SMART DATA FAST.™

VOLTDB

THE EXPERT GUIDE TO FAST DATA

Why VoltDB is the solution to “Fast”

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SMART DATA FAST.™

VOLTDB

THE EXPERT GUIDE TO FAST DATA

Why VoltDB is the solution to “Fast”

OUR SPEAKERS

Dr. Mike Stonebraker of MIT
Co-founder of VoltDB

John Hugg
Senior Software Engineer, VoltDB

OUTLINE

- Characteristics of fast data
- Non-workable solutions
- VoltDB solution
- Lambda architecture solution

FAST DATA

- Comes from humans
  - State management in multi-player internet games
  - E.g., leaderboards
- Comes from the Internet of Things (IoT)
  - Real-time geo-positioning
  - E.g., Waze
- Comes from both
- E.g., stock market transactions

FAST DATA RATES

- 10 messages (transactions) per second
  - Use you cell phone
- 1,000 transactions per second
  - Use RDBMS (or whatever)
- 100,000 transactions per second
  - Now it gets interesting…

- From now on we will use “transaction” and “message” interchangeably

REQUIREMENTS FOR FAST DATA APPLICATIONS

- Keep up
  - Obviously
  - And continue to do so when your load changes
- Only game in town is “scale out”
  - Not “scale up”
- Avoid pokey products
  - Product 1 executes 1,000 messages per core
  - Product 2 executes 25,000 messages per core
  - Difference between P1 and P2 on 100,000 messages per second is 4 cores versus 100 cores

REQUIREMENTS FOR FAST DATA APPLICATIONS

- High level language
  - SQL!
  - Don’t want to code in “message assembler”
- Augmented by windowing operations
  - E.g., moving average of IBM stock price every over last 10 trades
  - So-called windowed aggregates

REQUIREMENTS FOR FAST DATA APPLICATIONS

- High availability (HA)
  - I don’t know anybody who will take down time these days
- Requires a backup machine
  - And real-time failover
  - As well as restore on recovery

REQUIREMENTS FOR FAST DATA APPLICATIONS

- Never lose my data
  - Unacceptable to lose my airline reservation
  - Or my standing on the leaderboard
- Requires no data loss during failover
  - Unacceptable to drop transactions on the floor

REQUIREMENTS FOR FAST DATA APPLICATIONS

- Data Consistency
  - Unacceptable to sell the last widget to multiple customers
  - Or do a money transfer, where only half of it gets done
  - Or produce an incorrect leaderboard
- Requires standard ACID transactions

REQUIREMENTS FOR FAST DATA APPLICATIONS

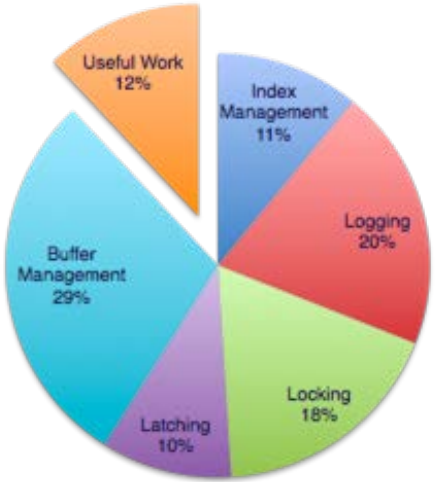
- Data Consistency for replicas
  - Unacceptable to sell the last widget to multiple customers during a node failure
  - Or do a money transfer, where only half of it gets done during a node failure
- Requires standard ACID transactions
  - On replicas as well as data
  - Eventual consistency does not work!

