



# Building Modern Data Streaming Apps

Tim Spann  
Principal Developer Advocate

10-May-2023

THE LINUX FOUNDATION





CLOUDERA



CLOUDERA

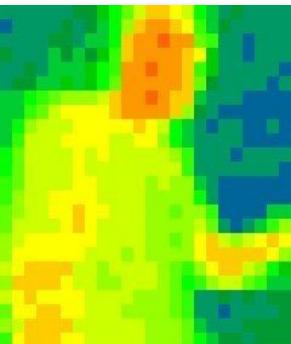


EDGE  
2AI

CLOUDERA



# FLiPN-FLaNK Stack



**Tim Spann**

@PaasDev // Blog: [www.datainmotion.dev](http://www.datainmotion.dev)

Principal Developer Advocate.

Princeton Future of Data Meetup.

ex-Pivotal, ex-Hortonworks, ex-StreamNative, ex-PwC

<https://github.com/tspannhw/EverythingApacheNiFi>

<https://medium.com/@tspann>

Apache NiFi x Apache Kafka x Apache Flink x Java



# FLiP Stack Weekly



<https://bit.ly/32dAJft>



This week in Apache NiFi, Apache Flink, Apache Pulsar, Apache Spark, Apache Iceberg, Python, Java and Open Source friends.

# Future of Data - Princeton + Virtual



<https://www.meetup.com/futureofdata-princeton/>

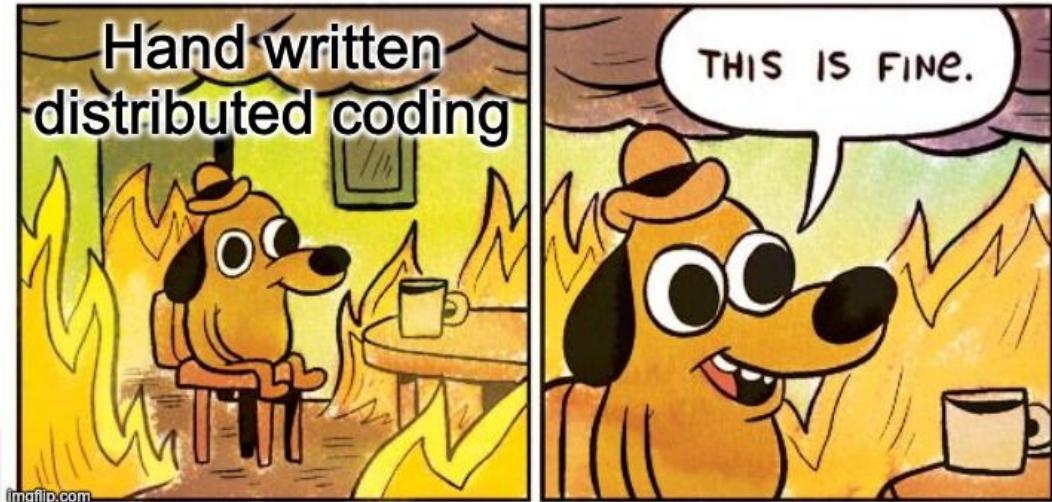
From Big Data to AI to Streaming to Containers to Cloud to Analytics to Cloud Storage to Fast Data to Machine Learning to Microservices to ...



@PaasDev

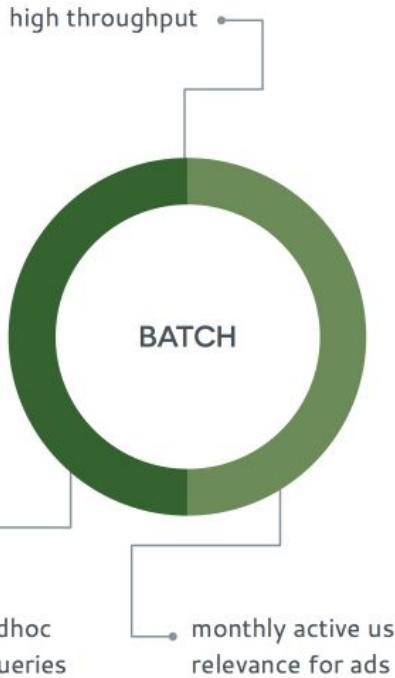
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# STREAMING

