
  - Separate data for each customer/tenant in the same DB
- Finer-grained visibility control (row vs table)

How does RLS work? (i)

- From user perspective, rows they're not allowed to see "don't exist"
- Key concepts:
  - Policy
    - Conditions for reading/modifying rows
  - Security barrier
    - Query optimizer doesn't inline/restructure query to bypass RLS

How does RLS work? (ii)

- It's exactly an ACL
- Internally, you are effectively adding `WHERE` conditions to the query
- Permissive / Restrictive policies
  - Permissive: `policy_A OR policy_B` (default)
  - Restrictive: `policy_C AND policy_D`

How does RLS work? (iii)

- `pg_catalog.pg_policy`
  - `polrelid`: The table to which the policy applies
  - `polcmd`: The command for which the policy is: **`SELECT`**, **`INSERT`**, **`UPDATE`**, **`DELETE`**, all
  - `polpermissive`: Policy permissive (`true`) or restrictive
  - `polroles`: Array of roles that the policy applies to
  - `polqual`: **`USING`** clause
  - `polwithcheck`: **`WITH CHECK`** clause

How do I use RLS?


```
ALTER TABLE customers
ENABLE ROW LEVEL SECURITY;
```

- Remember: deny by default

How do I use RLS? (ii)

```
CREATE POLICY custpolicy
ON customer
FOR ALL
TO public
USING customer_user = CURRENT_USER;
```

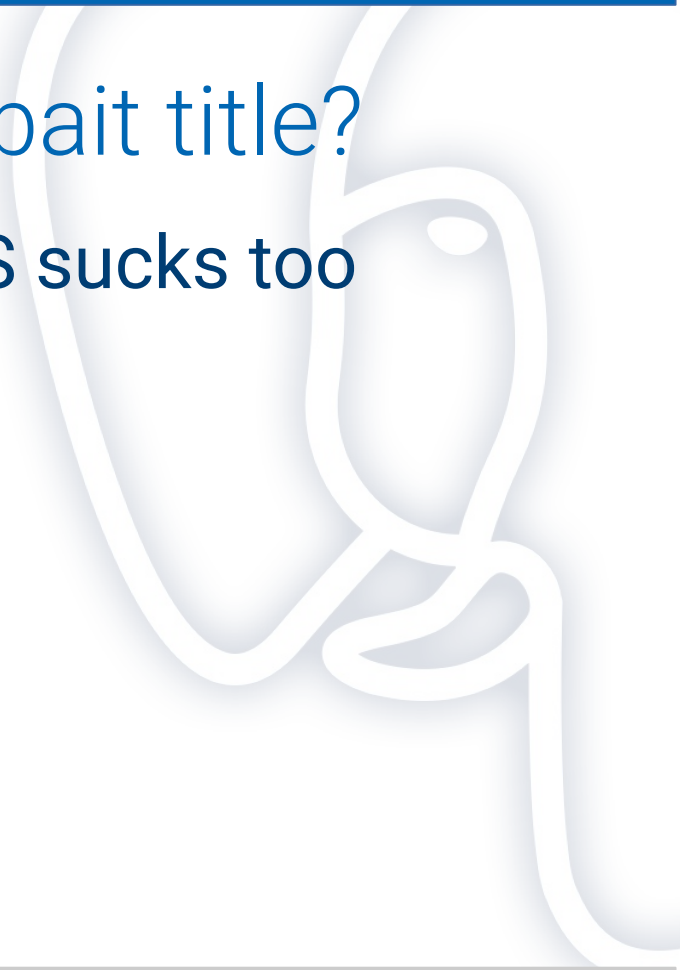
How do I use RLS? (iii)

```
SELECT * FROM customer;
```

```
SELECT * FROM customer
(WHERE customer_user = CURRENT_USER);
```

Okay, but what about your clickbait title?

- It does suck
- And RLS sucks too
- Why?



What's wrong with how RLS works? (i)

- It assumes that your application works a certain way
- People generally don't have data separated **by database user** that accesses it
- You don't want Postgres to manage your application users
  - Roles system has global scope
  - Can't store user attributes/preferences

What's wrong with how RLS works? (ii)

- Your application connects to DB using a single user
  - Makes auditing difficult
  - Changing this would require a significant rewrite
- Aligning application users and DB roles is tedious
  - Spaghetti of **`GRANT`**s
  - You have to keep them in sync too

What can we do?

