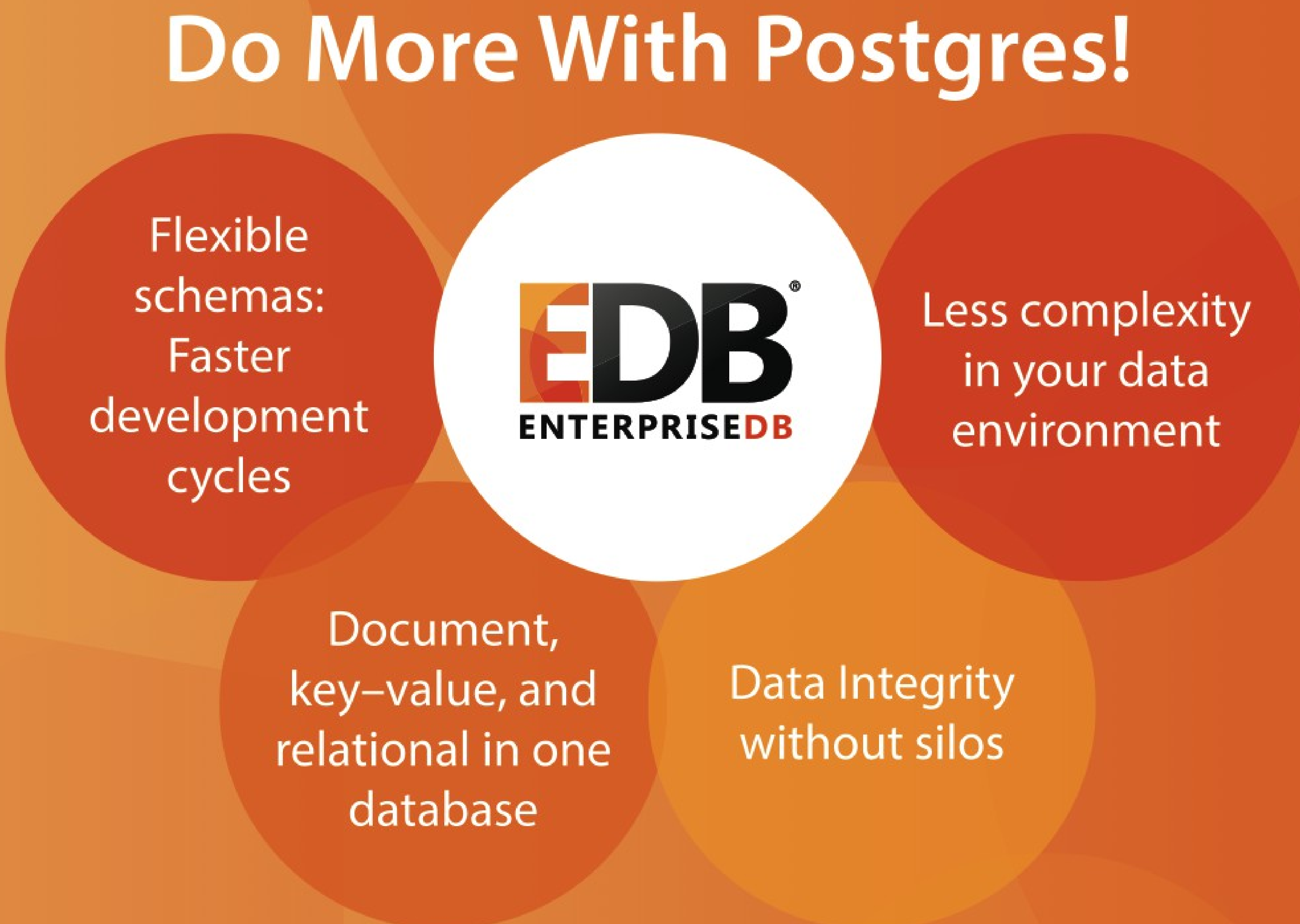


NoSQL On ACID

October 21, 2014

Let's Ask Ourselves, Why NoSQL?

- `Where did NoSQL come from?`
  - Where all cool tech stuff comes from – Internet companies
- `Why did they make NoSQL?`
  - To support huge data volumes and evolving demands for ways to work with new data types
- `What does NoSQL accomplish?`
  - Enables you to work with new data types: email, mobile interactions, machine data, social connections
  - Enables you to work in new ways: incremental development and continuous release
- `Why did they have to build something new?`
  - There were limitations to most relational databases

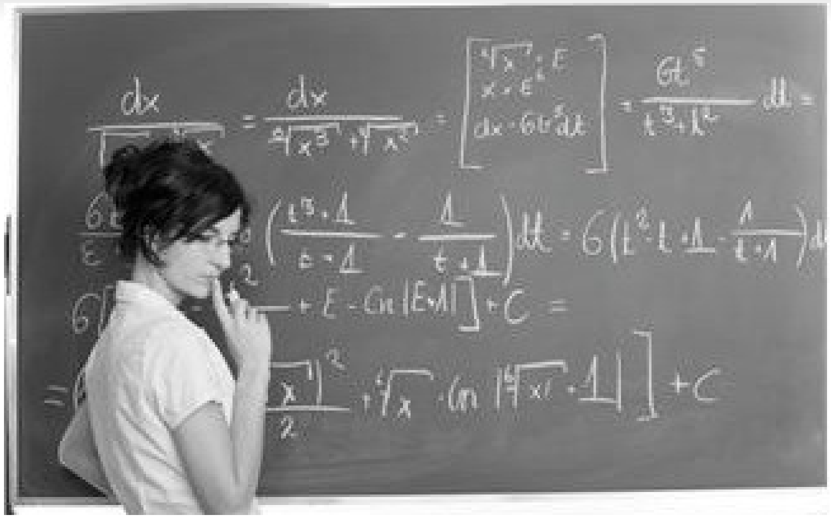
EDB ENTERPRISEDB

NoSQL: Real-world Applications

- Emergency Management System
  - High variability among data sources required high schema flexibility
- Massively Open Online Course
  - Massive read scalability, content integration, low latency
- Patient Data and Prescription Records
  - Efficient write scalability
- Social Marketing Analytics
  - Map reduce analytical approaches

