Aalto University
School of Science

Service and Integration Models in Big Data Platforms

Hong-Linh Truong
Department of Computer Science
linh.truong@aalto.fi, *https://rdsea.github.io*

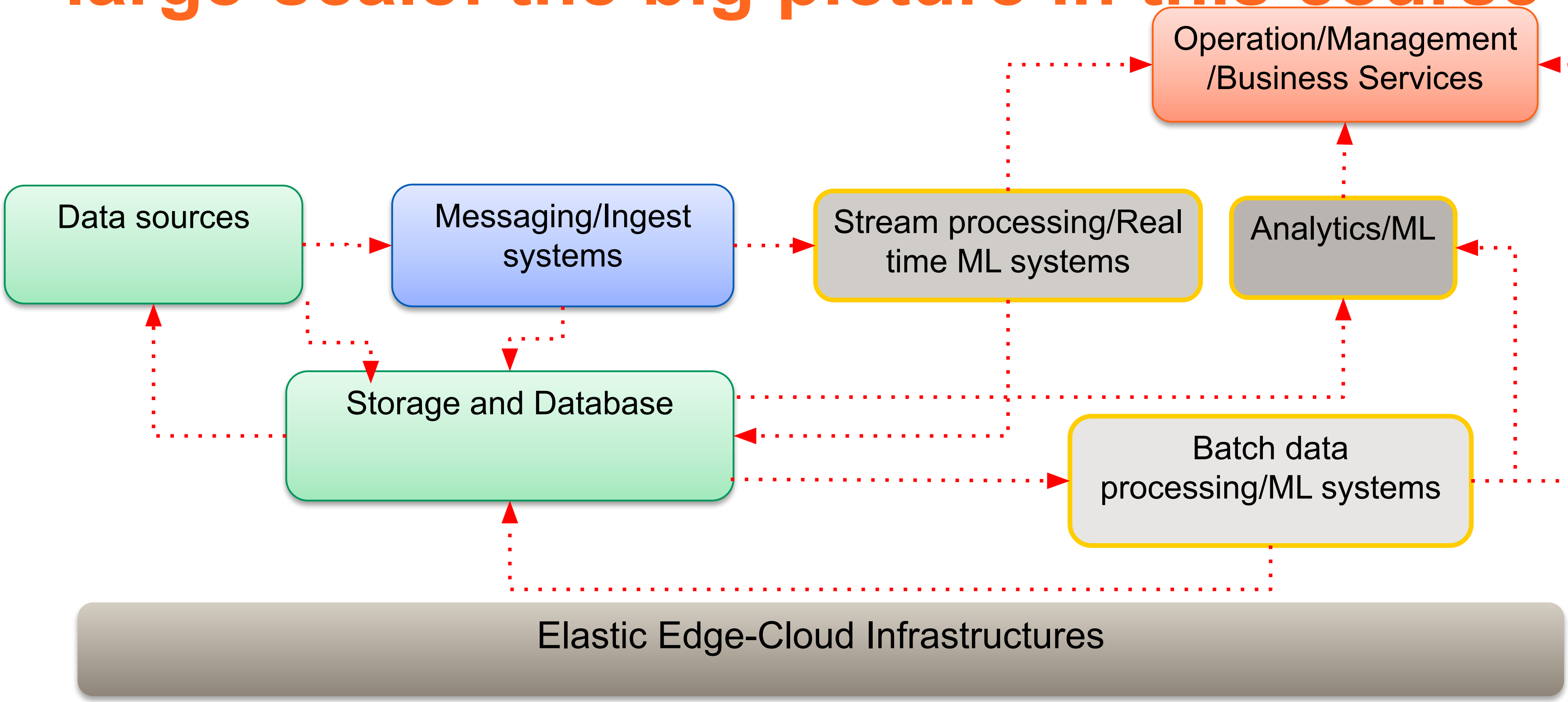
Learning objectives

- Understand common ways to bring data into platforms
- Study service requests and data partition for optimizing integration models
- Understand the role of service discovery and consensus
- Establish the links to follow-up lectures

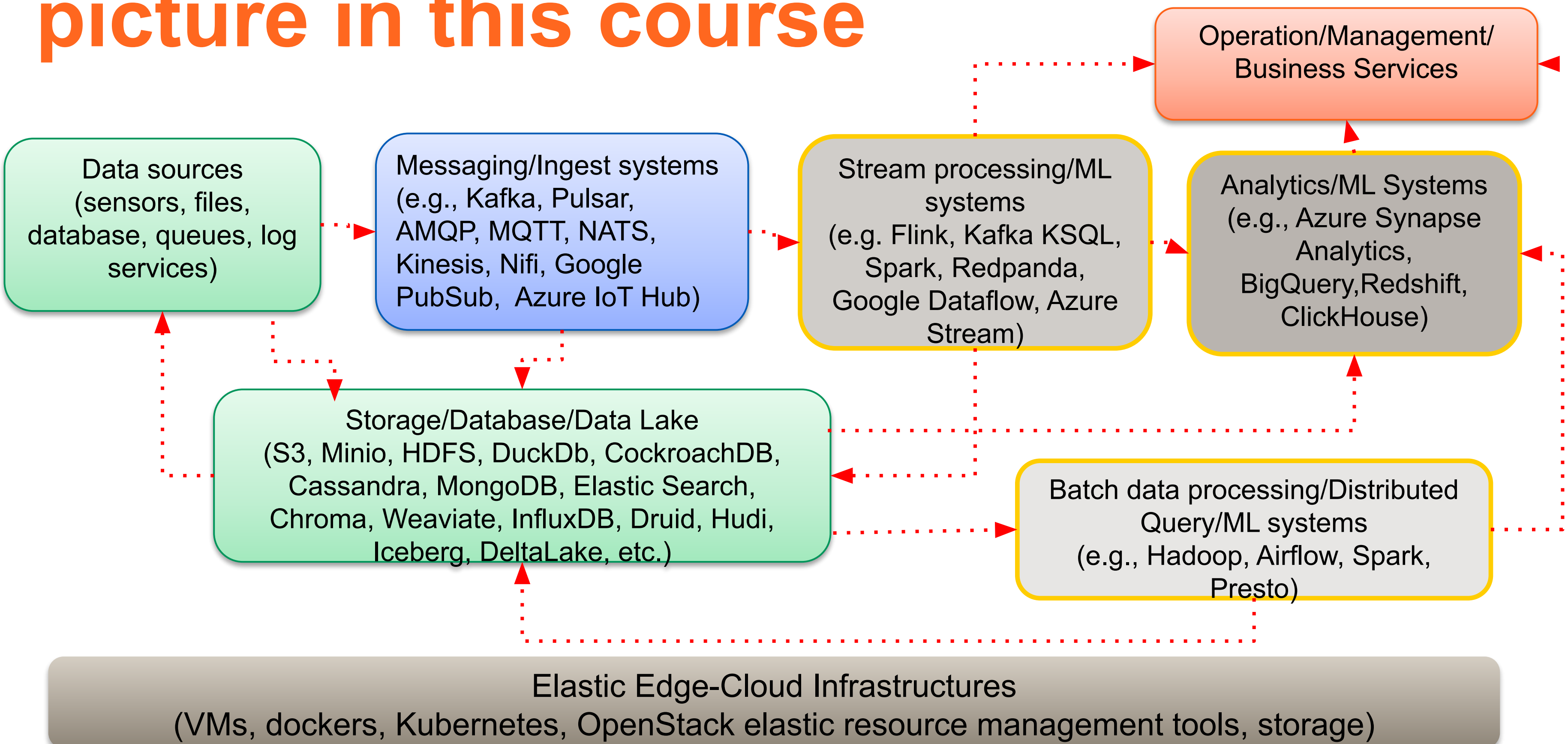
Recall

- **Platforms must facilitate exchanges between many stakeholders centered around data products**
- **Platform services support many types of interactions with different protocols and APIs**
- **Some important aspects of interactions**
  - APIs for encapsulating low-level details
  - protocols for interoperability
  - performance management
  - service/data discovery

Basic building blocks for big data at large-scale: the big picture in this course