NON-SOLUTIONS FOR FAST DATA

- RDBMSs (Oracle, MySQL, …)
- NoSQL (Cassandra, Mongo, …)

NON-SOLUTIONS FOR FAST DATA -- RDBMSS

- Four major sources of overhead (assuming data sits in main memory)
  - Buffer pool overhead
  - Locking overhead
  - Write-ahead log overhead
  - Threading overhead
- In aggregate these account for ~90% of the total time



NON-SOLUTIONS FOR FAST DATA -- RDBMSS

- Slow, slow, slow, slow
  - Disk-based system (buffer pool overhead)
  - Record-level locking too expensive
  - Aries-style write ahead logging too expensive
  - Multi-threading latches are killing
- Limited to a few thousand transactions per second
- If you know you will never need to go faster, then this will work

NON-SOLUTIONS FOR FAST DATA -- NOSQL

- Low level language (message assembler)
- No ACID!!!!
- Buffer pool and threading overhead still present
- Worst of all worlds – low performance and low function

SOLUTIONS FOR FAST DATA

- High performance main memory SQL-ACID DBMS (VoltDB, Hekaton, Hana, …)
- Complex event processing engine (CEP) (Storm, Streambase, …)

EXAMPLE OPERATION ON FAST DATA

- First hedge fund example
  - Find me a strawberry followed within 5 msec by a banana followed with 10 msec by a grape
  - Look for complex patterns in a fire hose
  - CEP is a natural here

EXAMPLE OPERATION ON FAST DATA

- Second hedge fund example
  - In a worldwide trading system
  - Keep the global state on the enterprise
    - For or against every stock in real time (msecs)
  - And ring the red telephone if there is too much risk
  - And don’t lose any messages!!!
- Sweet spot for SQL-ACID-main-memory

CHARACTERIZATION

- CEP natural for “big pattern little state” applications
- Main memory SQL natural for “big state little pattern” applications
- Note that analytics applications are all in the second bucket
- Anecdotal evidence that there are 3-4 big state problems for every big pattern problem
    - “an unnamed but reliable source”

VOLTDB SOLUTION

- SQL plus windows
- Main memory
- Scale out on N nodes
- Very high performance
  - Figure 40,000 messages/transactions per core per second

VOLTDB SOLUTION

- ACID
  - With a lot of detailed trickery
- ACID on local replicas
  - With more trickery
- Optional ACID on remote replicas
  - Nobody is willing to pay the latency cost….

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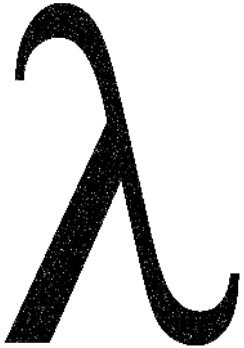
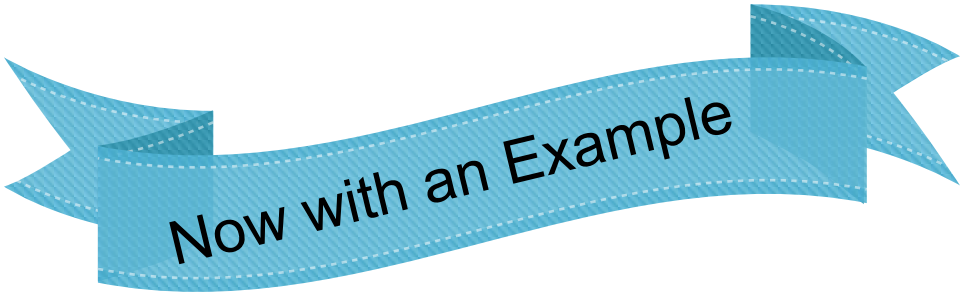
VOLTDB FAST DATA DEMO

