Using PostgreSQL with Java

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Who I am

- What we do @8Kdata:
  - ✓Creators of ToroDB.com, NoSQL & SQL database
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  - ✓Training and consulting in PostgreSQL
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Agenda

1. Introduction to Java and PostgreSQL
2. Ways of connecting to PostgreSQL from Java (not only JDBC!)
3. Introduction to JDBC. JDBC types. PostgreSQL JDBC
4. Code demo: JDBC with PostgreSQL. From Java 1.7 to Java 8, best practices and code samples
5. Code demo: MyBatis, jOOQ
6. Java inside PostgreSQL
7. JDBC performance
8. HikariCP + FlexyPool
9. The future of Java and PostgreSQL

PostgreSQL and Java

PostgreSQL and Java. Do they fit well?

- There seems to be small interest within the community:

  ✓ pgsql-jdbc is not a high traffic ml (2.15 msg/day)

  ✓ pl-java started strong, faded away, came back as 1.5 and now works for 9.4 & 9.5

  ✓ JavaScript, Python, Ruby, Go seem to rule the programming ecosystem around postgresql

- There are no native APIs for Java
- Java = ORM = Hibernate = suckz → Java suckz

PostgreSQL and Java. They do fit well

- Java IS the enterprise language
- Arguably, there is more Java code accessing PostgreSQL than from any other programming language
- Both Java and PostgreSQL are mature, reliable and trusted
- Several commercial, big data and postgres derivatives use and/or are interfaced via Java
- There is a mature and reliable option to connect to PostgreSQL (the JDBC PostgreSQL driver)

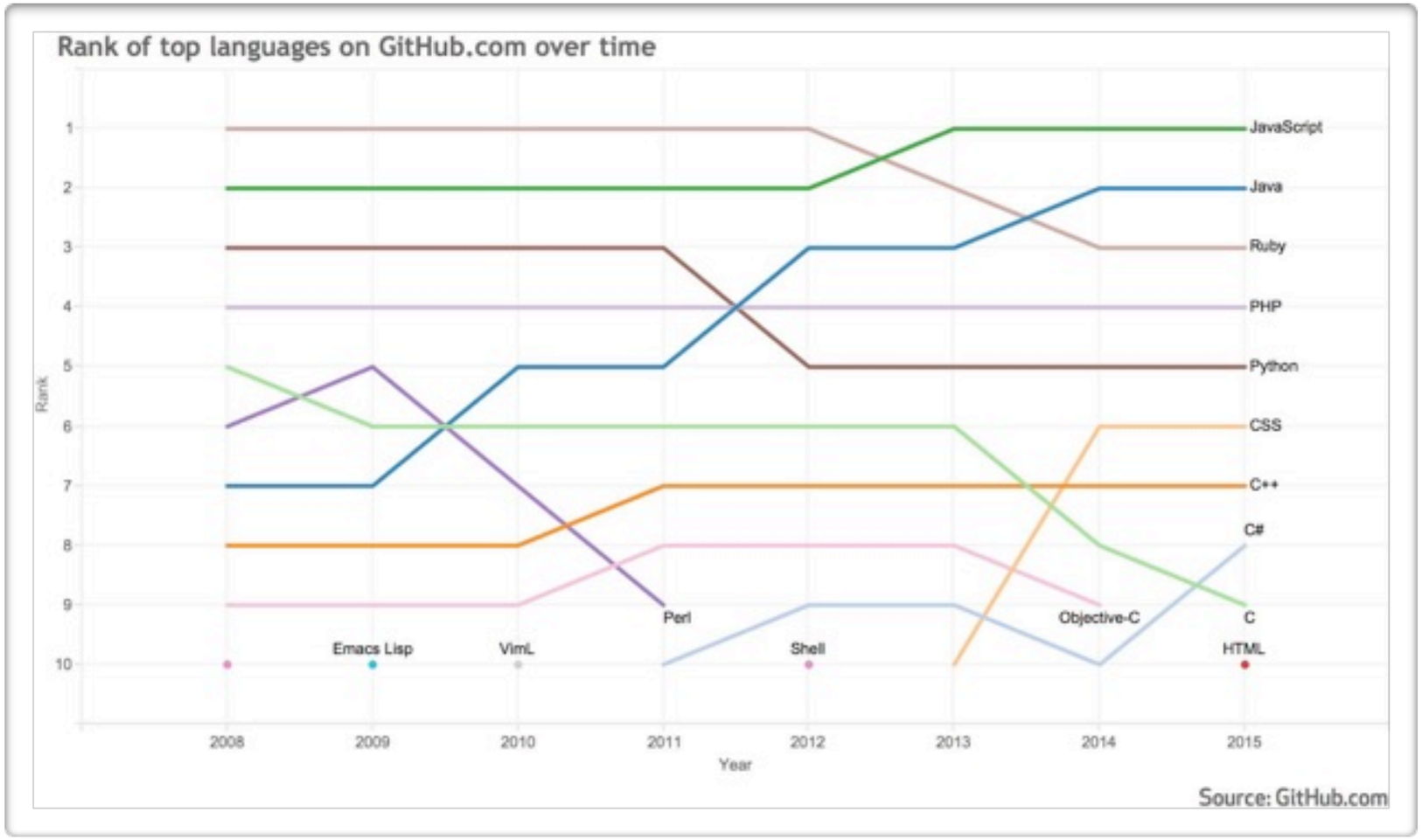
PostgreSQL and Java. Java popularity

Mar 2017	Mar 2016	Change	Programming Language	Ratings	Change
1	1		Java	16.384%	-4.14%
2	2		C	7.742%	-6.86%
3	3		C++	5.184%	-1.54%
4	4		C#	4.409%	+0.14%
5	5		Python	3.919%	-0.34%
6	7	^	Visual Basic .NET	3.174%	+0.61%
7	6	v	PHP	3.009%	+0.24%
8	8		JavaScript	2.667%	+0.33%
9	11	^	Delphi/Object Pascal	2.544%	+0.54%
10	14	^^	Swift	2.268%	+0.68%