Source: Gartner, A Tour of NoSQL in 8 Use Cases,
by Nick Heudecker and Merv Adrian, February 28, 2014

Postgres' Response



- HSTORE
  - Key-value pair
  - Simple, fast and easy
  - Postgres v 8.2 – pre-dates many NoSQL-only solutions
  - Ideal for flat data structures that are sparsely populated
- JSON
  - Hierarchical document model
  - Introduced in Postgres 9.2, perfected in 9.3
- JSONB
  - Binary version of JSON
  - Faster, more operators and even more robust
  - Postgres 9.4

Postgres: Key-value Store

- Supported since 2006, the HStore contrib module enables storing key/value pairs within a single column
- Allows you to create a schema-less, ACID compliant data store within Postgres

- Create single HStore column and include, for each row, only those keys which pertain to the record
- Add attributes to a table and query without advance planning

•Combines flexibility with ACID compliance

HSTORE Examples

- Create a table with HSTORE field

```
CREATE TABLE hstore_data (data HSTORE);
```

- Insert a record into hstore_data

```
INSERT INTO hstore_data (data) VALUES (’
          "cost"=>"500",
          "product"=>"iphone",
          "provider"=>"apple"');
```

- Select data from hstore_data

```
SELECT data FROM hstore_data ;
------------------------------------------
"cost"=>"500”,"product"=>"iphone”,"provider"=>"Apple"
(1 row)
```

Postgres: Document Store

- JSON is the most popular data-interchange format on the web
- Derived from the ECMAScript Programming Language Standard (European Computer Manufacturers Association).
- Supported by virtually every programming language
- New supporting technologies continue to expand JSON's utility
  - PL/V8 JavaScript extension
  - Node.js
- Postgres has a native JSON data type (v9.2) and a JSON parser and a variety of JSON functions (v9.3)
- Postgres will have a JSONB data type with binary storage and indexing (coming – v9.4)

Why JSON

- Wherever is JAVA Script. especially Browser.
- Most of Languages Support it.
- Node.Js is becoming popular.
- Lighter and more compact than XML.
- Most application don't need richer structure like XML.
- Flexible Structure.
- Due to its flexible Structure, good data type for NoSQL.

JSON Examples

- Creating a table with a JSONB field

```
CREATE TABLE json_data (data JSONB);
```

- Simple JSON data element:

```
{"name": "Apple Phone", "type": "phone", "brand":
"ACME", "price": 200, "available": true,
"warranty_years": 1}
```

- Inserting this data element into the table json_data

```
INSERT INTO json_data (data) VALUES
(' {"name": "Apple Phone",
"type": "phone",
"brand": "ACME",
"price": 200,
"available": true,
"warranty_years": 1
} ');
```

JSON Examples

- JSON data element with nesting:

```
{"full name": "John Joseph Carl Salinger",
"names":
   [
    {"type": "firstname", "value": "John"},
    {"type": "middlename", "value": "Joseph"},
    {"type": "middlename", "value": "Carl"},
    {"type": "lastname", "value": "Salinger"}
   ]
}
```

A simple query for JSON data

```
SELECT DISTINCT
data->>'name' as products
FROM json_data;

            products
------------------------------
 Cable TV Basic Service Package
 AC3 Case Black
 Phone Service Basic Plan
 AC3 Phone
 AC3 Case Green
 Phone Service Family Plan
 AC3 Case Red
 AC7 Phone
```

This query does not return JSON data – it returns text values associated with the key ‘name’

A query that returns JSON data

```
SELECT data FROM json_data;

data

------------------------------------------

 {"name": "Apple Phone", "type": "phone", "brand":
"ACME", "price": 200, "available": true,
"warranty_years": 1}
```

This query returns the JSON data in its original format

JSON is defined per RFC – 7159
For more detail please refer
http://tools.ietf.org/html/rfc7159

JSON Data Types

- `1. Number:`
  - Signed decimal number that may contain a fractional part and may use exponential notation.
  - No distinction between integer and floating-point
- `2. String`
  - A sequence of zero or more Unicode characters.
  - Strings are delimited with double-quotation mark
  - Supports a backslash escaping syntax.
- `3. Boolean`
  - Either of the values true or false.
- `4. Array`
  - An ordered list of zero or more values,
  - Each values may be of any type.
  - Arrays use square bracket notation with elements being comma-separated.
- `5. Object`
  - An unordered associative array (name/value pairs).
  - Objects are delimited with curly brackets
  - Commas to separate each pair
  - Each pair the colon ':' character separates the key or name from its value.
  - All keys must be strings and should be distinct from each other within that object.
- `6. null`
  - An empty value, using the word null