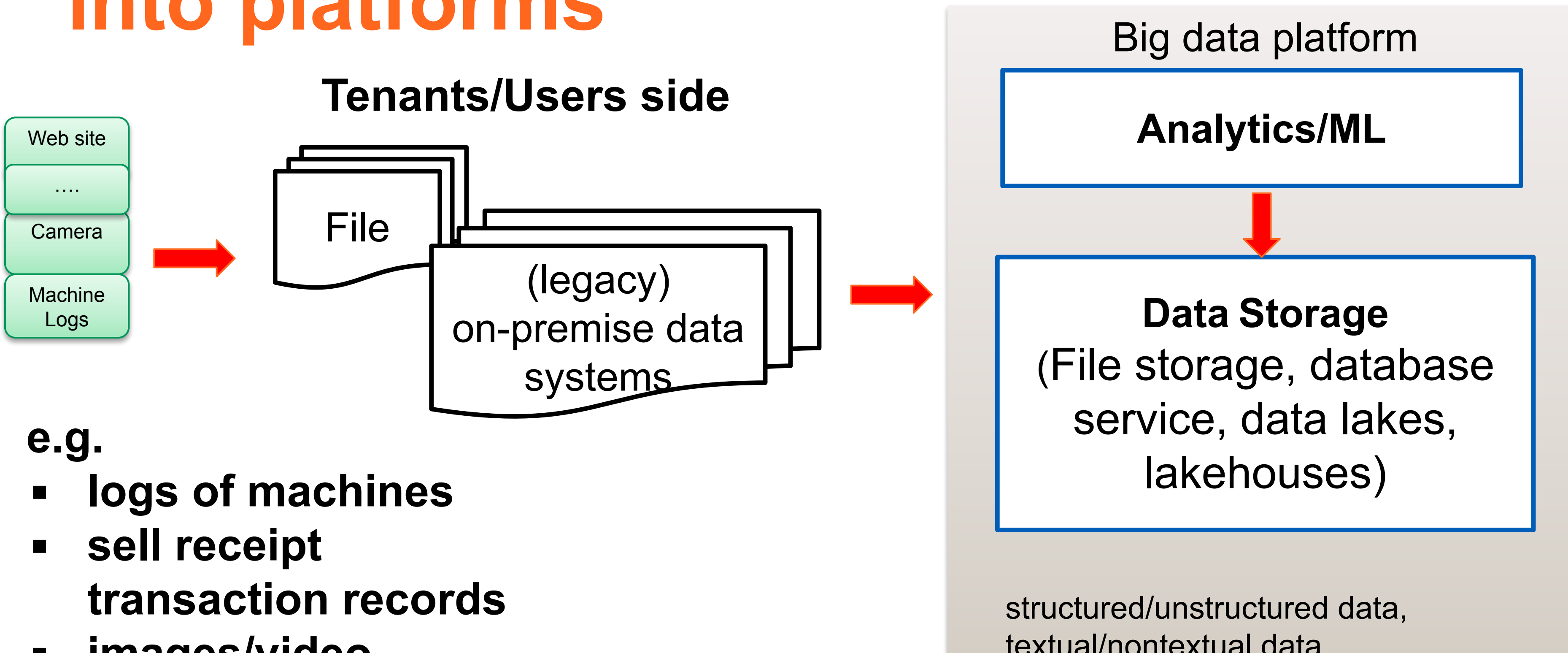
Big data at large-scale: the big picture in this course



Aalto University
School of Science

Basics of moving big data into the platform

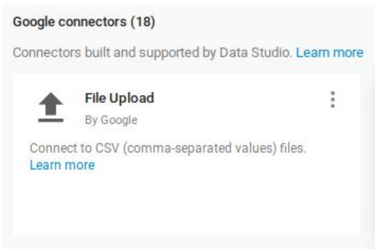
Integrate files/static datasets/sources into platforms

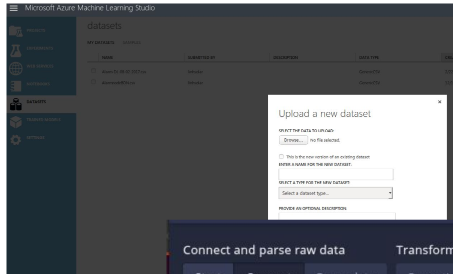


e.g.

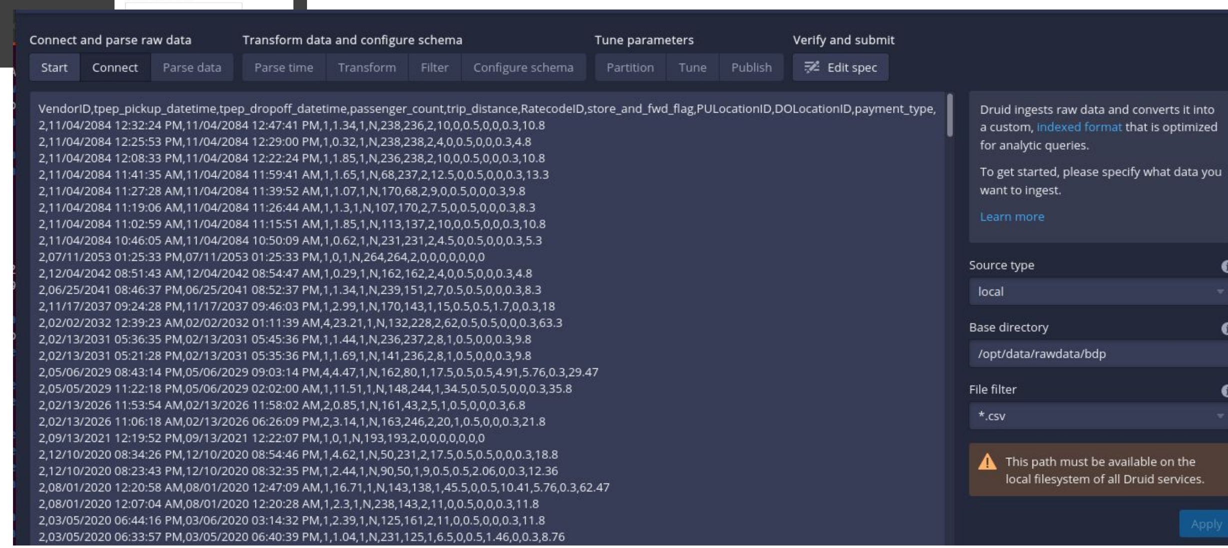
- logs of machines
- sell receipt transaction records
- images/video

First obstacle: ingesting big data into cloud data storage/database services



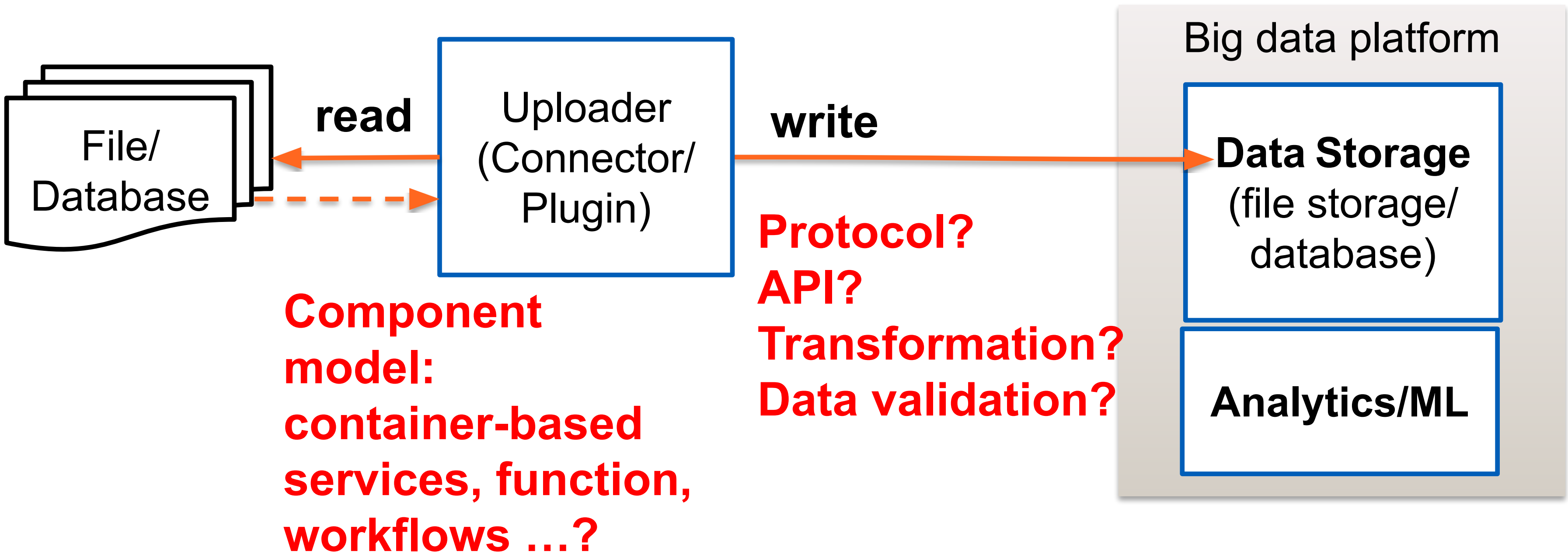


What would be a good way? Using Flask/FastAPI REST API?