Programming Language	2017	2012	2007
Java	1	1	1
C	2	2	2
C++	3	3	3
C#	4	4	7
Python	5	7	6
PHP	6	5	4
JavaScript	7	9	8

http://www.tiobe.com/tiobe-index/

PostgreSQL and Java. Open Source Java



http://www.tiobe.com/tiobe-index/

PostgreSQL from Java: Methods to connect

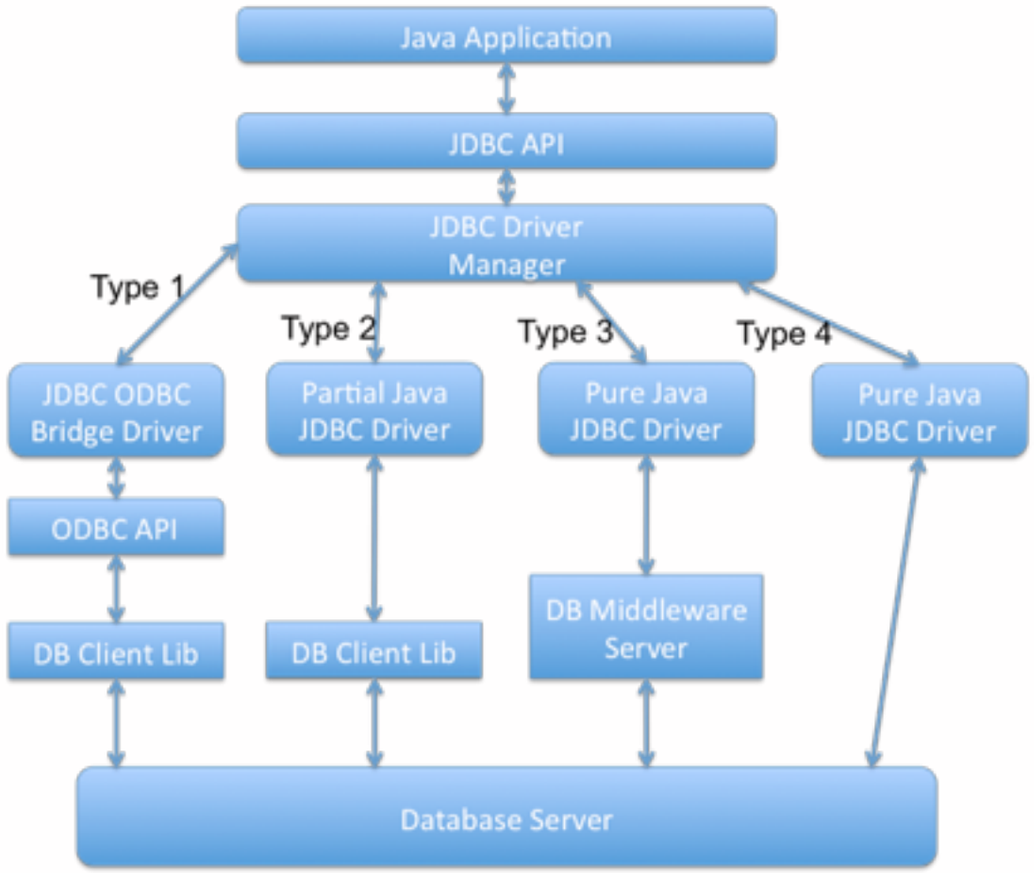
- JDBC is the de facto standard --and also a standard :)
- But there are also other ways
  - ✓ Pgjdbc-ng driver (alternative/extension of JDBC driver)
  - ✓ Phoebe (WIP)
  - ✓ Exec psql from Java through ProcessBuilder (!!)
  - ✓ Wrap PQ's C library in Java :)
  - ✓ Roll your own Java implementation of FE/BE.

PostgreSQL from Java: JDBC

- Java DataBase Connectivity. Available since Java 1.1
- Classes contained in packages java.sql and javax.sql
- Current JDBC version is 4.2 (Java 8)
- It's standard, and database-independent
- Provides a call-level API for SQL-based database access
- Allows you to use the Java programming language to exploit "Write Once, Run Anywhere" capabilities
- It consists of a client layer and a database-dependent layer, used to implement the database driver

PostgreSQL from Java: JDBC types

- There are four JDBC driver types:
  - ✓ **JDBC Type 1:** It is just a JDBC-ODBC bridge.
    Requires a working ODBC connection and driver to the database
  - ✓ **JDBC Type 2:** Native database interface (for Java dbs)
    or JNI-wrapped client interfaces.
    Eliminates ODBC's overhead.
  - ✓ **JDBC Type 3:** Native Java driver that talks to middleware
    (which exposes an API and interfaces to database)
  - ✓ **JDBC Type 4:** 100% Pure Java-based driver,
    Implements database communication protocol.