JSON Data Type Example

```
{
  "firstName": "John",              -- String Type
  "lastName": "Smith",              -- String Type
  "isAlive": true,                  -- Boolean Type
  "age": 25,                        -- Number Type
  "height_cm": 167.6,               -- Number Type
  "address": {                      -- Object Type
    "streetAddress": "21 2nd Street”,
    "city": "New York”,
    "state": "NY”,
    "postalCode": "10021-3100”
  }
  "phoneNumbers": [        -- Object Array
    {                      --  Object
      "type": "home”,
      "number": "212 555-1234”
    },
    {
      "type": "office”,
      "number": "646 555-4567”
    }
  ],
  "children": [],
  "spouse": null          -- Null
}
```

History of JSON in PostgreSQL

History: JSON – Before 9.2

- JSON could only be stored as simple text.
- Did not have structure Validation.
- Did not have Supported functions/operated
- Application had to do most of work for
  - Validation
  - Verification
  - Extraction

History: JSON – In 9.2

- New data type JSON.
- Data can also be stored as text.
- Validate stored value is valid JSON.
- Proved following two supported functions:
  - array_to_json(anyarray [, pretty_bool])
  - row_to_json(record [, pretty_bool])
- Missing feature:
  - JSON processing was missing
  - User has to use PLV8, PLPerl etc..

History: JSON – In 9.3

- Add operators and functions to extract elements from JSON values
  - Allow JSON values to be converted into records.
  - Add functions to convert scalars, records, and hstore values to JSON
- Functions honour casts to JSON for non built-in types.
- New functions for HSTORE to JSON
  - hstore_to_json(hstore)
  - hstore_to_json_loose(hstore).
- Parser exposed for use by other modules such as extensions as an API.

Operators and Functions

- `extraction operators:`
  - `->` fetch an array element or object member as json
  - json arrays are 0 based, unlike SQL arrays
  - `'[4,5,6]'::json->2` $\Longrightarrow$ `6`
  - `'{"a":1,"b":2}'::json->'b'` $\Longrightarrow$ `2`
- `9.3 extraction operators:`
  - ->> fetch an array element or object member as text
  - `'["a","b","c"]'::json->2` $\Longrightarrow$ `c`
  - Instead of "c"

Operators and Functions

- JSON Extraction Functions:
  - `json_extract_path(json, VARIADIC path_elems text[]);`
  - `json_extract_path_text(json, VARIADIC path_elems text[]);`

- Same as #> and #>> operators, but you can pass the path as a variadic array
- `json_extract_path('{"a":[6,7,8]}','a','1')` ⟹7

Operators and Functions

- 9.3 turn JSON into records:

- CREATE TYPE x AS (a int, b int);
- SELECT * FROM json_populate_record(null::x, '{"a":1,"b":2}', false);
- SELECT * FROM json_populate_recordset(null::x,'[{"a":1," b":2},{"a":3,"b":4}]', false);

Operators and Functions

- 9.3 turn JSON into key/value pairs
  - `SELECT * FROM json_each('{"a":1,"b":"foo"}')`
  - `SELECT * FROM json_each_text('{"a":1,"b":"foo"}')`

- Deliver columns named “key” and “value”

Operators and Functions

- 9.3 get keys from JSON object:
- SELECT * FROM json_object_keys('{"a":1,"b":"foo"}')

- 9.3 JSON array processing:
- SELECT json_array_length('[1,2,3,4]');
- SELECT * FROM json_array_elements('[1,2,3,4]')

JSON 9.4 – New Operators and Functions

- JSON
  - New JSON creation functions (json_build_object, json_build_array)
  - json_typeof – returns text data type (‘number’, ‘boolean’, …)
- JSONB data type
  - Canonical representation
    - Whitespace and punctuation dissolved away
    - Only one value per object key is kept
    - Last insert wins
    - Key order determined by length, then bytewise comparison
  - Equality, containment and key/element presence tests
  - New JSONB creation functions
  - Smaller, faster GIN indexes
  - jsonb subdocument indexes
    - Use “get” operators to construct expression indexes on subdocument:
    - `CREATE INDEX author_index ON books USING GIN ((jsondata -> 'authors'));`
    - `SELECT * FROM books WHERE jsondata -> 'authors' ? 'Carl Bernstein'`

9.4 Features Set:

- New json creation functions
- New utility functions
- jsonb type
- Efficient operations Indexable Canonical

9.4 Features – new json aggregate

- json_object_agg(“any”, “any”)
- Turn a set of key value pairs into a json object
- SELECT json_object_agg(name, population) from cities;
  - { “Smallville”: 300, “Metropolis”: 1000000}

9.4 Features – json creation functions

- json_build_object(VARIADIC “any”)
- json_build_array(VARIADIC “any”)
- json_object(text[])
- json_object(keys text[], values text[])

9.4 Features – json creation functions (Examples)

- `SELECT json_build_object('a',1,'b',true)`
  - `{“a”: 1, “b”: true}`
- `SELECT json_build_array('a',1,'b',true)`
  - `[“a”, 1, “b”, true]`
- `SELECT json_object(array['a','b','c','d']`
- `Or SELECT json_object(array[['a','b'],['c','d']]`
- `Or SELECT json_object(array['a','c'],array['b','d'])`
  - `{“a”:”b”, “c”:”d”}`

9.4 features – json_typeof

- json_typeof(json) returns text Result is one of:
  - 'object’
  - 'array’
  - 'string’
  - 'number'
  - 'boolean'
  - 'null’
  - Null

