Scaling up data science applications

How switching to Spark improved performance, realizability and reduced cost

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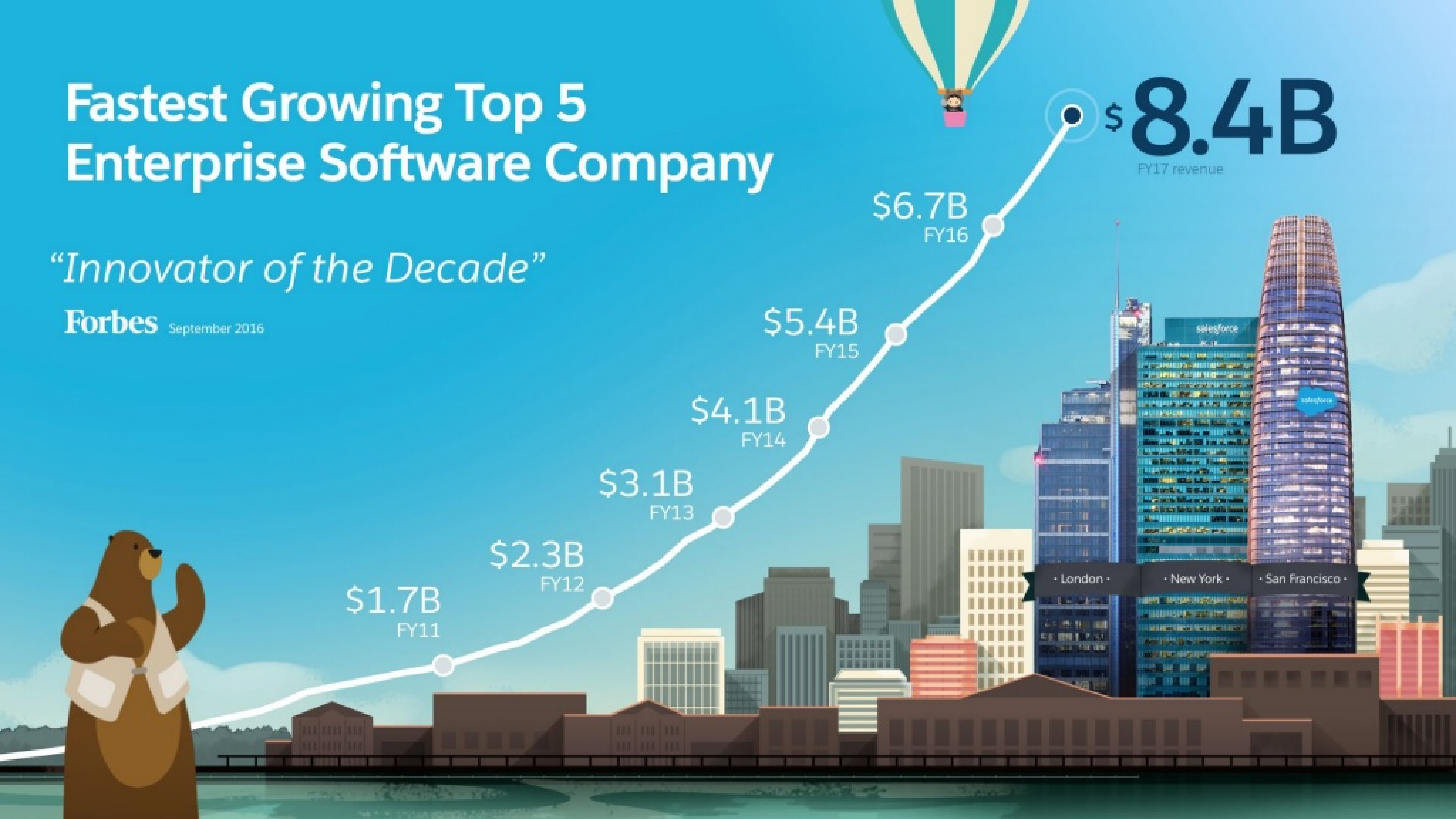
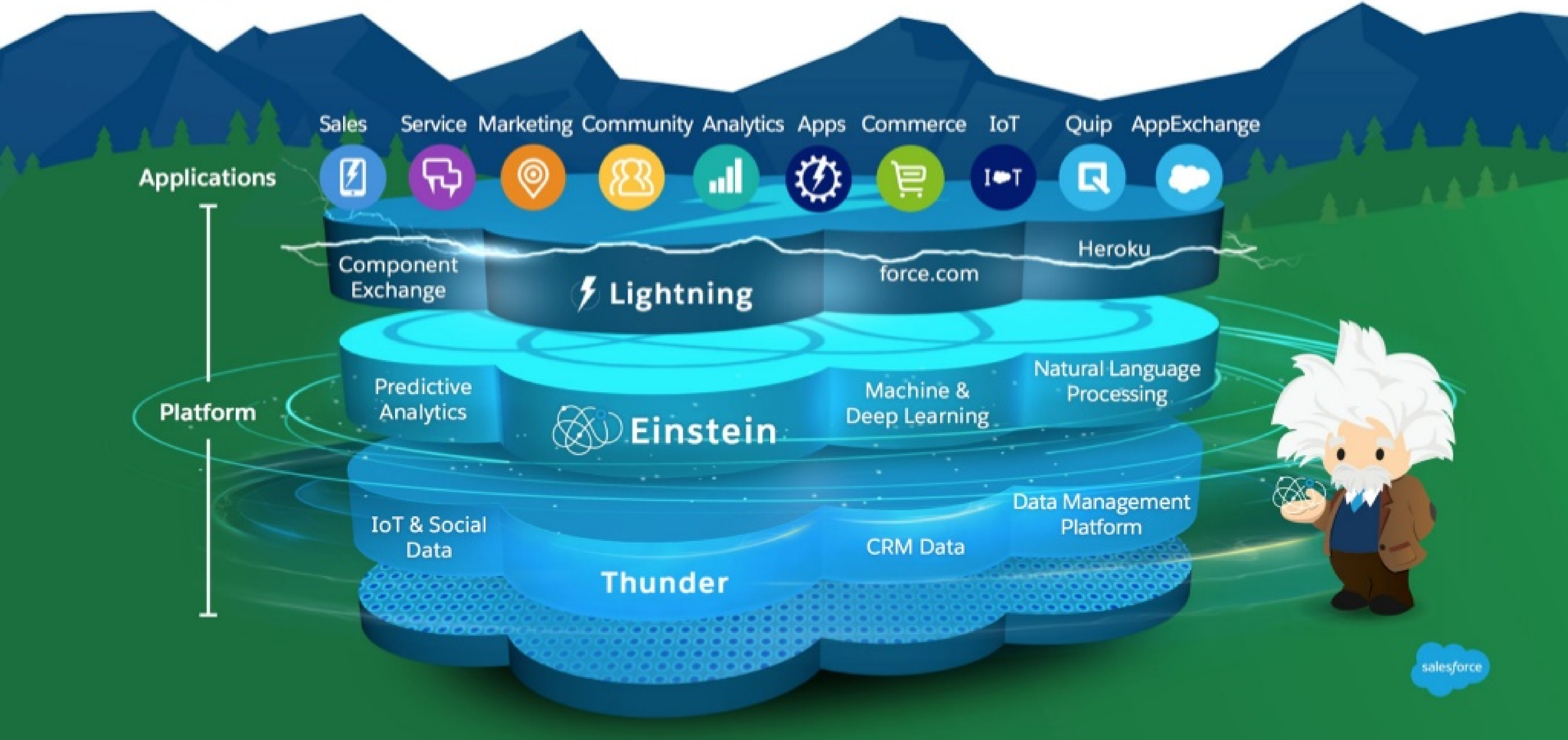
Fastest Growing Top 5 Enterprise Software Company

"Innovator of the Decade"