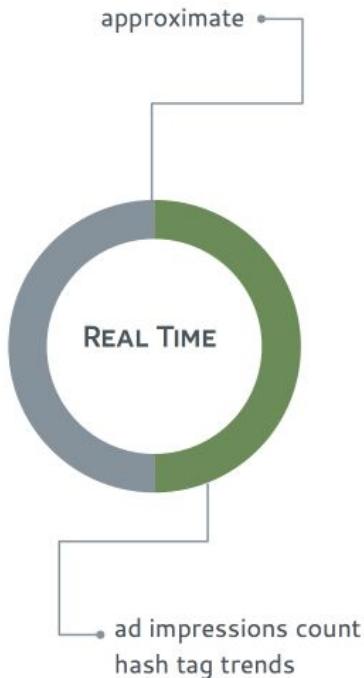


# What is Real-Time?

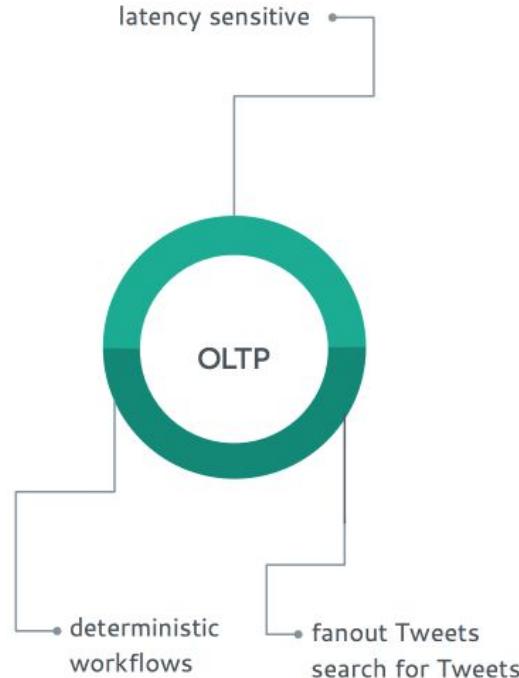
> 1 HOUR



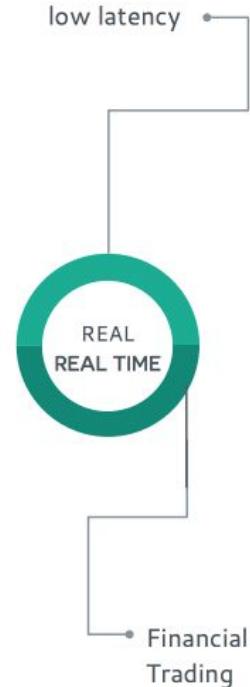
10 MS - 1 SEC



< 500 MS

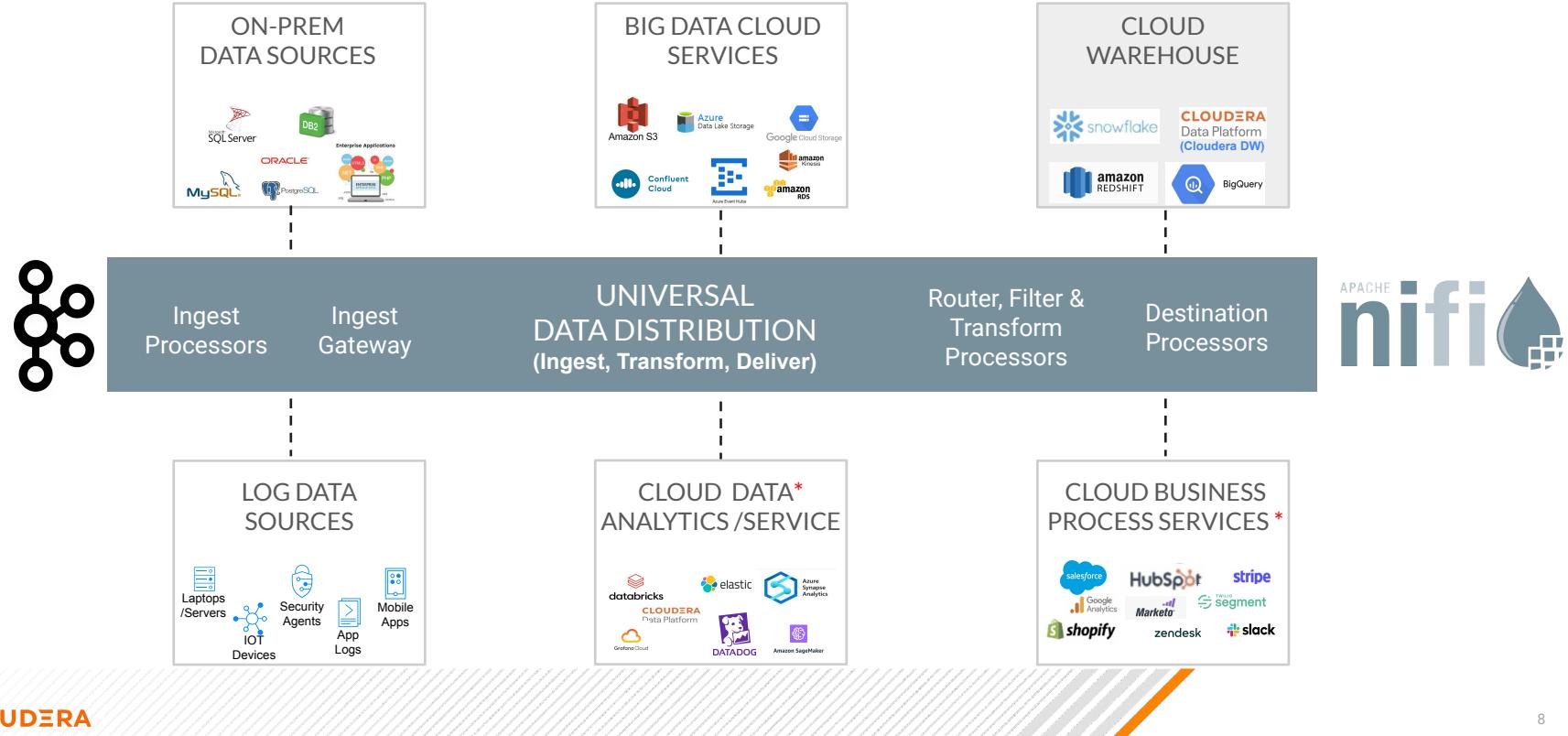


< 1 MS



# Streaming From ... To ...

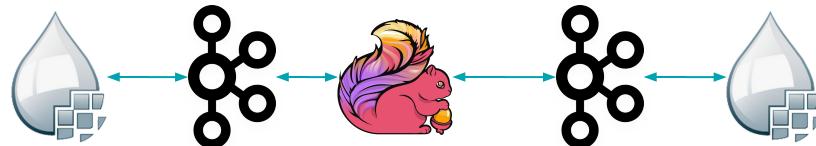
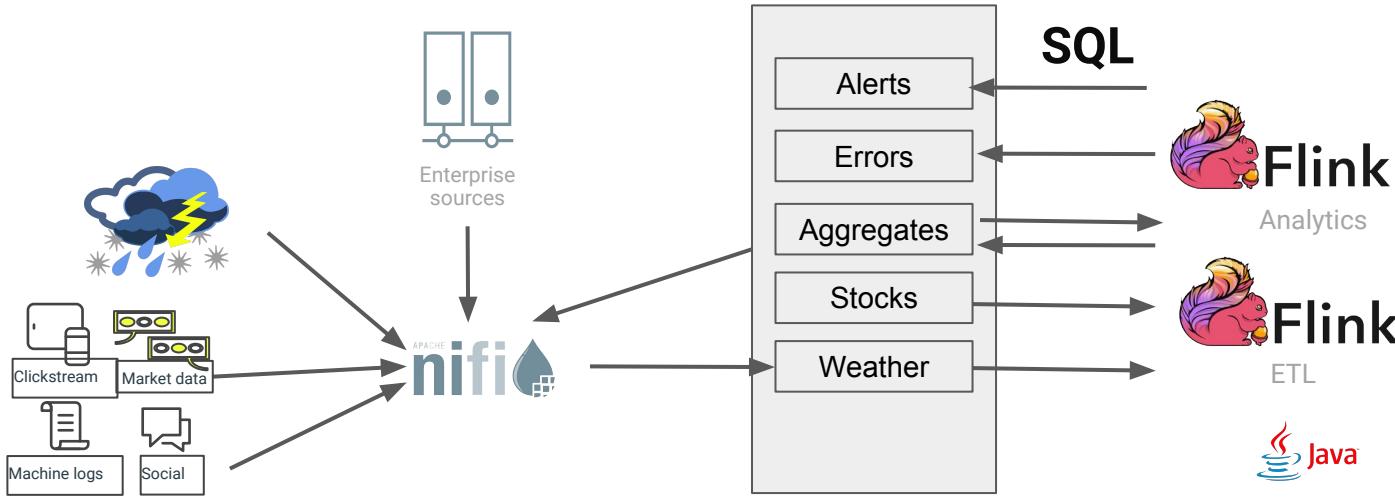
Data distribution as a first class citizen



# BUILDING REAL-TIME REQUIRES A TEAM



# End to End Streaming Pipeline Example

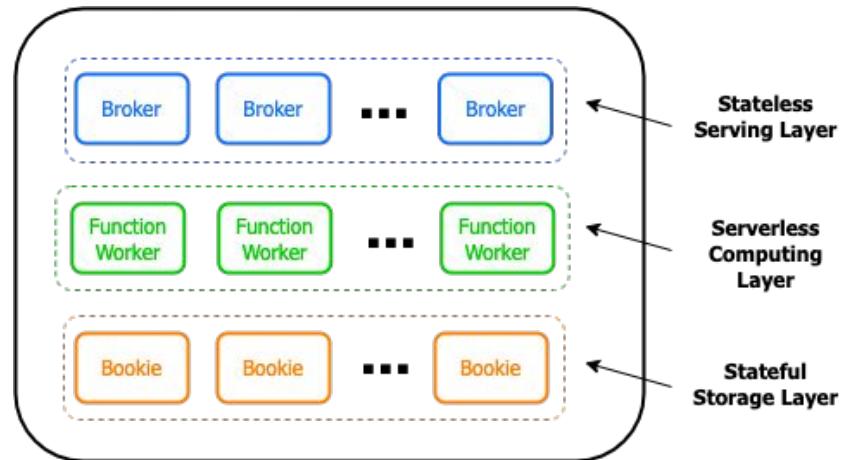


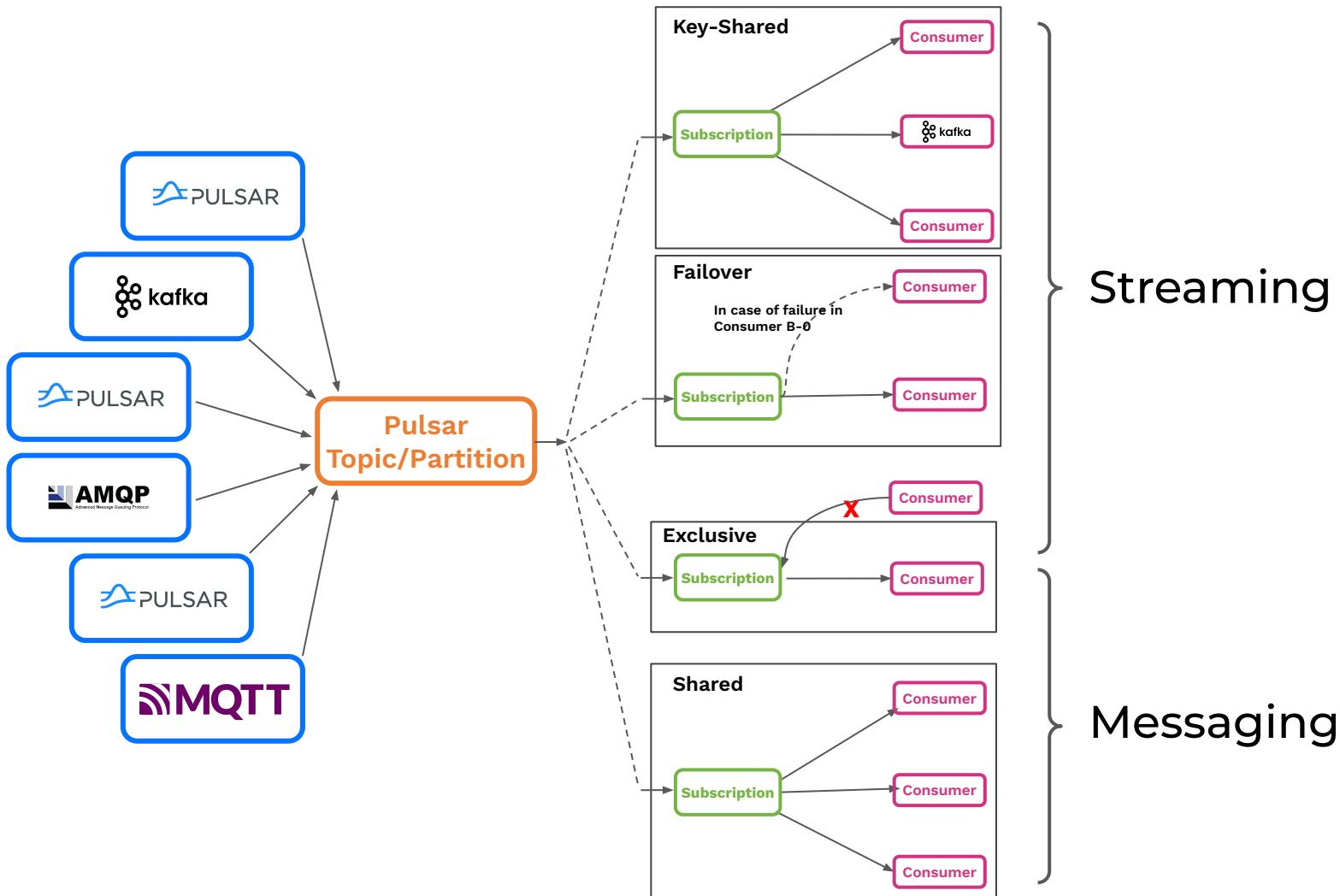
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# APACHE PULSAR