9.4 features – jsonb type

- Accepts the same inputs as json
- Uses the 9.3 parsing API
- Checks Unicode escapes, especially use of surrogate pairs, more thoroughly than json.
- Representation closely mirrors json syntax

9.4 Features – jsonb canonical representation

- Whitespace and punctuation dissolved away
- Only one value per object key is kept
- Last one wins.
- Key order determined by length, then bytewise comparison

9.4 Features – jsonb operators

- Has the json operators with the same semantics:
  - -> ->> #> #>>
- Has standard equality and inequality operators
  - = <> > < >= <=
- Has new operations testing containment, key/element presence
  - @> <@ ? ?| ?&

9.4 Features – jsonb equality and inequality

- Comparison is piecewise
  - Object > Array > Boolean > Number > String > Null
    Object with n pairs > object with n - 1 pairs
- Array with n elements > array with n - 1 elements
- Not particularly intuitive
- Not ECMA standard ordering, which is possibly not suitable anyway

9.4 features – jsonb functions

- jsonb has all the json processing functions, with the same semantics
- i.e. functions that take json arguments
- Function names start with jsonb_ instead of json_

- jsonb does not have any of the json creation functions
- i.e. functions that take non-json arguments and output json
- Workaround: cast result to jsonb

9.4 features – jsonb indexing

- `2 ops classes for GIN indexes`
- `Default supports contains and exists operators:`
  - @> ? ?& ?|
- `Non-default ops class jsonb_path_ops only supports`
  - @> operator
  - Faster
  - Smaller indexes

9.4 features – jsonb subdocument indexes

- Use “get” operators to construct expression indexes on subdocument:

- `CREATE INDEX author_index ON books USING GIN ((jsondata -> 'authors'));`
- `SELECT * FROM books WHERE jsondata -> 'authors' ? 'Carl Bernstein'`

PLV8

Java Script Language In database

PLV8: V8 Engine Java Script language

- PLV8 is a shared library that provides a PostgreSQL procedural language powered by
- V8 JavaScript Engine.
- Language you can write in your JavaScript function that is callable from SQL.

PLV8: Installation

- Requires g++ version 4.5.1 or 4.4.x
- For Installation of PLV8, we need V8 engine on server
  - V8 JavaScript Engine is an open source JavaScript engine developed by Google for the Google Chrome web browser.
- To install V8, you can use RPMS:
  - v8-devel-3.14.5.10-9.el6.x86_64
  - v8-3.14.5.10-9.el6.x86_64
- OR
- Using source code.

PLV8: Installation

- `cd ~/build`
- `git clone https://code.google.com/p/plv8js/`
- `cd plv8js`
- `make`
- `make install`
- `psql -d` *`dbname`* `-c "CREATE EXTENSION plv8"`

PLV8: Examples

```
CREATE OR REPLACE FUNCTION plv8_test(keys text[], vals
text[]) RETURNS
  text AS $$
  var o = {};
  for(var i=0; i<keys.length; i++){
    o[keys[i]] = vals[i];
  }
  return JSON.stringify(o);
$$ LANGUAGE plv8 IMMUTABLE STRICT;
```

- `SELECT plv8_test(ARRAY['name', 'age'], ARRAY['Tom', '29']);`

PLV8: Examples

```
CREATE TYPE rec AS (i integer, t text);
CREATE FUNCTION set_of_records() RETURNS SETOF rec AS
$$
// plv8.return_next() stores records in an internal tuplestore,
// and return all of them at the end of function.
    plv8.return_next( { "i": 1, "t": "a" } );
    plv8.return_next( { "i": 2, "t": "b" } );

 // You can also return records with an array of JSON.
    return [ { "i": 3, "t": "c" }, { "i": 4, "t": "d" } ];
$$
LANGUAGE plv8;
```

PLV8: Examples

```
SELECT * FROM set_of_records();
 i | t
---+---
 1 | a
 2 | b
 3 | c
 4 | d
(4 rows)
```

PLV8: Built in functions

- `plv8.elog( elevel, ... )`
- Function print messages to server and/or client logs just like as RAISE in PL/pgSQL
- Acceptable elevels are
  - DEBUG[1-5],
  - LOG,
  - INFO,
  - NOTICE,
  - WARNING and
  - ERROR.

PLV8: Built in functions

- `plv8.execute( sql [, args] )`
- Execute SQL statements and retrieve the result. "args" is an optional argument that replaces $n placeholders in "sql".
- Example:
- `var json_result = plv8.execute( 'SELECT * FROM tbl' );`
- `var num_affected = plv8.execute( 'DELETE FROM tbl WHERE price > $1', [ 1000 ] );`

PLV8: Built in functions

- `plv8.prepare( sql, [, typenames] )`
- Create a prepared statement. The *typename* parameter is an array where each element is a string to indicate PostgreSQL type name for bind parameters. Returned value is an object of PreparedPlan.
- object must be freed by plan.free() before leaving the function.
- Example:
- `var plan = plv8.prepare( 'SELECT * FROM tbl WHERE col = $1', ['int'] );`
- `var rows = plan.execute( [1] );`

PLV8: Built in functions

- `PreparedPlan.execute( [args] )`
- *args* parameter is as plv8.execute(), and
- can be omitted if the statement doesn't have parameters at all.
- The result of this method is same as in plv8.execute().

