# Choosing a Logical Replication System

David Christensen
david@endpoint.com

END POINT

# Introduction

- Physical Replication
- Logical Replication
- Slony vs Bucardo

# Is there one right choice?

- No!
- If you were expecting an absolute answer to this, there's still time to go to another talk.
- A matter of understanding the constraints and applying engineering decisions
    - Aw, man!

# Why Replication?

- Replication used for many reasons:
  - Disaster recovery
  - High Availability/Failover
  - Read/write scaling
  - Backups

# Logical vs Physical Replication

- The big question: Why do we need logical replication systems when PostgreSQL includes native replication?

# Logical vs Physical Replication

- supports differing hardware/PostgreSQL versions
- replicate only specific databases or tables
- need writable clusters on the slaves
- not everyone running latest/greatest

# Physical Replication

# Physical Replication: Overview

- Warm/Hot Standby
- Refers to the physical files on-disk
- PostgreSQL's core replication facilities are built atop its recovery system
- As WAL records are processed on the standby it will make the same changes to the disk files as was made on the master

# Physical Replication: History

- Warm Standby recovery - better than nothing but management very primitive
- 16MB WAL files, unless you were super-busy need Standby to stay up-to-date and not lose changes, things like **`archive_timeout`**
- Huge upgrades in Postgres 9.0: Hot Standby / Streaming Replication
- Now can query standbys, streaming means we're never too far behind
- Cascading replication
- Postgres 9.4 brought big changes -> introduced logical decoding
    - We'll cover this later

# Physical Replication: Benefits

- Easy to setup/use
  - **`pg_basebackup`**
- Ideal for High Availability/Read Scaling
- Supports synchronous replication
- All changes (DDL, DML) automatically propagated

# Physical Replication: Limitations

- Requires same PostgreSQL versions, hardware architecture, etc
- Standby servers are strictly read-only, no local changes at all
- Every change in the entire cluster replicated; can't replicate only a subset of tables or databases

# Logical Replication in 9.4

# Logical Replication: Pg 9.4

- Big changes in Pg 9.4 for LR
- Logical log decoding
  - Works via parsing the WAL stream and extracting information about modified tuples
- New **`postgresql.conf`** settings:
  - **`wal_level = logical`**
  - **`max_replication_slots`**

# Replication Slots

- In order to ensure WAL stream changes are consumed once, 9.4 introduced the concept of replication slots
- Replication slots keep track of a WAL location
- Changes are available in order as committed
- Slots have a unique identifier across the database cluster
- Enable consumers to read WAL events

# Replication Slots

- Slots are created / managed via the replication protocol
- Can more easily interface with **`pg_recvlogical`**
- Also SQL functions

# Replication Slots: `pg_recvlogical`

- Create slots:

  **`pg_recvlogical –slot=foo -d <database> –create-slot`**

- Drop slots:

  **`pg_recvlogical –slot=foo -d <database> –drop-slot`**

- Start reading events:

  **`pg_recvlogical –slot=foo -d <database> –start`**

# Replication Slots: SQL functions

- Create with:
  **`pg_create_logical_replication_slot()`**
- Drop with:
  **`pg_drop_replication_slot()`**
- Consume changes:
  **`pg_logical_slot_get_changes()`**
- Peek at changes without consuming them:
  **`pg_logical_slot_peek_changes()`**

# Output Plugin

- WAL has to be decoded; this is the job of an Output Plugin
- The Output is selected when you create a logical replication slot
- In **`pg_recvlogical`**, use the **`–plugin`** option
- Can be used to write your own methods for translating the data

# The future?

- That’s great for clients on 9.4 and future versions
- Clients still need things done yesterday
- Don’t want / can’t upgrade
- Even on 9.4 this isn’t an entire solution

# Logical Replication for Now()

# Logical Replication: Overview

- Refers to capturing/replicating the "logical" changes made to the database
- Propagate any changes (inserts, updates, deletes) to replica databases
- Generally work via triggers on the tables to record changes and daemons to propagate changes to the intended nodes
- Inherently asynchronous in nature

# Logical Replication: Overview

- Traditionally, this has been done using trigger-based systems
- Slony, Bucardo, Londiste, etc

# Logical Replication: Benefits

- Can run on different architectures, PostgreSQL versions
- Can replicate only a subset of database changes; specific tables, sequences, etc
- Database clusters are independently writable

# Logical Replication: Limitations

- Need to specify replication explicitly
  - itemize all replicated tables
  - new tables not automatically added
  - requires more planning (aw, man...)
- Require special handling for DDL/structural changes
- Requires daemons/external processes to monitor/manage
  - More moving parts = more things that might break