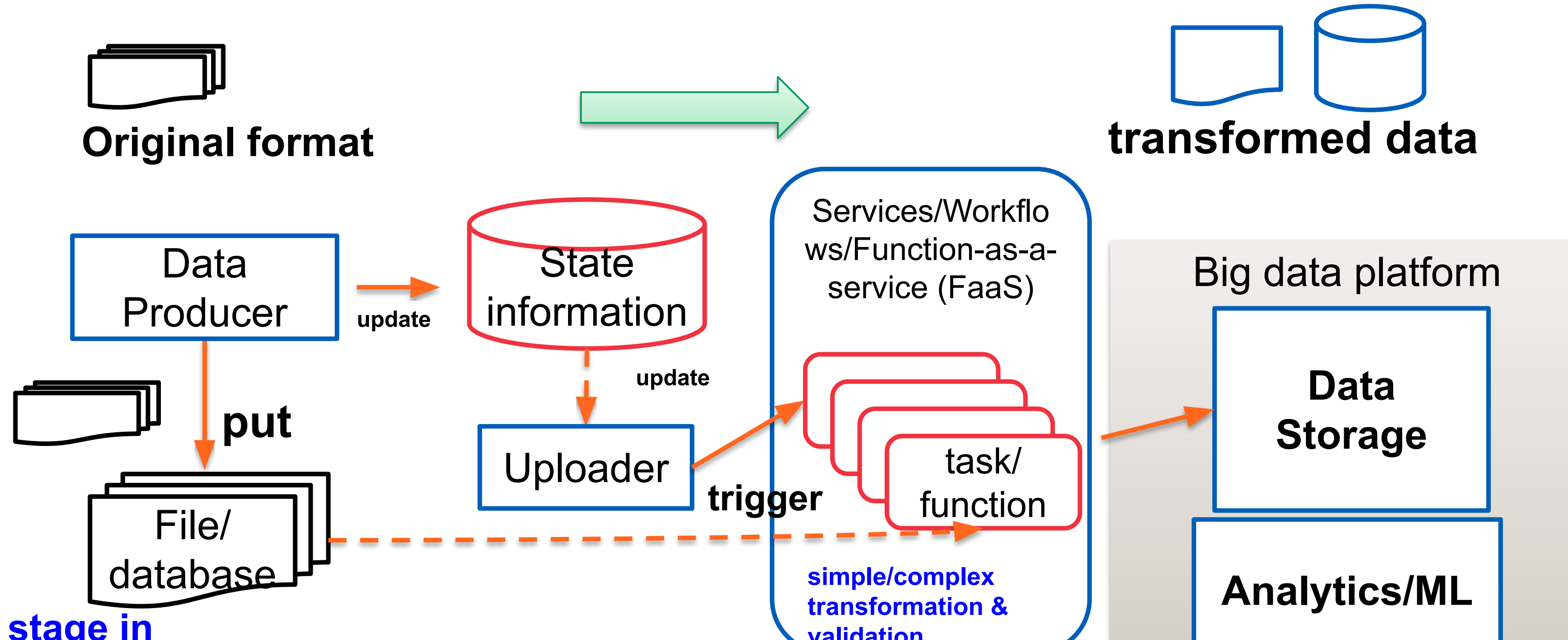
e.g., upload data into the cloud storage and run machine learning

Complex design details



- **Practical issues for optimization:**
  - **Handle very big files vs a lot of small files**
  - **Different transformation/integration models**

Complex design details

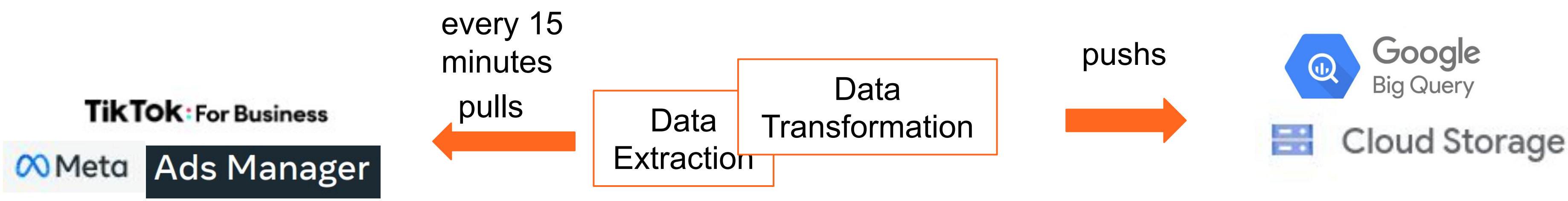


Where? next to data source or next to/within destination data storage?

Several ways of implementation

- **REST/gRPC APIs for uploading**
  - APIs for calling/running batch of jobs
- **File transfers and ingestion**
  - move files into a stage space and run parallel tasks to process data files
- **Containerized microservices moving files**
  - detect and move files
- **Cron/workflow tasks**
  - Workflows, Serverless/Function-as-a-service
- **Complex design, including task management for multi tenants/users**

Simple example: a Customer Data Platform



Say we want to store data into Google Storage in different spaces:

- **hot, warm, cold and archive**

We need uploaders and also movers (moving data between different spaces). Mapped into specific technologies:

- **Cloud Run: microservices/containers whose APIs can be triggered based on events**
- **Cloud Function: as serverless/function-as-a-service**
- **Cloud Composer (Airflow): a workflow engine**
- **bare Containers/VMs: write your own code, do your own way**

Parallel/distributed processing

- **Individual data file/dataset is big**
  - parallel/distributed processing for single file
  - using suitable models
    - *MapReduce, Workflow, etc.*
- **Multiple files/datasets but small individuals**
  - parallel/distributed processing of tasks
  - task for a single file
    - *multi-thread, Dask, etc.*
- **Change data capture and failure handle could be tricky**
- **Bursty/ephemeral data processing**

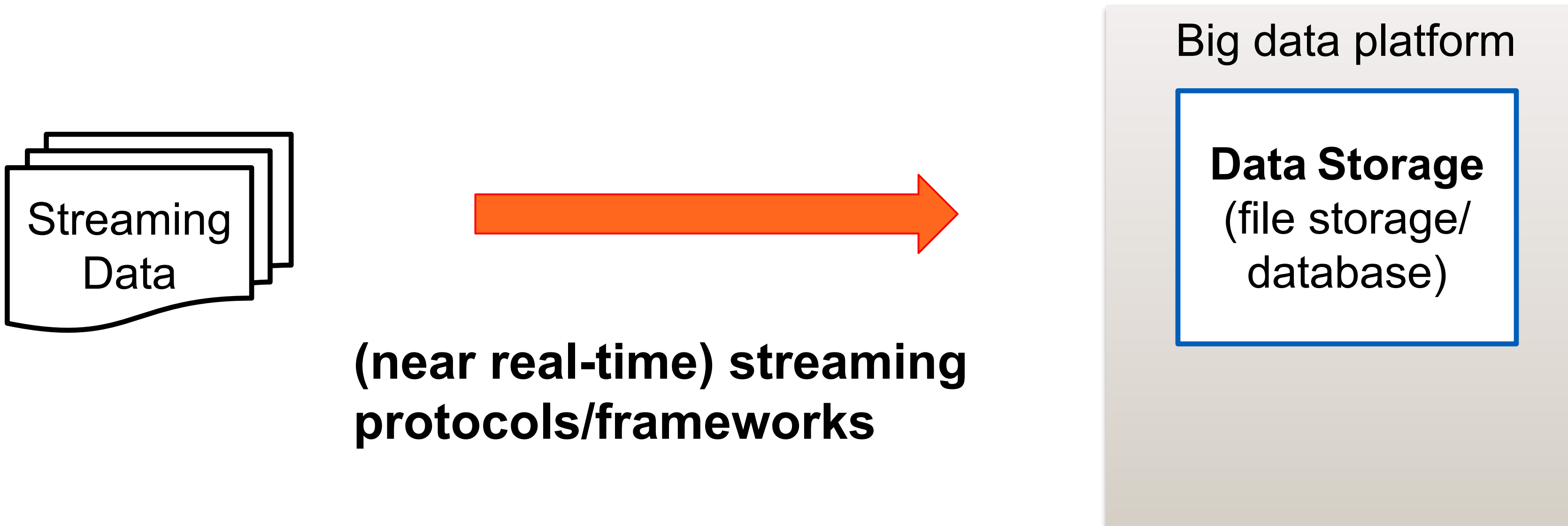
Remember we have a lot of data (files)

Aalto University
School of Science

Check the simple example in

https://github.com/rdsea/bigdataplatforms/tree/master/tutorials/queuebaseddataingestion

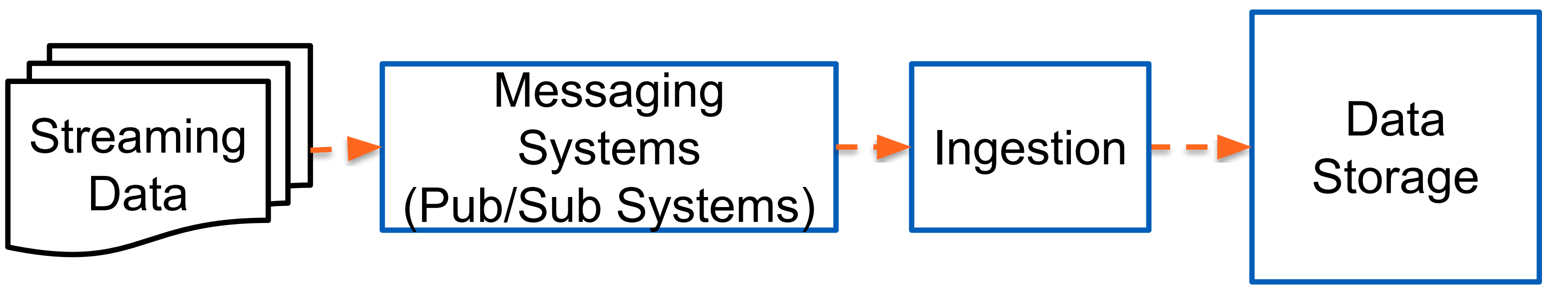
Integrate streaming data sources into platforms



Quick check

"A big data platform monitors network usage of devices from million+ customers. We have different levels: Sensor/Customer, Node (concentrator of multiple customers), Agent (concentrator of multiple Nodes) and the whole network. In a region, the real operator can generate 1.4 billion records per day ~ 72GB per day"

How do I move streaming data into the cloud?