PLV8: Built in functions

- `PreparedPlan.cursor( [args] )`
- Open a cursor from the prepared statement.
- *args* parameter is as plv8.execute(), and
- can be omitted if the statement doesn't have parameters at all.
- The returned object is of Cursor.
- It must be closed by Cursor.close() before leaving the function.

PLV8: Built in functions

```
PreparedPlan.cursor( [args] )


var plan = plv8.prepare( 'SELECT * FROM tbl WHERE col = $1',
['int'] );
var cursor = plan.cursor( [1] );
var sum = 0, row;
while (row = cursor.fetch()) {
  sum += row.num;
}
cursor.close();
plan.free();
return sum;
```

PLV8: Built in functions

- `PreparedPlan.free()`
  - Free the prepared statement.
- `Cursor.fetch()`
  - Fetch a row from the cursor and return as an object (note: not an array.) Fetching more than one row, and move() aren't currently implemented.
- `Cursor.close()`
  - Close the cursor.

PLV8: Built in functions

- `plv8.subtransaction( func )`
- Function runs the argument function within a sub-transaction.
- Needed when you want multiple “execute(query)” commands to be run atomically.
- If one of the statements fails then everything which is run in this function will be rolled back.
- **Note:** if an exception is thrown from the subtransaction function, the exception goes out of subtransaction(), so you'll typically need another try-catch block outside.

PLV8: Built in functions

- `plv8.subtransaction( func )`
- Example:

```
try{
  plv8.subtransaction(function(){
    plv8.execute("INSERT INTO tbl VALUES(1)");  -- should be rolled back!
    plv8.execute("INSERT INTO tbl VALUES(1/0)");-- occurs an exception
  });
} catch(e) {
  ... do fall back plan ...
}
```

JSON and ANSI SQL - PB&J for the DBA

- JSON is naturally integrated with ANSI SQL in Postgres
- JSON and SQL queries use the same language, the same planner, and the same ACID compliant transaction framework
- JSON and HSTORE are elegant and easy to use extensions of the underlying object-relational model

JSON and ANSI SQL Example

ANSI SQL

JSON

```
SELECT DISTINCT
    product_type,
    data->>'brand' as Brand,
    data->>'available' as Availability
FROM json_data
JOIN products
ON (products.product_type=json_data.data->>'name')
WHERE json_data.data->>'available'=true;
```

```
product_type              | brand     | availability
--------------------------+-----------+--------------
AC3 Phone                 | ACME      | true
```

No need for programmatic logic to combine SQL and NoSQL in the application – Postgres does it all

Bridging between SQL and JSON

Simple ANSI SQL Table Definition

```
CREATE TABLE products (id integer, product_name text );
```

Select query returning standard data set

```
SELECT * FROM products;

 id | product_name
----+--------------
  1 | iPhone
  2 | Samsung
  3 | Nokia
```

Select query returning the same result as a JSON data set

```
SELECT ROW_TO_JSON(products) FROM products;

{"id":1,"product_name":"iPhone"}
{"id":2,"product_name":"Samsung"}
{"id":3,"product_name":"Nokia”}
```

JSON and BSON

- `BSON – stands for 'Binary JSON'`
- `BSON != JSONB`
  - BSON cannot represent an integer or floating-point number with more than 64 bits of precision.
  - JSONB can represent arbitrary JSON values.
- `Caveat Emptor!`
  - This limitation will not be obvious during early stages of a project!

JSON, JSONB or HSTORE?

- JSON/JSONB is more versatile than HSTORE
- HSTORE provides more structure
- JSON or JSONB?
  - if you need any of the following, use JSON
    - Storage of validated json, without processing or indexing it
    - Preservation of white space in json text
    - Preservation of object key order Preservation of duplicate object keys
    - Maximum input/output speed
- For any other case, use JSONB

JSONB and Node.js - Easy as π

```
// require the Postgres connector
var pg = require("pg");

// connection to local database
var conString = "pg://postgres:password@localhost:5432/nodetraining";

var client = new pg.Client(conString);
client.connect();

// initiate the sample database
 client.query("CREATE TABLE IF NOT EXISTS emps(data jsonb)");
 client.query("TRUNCATE TABLE emps;");
 client.query('INSERT INTO emps VALUES($JSON$ {"firstname": "Ronald" , "lastname":"McDonald" }$JSON$)')
 client.query('INSERT  INTO emps values($JSON$ {"firstname": "Mayor", "lastname": "McCheese"}$JSON$)')

// run SELECT query
 client.query("SELECT * FROM emps",function(err,result){
     console.log("Test Output of JSON Result Object");
     console.log(result);
     console.log("Parsed rows");

// parse the result set
    for (var i = 0; i< result.rows.length ; i++ ){
        var data = JSON.parse(result.rows[i].data);
        console.log("First Name => "+ data.firstname + "\t| Last Name => " + data.lastname);
    }
 client.end();
})
```

JSON Performance Evaluation

- Goal
  - Help our customers understand when to chose Postgres and when to chose a specialty solution
  - Help us understand where the NoSQL limits of Postgres are
- Setup
  - Compare Postgres 9.4 to Mongo 2.6
  - Single instance setup on AWS M3.2XLARGE (32GB)
- Test Focus
  - Data ingestion (bulk and individual)
  - Data retrieval

