Before We Start

Setup a Citus Cloud account for the exercises:

https://**bit.ly/citustutorial**

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Designing a Multi-tenant Database for Scale

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Tutorial Outline

1. Introduction & Data Modeling (20 mins)
   - Scaling & Multi-tenant Databases
2. Scaling a multi-tenant database (#1) (50 mins)
3. Break (15 mins)
4. Three Approaches to Scaling (20 mins)
5. Scaling a multi-tenant database (#2) (50 mins)
6. Q & A (30 mins)

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What does it mean to “scale”?

- Scaling: Allocating more resources to your application or database to improve performance.
- Scaling databases is harder than scaling apps.
- Types of resources you can scale:
  1. Software resources: Connections, number of processes
  2. Hardware resources: CPU, memory, and storage

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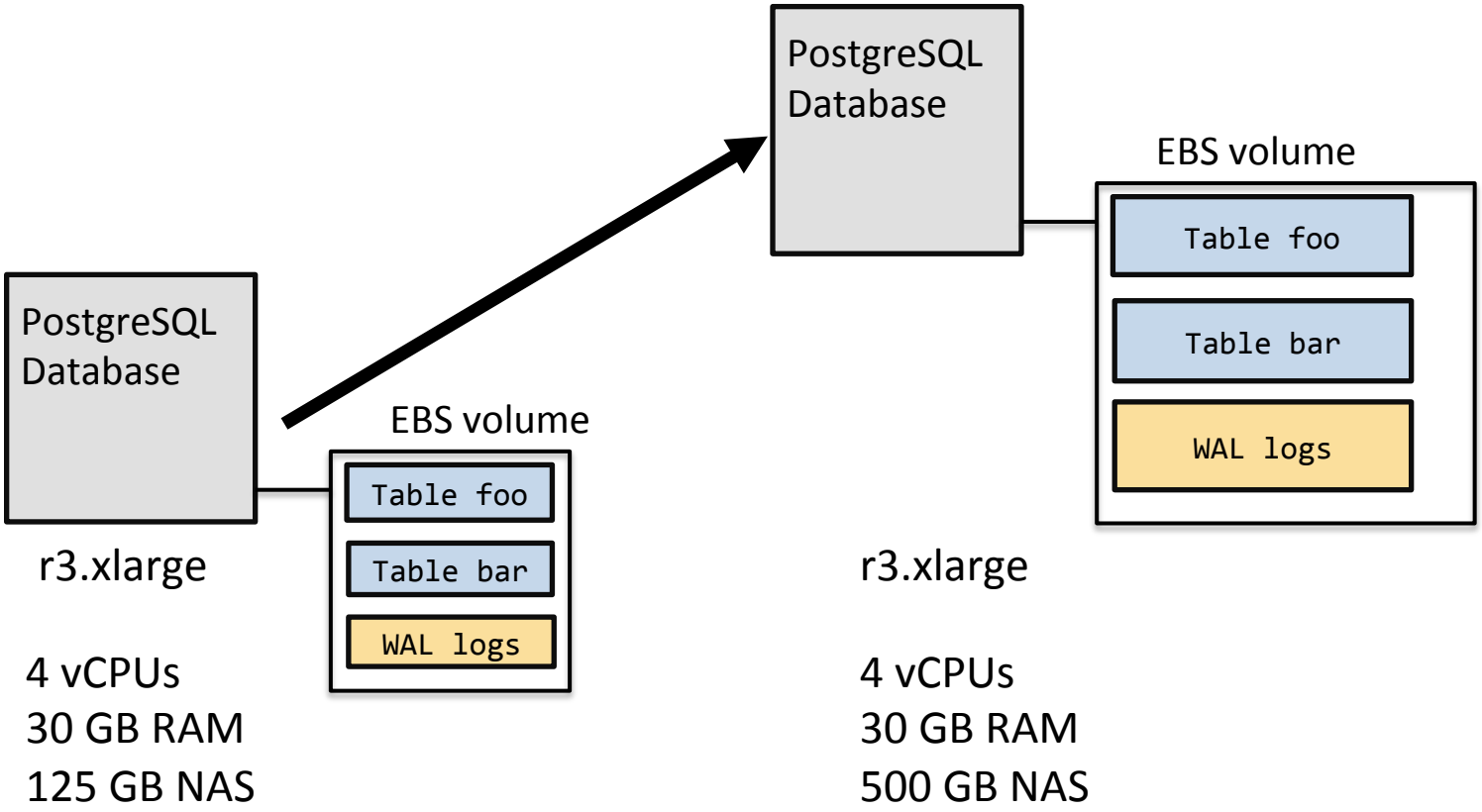
Scaling Storage



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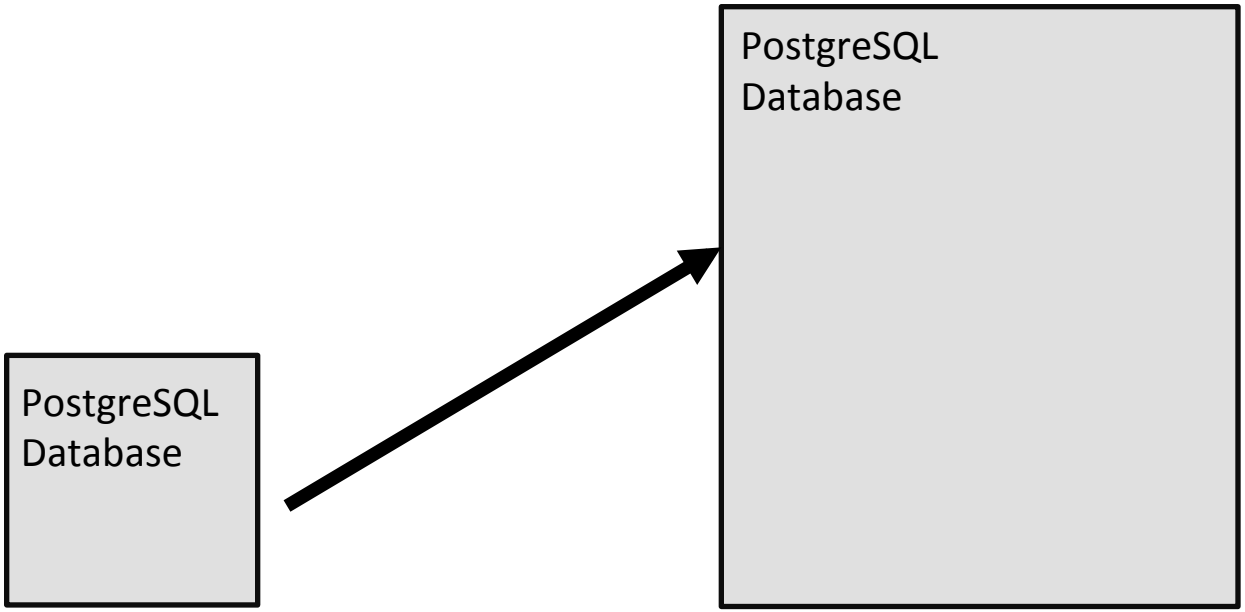
Scaling Up Hardware