Protocol?
Data format
Message structure

Real-world technologies

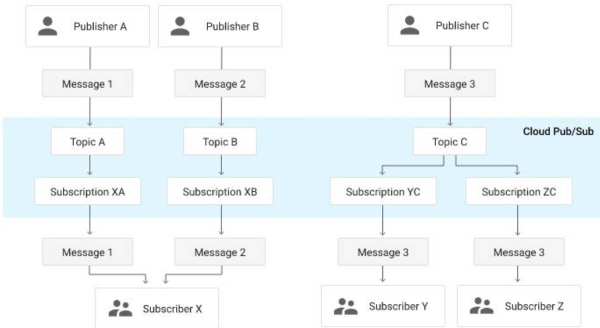


Figure source: https://cloud.google.com/pubsub/docs/overview

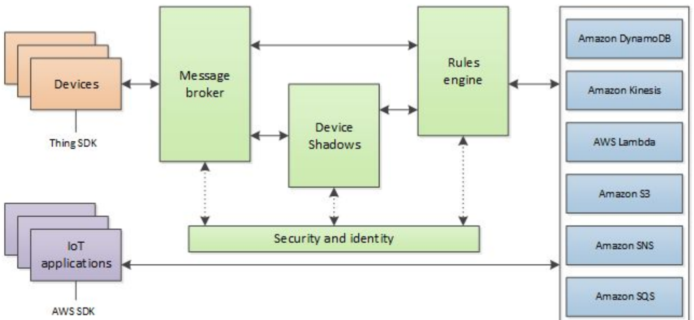


Figure source:
https://docs.aws.amazon.com/iot/latest/developerguide/aws-iot-how-it-works.html

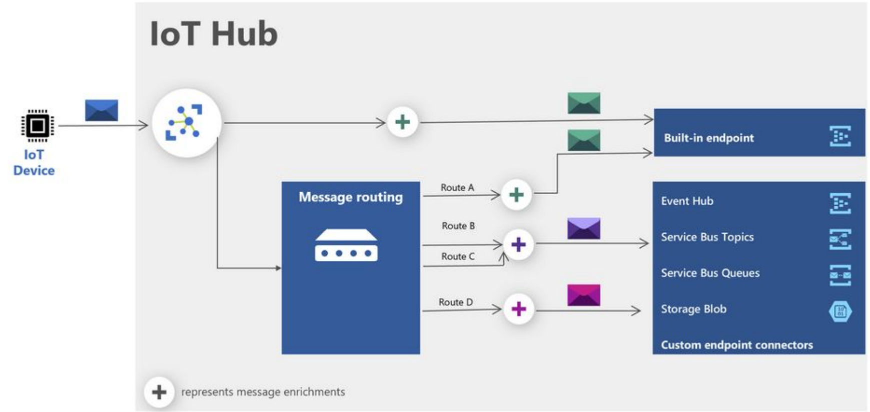


Figure source:
https://docs.microsoft.com/en-us/azure/iot-hub/iot-hub-message-enrichments-overview

Do you see common concepts/terms?

Some important protocols

- **Protocols**
  - AMQP, MQTT, NATS (https://nats.io/)
- **Systems**
  - Apache Kafka, Apache Pulsar, Apache RocketMQ, RedPanda, Google PubSub

- **Distinguish between “protocols” and “specific frameworks”**
  - how would they affect your design?

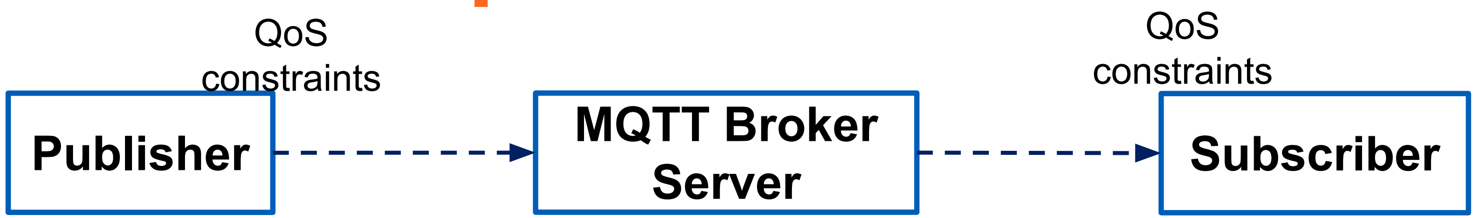
AMQP - Overview

- **Protocol for message-oriented middleware**
  - Not language- or platform- specific
  - For Java, C#, Python, ...
- **Binary wire-level protocol for message exchange, rather than APIs**
- **http://www.amqp.org**
- **We use it for *big data movement and tasks coordination***

MQTT Overview

- **https://mqtt.org/**
- **OASIS Standard**
    - ISO/IEC 20922:2016 (Message Queuing Telemetry Transport (MQTT) v3.1.1)
- **IoT/M2M connectivity protocol atop TCP/IP**
- **MQTT brokers enable publish/subscribe messaging systems**
    - Publisher can publish a message within a topic that can be subscribed by many Subscribers
- **We use it mostly for *big data movement***

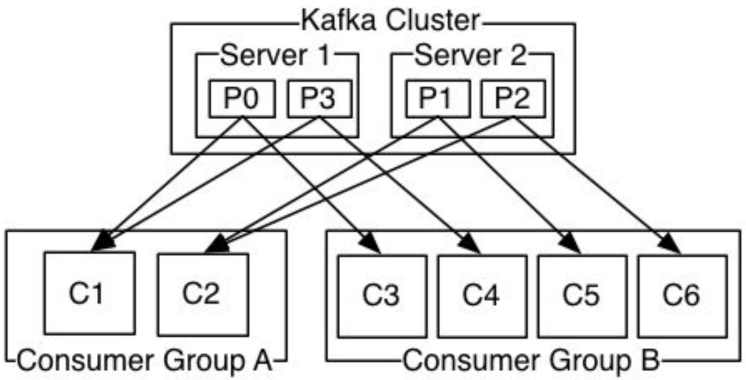
Model and Implementation



- **Different programming languages for OS/devices**
- **Implementation examples**
  - Mosquitto (http://projects.eclipse.org/projects/technology.mosquitto)
    - docker pull eclipse-mosquitto
  - Paho: http://www.eclipse.org/paho/
  - RabbitMQ: https://www.rabbitmq.com/
  - Cloud providers: http://cloudmqtt.com (offer a free instance)
  - Cluster of MQTT brokers: VerneMQ (https://vernemq.com/), EMQ (https://www.emqx.io/)

Apache Kafka

- **http://kafka.apache.org/**
  - originally from LinkedIn, not a protocol!
- **Some components are commercialized by Confluent**
  - https://www.confluent.io/
- **Widely used for big data use cases**
  - including message processing in large-scale enterprise service platforms



Figures source: https://kafka.apache.org/documentation.html

So which one you think is suitable for this?