# Apache Pulsar

- Serverless computing framework.
- Unbounded storage, multi-tiered architecture, and tiered-storage.
- Streaming & Pub/Sub messaging semantics.
- Multi-protocol support.
- Open Source
- Cloud-Native

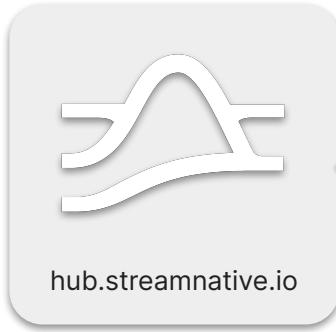




# Messages - the Basic Unit of Apache Pulsar

Component	Description
Value / data payload	The data carried by the message. All Pulsar messages contain raw bytes, although message data can also conform to data schemas.
Key	Messages are optionally tagged with keys, used in partitioning and also is useful for things like topic compaction.
Properties	An optional key/value map of user-defined properties.
Producer name	The name of the producer who produces the message. If you do not specify a producer name, the default name is used.
Sequence ID	Each Pulsar message belongs to an ordered sequence on its topic. The sequence ID of the message is its order in that sequence.

# Apache Pulsar Ecosystem



## Protocol Handlers



## Client Libraries



## Connectors (Sources & Sinks)



## Pulsar Functions (Lightweight Stream Processing)



## Processing Engines



## Data Offloaders (Tiered Storage)



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# APACHE KAFKA

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# What is Apache Kafka?

**Distributed:** horizontally scalable

**Partitioned:** the data is split-up and distributed across the brokers

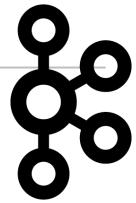
**Replicated:** allows for automatic failover

**Unique:** Kafka does not track the consumption of messages (the consumers do)

**Fast:** designed from the ground up with a focus on performance and throughput

Kafka was built at LinkedIn in 2011

Open sourced as an Apache project



# Yes, Franz, It's Kafka

Let's do a metamorphosis on your data. Don't fear changing data.

**You don't need to be a brilliant writer to stream data.**



Franz Kafka was a German-speaking Bohemian novelist and short-story writer, widely regarded as one of the major figures of 20th-century literature. His work fuses elements of realism and the fantastic.

[Wikipedia](#)



# What is Can You Do With Apache Kafka?

Web site activity: track page views, searches, etc. in real time

Events & log aggregation: particularly in distributed systems where messages come from multiple sources

Monitoring and metrics: aggregate statistics from distributed applications and build a dashboard application

Stream processing: process raw data, clean it up, and forward it on to another topic or messaging system

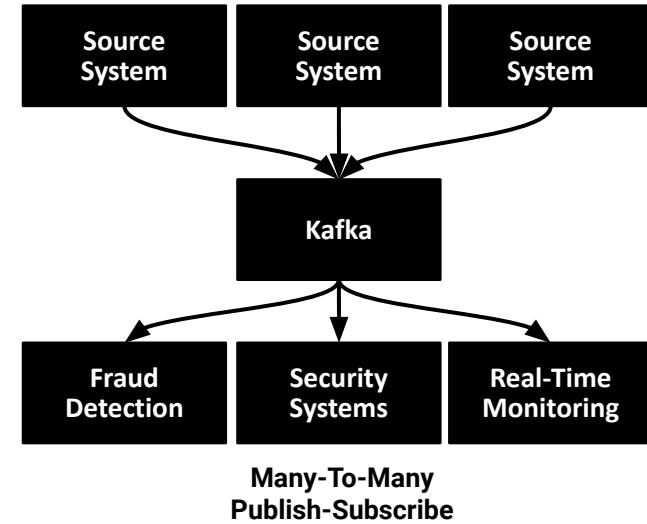
Real-time data ingestion: fast processing of a very large volume of messages

# Kafka Terms

- Kafka is a publish/subscribe messaging system comprised of the following components:
  - **Topic:** a message feed
  - **Producer:** a process that publishes messages to a topic
  - **Consumer:** a process that subscribes to a topic and processes its messages
  - **Broker:** a server in a Kafka cluster

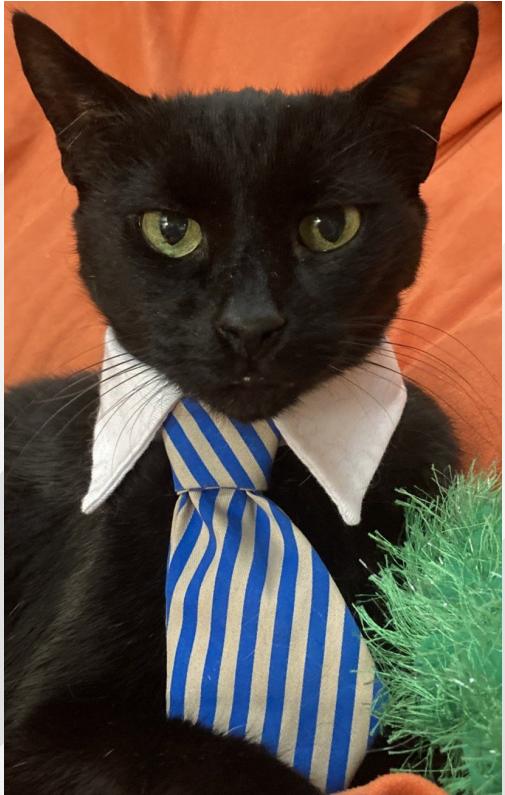
- Highly reliable distributed messaging system
- Decouple applications, enables many-to-many patterns
- Publish-Subscribe semantics
- Horizontal scalability
- Efficient implementation to operate at speed with big data volumes
- Organized by topic to support several use cases

## EVENTS



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# APACHE FLINK



# Flink SQL



- Streaming Analytics
- Continuous SQL
- Continuous ETL
- Complex Event Processing
- Standard SQL Powered by Apache Calcite

The screenshot shows the Apache Flink Dashboard interface. A job named "xenodochial\_noyce" is running. The job configuration includes a Kafka source reading from topic "weather2" and writing to a Sink. The data flow is visualized with arrows between components: KafkaSource -> Kafka TS assigner -> SourceConversionTablet (Parallelism: 1) -> Map (Parallelism: 1) -> Filter (Parallelism: 1) -> Reduce (Parallelism: 1) -> Webhook Process -> Sink. Task details show a start time of 2021-04-07 10:08:37 and a duration of 3h 56m 21s. Metrics include bytes received (0 B), records received (0), bytes sent (8.33 MB), and records sent (8,933).

<https://www.datainmotion.dev/2021/04/cloudera-sql-stream-builder-ssb-updated.html>

# Flink SQL

**Key Takeaway: Rich SQL grammar with advanced time and aggregation tools**

```
-- specify Kafka partition key on output
SELECT foo AS _eventKey FROM sensors

-- use event time timestamp from kafka
-- exactly once compatible
SELECT eventTimestamp FROM sensors

-- nested structures access
SELECT foo.'bar' FROM table; -- must quote nested
column

-- timestamps
SELECT * FROM payments
WHERE eventTimestamp > CURRENT_TIMESTAMP-interval
'10' second;

-- unnest
SELECT b.* , u.*
FROM bgp_avro b,
UNNEST(b.path) AS u(pathitem)

-- aggregations and windows
SELECT card,
MAX(amount) as theamount,
TUMBLE_END(eventTimestamp, interval '5' minute) as
ts
FROM payments
WHERE lat IS NOT NULL
AND lon IS NOT NULL
GROUP BY card,
TUMBLE(eventTimestamp, interval '5' minute)
HAVING COUNT(*) > 4 -- >4==fraud

-- try to do this ksql!
SELECT us_west.user_score+ap_south.user_score
FROM kafka_in_zone_us_west us_west
FULL OUTER JOIN kafka_in_zone_ap_south ap_south
ON us_west.user_id = ap_south.user_id;
```

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# DATAFLOW APACHE NIFI



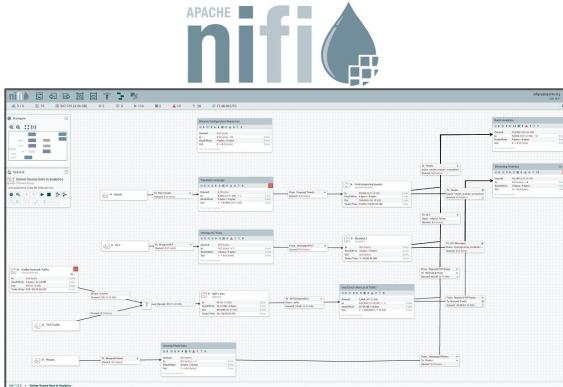
# What is Apache NiFi?