# Specifics

# Specific LR systems

- We will look at:
  - Slony
  - Bucardo
  - (briefly) BDR

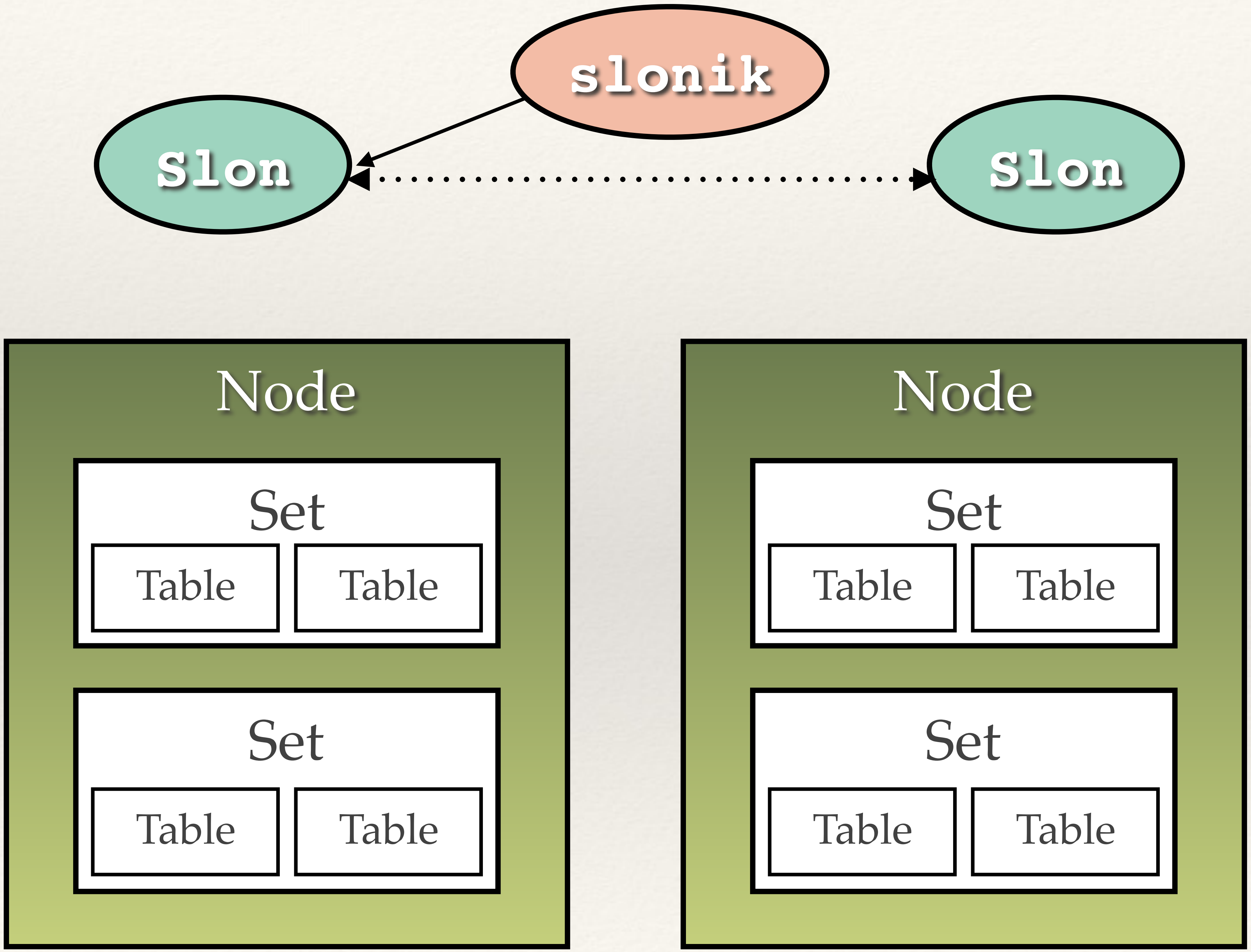
# Feature Summary

| | Slony | Bucardo | BDR |
|---|---|---|---|
| Master/Slave | X | X | X |
| Multimaster | | X | X |
| Custom conflict resolution | | X | X |
| Custom data transforms/ | | X | |
| Multiple replication groups | X | X | X |
| Non-Pg target DB | | X | |
| Cascaded/custom topologies | X | X | |