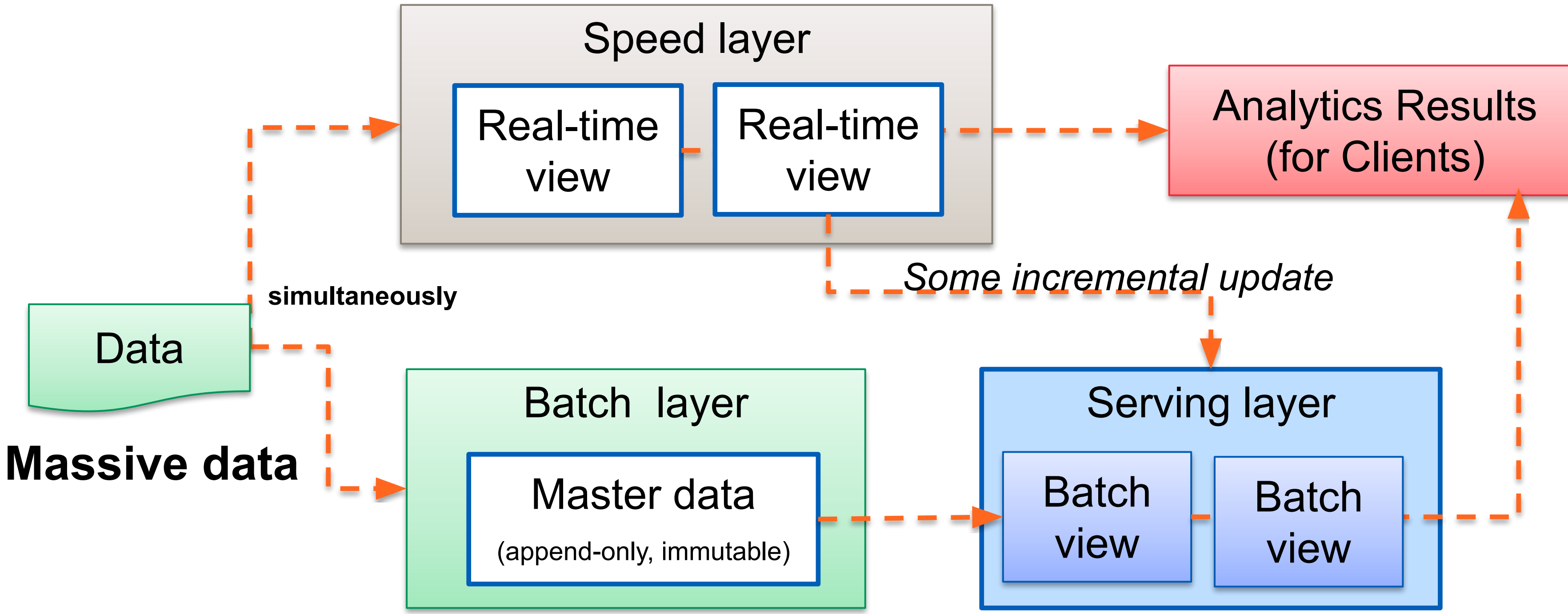
“A big data platform monitors network usage of devices from million+ customers. We have different levels: Sensor/Customer, Node (concentrator of multiple customers), Agent (concentrator of multiple Nodes) and the whole network. In a region, the real operator can generate 1.4 billion records per day ~ 72GB per day”

Hybrid data processing architectures

Batch processing, micro-batching, and streaming

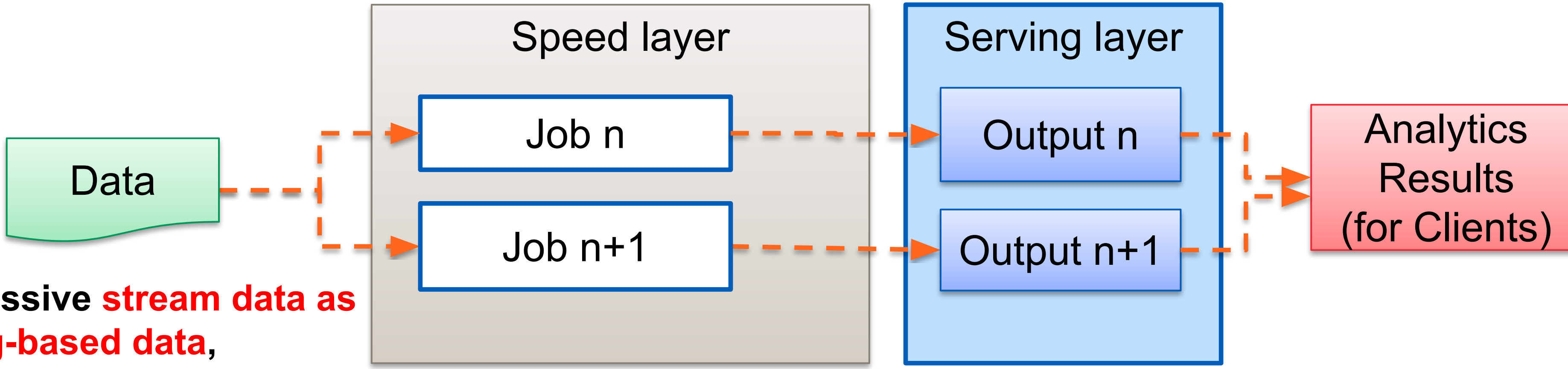
- **Batch processing**
  - data to be processed: complete with a large size
  - high throughput but also high latency
  - triggered by scheduled/manual time or by data completion (size or time)
- **Micro-batching**
  - data to be processed: small; collected over a short, regular time; small batches
  - near real-time and low latency
- **Streaming**
  - data to be processed: as soon when it arrives; record-by-record
  - very low latency and real time

Lambda architectural style



Check: https://docs.microsoft.com/en-us/azure/architecture/data-guide/big-data/
https://www.oreilly.com/radar/questioning-the-lambda-architecture/

Kappa architectural style



Massive stream data as log-based data, retained enough for different analytics needed

Job n: analytics/processing
Can switch from version n to version n+1 using a single software stack

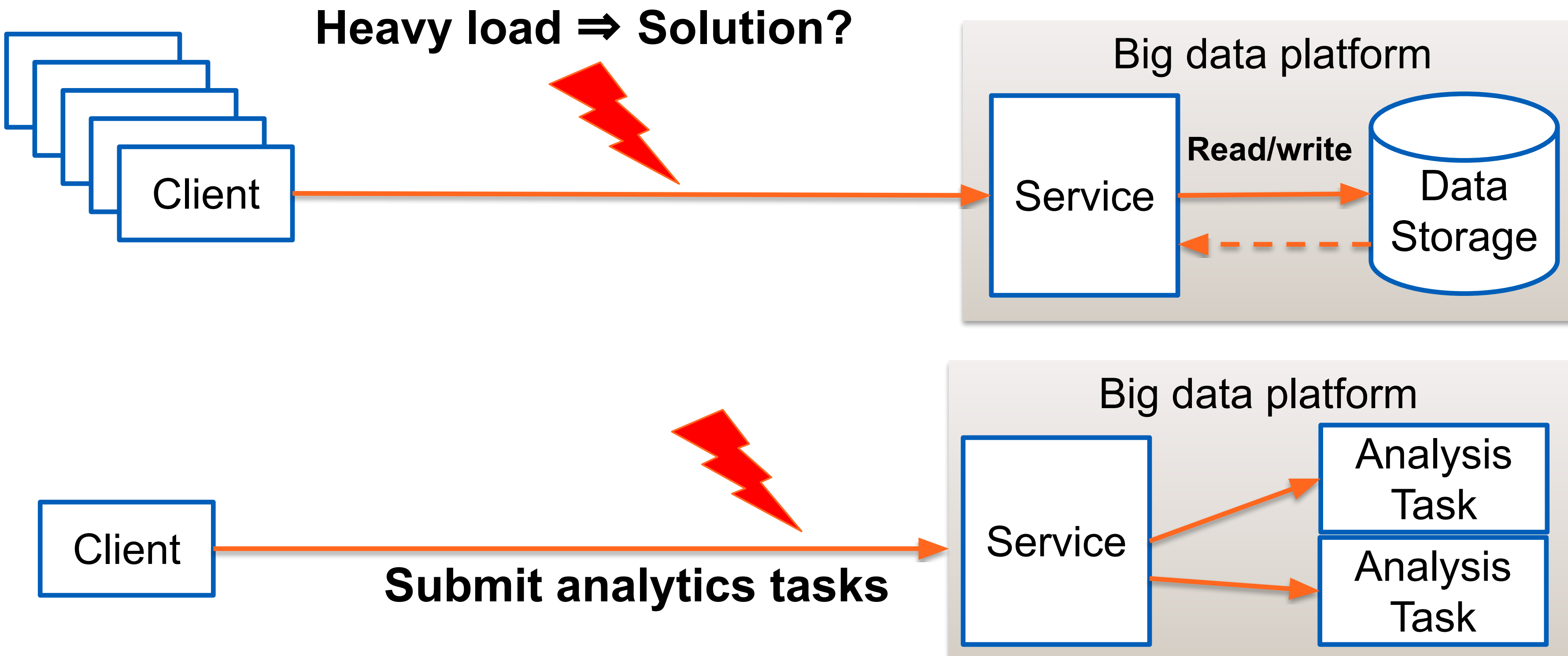
Check: https://milinda.pathirage.org/kappa-architecture.com/ & http://radar.oreilly.com/2014/07/questioning-the-lambda-architecture.html

Recall:

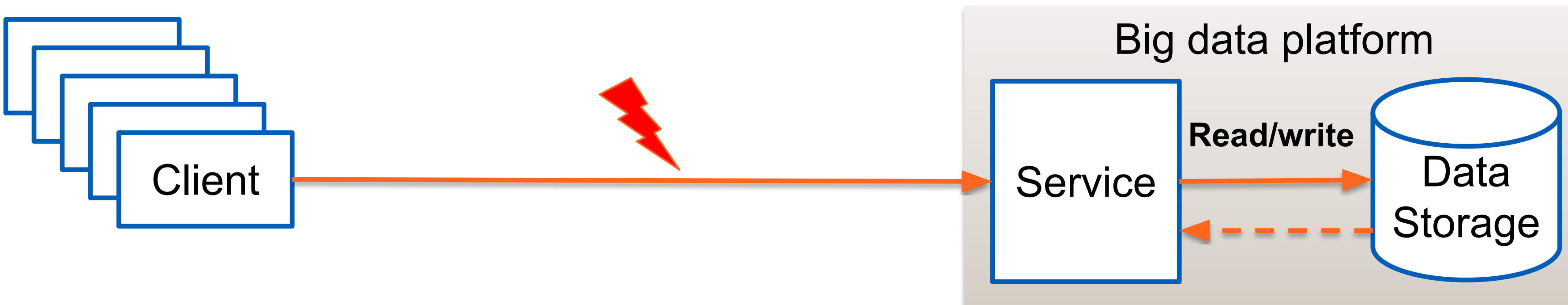
“A big data platform monitors network usage of devices from million+ customers. We have different levels: Sensor/Customer, Node (concentrator of multiple customers), Agent (concentrator of multiple Nodes) and the whole network. In a region, the real operator can generate 1.4 billion records per day ~ 72GB per day”