Forbes September 2016



Intelligent Customer Success Platform



Applications

Sales Service Marketing Community Analytics Apps Commerce IoT Quip AppExchange

Platform

Component Exchange

Lightning

force.com

Heroku

Predictive Analytics

Einstein

Machine & Deep Learning

Natural Language Processing

IoT & Social Data

Thunder

CRM Data

Data Management Platform

salesforce DMP

Boom
Coca-Cola
L'ORÉAL
Red Bull
LOWE'S
Nestlé

Mondelēz International
CONAGRA BRANDS
Kellogg's
ABInBev
Heineken
Reckitt Benckiser
PEUGEOT

KEURIG
HERSHEY'S
Hotels.com
GP Georgia-Pacific
LIONSGATE
turner
DURACELL

ticketmaster
WB
pandora
NBCUniversal
Campbell's
Hallmark
SONY

E*TRADE
Carrefour
CARMAX
Expedia
Liberty Mutual
jetBlue
KIT ACE

UNDER ARMOUR
The New York Times
Time Inc.
YAHOO!
MAJOR LEAGUE BASEBALL
cars.com
HBO

2015-2016

Casper
BUSINESS INSIDER
meredith
News Corp
Slate
match

Bloomberg
VICE
BBC
Spotify
SOCIETE GENERALE
priceline.com

In an Internet Minute

4.1 million
videos viewed

342,000
apps downloaded

156 million
emails sent

452,000
tweets sent

40,000
hours listened

3.5 million
search queries

900,000
logins

$751,522
spent online

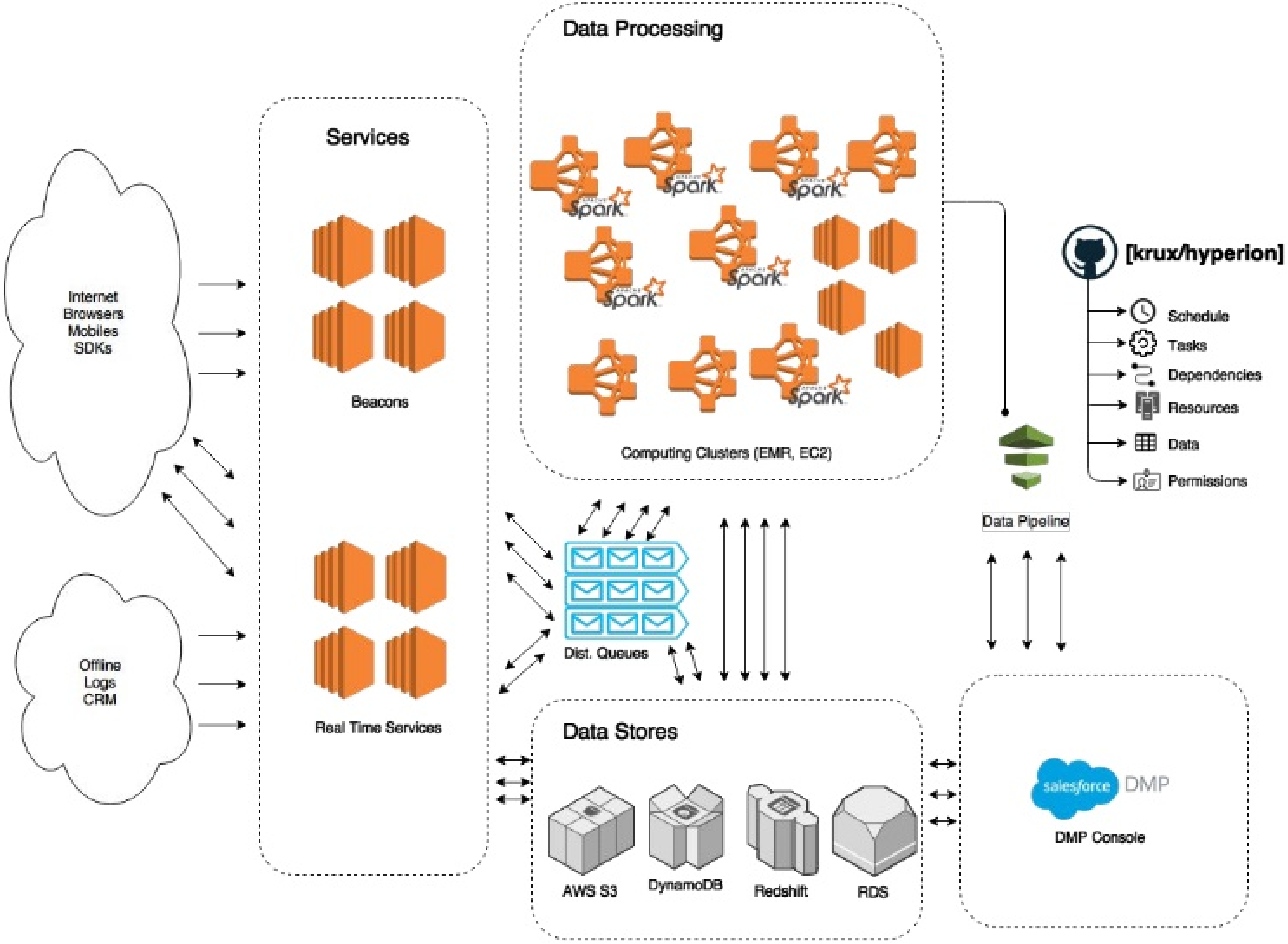
Salesforce DMP is at Internet Scale

4.2 million
user match requests

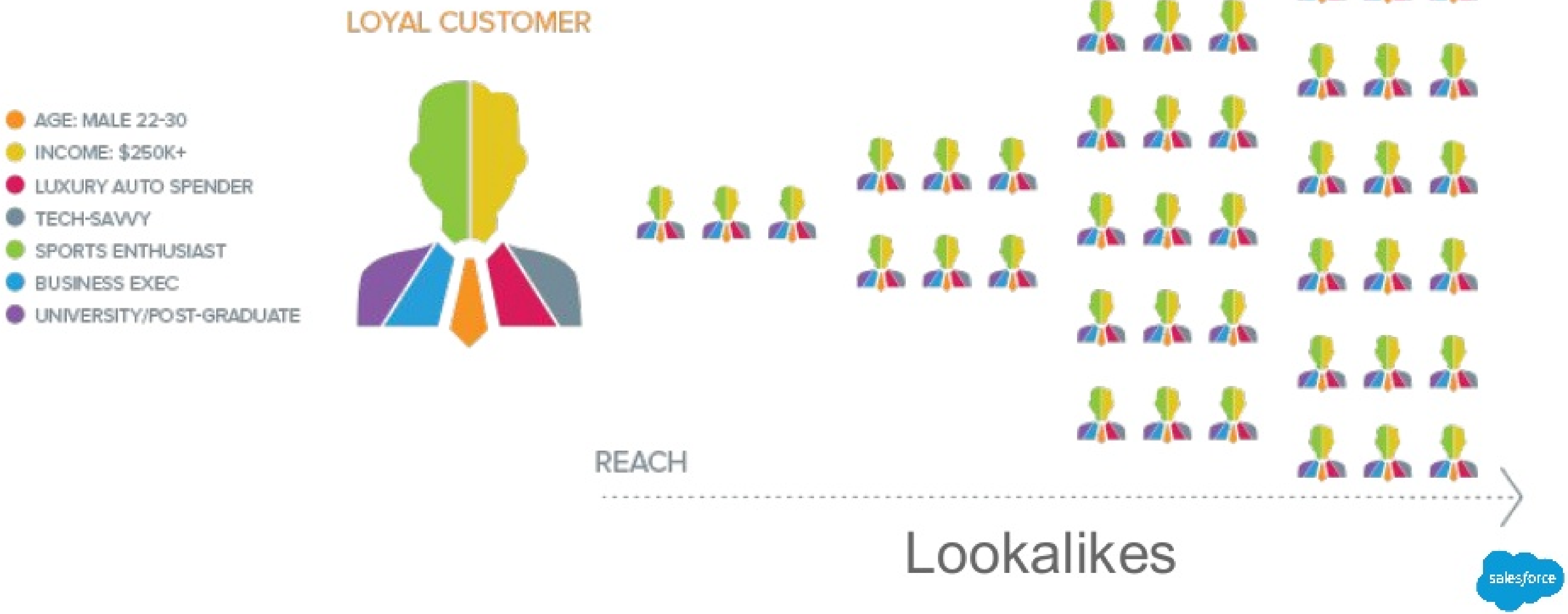
1.6 million
page views

4.75 million
data capture events

700,000
Ad impressions


Data Processing
Computing Clusters (EMR, EC2)
Services
Beacons
Real Time Services
Internet
Browsers
Mobiles
SDKs
Offline
Logs
CRM
Dist. Queues
Data Stores
AWS S3
DynamoDB
Redshift
RDS
Data Pipeline
[krux/hyperion]
Schedule
Tasks
Dependencies
Resources
Data
Permissions
salesforce DMP
DMP Console