r3.xlarge

4 vCPUs
30 GB RAM
80 GB SSD

r3.4xlarge

16 vCPUs
120 GB RAM
320 GB SSD

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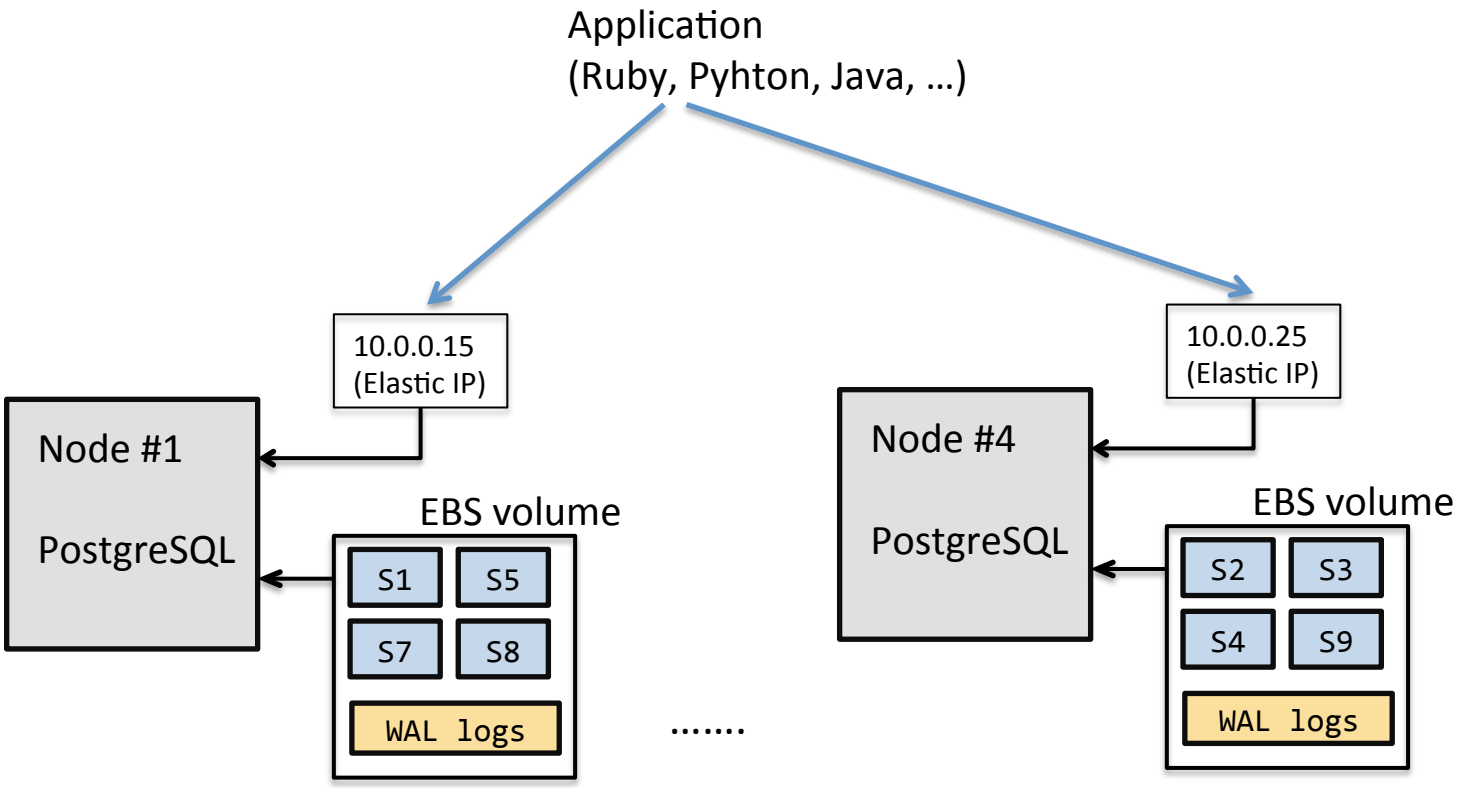
Scaling Out Hardware



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When is the right time to scale out

- Scaling up is easier than scaling out. If you can throw more hardware at the problem, that's the easiest way to scale.
- Also tune your database: http://pgconfsv.com/postgresql-when-its-not-your-day-job
- When is the right time to start thinking about scaling out?

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Heuristic #1 on when to scale

- Your SaaS business is growing, you're on the second largest instance type available on your cloud / infrastructure provider
- Example tipping points
  - We signed a big customer, and now all our customers are hurting
  - One-off operational queries are bringing the database to a halt
  - We expect to grow by 10x next year

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Heuristic #2

- Even after tuning, PostgreSQL's autovacuum daemon can't catch up with our write traffic

Variable	PG Default	Suggested
autovacuum max workers	3	5 or 6
maintenance work mem	64MB	system ram * 3/(8*autovacuum max workers)
autovacuum vacuum scale factor	0.2	Smaller for big tables, try 0.01

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Heuristic #3

- Databases will cache recent and frequently accessed data in memory for you
- The database will track how often you use the cache and hit disk

- For OLTP applications, most of your working set should be fulfilled from the cache
  - Look to serve 99% from the cache

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Heuristic #3 – cache hit ratio query