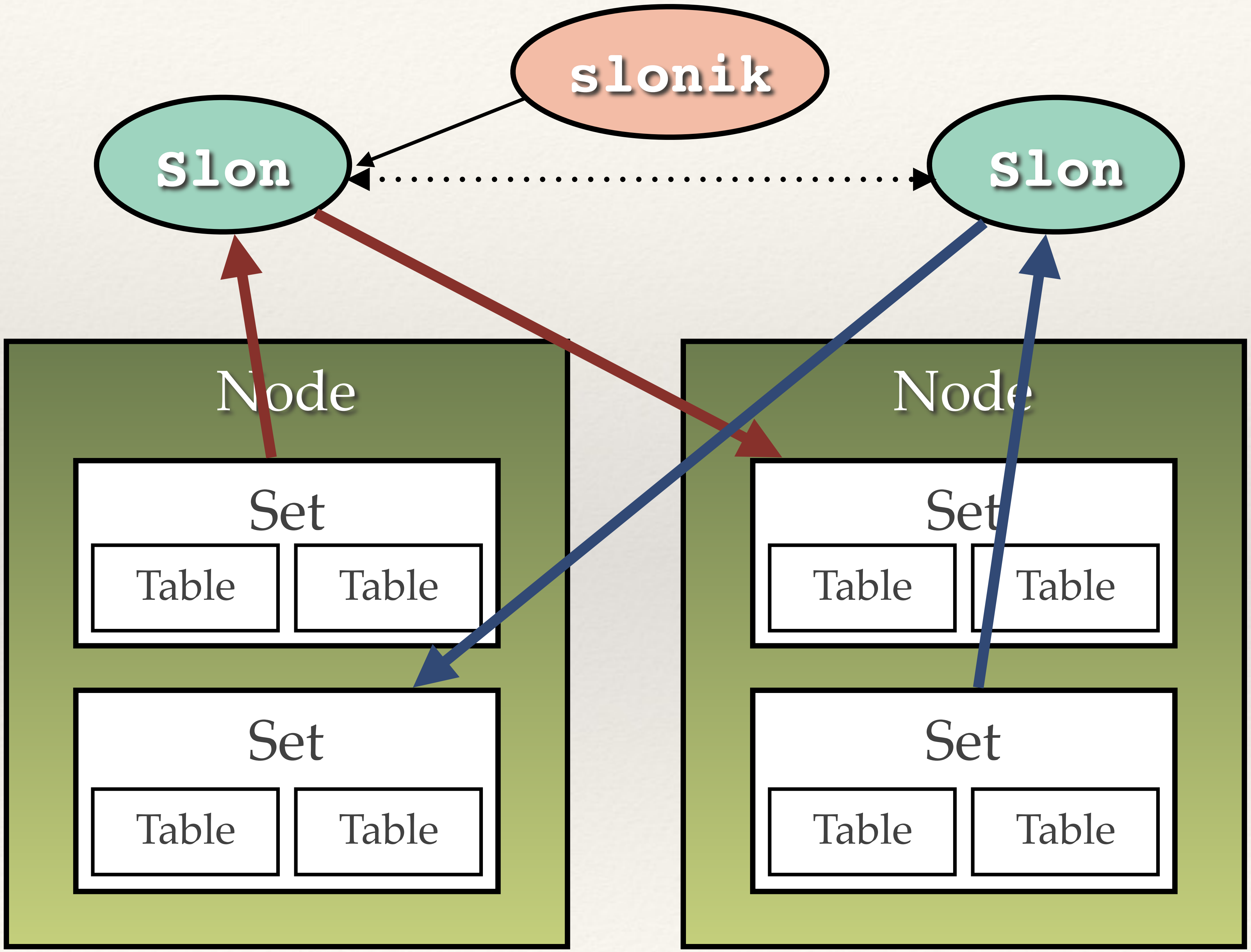
# Slony

- System designed explicitly for single master, multiple slaves

# Anatomy of a Slony System



# Anatomy of a Slony System



# Slony: Nomenclature

- Node
- Table
- Set
- Path
- Subscribers
- Origins

# Slony Fundamentals

- At its core, Slony is a distributed, serialized event system
- Slony's internals stored in a **`_slony`** schema in each node's database
- This schema contains all support functions, triggers, etc needed for the database-level part of Slony
- **`slon`** daemons run for each node, listening for and processing events
- interface to **`slon`** usually done via **`slonik`**, a tool with its own DSL for creating the necessary events and distributing across the cluster

# Slony: Architecture

- Each involved database node has a **`slon`** daemon
- Custom schema in the database to hold metadata / track events that are logged
- Replicated tables are defined / added to sets
- Database triggers used to log changes (on origin) or prevent access (on replica node)
- Sets are the base unit of what is replicated

# `slon` daemon

- Each node has a **`slon`** dameon, which listens for events and handles them
- Can run anywhere, but generally runs on the same machine as the database

# Slony: Nodes

- A Slony node corresponds to a specific logical database instance
- Each node in the cluster is an independent source of events
- Each node has its own unique ID and queue of events, stored in the **`sl_node`** and **`sl_event`** table.
- Different types of events corresponding to different actions on the cluster
- Any node additions, changes, etc are each their own event type

# Slony: Paths

- Stores connection information for any two nodes in the cluster
- Connections only made between nodes if there is a defined listener
- Generally best to define paths for all combinations of nodes
- Stored in **`sl_path`**
- slonik: **`CREATE PATH`**

# Slony: Sets

- Slony sets are groups of tables which are replicated together
- Each set has an "origin node" which is the node id "master" for the set
  - only node on which you can make changes
- Sets of tables replicated together are contained in the **`sl_set`** table
- Replicated tables are contained in the **`sl_table`** table
- Each tracked table is in only 1 set
- slonik: **`CREATE SET`**, **`SET ADD TABLE`**

# Slony: Subscriptions

- Subscriptions are basically a mapping of sets to nodes
- If a node is subscribed to a set, it will receive the data changes related to this set
- Must be a listener to be a subscriber

# Slony: Cascaded Subscriptions

- With more complex topologies, a non-origin node can still be a provider for other nodes
- This is considered a "cascaded" subscription
- When subscribing a non-origin node as a provider, must be configured to forward log data
- e.g.: **`SUBSCRIBE SET (set id = 3, origin = 1, forward = yes)`**

# Slony: Triggers

- When a table is added to a replication set, Slony installs the necessary log/deny triggers to the table
- When a node is subscribed to a set, Slony will truncate the table on the receiver side and copy the data as part of its event processing
- This ensures the data is guaranteed identical at each step

# Slony: Tracking Changes

- Slony takes "ownership" of tracked tables:
  - on an "origin" node:
    - adds log triggers
    - log triggers are triggers which fire after any DML change on tracked tables.
    - stores information about the row affected (PK), the tuple data, and the current snapshot.
  - on a "subscriber" node:
    - deny access triggers
    - prevent any change to the table data, accidental or otherwise
    - ensures slony is the only process able to change the data

