Building Cloud Infrastructure

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CS 349D

databricks

Who am I?

- Early Databricks engineer (4 years)
- Apache Spark committer & PMC member
- Worked on a lot of things @ DB
- Most recently, cloud infrastructure
  - Helping eng produce efficient, secure, and reliable software.

What is Databricks?

- Big Data & Machine Learning in the Cloud
  - Yes - our customers are *data scientists* and *data engineers*
- Thinking about getting into self-driving cars
- Yes, we have some Go and Rust code, but prefer FP

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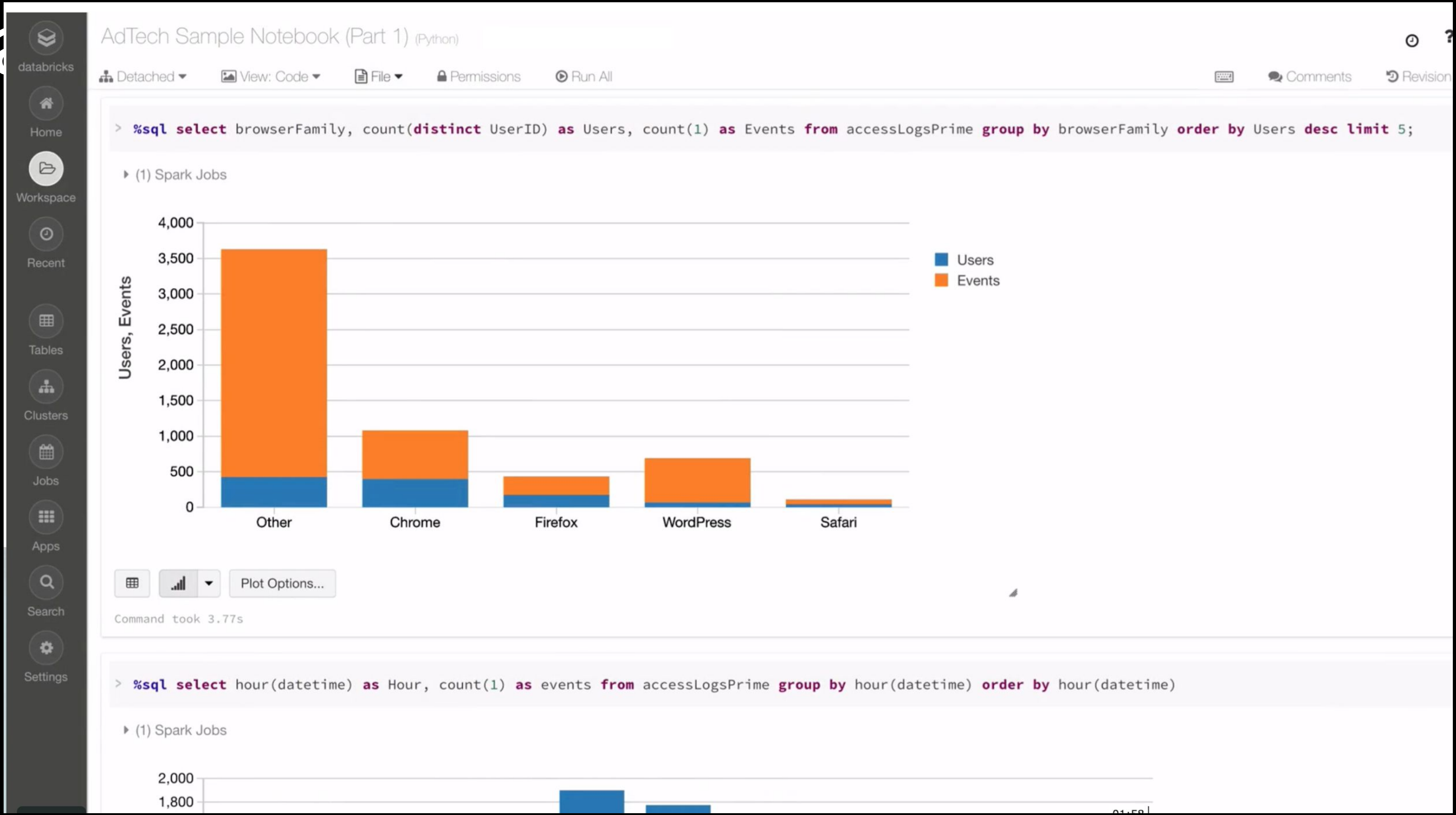
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Home
Workspace
Recent
Tables
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AdTech Sample Notebook (Part 1) (Python)
Detached
View: Code
File
Permissions
Run All
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Revision
%sql select browserFamily, count(distinct UserID) as Users, count(1) as Events from accessLogsPrime group by browserFamily order by Users desc limit 5;
(1) Spark Jobs
Users, Events
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Other
Chrome
Firefox
WordPress
Safari
Users
Events
Plot Options...
Command took 3.77s
%sql select hour(datetime) as Hour, count(1) as events from accessLogsPrime group by hour(datetime) order by hour(datetime)
(1) Spark Jobs
2,000
1,800

Databricks Product

- People love Spark, but:
  - How do I get and maintain a Spark cluster?
  - How do I configure that cluster?
  - How do I run jobs reliably and periodically?
  - How do I interface with Spark?

Operations

Usability

Databricks Product

- People love Spark, but:
  - How do I get and maintain a Spark cluster?
  - How do I configure that cluster?
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Operations

Usability

- Enter Databricks…

Databricks Product

- People love Spark, but:
  - How do I get and maintain a Spark cluster?
  - How do I configure that cluster?
  - How do I run jobs reliably and periodically?
  - How do I interface with Spark?

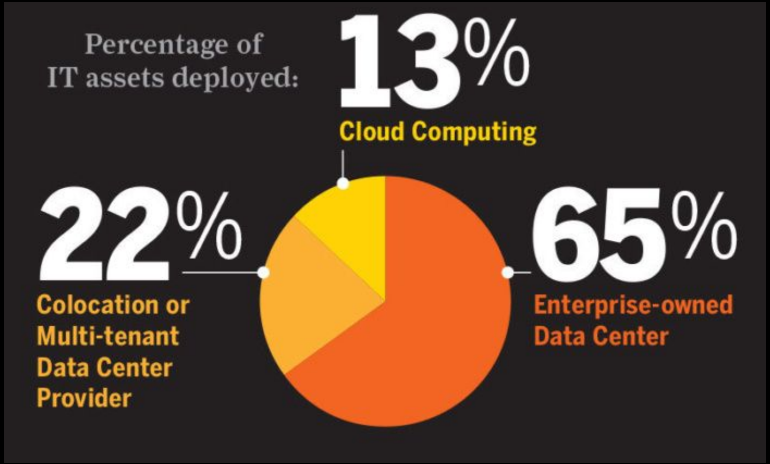
Operations

Usability

- Enter Databricks…
- What hardware do we have?

What does it mean to be a Cloud Company?

- Most money is **still** in on-premise, but trend is towards Cloud.
- “Enterprise:” Financial institutions, government, health care, etc.
- Berkeley & probably Stanford, too



What does it mean to be a Cloud Company?

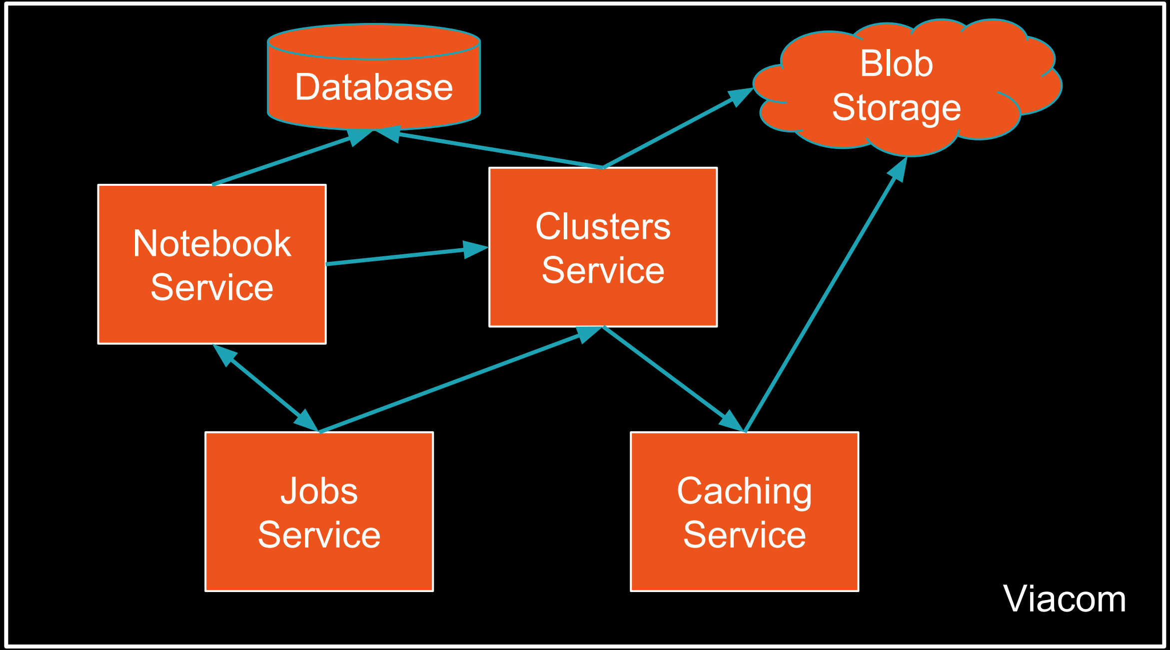
- Infrastructure in the Cloud (vs on-prem infrastructure):
  - **Infrastructure is dynamic** -- provisioning new hardware in O(minutes) rather than O(months).
  - No operations team, but high-level primitives provided instead.
    - Storage (DBs, blob storage), networking (routing/firewalls), etc
- Running Software as a Service (vs on-prem appliance) means:
  - We operate the product on behalf of our customers.
  - Often, the software we run is **multitenant**.
  - **Update often** -- deliver features and fixes faster than 3/6/12 months

In this talk

- We’ll use a real-life motivating example from Databricks to talk about building a **cloud service**.
- Focus on three major aspects:
  - Scaling out a multitenant service
  - Updating services safely
  - Deploying the infrastructure to run our service.

Databricks Community Edition

- In The Beginning, Databricks provided a single-tenant product
- Easier:
  - Security
  - Isolation
  - Selling
- But:
  - Costly
  - Failures



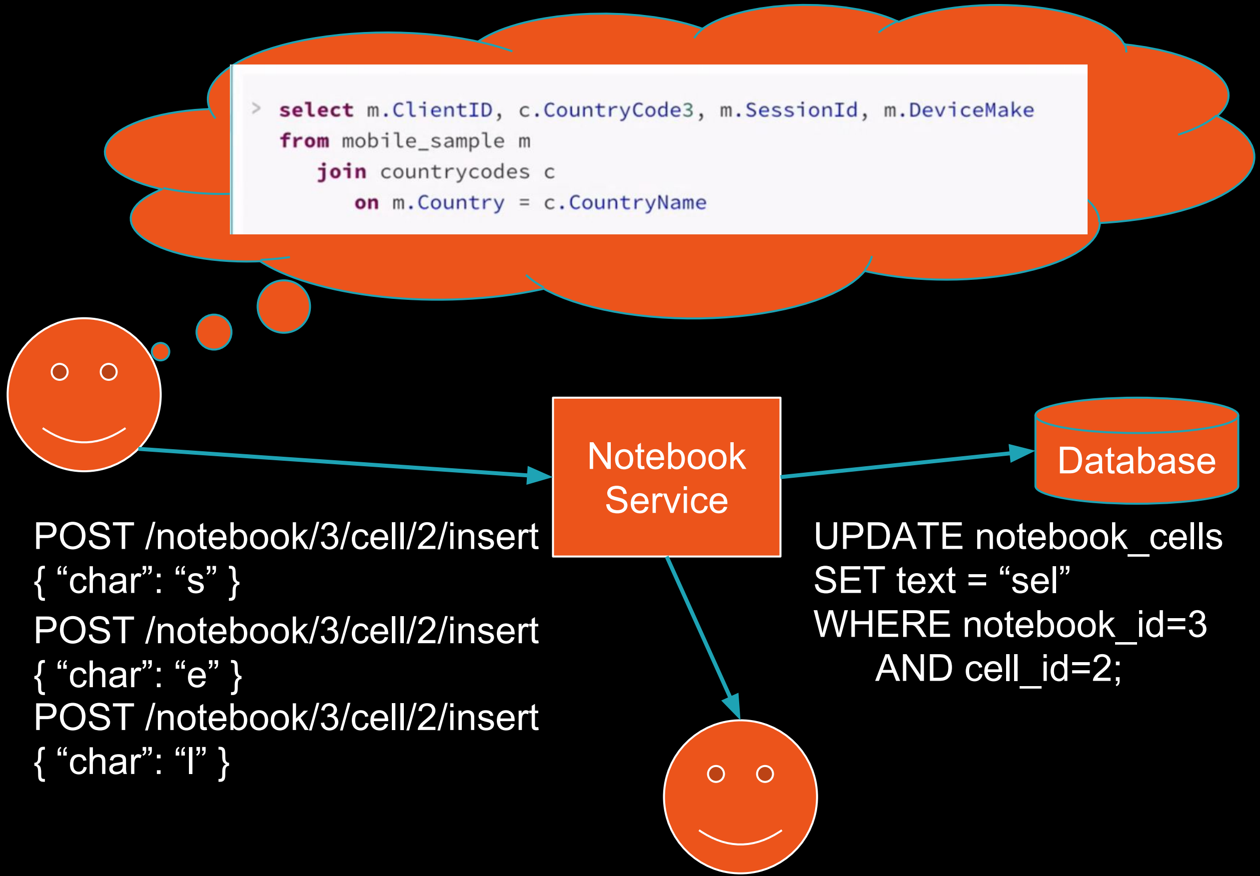
Databricks Community Edition

- We wanted to make a free, multitenant version
- Use-cases: people playing around with Spark, training/classes, MOOCs (now: all new customers)
- Problems:
  - How do we scale our single-tenant services out?
  - How do we update when there is constant usage?
  - How do we maintain this larger, more dynamic infrastructure?

The Notebook Service

- Collaborative notebook UI
  - Users mainly edit their own notebooks, but sometimes want to collaborate
  - Collaboration requires merging changes from multiple users in real-time.
- Originally: ~10 concurrent users.
- Now: Training of 500 people -- or a 50,000-person MOOC!
- How do we scale this service out?