To measure the cache hit ratio for tables:

```
SELECT
    'cache hit rate' AS name,
     sum(heap_blks_hit) / (sum(heap_blks_hit) + sum(heap_blks_read)) AS ratio
FROM pg_statio_user_tables;
```

or the cache hit ratio for indexes:

```
SELECT
    'index hit rate' AS name,
    (sum(idx_blks_hit)) / sum(idx_blks_hit + idx_blks_read) AS ratio
FROM pg_statio_user_indexes
```

Source: Heroku -- Determining Cache Size

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Plan ahead

- Plan ahead, optimize queries, and don't wait until there isn't another option
- When it's time to scale out, you need to better understand your workload.
  1. B2B (multi-tenant databases) or B2C applications
  2. Transactional (OLTP) or analytical (OLAP)

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Why are B2B workloads different

- Databases serving B2B workloads store richer data that has more inter-dependencies.
- This data richness benefits from key relational database features:
  - Transactions
  - Joins – avoid data duplication
  - Primary and foreign key constraints

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What is a multi-tenant database

- If you're building a B2B application, you already have the notion of tenancy built into your data model
- B2B applications that serve other tenants / accounts / organizations use multi-tenant dbs
  - Physical service providers. For example, food services to other businesses
  - Digital service providers: Advertising, marketing, and sales automation

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Trends in scaling multi-tenant apps

- Multi-tenant databases were commonplace in on-premises
- SaaS applications introduced the motivation to scale further
  - Cloud enables serving many smaller tenants
  - Instead of dozens of tenants, new SaaS apps reach to and handle 1K-100K tenants
  - Storage is cheap: You can store events or track a field's history

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Google F1 – An Example

- Google F1 is an example that demonstrates a multi-tenant database.
- AdWords serves more than 1M tenants.
- How do you model your data to scale out transactions, joins, and database constraints?

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Data modeling for multi-tenant

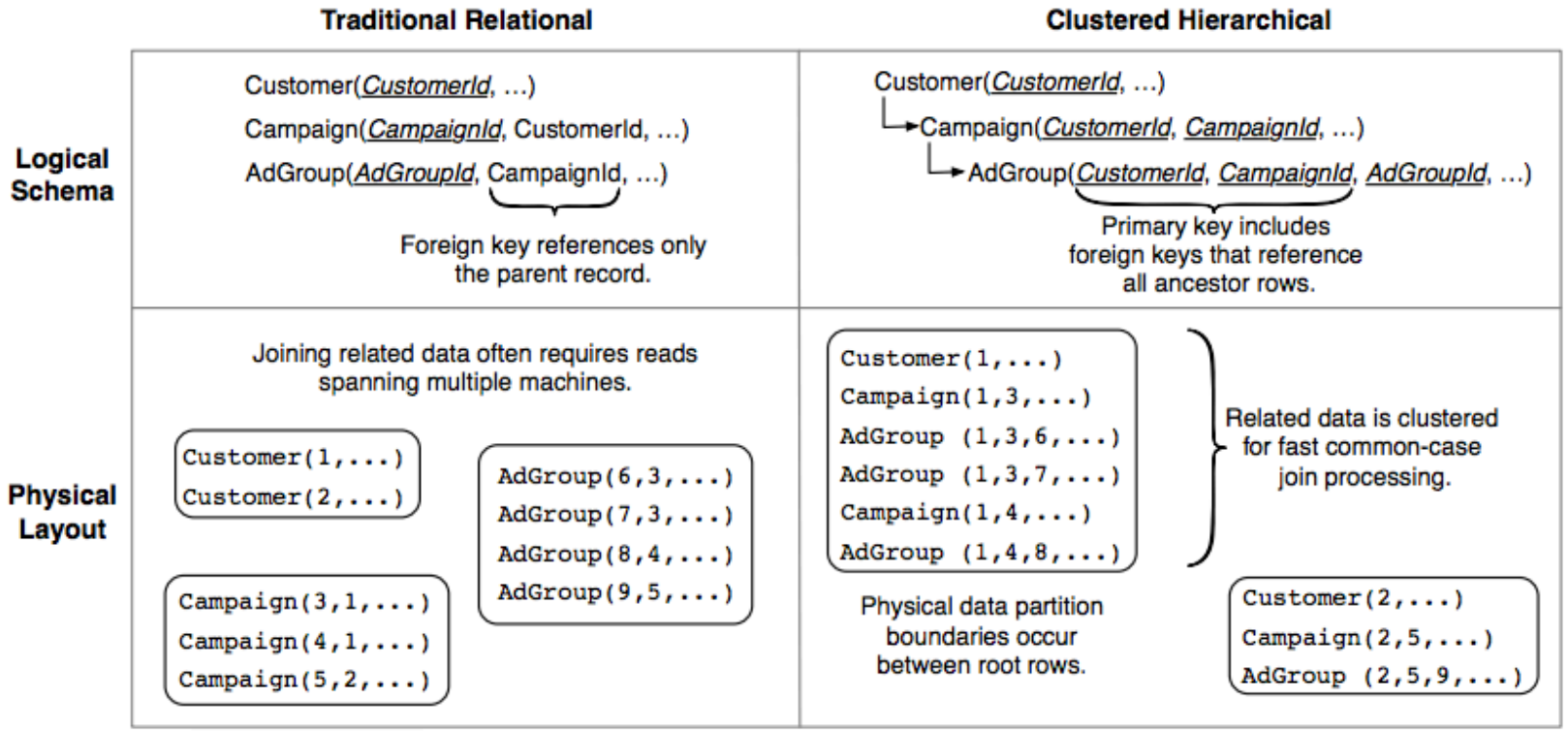

Figure 2: The logical and physical properties of data storage in a traditional normalized relational schema compared with a clustered hierarchical schema used in an F1 database.

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Key Insight

- If you shard your tables on their primary key (in the relational model), then distributed transactions, joins, and foreign key constraints become expensive.

- Model your tables using the hierarchical database model by adding tenant_id. This colocates data for the same tenant together and dramatically reduces cost.

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Concept of co-location

Stores

id	name
1	my book store
5	my other store

Products

id	name	store_id
1	foo	1
2	bar	1
3	baz	1

Purchases

id	product_id	store_id	price
1	2	1	1000
2	1	1	1200
3	3	1	1199

Stores

id	name
2	my sock store
6	old things

Products

id	name	store_id
33	new socks	2
34	old socks	6
35	old tie	6

Purchases

id	product_id	store_id	price
102	35	6	600
43	33	2	800

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Does everything fit into hierarchical?