Optimize data service requests and functionalities → handling "unlimited vs limited amount of data"

Concurrent contention

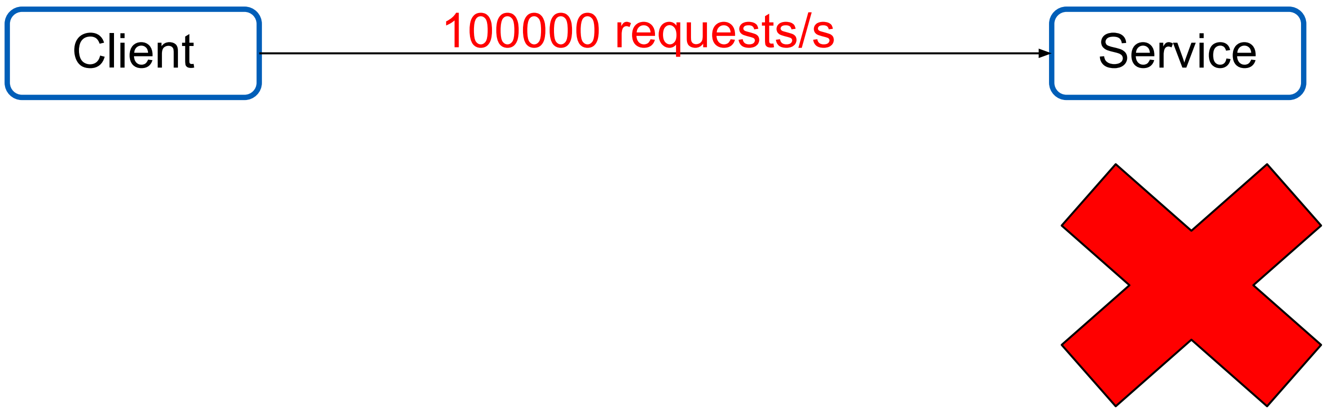


Back-pressure or elasticity



Back-pressure: control, drop, and buffer

Prevent too many accesses?

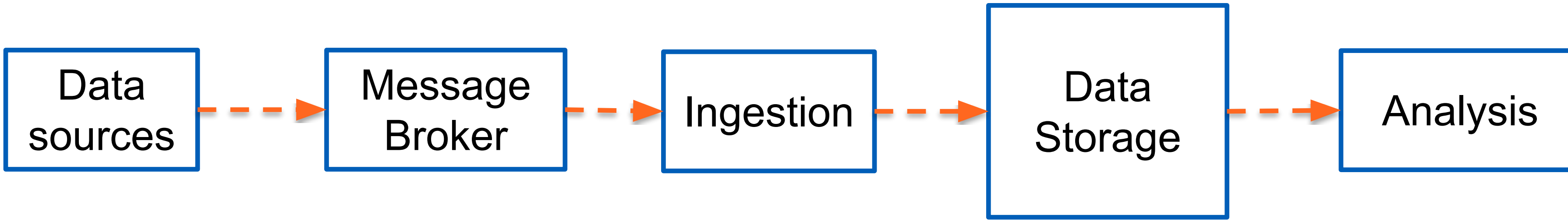


A related situation: prevents clients to retry a (failed) operation

http://martinfowler.com/bliki/CircuitBreaker.html

https://msdn.microsoft.com/en-us/library/dn589784.aspx

Scaling in every place of big data pipelines

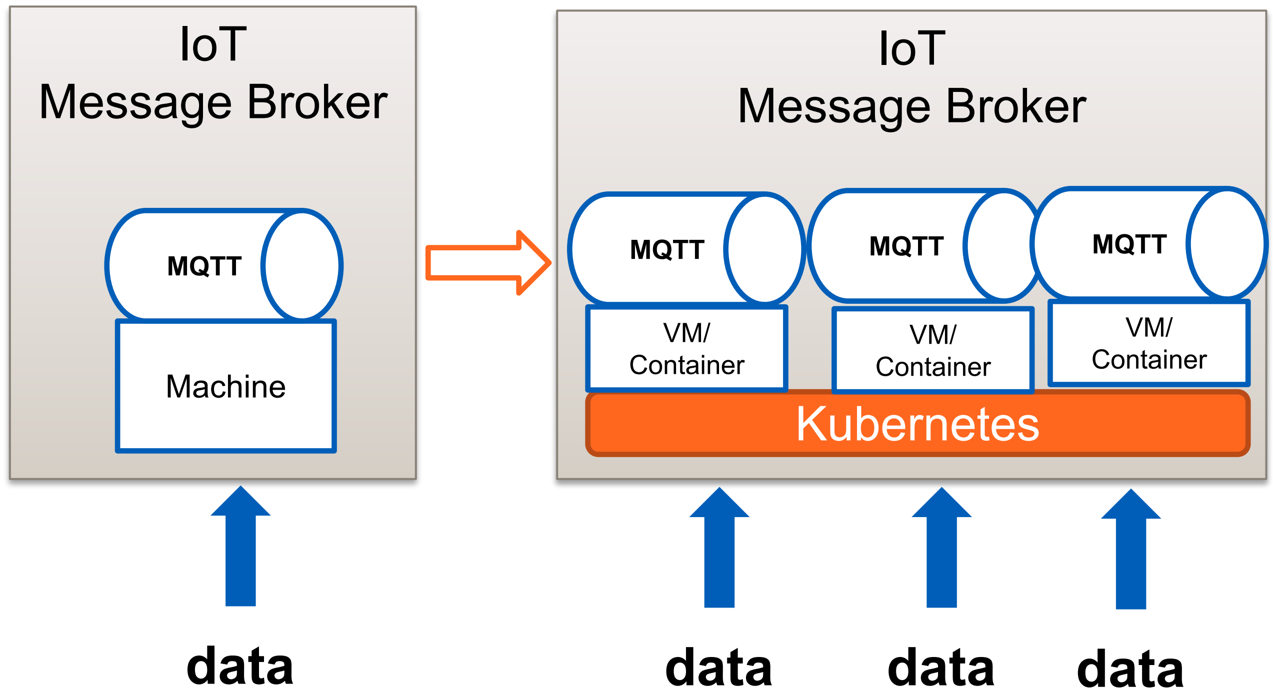


- **Scaling**
  - disk spaces for file storage
  - resources for data ingestion
  - resources for data analysis

Happen at different times and location

Scaling middleware nodes

- **Increase the number of brokers when more data arrive**
- **Provide dedicated brokers on-demand**



Example: scaling compute nodes for data analysis

Monitoring | Jobs | VM Instances | Configuration | Web Interfaces

Name	Role	
thebasecluster-m	Master	SSH ▾
thebasecluster-w-0	Worker	
thebasecluster-w-1	Worker	
thebasecluster-w-2	Worker	
thebasecluster-w-3	Worker	

Equivalent REST

4 nodes

On-demand change

Name	thebasecluster
Region	europe-north1
Zone	europe-north1-a
Autoscaling	Off
Scheduled deletion	Off
Enhanced flexibility mode	Off
Master node	Standard (1 master, N workers)
Machine type	n1-standard-2 (2 vCPU, 7.50 GB memory)
Primary disk type	pd-standard
Primary disk size	500 GB
Worker nodes	6
Machine type	n1-standard-1 (1 vCPU, 3.75 GB memory)