The Notebook Service



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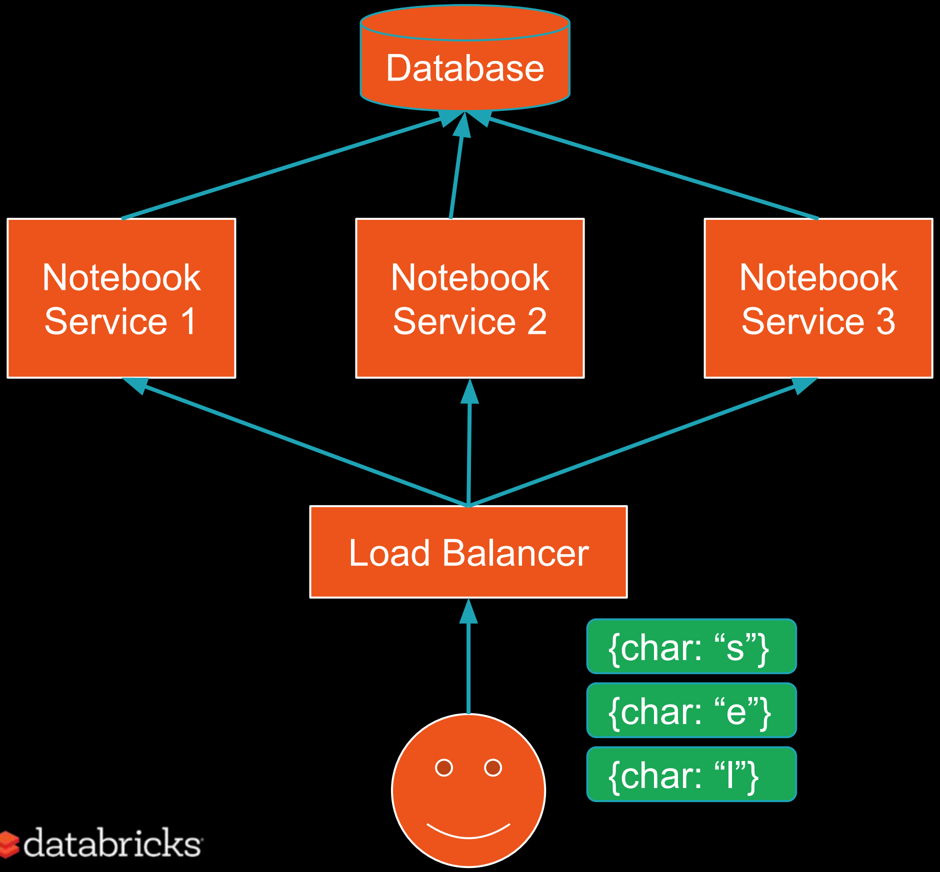
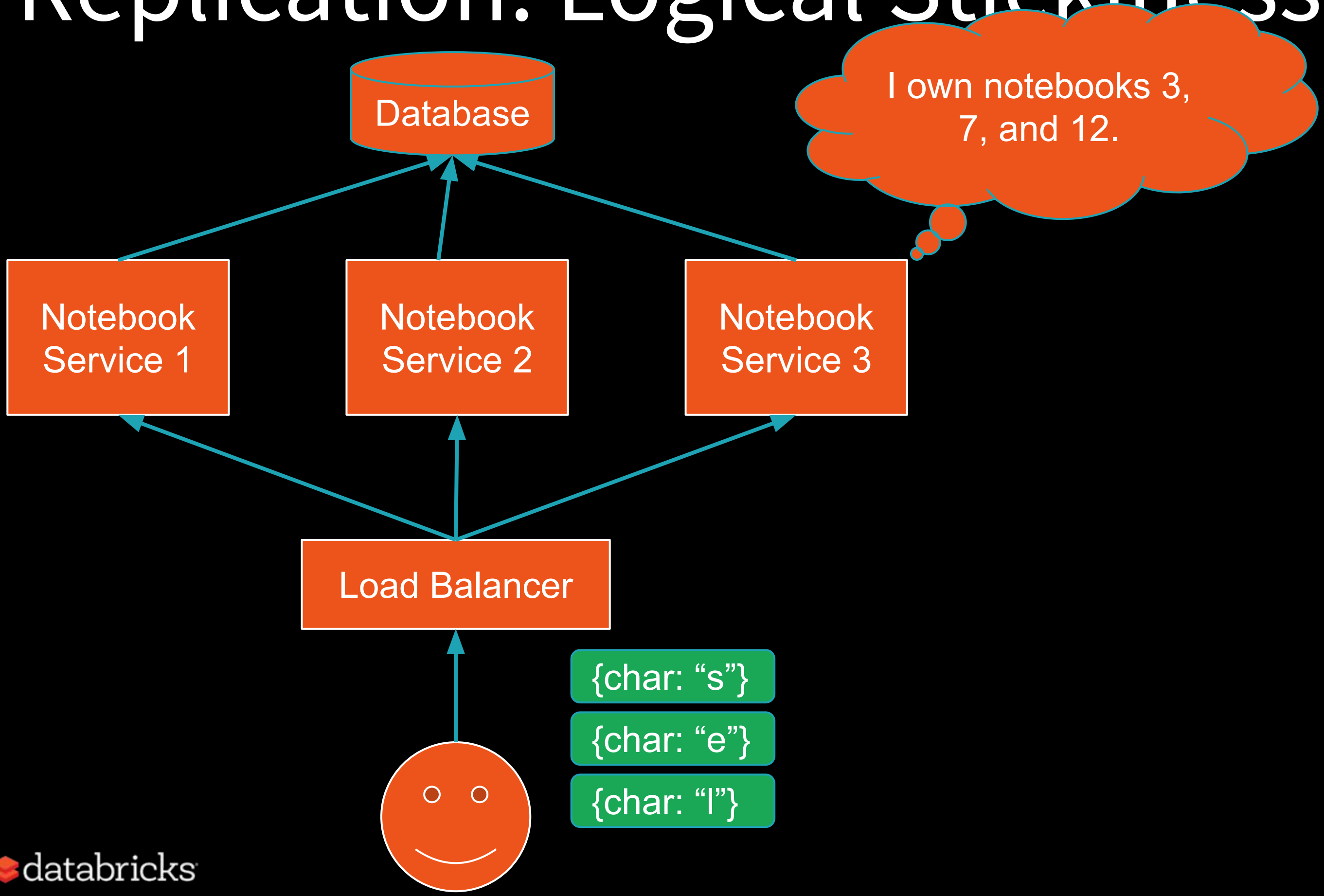
Service Replication



Replication: Logical Stickiness



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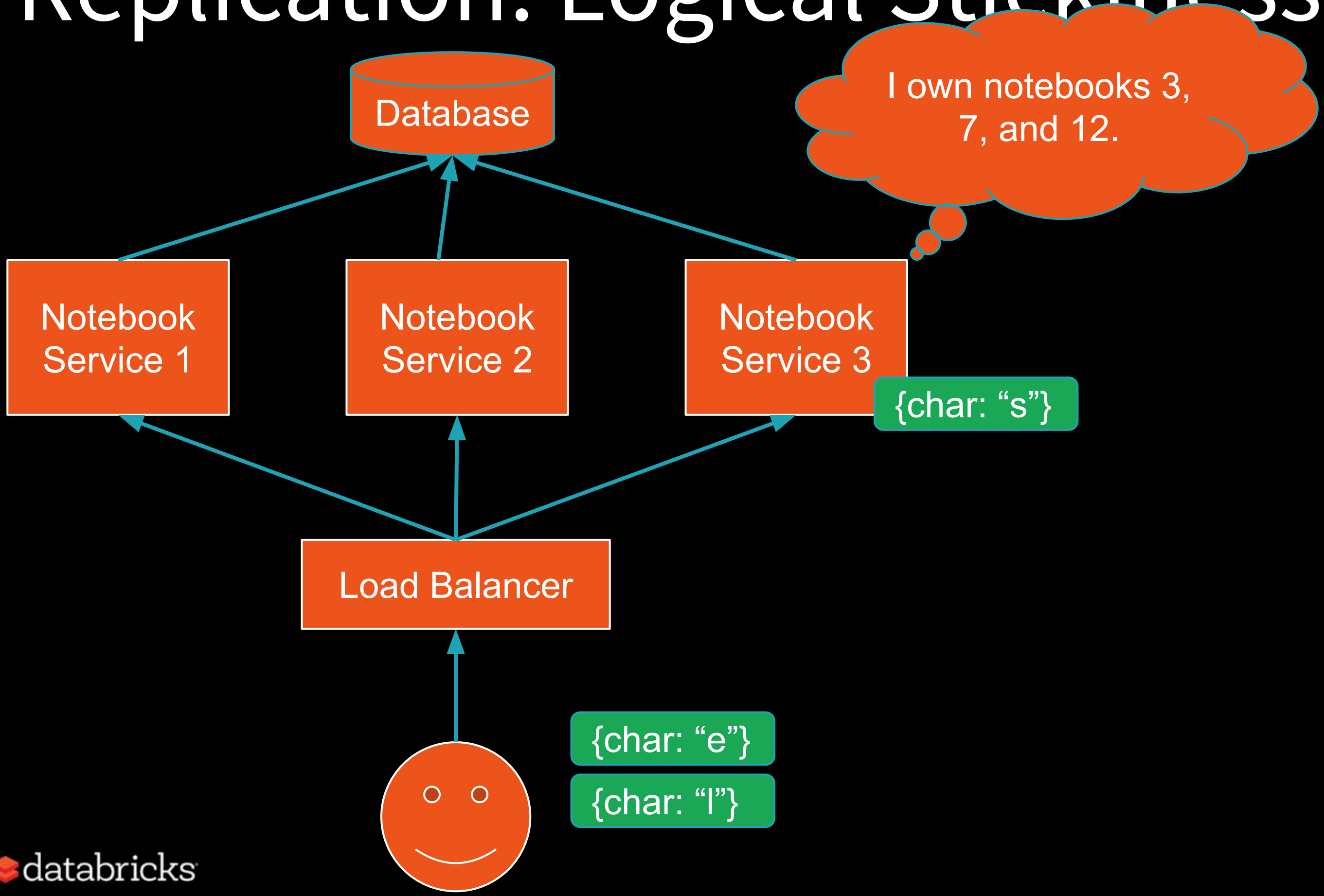

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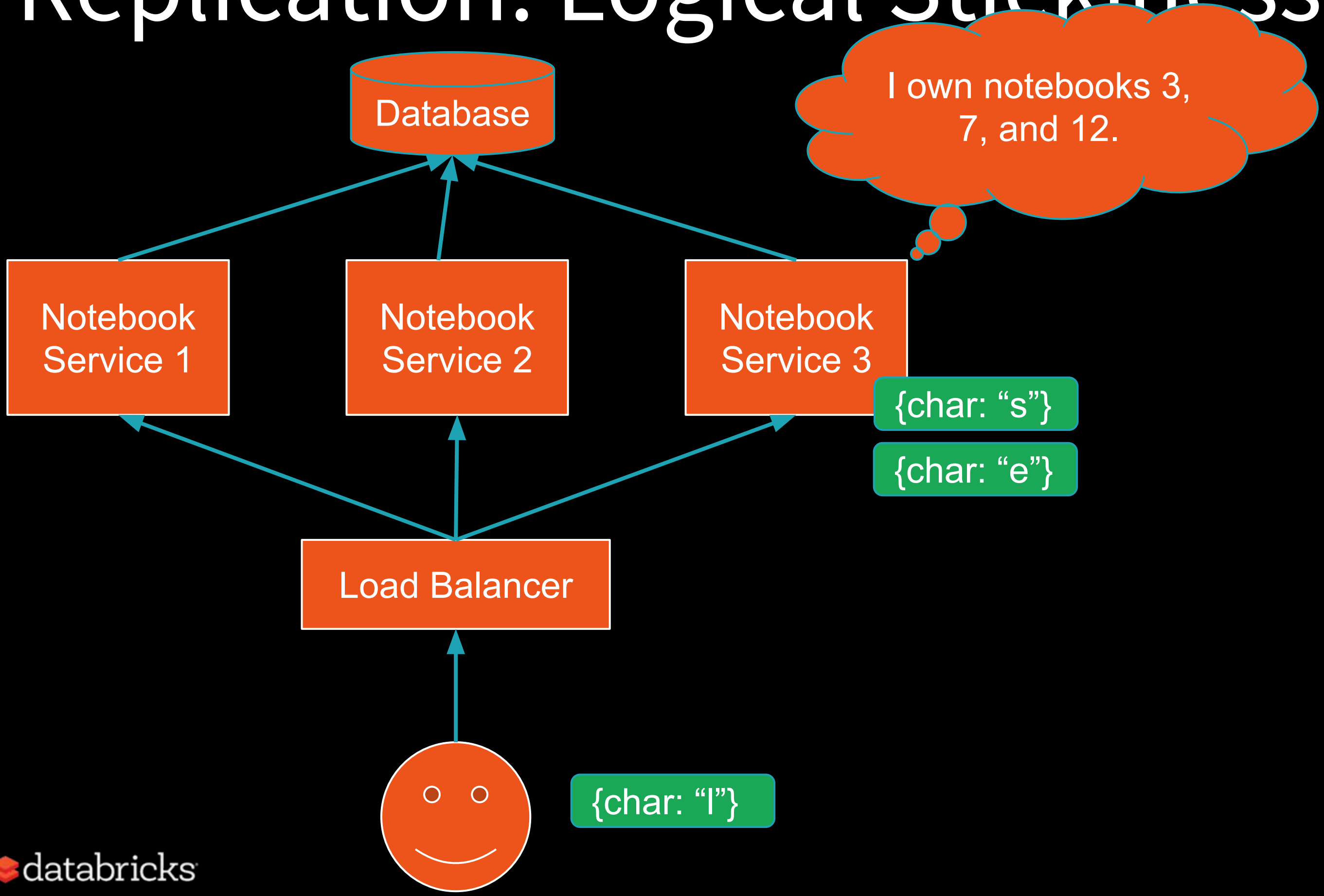