Marketers want to find more customers like their loyal customer

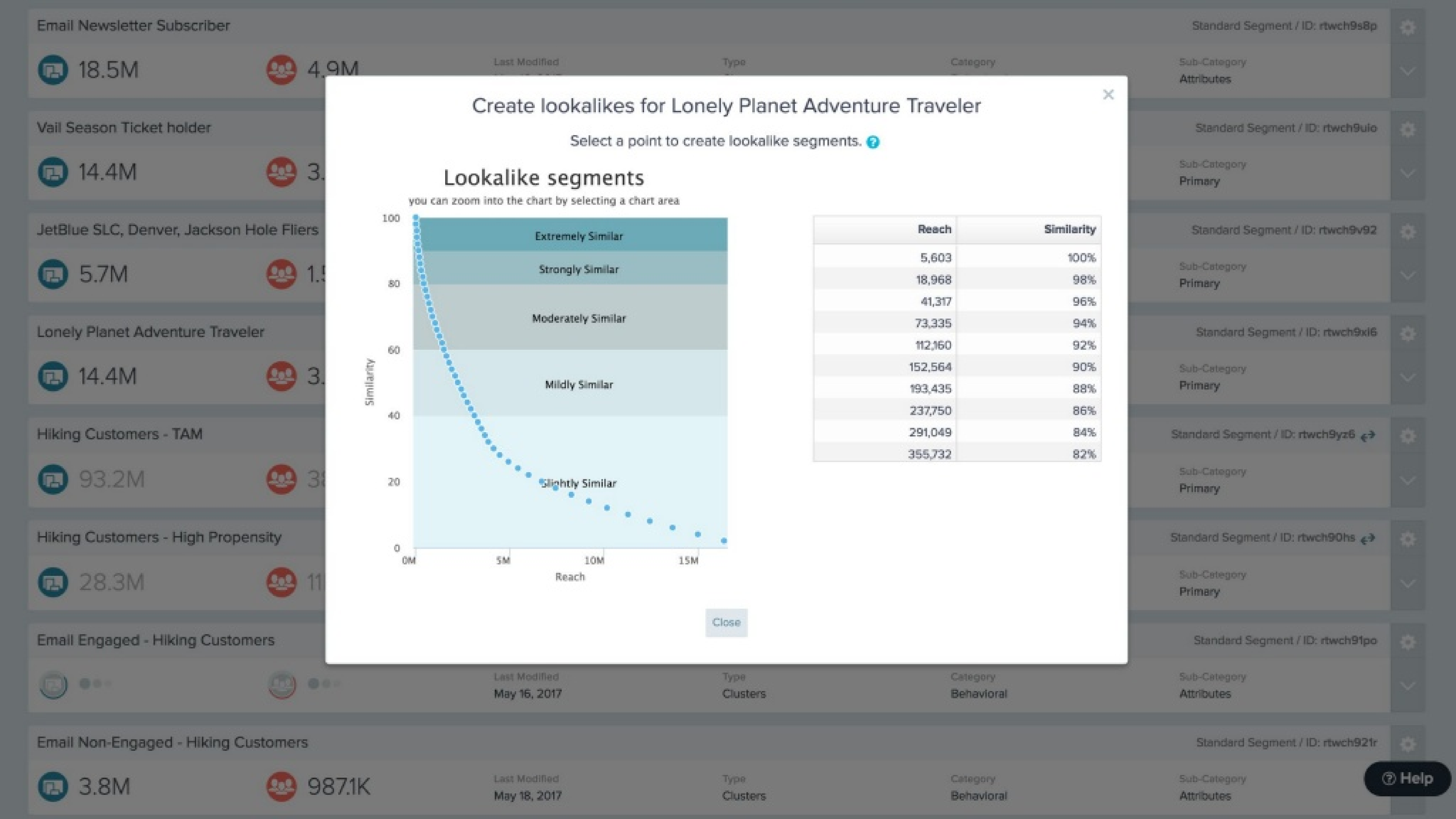


LOYAL CUSTOMER

- ● AGE: MALE 22-30
- ● INCOME: $250K+
- ● LUXURY AUTO SPENDER
- ● TECH-SAVVY
- ● SPORTS ENTHUSIAST
- ● BUSINESS EXEC
- ● UNIVERSITY/POST-GRADUATE

REACH

Lookalikes



Email Newsletter Subscriber

Standard Segment / ID: rtwch9s8p

18.5M 4.9M Last Modified Type Category Sub-Category Attributes

Vail Season Ticket holder

Standard Segment / ID: rtwch9uio

14.4M 3. Sub-Category Primary

JetBlue SLC, Denver, Jackson Hole Fliers

Standard Segment / ID: rtwch9v92

5.7M 1.5 Sub-Category Primary

Lonely Planet Adventure Traveler

Standard Segment / ID: rtwch9xi6

14.4M 3. Sub-Category Primary

Hiking Customers - TAM

Standard Segment / ID: rtwch9yz6

93.2M 3 Sub-Category Primary

Hiking Customers - High Propensity

Standard Segment / ID: rtwch90hs

28.3M 11 Sub-Category Primary

Email Engaged - Hiking Customers

Standard Segment / ID: rtwch91po

Last Modified May 16, 2017 Type Clusters Category Behavioral Sub-Category Attributes

Email Non-Engaged - Hiking Customers

Standard Segment / ID: rtwch921r

3.8M 987.1K Last Modified May 18, 2017 Type Clusters Category Behavioral Sub-Category Attributes

Create lookalikes for Lonely Planet Adventure Traveler

Select a point to create lookalike segments.

Lookalike segments

you can zoom into the chart by selecting a chart area

Reach	Similarity
5,603	100%
18,968	98%
41,317	96%
73,335	94%
112,160	92%
152,564	90%
193,435	88%
237,750	86%
291,049	84%
355,732	82%

