ADVENTURES IN SCALING FROM **ZERO** TO **5 BILLION** DATA POINTS PER DAY

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Distinguished Architect

Comcast Corporation

2 April, 2019

Flink Forward – San Francisco 2019

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COMCAST CUSTOMER RELATIONSHIPS

30.3 MILLION OVERALL CUSTOMER RELATIONSHIPS AT 2018 YEAR END

25.1 MILLION RESIDENTIAL HIGH-SPEED INTERNET CUSTOMERS AT 2018 YEAR END

1.2 MILLION RESIDENTIAL HIGH-SPEED INTERNET CUSTOMER NET ADDITIONS IN 2018

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DELIVER THE ULTIMATE CUSTOMER EXPERIENCE

IS THE CUSTOMER HAVING A GOOD EXPERIENCE FOR HIGH SPEED DATA (HSD) SERVICE?

IF THE CUSTOMER ENGAGES US DIGITALLY, CAN WE OFFER A SELF-SERVICE SOLUTION?

IF THERE IS AN ISSUE CAN WE OFFER OUR AGENTS AND TECHNICIANS A DIAGNOSIS TO HELP SOLVE THE PROBLEM QUICKER?

REDUCE THE TIME TO RESOLVE ISSUES

REDUCE COST TO THE BUSINESS AND THE CUSTOMER

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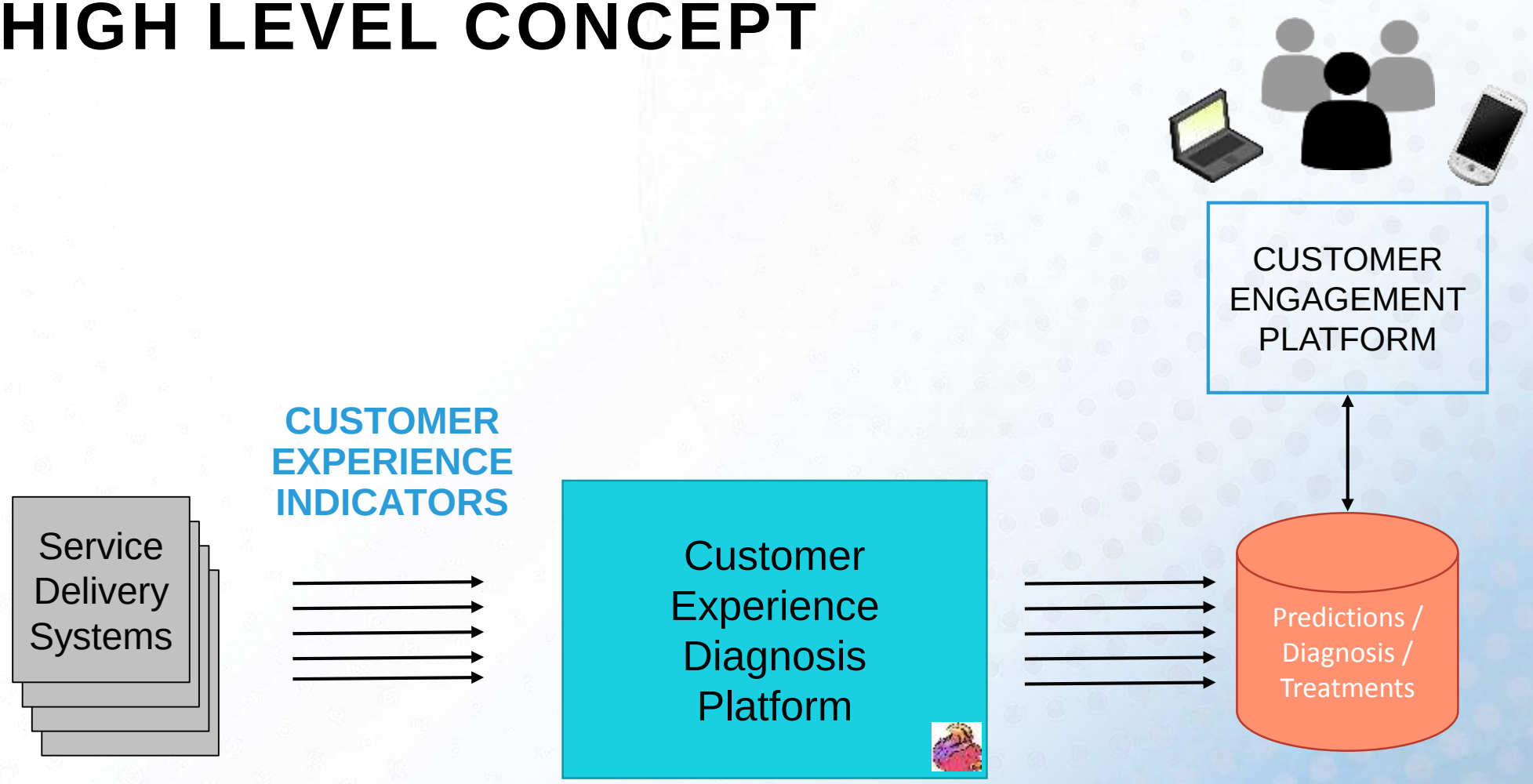
HIGH LEVEL CONCEPT



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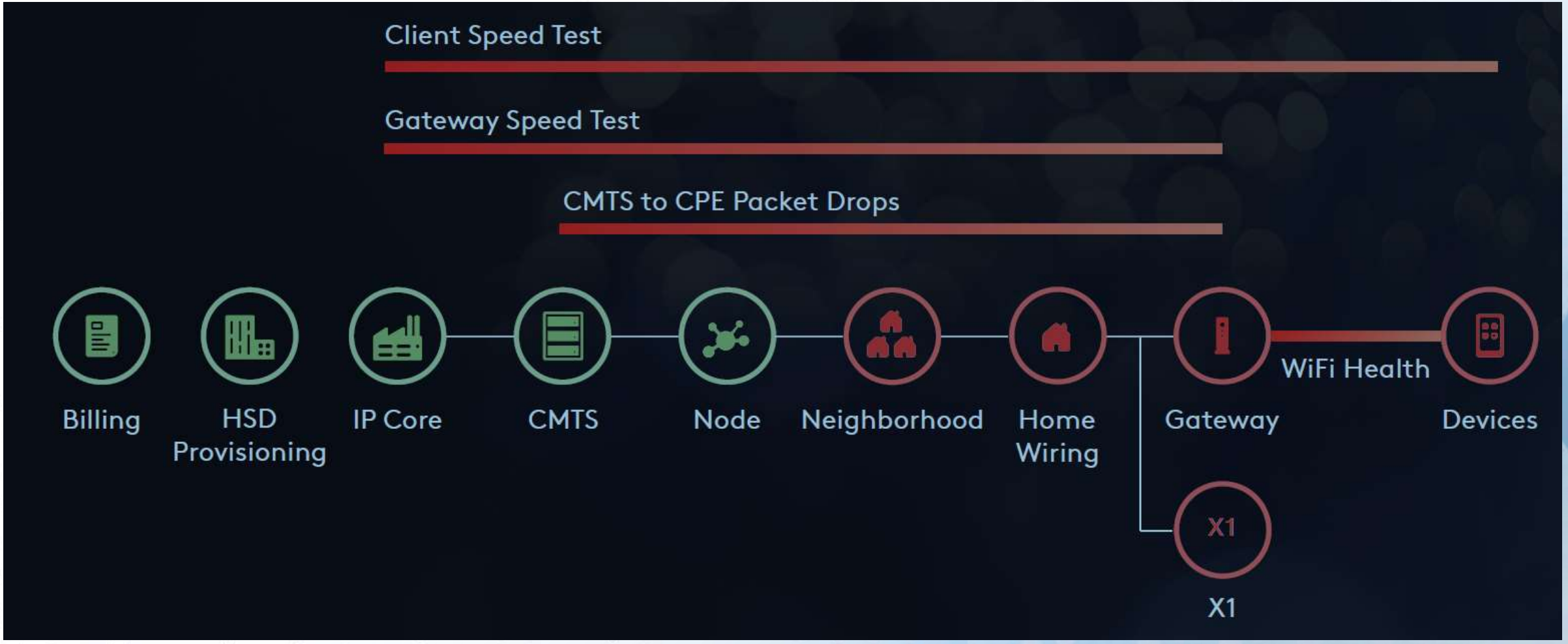
CUSTOMER EXPERIENCE INDICATORS



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NINE ADVENTURES IN SCALING

THE **TRIGGER AND DIAGNOSIS** PROBLEM

THE **REST** PROBLEM

THE **INEFFICIENT OBJECT HANDLING** PROBLEM

THE **FEATURE STORE** PROBLEM

THE **VOLUME** PROBLEM

THE **CUSTOMER STATE** PROBLEM

THE **CHECKPOINT** PROBLEM

THE **TRIGGER AND DIAGNOSIS** PROBLEM

THE **REALLY HIGH VOLUME AND FEATURE STORE** PROBLEM #2

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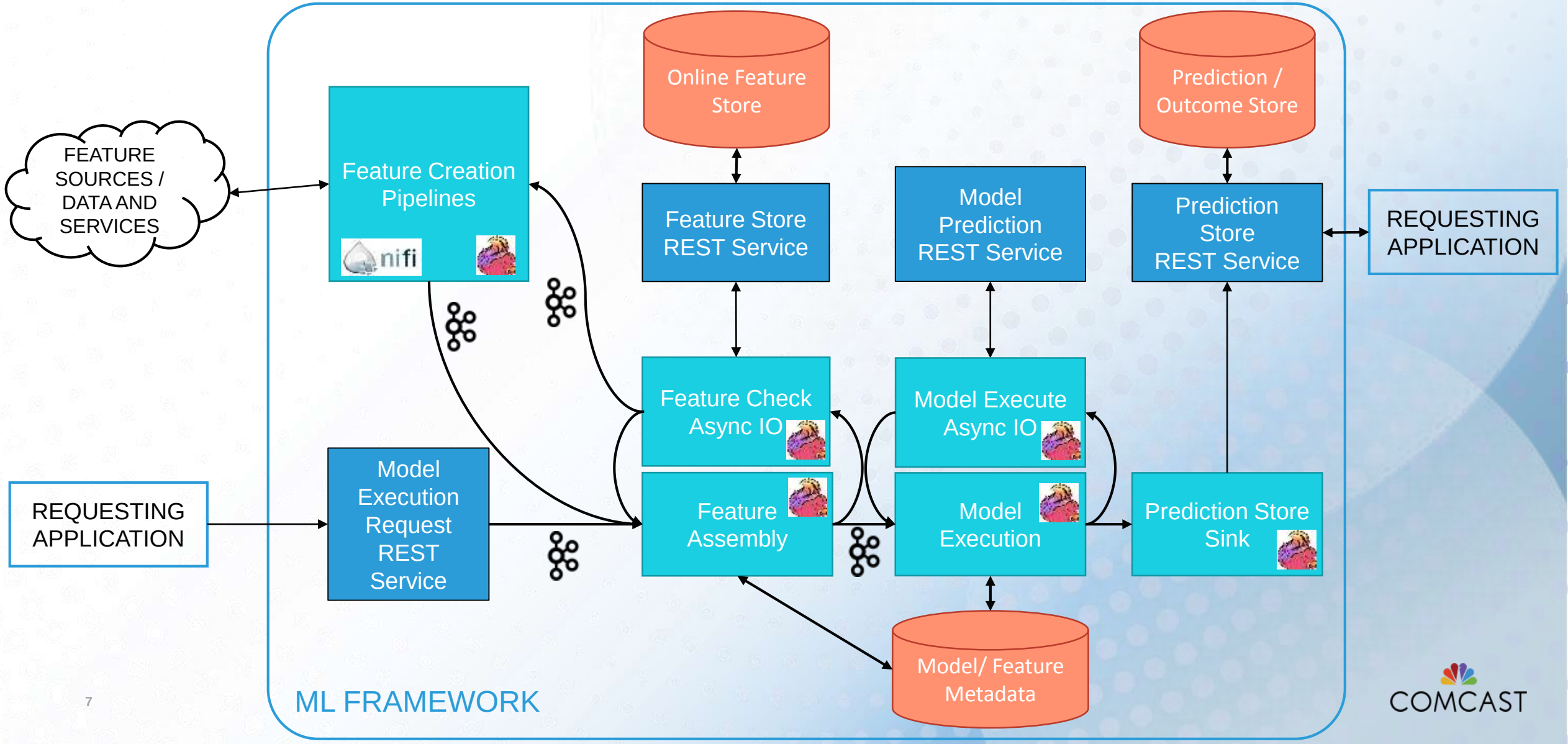
ML FRAMEWORK ARCHITECTURE – 2018

"EMBEDDING FLINK THROUGHOUT AN OPERATIONALIZED STREAMING ML LIFECYCLE" – SF FLINK FORWARD 2018



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THE **TRIGGER AND DIAGNOSIS** PROBLEM

MAY 2018 – INITIAL VOLUMES

INDICATOR #1

9 MILLION

INDICATOR #2

166 MILLION

INDICATOR #3

1.2 MILLION

INDICATOR #4

2500 (SMALL TRIAL)

TOTAL

175

MILLION / DAY

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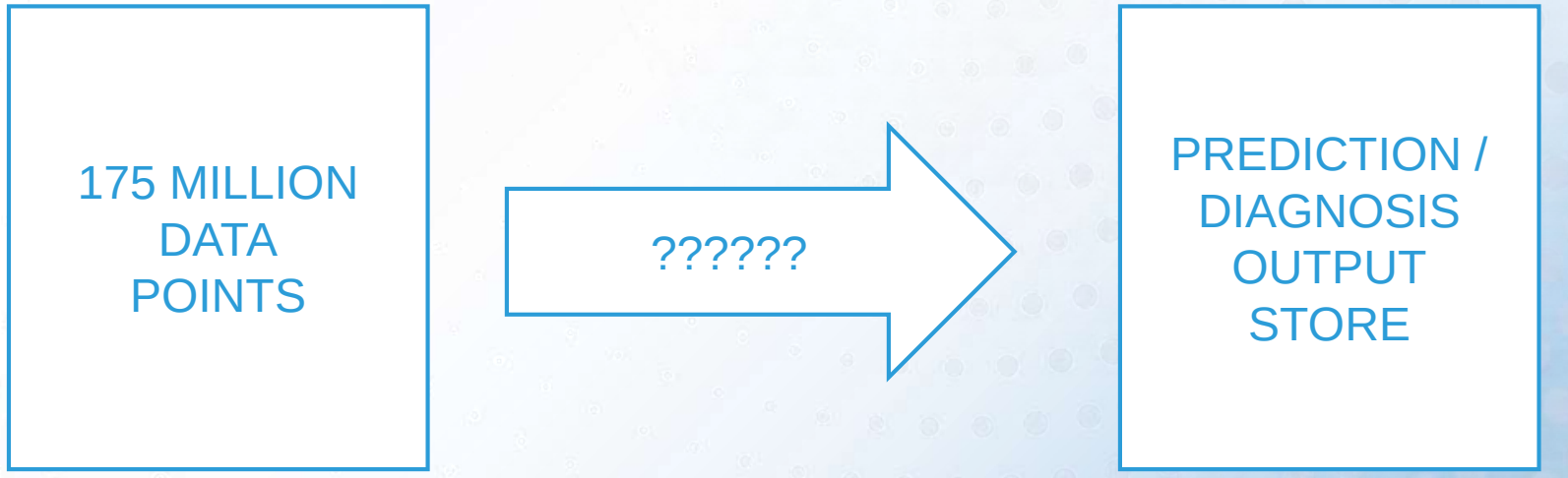
175 MILLION PREDICTIONS?