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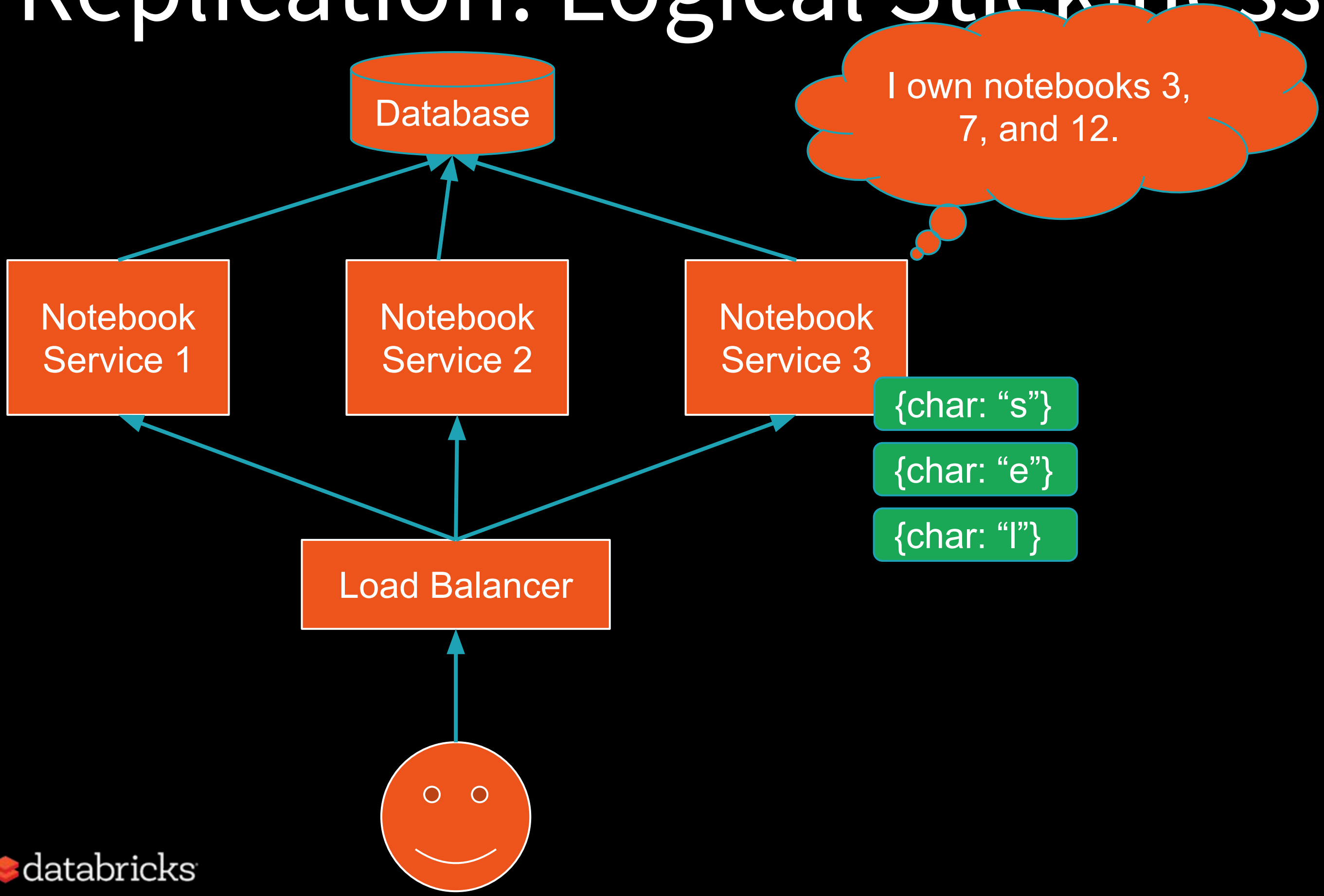

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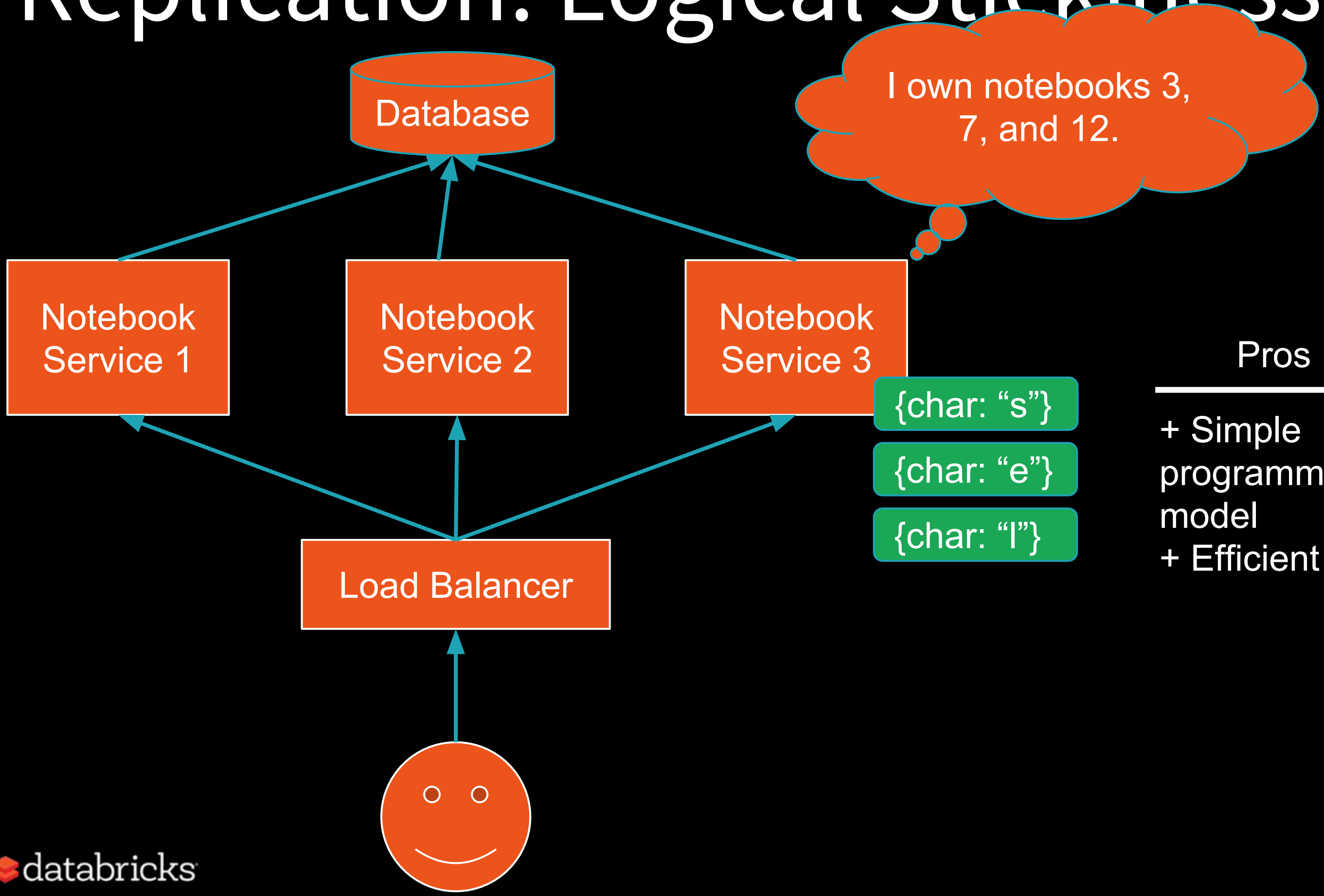
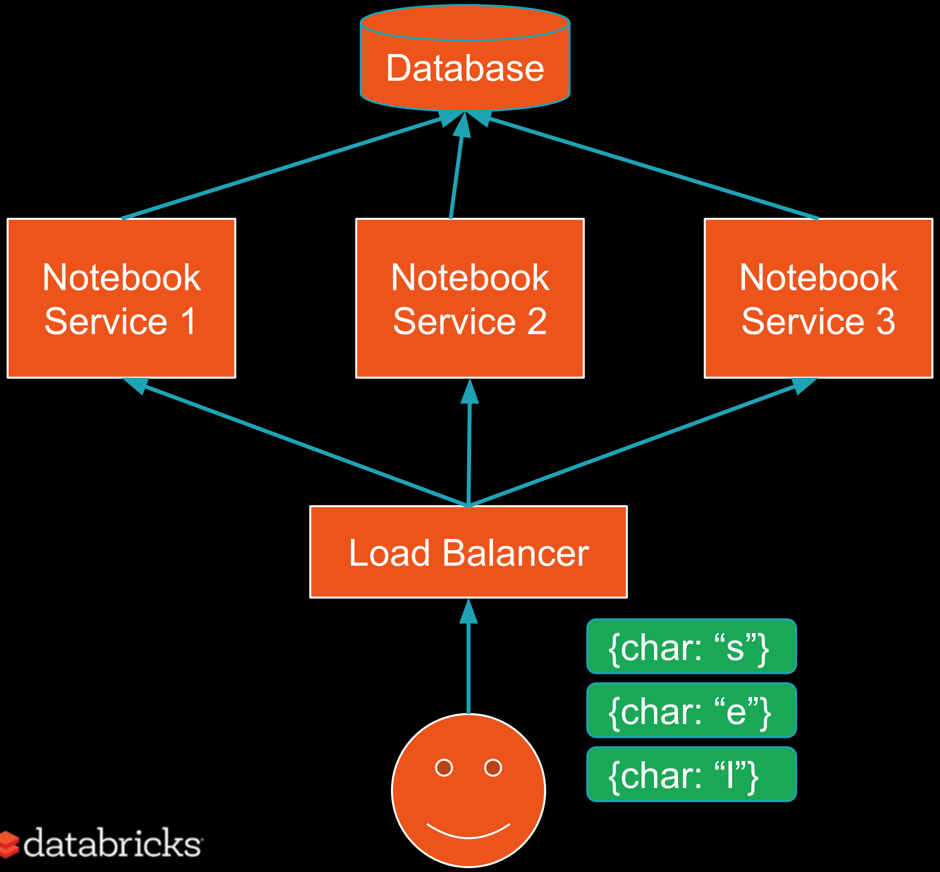


Pros	Cons
+ Simple programming model + Efficient	- Requires complex load balancing infrastructure - Fault recovery complicated - Scalability constrained

Replication: Stateless



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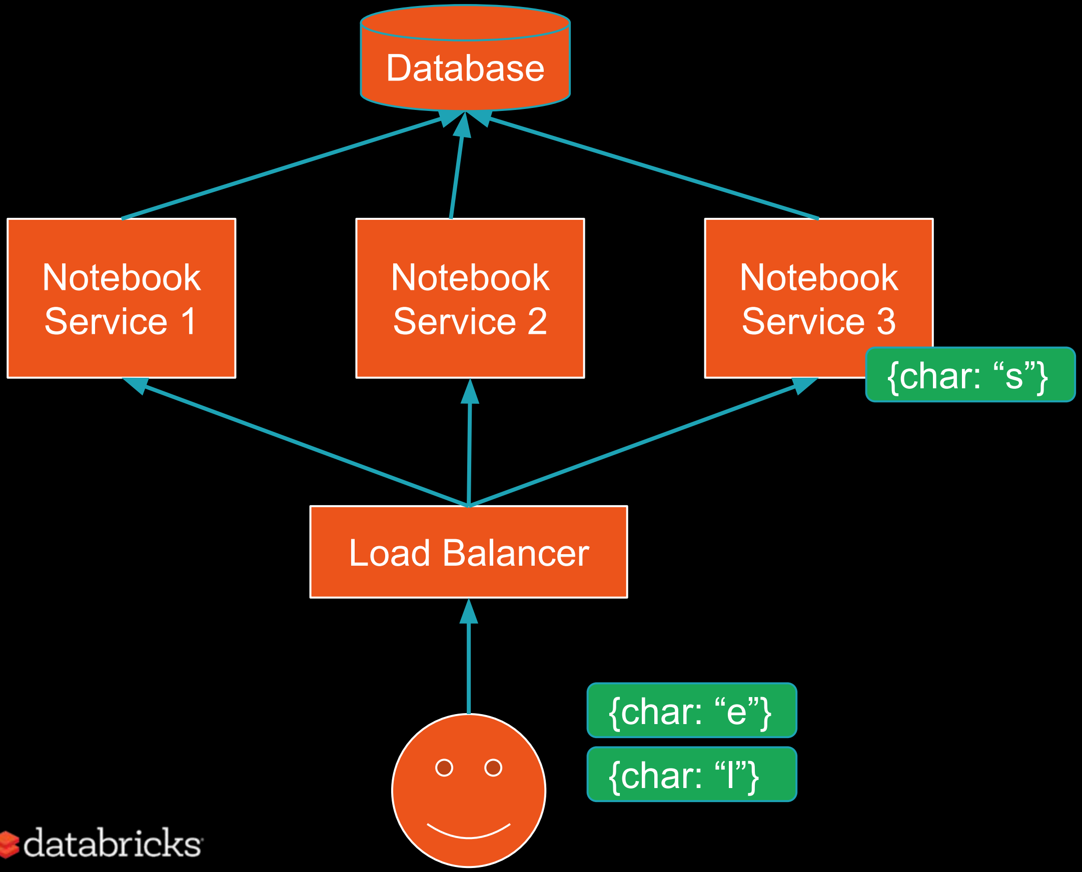

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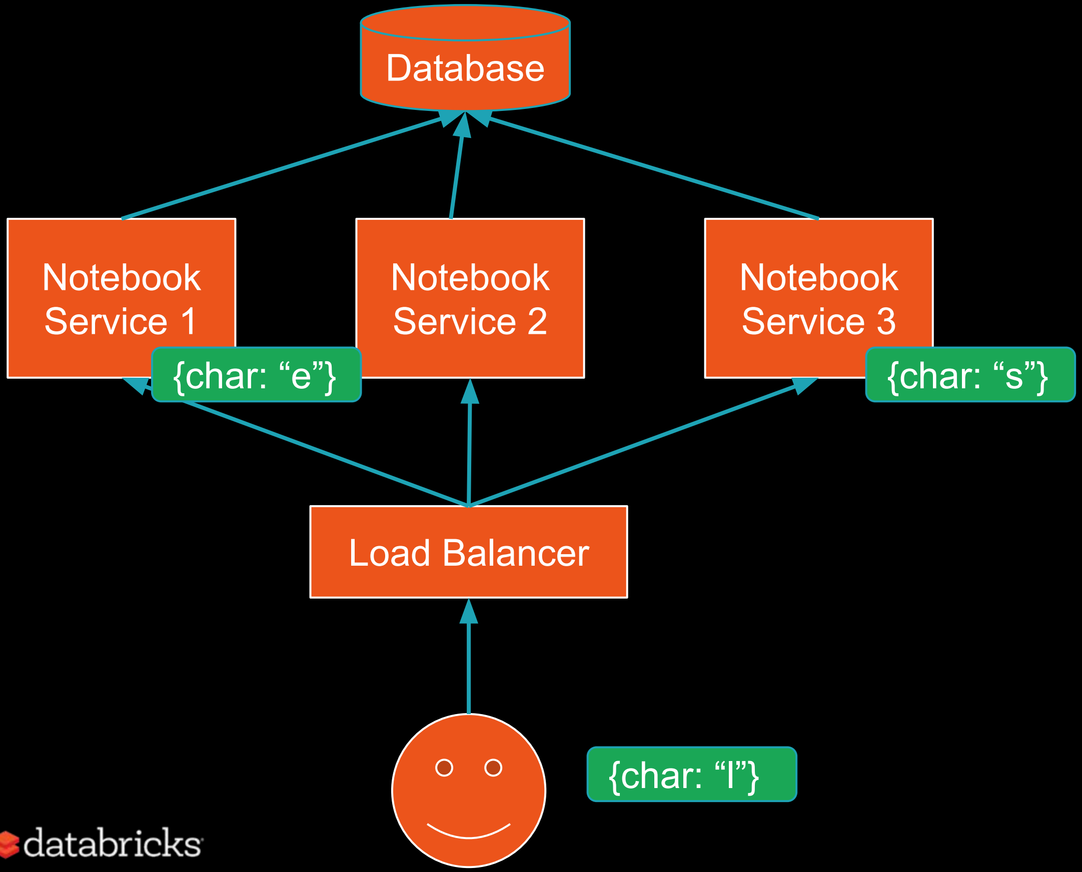