Model	Naive Bayes Framework

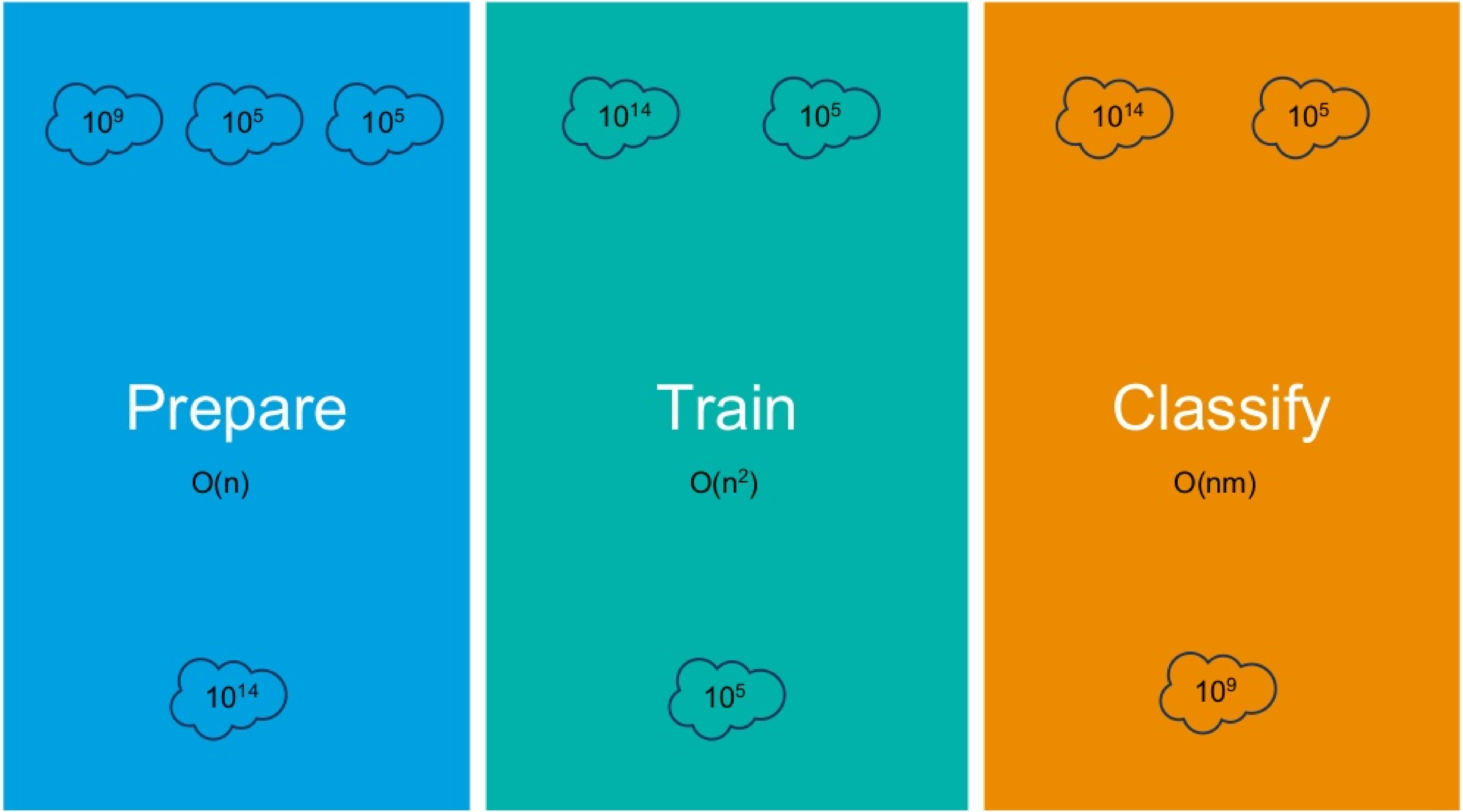
Model	Naive Bayes Framework
Feature Selection	Linear Discriminant Analysis

Model	Naive Bayes Framework
Feature Selection	Linear Discriminant Analysis
Science / Art	Correct for autocorrelation in feature space (paper pending)