**Apache NiFi** is a scalable, real-time streaming data platform that collects, curates, and analyzes data so customers gain key insights for immediate actionable intelligence.

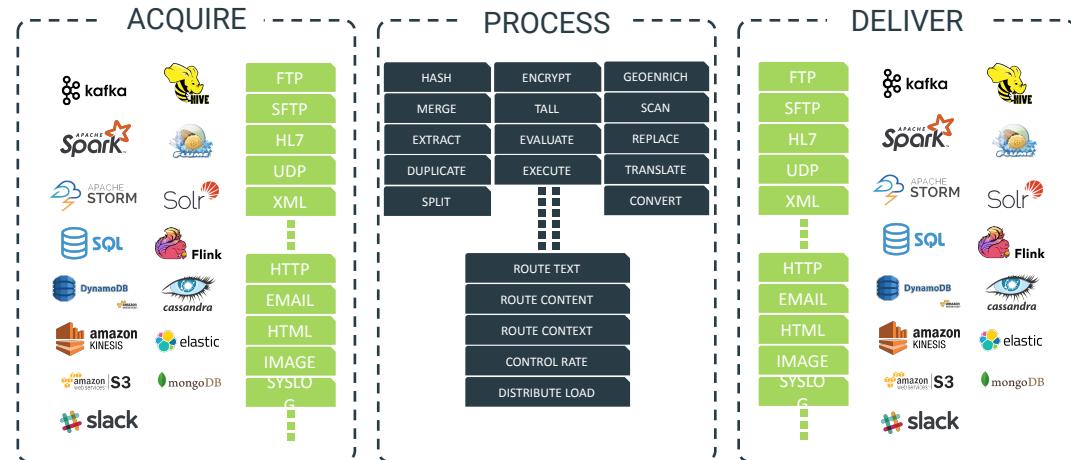


# Apache NiFi

Enable easy ingestion, routing, management and delivery of any data anywhere (Edge, cloud, data center) to any downstream system with built in end-to-end security and provenance



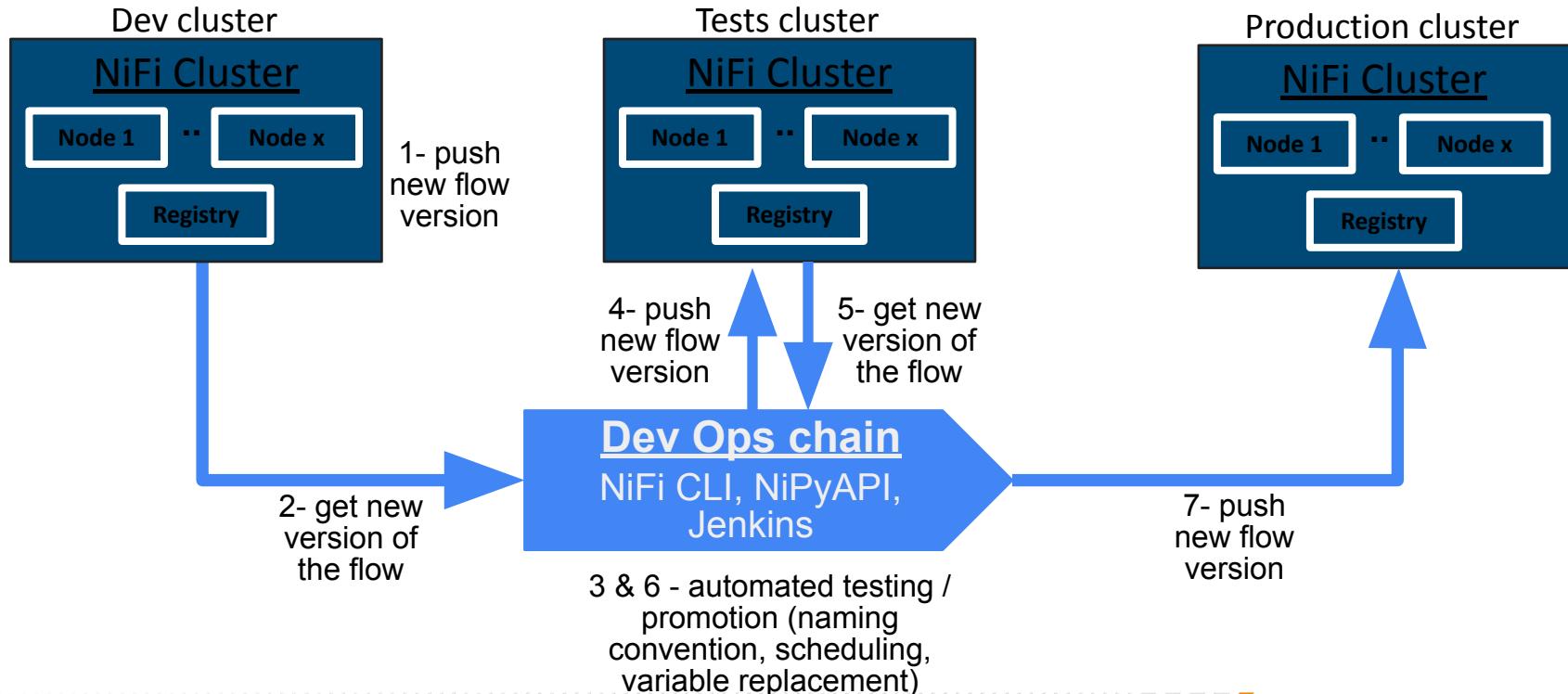
Advanced tooling to industrialize flow development  
(Flow Development Life Cycle)



- Over 300 Prebuilt Processors
- Easy to build your own
- Parse, Enrich & Apply Schema
- Filter, Split, Merger & Route
- Throttle & Backpressure

- Guaranteed Delivery
- Full data provenance from acquisition to delivery
- Diverse, Non-Traditional Sources
- Eco-system integration

# FDLC: Flow Development Lifecycle



# Provenance

Displaying 13 of 104  
Oldest event available: 11/15/2016 13:34:50 EST  
Showing the most recent events.

Date/Time	Type	FlowFile Uuid	Size	Component Name	Component Type
11/15/2016 13:35:03.8...	RECEIVE	379fc4f6-60e0-4151-9743-28...	44 bytes	ConsumeKafka	ConsumeKafka
11/15/2016 13:35:02.7...	RECEIVE	78f8c38b-89fc-4d00-a8d8-51...	44 bytes	ConsumeKafka	ConsumeKafka
11/15/2016 13:35:01.6...	RECEIVE	2bcd5124-bb78-489f-ad8a-7...	44 bytes	ConsumeKafka	ConsumeKafka

- Tracks data at each point as it flows through the system
- Records, indexes, and makes events available for display
- Handles fan-in/fan-out, i.e. merging and splitting data
- View attributes and content at given points in time

The diagram illustrates a data flow process. It starts with a red circle labeled "RECEIVE", which has an arrow pointing down to a grey circle labeled "JOIN". From the "JOIN" circle, an arrow points down to a grey circle labeled "DROP". Two green arrows originate from the "RECEIVE" and "JOIN" circles and point to a separate "Provenance Event" panel on the right.