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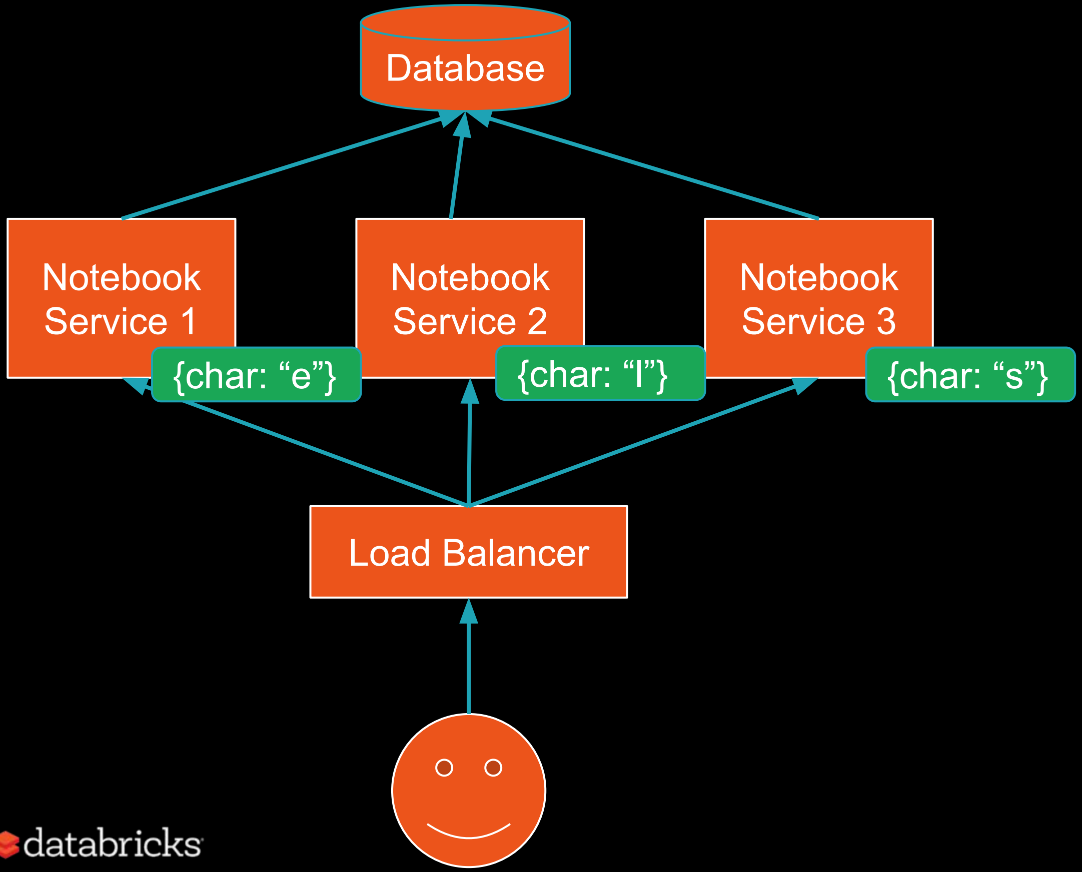
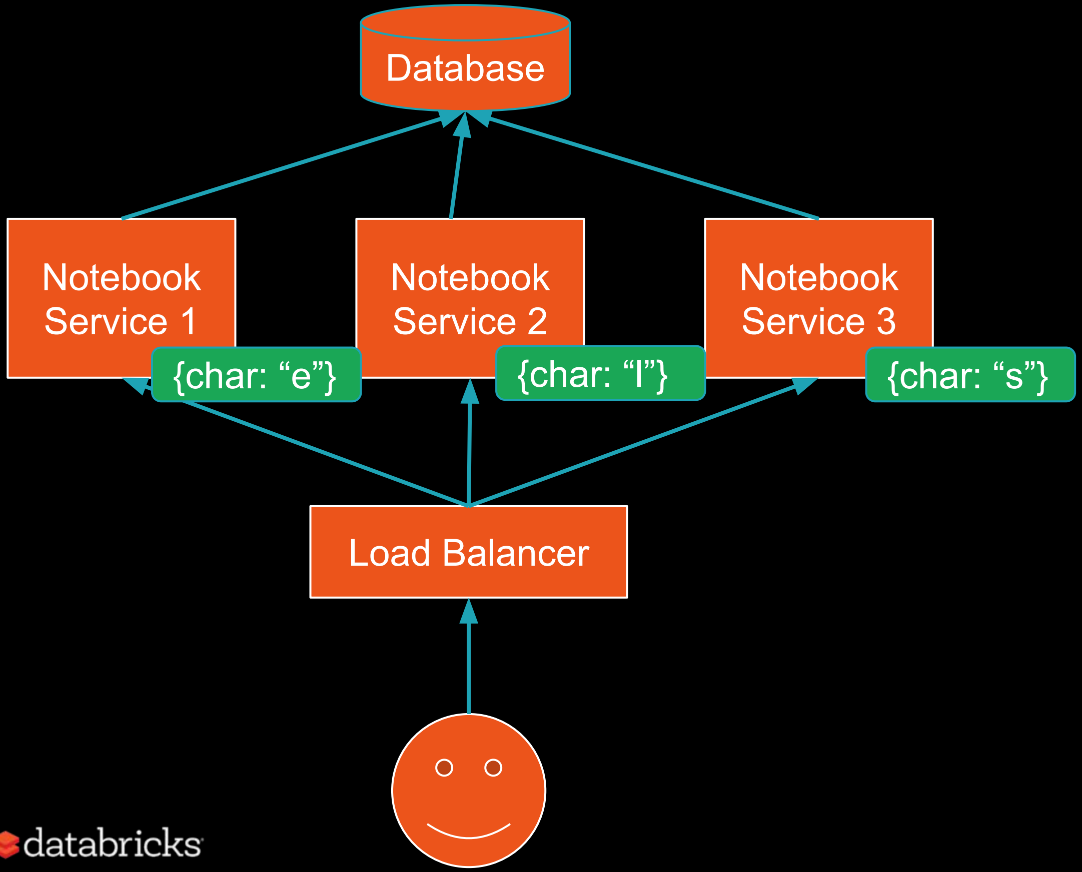


How do we deal?
- Push logic into database
- Take fine-grained locks

Replication: Stateless



How do we deal?
- Push logic into database
- Take fine-grained locks

Pros	Cons
+ Inter-changeable services + “Trivial” 0-downtime	- Hardest/least efficient programming model

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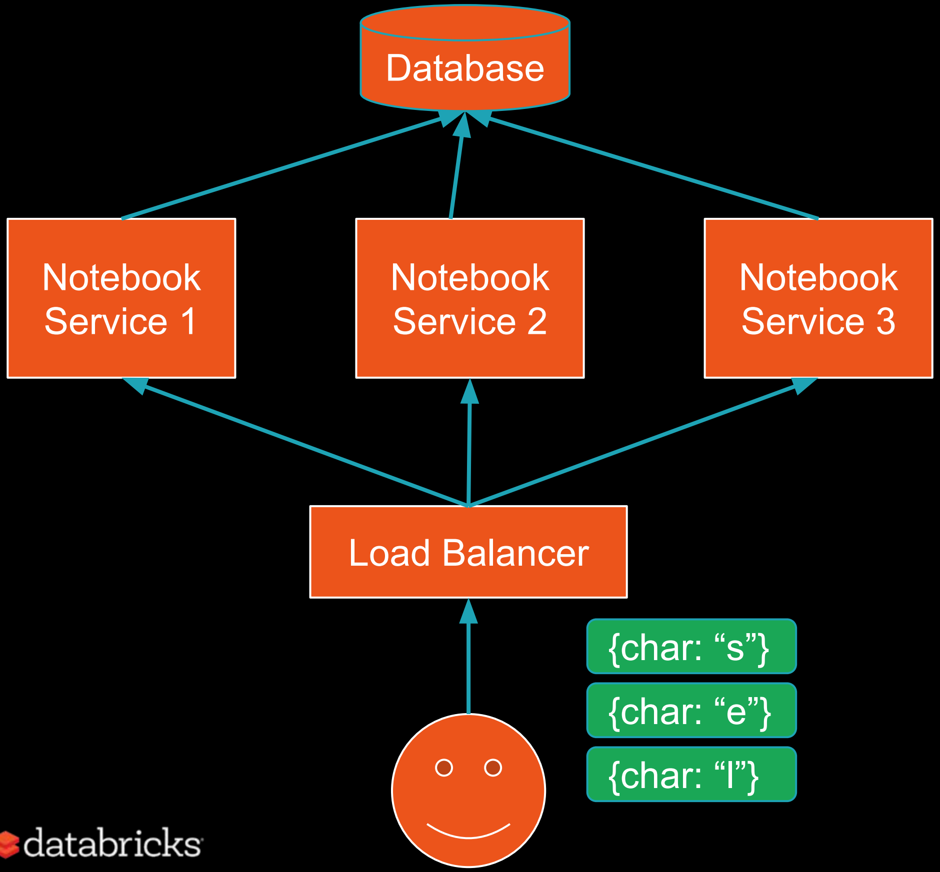
Replication: User/Session Stickiness



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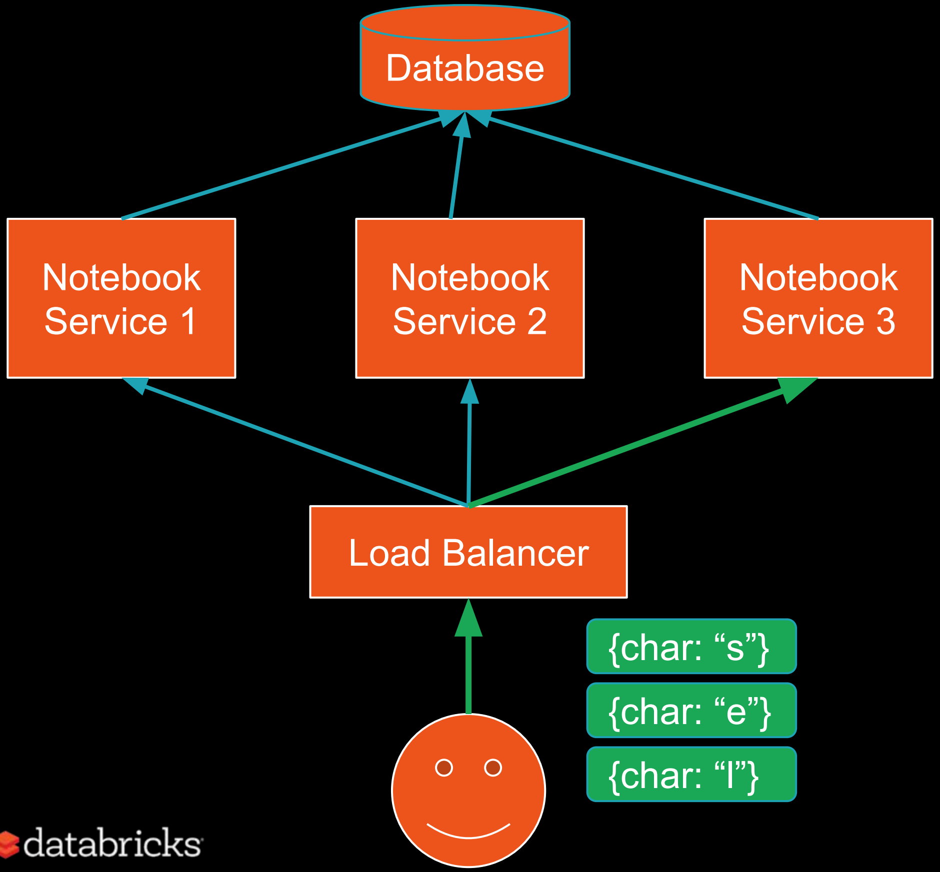

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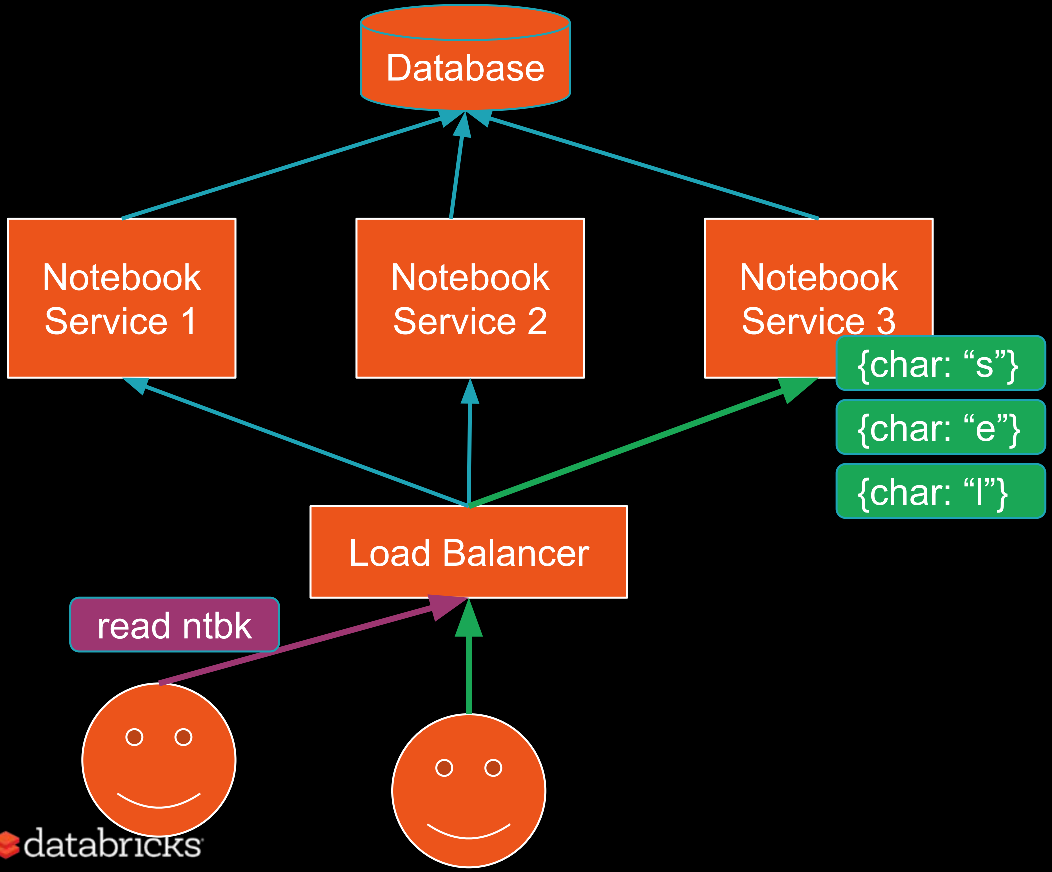