- What happens **if** I have a table that doesn't fit into the hierarchical database model?

1. Large table outside the hierarchy: Orgs and users that are shared across orgs
   - Shard on different column and don't join
2. Small table that is common to hierarchy
   - Create reference table replicated across all nodes

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Summary

- First, tune your multi-tenant (B2B) database. Then, start thinking about scaling.
- The hierarchical database model colocates all data that relates to a particular tenant, to the same machine.

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Hands-on Session: Terminology

- Distributed Table: Table that is distributed across nodes by splitting the data set into shards
- Reference Table: JOINs with distributed tables (e.g. “timezones”)
- Coordinator Table: Large tables that are independent of a tenant (e.g. users)

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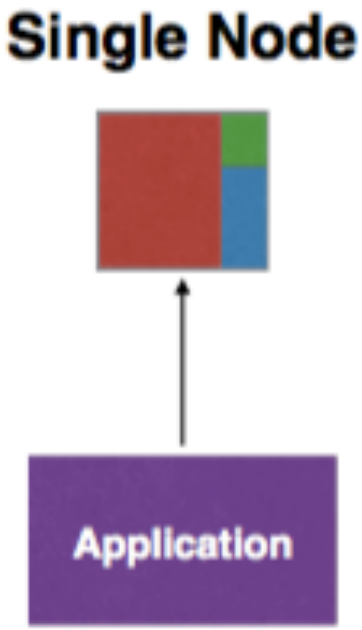
Example: Scaling Multi-tenant App (1)



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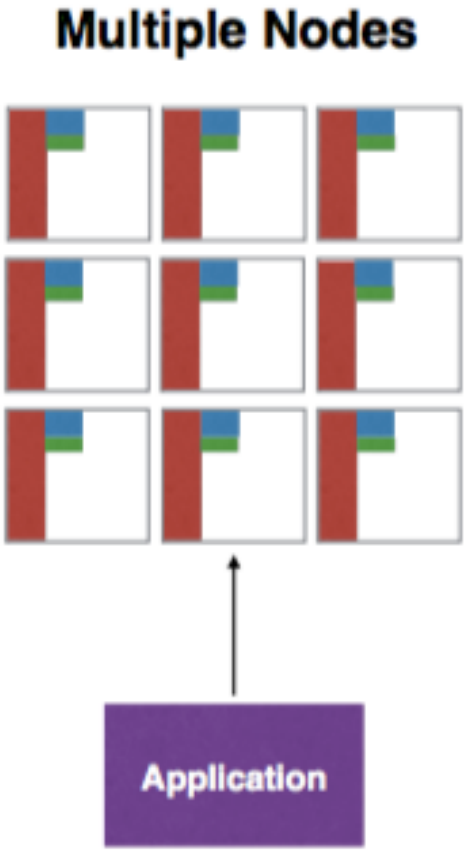
Example: Scaling Multi-tenant App (2)



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Example: Database Schema (3)

- Example Database Schema: B2B Online Store

  Users

  Stores

  Products

  Orders

  Shipping Details

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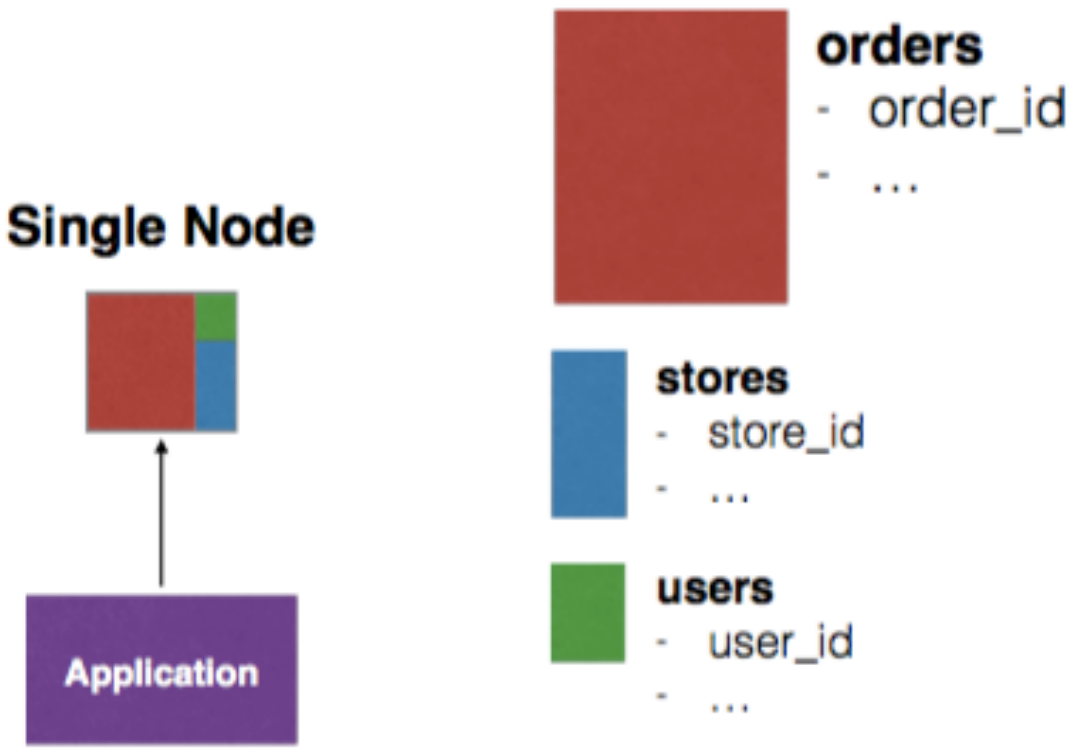
Example: Single Node Schema (4)