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INTRODUCE A ‘TRIGGER’ CONDITION

GREEN

GREEN

GREEN

RED

GREEN

GREEN

COMCAST

INTRODUCE A ‘TRIGGER’ CONDITION

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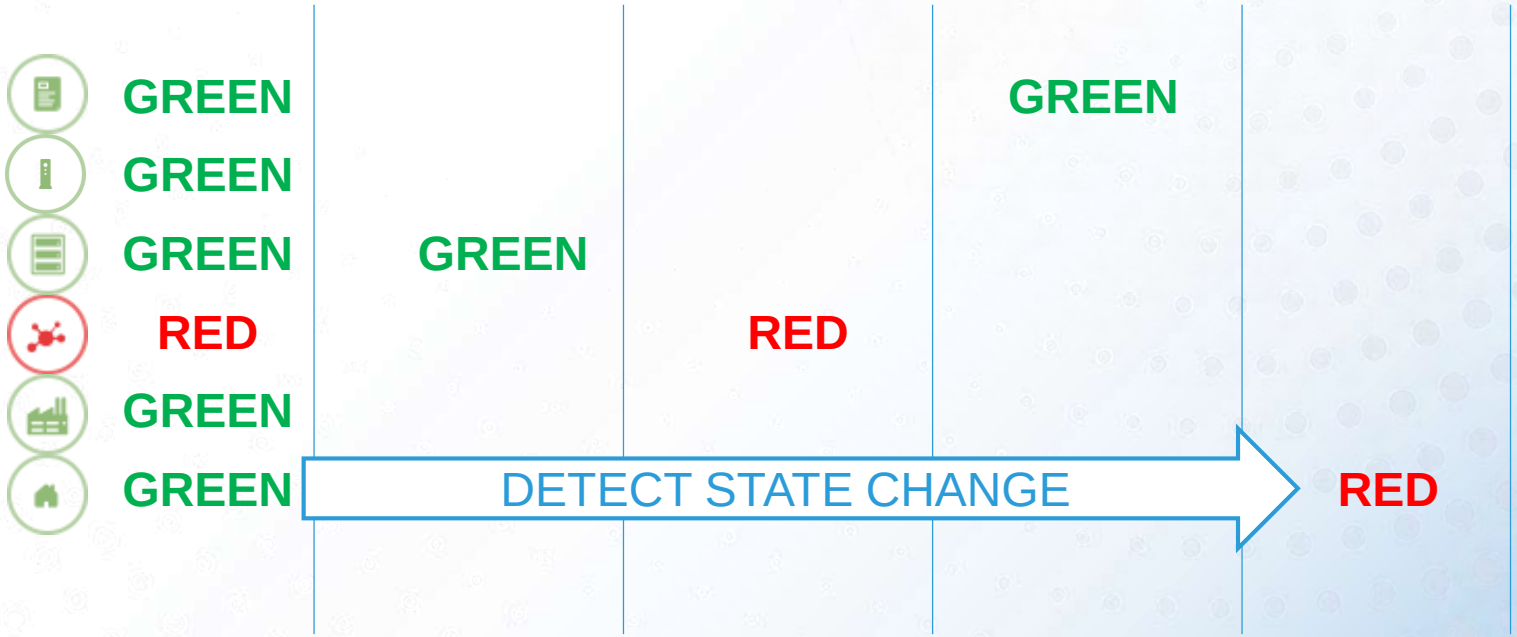
INTRODUCE A ‘TRIGGER’ CONDITION



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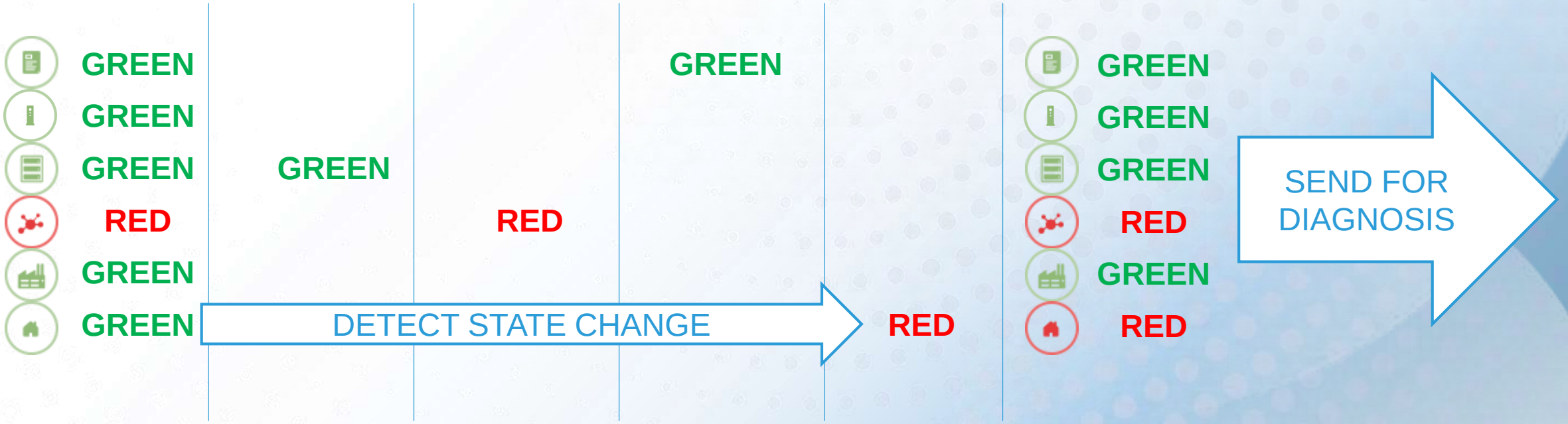
INTRODUCE A ‘TRIGGER’ CONDITION



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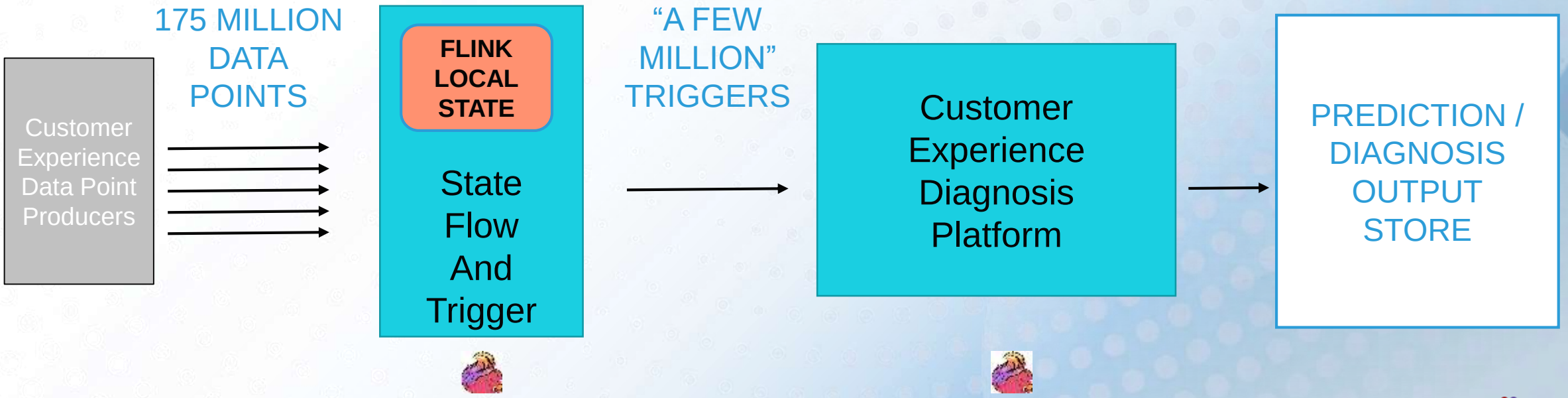
STATE MANAGER AND TRIGGER

INTRODUCE FLINK LOCAL STATE



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THE **REST** PROBLEM

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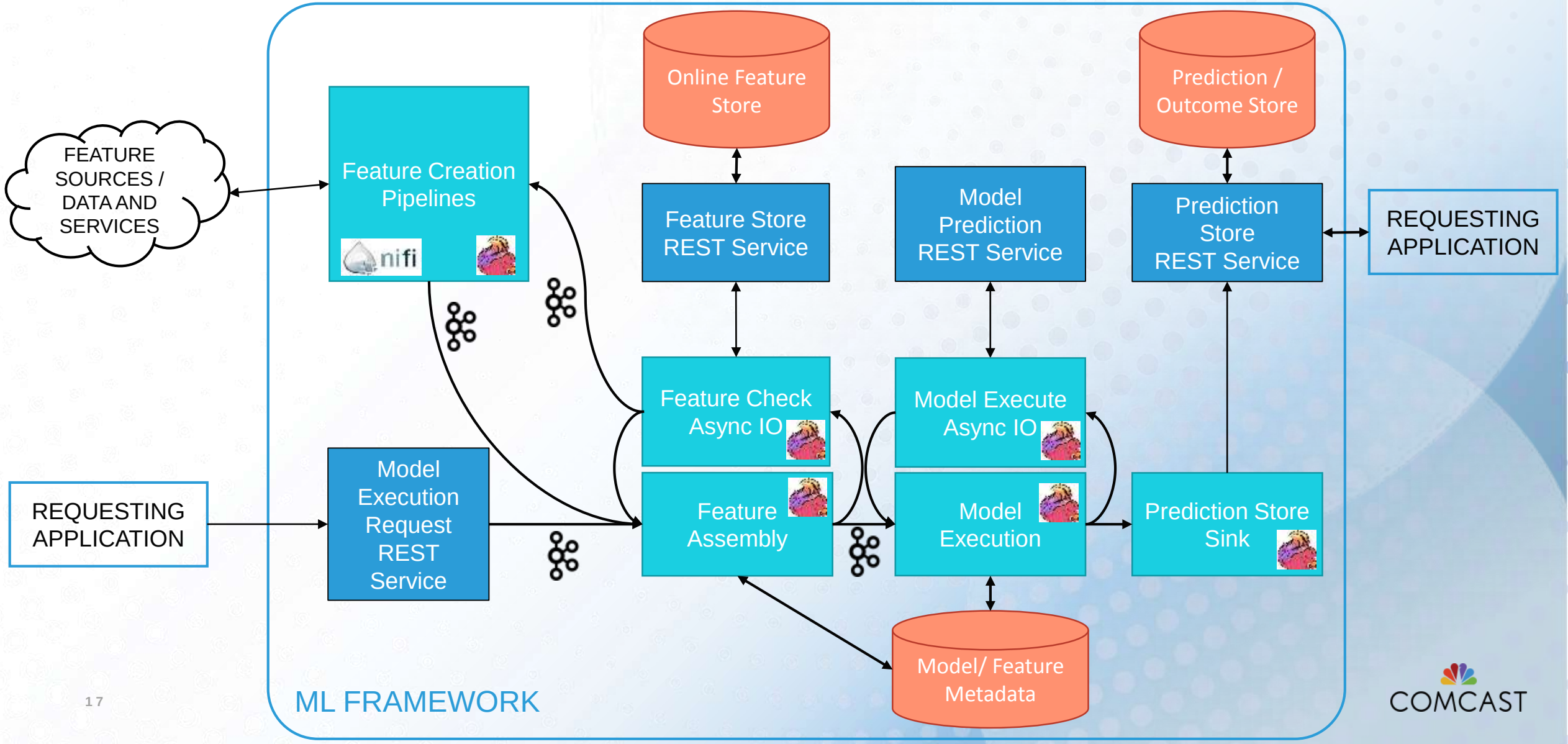