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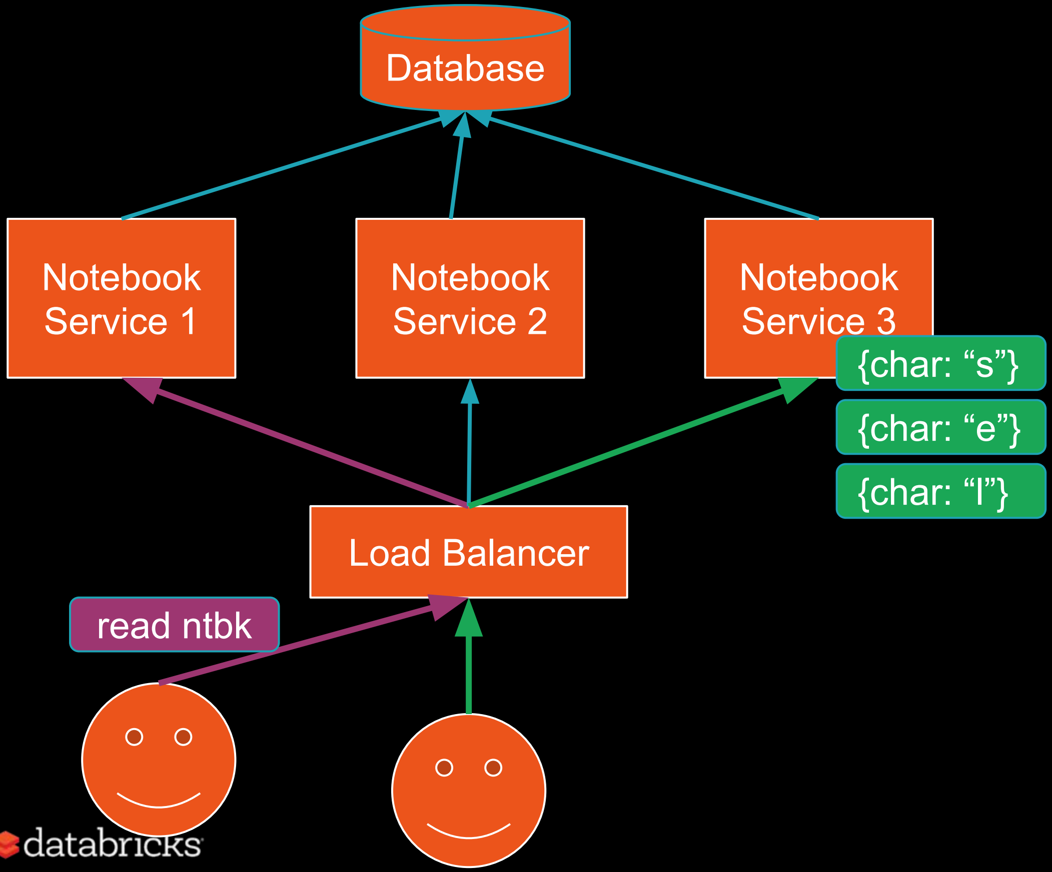

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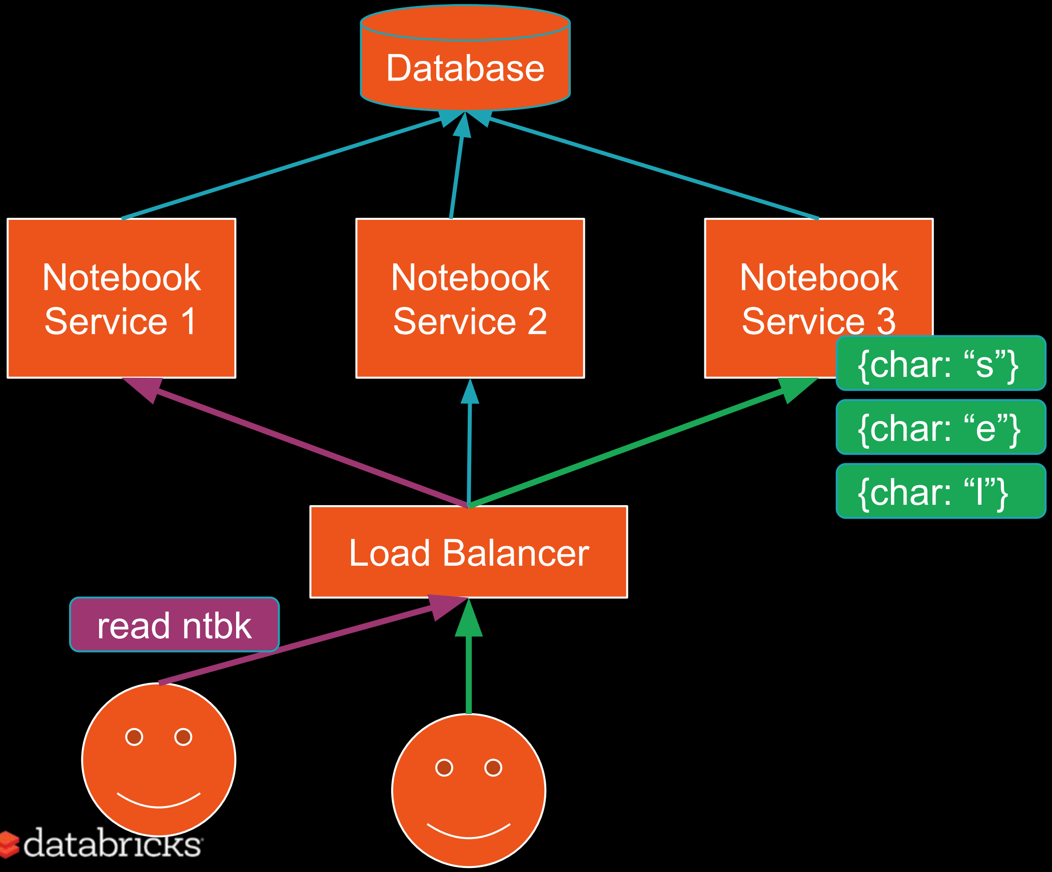
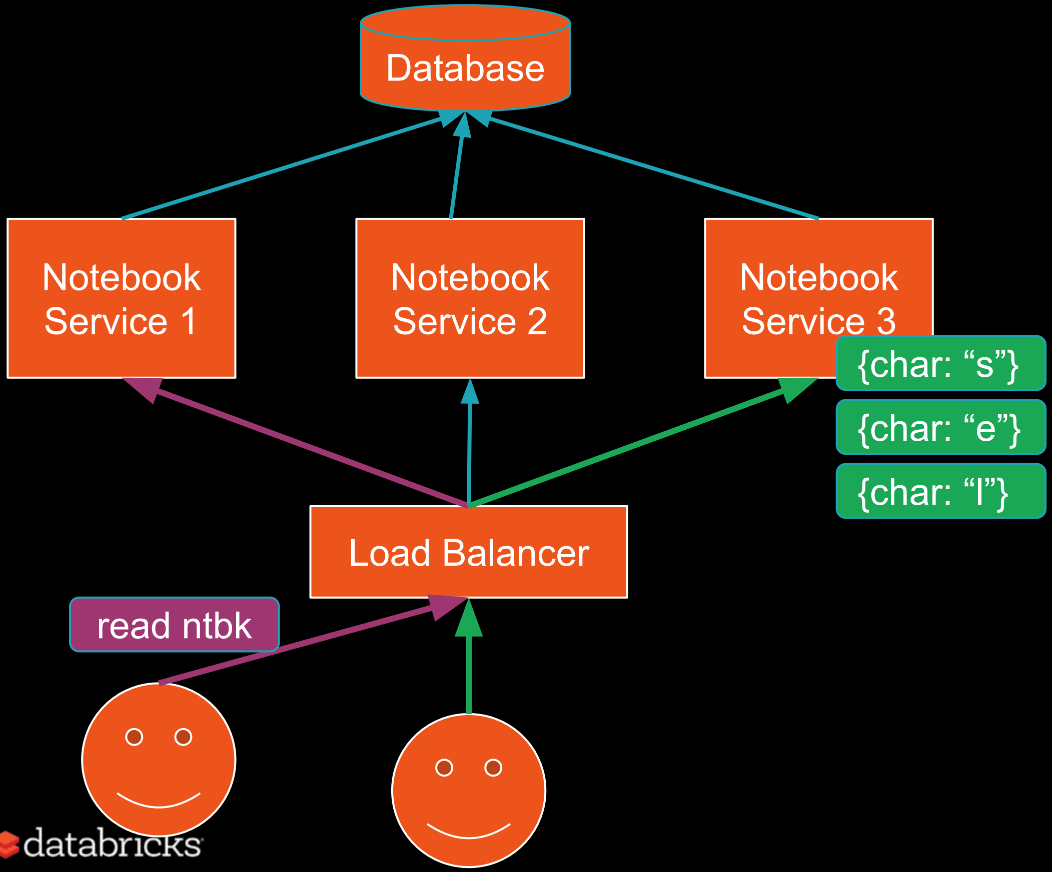


<u>TCP-sticky load balancer</u>
Easy to find -- probably default!

<u>HTTP-sticky load balancer</u>
Cookie-based -- a bit more complicated, but also common

Replication: User/Session Stickiness



TCP-sticky load balancer
Easy to find -- probably default!

HTTP-sticky load balancer
Cookie-based -- a bit more complicated, but also common

Pros	Cons
+ Easy to find + Built-in fault recovery	- Only supports single-flow/user locality - Failures may be harder to reason about

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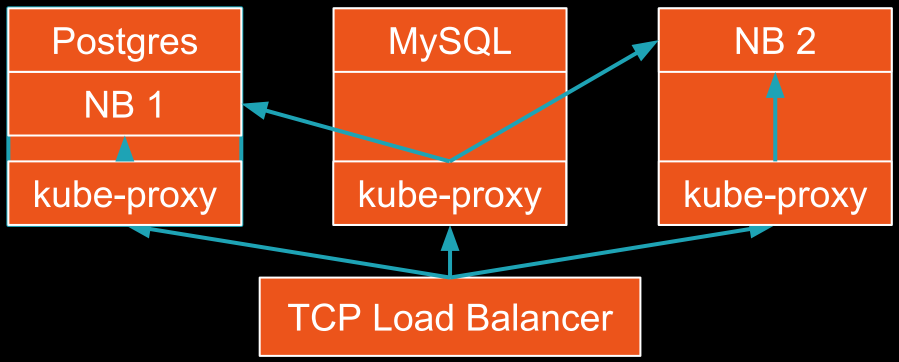
Service replication: How to decide?

- Review:
  - Stateless replication: Simplest
    - Simplest (“best”) replication model, hardest to program against
  - Session/user stickiness
    - Particularly common replication model -- well-supported by tooling
  - Logical/tenant stickiness
    - Most complicated (“worst”) replication model, easiest to program against
- Considerations:
  - Higher is better, but have to start thinking from beginning.
  - If not, then the last will be the only option (that’s exactly what we did for notebooks!)

Service replication: How to implement?

- VM-level: Cloud providers have TCP & HTTP load balancers:
  - Static or scalable pool of machines registered with a port & protocol.
  - Health checking mechanism to remove machines from routable pool.
- Container-level: YMMV; Kubernetes also provides TCP- and HTTP-level load balancing, between containers.



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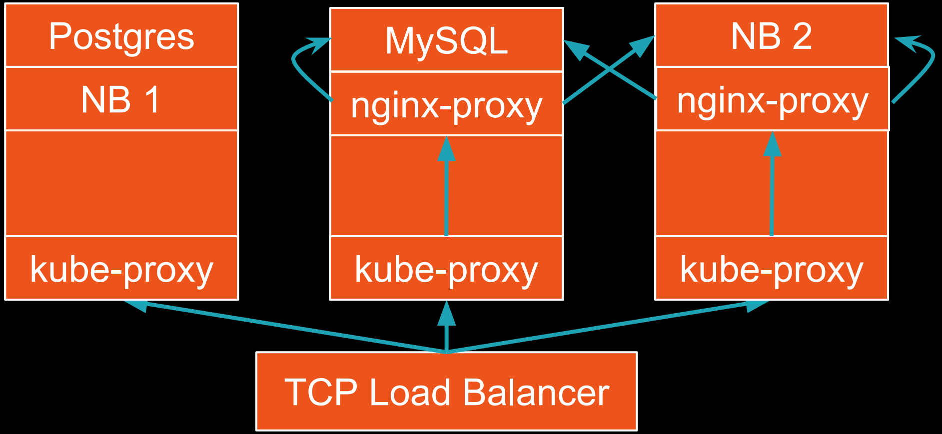
Service replication: How to implement?