PostgreSQL from Java: JDBC drivers

- For PostgreSQL, there are several JDBC drivers:
  - ✓ The official, most widely used, JDBC driver:
  - ✓ jdbc.postgresql.org
  - ✓ Pgjdbc-ng (presented later)
  - ✓ EnterpriseDB's JDBC driver for Postgres Plus
  - ✓ Progress' DataDirect "Type 5" Java JDBC Driver
  - ✓ (https://www.progress.com/jdbc/postgresql)

If in doubt, just use jdbc.postgresql.org

PostgreSQL from Java: JDBC driver

- It is a Type 4 driver, natively written in Java, implementing the FE/BE protocol.
- Once compiled, it is system independent.
- Download from jdbc.postgresql.org or use it directly from Maven & friends (g: org.postgresql, a: postgresql)
- Supports trust, ident, password, md5 and crypt authentication methods
- Use UTF-8 encoding for the database
- Supports protocol versions 2 and 3, and SSL

PostgreSQL from Java: JDBC driver

- Mainly uses text mode of the protocol. Has non-standard options for COPY mode and other extensions
- Connection URL

```
jdbc:postgresql://host:port/database?options
```

- Latest version: 42.0.0 (2017-02-20)
  - ✓ Version bumped 9.4.1212 to 42.0.0 to avoid version clash with PostgreSQL version
  - ✓ Supports PostgreSQL versions below 8.2 was dropped
  - ✓ Replication protocol API was added!!!
- JDBC 4.0 (Java 6), JDBC 4.1 (Java 7), JDBC 4.2 (Java 8)

PostgreSQL from Java: JDBC driver

PostgreSQL from Java: JDBC driver options

- The connection parameters can be set via the connection URL or via the setProperty() method of Properties class.
- Relevant params:

```
ssl = true | false

loglevel =  OFF | DEBUG | TRACE

logUnclosedConnections = true | false

loginTimeout = int (seconds)

socketTimeout = int (seconds)
```

Full list of parameters: https://jdbc.postgresql.org/documentation/head/connect.html

PostgreSQL from Java: JDBC driver and SSL

- The JDBC driver, by default, validates SSL certificate CA's signature.
- Connection is refused if validation fails (psql does not behave this way)
- If your certificate server is self-signed or signed by a CA whose certificate is not in the Java keystore, you may:
  - Add the CA certificate to the Java keystore (preferred method):

    https://jdbc.postgresql.org/documentation/head/ssl-client.html
  - Or set sslfactory connection parameter to *org.postgresql.ssl.NonValidatingFactory* will turn off all SSL validation (not recommended, but simpler)

PostgreSQL from Java: JDBC driver statements

- In JDBC there are Statement and PreparedStatement objects to represent the queries.
- Except for complex dynamic queries, use PreparedStatement (more secure, no SQL injection)
- PreparedStatement objects do not result in server-side prepared statements until the query is executed a minimum number of times (5 by default)
- Adjust connection parameter PrepareThreshold=int to control when to switch to server side prepared statements

PostgreSQL from Java: JDBC driver & concurrency

- JDBC driver is thread-safe. However, a given Connection can only be used by a single thread at a time (others threads block)
- if it is needed to use it concurrently, create a new Connection per thread.
- Obviously, you may want to use connection pooling. The JDBC driver offers connection pooling, but is recommended to use an external pooler: https://jdbc.postgresql.org/documentation/head/ds-ds.html

PostgreSQL from Java: JDBC driver & app servers

- If not included by default, copy JDBC jar file to app server library include dir
- Create a JDBC connection pool within the app server. Use org.postgresql.ds.PGSimpleDataSource for the Datasource classname property (of type javax.sql.DataSource)
- At least, set the JDBC connection pool properties:

```
databaseName
portNumber
serverName
user
password
```

Optionally (recommended) export the connection pool as a JNDI resource

PostgreSQL from Java: Logical decoding and JSON

- Significant novelty appeared in pgjdbc 42
- In PostgreSQL, logical decoding is implemented by decoding the contents of the WAL.

PostgreSQL from Java: pgjdbc-ng

- T“A new JDBC driver for PostgreSQL aimed at supporting the advanced features of JDBC and Postgres”
- Project started in 2013 by Kevin Wooten to overcome some limitations of the “standard” JDBC driver
- Last version 0.7.1 (February 2017):

```
Netty 4.1.8 support

SSL support

Support for JSON/JSONB data types

OSGi support

Better Windows support

Travis CI support
```

BSD licensed http://impossibl.github.io/pgjdbc-ng/

PostgreSQL from Java: pgjdbc-ng

- Completely written from scratch. Does not support legacy versions of Java (requires Java 8+) nor PostgreSQL (requires 9.1+).
- Built via Maven
- Uses netty 4.1.8 as a network framework. Greater performance, less threading overhead, enabler for async ops
- Speaks (mostly) the binary version of the FEBE protocol
- Supports advanced and composite, custom, array and JSON/JSONB type
- DataSource / ConnectionPoolDataSource / XADataSource support

PostgreSQL from Java: pgjdbc-ng

- Download latest release from: http://impossibl.github.io/pgjdbc-ng/get.html or compile from git repo (mvn clean package)
- Use the JDBC URL:

```
jdbc:pgsql://<server>[:<port>]/<database>
```

- If configuring a DataSource / ConnectionPoolDataSource / XADataSource, classes are:

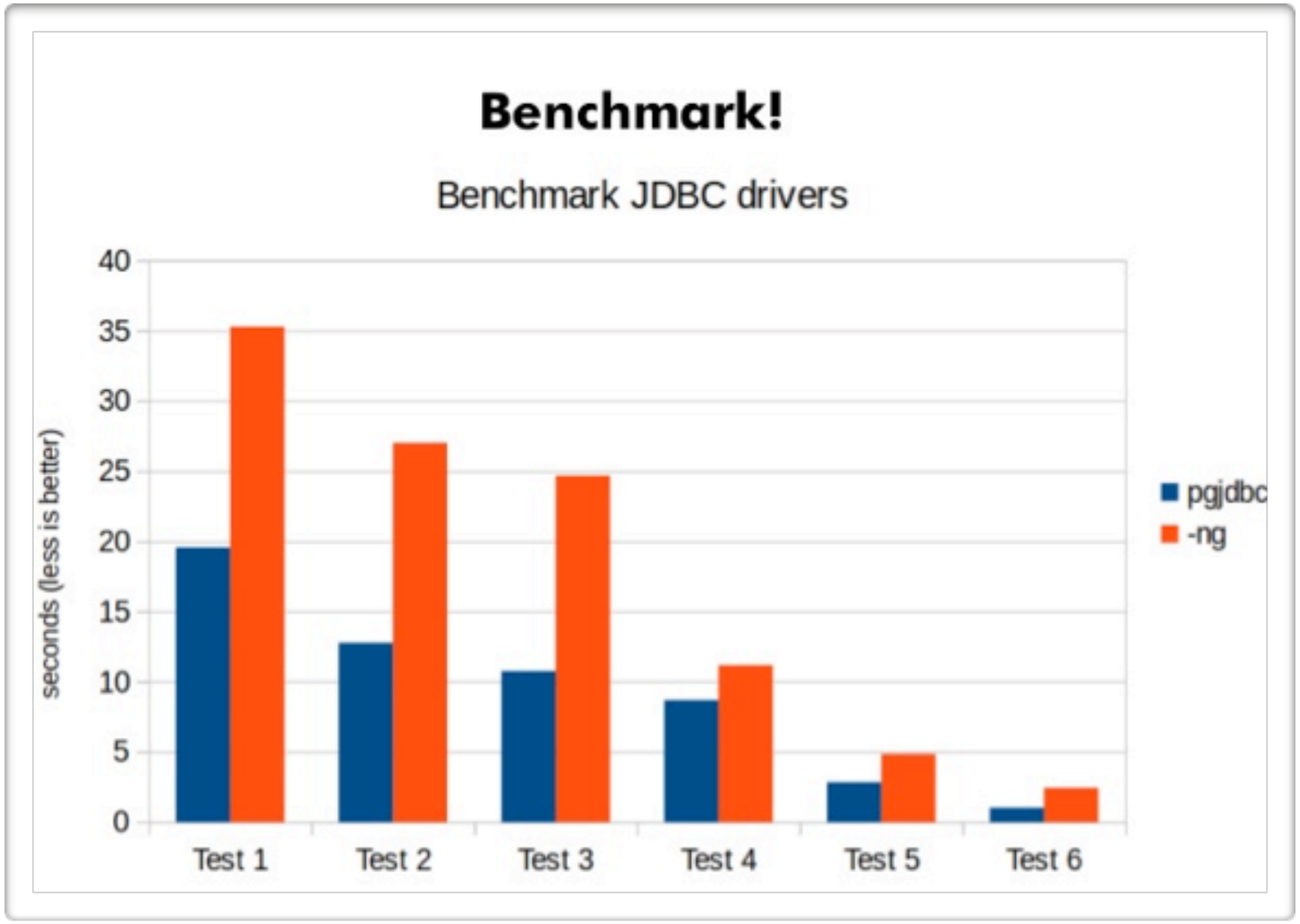
```
com.impossibl.postgres.jdbc.PGDataSource

com.impossibl.postgres.jdbc.PGConnectionPoolDataSource

com.impossibl.postgres.jdbc.xa.PGXADataSource
```

- Report success cases / bugs!

PostgreSQL from Java: pgjdbc vs pgjdbc-ng



PostgreSQL from Java: ProcessBuilder

- Hack only suitable for very specific use cases:
  - ✓psql or client program available in the same machine as the JVM
  - ✓Very simple operations (usually not involving returning a lot of information or complex types from the database), as they require manual text parsing.
- Using ProcessBuilder, an external process is executed. This process (typically psql) use the database. Commands and results are accessed via pipes connected to the process.
- it's very simple to use, no Java dependencies.

Works great!

PostgreSQL from Java: ProcessBuilder

PostgreSQL from Java: Phoebe (WIP)

- New PostgreSQL driver
- Async & Reactive by design. RxJava based
- Target clusters, not only individual servers
- Netty-based, async off-heap I/O

PostgreSQL from Java: Phoebe (WIP)

- Expected features:

  - ✓ Binary mode
  - ✓ Unix Domain Sockets
  - ✓ Logical decoding
  - ✓ Query pipelining
  - ✓ Fully asynchronous operation
  - ✓ Execute query on rw or ro nodes
  - ✓ Fluent-style API
  - ✓ Compatible with Java >= 6 Phoebe (WIP)

PostgreSQL from Java: Phoebe (WIP)

- Current API design:

```
RxPostgresClient client = RxPostgresClient
.create()
.tcpIp("::1", 5432)
.tcpIp("localhost", 5433)
.allHosts()
.init();
client.onConnectedObservable().subscribe(
c -> System.out.println(c) );
```

PostgreSQL from Java: wrap libPQ in Java

- libpq is the C application programmer's interface to PostgreSQL, allowing programs to pass queries to the PostgreSQL backend server and to receive the results https://www.postgresql.org/docs/current/static/libpq.html

- Has interfaces for C++, Perl, Python, Tcl and ECPG

- Why not wrap it in Java?
  - ✓ The only reason would be to have support for features exported by libpq but not available in JDBC driver