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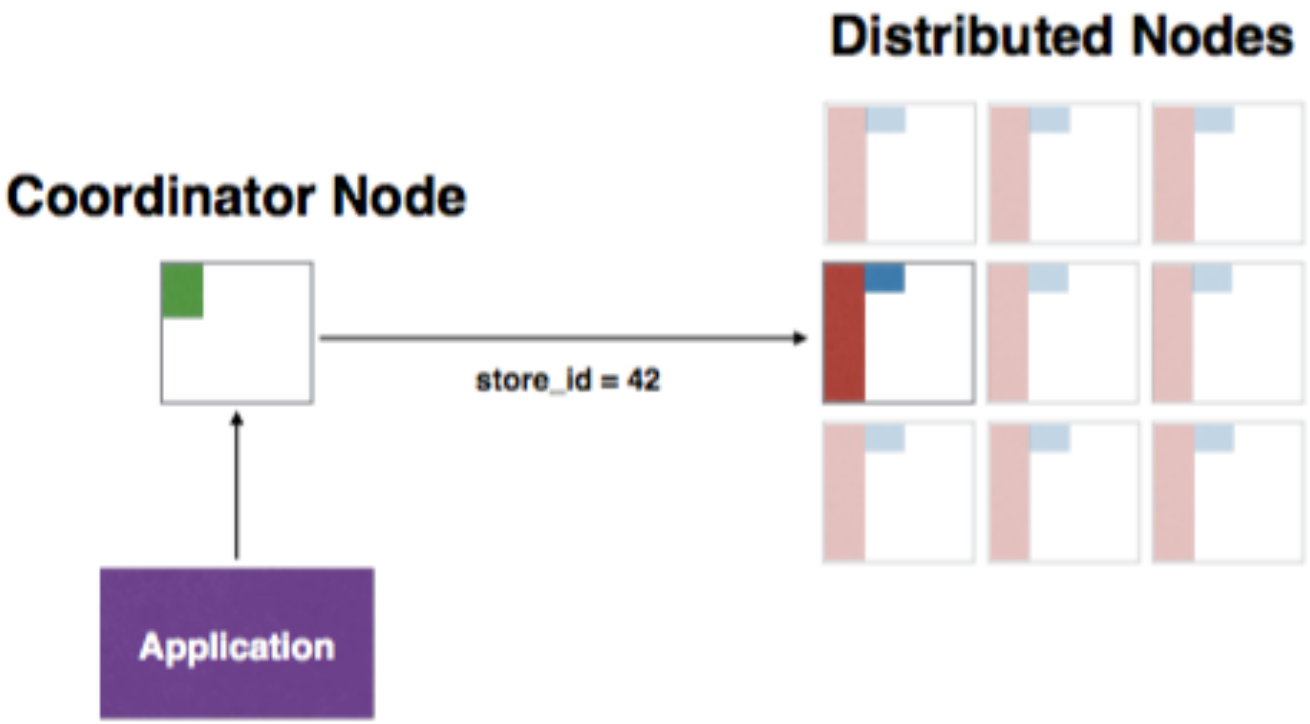
Example: Distributed Schema (5)



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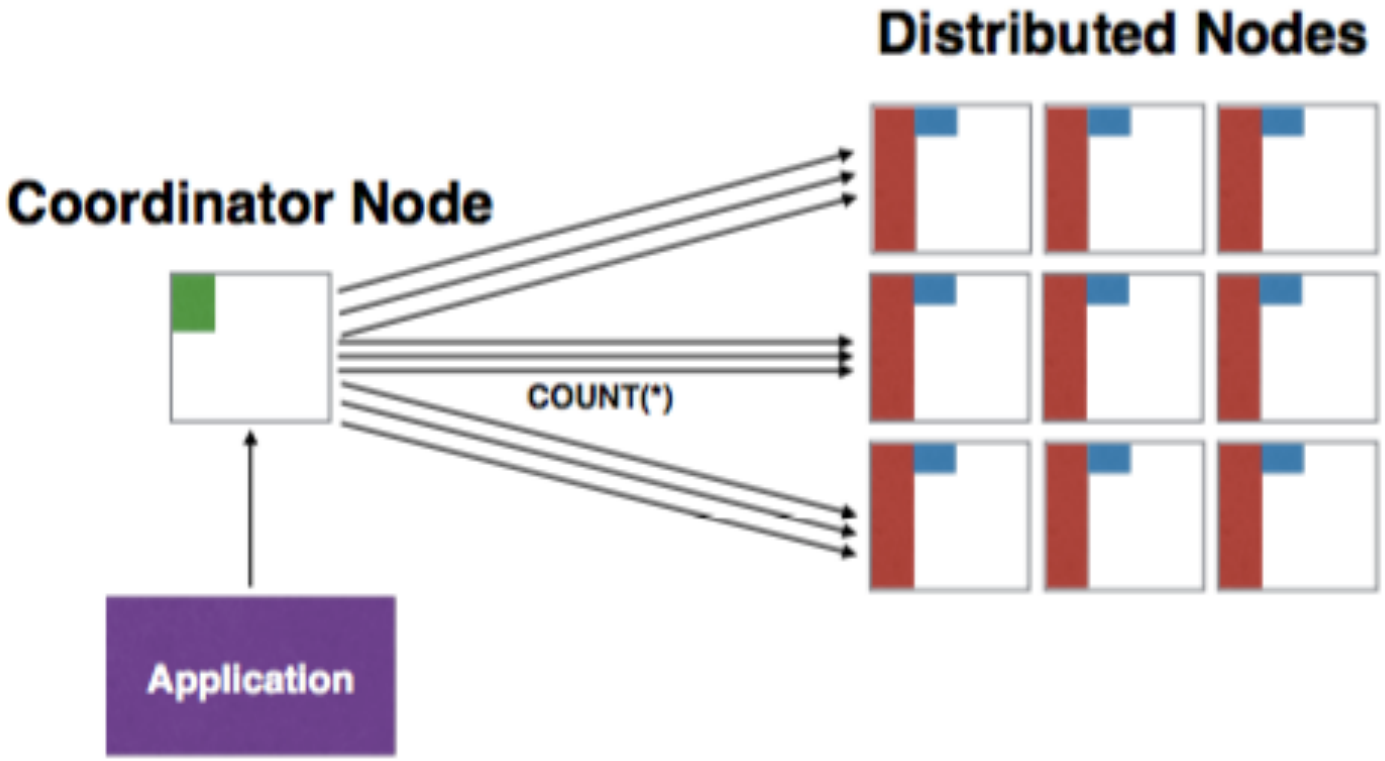
Example: Distributed Schema (6)