- Tenant-stickiness?
- Need a consistent, highly-available leader election store
  - ZooKeeper, consul, etcd (Googlers: Chubby)
- Need an HTTP load balancer
  - Probably nginx or go -- not recommended to build your own, in JVM



Recap: Databricks Community Edition

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- Use-cases: people playing around with Spark, training/classes, MOOCs (now: all new customers)
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  - How do we update when there is constant usage?
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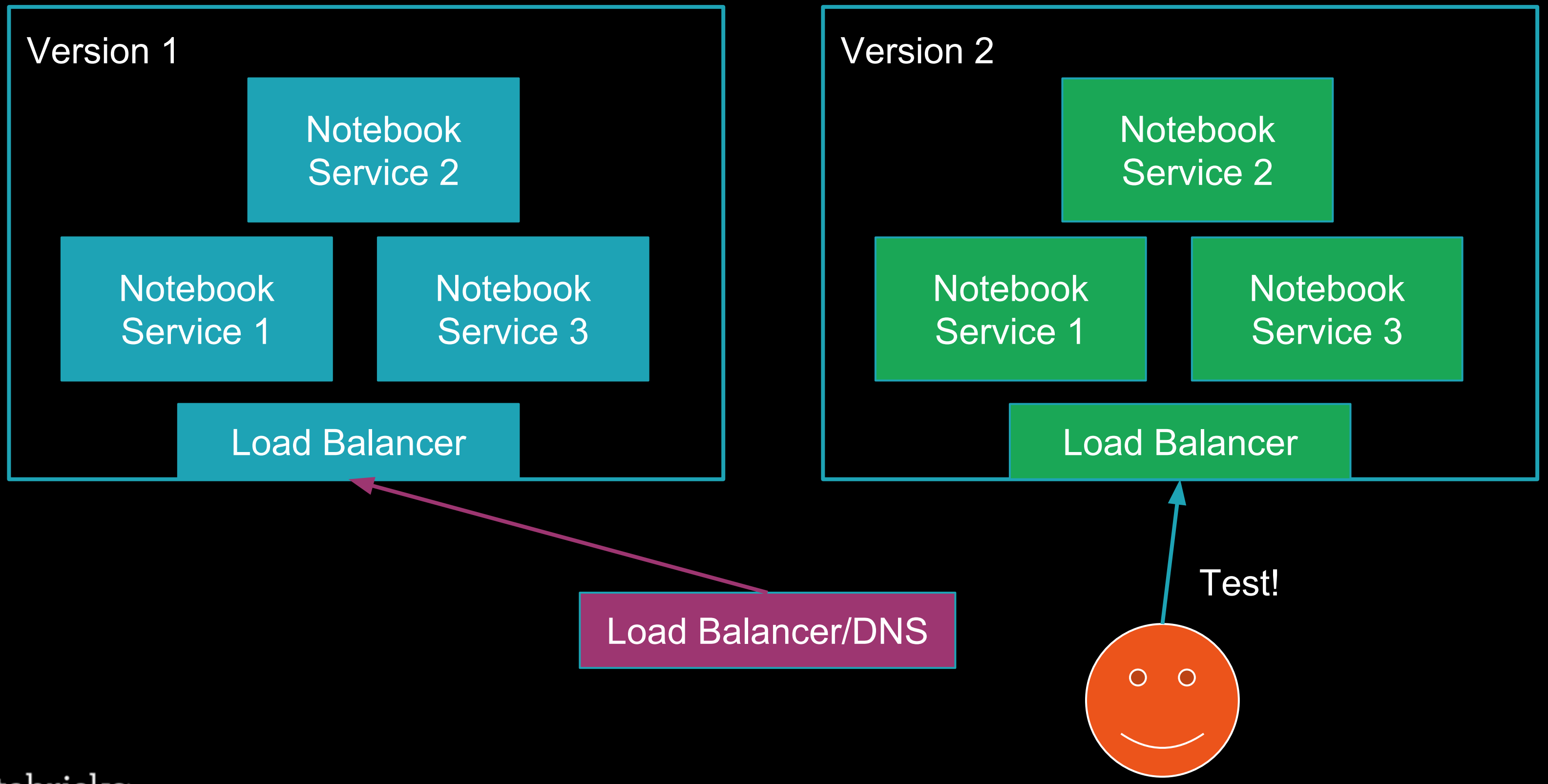
Service updates

- Can leverage our earlier work in service replication to perform updates without downtime.
- Update strategies:
  - The ol’ off ‘n’ on
  - Blue-green
  - Rolling
  - Traffic control

Service updates: Blue/green



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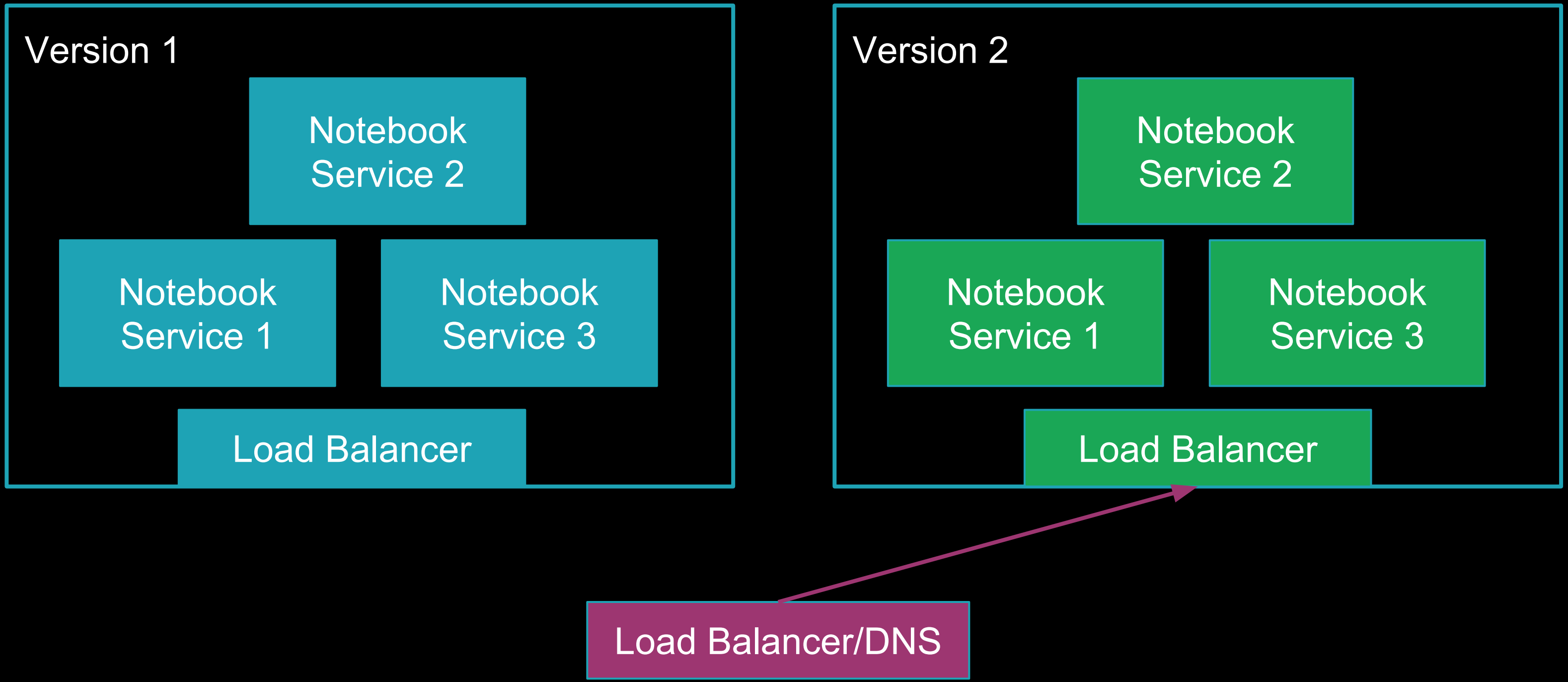
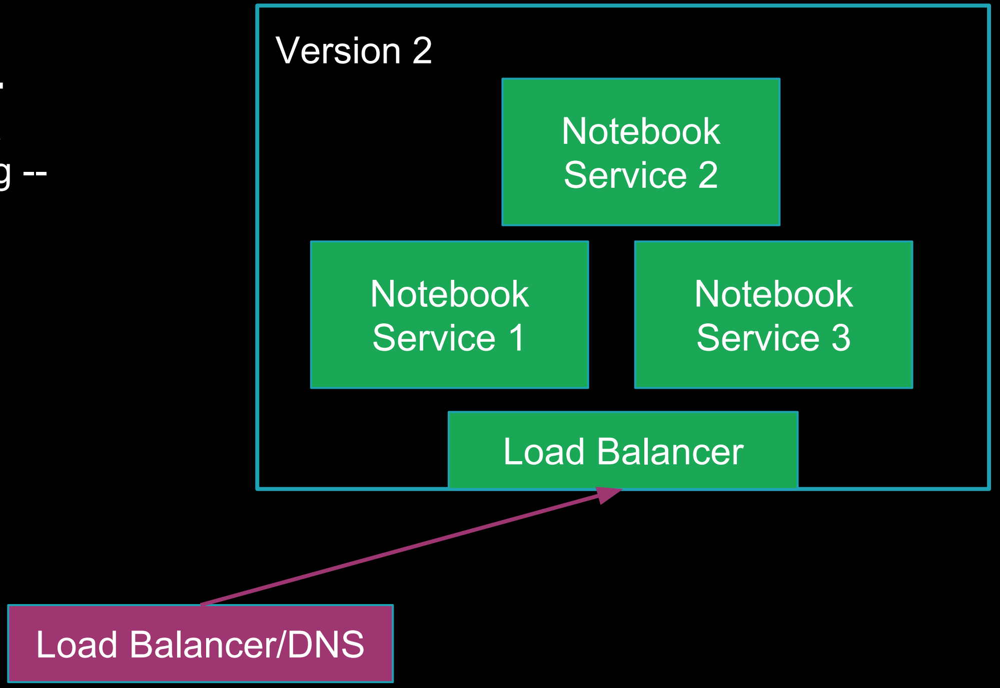
Service updates: Blue/green

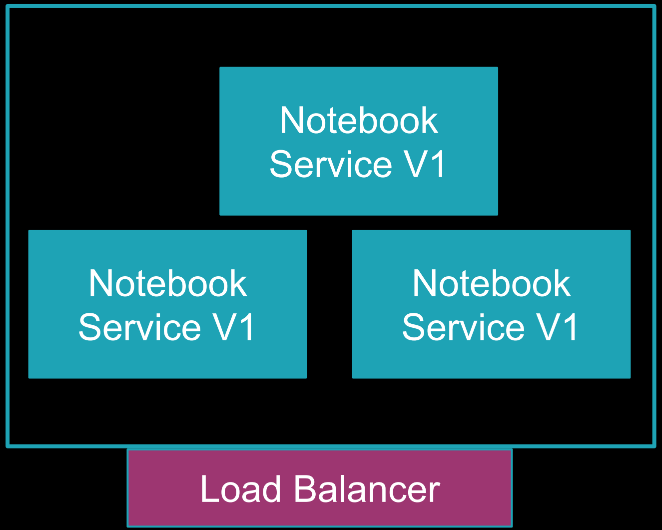


Service updates: Blue/green

Pros	Cons
+ Easy to implement + Can work with single replica	- Unused infra - All-or-nothing -- bugs exposed immediately



Service updates: Rolling update



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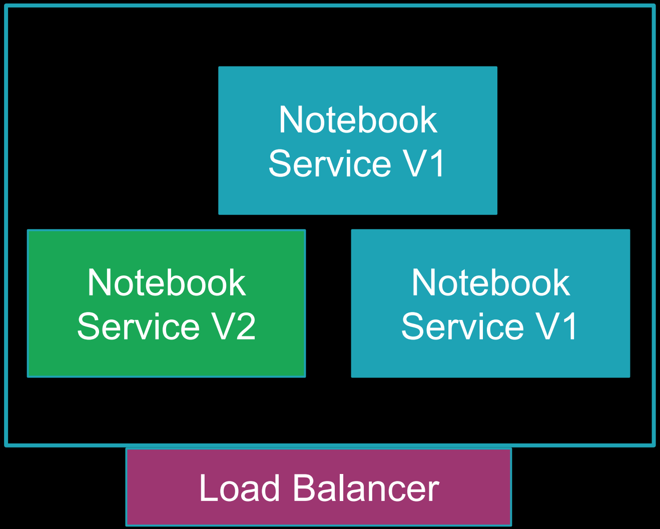

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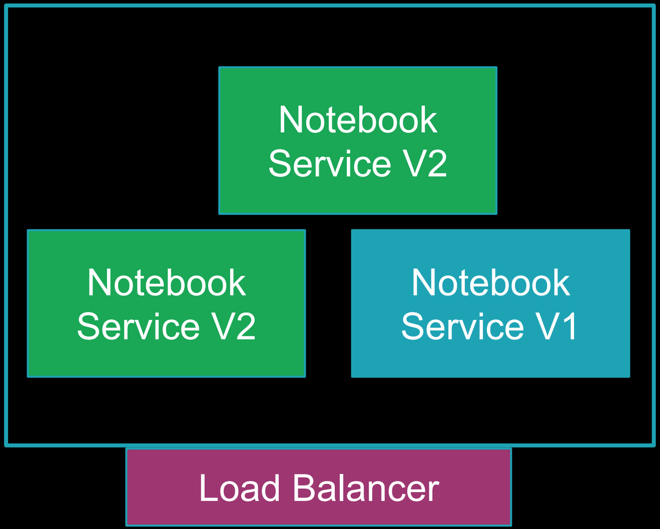

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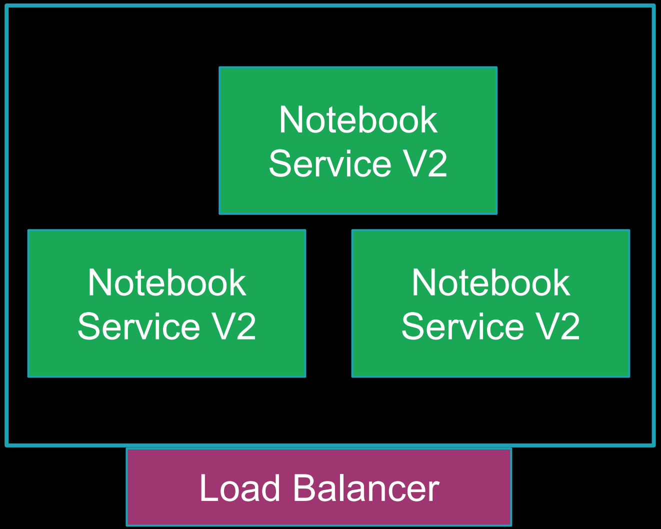