PostgreSQL from Java: wrap libPQ in Java

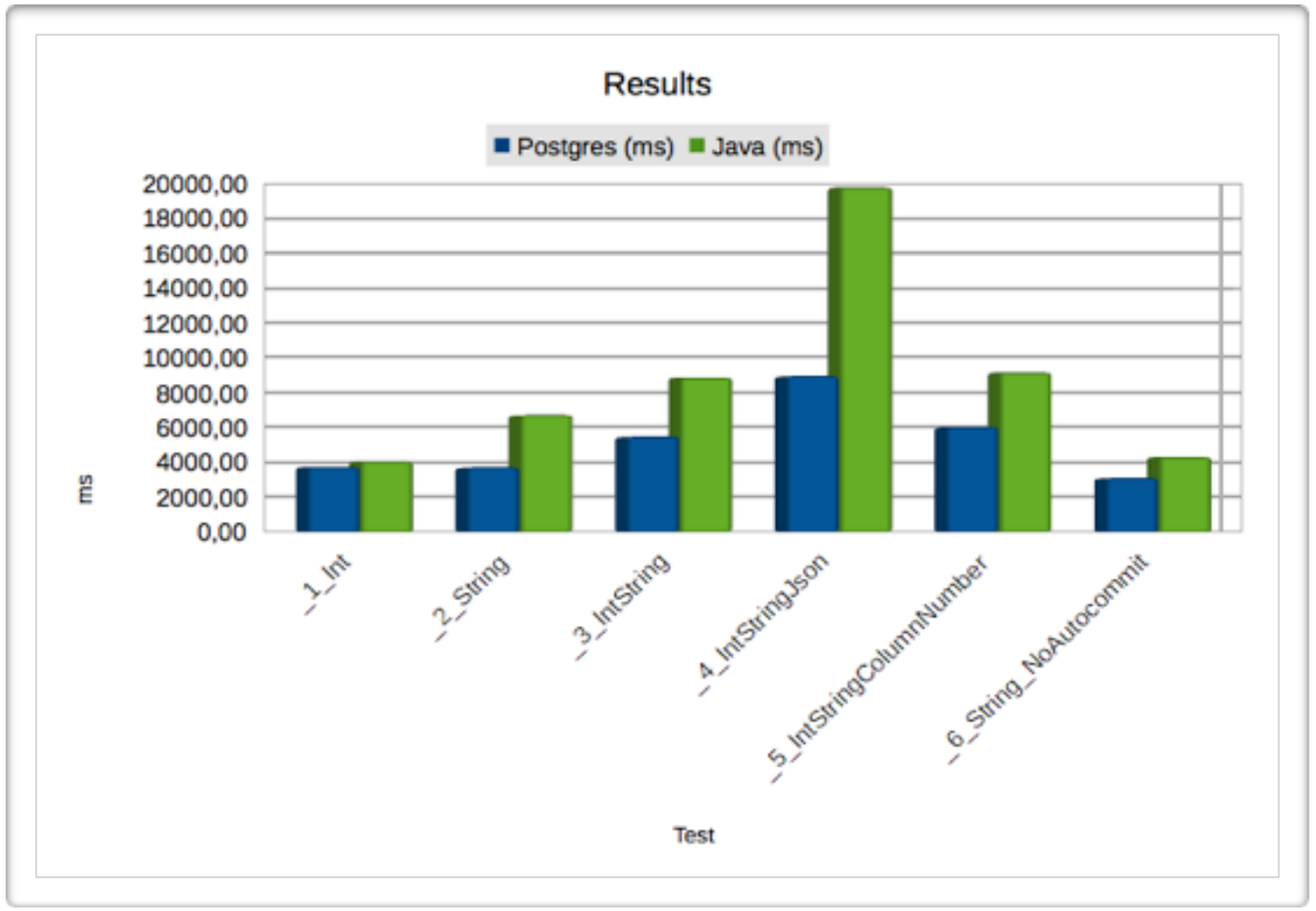
- A simple way to wrap it is to use swig: http://www.swig.org
- Tell swig to wrap libpq-fe.h
- Generate C files, compile, generate wrapper lib and add to the java.library.path
- Detailed instructions and example code: http://benfante.blogspot.com.es/2013/02/using-postgresql-in-java-without-jdbc.html

PostgreSQL from Java: own FE/BE implementation

- JDBC is verbose, complex and sometimes too low-level (ex. SQLException). Its design is quite old
- There are libraries of higher level, but ultimately depend on JDBC
- Why not a modern, non-JDBC Java API?
- Steps:

1. Study the FE/BE protocol: https://www.postgresql.org/docs/current/static/protocol.html
2. Write your own implementation
3. Publish it (preferably as open source)

PostgreSQL from Java: JDBC performance



- Total Java execution time =
  - ✓ PostgreSQL query execution
  - ✓ + Network costs (eth + tcp overhead, bw)
  - ✓ + Java driver overhead
  - ✓ + Java app processing Let's drill down the execution time