**Provenance Event**

DETAILS	ATTRIBUTES	CONTENT
Attribute Values		
filename	328717796819631	No value previously set
kafka.offset	44815	No value previously set
kafka.partition	6	No value previously set
kafka.topic	nifi-testing	No value previously set
path	/	No value previously set
uuid	328717796819631-44800-10519073-0E	

# Extensibility

- Built from the ground up with extensions in mind
- Service-loader pattern for...
  - Processors
  - Controller Services
  - Reporting Tasks
  - Prioritizers
- Extensions packaged as NiFi Archives (NARs)
  - Deploy NiFi lib directory and restart
  - Same model as standard components

The screenshot shows the IntelliJ IDEA interface with the project 'nifi-mxnetinference-processors' open. The code editor displays `InferenceProcessorTest.java` with annotations for `LinkProcessor`, `UpdateAttribute`, and `PutHDFS`. Below the code editor is a flowchart illustrating the data processing pipeline:

```
graph TD; A[LinkProcessor] --> B[UpdateAttribute]; B --> C[PutHDFS]
```

Processor details:

- LinkProcessor**:
  - In: 0 bytes
  - Read/Write: 0 bytes / 31.45 KB
  - Out: 2 (31.45 KB)
  - Tasks/Time: 2 / 00:00:04.808
- UpdateAttribute**:
  - In: 2 (31.45 KB)
  - Read/Write: 0 bytes / 0 bytes
  - Out: 2 (31.45 KB)
  - Tasks/Time: 2 / 00:00:00.005
- PutHDFS**:
  - In: 2 (31.45 KB)
  - Read/Write: 31.45 KB / 0 bytes
  - Out: 0 (0 bytes)
  - Tasks/Time: 2 / 00:00:00.603

# Custom Processors

<https://github.com/tspannhw/nifi-extracttext-processor>

<https://github.com/tspannhw/nifi-tensorflow-processor>

<https://github.com/tspannhw/nifi-nlp-processor>

<https://github.com/tspannhw/nifi-convertjsontodd1-processor>

<https://github.com/tspannhw/nifi-corenlp-processor>

<https://github.com/tspannhw/nifi-imageextractor-processor>

<https://github.com/tspannhw/nifi-attributecleaner-processor>

<https://github.com/tspannhw/linkextractorprocessor>

<https://github.com/tspannhw/GetWebCamera>

<https://github.com/tspannhw/nifi-langdetect-processor>

<https://github.com/tspannhw/nifi-postimage-processor>

# STATELESS ENGINE

- See also Parameters
- Docker
- YARN
- Kubernetes (K8)
- Stateful NiFi clusters
- Apache OpenWhisk (FaaS)
- AWS Lambda, ...

```
{"registryUrl": "http://tspann-mbp15-hw14277:18080",
"bucketId": "140b30f0-5a47-4747-9021-19d4fde7f993",
"flowId": "0540e1fd-c7ca-46fb-9296-e37632021945",
"ssl": {
  "keystoreFile": "", "keystorePass": "", "keyPass": "", "keystoreType": "",
  "truststoreFile": "/Library/Java/JavaVirtualMachines/amazon-corretto-11.jdk/Contents/Home/lib/security/cacerts",
  "truststorePass": "changeit", "truststoreType": "JKS"
},
"parameters": {
  "broker": "4.317.852.100:9092",
  "topic": "iot",
  "group_id": "nifi-stateless-kafka-consumer",
  "DestinationDirectory": "/tmp/nifistateless/output2/",
  "output_dir": "/Users/tspann/Documents/nifi-1.10.0-SNAPSHOT/logs/output"
}
}
```

# Parquet Reader/ Writers

- Native Record Processors for Apache Parquet Files!
- CVS <-> Parquet
- XML <-> Parquet
- AVRO <-> Parquet
- JSON <-> Parquet
- More...

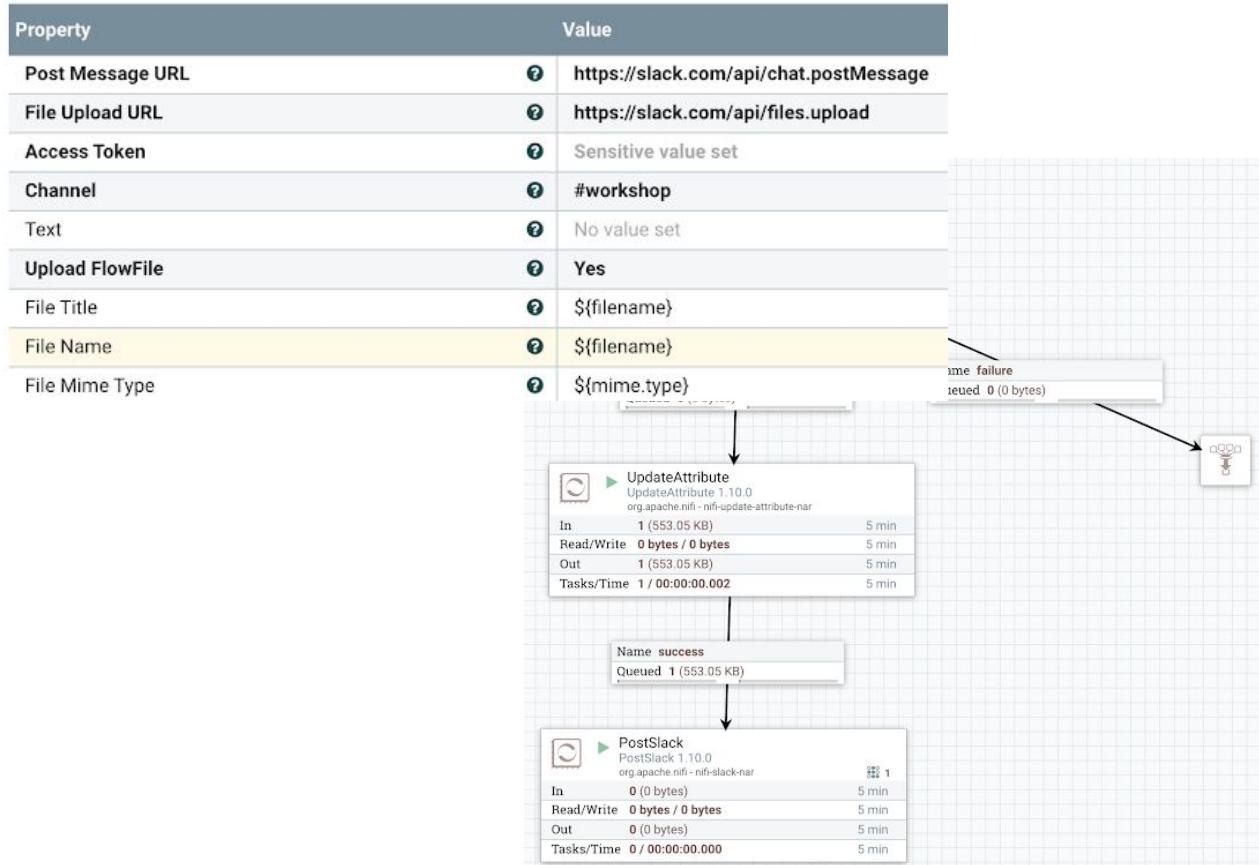
Property	Value
Record Reader	JsonTreeReader
Record Writer	ParquetRecordSetWriter
Merge Strategy	Bin-Packing Algorithm
Correlation Attribute Name	No value set
Attribute Strategy	Keep Only Common Attributes
Minimum Number of Records	10
Maximum Number of Records	
Minimum Bin Size	Requires Controller Service RecordReaderFactory 1.10.0.2.0.0.0-35 from org.apache.nifi - nifi-standard-services-api-nar
Maximum Bin Size	
Max Bin Age	Compatible Controller Services
Maximum Number of Bins	ParquetReader 1.10.0.2.0.0.0-35
Controller Service Name	ParquetReader
Bundle	org.apache.nifi - nifi-parquet-nar
Tags	reader, record, parse, row, parquet
Description	

Add Controller Service

CANCEL CREATE

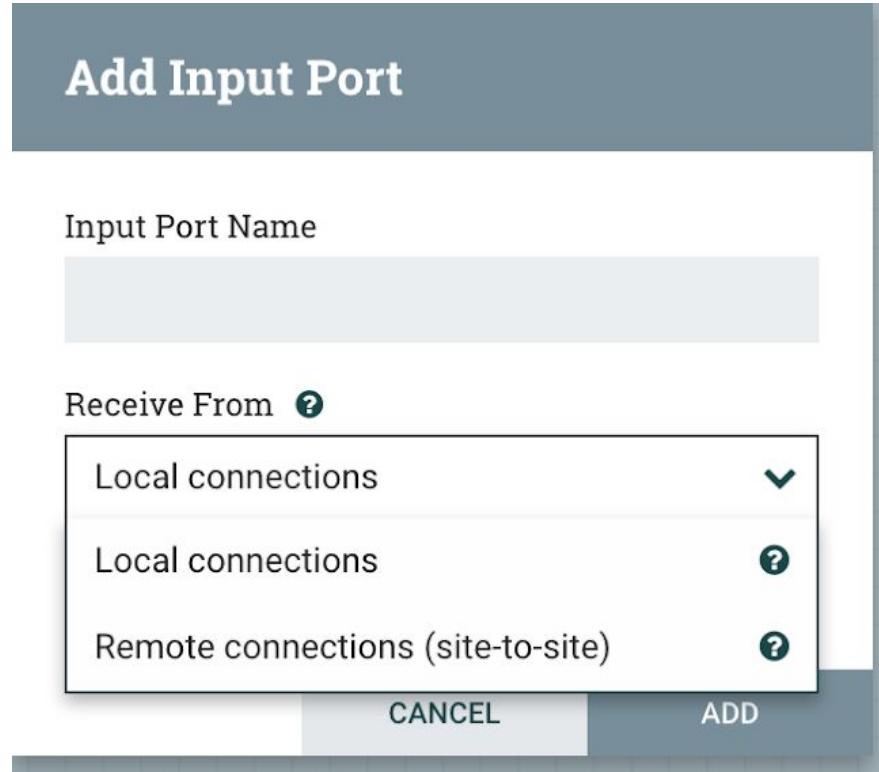
# Post Slack

## Post Images to Slack



# Remote Input Port

- Put Remote Connections for Site-To-Site (S2S) Anywhere!
- Not only top level
- Drop down simplicity



# NiFi Load Balancing

- Improve NiFi cluster throughput
- Defined at connection level
- Configurable balancing strategies
- Critical for scale up paradigm in Kubernetes

The screenshot shows the NiFi user interface with a flow diagram and configuration panels.