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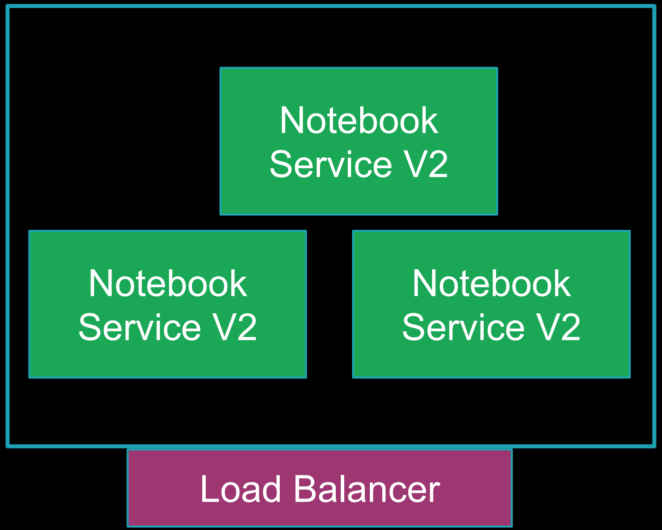
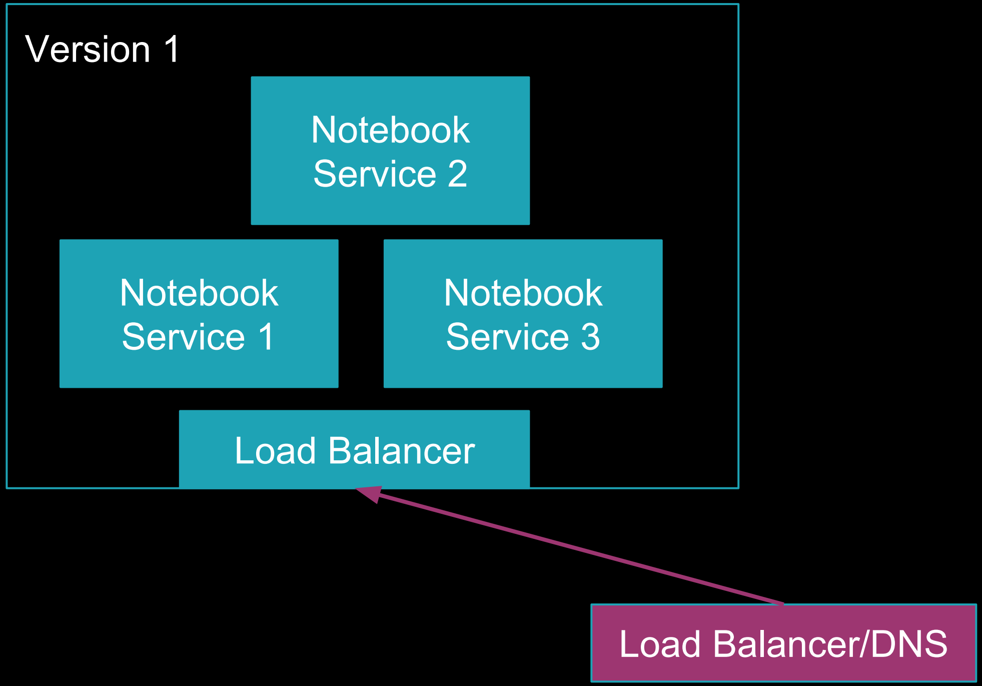


Pros	Cons
+ Gradual roll out	- Coarse-grained
+ All infra used	

Service updates: Traffic control



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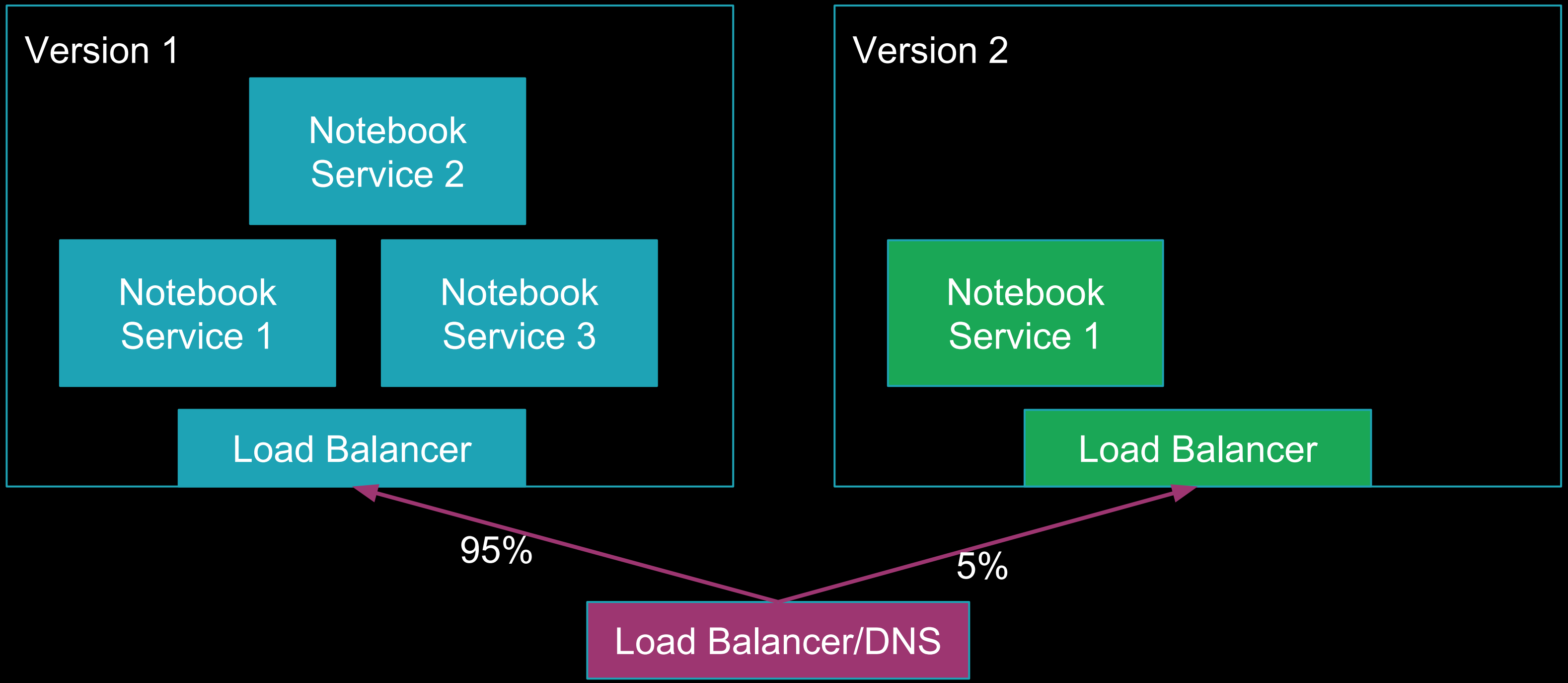

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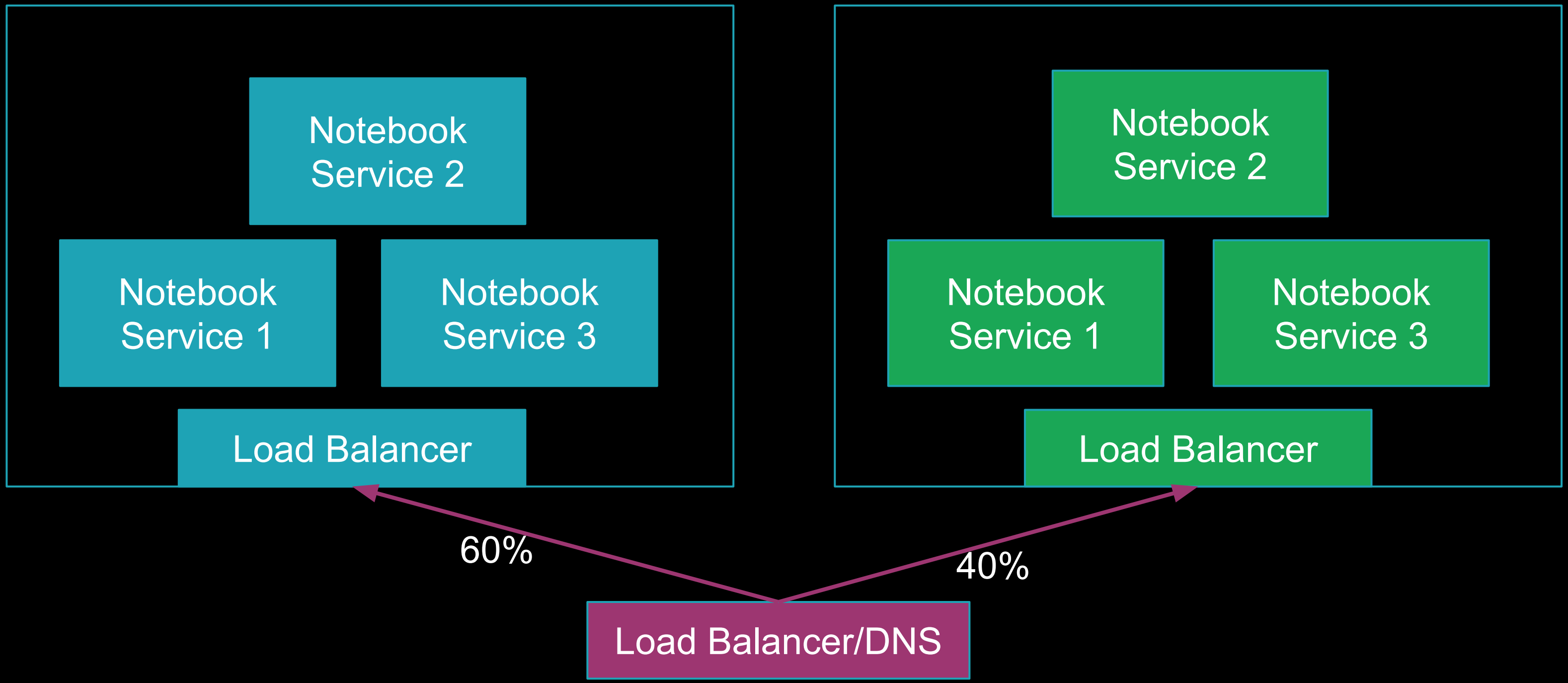

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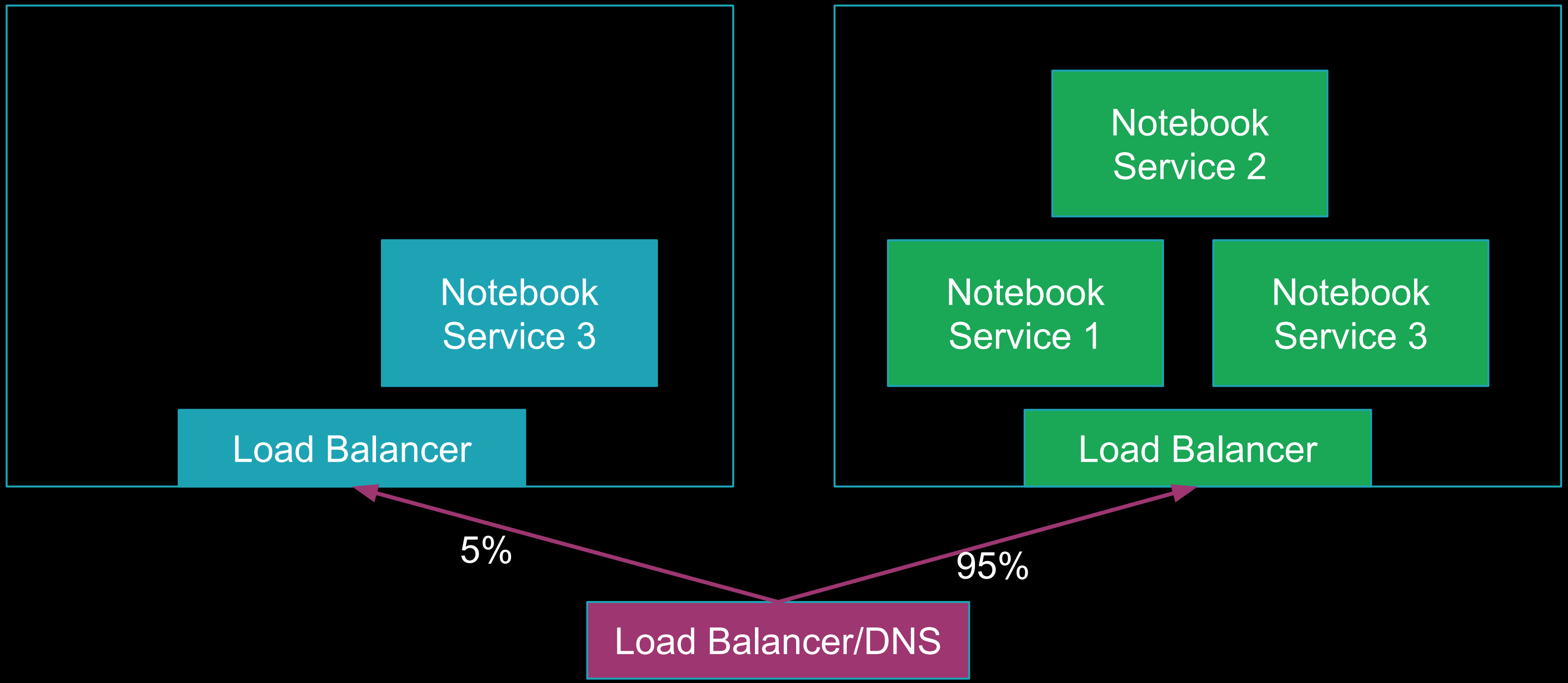
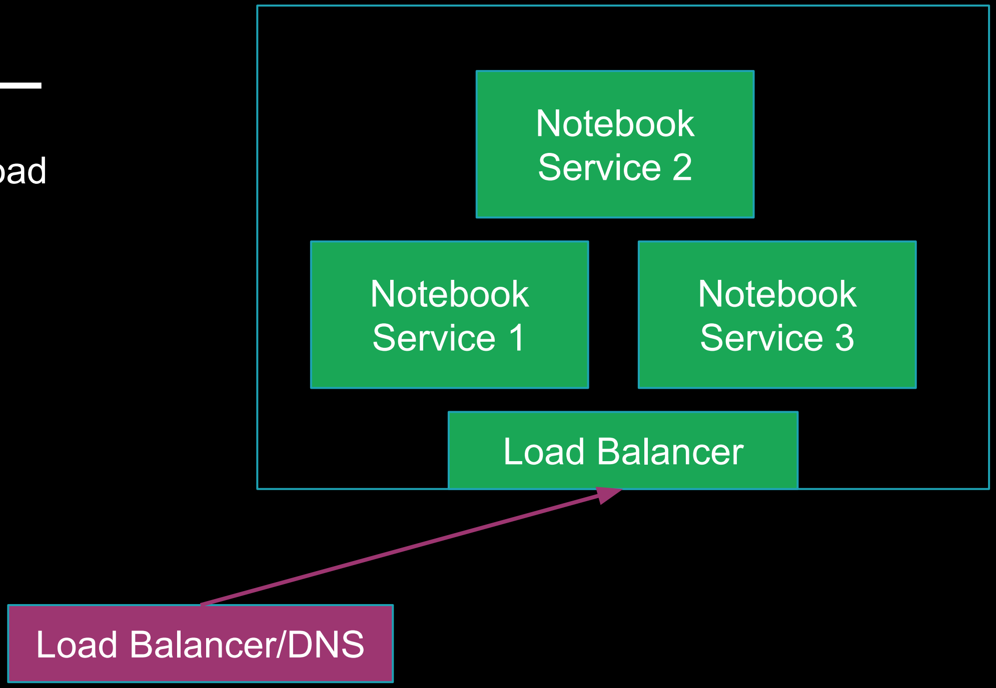
Service updates: Traffic control



Service updates: Traffic control

Pros	Cons
+ Google-scale quality control + Simple extension: shadowing traffic	- Requires complicated load balancer

Gaining traction:
Envoy & Istio starting to add support



Update strategy: How to decide?