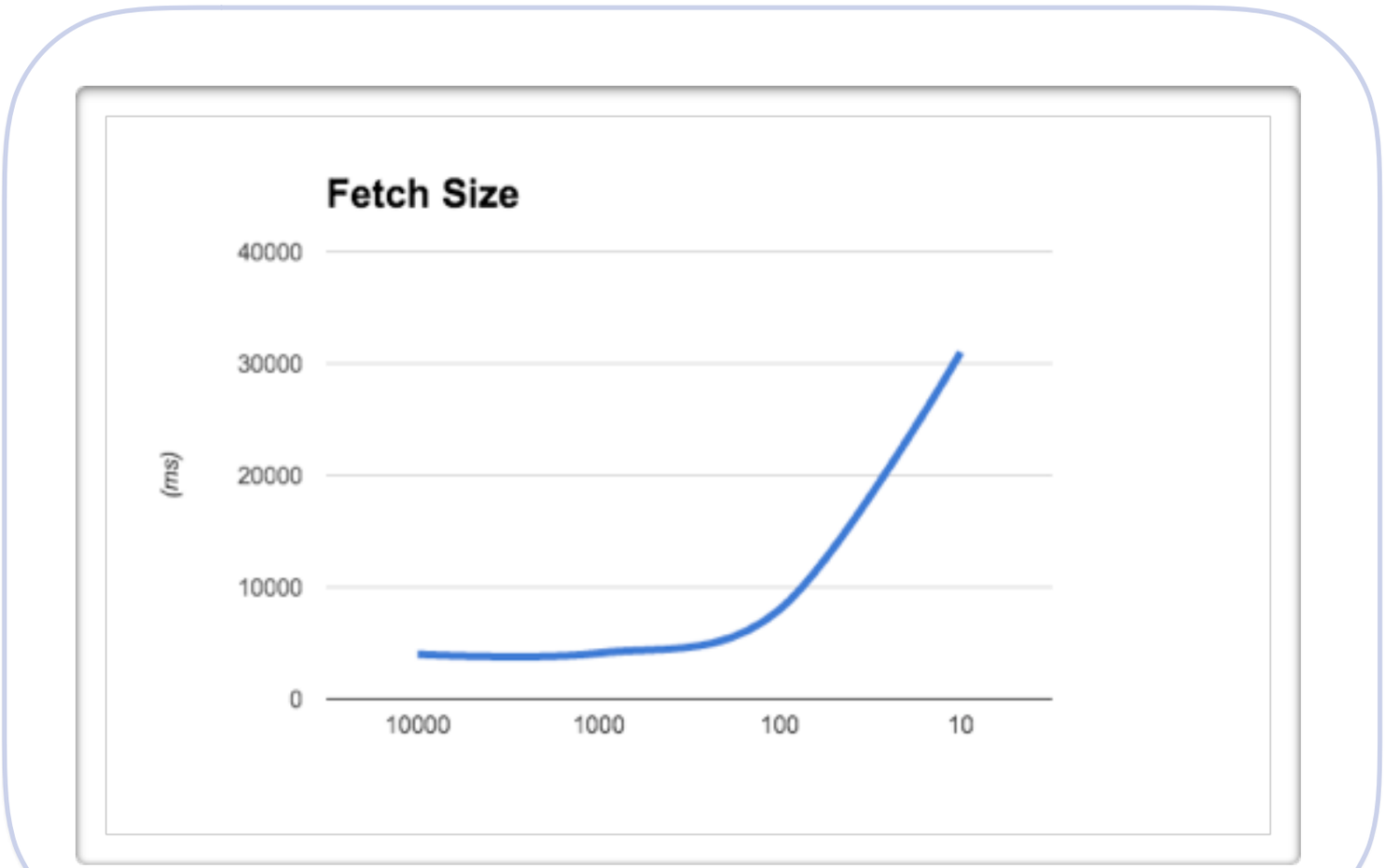
Java overhead is up 120%!!! (run on localhost to minimize network)

- ➡ Data facts: 10M records
- ➡ 1.6GB table

PostgreSQL from Java: JDBC performance

- Some things that really did improve performance
- Set **Fetch Size**: Fetch a large amount of data with different fetch sizes

```
PGProperty.DEFAULT_ROW_FETCH_SIZE.set(properties, FETCH_SIZE);
```



PostgreSQL from Java: JDBC performance

- What are the options for inserting lots of data:

  ✓ For each row Insert values (row1), (row2), … (rowN) hand rolled code

  ✓ For each row insertBatch:

    ➡ For each row Insert into perf (a,b,c) values (?,?,?)