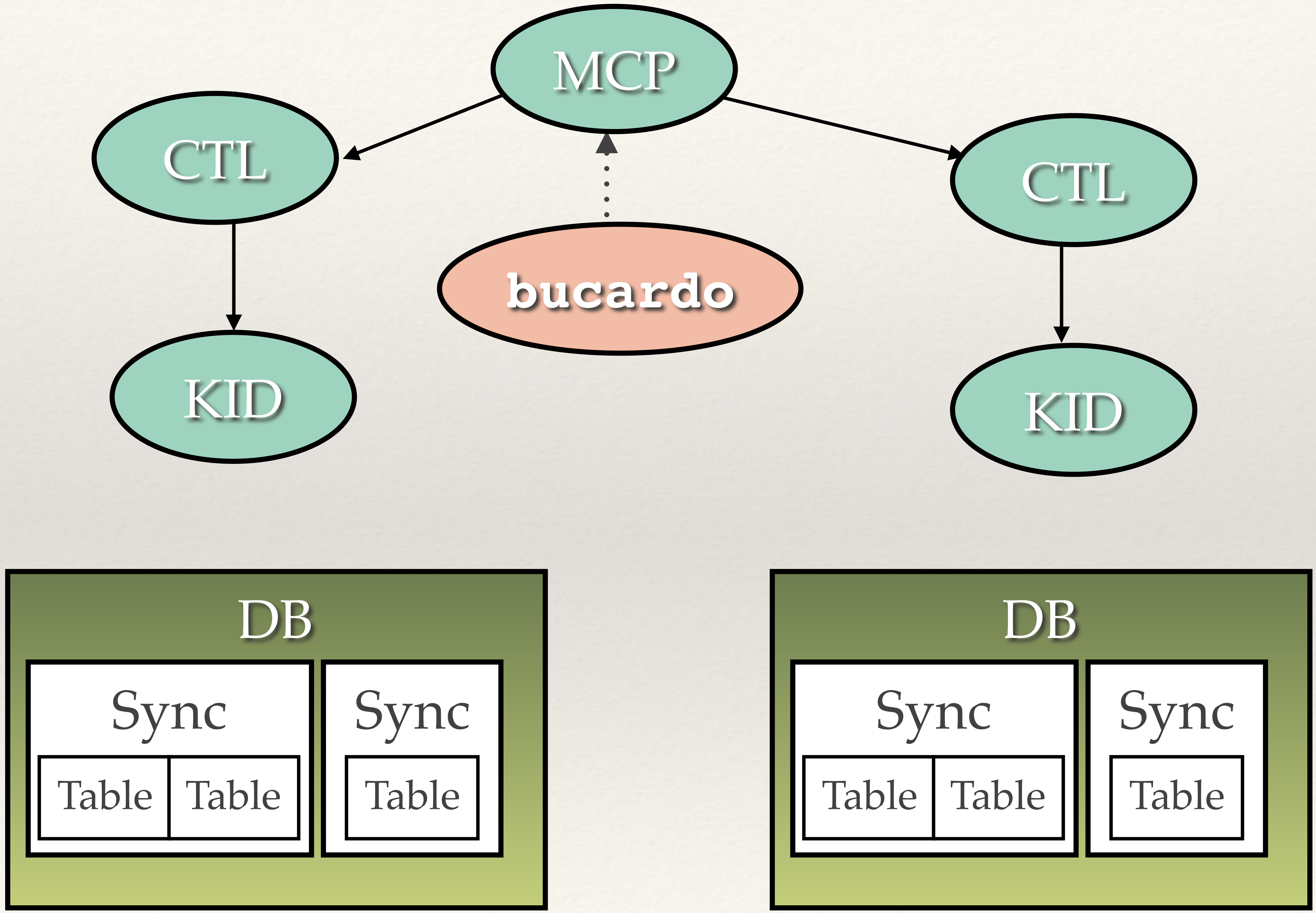
# Slony: Applying Changes

- The node's **`slon`** daemon listens for **`SYNC`** event notifications
- Gathers event data from the provider node since last applied **`SYNC`** event
- Applies the data from the **`sl_log_*`** tables
- Confirms the event on the remote node
- Process is inherently serial

# Bucardo

- A stand-alone replication system
- Push changes from Postgres to other databases
- Trigger-based, asynchronous
- Both Master/Slave and Multi-master

# Anatomy of a Bucardo System



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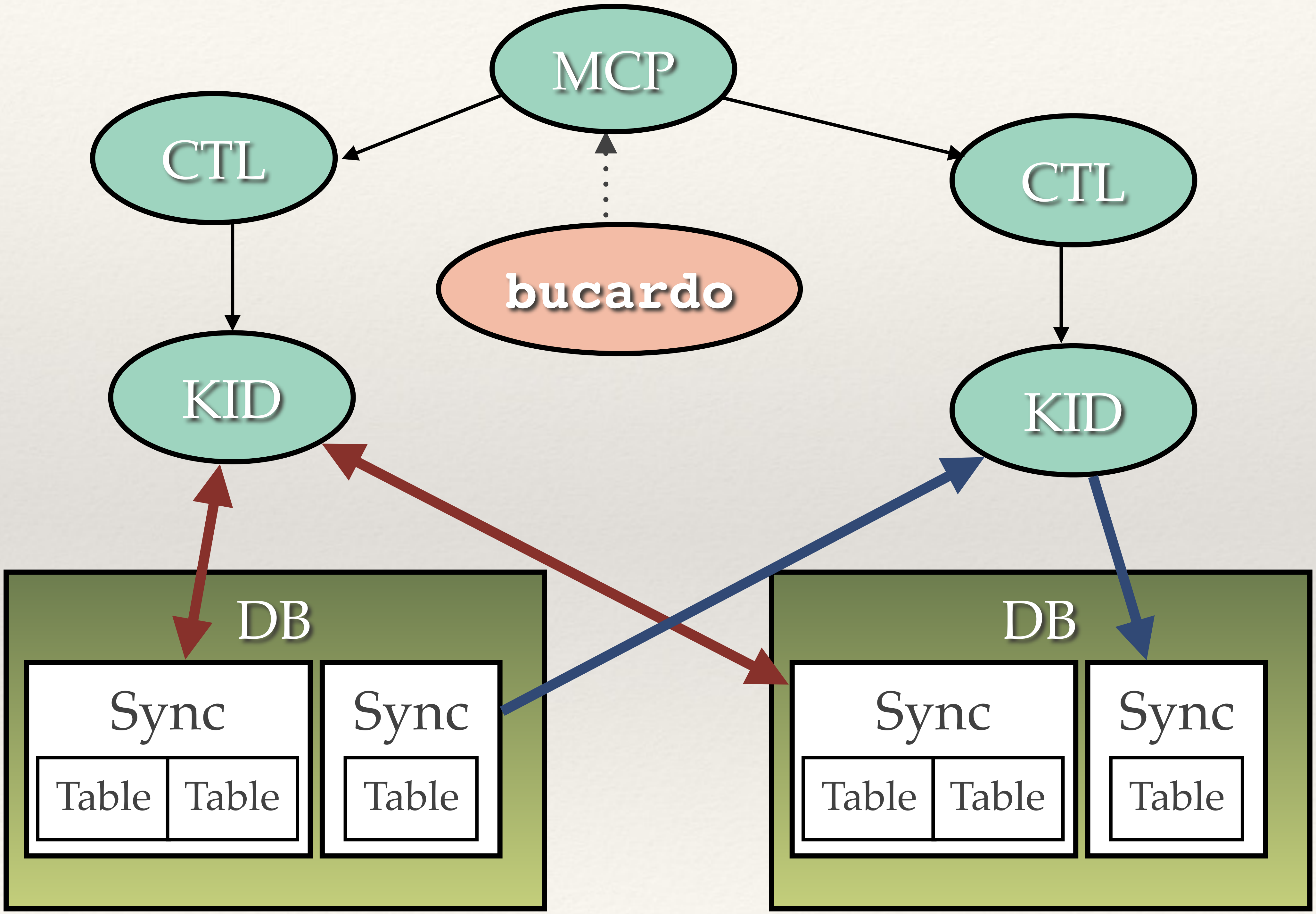