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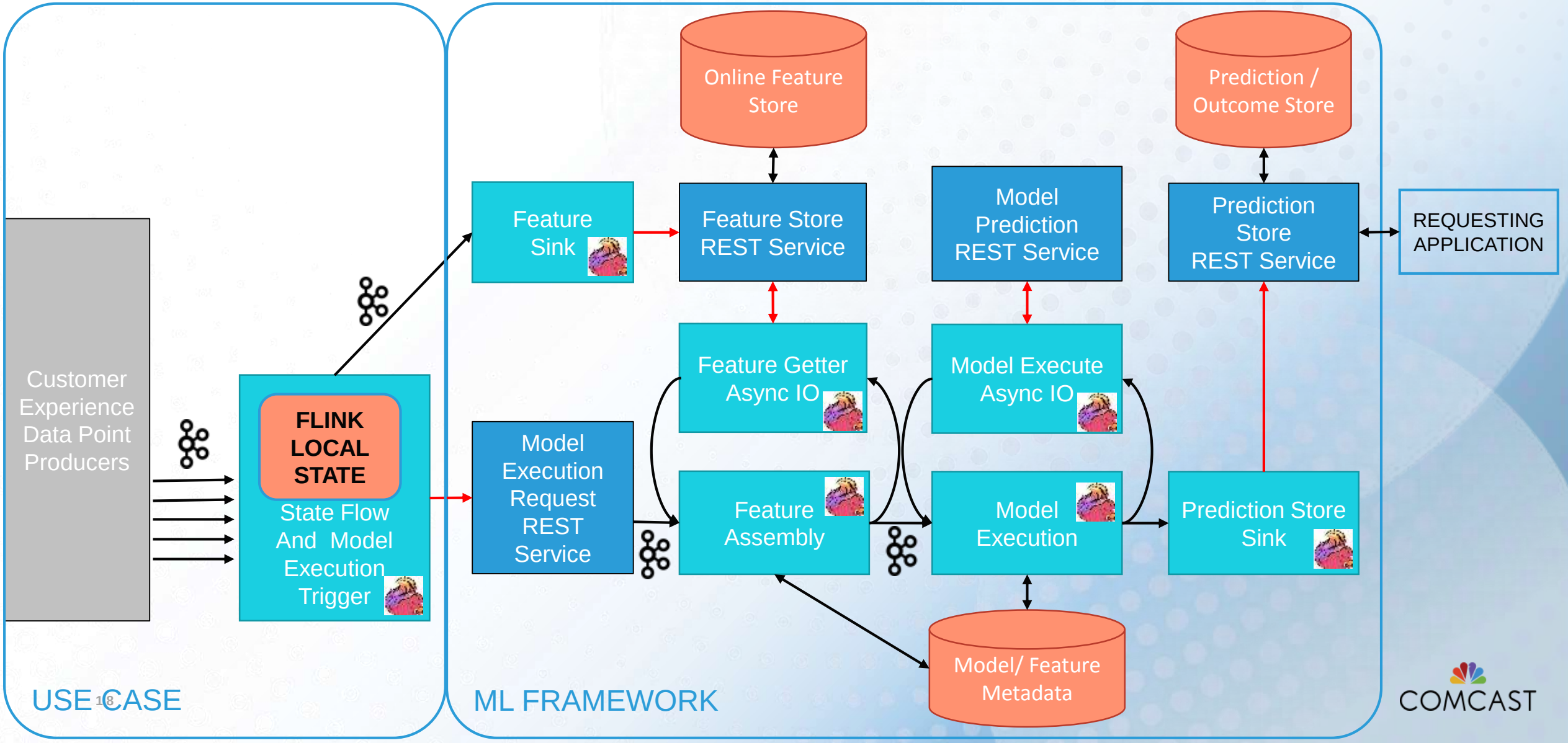
INITIAL PLATFORM ARCHITECTURE



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ORIGINAL ML FRAMEWORK ARCHITECTURE

EVERY COMMUNICATION WAS A REST SERVICE

ML FRAMEWORK ISOLATED FROM DATA POINT USE CASE BY DESIGN

FLINK ASYNC + REST IS DIFFICULT TO SCALE ELASTICALLY

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TUNING ASYNC I/O – LATENCY AND VOLUME

MAX THROUGHPUT PER SECOND = (SLOTS) * (THREADS) * (1000 / TASK DURATION MSEC)

(12 SLOTS) * (20 THREADS) * (1000 / 300) = 800 / SECOND

APACHE HTTP CLIENT / EXECUTOR THREADS

setMaxTotal

setDefaultMaxPerRoute (THREADS)

FLINK ASYNC MAX OUTSTANDING

RichAsyncFunction “Capacity”

AsyncDataStream.unorderedWait() with max capacity parameter

RATE THROTTLING

```
if (numberOfRequestsPerPeriod > 0) {
int numberOfProcesses = getRuntimeContext()
.getNumberOfParallelSubtasks();
        numberOfRequestsPerPeriodPerProcess =
Math.max(1, numberOfRequestsPerPeriod /
numberOfProcesses);
}
```


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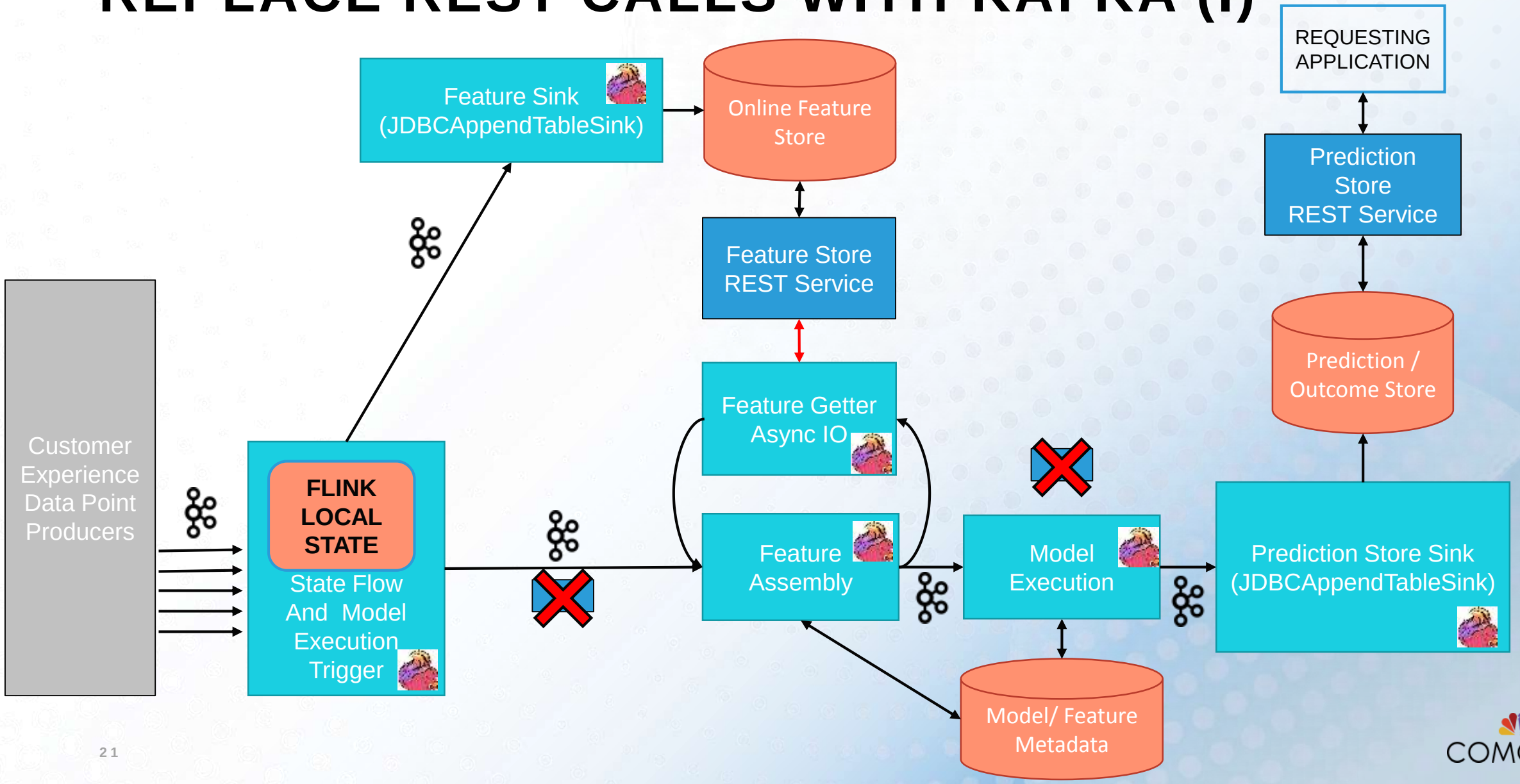
REPLACE REST CALLS WITH KAFKA (I)



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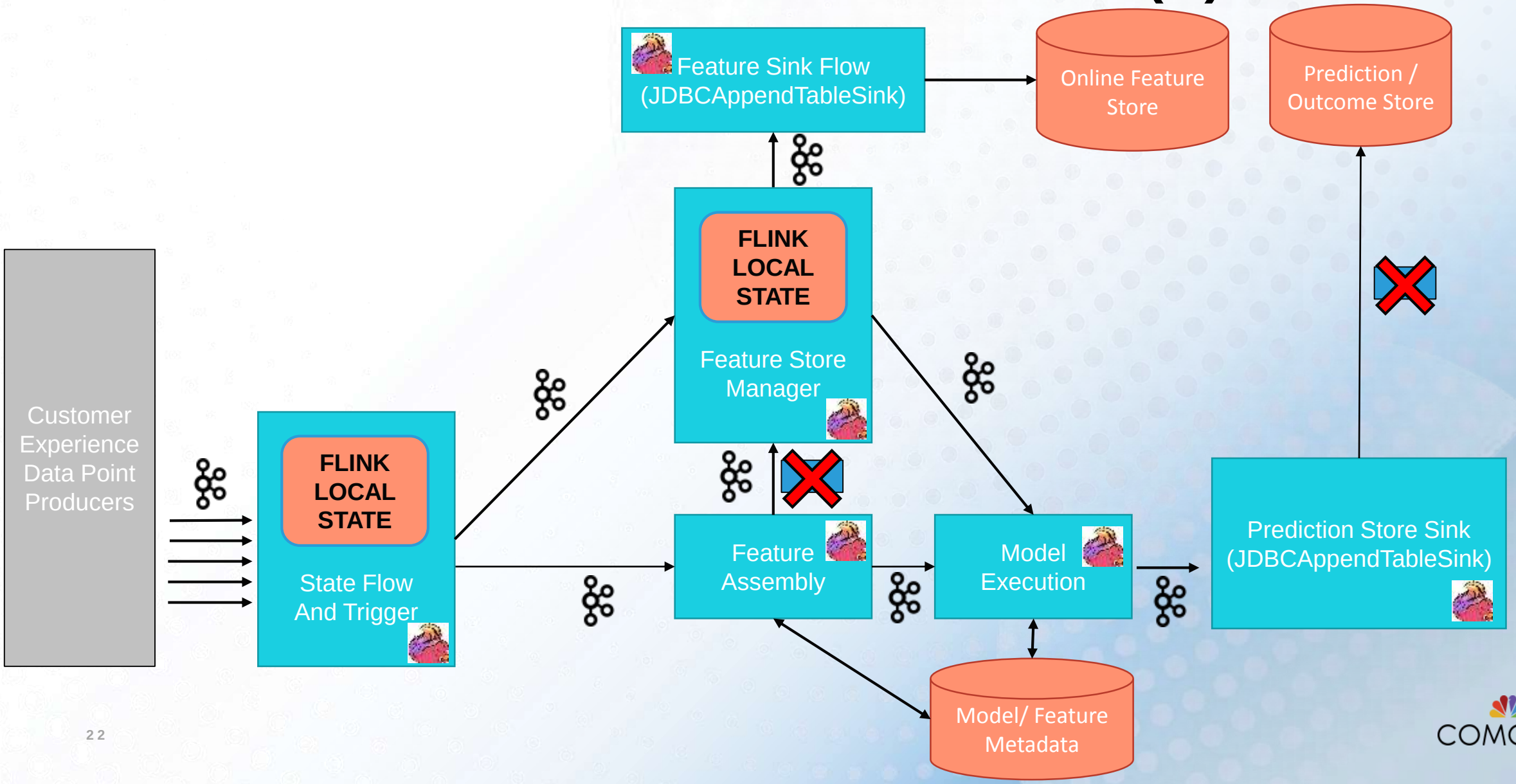
REPLACE REST CALL WITH KAFKA (II)



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THE **INEFFICIENT OBJECT HANDLING** PROBLEM

HAS THIS EVER HAPPENED TO YOU?

```
String transformedJson =
new JoltJsonTransformer()
        .transformJson(myJsonValue,
        pTool.getRequired(SPEC_PATH));
JSONObject inputPayload = new
JSONObject(transformedJson);
try {
aType = inputPayload.getJSONObject("info")
        .getJSONObject(“aType").
        getString("string");
} catch (Exception e) {
// ignore, invalid object
aType = STATUS_INVALID;
}
```

New “JOLT” JSON Transformer

(but don’t cache it)

→ New ObjectMapper()

(but don’t cache it)

→ Parse JSON string into Map

→ Load and parse “Transform” JSON from the resource path

(but don’t cache it)

→ Serialize transformed Map *back* into string result

COMCAST

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Then let's make a NEW JSONObject from that string

COMCAST

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Go deep into the path to get value

COMCAST

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Go deep into the path to get value

Cast exception? STATUS_INVALID

SLIGHTLY MORE EFFICIENT SOLUTION

```
if (mapper == null)
  mapper = new ObjectMapper();
```