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Example: Hands-on Exercise

Scaling an Example Multi-tenant Application & Database

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Scaling Multi-tenant Databases

- How to do you scale your multi-tenant database?
- Three high level options:

1. Create one database per tenant
2. Create one schema per tenant
3. Have all tenants share the same tables (and partition / shard tables)

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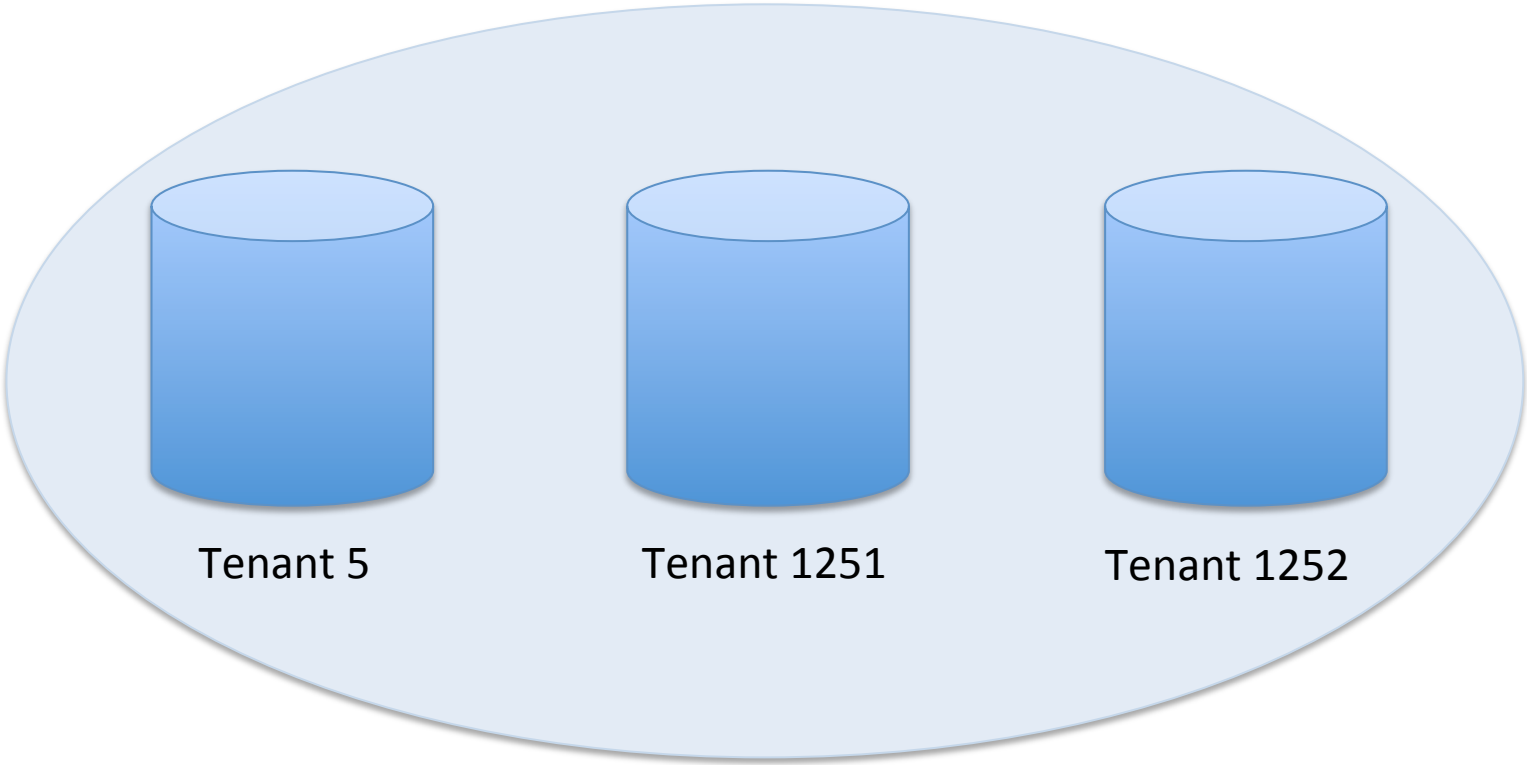
Create one database per tenant



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Create one database per tenant

- Create a separate database for each tenant

- Isolation of tenants and more predictable compliance story
- DBA responsible for managing separate databases and resource allocation between them