**Flow Diagram:**

```
graph LR; A[GenerateFlowFile] --> B[LogAttribute]; B --> C[LogAttribute]
```

**Component Details:**

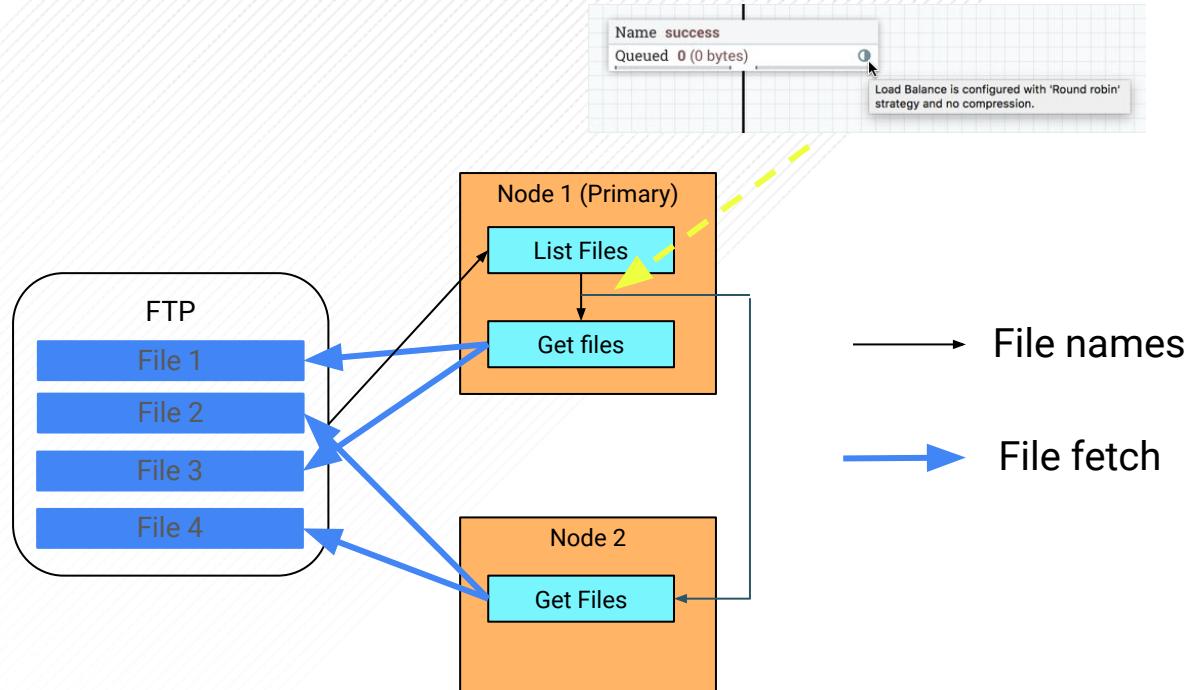
- GenerateFlowFile:** GenerateFlowFile 1.8.0.3.3.0.0-165  
org.apache.nifi - nifi-standard-nar
  - In: 0 (0 bytes) 5 min
  - Read/Write: 0 bytes / 42 KB 5 min
  - Out: 42 (42 KB) 5 min
  - Tasks/Time: 42 / 00:00:00.117 5 min
- LogAttribute:** LogAttribute 1.8.0.3.3.0.0-165  
org.apache.nifi - nifi-standard-nar
  - In: 41 (41 KB) 5 min
  - Read/Write: 0 bytes / 0 bytes 5 min
  - Out: 0 (0 bytes) 5 min
  - Tasks/Time: 41 / 00:00:00.141 5 min

**FlowFile Details Table:**

FlowFile UUID	Size	Component Name	Component Type	Node
0733ad94-3c80-44d7-9fc2-480ccaa...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe0.field.hortonworks.com:9... ➔
2bc7b5c1-c164-40fb-9e7e-da57884...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe0.field.hortonworks.com:9... ➔
80dece7a-15c8-4eb7-80ad-176bfe9...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe1.field.hortonworks.com:9... ➔
98d9f9c4-bb47-4fe7-9786-964d027...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe2.field.hortonworks.com:9... ➔
26c165ca-2f6d-4714-8c0c-e1de6e2...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe1.field.hortonworks.com:9... ➔
8bf920b-97a3-4b64-998d-046324a...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe2.field.hortonworks.com:9... ➔
6345a326-4843-442e-b77d-480d20...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe1.field.hortonworks.com:9... ➔
5fc30a5a-641e-4aa0-9c67-3b1d438...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe2.field.hortonworks.com:9... ➔
1e90e7ee-92fe-47b3-9aa4-4094fa8...	1,024 bytes	LogAttribute	LogAttribute	hdf-pm-fe1.field.hortonworks.com:9... ➔

# List Fetch Patterns

- Use load balancing feature to distribute some type of list
- Distribute files to ingest from an ftp ( List file + fetch files )
- Distribute rows to ingest from a DB
- Distribute files to ingest from S3



# Site-to-Site (S2S)

- Send data from a NiFi instance/cluster to one or multiple NiFi instances/clusters
- Preferred communications protocol when NiFi on both ends
- 2-way secure protocol, push & pull, high availability and load balancing

GenerateFlowFile  
GenerateFlowFile 1.3.0  
org.apache.nifi - nifi-standard-nar

In	0 (0 bytes)	5 min
Read/Write	0 bytes / 0 bytes	5 min
Out	0 (0 bytes)	5 min
Tasks/Time	0 / 00:00:00.000	5 min

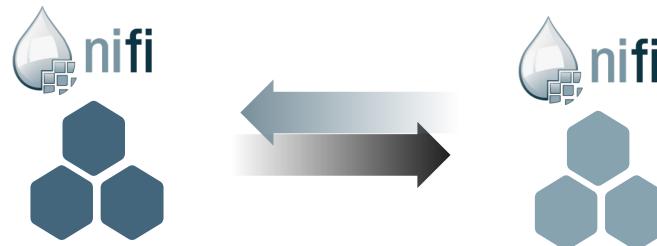
To from self  
Name success  
Queued 0 (0 bytes)

<http://nifi:8080/nifi/>  
<http://nifi:8080/nifi/>

Sent	0 (0 bytes) → 1	5 min
Received	0 → 0 (0 bytes)	5 min

No comments specified

10/02/2017 15:48:00 CEST



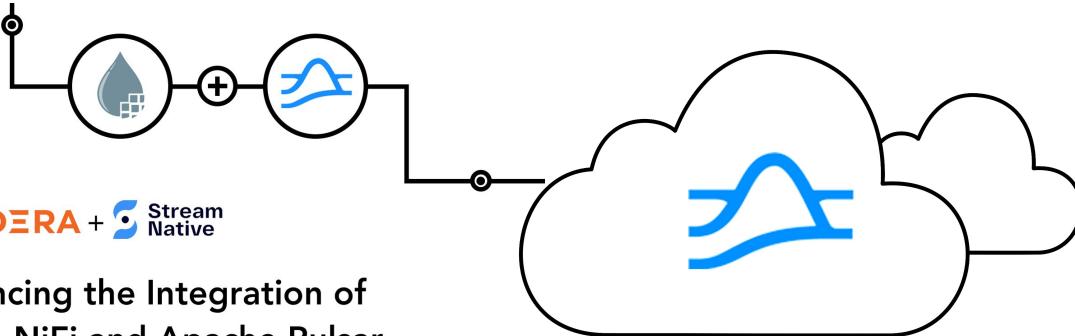
From nifi-1

Queued 0 (0 bytes)

LogAttribute  
LogAttribute

In	0 (0 bytes)	5 min
Read/Write	0 bytes / 0 bytes	5 min
Out	0 (0 bytes)	5 min
Tasks/Time	0 / 00:00:00.000	5 min