- Review:
  - Blue/green
    - Useful for stateful applications
    - Useful for acceptance testing
    - Complicated roll-out procedure
  - Rolling update
    - Most common -- simple roll-out procedure
  - Traffic control
    - Best-in-class -- requires complicated load balancer
- Considerations:
  - Design with at least one updates strategy in mind and you can keep downtime minimal, even for unreplicated services.

Update strategy: How to implement?

- VM-level: Cloud providers have (auto)scaling groups.
  - Create a new group for the new version.
  - For blue-green, switch DNS when tested.
  - For rolling update, have load balancer use both groups and increase/decrease replicas.
  - Netflix does this -- see Spinnaker
- Container-level: Kubernetes provides first-class support for rolling updates within one cluster, other stuff is as manual as VM case.

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- Problems:
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Infrastructure as Code

- I want to provision 3 VMs for my Notebook Service.
- On-prem: Ask ops team for 3 machines, wait 1-3 months
- Cloud: 

- Scenarios:
  - Scale out to 5 VMs.
  - VM crashes, need to replace it.
  - Change VM parameter (e.g., instance size)
  - Replicate environment to a new region.
  - Create a testing environment.
  - Security breach! Tear it all down and recreate everything.

Infrastructure as Imperative Code

```
def createInfra():
  for i in range(3):
    ec2.createInstance(
      name = s“NotebookService-$i”,
      type = “m4.xlarge”)
```

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```
def createInfra(region):
  for i in range(3):
    ec2.createInstance(
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      type = “m4.xlarge”,
      region = region)
```

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Infrastructure as Imperative Code

```
def createInfra(region, accountId):
  for i in range(3):
    ec2.createInstance(
      name = s“NotebookService-$i”,
      type = “m4.xlarge”,
      region = region,
      accountId = accountId)
```

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Infrastructure as Imperative Code

```
def createInfra(region, accountId, oldCount, newCount):
  for i in range(oldCount, newCount):
    ec2.createInstance(
      name = s“NotebookService-$i”,
      type = “m4.xlarge”,
      region = region,
      accountId = accountId)
```

- Scenarios:
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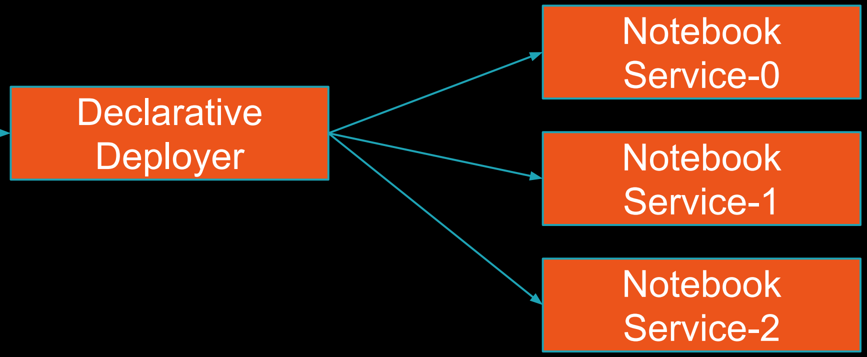
  - ✓ Replicate environment to a new region.
  - ✓ Create a testing environment.
  - ✓ Security breach! Tear it all down and recreate everything.
- Problems:
  - Specific: Each scenario needs new code, new parameters. Not necessarily shared between use-cases, either (e.g., create a database)
  - Stateful: Correctness requires either maintaining state, writing state resolution logic, or having a human enter the state.
  - Fallible: Did you spot the incorrect error handling?

Infrastructure as Declarative Code

```
[{ kind: "EC2::Instance",
   type: "m4.xlarge",
   name: "NotebookService-0",
   region: "oregon",
   accountId: 1234567,
 }, … ]
```



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  - ✓ Change VM parameter (e.g., instance size).
  - ✓ Replicate environment to a new region.
  - ✓ Create a testing environment.
  - ✓ Security breach! Tear it all down and recreate everything.
- Benefits: State, API, and error handling are all managed for us
  - Difficult to manage large, dynamic infrastructure due to duplication. (One solution here is to introduce a layer of templating)
  - Needs an implementation of "Declarative Deployer"
    - All cloud providers have a native way of doing this (e.g., CloudFormation)
    - Terraform is a cloud semi-agnostic tool
    - Quilt?

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Summary

- Cloud infrastructure is dynamic
  - Replicate multitenant services for scale-out
  - Automate deployment (imperatively or declaratively)
  - Leverage cloud provider abstractions (VMs, load balancers, databases)

- Software as a Service allows us to move quickly
  - Deliver updates on weekly cadence rather than 3/6/12-monthly
  - Reduce friction of use by taking over operational burden
  - Just make sure your updates aren’t breaking things *too* often!

Thank you!

We’re hiring -- come intern with us!

Aaron Davidson - aaron@databricks.com

Try Community Edition:
https://databricks.com/try-databricks

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Appendix: Container Engines (Kubernetes)

What problem are we trying to solve?

- I want to run my code on a remote server.
- How do I get my code there?
  - What about my code's dependencies (e.g., library A)?
  - What about my code's system dependencies (e.g., curl or ntp)?
- How do I know what's going on?
  - Logging?
  - SSHing into the machine?
- How do I update my code? How do I roll back?

World V1: Ansible and “bare-metal”

- I want to run my code on a remote server.
- How do I get my code there?
    - Script which copies my JAR and any dependent jars.
    - Script also can install dependencies on target host.
- How do I know what’s going on?
    - SSH in and find out.
- How do I update my code? How do I roll back?
    - Rerun script (how to undo dependencies?)
- Problems:
    - Script is not very general! New one per service.
    - Have to manually place services on hosts (what about node failure?)

World V2: Ansible and Docker

- I want to run my code on a remote server.
- How do I get my code there?
  - I build a Docker container which contains all my dependencies!
  - I run a script which starts that script.
- How do I know what's going on?
  - SSH in and find out.
- How do I update my code? How do I roll back?
  - Rerun script -- dependencies inside container so can roll back.
- Problems:
  - Script is now pretty general, service-specific stuff is in container.
  - Still have to manually place services on hosts (node failures)

World V3: Kubernetes (w/Docker)

- I want to run my code on a remote server.
- How do I get my code there?
  - I build a Docker container which contains all my dependencies!
  - I ask Kubernetes to find somewhere to put that container.
- How do I know what's going on?
  - I ask Kubernetes for logs or to SSH into the container directly.
- How do I update my code? How do I roll back?
  - I ask Kubernetes to do a rolling update.
- Problems:
  - Kubernetes replaces my custom script entirely
  - Kubernetes deals with placement of containers within a cluster, and with node failure.

Other Kubernetes Features

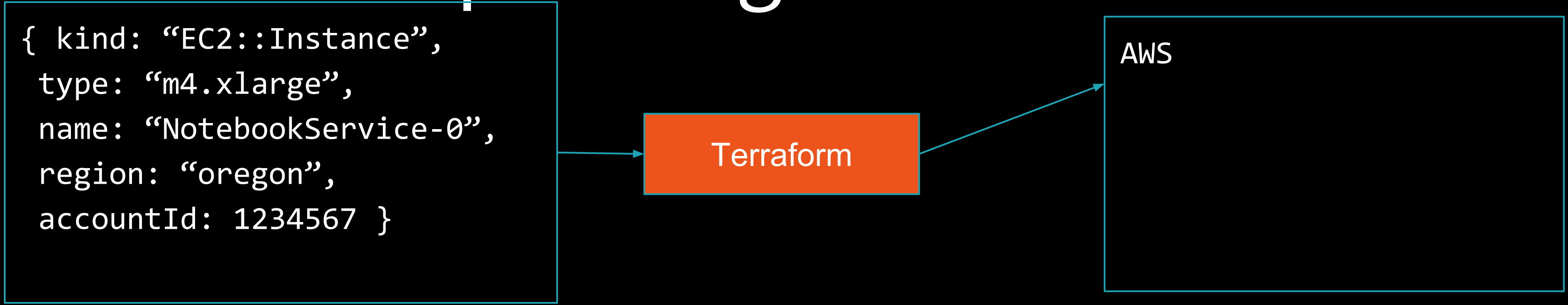
- In addition to managing containers, Kubernetes helps with:
  - Exposing services to the outside world via Load Balancers
  - Maintaining a fixed set of replicas of a node.
  - Health checking and restarting services (provided service-specific health checks).
  - Managing network-attached storage.
  - Providing cross-cloud abstractions.
  - (And more!)
- Similar systems: DC/OS, Docker Swarm, Google's Borg

Container Engines: Unsolved Problems

- Solid, authn/authz inter-service networking
  - Envoy & istio approach problem from proxy layer
  - Calico approaches problem from network layer (BGP!)
- Geo-replicated (multi-cluster) services
- Easy-to-use logical stickiness abstraction (e.g., notebooks)

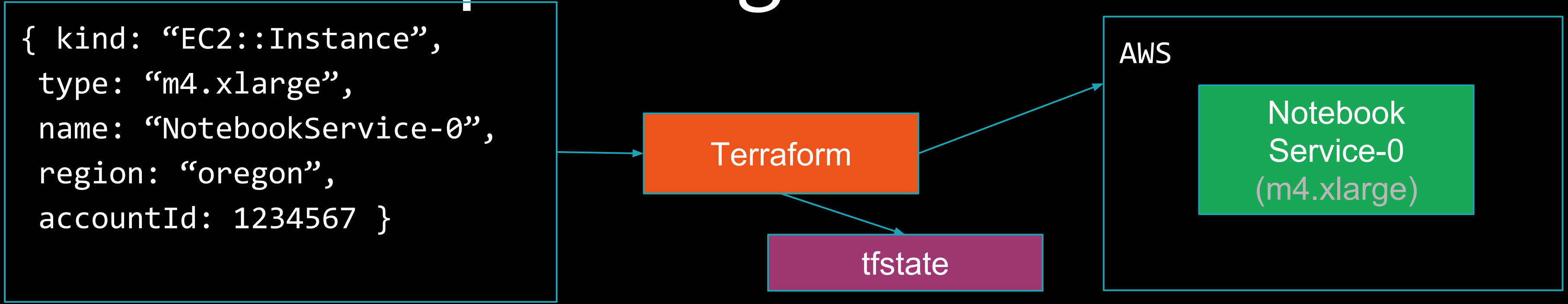
Appendix: Terraform

Terraform Operating Model



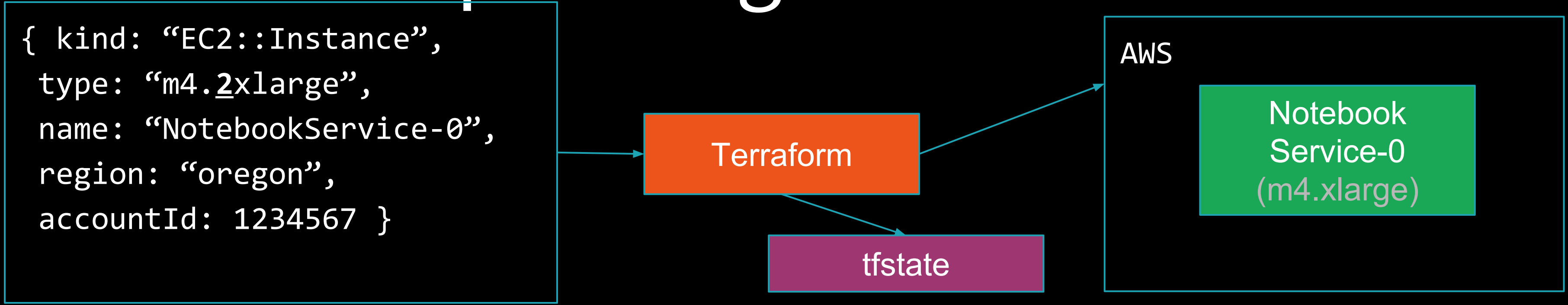
- Input: Template, state file, and cloud resources
- Output: Plan of how to converge state

Terraform Operating Model



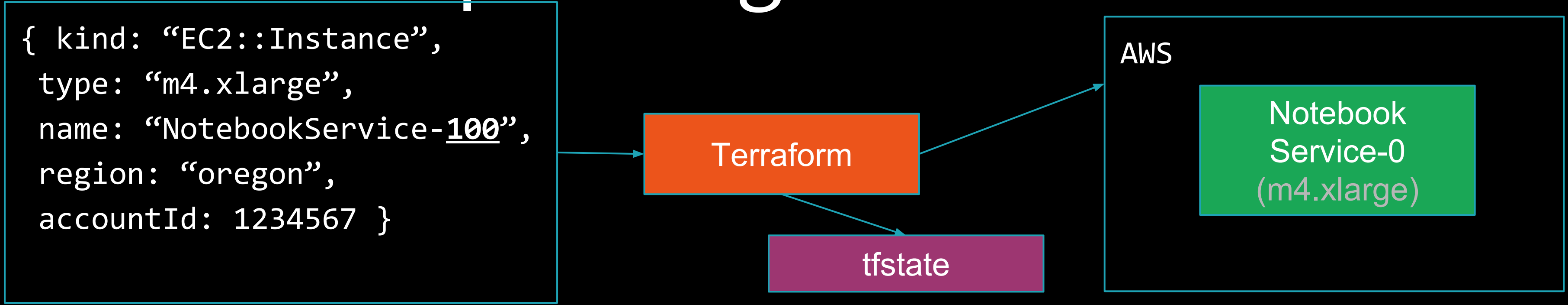
- Input: Template, state file, and cloud resources
- Output: Plan of how to converge state

Terraform Operating Model



- Different properties require different change procedures.
  - Changing EC2 VM instance size requires tearing down and recreating.
  - Changing RDS database instance size requires just restarting.

Terraform Operating Model



- State file used so Terraform knows when it should delete objects.
- Otherwise, we would just create a second instance and keep the old one around.

Declarative Deploy: Unsolved Problems

- Cloud agnostic terminology & semantics is elusive
- Declaring different classes of resources (e.g., cloud provider versus Kubernetes objects) requires different systems
- Enacting a certain change may require several intermediate templates
- No standard for templating.