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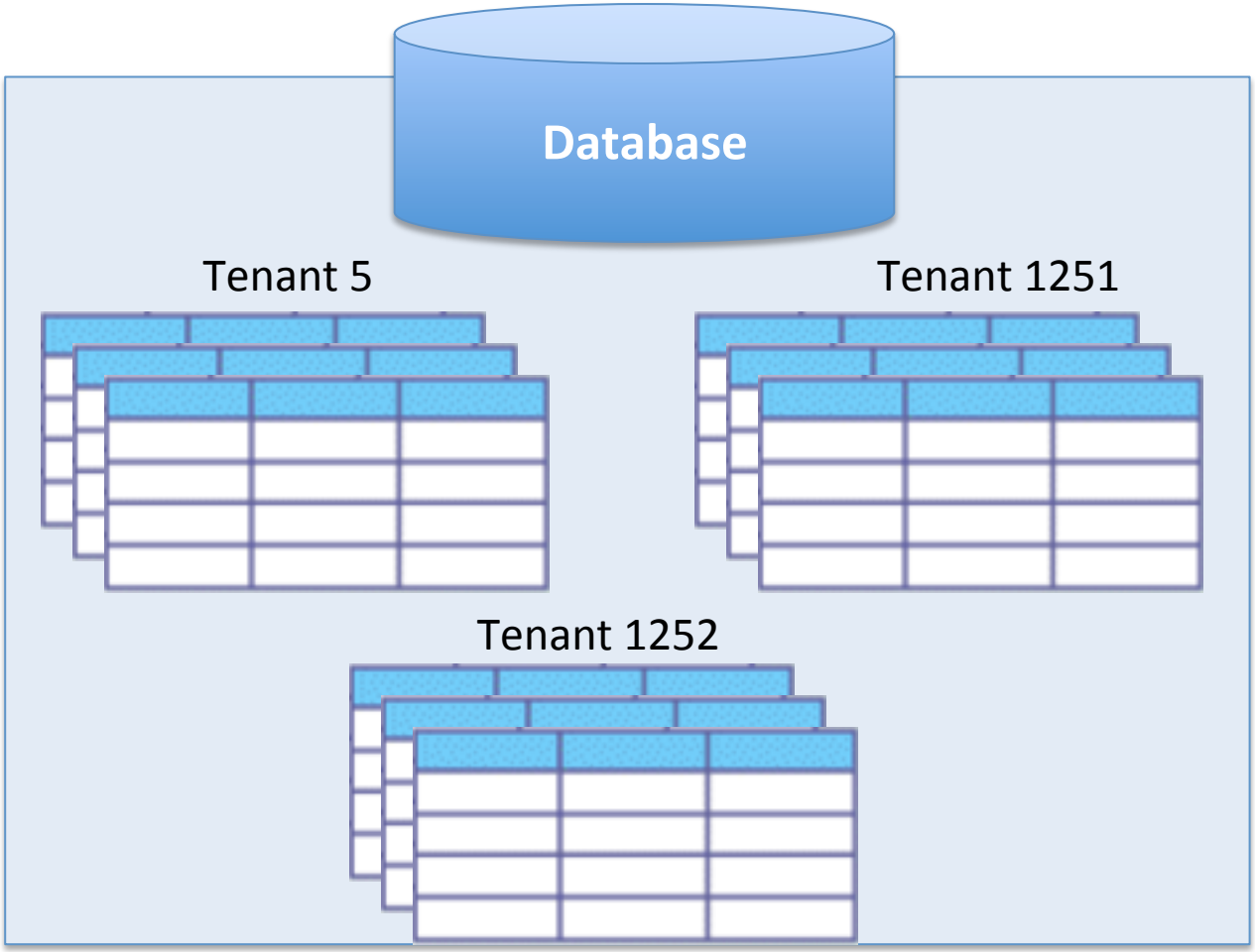
Create one schema per tenant



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Create one schema per tenant

- Create a separate namespace (schema) for each tenant

- Isolate data / queries for one tenant in a schema. Make better use of resources than the “one database per tenant” model

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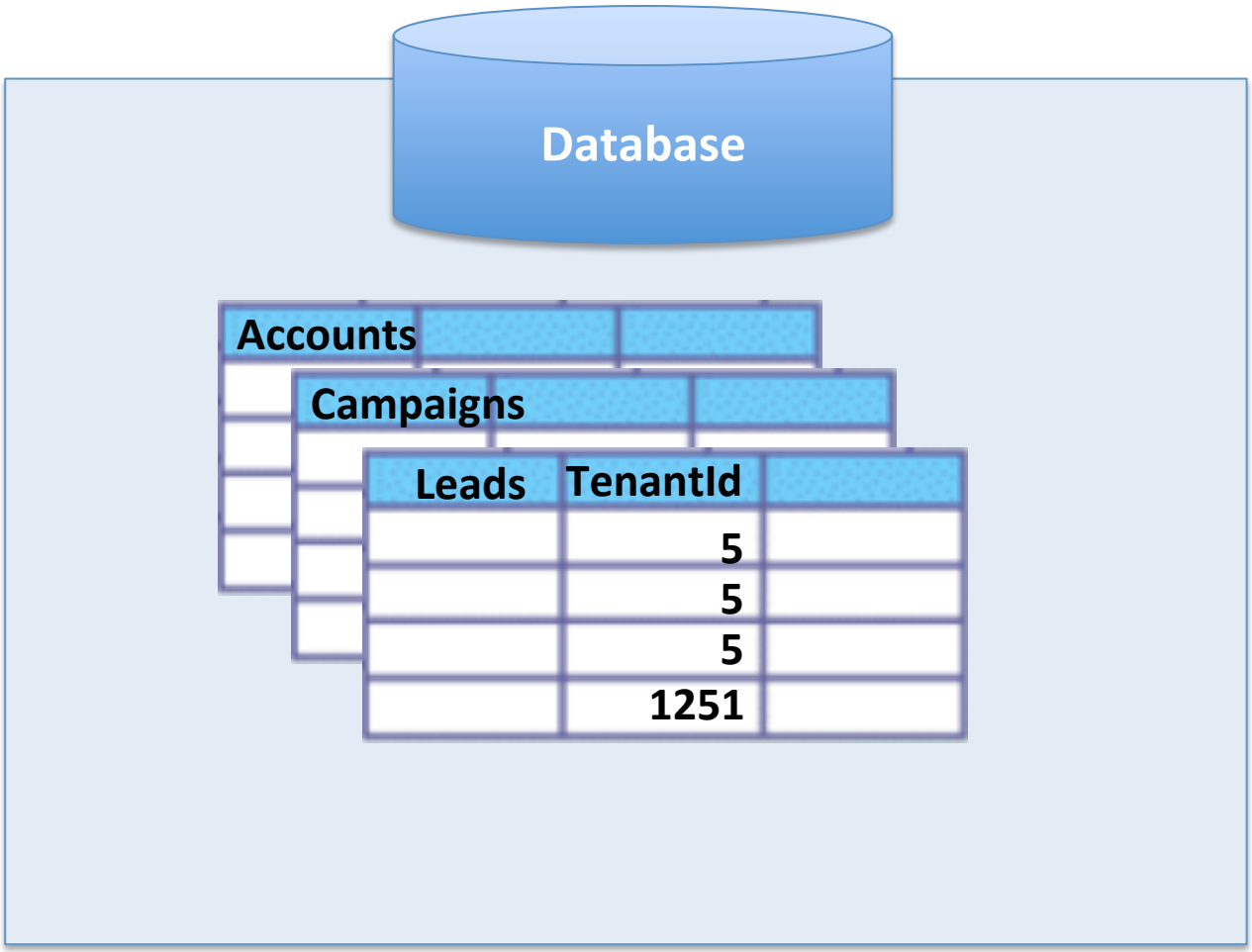
Have all tenants share the same tables



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Have all tenants share the same tables

- Have all tenants share the same tables by adding a tenant_id column (and shard)

- Requires the application to control access to database, or row based access controls
- Scales to 1K-100K tenants through better resource sharing and simplifies operations and maintenance

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Rule of thumb (simplified)

- Each design option can address questions around scale and isolation with enough effort. What's the primary criteria for you app?