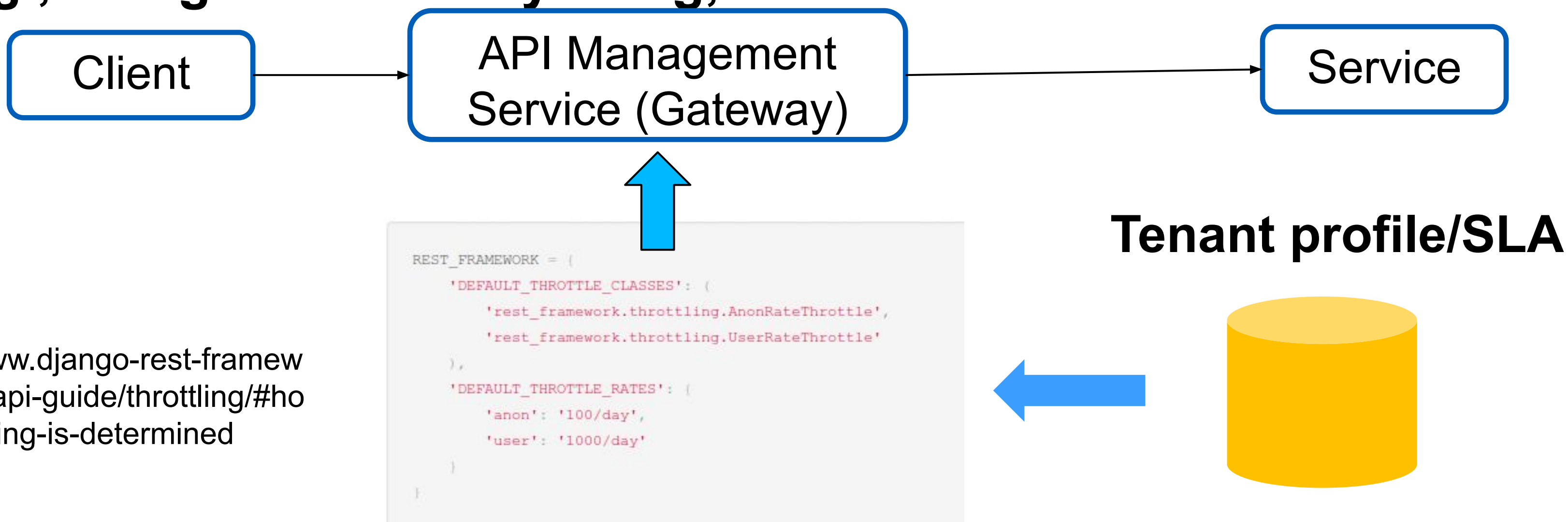
Monitoring | Jobs | VM Instances | Configuration | Web Interfaces

Name	Role	
thebasecluster-m	Master	SSH ▾
thebasecluster-w-0	Worker	
thebasecluster-w-1	Worker	
thebasecluster-w-2	Worker	
thebasecluster-w-3	Worker	
thebasecluster-w-4	Worker	
thebasecluster-w-5	Worker	

6 nodes

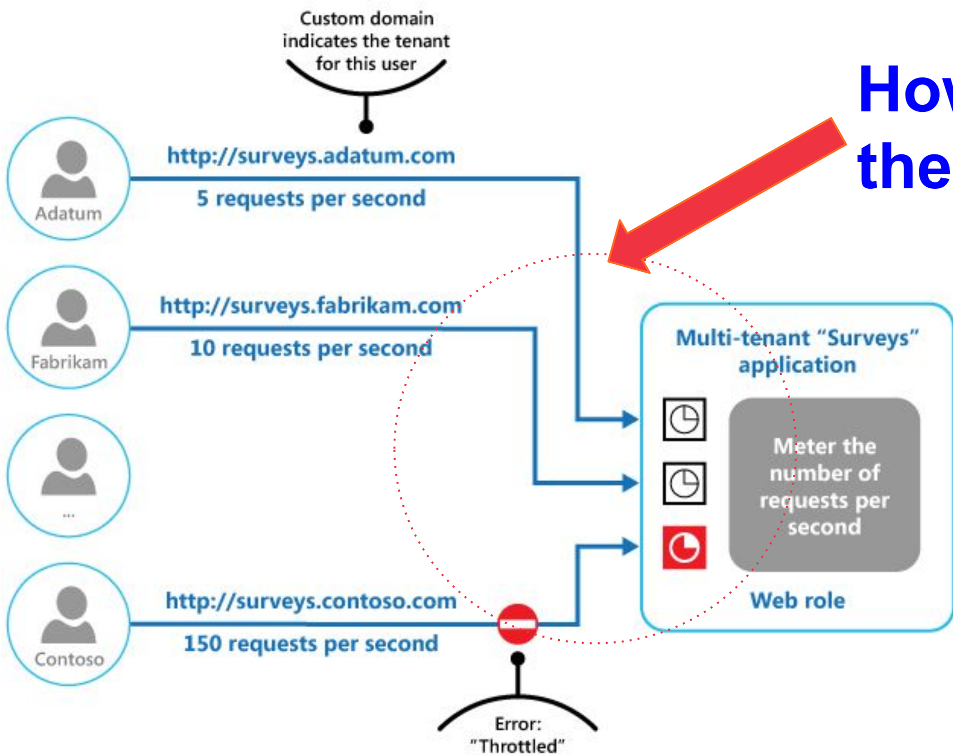
Throttling principle

- **Drop strategy: disable too many accesses and disable unessential services**
  - dynamic vs static configuration
- **E.g., using API Gateway Kong, Kubernetes**



Code: http://www.django-rest-framework.org/api-guide/throttling/#how-throttling-is-determined

Example of throttling based on roles

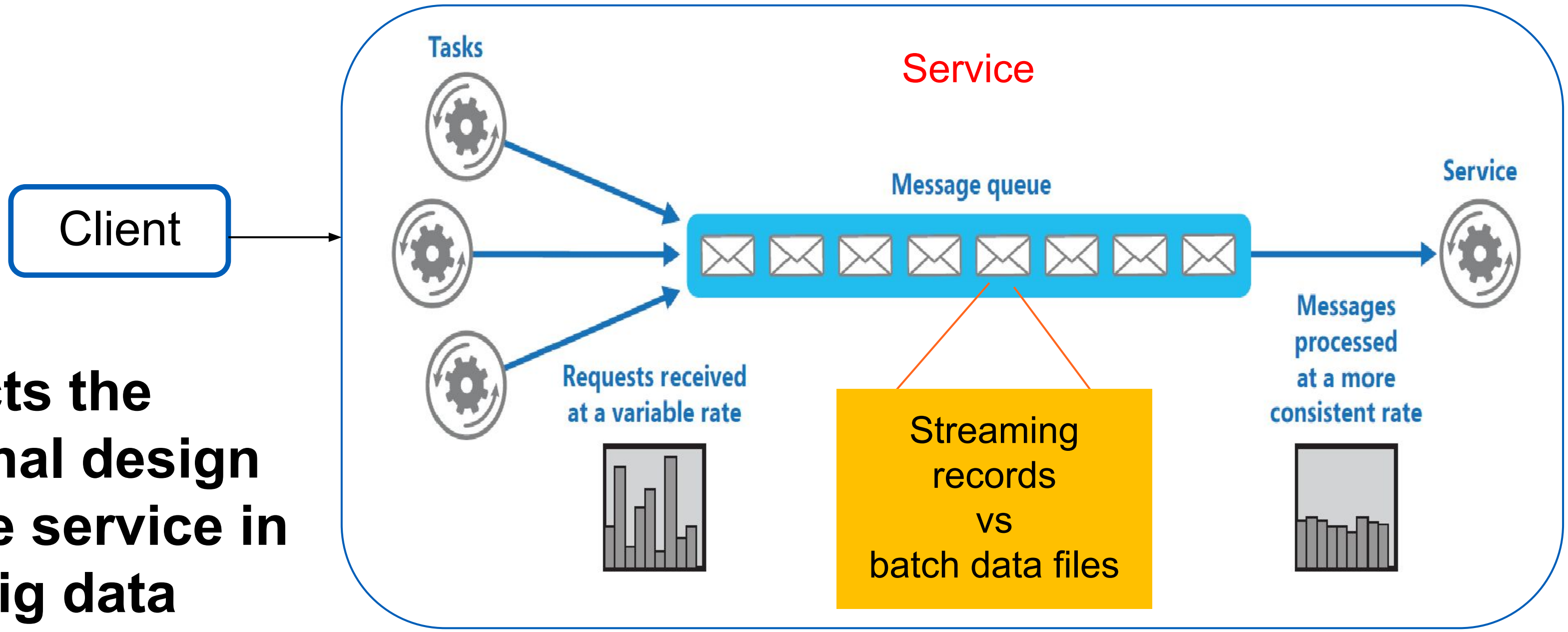


How would you do this in the big data platform?