Cache our new ObjectMapper()

```
Map<?, ?> resultMap =
JsonUtils.readValue(mapper, (String)
result, Map.class);
```

Parse JSON string into Map *ONCE*

```
MapTreeWalker mapWalker = new
MapTreeWalker(resultMap);
```

Lightweight Map Traversal utility

```
final String aType =
       mapWalker.step("info")
      .step(“aSchemaInfo")
      .step(“aType")
      .step("string")
      .<String>get().
      orElse(STATUS_INVALID);
```

Java Stream syntax

Optional.ofNullable

Optional.orElse

FLINK OBJECT EFFICIENCIES

```
StreamExecutionEnvironment env;
env.getConfig().enableObjectReuse();
```

REDUCE OBJECT CREATION AND GARBAGE COLLECTION

SEMANTIC ANNOTATIONS

```
@NonForwardedFields
@ForwardedFields
```

BE CAREFUL OF SIDE EFFECTS WITHIN OPERATORS

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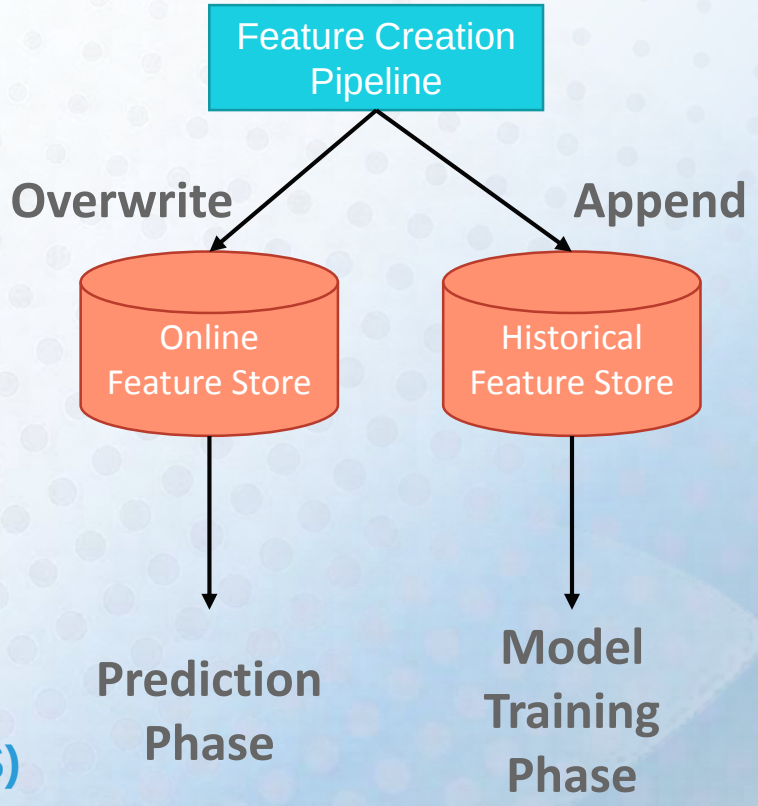
THE **FEATURE STORE** PROBLEM

WHAT IS A FEATURE STORE?

“FEATURE” IS A DATA POINT INPUT TO ML MODEL



WE NEED TO:

- **STORE ALL THE INPUT DATA POINTS**
- **SNAPSHOT AT ANY MOMENT IN TIME**
- **ASSOCIATE WITH A DIAGNOSIS (MODEL OUTPUT)**
- **HAVE ACCESS TO THE DATA POINTS (API FOR OTHER APPS)**
- **STORE ALL DATA POINTS FOR ML MODEL TRAINING**

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FIRST TRY: AWS AURORA RDBMS

"HEY IT SHOULD GET US UP TO 10,000 / SECOND"

…THE UPSERT PROBLEM

DIDN'T WORK MUCH PAST 3,000 / SECOND

…SOON OUR INPUT RATE WAS 20,000 / SECOND

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MITIGATION: STORE ONLY AT DIAGNOSIS TIME

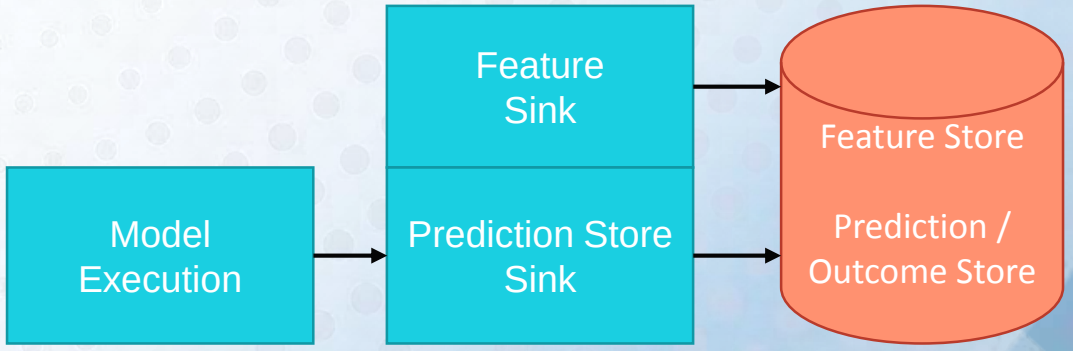
STOPPED STORING ALL RAW DATA POINTS

ONLY STORE DATA POINTS ALONGSIDE DIAGNOSIS

CON: ONLY A SMALL % OF DATA POINTS

CON: DATA NOT CURRENT, ONLY AS OF RECENT DIAGNOSIS

CON: LIMITED USEFULNESS



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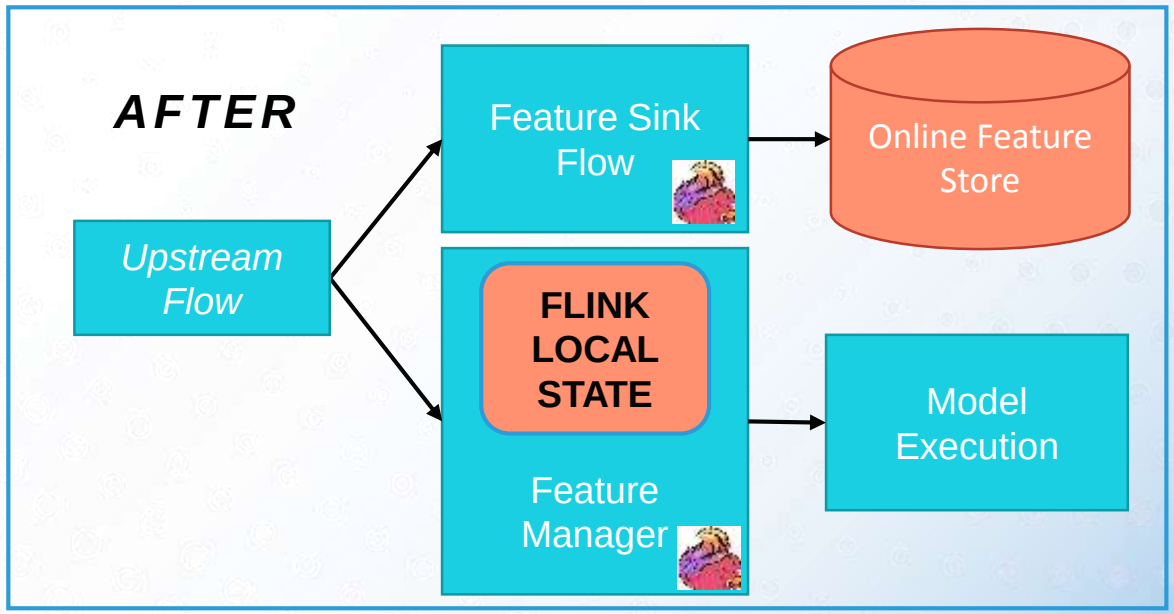
OPTIMIZING THE WRITE PATH

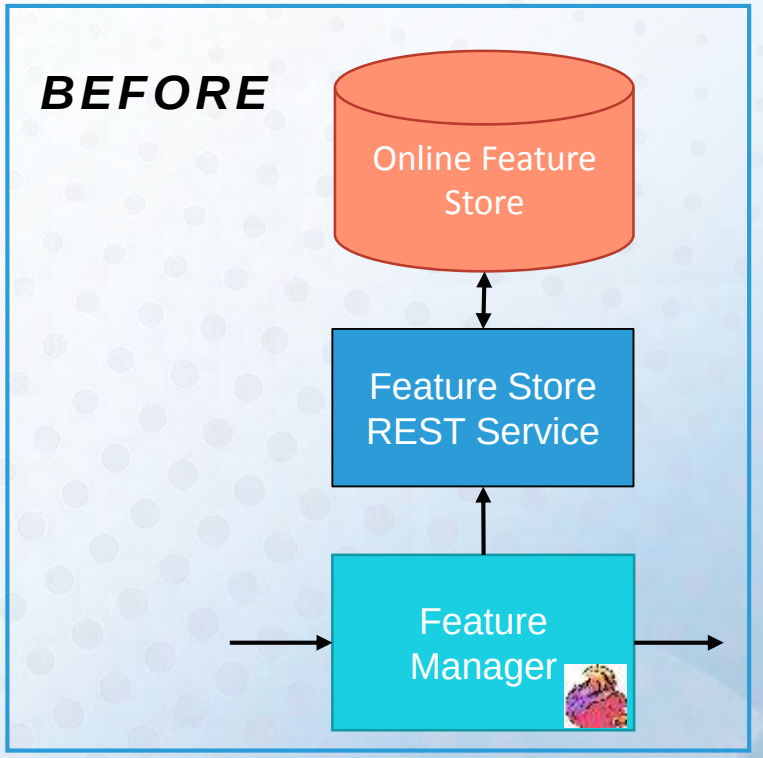
WHICH FLINK FLOW WRITES TO FEATURE STORE?

FEATURE STORE NOT NEEDED FOR TRIGGER

FEATURE STORE NOT NEEDED FOR MODEL EXECUTION

SEPARATE ‘TRANSFORM AND SINK’ FLOW





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ALTERNATIVE DATA STORES

REDIS

STORE ONLY LATEST DATA POINTS?

CASSANDRA

COST AND COMPLEXITY?

FLINK QUERYABLE STATE

PRODUCTION HARDENING?

READ VOLUME?

TIME SERIES DB

DRUID

INFLUX

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REDIS

WE ONLY NEED < 7 DAYS OF DATA, ONLY LATEST VALUE, SO USE REDIS AS THE KV STORE

ACCESSIBLE BY OTHER CONSUMERS OR VIA A SERVICE

COULDN'T PUT MORE THAN 8,000 / SECOND FOR A 'REASONABLE' CLUSTER SIZE

FLINK SINK CONNECTOR IS NOT CLUSTER-ENABLED

ONE OBJECT PUT PER CALL

JEDIS VS LETTUCE FRAMEWORK AND PIPELINING

SOME OPTIMIZATION IF ABLE TO BATCH REDIS SHARDS BY PRE-COMPUTING

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FLINK QUERYABLE STATE

REUSE OUR FEATURE REQUEST/RESPONSE FRAMEWORK

SCALABLE, FAST

OUR READ LOAD IS LOW (10 / SECOND)

EXPENSIVE (RELATIVELY)

NOT A “PRODUCTION” CAPABILITY

NOT A “DATABASE” TECHNOLOGY

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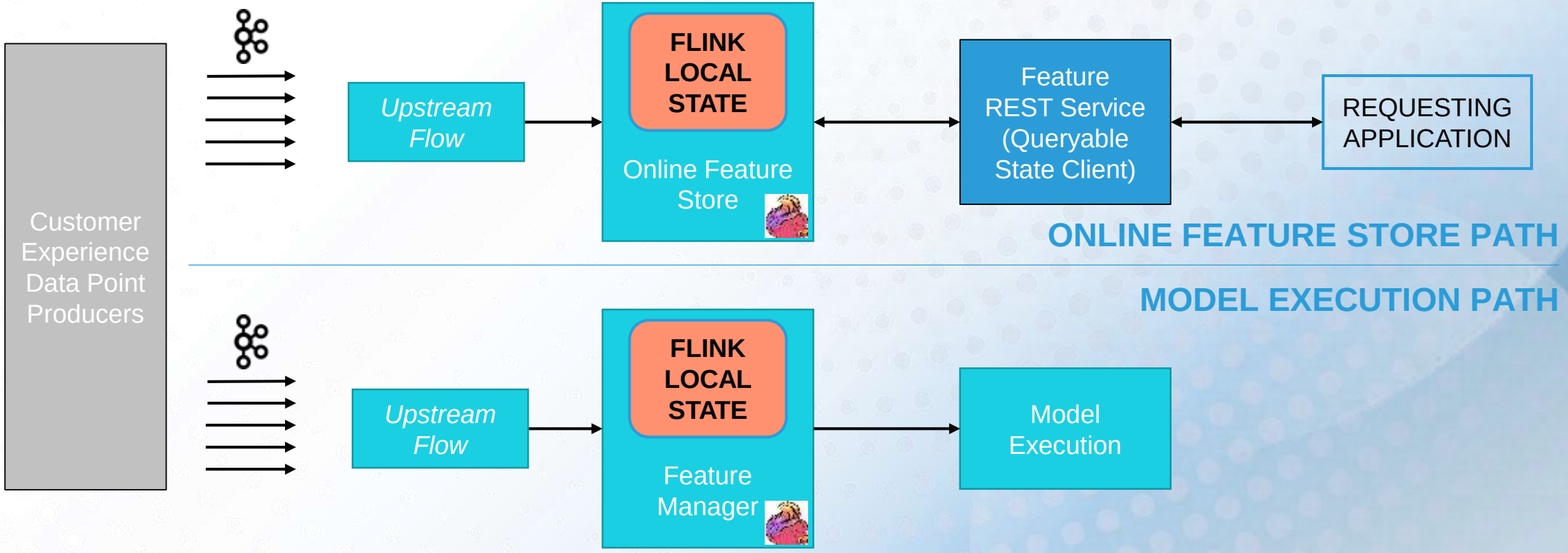
QUERYABLE STATE - ONLINE FEATURE STORE