Prepare

Train

Classify



10^9 10^5 10^5

Prepare

$O(n)$

10^{14}

10^{14} 10^5

Train

$O(n^2)$

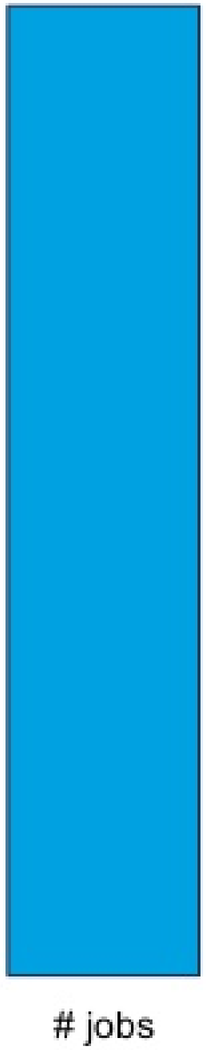
10^5

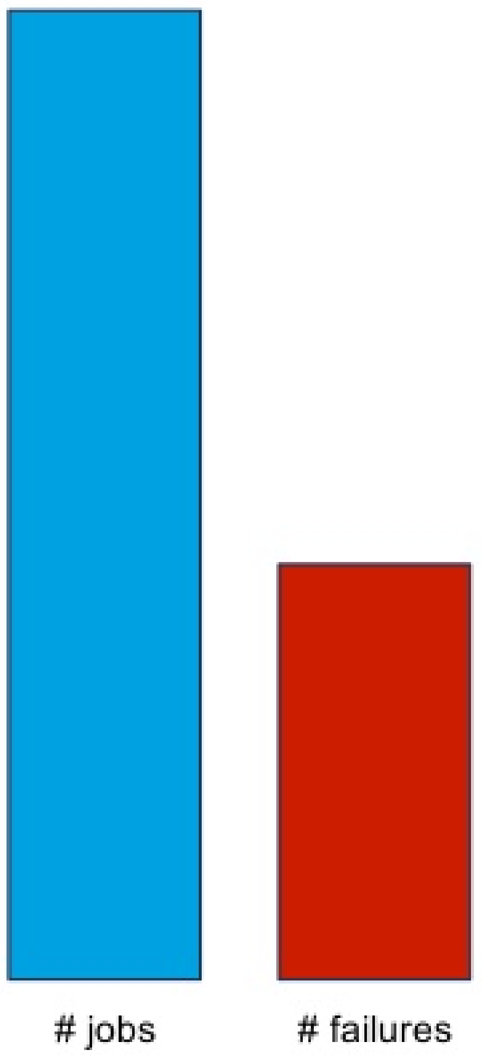
10^{14} 10^5

Classify

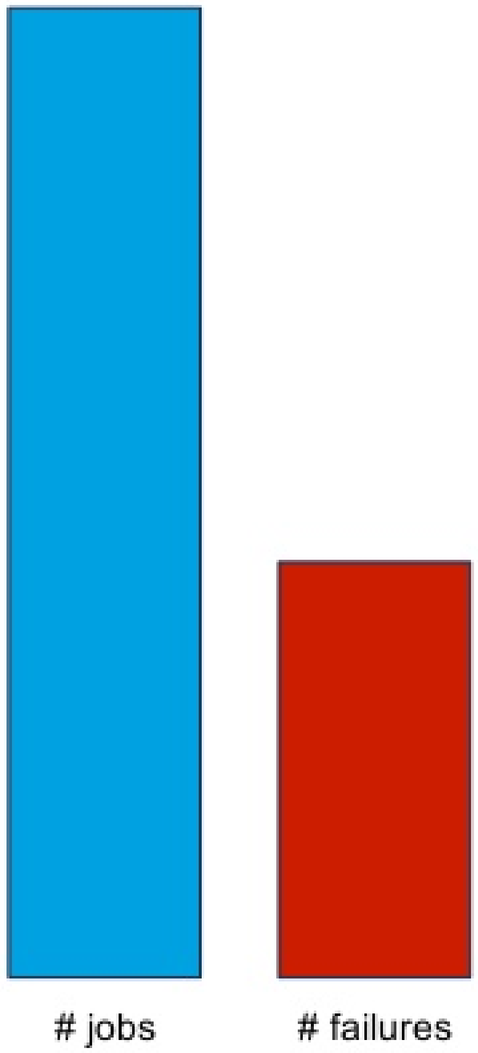
$O(nm)$

10^9


# jobs



# jobs
# failures



StackOverflowException

Job Stuck

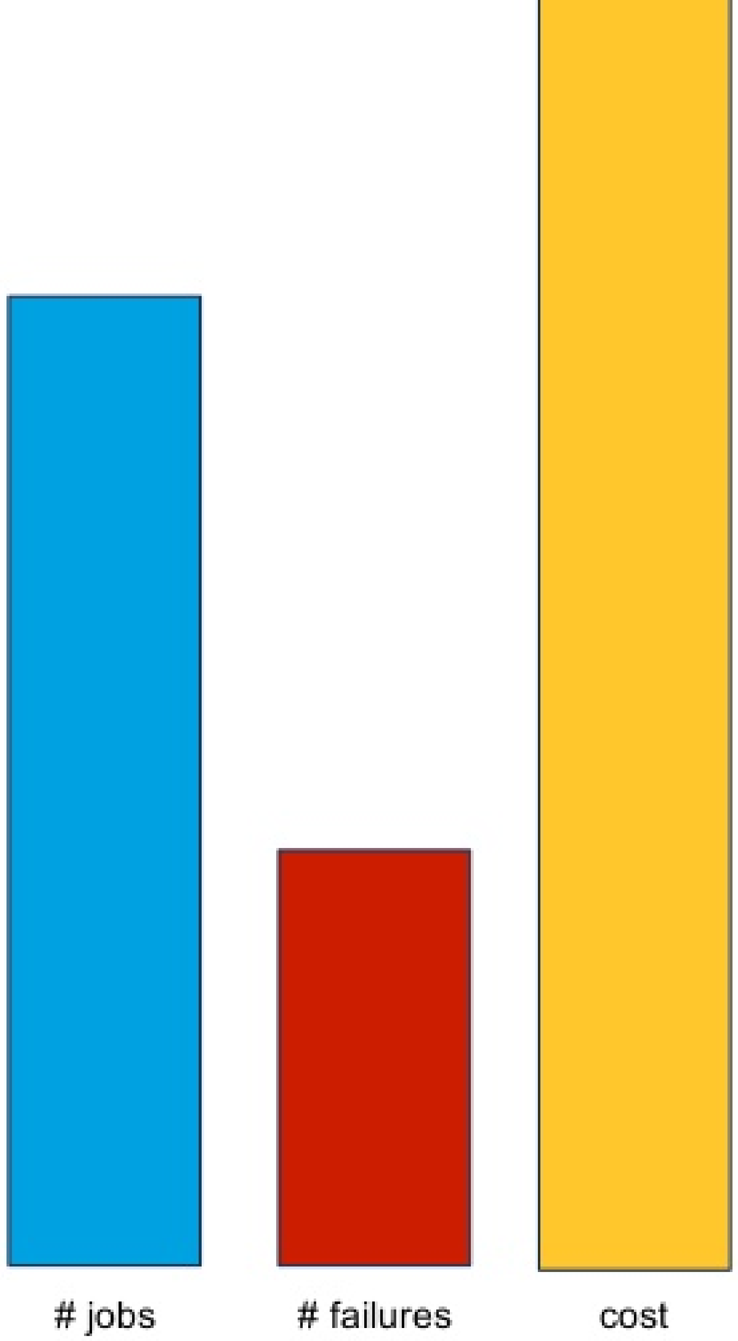
Slave Node Keeps Dying

Idle Slave Nodes

Code Complexity

Out Of Memory

Intermediate Result Serialization



StackOverflowException

Job Stuck

Slave Node Keeps Dying

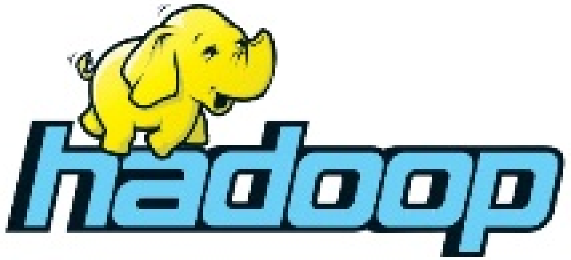
Idle Slave Nodes

Code Complexity

Out Of Memory

Intermediate Result Serialization

Reality: Framework



Big I/O Cost

Code Complexity

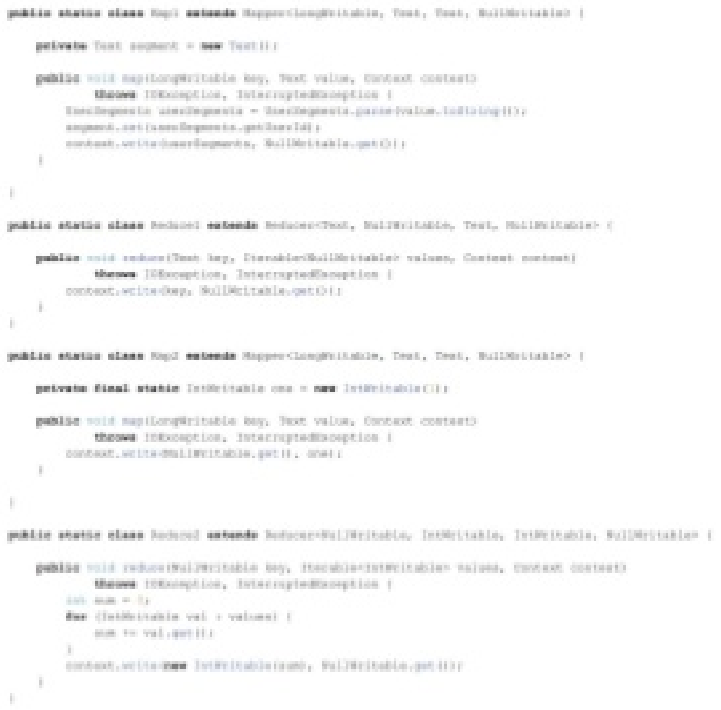
Flexibility

Number of Features

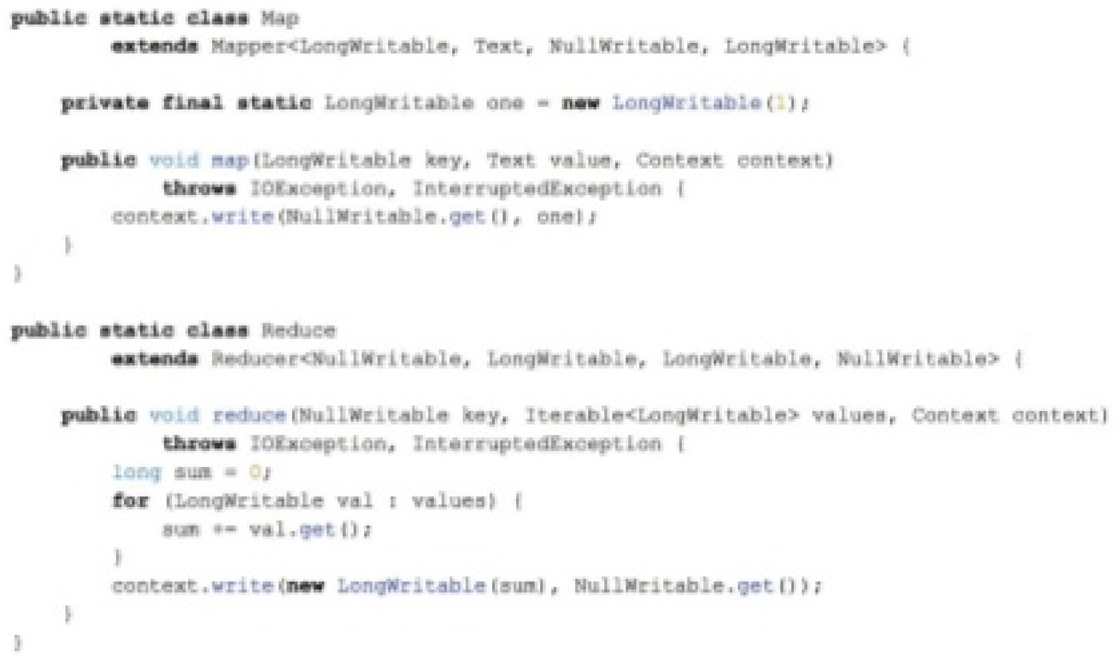
Total Population

Segment Populations

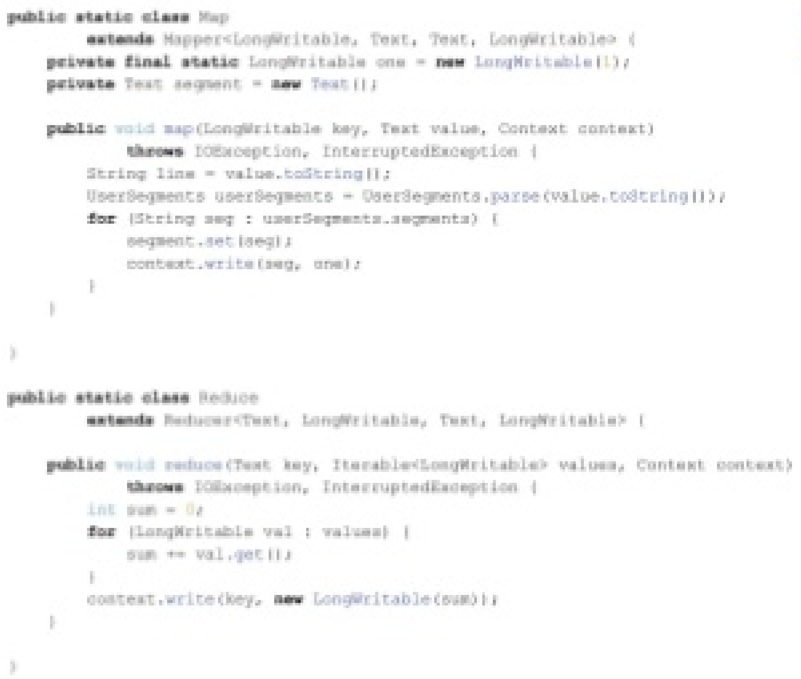
Segment Population Overlap



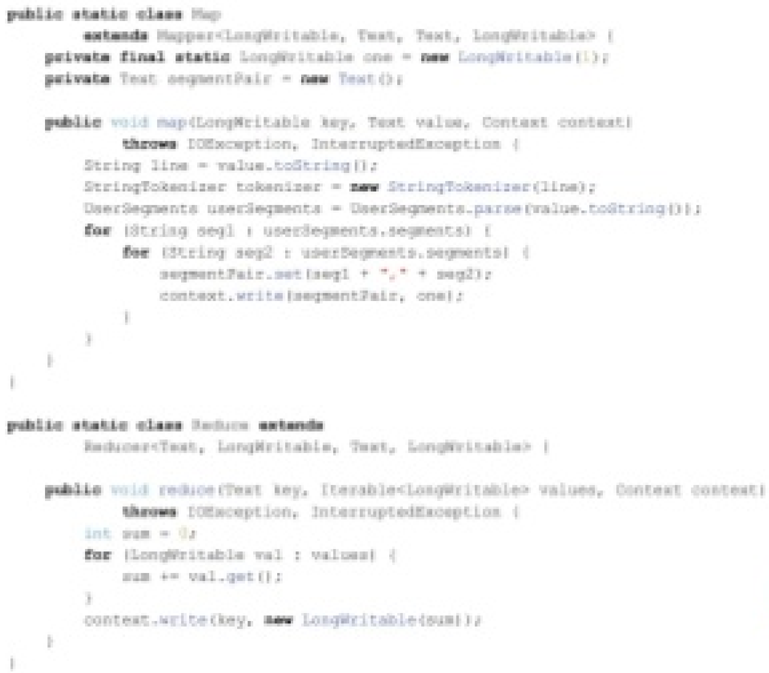
```
public static class Map1 extends Mapper<LongWritable, Text, Text, NullWritable> {

    private Text segment = new Text();

    public void map(LongWritable key, Text value, Context context)
            throws IOException, InterruptedException {
        UserSegments userSegments = UserSegments.parse(value.toString());
        segment.set(userSegments.getUserId());
        context.write(userSegments, NullWritable.get());
    }

}

public static class Reduce1 extends Reducer<Text, NullWritable, Text, NullWritable> {

    public void reduce(Text key, Iterable<NullWritable> values, Context context)
            throws IOException, InterruptedException {
        context.write(key, NullWritable.get());
    }
}

public static class Map2 extends Mapper<LongWritable, Text, Text, NullWritable> {

    private final static IntWritable one = new IntWritable(1);

    public void map(LongWritable key, Text value, Context context)
            throws IOException, InterruptedException {
        context.write(NullWritable.get(), one);
    }

}

public static class Reduce2 extends Reducer<NullWritable, IntWritable, IntWritable, NullWritable> {

    public void reduce(NullWritable key, Iterable<IntWritable> values, Context context)
            throws IOException, InterruptedException {
        int sum = 0;
        for (IntWritable val : values) {
            sum += val.get();
        }
        context.write(new IntWritable(sum), NullWritable.get());
    }
}
```



```
public static class Map
        extends Mapper<LongWritable, Text, NullWritable, LongWritable> {

    private final static LongWritable one = new LongWritable(1);

    public void map(LongWritable key, Text value, Context context)
            throws IOException, InterruptedException {
        context.write(NullWritable.get(), one);
    }
}

public static class Reduce
        extends Reducer<NullWritable, LongWritable, LongWritable, NullWritable> {

    public void reduce(NullWritable key, Iterable<LongWritable> values, Context context)
            throws IOException, InterruptedException {
        long sum = 0;
        for (LongWritable val : values) {
            sum += val.get();
        }
        context.write(new LongWritable(sum), NullWritable.get());
    }
}
```



```
public static class Map
        extends Mapper<LongWritable, Text, Text, LongWritable> {