John Hugg
VoltDB Founding Engineering



The Lambda Architecture



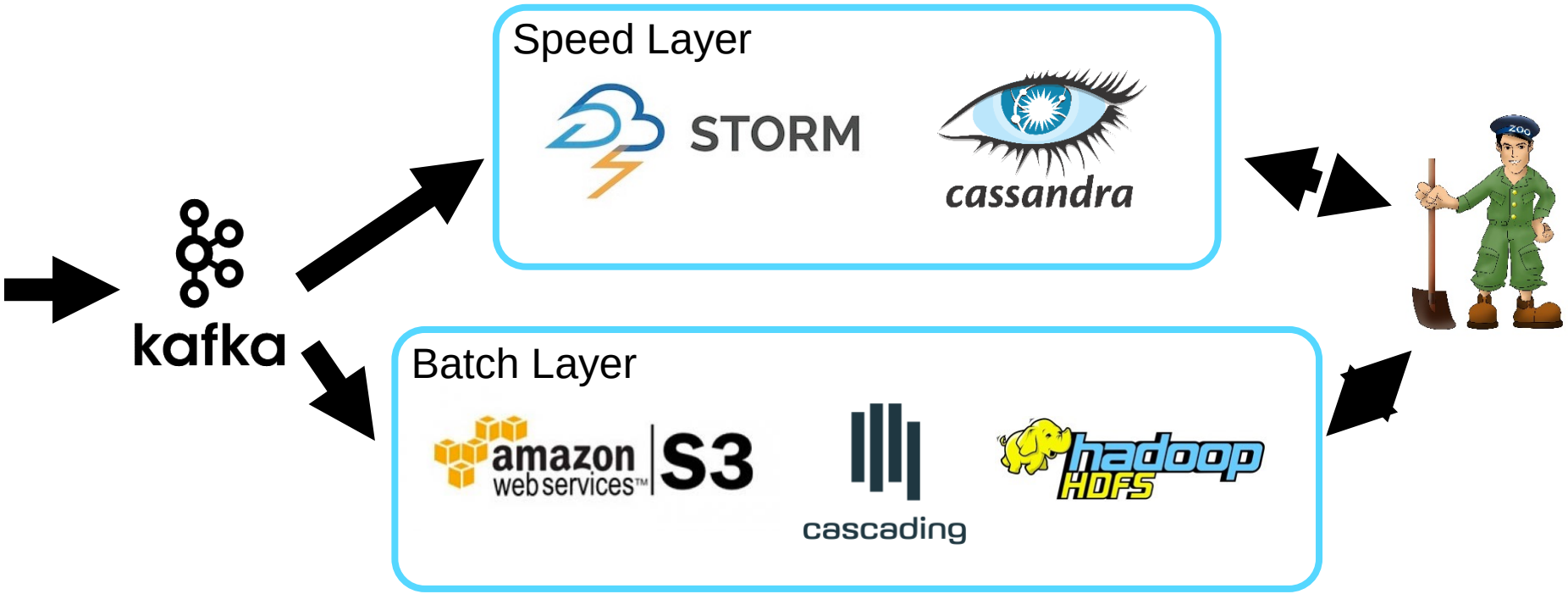
LAMBDA OVERVIEW

- Batch processing is well understood and robust.
  Latency is pretty horrific.
- Stream processing is immediate.
  Complex and not as robust to hardware or user failure.

- Lambda Architecture says do both in parallel to compensate.

Speed Layer & Batch Layer

EXAMPLE LAMBDA STACK



EXAMPLE PROBLEM

HOW MANY PEOPLE USED MY APP TODAY?

HOW MANY UNIQUE USERS INTERACTED WITH MY APP TODAY?