    ➡ After N rows executeBatch

    ➡ More data inserted per statement, less statements

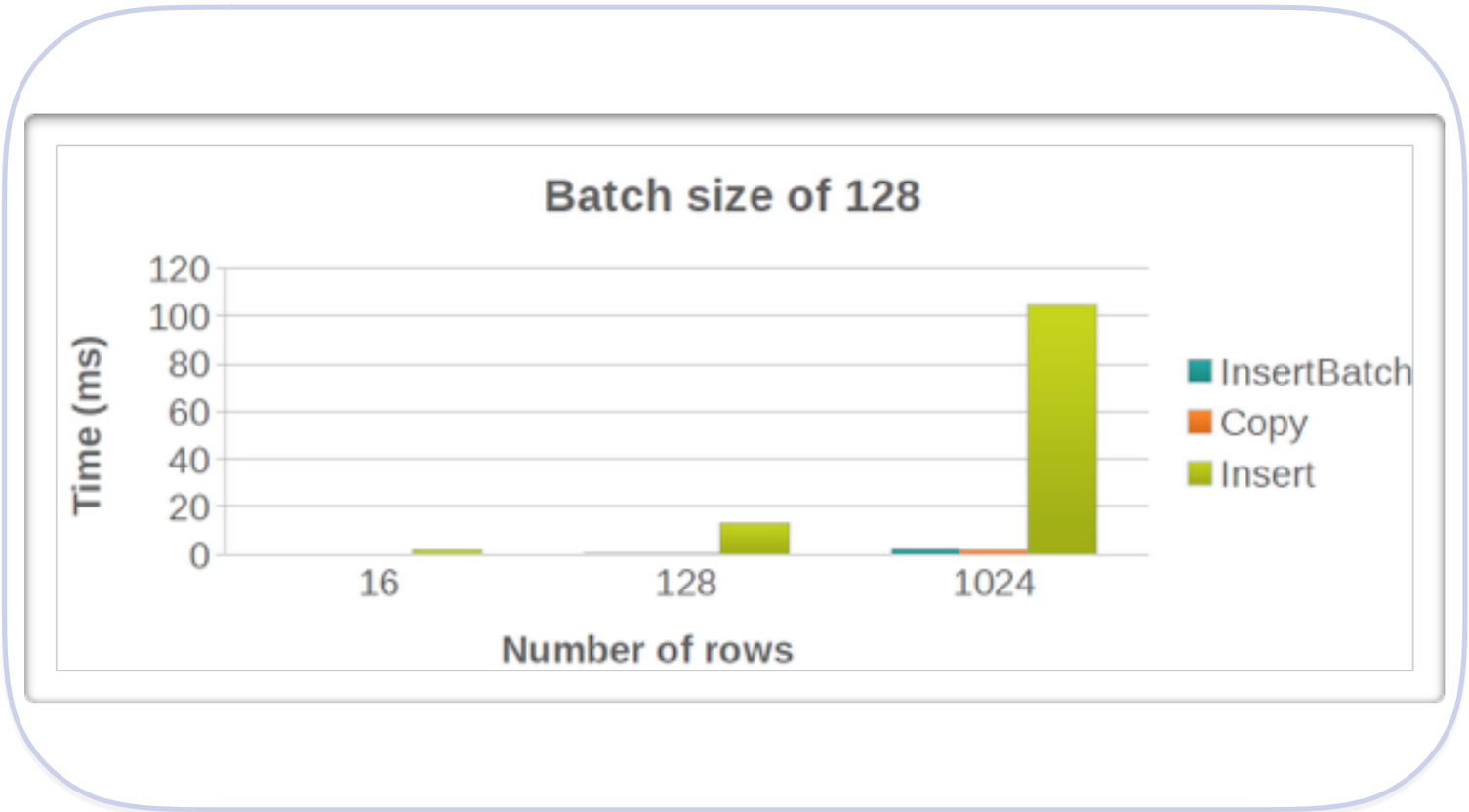
  ✓ Copy:

    ➡ Loop over the rows creating

    ➡ the input string in memory

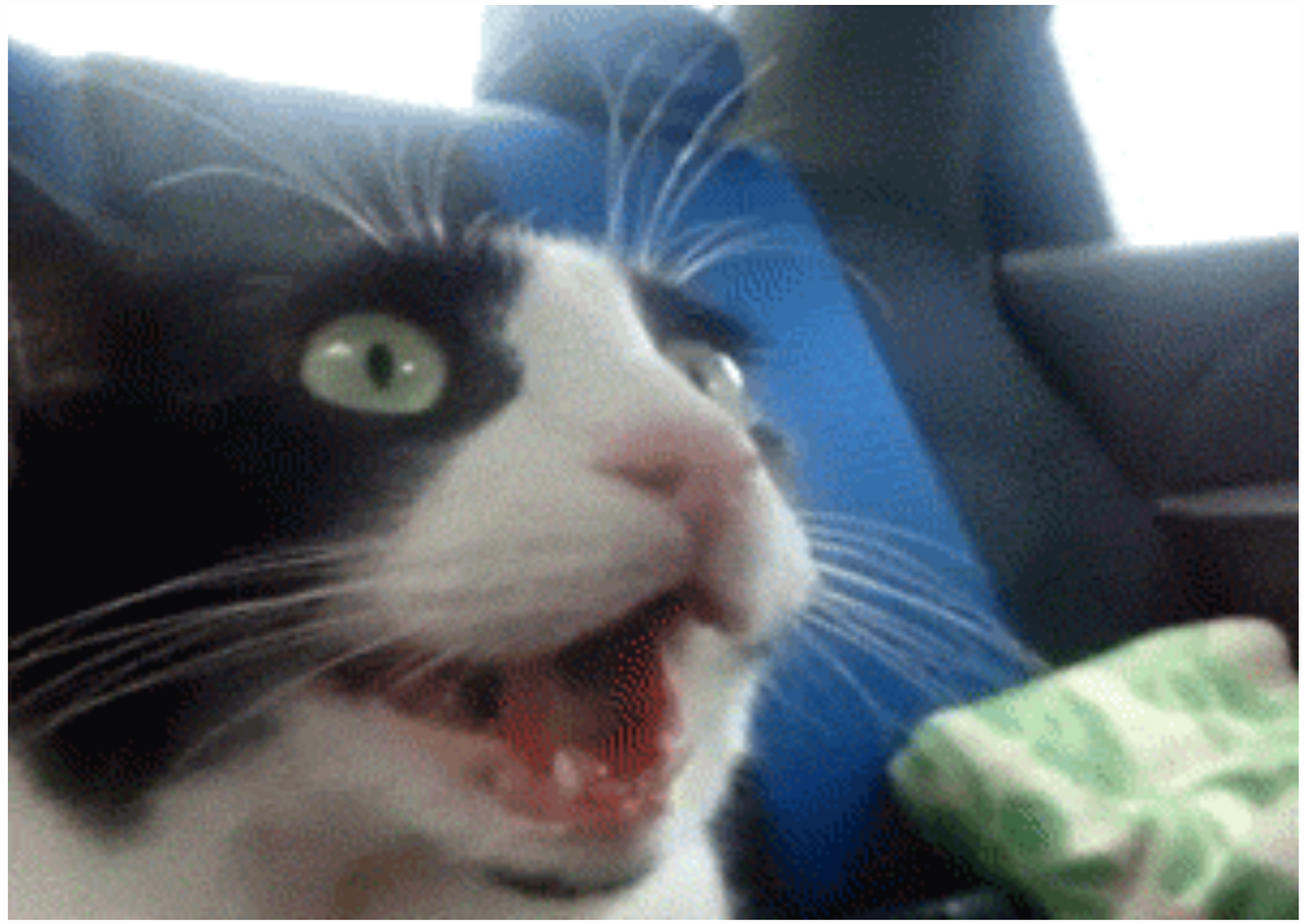
    ➡ Require using specific driver classes to execute