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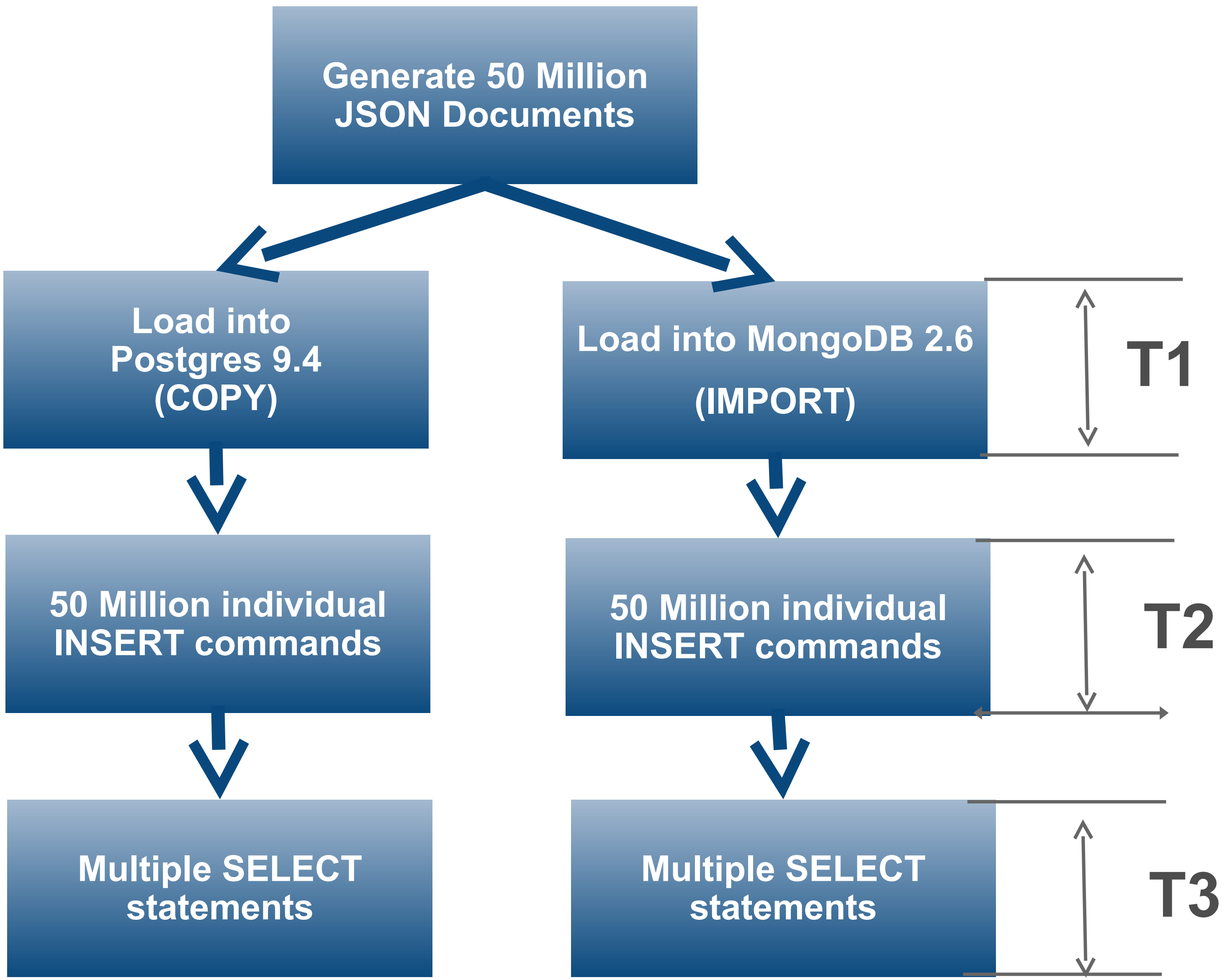
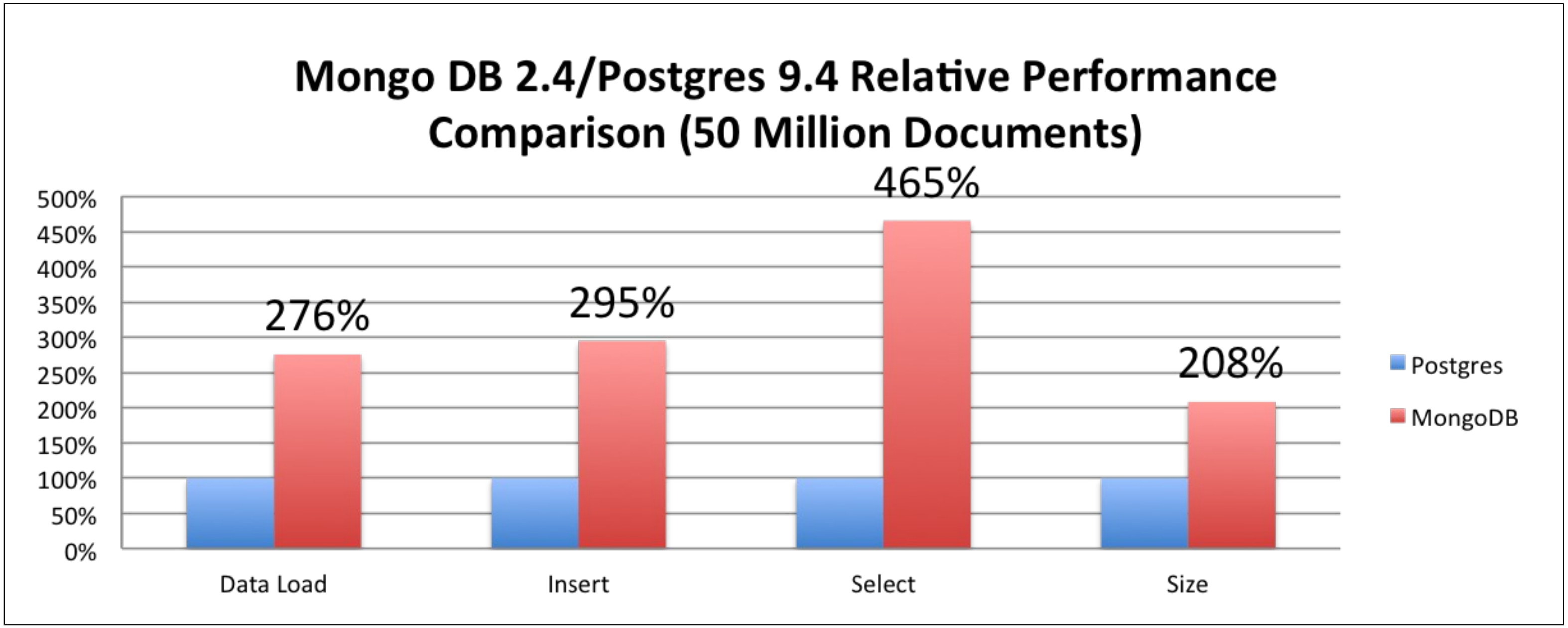
Performance Evaluation