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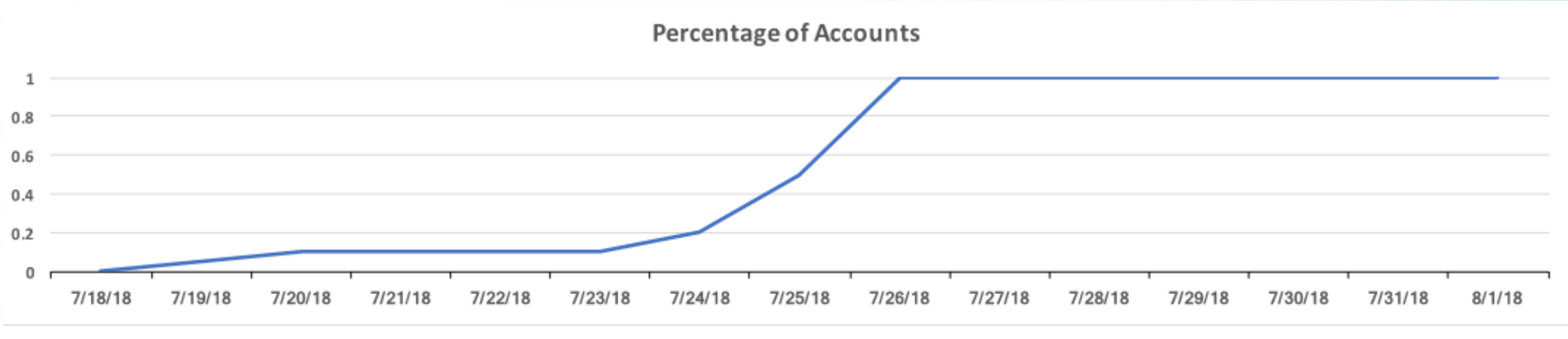
THE **VOLUME** PROBLEM

RAMPED UP PRODUCTION – JULY 2018



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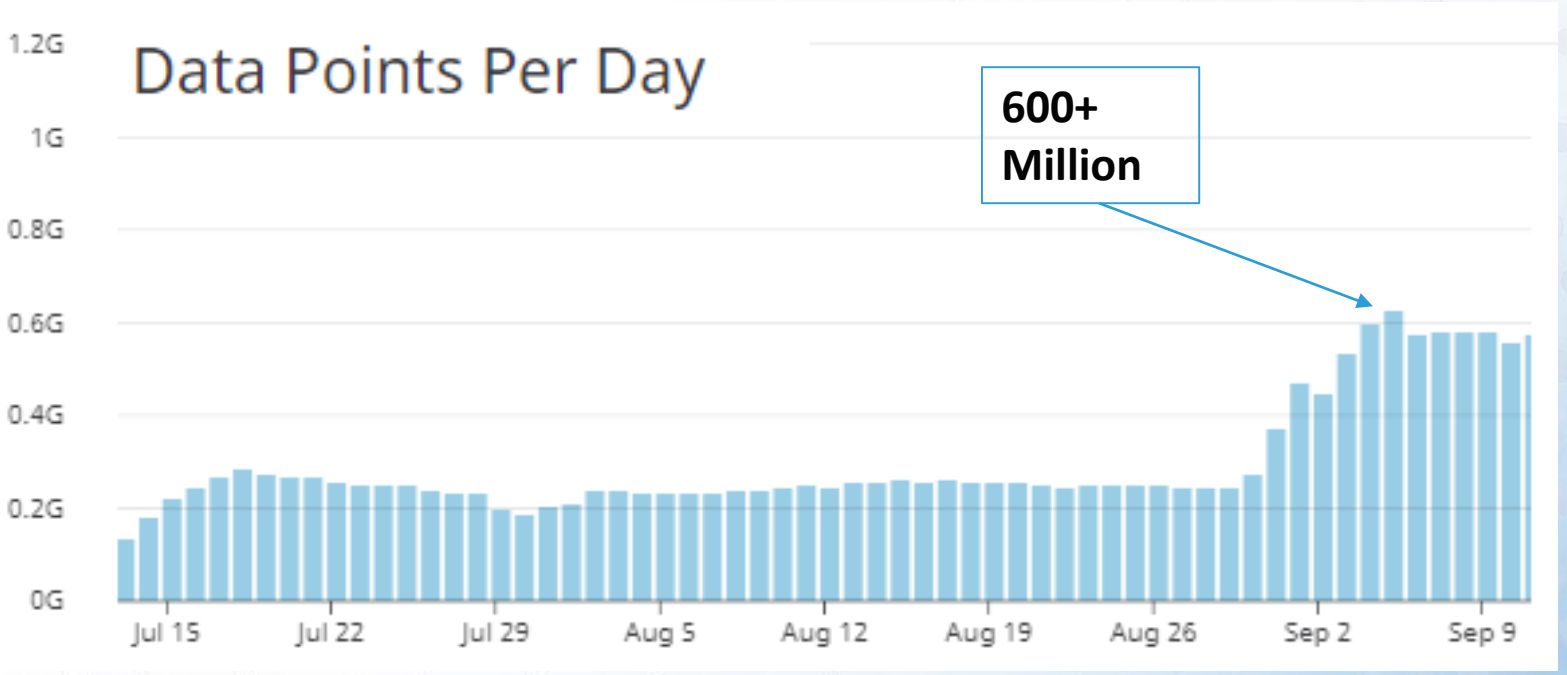
ADDED NEW DATA POINT TYPES



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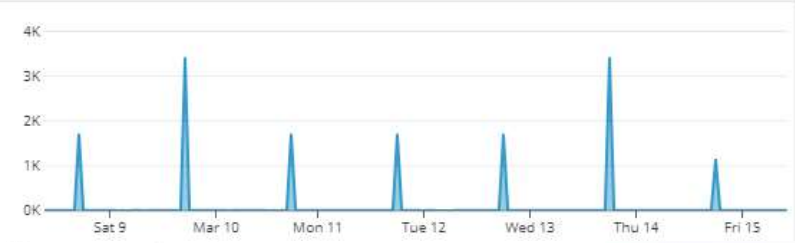
INCREASED DATA POINT FREQUENCY

ONCE EVERY 24 HOURS



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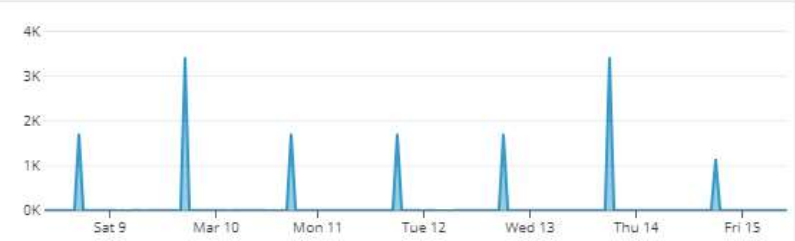
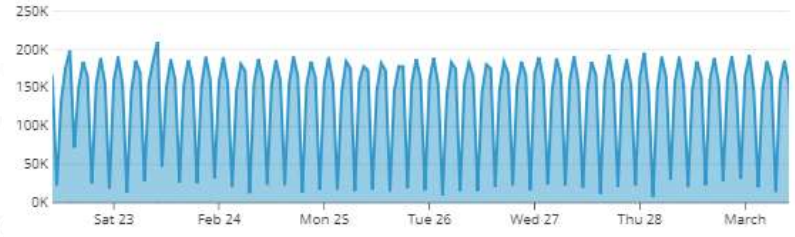


ONCE EVERY 4 HOURS



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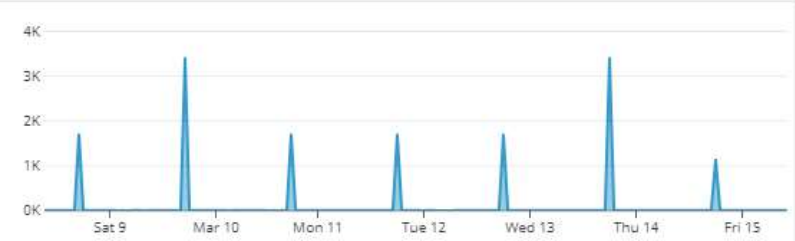

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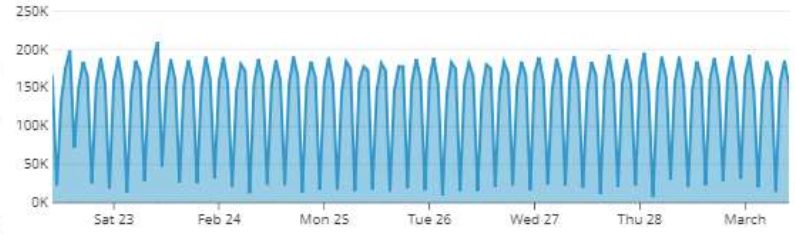

ONCE EVERY 5 MINUTES ???

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SYMPTOM: KAFKA LATENCY INCREASING

FLINK CLUSTER COULDN'T KEEP UP WITH KAFKA VOLUME

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KAFKA OPTIMIZATION

INCREASE PARTITIONS

1 KAFKA PARTITION

READ BY

1 FLINK TASK THREAD

MATCH PARALLELISM TO PARTITIONS (OR EVEN MULTIPLE)

100 KAFKA PARTITIONS

50 SLOT PARALLELISM

50 KAFKA PARTITIONS

50 SLOT PARALLELISM

ADJUST KAFKA CONFIGURATION

 # KAFKA CONSUMER SETTINGS

MAX.POLL.RECORDS = ~~500~~ 10000

FETCH.MIN.BYTES = ~~1~~ 102400

FETCH.MAX.WAIT.MS = ~~500~~ 1000

 # KAFKA PRODUCER SETTINGS

BUFFER.MEMORY = 268435456

BATCH.SIZE = ~~131072~~ 524288

LINGER.MS = ~~0~~ 50

REQUEST.TIMEOUT.MS = ~~90000~~ 600000

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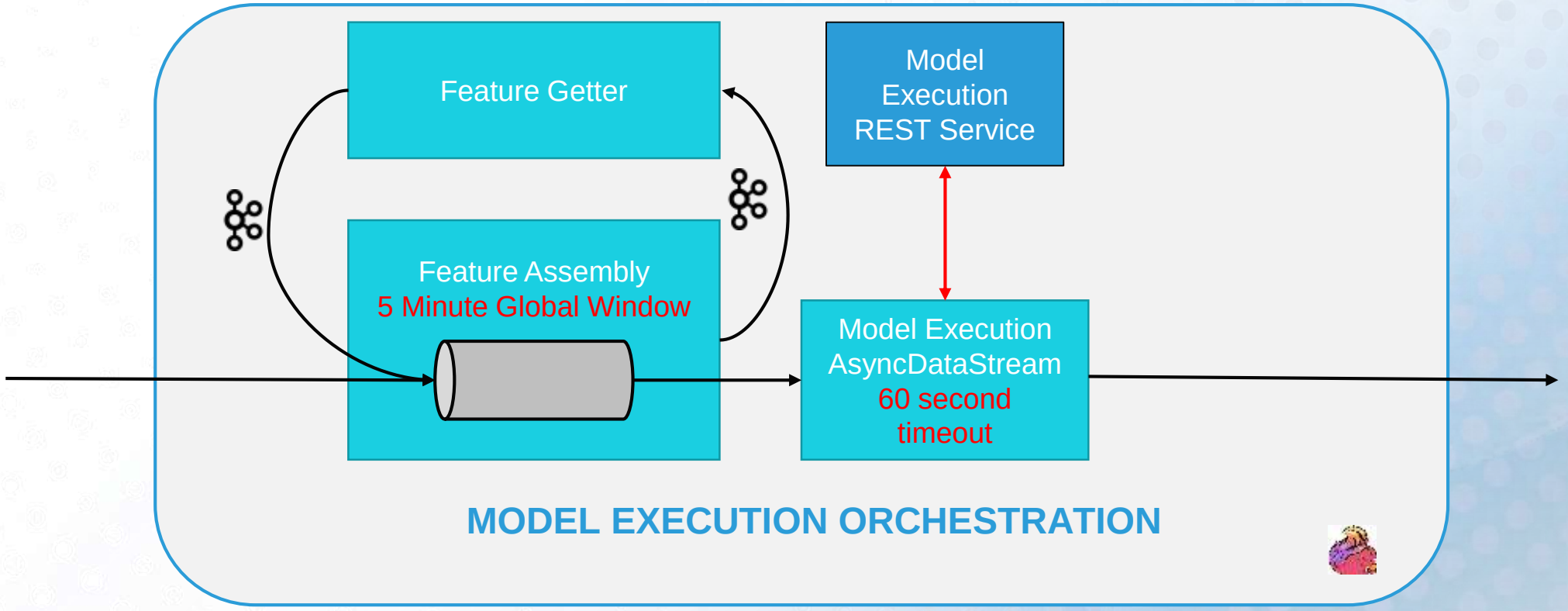
MODEL EXECUTION BACKUP PROBLEM