    ➡ Can be used for reading also



PostgreSQL from Java: ProcessBuilder

Let see a DEMO !!



PostgreSQL from Java: HikariCP + FlexyPool

- HikariCP:

✓ Optimized down to the bytecode to minimize pooling impact on JIT.

✓ Use elision logic and do not fear connection spikes.

✓ Has basic metrics (use dropwizard metrics).

✓ Nice configuration but less compared to other pool... and this does not mean it is bad.

✓ Remove the caching of statement since it is an anti-pattern. Delegates on driver that knows how to cache that stuff!

✓ Same as above for logging statements / slow queries

✓ ...and do not forget to keep you clock synchronized or you'll be taunted on twitter!!!

PostgreSQL from Java: HikariCP + FlexyPool

- FlexyPool:
  - ✓ From the guy who wrote “High-Performance Java Persistence”.
  - ✓ Powerful metrics (use dropwizard metrics too).
  - ✓ Dynamic configuration strategies that allow resizing the pool beyond the configured maximum.
  - ✓ It can be attached to many other connection pool!

PostgreSQL from Java: HikariCP + FlexyPool

Let see a DEMO !!

ORMs: JPA, Hibernate, is this what you need?

- Most certainly, not: “To ORM or not to ORM” (http://www.pgcon.org/2010/schedule/events/235.en.html)
- ORM-ing is inherently hard (“Vietnam of CS”)
- They help with CRUD-like operations, but they don't support, either natively or without breaking the abstraction:
  - ✓Custom SQL
  - ✓Database functions, triggers
  - ✓Query projections and views
- They may introduce significant inefficiencies and performance problems (eager/lazy joins)

ORMs: Return to SQL

- With the advent of NoSQL, “industry” seemed to ditch SQL.Now, it has come back (never gone, really) stronger than ever

- SQL is a very powerful, high-level, declarative language. Disqus achieved x20 improvement using recursive queries

- PostgreSQL is a very powerful database, don't reduce it to a CRUD-only data store. Unleash the power of window functions, CTEs, custom data types, aggregates, etc

- Don't create the database from Java objects, write your schema directly using database tools

Return to SQL: DRY

- DRY: don't do SQL by hand, mapping by hand. Too much boilerplate, error-prone, not focused on business logic
- Non-ORM, SQL-oriented, helper tools:
  - ✓Spring's JDBC Template
  - ✓Apache DbUtils
  - ✓MyBatis
  - ✓jOOQ
  - ✓…
- Write DAOs or similar abstractions to wrap your SQL and your database access methods and drivers

MyBatis: a great mapper for PostgreSQL

- MyBatis (formerly iBatis) is a mapper tool: you write the SQL code, MyBatis maps queries to POJOs
- You basically need a POJO (which basically becomes a DTO) per query, plus a method in an interface
- Alternatively, queries may be mapped to Maps
- Queries are written in SQL in XML files, with support for:
  - ✓Query parameters (Java POJOs)
  - ✓Dynamic SQL (if-then, loops, etc)
  - ✓Arbitrary classification of queries into separate files

MyBatis: a great mapper for PostgreSQL

Let see a DEMO !!

jOOQ: Get back in control of your SQL

- jOOQ lets you write SQL in a programmatic way
- Unlike other SQL "APIs", it does not restrict you to a very basic subset of SQL (least common denominator of all databases, intersection the "easy" part of SQL)
- It even simulates some features not present in some databases by crafting more complex SQL behind the scenes
- Uses a fluent API (nice, short to write) which supports almost all the standards SQL features

jOOQ: Get back in control of your SQL

- There's basic syntax validation support in the API, to check for invalid queries
- It shines when you use jOOQ's code generator: with it, all the queries are strongly-typed and completely syntax validated. The code generator supports every database object you could use, including data types, procedures...
- It gives you database independence, hiding in the API implementation the details of SQL dialects
- Even implements as part of the API some “clever SQL tricks” like the seek (aka pagination done right)
- You can use it with Java 8’s lambdas

jOOQ: Get back in control of your SQL

Let see a DEMO !!

Java inside PostgreSQL: PL/Java

- PL/Java
  - ✓Latest version 1.5
  - ✓Coming back! First release since 2011
  - ✓Do not support postgres below 8.2
  - ✓Modernized, more active community
  - ✓Works with 9.4 & 9.5, Java 6-8 :)

PostgreSQL from Java: PL/Java

Let see a DEMO !!

Java inside PostgreSQL: Introducing pgj

- Run Java code **inside** PostgreSQL
- PL/Java is cool but not enough: it has to be like a server, run independently of the user
- Background workers provide the base
- Wrap SPI calls with JNI and profit!
- Join the pgj project and run Java code inside PostgreSQL with minimal overhead

Let's Talk!

Using PostgreSQL with Java

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