NoSQL Performance Evaluation



	Postgres	MongoDB
Data Load (s)	4,732	13,046
Insert (s)	29,236	86,253
Select (s)	594	2,763
Size (GB)	69	145

Correction to earlier versions:

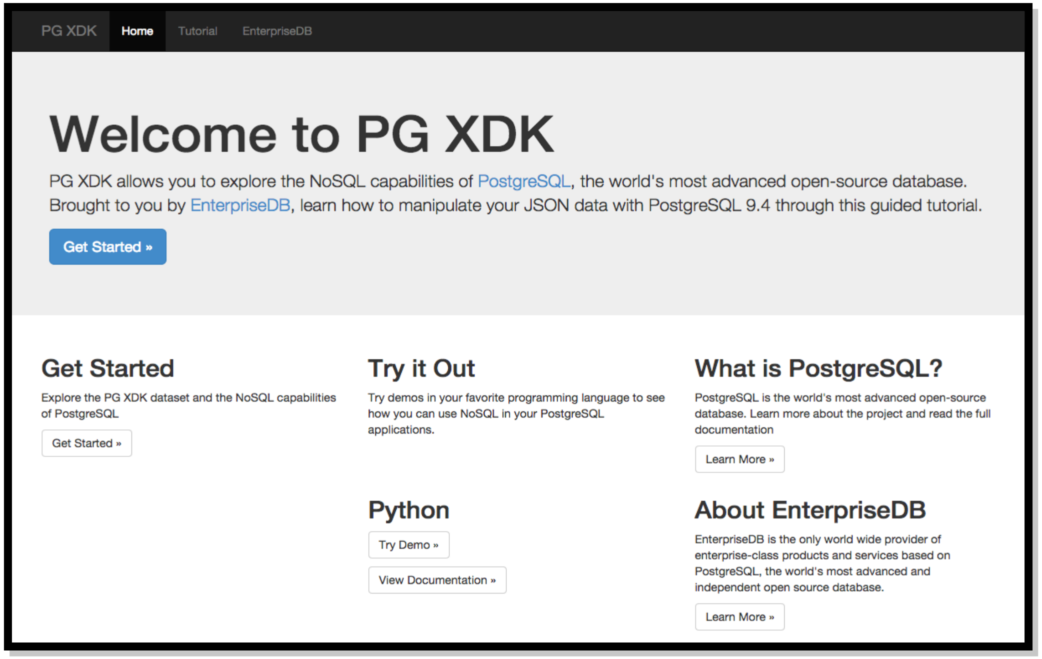
MongoDB console does not allow for INSERT of documents > 4K. This lead to truncation of the MongoDB size by approx. 25% of all records in the benchmark.

Performance Evaluations – Next Steps

- Initial tests confirm that Postgres' can handle many NoSQL workloads
- EDB is making the test scripts publicly available
- EDB encourages community participation to better define where Postgres should be used and where specialty solutions are appropriate
- Download the source at https://github.com/EnterpriseDB/pg_nosql_benchmark
- Join us to discuss the findings at http://bit.ly/EDB-NoSQL-Postgres-Benchmark

PG XDK

- Postgres Extended Document Type Developer Kit
- Provides end-to-end Web 2.0 example
- Deployed as free AMI
- First Version
  - Postgres 9.4 (beta) w. HSTORE and JSONB
  - Python, Django, Bootstrap, psycopg2 and nginx
- Next Version:
  PL/V8 & Node.js
- Final Version:
  Ruby on Rails