GENERAL SLOWNESS BACKS UP MODEL EXECUTION PIPELINE



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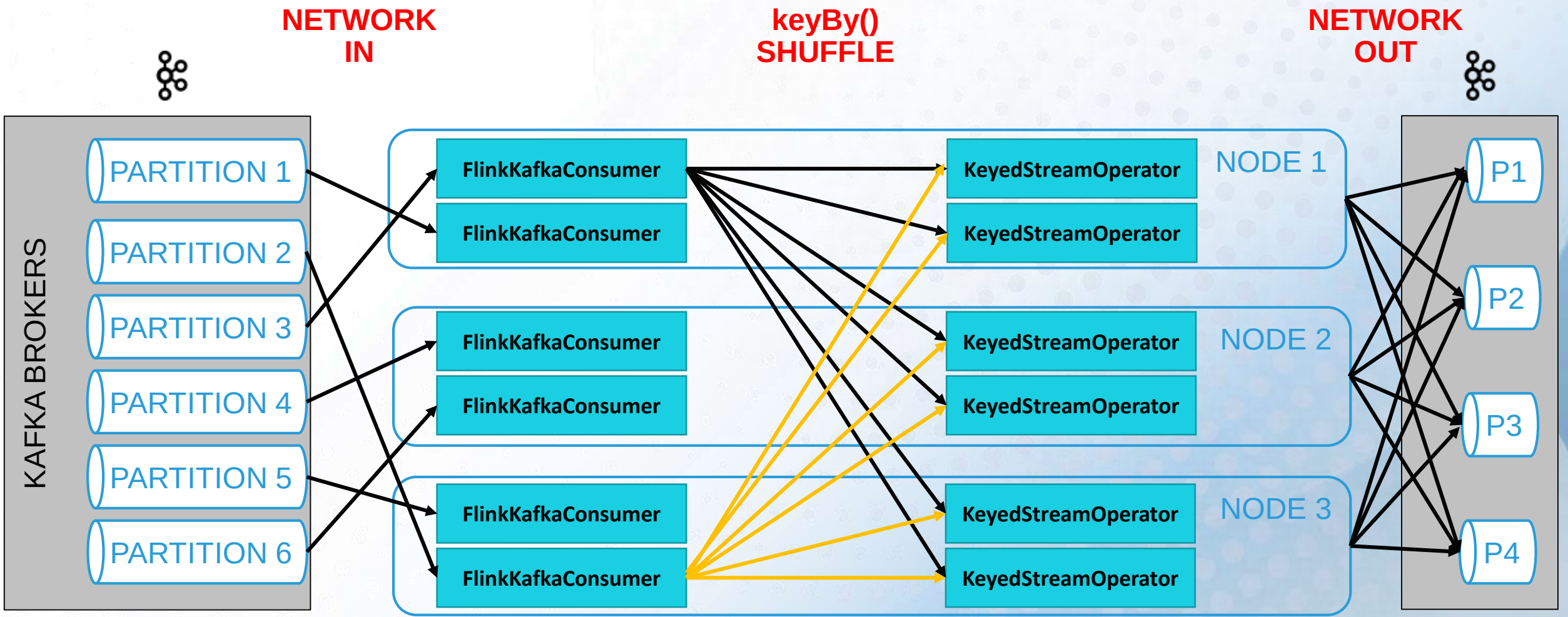
CLUSTER NETWORK I/O TRAFFIC



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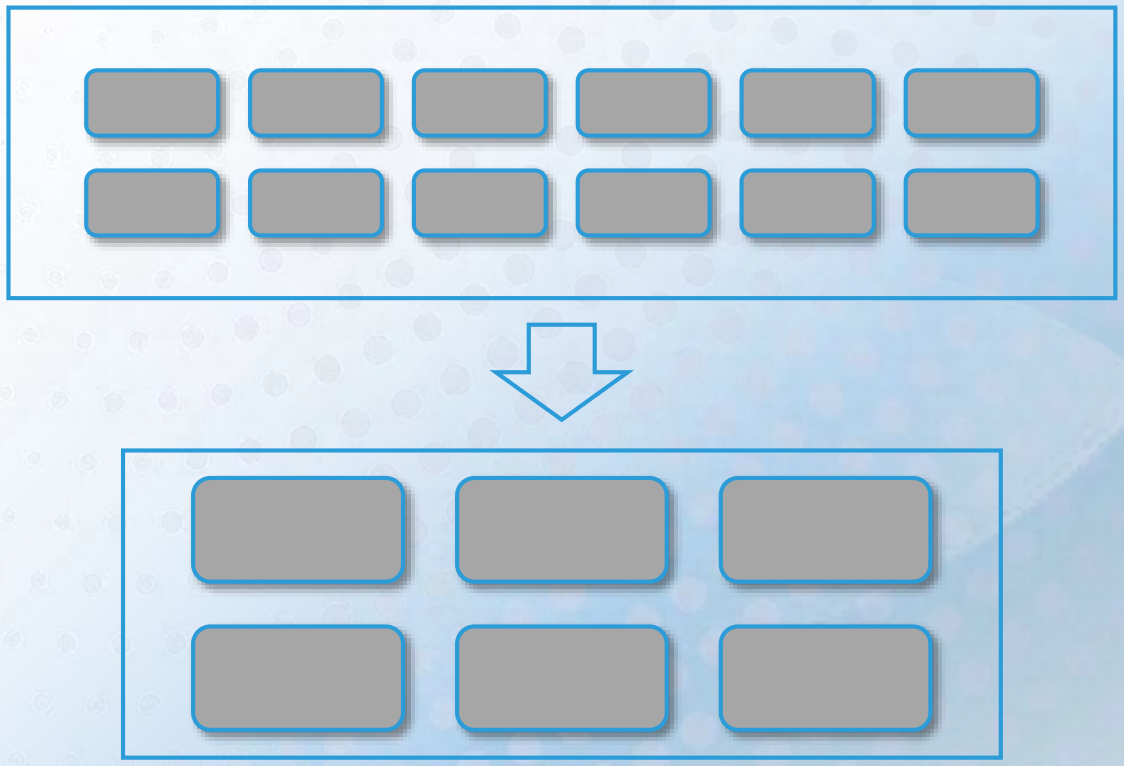
CLUSTER NETWORK I/O VOLUME

(10,000 MESSAGES / SECOND) * (1KB / MESSAGE) =
10 MB / SECOND

100 MBITS/SEC NETWORK

SOLUTION – LARGER NODE TYPES WITH MORE VCPU AND HIGHER PARALLELISM… FEWER NODES IN CLUSTER

SWEET SPOT SEEMED TO BE ~20 NODES



GOOD READ: HTTPS://WWW.VERVERICA.COM/BLOG/HOW-TO-SIZE-YOUR-APACHE-FLINK-CLUSTER-GENERAL-GUIDELINES

COMCAST

THE **CUSTOMER STATE** PROBLEM

KEEPING TRACK OF DATA POINT STATE

25+ MILLION HIGH SPEED INTERNET CUSTOMERS

10+ DATA POINT TYPES

TWO FLINK STATES TO MANAGE:

RED / GREEN "TRIGGER"

MAPSTATE () / KEYBY (ENTITY ID)

[ENTITY ID] (DATA POINT TYPE, STATE)

25 MILLION CUSTOMERS

10+ DATA POINT TYPES

AVG 33 BYTES PER ENTITY ID

~1GB TOTAL

QUERYABLE STATE FEATURE STORE

UP TO 15KB (JSON) PER DATA POINT

10KB * 25 MILLION = 250 GB

1KB * 25 MILLION = 25 GB

APPROXIMATE TOTAL = 1 TB

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THE **CHECKPOINT** PROBLEM

CHECKPOINT TUNING

FEATURE MANAGER – UP TO 1TB OF STATE

2.5 MINUTES WRITING A CHECKPOINT EVERY 10 MINUTES

TURNED OFF FOR AWHILE!

(RATIONALE: WOULD ONLY TAKE A FEW HOURS TO RECOVER ALL STATE)

INCREMENTAL CHECKPOINTING HELPED

LONG ALIGNMENT TIMES ON HIGH PARALLELISM

REDUCED THE SIZE OF STATE FOR 4 AND 24 HOUR WINDOWS USING FEATURE LOOKUP TABLE

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THE **HA** PROBLEM

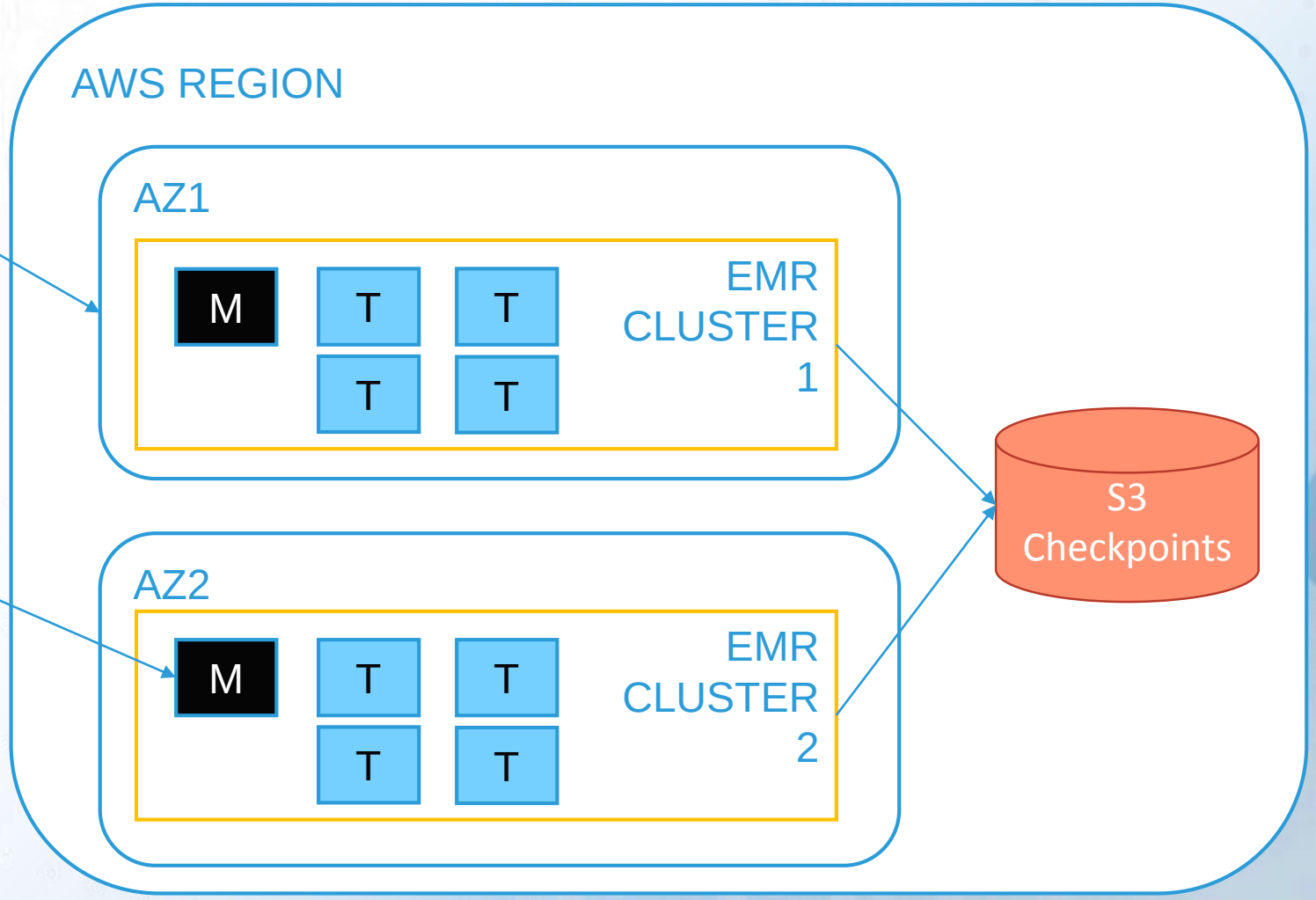
AMAZON EMR AND HIGH AVAILABILITY

EMR FLINK CLUSTER

SINGLE AVAILABILITY ZONE (AZ)

SINGLE MASTER NODE

NOT HA



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AMAZON AWS EMR

SESSIONS KEPT DYING

TMP DIR IS PERIODICALLY CLEARED

BREAKS ‘BLOB STORE’ ON LONG RUNNING JOBS

SOLUTION - CONFIGURE TO NOT BE IN /TMP

jobmanager.web.tmpdir

blob.storage.directory

EMR FLINK VERSION LAGS

APACHE RELEASE BY 1-2 MONTHS

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TECHNOLOGY OPTIONS

FLINK ON KUBERNETES

AMAZON EKS (ELASTIC KUBERNETES SERVICE)