Open Cupcake Time

App Identifier
Unique Device ID

appid = 87
deviceid = 12

Open Cupcake Time

App Identifier
Unique Device ID

appid = 87
deviceid = 12

The Lambda Architecture

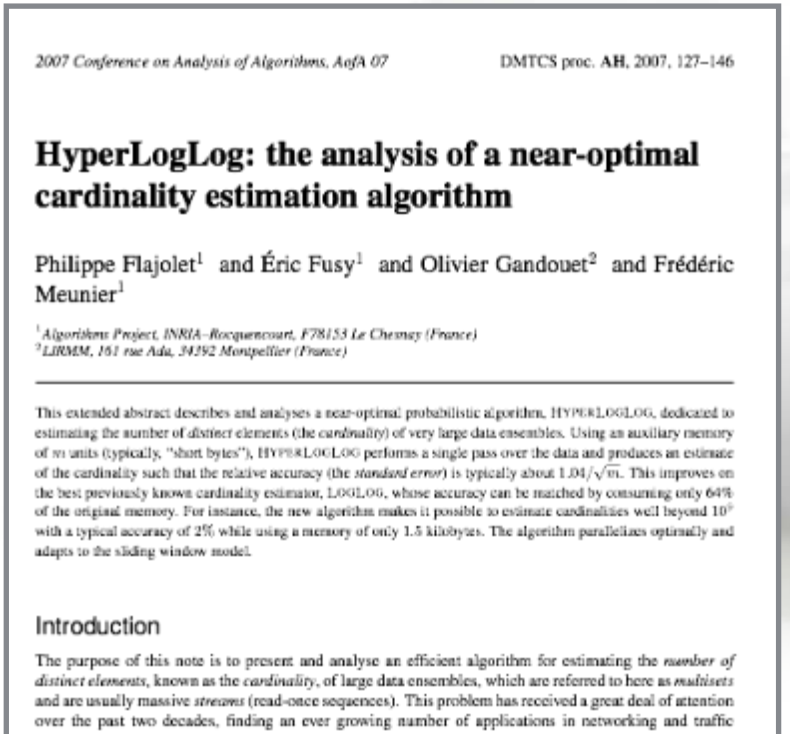
VOLTDB
SMART DATA FAST.™

1 MILLION

APPID,DEVICEID

PAIRS PER SECOND

Enter HyperLogLog



2007 Conference on Analysis of Algorithms, AofA 07 DMTCS proc. AH, 2007, 127–146

HyperLogLog: the analysis of a near-optimal cardinality estimation algorithm

Philippe Flajolet[1] and Éric Fusy[1] and Olivier Gandouet[2] and Frédéric Meunier[1]

[1] *Algorithms Project, INRIA–Rocquencourt, F78153 Le Chesnay (France)*
[2] *LIRMM, 161 rue Ada, 34392 Montpellier (France)*

This extended abstract describes and analyses a near-optimal probabilistic algorithm, HYPERLOGLOG, dedicated to estimating the number of distinct elements (the *cardinality*) of very large data ensembles. Using an auxiliary memory of m units (typically, "short bytes"), HYPERLOGLOG performs a single pass over the data and produces an estimate of the cardinality such that the relative accuracy (the *standard error*) is typically about $1.04/\sqrt{m}$. This improves on the best previously known cardinality estimator, LOGLOG, whose accuracy can be matched by consuming only 64% of the original memory. For instance, the new algorithm makes it possible to estimate cardinalities well beyond 10^9 with a typical accuracy of 2% while using a memory of only 1.5 kilobytes. The algorithm parallelizes optimally and adapts to the sliding window model.

Introduction

The purpose of this note is to present and analyse an efficient algorithm for estimating the *number of distinct elements*, known as the *cardinality*, of large data ensembles, which are referred to here as *multisets* and are usually massive *streams* (read-once sequences). This problem has received a great deal of attention over the past two decades, finding an ever growing number of applications in networking and traffic

A method of estimating cardinality.

```
blob = update(integer, blob)

integer = estimate(blob)
```

Fixed blob size.

A few kilobytes to get 99% accuracy.

Open Cupcake Time

App Identifier
Unique Device ID

appid = 87
deviceid = 12

VoltDB Server

Stored Procedure
"CountDeviceEstimate"

Java SQL

State
"estimates"