AWS AMI PG XDK v0.2 - ami-1616b57e

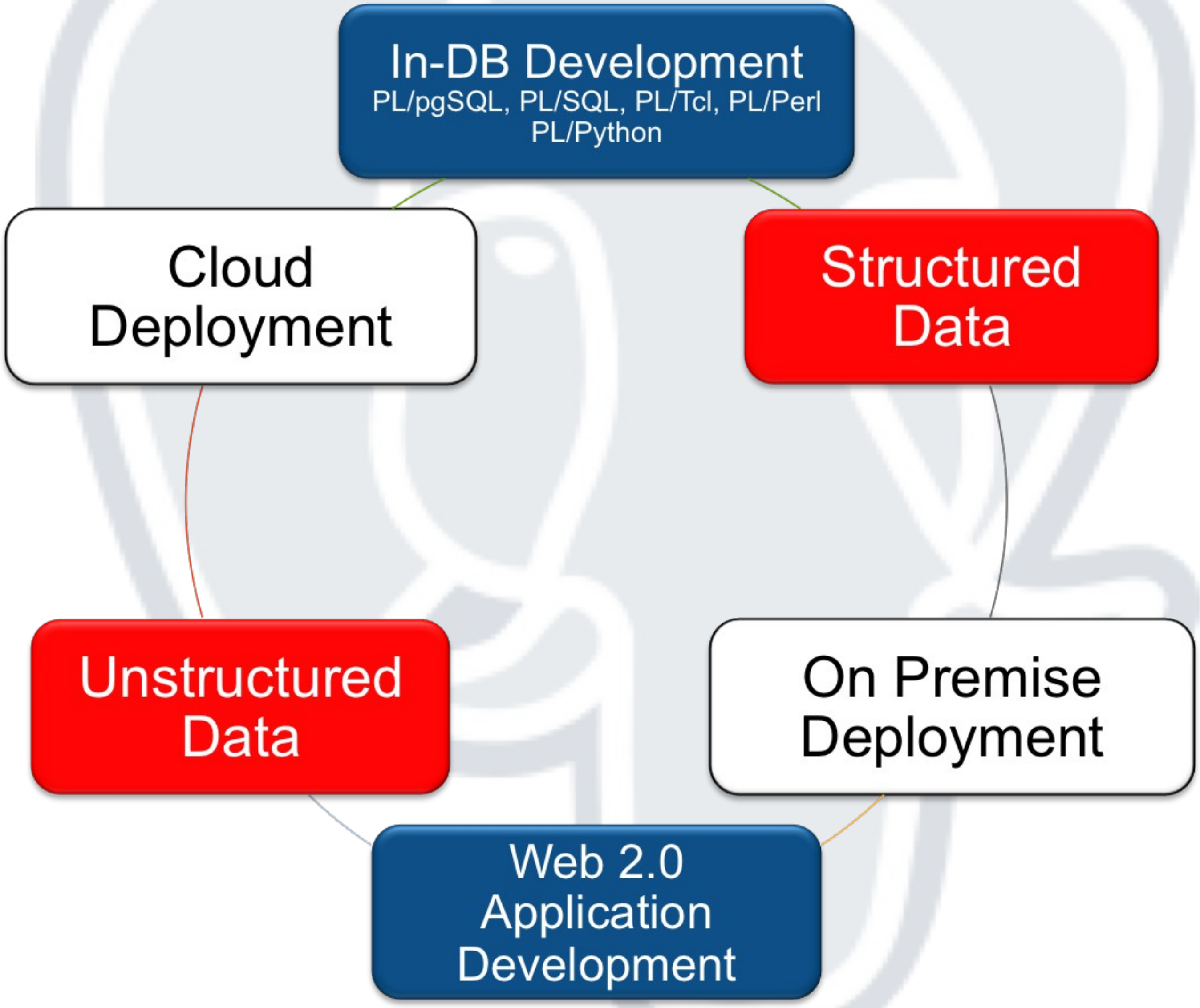
Installing PG XDK

- Select PG XDK v0.2 - ami-1616b57e on the AWS Console
- Use https://console.aws.amazon.com/ec2/v2/home?region=us-east-1#LaunchInstanceWizard:ami=ami-1616b57e
- Works with t2.micro (AWS Free Tier)
- Remember to enable HHTP access in the AWS console

Structured or Unstructured? “No SQL Only” or “Not Only SQL”?

- Structures and standards emerge!
- Data has references (products link to catalogues; products have bills of material; components appear in multiple products; storage locations link to ISO country tables)
- When the database has duplicate data entries, then the application has to manage updates in multiple places – what happens when there is no ACID transactional model?

Ultimate Flexibility with Postgres



Say yes to 'Not only SQL'

- Postgres overcomes many of the standard objections "It can't be done with a conventional database system"
- Postgres
  - Combines structured data and unstructured data (ANSI SQL and JSON/HSTORE)
  - Is faster (for many workloads) than than the leading NoSQL-only solution
  - Integrates easily with Web 2.0 application development environments
  - Can be deployed on-premise or in the cloud

Do more with Postgres – the Enterprise NoSQL Solution

Useful Resources

- Whitepapers @ **http://www.enterprisedb.com/nosql-for-enterprise**
  - PostgreSQL Advances to Meet NoSQL Challenges (business oriented)
  - Using the NoSQL Capabilities in Postgres (full of code examples)
- Run the NoSQL benchmark
  - **https://github.com/EnterpriseDB/pg_nosql_benchmark**
- Test drive PG XDK
- Check out the jsonbx repo: **https://github.com/erthalion/jsonbx**
  - JSON-modifying operators and functions (hopefully coming to PostgreSQL 9.5)

Do More With Postgres!

Flexible schemas: Faster development cycles

ENTERPRISEDB

Less complexity in your data environment

Document, key–value, and relational in one database

Data Integrity without silos