- If you're building for scale: Have all tenants share the same table(s)
- If you're building for isolation: Create one database per tenant

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Scaling: Resources

- If you create a separate database / schema for each tenant, you need to allocate resources to that database.
- Hardware: disk, memory, cpu, and network management
- Database software: shared_buffers, connection counts, backend processes
- ORM software: Cached information about databases / schemas

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Scaling: Operational Simplicity

- Your database grows with your SaaS application.
- Schema changes (Alter Table … Add Column) and index creations (Create Index) are common operations.
- What happens when you have 10K tenants and you changed the schema for 5,000 of those tenants and observed a failure?

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Scaling: Data that varies across tenants

- What about data that varies across tenants?
- One tenant per database / schema approach offers the most flexibility. You can tailor each tenant's schema to have its own tables that are independent of another tenant.

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Scaling: Data that varies across tenants

- What about data that varies across tenants?
- Different tenants / organizations may have their own needs that a rigid data model won't be able to address.
- One organization may need to track their stores in the US through their zip codes. Another customer in Europe may only want to keep tax ratios for each store.

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Scaling: Salesforce Architecture

- If your tenants share the same table(s), one approach is creating a huge table with many string columns (Value0, Value1, …, Value500).

campaign_id	name	account_id	V1	V2	V3
1202	tv series	1	null	"Paris"	null
1204	big bang	1	null	94210	0.08
3492	World Cup	93	null	"processed"	"2016-08-02"
352042	Chocolate	1252	8600	"paym.due"	0.08

(*) Salesforce's multi-tenant arch: www.developerforce.com/media/ForcedotcomBookLibrary/Force.com_Multitenancy_WP_101508.pdf

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Scaling: Semi-structured data types

- PostgreSQL has powerful semi-structured data types: hstore, json, and jsonb. These data types can express scalar, array, and nested fields.

```
campaign_id |    name    | account_id |              payment_info
------------+------------+------------+--------------------------------
       1202 | tv series  |      1     | "location": "Paris"
       1204 | big bang   |      1     | "zip": 94210, "tax": 0.08
       3492 | World Cup  |     93     | "status": "processed", "date": "2016-08-02"
     352042 | Chocolate  |   1252     | "status":"paym.due", “amount": 8600
```

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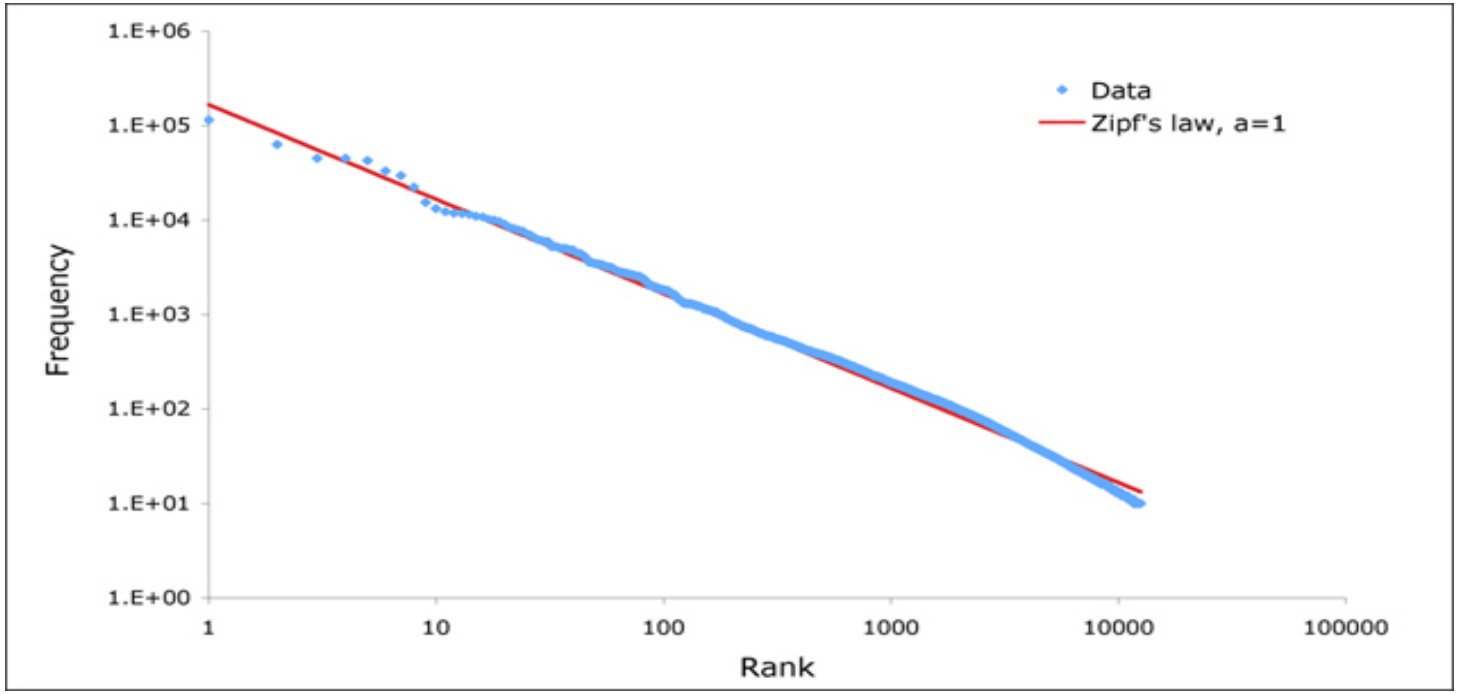
FAQ: How does largest tenant impact scale?

- Multi-tenant databases usually follow a Zipf / Power law distribution



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FAQ: How does largest tenant impact scale?

- What percentage of the total data size belongs to the largest tenant?
- Guidelines around a standard Zipf distribution and different tenant counts:
  - 10 tenants: Largest tenant holds 60% of data (*)
  - 10K tenants: Largest tenant holds 2% of data (*)
- Look at your data's distribution to make informed scaling decisions

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Thanks!

Q&A