# Bucardo: History

- Started at backcountry.com in 2002, using Postgres 7.2
- Released publicly in 2007
- Bucardo 5 introduced true multi-master, lots of improvements over previous versions

# Bucardo: Strengths

- Low requirements (Pg 8.3, plperlu, DBD::Pg)
- No changes to Postgres or its configuration
- Only 1 daemon, can be run anywhere as long as it can connect to all DBs
- Fast, handles poor network connectivity
- Good command-line monitoring
- Easy install/setup

# Bucardo: Strengths

- Targets (slaves) are not locked
- Configuration in the database
- Customcode (conflict handlers, data transforms)
- Multiple target types (Oracle, MySQL, Mongo, etc)
- In case of multiple modifications to the same table row, replicates only the final state for replicated rows
- Good for heterogenous environments

# Bucardo: Limitations

- No automatic handling of DDL
- No built-in failover
- Requires PKs
- Targets (slaves) not locked
  - (hey, wasn't that just a strength?)
- Replicates only final state of affected rows
  - (hey, wasn't that just a strength?)

# Bucardo: Nomenclature

- Goat - Replicated object (table/sequence)
- Herd - Named group of Goats (= "set" in Slony)
- Sync - Specification for what kind of data is replication and how

# Bucardo: Architecture

- Master Control Process (MCP)
    - runs and monitors the overall process
- Controller Processes (CTL)
    - spawned by MCP, responsible for handling/monitoring KID processes
- KID processes
    - handle the actual hard work of replication
- I can't get enough of goat puns

# Bucardo CLI

- The main user interface to Bucardo.
- Performs all control-related actions
- Sends commands to the running "bucardo" daemon

# Bucardo CLI, cont

- `$ bucardo install`
- `$ bucardo add ...`
- `$ bucardo status`
- `$ bucardo kick`
- `$ bucardo help`

# Bucardo Configuration

- Configuration stored in a special database “bucardo”
- Bucardo keeps track of dbs, tables, herds, syncs, settings, etc in its own database.
- Database owned by the "bucardo" superuser.
- created for you via **`bucardo install`**.
- The **`bucardo`** tool uses the "bucardo" database to store state for the Bucardo daemon and information about the replication at hand.

# Bucardo: Tracking Changes

- Whenever a change is made on a table (I,U,D), the PK of the table is logged in a special table in the **`bucardo`** schema (known as the delta table)
- Depending on the sync settings, this will also trigger a notification that data has changed
- Bucardo will get the notification and process/apply the changes

# Bucardo: Applying Changes

- When Bucardo runs syncs (either automatically or manually kicked) it:
  - checks the delta tables for all affected PKs
  - then deletes them on the target
  - copies current row (if any in case of deletes)

# Bucardo: Multi-master

- Bucardo 5 has true multi-master, using round-robin syncing approach
- Each master in the cluster logs changed rows (by PK) into a custom table

# Bucardo: Multi-master Conflicts

- When there are conflicts, Bucardo runs customcode handlers to determine how to resolve the conflicts.
- When using master-master, have the potential to have both nodes modify the same row = conflict.
- Conflicts = BAD; we need to choose which row is "right" in this situation.
- Bucardo has some standard conflict resolution methods: source, target, random, or latest.
- Can always write your own custom conflict resolution

# BDR

- The “New Kid on the Block”
- Bi-Directional Replication
- Works via the Logical Log Streaming features of Pg
- Not covering extensively in this talk…but seems very cool and powerful

# BDR: Strengths

- Doesn’t use triggers, so no write magnification
- Handles many DDL modifications automatically throughout the cluster
- New tables are automatically replicated by default

# BDR: Limitations

- Requires a custom/patched Pg install
    - will likely go away in future versions, trying to get into core
- Some DDL/Pg features are restricted
- Only works on Pg >= 9.4
- Limited control on cluster topologies

# Side-by-side Overview

- Comparing how to manage clusters across Slony and Bucardo

# Constructing the Cluster: Slony

- cluster defined via **`slonik`** scripts
- **`INIT CLUSTER`**
- each node has its own immutable id, defined at node creation time
- **`CREATE NODE`**
- define pathways between nodes via **`CREATE PATH`**
- define topology via **`CREATE LISTEN`**
- cluster configuration is stored in the **`_slony`** schema in each database

## Constructing the Cluster: Bucardo

- cluster defined using **`bucardo`** tool
- **`bucardo install`**
- **`bucardo add db <dbname> [options]`**
- **`bucardo add dbgroup [db db]`**

## Specifying Replication Groups: Slony

- define sets containing tables to be replicated
- **`CREATE SET (id = ...)`**
- **`SET ADD TABLE (...)`**

# Specifying Replication Groups: Bucardo

- define "herds" via **bucardo**
- **bucardo add table <tablename> db=<dbname>**
- **bucardo add herd <name> [goat goat]**
- **bucardo add sync <name> source=<herdname> type=<synctype> target=**

# Modifying Replication: Slony

- to add new tables to the same set:
- `CREATE SET` with temporary set.
- `SUBSCRIBE SET` to match the subscriptions for original set
- `MERGE SET` to join the sets together

# Modifying Replication: Bucardo

- - modify the sync definition using **`bucardo`**
- - validate the sync via **`bucardo`**

## DML logging differences: Slony

- changes are logged per-transaction
- logs the data for the whole changed tuple as it exists
- multiple DML changes to the same row end up with multiple entries in the log table with the latest data

# DML logging differences: Bucardo

- only PK fields are logged
- doesn't differentiate between type of change (I,U,D)
- row values at time of event irrelevant
- when syncing, deletes the noted PK on the target, then inserts the current value of the row (if it still exists)
- multiple changes to the same record don't matter and aren't logged; final state only