SELF-MANAGED KUBERNETES ON EC2

~~DATA ARTISANS~~ VERVERICA PLATFORM

Bonus:
Reduced Cost / Overhead by having fewer Master Nodes

Less overhead for smaller (low parallelism) flows

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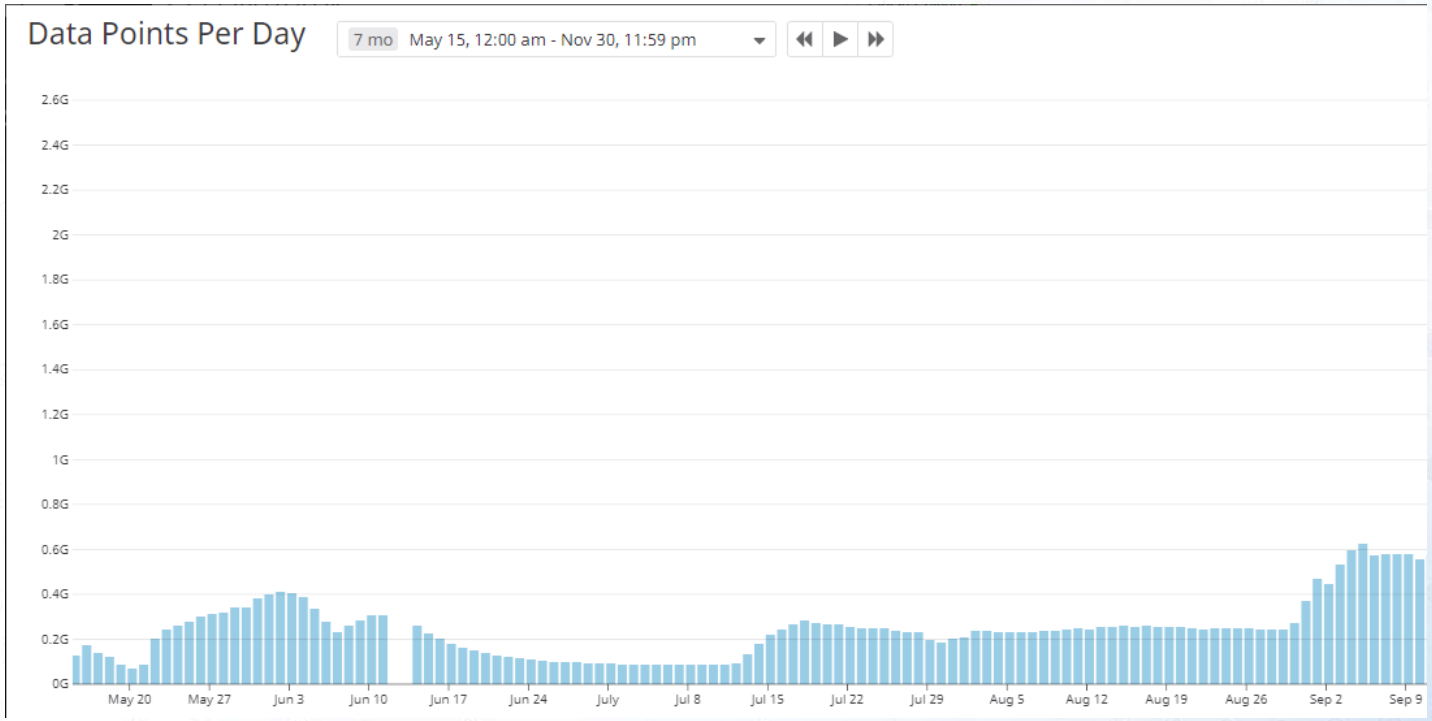
THE **REALLY HIGH VOLUME AND FEATURE STORE** PROBLEM #2

DATA POINT VOLUME MAY–NOVEMBER 2018



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DATA POINT VOLUME MAY–NOVEMBER 2018

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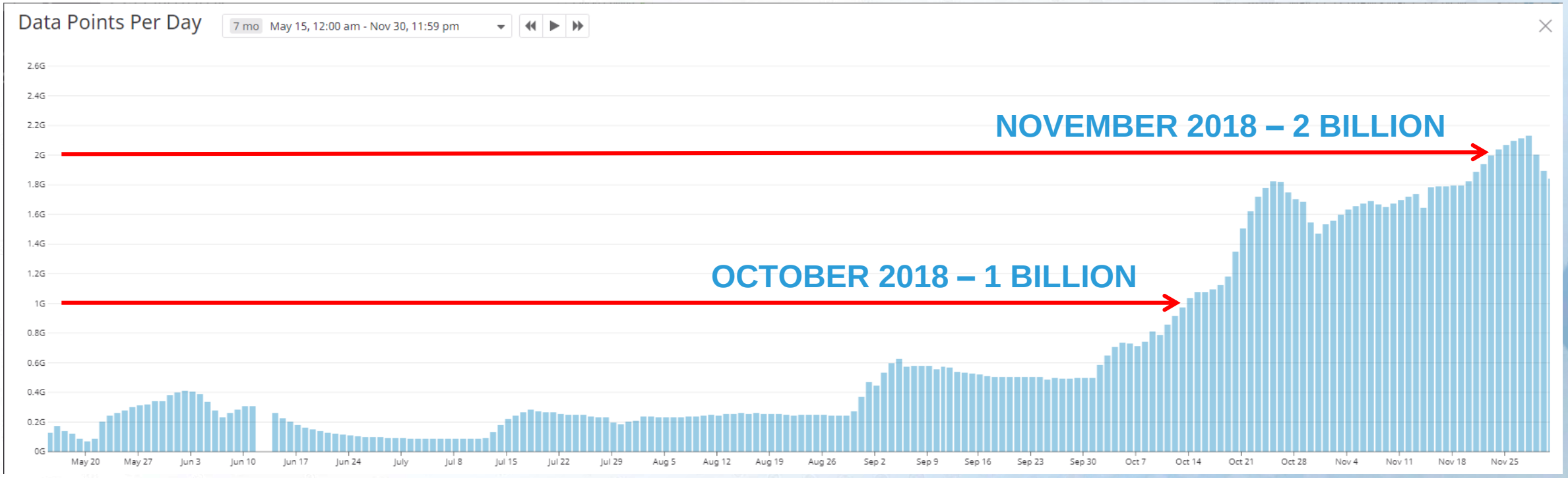
DATA POINT VOLUME MAY–NOVEMBER 2018



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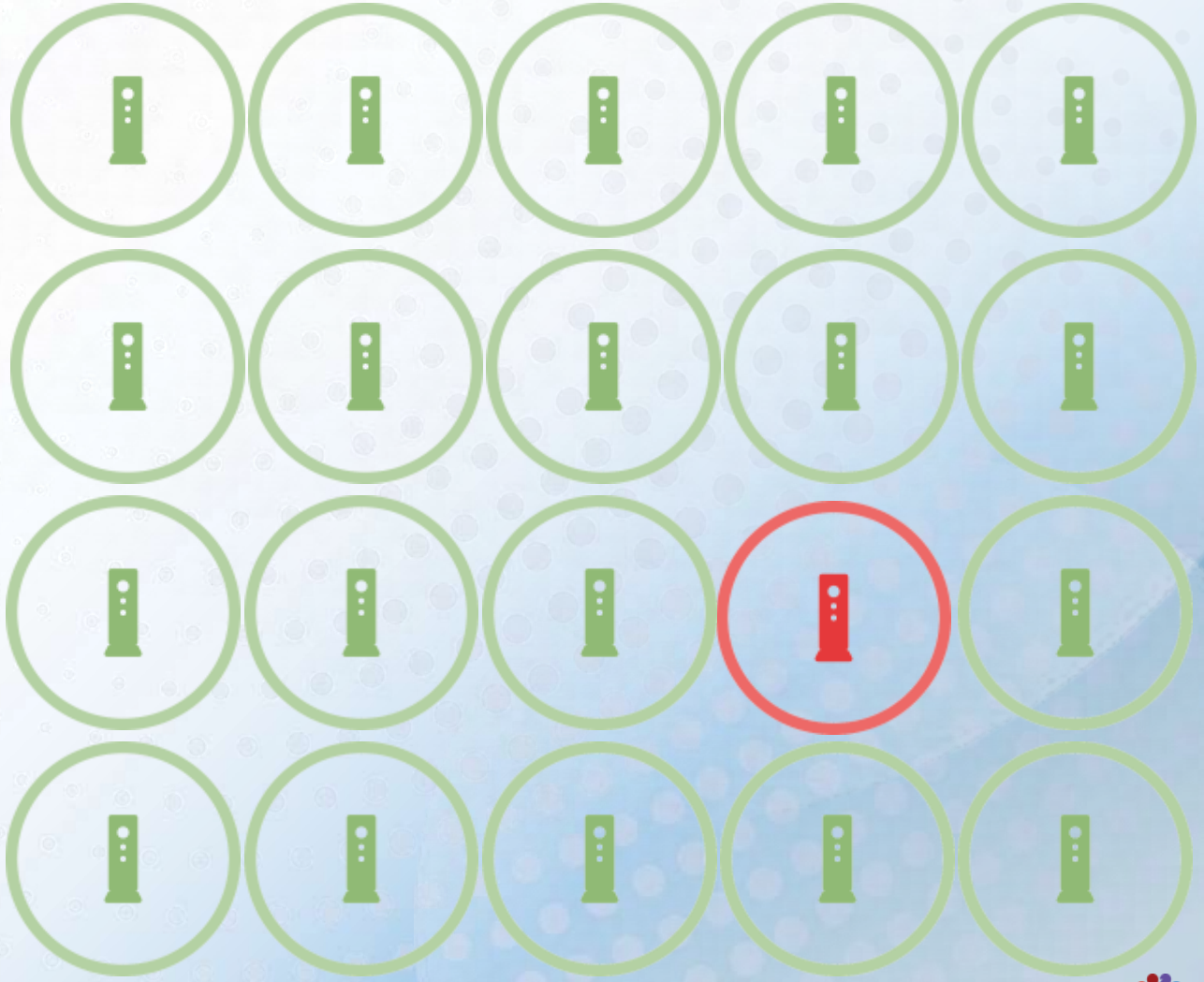
LET'S ADD ANOTHER 3 BILLION!

15 MILLION DEVICES

3 BILLION DATA POINTS



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SOLUTION APPROACH

1 ISOLATE TRIGGER FOR HIGH-VOLUME DATA POINT TYPES

2 ISOLATE ONLINE FEATURE STORE FOR HIGH- VOLUME DATA POINT TYPES

3 ISOLATE DEDICATED FEATURE STORAGE FLOW TO HIGH-SPEED FEATURE STORE

4 SEPARATE HISTORICAL FEATURE STORAGE (S3 WRITER) FROM REAL TIME MODEL EXECUTION FLOWS

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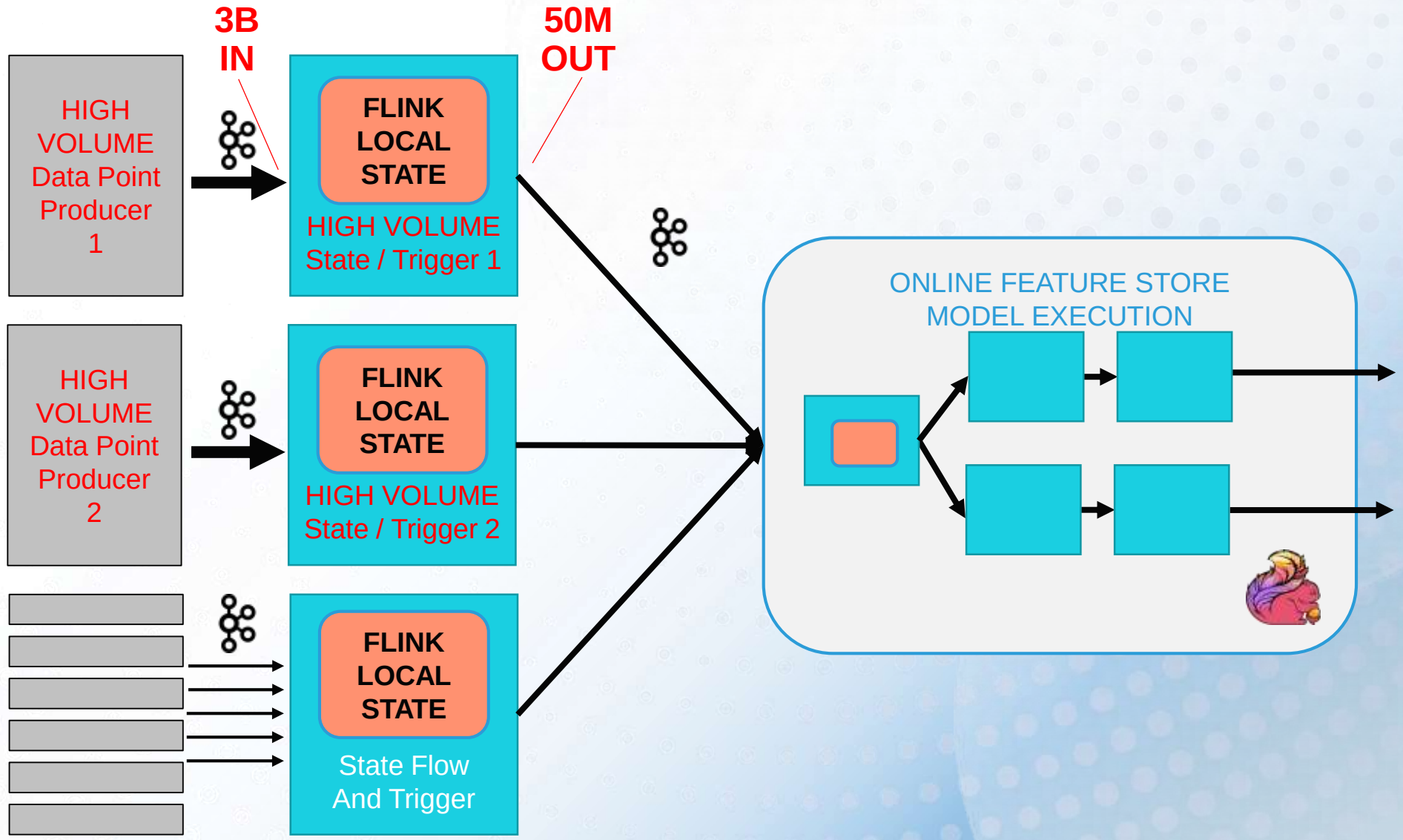
1: SEPARATE HIGH VOLUME TRIGGER FLOWS