A possible solution (i)

- **SET** variables and use those in the **POLICY**

```
CREATE POLICY transpolicy
ON transaction FOR ALL TO public
USING
     (tenant = current_setting('app.tenant'));
SET app.tenant = 'Megacorp';
```

A possible solution (ii)

- Feeling paranoid?

```
CREATE POLICY transpolicy
ON transaction FOR ALL TO public
USING (tenant =
    current_setting('app.tenant')::uuid);

SET app.tenant =
    '465f2480-bbca-4eb0-8dd5-c6310b724e37';
```

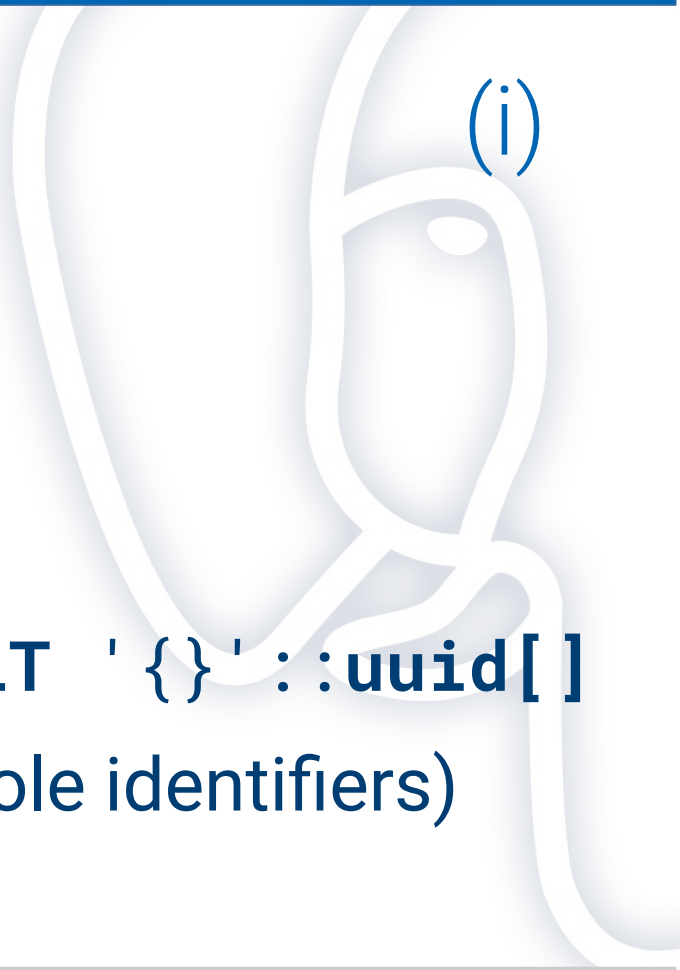
A possible solution (iii)

- Depending on whether you use connection pooling:

```
SET LOCAL app.tenant =
    '465f2480-bbca-4eb0-8dd5-c6310b724e37';
```

Want to take this a step further?

ACL + RBAC



- Explicit Access Control List
  and Role-Based Access Control
- Add an ACL column to the table:

```
ALTER TABLE transaction
ADD acl uuid[] NOT NULL DEFAULT '{}'::uuid[]
```

- **ARRAY** of **uuid** (if we use UUIDs for role identifiers)

ACL + RBAC (ii)

- **SET** the **roles** that are granted access in the ACL

```
SET app.tenant_roles =
    '{dda71d2d-67d8-4f00-b877-41ab442e62ea,
      039746dc-48a1-4e2a-b765-968f689ac84f}';
```

ACL + RBAC

(iii)

- What does the RLS policy look like?

```
CREATE POLICY transrolepolicy
ON transaction FOR ALL TO public
USING (acl &&
current_setting('app.tenant_roles')::uuid[]
= true);

ALTER TABLE transaction
ENABLE ROW LEVEL SECURITY;
```

ACL + RBAC (iv)

- The policy checks if any of the tenant roles are inside the ACL
- RBAC
  - Roles can have attributes that define their privileges
  - Like Postgres roles, can be thought of as “groups” (of one or more tenants)
  - Can be granted to other roles, and then you have an aggregate of the privileges
  - Yes, we parallel the PostgreSQL roles system 😂😭

Want to dive even deeper?

How would you protect from application?