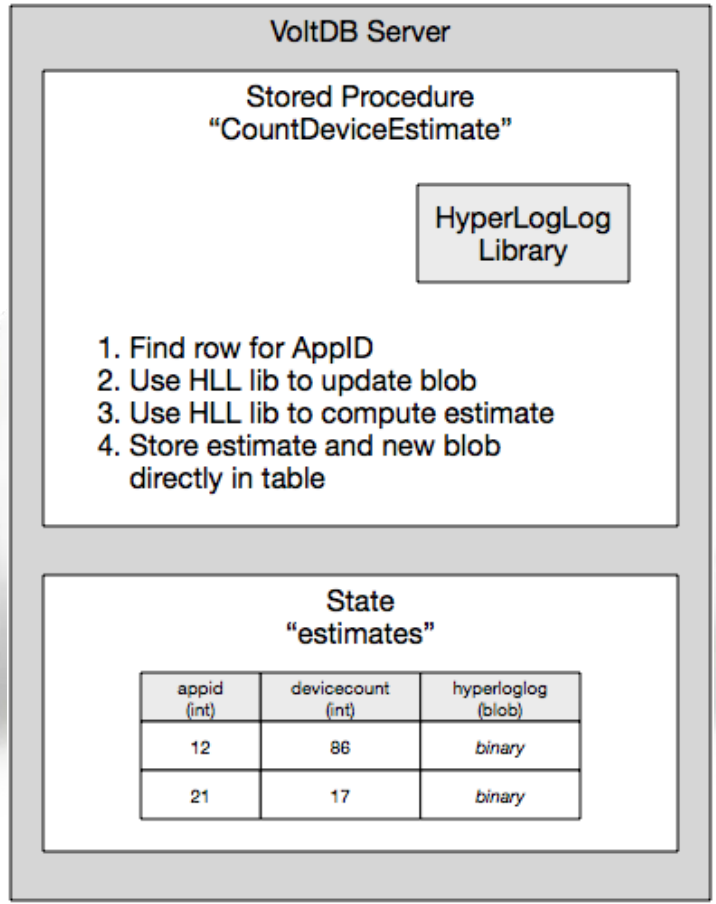
```
CREATE TABLE estimates
(
  appid       bigint           NOT NULL,
  devicecount bigint           NOT NULL,
  hll         varbinary(8192) DEFAULT NULL,
  PRIMARY KEY (appid)
);
PARTITION TABLE estimates ON COLUMN appid;
CREATE INDEX rank ON ESTIMATES
(devicecount);
```

Open Cupcake Time

App Identifier
Unique Device ID

→

appid = 87
deviceid = 12



DECLARE SQL STATEMENTS

```
final static SQLStmt estimatesSelect =
    new SQLStmt("select devicecount, hll from estimates where appid = ?;");
final static SQLStmt estimatesUpsert =
    new SQLStmt("upsert into estimates (appid, devicecount, hll) values (?, ?, ?);");
```

```
public VoltTable[] run(long appId, long hashedDeviceId) throws IOException {

    // get the HLL from the db
    voltQueueSQL(estimatesSelect, EXPECT_ZERO_OR_ONE_ROW, appId);
    VoltTable estimatesTable = voltExecuteSQL()[0];

    HyperLogLog hll = new HyperLogLog(12);
    // if the row with the hyperloglog blob exists...
    if (estimatesTable.advanceRow()) {
        byte[] hllBytes = estimatesTable.getVarbinary("hll");
        hll = HyperLogLog.fromBytes(hllBytes);
    }

    // offer the hashed device id to the HLL
    hll.offerHashed(hashedDeviceId);

    // update the state with exact estimate and update blob for the hll
    voltQueueSQL(estimatesUpsert, EXPECT_SCALAR_MATCH(1), appId, hll.cardinality(), hll.toBytes());
    return voltExecuteSQL();
}
```

PARAMS ARE APP ID & DEVICE ID

```
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}
```

GET ROW FOR THIS APP ID FROM STATE

```
final static SQLStmt estimatesSelect =
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}
```

CREATE A HYPERLOGLOG STRUCTURE FROM THE ROW OR CREATE A NEW HLL IF NO ROW

```
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}
```

ADD THIS UNIQUE ID TO THE HLL STRUCTURE

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    return voltExecuteSQL();
}
```

UPDATE ROW WITH NEW HLL BYTES AND THE COMPUTED ESTIMATE