# DDL changes: Slony

- create a SQL script to make the DDL changes
- **`EXECUTE SCRIPT`** to apply changes across the cluster
- events generated before/after will have the necessary data in the log tables when the other nodes replay the events in order
- ensures that the table will be in the correct state to run the DDL

# DDL changes:
# Bucardo

- stop replication
- perform DDL changes on all affected databases
- restart replication
- alternately, with simple column additions, you can apply the change first to the slaves then the master without affecting replication
- generally easier to just stop / start the replication

# Failover:
# Slony

- **`MOVE SET`** preferred method
- ensures cluster is sane
- if missing node comes back, it will properly hand-off control
- **`FAILOVER`** forcibly removes node from cluster
- use only when the node is likely to be unrecoverable

# Failover:
# Bucardo

- no formal failover
- available nodes still collect deltas
- if/when(?!) other node comes back, deltas are replayed
- can always adjust the syncs to remove the node from the sync definition

## Monitoring: Slony

- each node has **`sl_status`** view
- show status of other nodes confirmation of its generated events.
- displays number of events lagged, time

# Monitoring: Bucardo

- **`bucardo status`**
- shows all syncs, lag, statistics

# Sync Behavior:
# Slony

- SYNCs happen as quickly as possible

# Sync Behavior:
# Bucardo

- In Bucardo, syncs can be defined with multiple behaviors:
  - immediate
  - timed
  - manual

# Sync Behavior:
# Bucardo

- Immediate syncs
  - the general/expected way replication works

## Sync Behavior: Bucardo

- Timed syncs:
  - useful for data that changes frequently in the source but does not need to be up-to-date
  - can be handy with custom select behavior

# Sync Behavior:
# Bucardo

- Manual syncs:
  - Gives explicit control for specific syncs

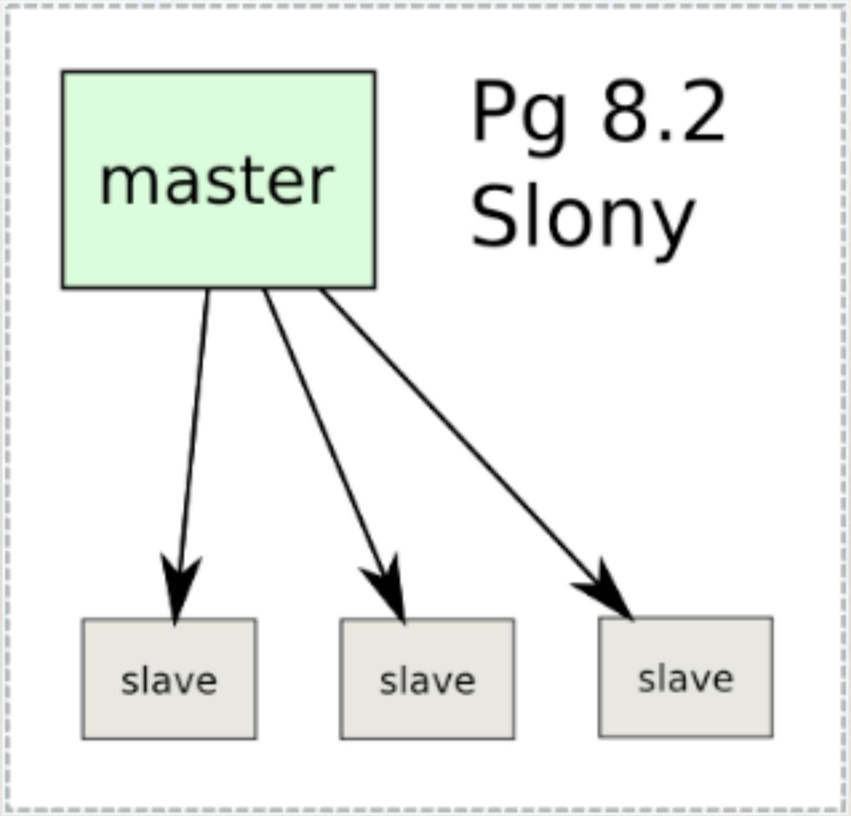
# Case Studies

- Choosing the Logical Replication system to use
  - No one right answer
  - Different scenarios cater to different strengths
  - Matter of picking the Right Tool For The Job™

# Case Study 1
# Minimal Downtime Upgrade

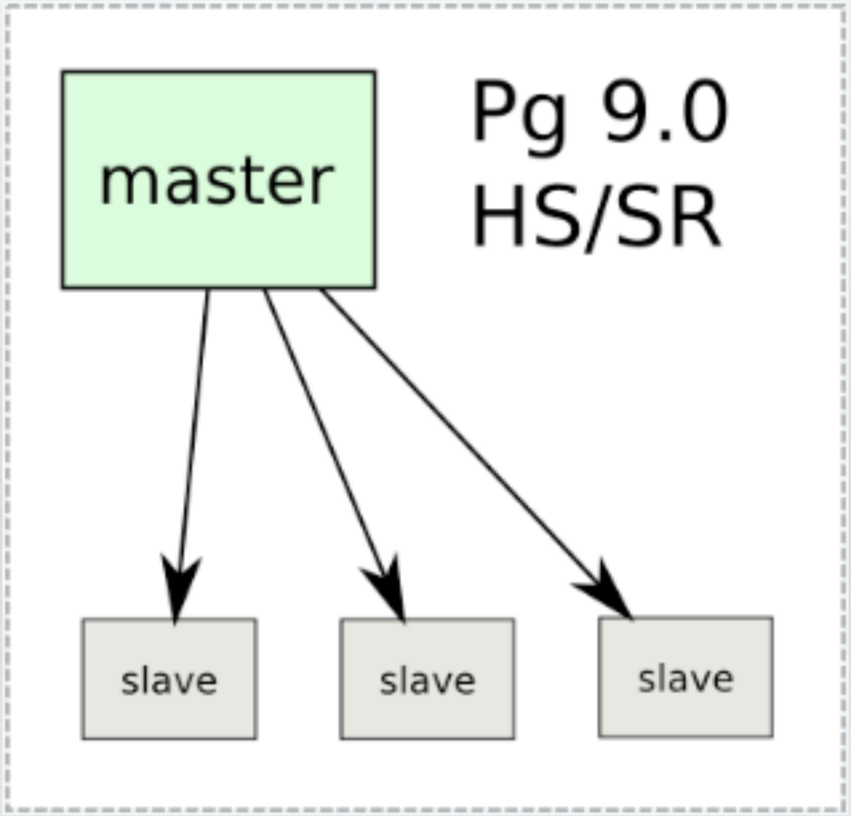
# Minimal Downtime Upgrade

We had:



# Minimal Downtime Upgrade

We wanted:



# Minimal Downtime Upgrade

We couldn’t upgrade Slony

The current version didn’t support Pg 9

Plus all those pesky:

# Minimal Downtime Upgrade

- Specific client issue:
- Upgrade Postgres 8.2/Slony cluster to Postgres 9 HS/SR
- Wanted migration with no application downtime (who doesn’t?)
- Couldn’t disrupt/upgrade the Slony cluster
- Very simple schema, but large table, lots of changes

# Minimal Downtime Upgrade

- Even though we couldn't modify the Slony cluster, we were able to use Bucardo in conjunction to accomplish this.
- Using Bucardo, total application downtime was measured in minutes, regardless of the size of the database.

# Minimal Downtime Upgrade

- Created the new Pg cluster in the new datacenter.
- Setup HS/SR, verified this was working.
- Configure/test remote access.

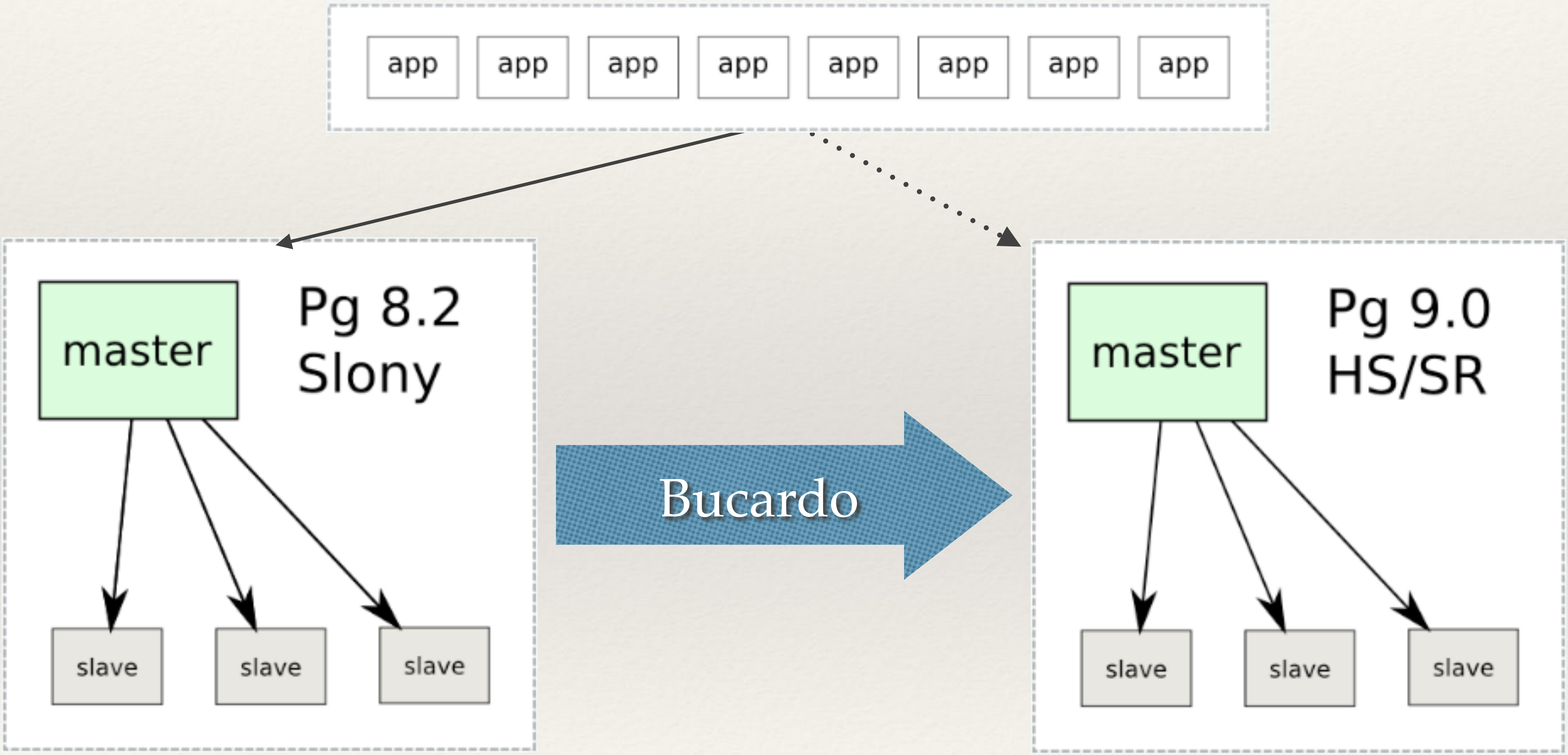
# Minimal Downtime Upgrade

- Installed Bucardo on the new cluster
- Dumped the schema/structure for the database, users, etc
- **`pg_dumpall –global`** and **`pg_dump –schema-only`**
- Defined Bucardo configuration, dbs, herds, sync
- With Bucardo setup, we were now capturing all deltas, so dump/load the data for an initial data load