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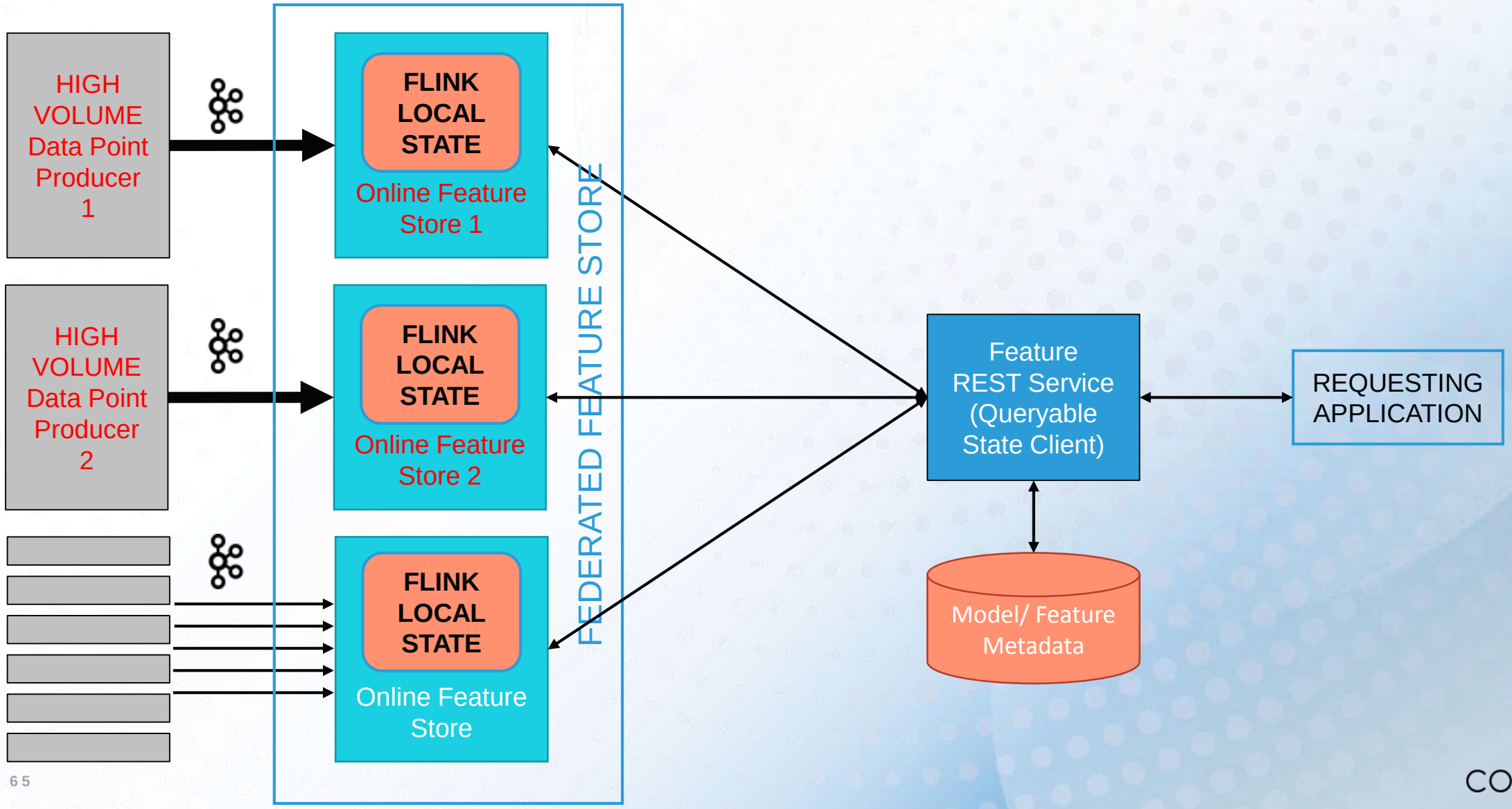
2: FEDERATED ONLINE FEATURE STORE



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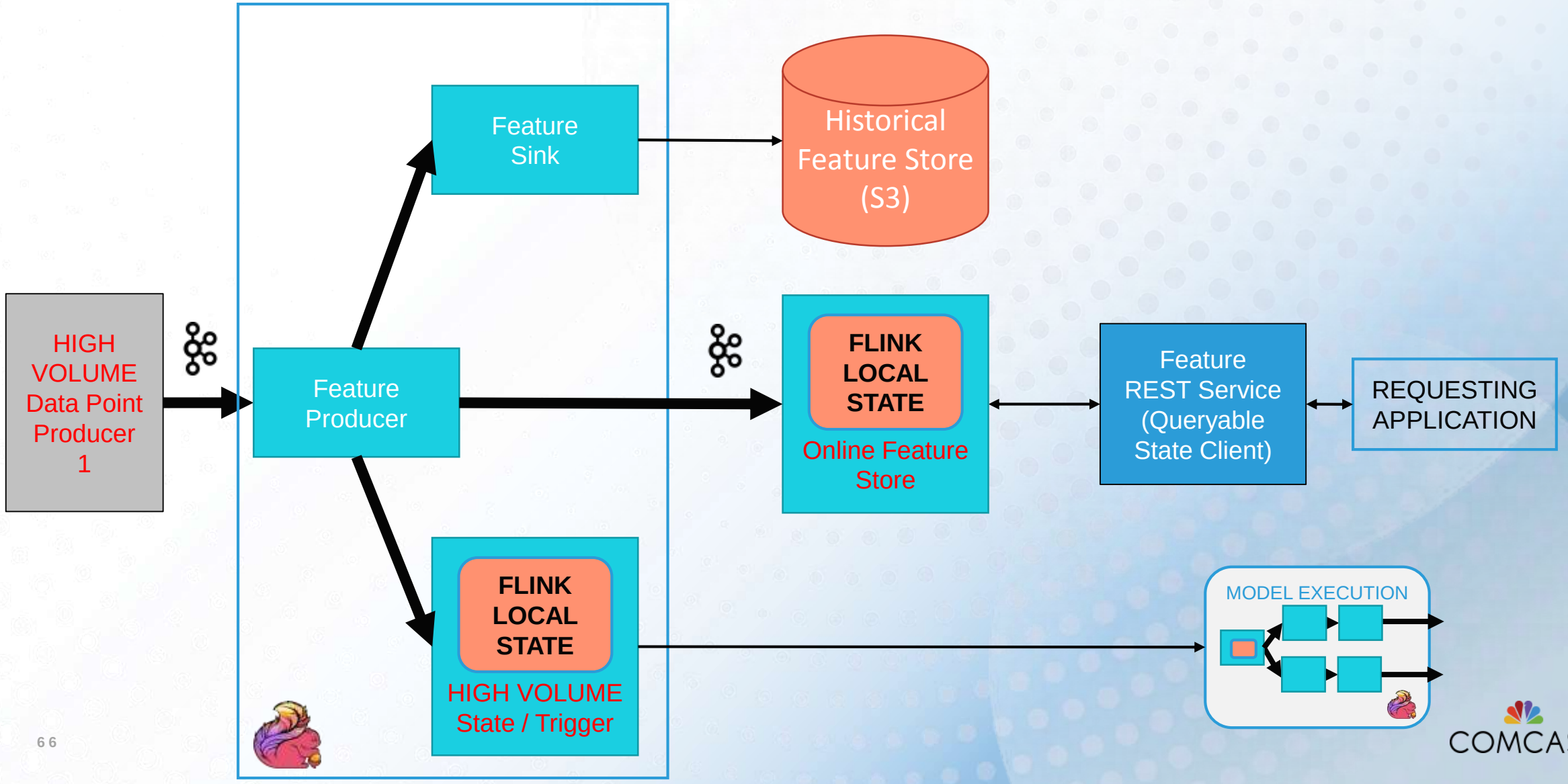
3+4: HISTORICAL FEATURE STORE



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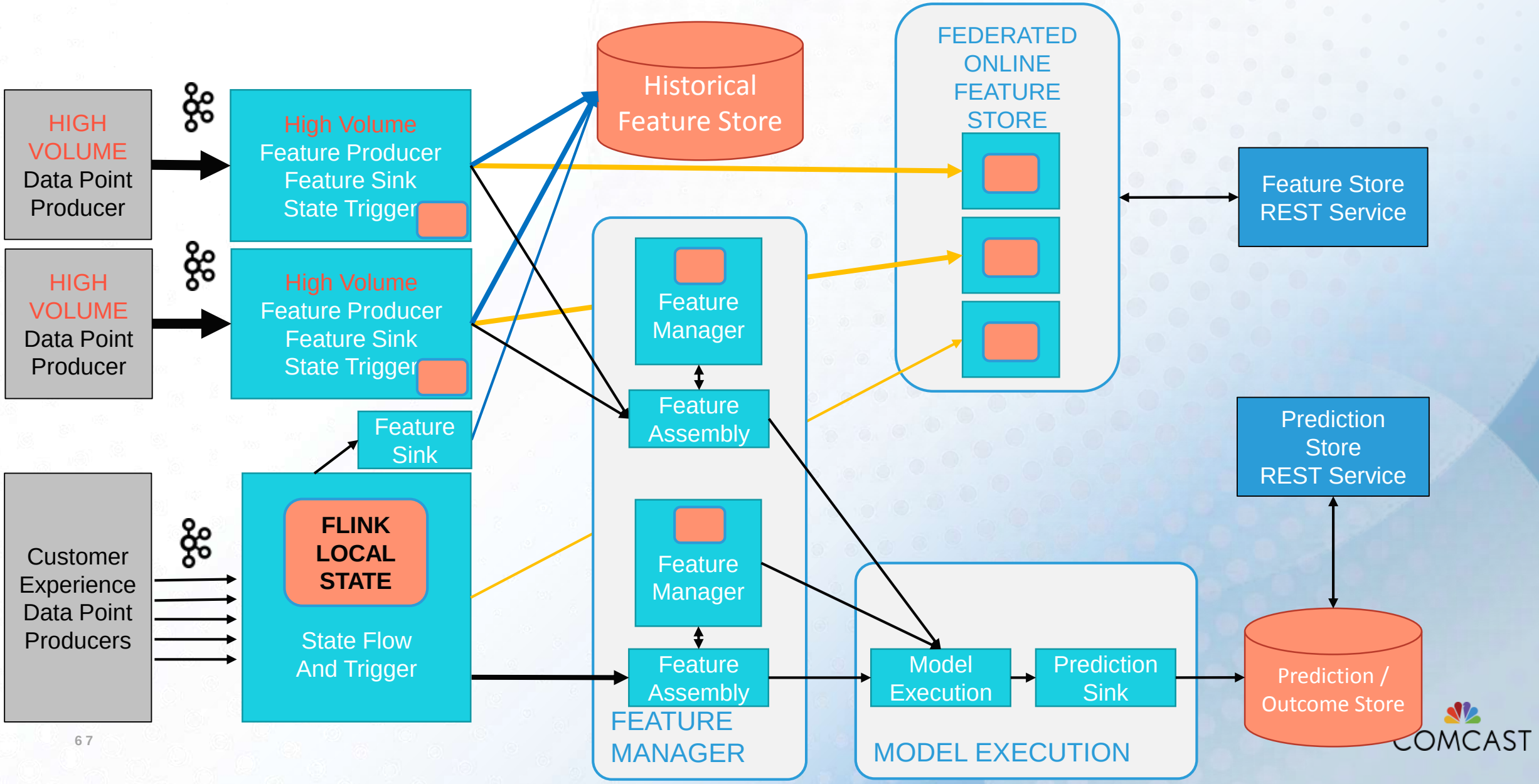
CURRENT ARCHITECTURE



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WHERE ARE WE TODAY

INDICATORS

725+ MILLION DATA POINTS PER DAY

HIGH-VOLUME INDICATORS

6 BILLION PER DAY

TOTAL

~7 BILLION DATA POINTS PER DAY

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WHERE ARE WE TODAY – FLINK CLUSTERS

CLUSTERS

14

INSTANCES

150

VCPU

1100

RAM

5.8 TB

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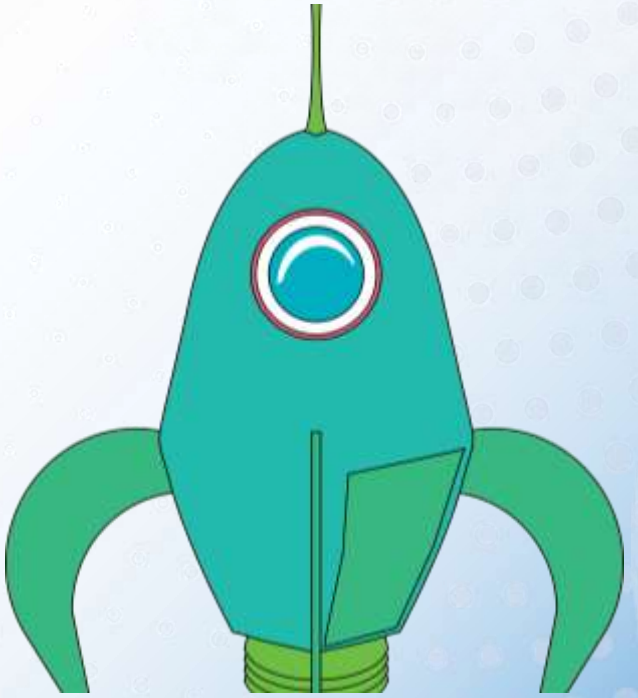
FUTURE WORK

EXPAND CUSTOMER EXPERIENCE INDICATORS TO OTHER COMCAST PRODUCTS

IMPROVED ML MODELS BASED ON RESULTS AND CONTINUOUS RETRAINING

MODULAR MODEL EXECUTION VIA KUBEFLOW AND GRPC CALLS



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WE'RE HIRING!

PHILADELPHIA
WASHINGTON, D.C.
MOUNTAIN VIEW
DENVER

COMCAST

THANK YOU!


COMCAST