- After all, the application can connect to the DB and change roles and policies
- You hide direct access to this system from the application
- Why?
  - You don’t trust your / third party application
- Let’s assume Django app

Database-side

(i)

```
CREATE ROLE django;

CREATE TABLE transaction (
  id uuid PRIMARY KEY DEFAULT
      gen_random_uuid(),
  amount numeric,
  created_at timestamptz DEFAULT CURRENT_TIME,
  acl uuid[] NOT NULL DEFAULT '{}'::uuid[]
);
```

Database-side (ii)

- To speed up ACL enforcement, we need an index that supports **ARRAY** operations on it:

```
CREATE INDEX ON transaction
USING GIN (acl array_ops);
```

Database-side (iii)

```
CREATE TABLE tenant_role (
   role_id uuid PRIMARY KEY,
   role_name text NOT NULL UNIQUE,
   role_description text
);
CREATE TABLE tenant_role_member (
   tenant_id uuid REFERENCES tenant(tenant_id),
   role_id uuid REFERENCES tenant_role(role_id);
);
CREATE INDEX ON tenant_role_member(tenant_id);
```

Database-side (iv)

- Remove the ability of DB user `django` to see inner workings:

```
REVOKE ALL ON tenant_role FROM django;
REVOKE ALL ON tenant_role_member FROM django;
REVOKE SELECT ON transaction FROM django;
GRANT SELECT (id, amount, created_at)
ON transaction TO django;
```

Database-side (v)

- Create the policy:

```
CREATE POLICY trans_rls ON transaction
USING (acl &&
current_setting('app.tenant_roles')::uuid[]
= true);

ALTER TABLE transaction
ENABLE ROW LEVEL SECURITY;
```

Expose RBAC to Django through functions

- `create_tenant_role(_role_name` **`text`**`, _role_description` **`text`**`)` **`RETURNS uuid`**
  enables creation of tenant roles
- `get_tenant_roles(_tenant_id` **`uuid`**`)` **`RETURNS uuid[]`**
  returns the roles that have been assigned to a tenant
- `set_tenant_roles(_tenant_id` **`uuid`**`, _roles` **`uuid[]`**`)`
  `RETURNS boolean`
  sets all roles for a tenant

One more thing...

- For each table, we need an “add role to row acl” function and a “remove role from row acl function”
- These can be called e.g. by overriding Django’s `.save()`
- Important when using **`SECURITY DEFINER`**:
  `SET` `search_path = public, pg_temp;`
  (at the bottom of each function definition)

"Add role to row ACL" function

```
CREATE OR REPLACE FUNCTION order_acl_add(_id uuid, _role_id uuid)
RETURNS boolean AS $$
DECLARE _current_roles uuid[]; r uuid;
BEGIN
UPDATE order SET acl = (
    CASE WHEN _role_id = ANY(acl) THEN acl
    ELSE array_append(acl, _role_id) END)
WHERE id = _id;
IF FOUND THEN RETURN true;
ELSE RETURN false;
END IF;
END $$
LANGUAGE plpgsql
SECURITY DEFINER
SET search_path = public, pg_temp; -- IMPORTANT with SECURITY DEFINER
```

Finally, a few potential RLS catches (i)

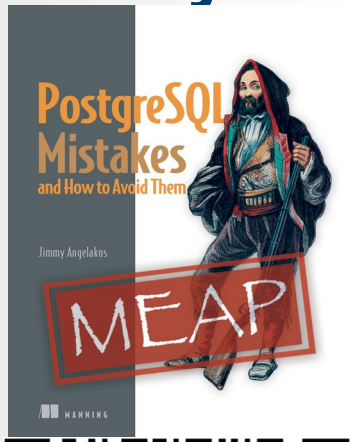
- Policies can add overhead to queries
  - Especially complex conditions
  - Keep policies simple and explicit
- Superuser can bypass all RLS checks
- Table owner can bypass RLS check if **`FORCE ROW LEVEL SECURITY`** is not specified

Finally, a few potential RLS catches (ii)

- Set a restrictive **DELETE** policy
  - So that people can't delete rows they can read but not update
- Make sure you reset variables between sessions
  - PgBouncer statement mode won't work with **`SET`**/**`SET LOCAL`**
- Ensure **`WITH (SECURITY BARRIER)`** is in place for views
  - To stop malicious function overrides with `cost 0.000000000001` etc.

Thank you ❤️

45% off everything!
Code: **`jascale22x`**



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