# Minimal Downtime Upgrade

- **`pg_dump`** took a while, changes ongoing, but still had delta triggers capturing everything
- Once the shiny new cluster had the base dump loaded, kicked Bucardo to start the replication
- Now we only had to replicate the rows that had been modified, a much smaller set

# Minimal Downtime Upgrade



# Minimal Downtime Upgrade

- Once **that** caught up, we could stop the application, let it finish, then re-point/test
- Slony cluster on old database still running as a backup, so we could fall back as needed
- Bucardo replicated the same tables/changes to the new HS/SR cluster
- Bucardo was then safely removed

# Case Study 2
# Data Center Migration

# Datacenter Migration

- Realizing/fully utilizing the capabilities of an existing tool
- Client Datacenter Migration

# Datacenter Migration

- Client had a large database with a Slony cluster and needed to move datacenters
- Datacenters were linked with very slow VPN
- Needed to migrate multiple nodes at the same time
- Test, potentially rollback
- Of course, 0-downtime

# Datacenter Migration

- Data set was large: subscription of a new node took > 14 hours
- VPN was flaky and sometimes dropped connections in the middle of subscription
- Needed to recreate 4 node cluster in the new datacenter
- Everything had to work

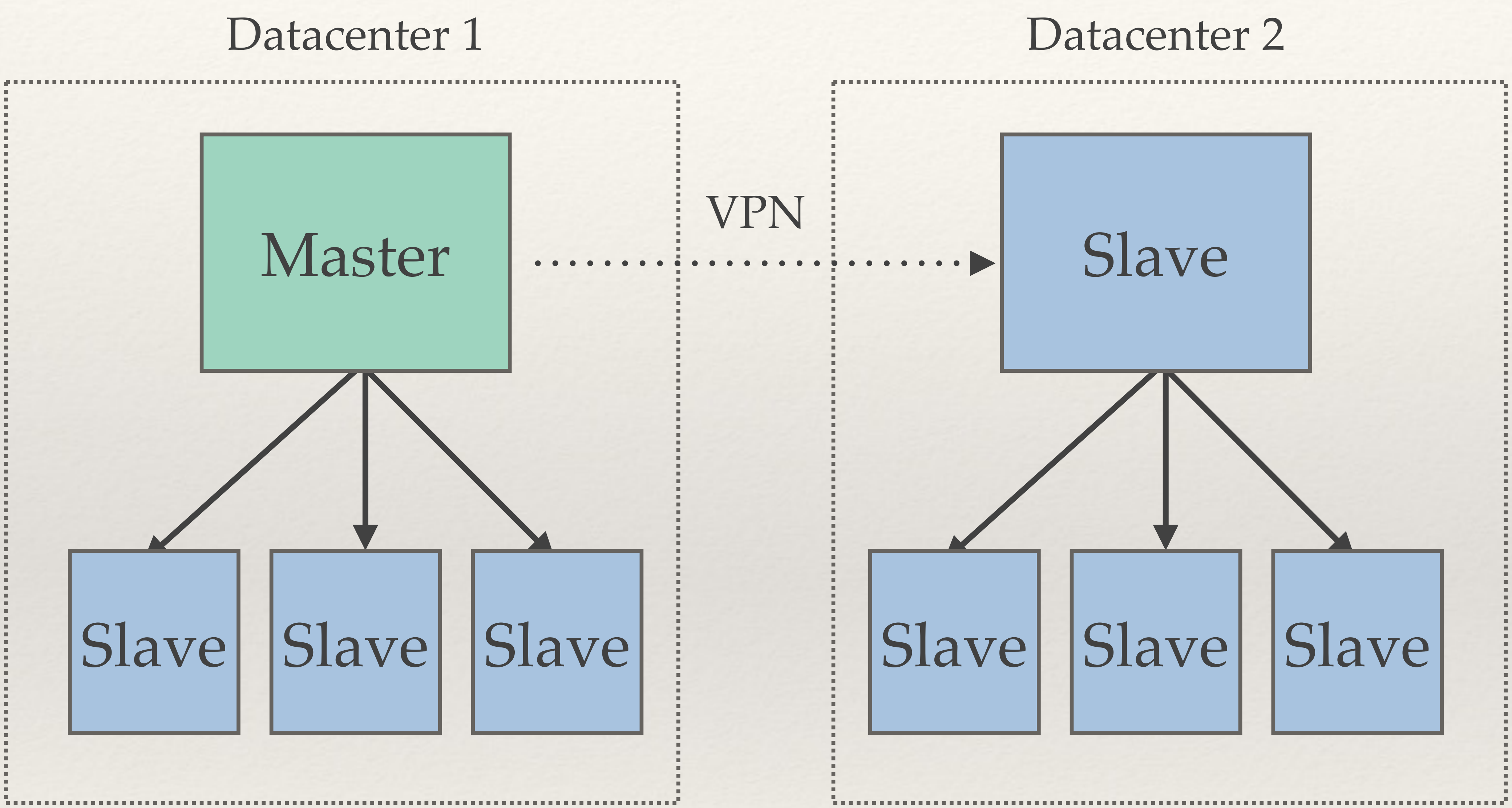
# Datacenter Migration

- Slony's cascaded replication and multiple sets to the rescue!

# Datacenter Migration

- Split sets:
  - VPN issues always happened on 1 specific table (the largest one, of course)
  - 2 really huge tables; related via FK
  - Split these tables off into their own replication set
  - Everything else subscribed fine

# Datacenter Migration



# Datacenter Migration

- Added all the new nodes to the Slony cluster without subscriptions yet
- Targeted the intended new master as the subscriber across the weak VPN link
- After that node subscribed, subscribed the new slave nodes directly from that node
- All while leaving the existing cluster in-place and running

# Datacenter Migration

- After testing, used **`MOVE SET`** to switch the origin node across the VPN
- Dropped the old nodes from the cluster

# Questions?

# Additional Information

- Slony:
  http://slony.info/
  #slony
- Bucardo:
  http://bucardo.org/
  #bucardo
- BDR:
  http://bdr-project.org/

Thanks!