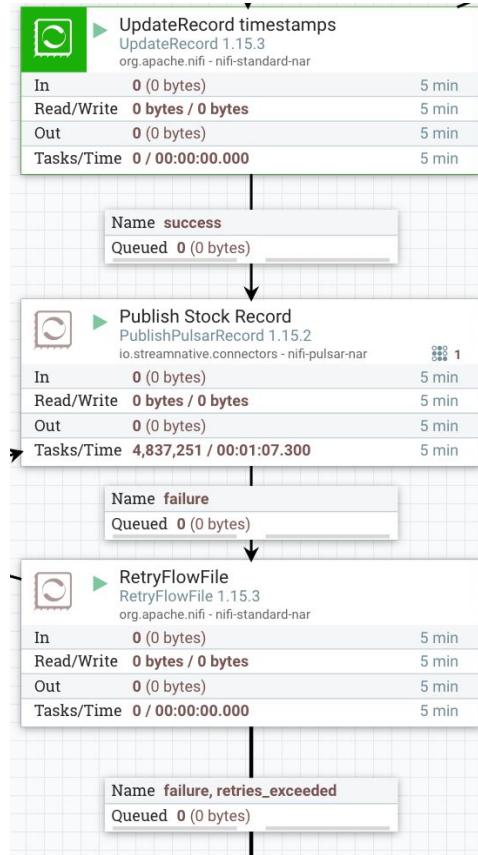
# Apache NiFi Pulsar Connector



CLOUDERA + Stream Native

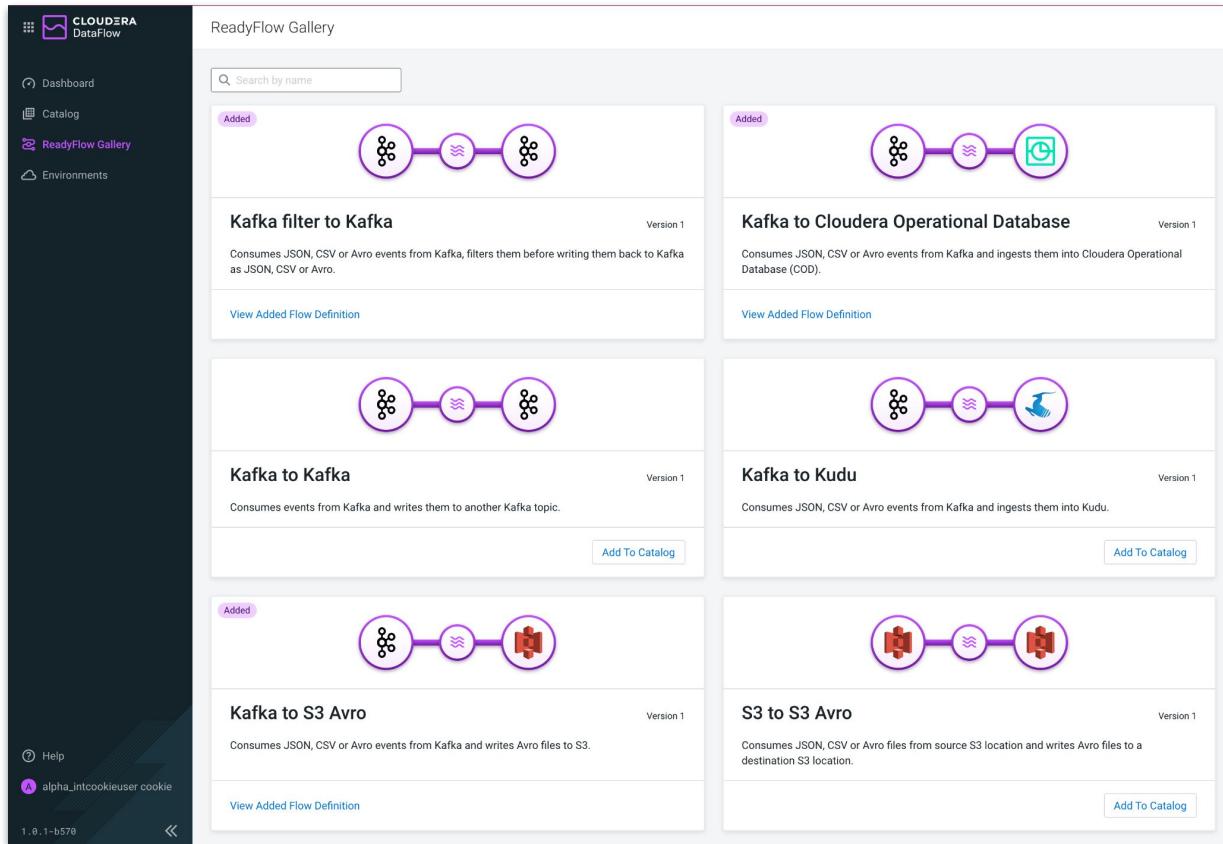
Announcing the Integration of  
Apache NiFi and Apache Pulsar

<https://streamnative.io/apache-nifi-connector/>



# ReadyFlow Gallery

- Cloudera provided flow definitions
- Cover most common data flow use cases
- Optimized to work with CDP sources/destinations
- Can be deployed and adjusted as needed



# Flow Catalog

- Central repository for flow definitions
- Import existing NiFi flows
- Manage flow definitions
- Initiate flow deployments

The screenshot shows the Cloudera DataFlow interface with the 'Catalog' tab selected. The main area is titled 'Flow Catalog' and displays a list of available flow definitions. A search bar at the top allows users to search by name. A blue button labeled 'Import Flow Definition' is located in the top right corner. The catalog table includes columns for Name, Type, Versions, and Last Updated. Each row in the table represents a different flow definition, with a 'View' link (indicated by a right arrow) next to each entry. At the bottom of the table, there are pagination controls for items per page (set to 10), and a footer showing '1 - 10 of 10'.

Name ↑	Type	Versions	Last Updated
cc_fraud_template_int101run	Custom Flow Definition	2	a day ago
cc_fraud_template_int101run2	Custom Flow Definition	1	9 days ago
JSON_Kafka_To_Avro_S3	Custom Flow Definition	2	a day ago
Kafka filter to Kafka	ReadyFlow	1	2 days ago
Kafka to Cloudera Operational Database	ReadyFlow	1	2 days ago
Kafka to S3 Avro	ReadyFlow	1	14 hours ago
nifi_flows	Custom Flow Definition	1	2 months ago
Weather Data Flow	Custom Flow Definition	1	a day ago
Weather_Data	Custom Flow Definition	1	15 days ago
Weather_JSON_Kafka_To_Avro_S3	Custom Flow Definition	1	21 days ago

# Apache NiFi with Python Custom Processors

## Python as a 1st class citizen

```
import cv2
import numpy as np
import json
from nifiapi.properties import PropertyDescriptor
from nifiapi.properties import ResourceDefinition
from nifiapi.flowfiletransform import FlowFileTransformResult

SCALE_FACTOR = 0.00392
NMS_THRESHOLD = 0.4 # non-maximum suppression threshold
CONFIDENCE_THRESHOLD = 0.5

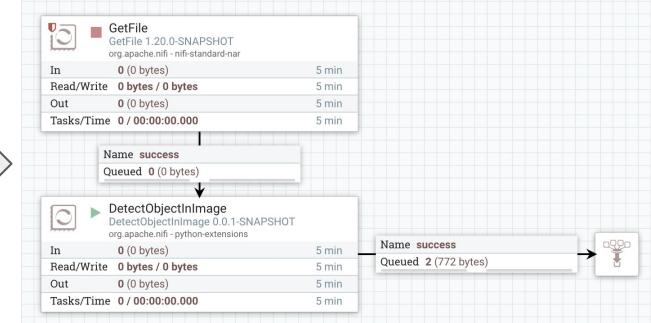
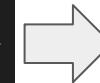
class DetectObjectInImage:
    class Java:
        implements = ['org.apache.nifi.python.processor.FlowFileTransform']
        class ProcessorDetails:
            version = '0.0.1-SNAPSHOT'
            dependencies = ['numpy >= 1.23.5', 'opencv-python >= 4.6']

    def __init__(self, jvm=None, **kwargs):
        self.jvm = jvm

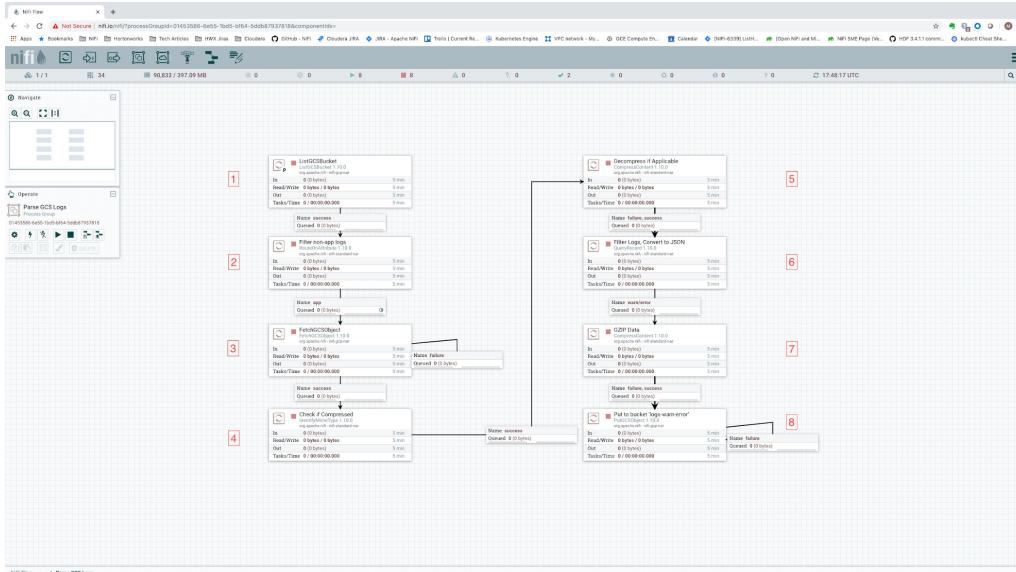
    # Build Property Descriptors
    self.model_file = PropertyDescriptor(
        name = 'Model File',
        description = 'The binary file containing the trained Deep Neural Network weights. Supports Caffe (*.caffemodel), TensorFlow (*.pb), Torch (*.t7, *.net), Darknet (*.weights), ' +
                    'DLDT (*.bin), and ONNX (*.onnx)',
        required = True,
        resource_definition = ResourceDefinition(allow_file = True)
    )
    self.config_file = PropertyDescriptor(
        name = 'Network Config File',
        description = 'The text file containing the Network configuration. Supports Caffe (*.prototxt), TensorFlow (*.pbtxt), Darknet (*.cfg), and DLDT (*.xml)',
        required = False,
        resource_definition = ResourceDefinition(allow_file = True)
    )
    self.class_name_file = PropertyDescriptor(
        name = 'Class Names File',
        description = 'A text file containing the names of the classes that may be detected by the model. Expected format is one class name per line, new-line terminated.',
        required = True,
        resource_definition = ResourceDefinition(allow_file = True)
    )
    self.descriptors = [self.model_file, self.config_file, self.class_name_file]

    def getPropertyDescriptors(self):
        return self.descriptors

    def onScheduled(self, context):
        # read class names from text file
        class_name_file = context.getProperty(self.class_name_file.name).getValue()
        if class_name_file is None:
```