    private final static LongWritable one = new LongWritable(1);
    private Text segment = new Text();

    public void map(LongWritable key, Text value, Context context)
            throws IOException, InterruptedException {
        String line = value.toString();
        UserSegments userSegments = UserSegments.parse(value.toString());
        for (String seg : userSegments.segments) {
            segment.set(seg);
            context.write(seg, one);
        }
    }

}

public static class Reduce
        extends Reducer<Text, LongWritable, Text, LongWritable> {

    public void reduce(Text key, Iterable<LongWritable> values, Context context)
            throws IOException, InterruptedException {
        int sum = 0;
        for (LongWritable val : values) {
            sum += val.get();
        }
        context.write(key, new LongWritable(sum));
    }

}
```



```
public static class Map
        extends Mapper<LongWritable, Text, Text, LongWritable> {
    private final static LongWritable one = new LongWritable(1);
    private Text segmentPair = new Text();

    public void map(LongWritable key, Text value, Context context)
            throws IOException, InterruptedException {
        String line = value.toString();
        StringTokenizer tokenizer = new StringTokenizer(line);
        UserSegments userSegments = UserSegments.parse(value.toString());
        for (String seg1 : userSegments.segments) {
            for (String seg2 : userSegments.segments) {
                segmentPair.set(seg1 + "," + seg2);
                context.write(segmentPair, one);
            }
        }
    }
}

public static class Reduce extends
        Reducer<Text, LongWritable, Text, LongWritable> {

    public void reduce(Text key, Iterable<LongWritable> values, Context context)
            throws IOException, InterruptedException {
        int sum = 0;
        for (LongWritable val : values) {
            sum += val.get();
        }
        context.write(key, new LongWritable(sum));
    }
}
```

```
userSegments
  .flatMap(_.segments)
  .distinct
  .count
```

```
userSegments.count
```

```
userSegments
  .flatMap(r => r.segments.map(_ -> 1L))
  .reduceByKey(_ + _)
```

```
val userSegmentPairs = userSegments
  .flatMap(r => r.segments.map(r.userId -> _))

userSegmentPairs
  .join(userSegmentPairs)
  .map { case (_, (feat1, feat2)) => (feat1, feat2) -> 1L }
  .reduceByKey(_ + _)
```

Reality: Data in many S3 prefixes/folders

```
val inputData = Seq(
  "s3://my-bucket/some-path/prefix1/" ,
  "s3://my-bucket/some-path/prefix2/" ,
  "s3://my-bucket/some-path/prefix2/" ,
  ...
  "s3://my-bucket/some-path/prefix2000/" ,
)
```

How about this?

```
val myRdd = inputData
  .map(sc.textFile)
  .reduceLeft(_ ++ _)
```

Or this?

```
val myRdd = sc.union(inputData.map(sc.textFile))
```

Solution

```
// get the s3 objects
val s3Objects = new AmazonS3Client()
  .listObjects("my-bucket", "some-path")
  .getObjectSummaries()
  .map(_.getKey())
  .filter(hasPrefix1to2000)
// send them to slave nodes and retrieve content
val myRdd = sc
  .parallelize(Random.shuffle(s3Objects.toSeq), parallelismFactor)
  .flatMap( key =>
    Source
      .fromInputStream(
        new AmazonS3Client().getObjectForKey("my-bucket", key)
          .getObjectContent
      )
      .getLines
  )
```