```
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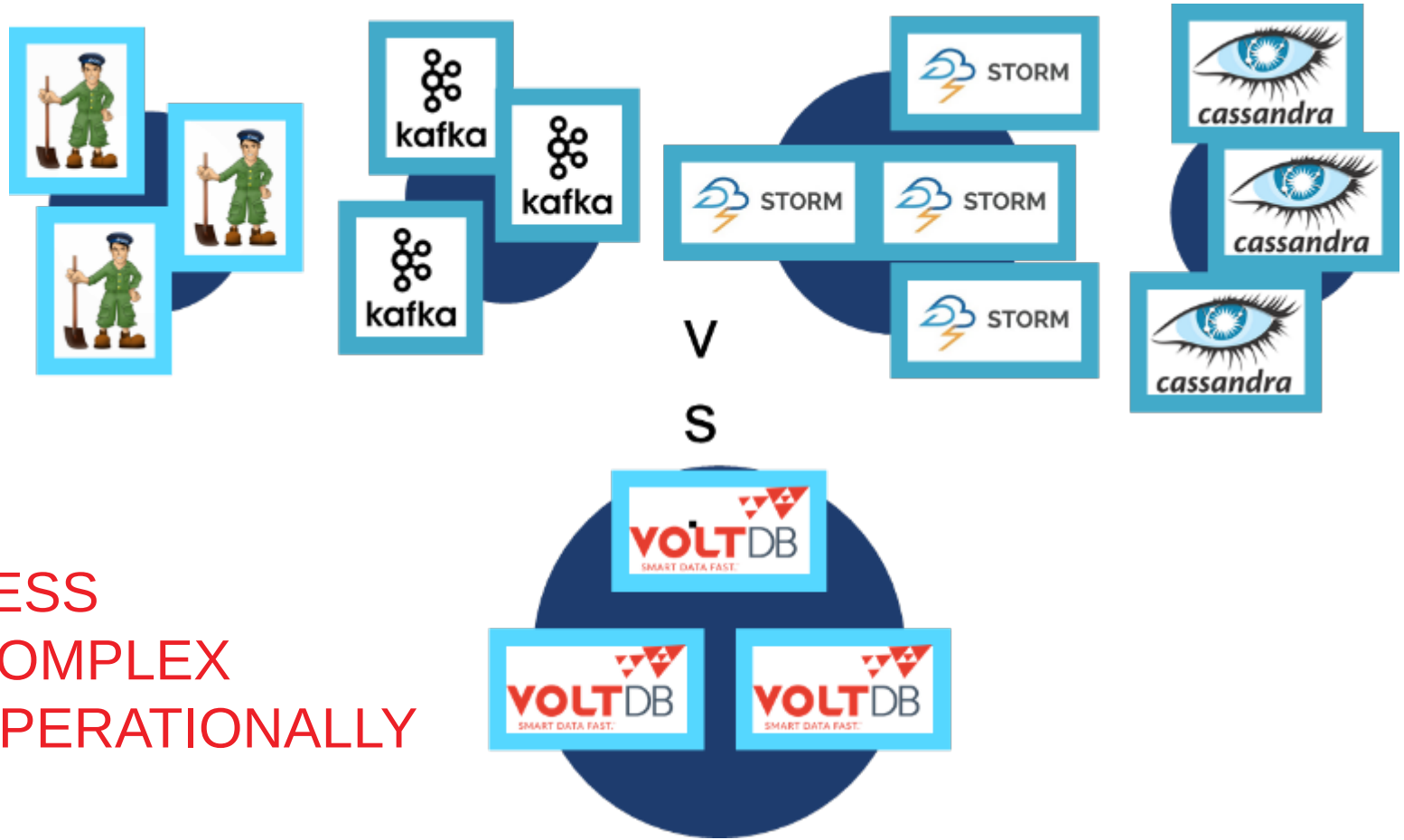
ADVANTAGES



LESS
COMPLEX
OPERATIONALLY

LESS CODE IN FEWER PLACES

- HyperLogLog code is used entirely within one stored procedure.
- Client uses SQL + simple schema for queries & reporting.

Less
Complex
Development

```
SELECT appid, devicecount
FROM estimates
ORDER BY devicecount DESC
LIMIT 10;
```

DEMO

WANT TO CELEBRATE MIKE?

Grab your commemorative Stonebraker Turing award t-shirt.

For more details visit:
www.voltdb.com/stonebrakershirt

QUESTIONS?

- Use the chat window to type in your questions
- Try VoltDB yourself:

  - Free trial of the Enterprise Edition:
    - www.voltdb.com/download
  - Try VoltDB in the Cloud
    - http://voltdb.com/products/cloud
  - Try the “Unique Devices” app
    - https://github.com/VoltDB/voltdb/tree/master/examples/uniquedevices
  - Open source version of VoltDB is available on github.com

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THANK YOU!

ACM: THE LEARNING CONTINUES...

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