# Processing one billion events per second with NiFi



Nodes	Data rate/sec	Events/sec	Data rate/day	Events/day
1	192.5 MB	946,000	16.6 TB	81.7 Billion
5	881 MB	4.97 Million	76 TB	429.4 Billion
25	5.8 GB	26 Million	501 TB	2.25 Trillion
100	22 GB	90 Million	1.9 PB	7.8 Trillion
150	32.6 GB	141.3 Million	2.75 PB	12.2 Trillion

---

# RESOURCES AND WRAP-UP

# Streaming Tech Debt Tips

- Version Control All Assets
- Operationalize with K8
- Use DevOps and APIs
- Latest Java and Python
- Stream Sizing (NiFi, Kafka, Flink)
- Unit and Integration Test
- Backup everything
- Scale in 3s



# Streaming Resources

- <https://dzone.com/articles/real-time-stream-processing-with-hazelcast-and-streamnative>
- <https://flipstackweekly.com/>
- <https://www.datainmotion.dev/>
- <https://www.flankstack.dev/>
- <https://github.com/tspannhw>
- <https://medium.com/@tspann>
- <https://medium.com/@tspann/predictions-for-streaming-in-2023-ad4d7395d714>
- [https://www.apachecon.com/acna2022/slides/04\\_Spann\\_Tim\\_Citizen\\_Streaming\\_Engineer.pdf](https://www.apachecon.com/acna2022/slides/04_Spann_Tim_Citizen_Streaming_Engineer.pdf)

# *Tim* **SPANN**

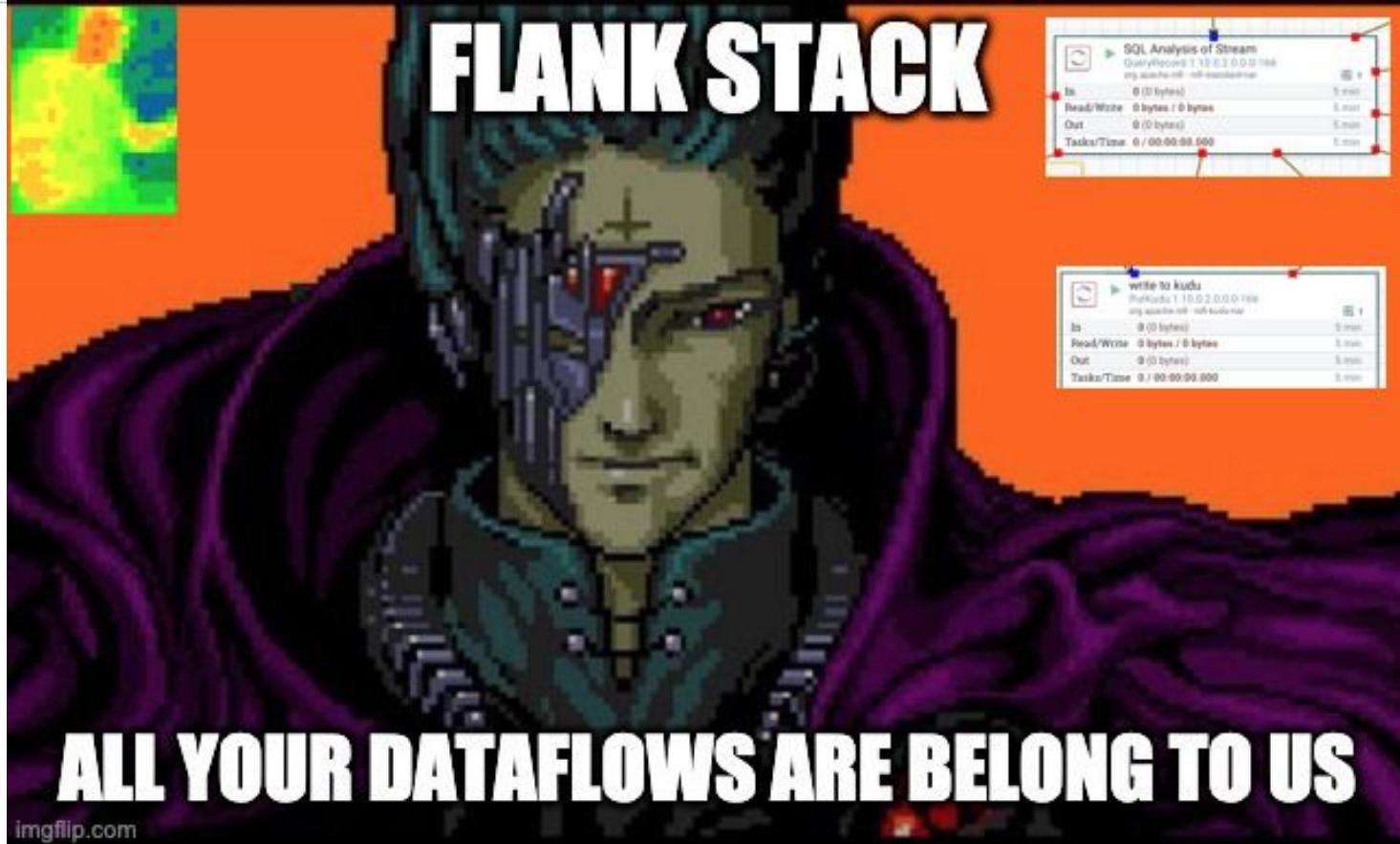
<https://github.com/tspannhw>

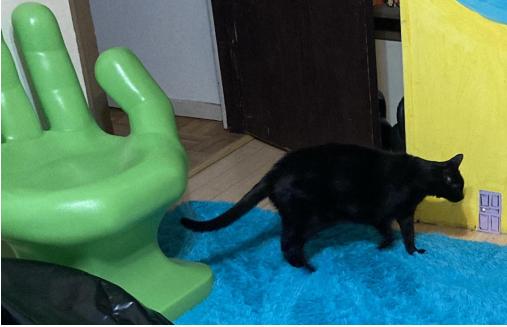
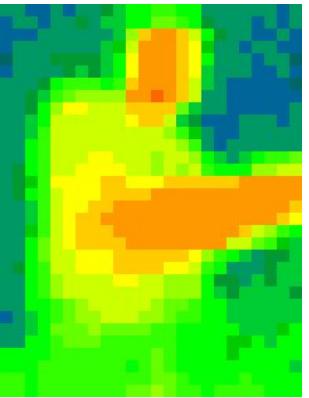
<https://www.datainmotion.dev/>



## Resources







TH<sub>N</sub>O Y<sub>U</sub> \*