Reality: Large Scale Overlap

```
val userSegmentPairs = userSegments
  .flatMap(r => r.segments.map(r.userId -> _))

userSegmentPairs
  .join(userSegmentPairs)
  .map { case (_, (feat1, feat2)) => (feat1, feat2) -> 1L }
  .reduceByKey(_ + _)
```

user1	a, b, c
user2	a, b, c
user3	a, b, c
user4	a, c
user5	a, c

user1	a
user1	b
user1	c
user2	a
user2	b
user2	c
user3	a
user3	b
user3	c
user4	a
user4	c
user5	a
user5	c

user1	a	b
user1	a	c
user1	b	c
user2	a	b
user2	a	c
user2	b	c
user3	a	b
user3	a	c
user3	b	c
user4	a	c
user5	a	c

1	a	b
1	a	c
1	b	c
1	a	b
1	a	c
1	b	c
1	a	b
1	a	c
1	b	c
1	a	c
1	a	c

a	b	3
a	c	5
b	c	3

user1	a, b, c
user2	a, b, c
user3	a, b, c
user4	a, c
user5	a, c

hash1	a, b, c	3
hash2	a, c	2

hash1	a	3
hash1	b	3
hash1	c	3
hash2	a	2
hash2	c	2

hash1	a	b	3
hash1	a	c	3
hash1	b	c	3
hash2	a	c	2

a	b	3
a	c	5
b	c	3

Solution

```
// Reduce the user space
val aggrUserSegmentPairs = userSegmentPairs
  .map(r => r.segments -> 1L)
  .reduceByKey(_ + _)
  .flatMap { case (segments, count) =>
    segments.map(s => (hash(segments), (segment, count))
  }

aggrUserSegmentPairs
  .join(aggrUserSegmentPairs)
  .map { case (_, (seg1, count), (seg2, _)) =>
    (seg1, seg2) -> count
  }
  .reduceByKey(_ + _)
```

Reality: Perform Join on Skewed Data

user1	a
user2	b
user3	c
user4	d
user5	e

X

user1	one
user1	two
user1	three
user1	four
user1	five
user1	six
user3	seven
user3	eight
user4	nine
user5	ten

```
data1.join(data2)
```

Executor 1

user1	a

user1	one
user1	two
user1	three
user1	four
user1	five
user1	six

Executor 2

user3	c
user4	d

user3	seven
user3	eight
user4	nine

Executor 3

user5	e
user2	b

user5	ten

Executor 1

user1	salt1	a

user1	salt1	one
user1	salt1	two

Executor 2

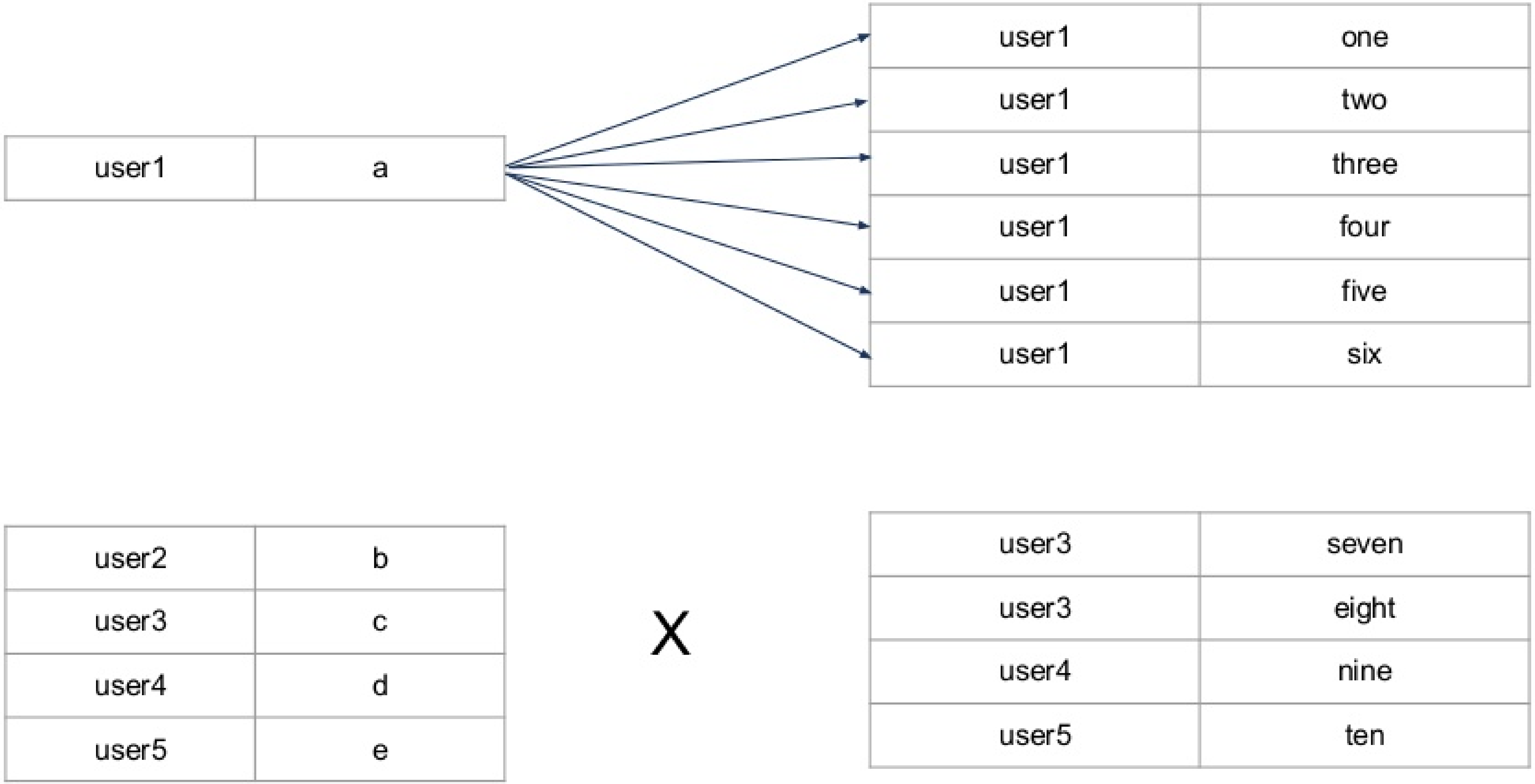
user1	salt2	a

user1	salt2	three
user1	salt2	four

Executor 3

user1	salt3	a

user1	salt3	five
user1	salt3	six



Solution

```
val topKeys = data2
  .mapValues(x => 1L)
  .reduceByKey(_ + _)
  .takeOrdered(10)(Ordering[(String, Long)].on(_._2).reverse)
  .toMap
  .keys

val topData1 = sc.broadcast(
  data1.filter(r => topKeys.contains(r._1)).collect.toMap
)

val bottomData1 = data1.filter(r => !topKeys.contains(r._1))

val topJoin = data2.flatMap {  case (k, v2) =>
  topData1.value.get(k).map(v1 => k -> (v1, v2))
}

topJoin ++ bottomData1.join(data2)
```

Hadoop to Spark → Maintainable codebase

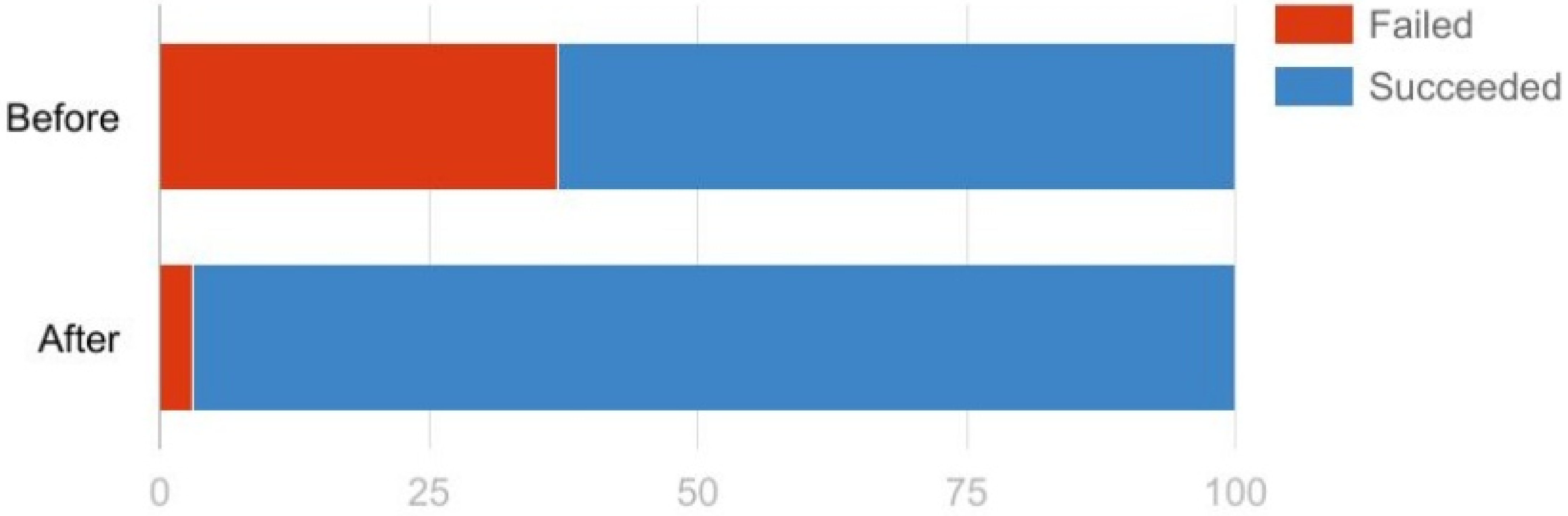
Smarter retrieval of data from S3 → Clients with more than 2000 S3 prefixes/folders

Before: 5 hours
After: 20 minutes

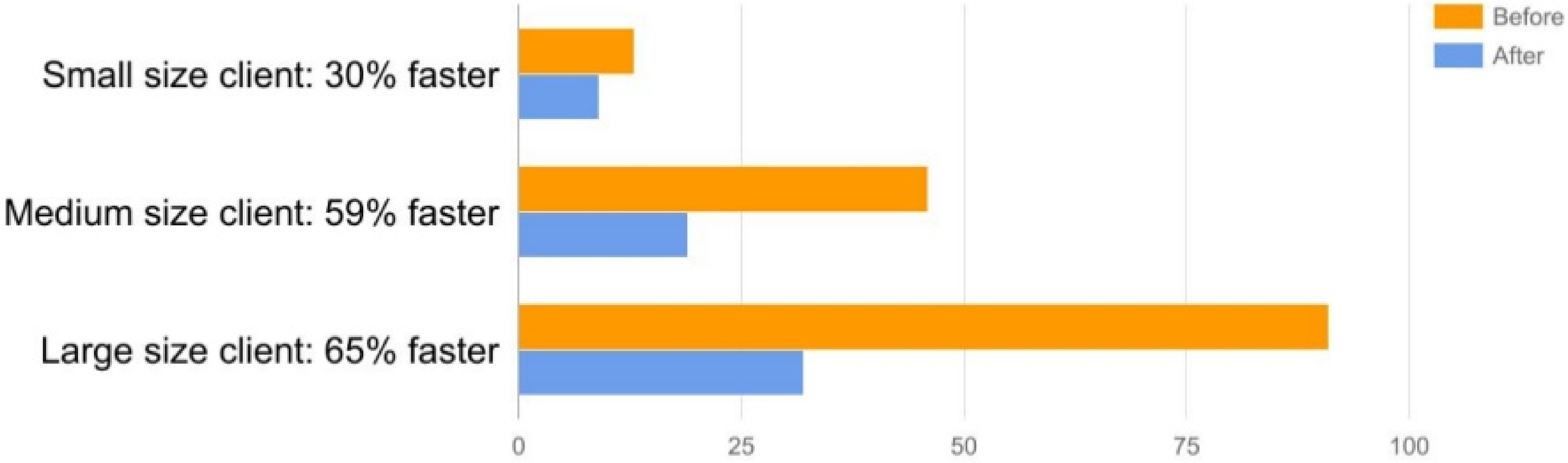
Condensed overlap algorithm → 100x faster and 10x less data for segment overlap

Hybrid join algorithm → Able to process joins for highly skewed data

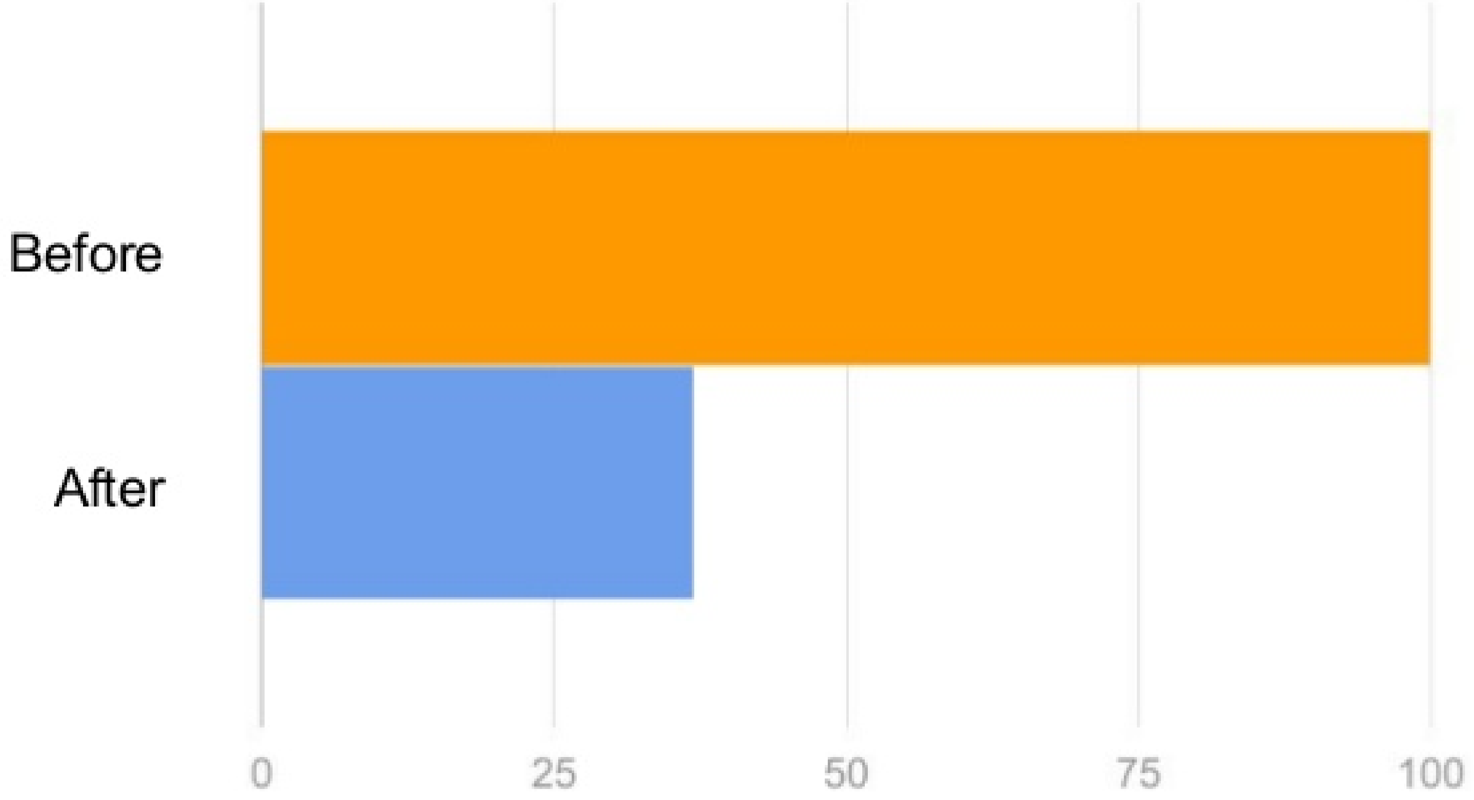
Failure Rate



Performance



Cost



Thank Y☁u