Big Data Platforms implement "business service models"/SLA for tenants

Figure source:
https://msdn.microsoft.com/en-us/library/dn589798.aspx

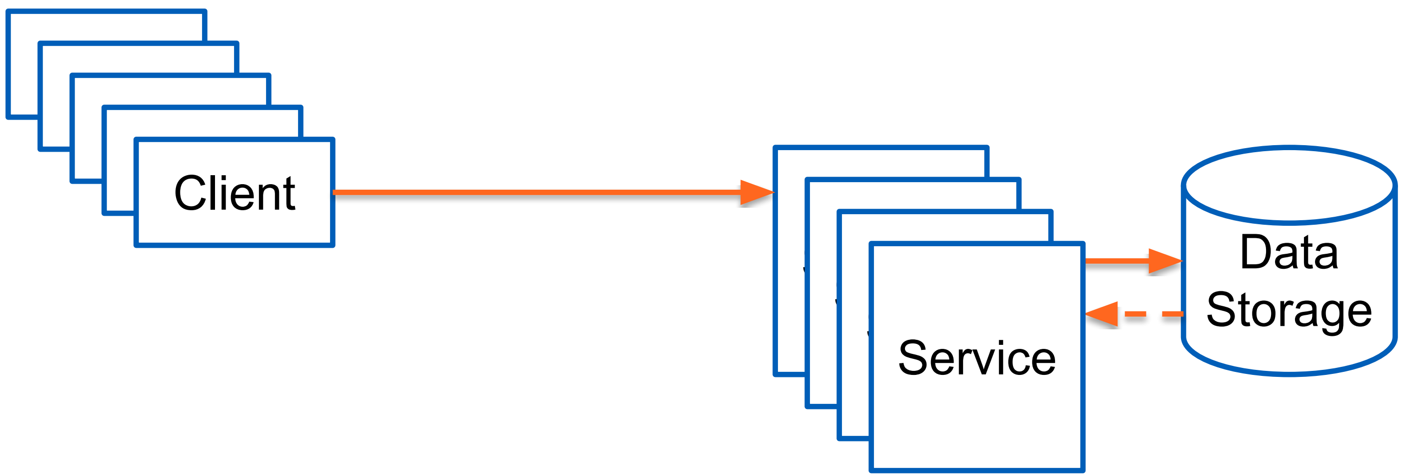
Using tasks and queue-based load leveling pattern



Affects the internal design of the service in the big data platforms

Figure source: https://msdn.microsoft.com/en-us/library/dn589783.aspx

Heavy load between service serving request and data storage



Elastic solution: scale out or up

Using multiple instances of services and queues

How do we control these instances in an efficient way?

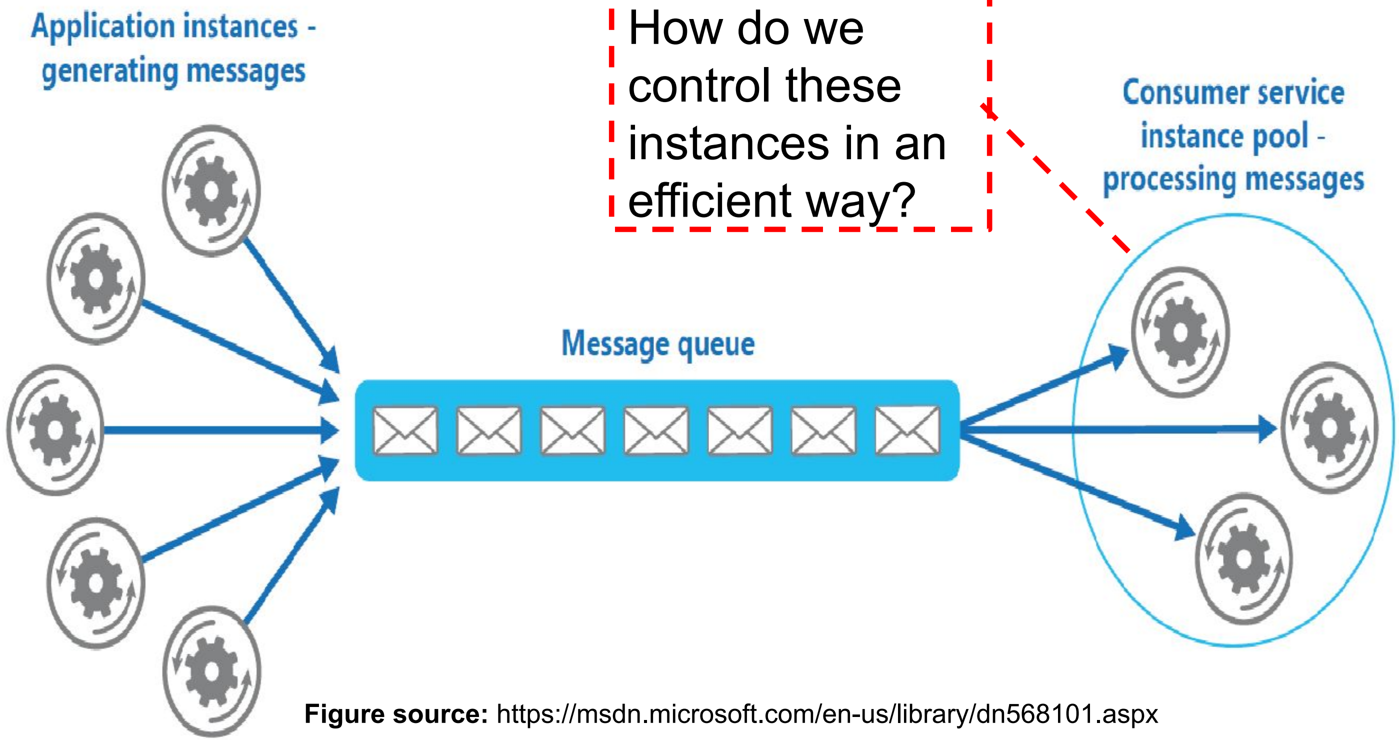


Figure source: https://msdn.microsoft.com/en-us/library/dn568101.aspx

Discovery and consensus

Where are available services and data?

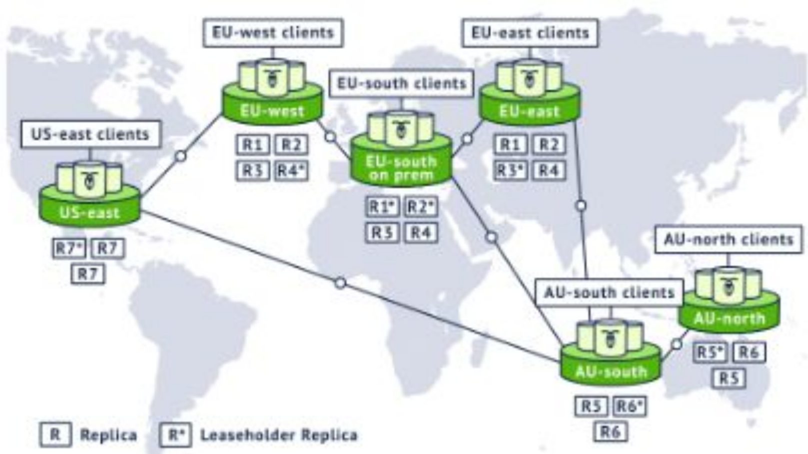


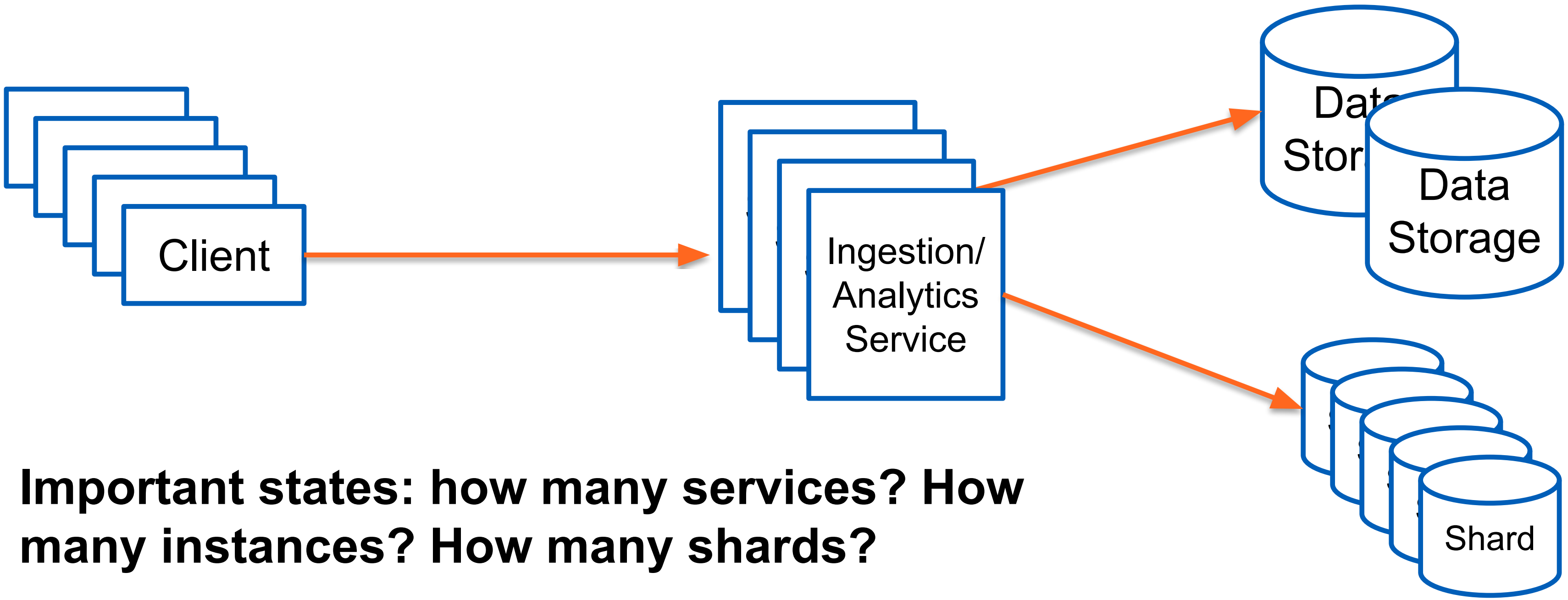
Figure 1: A global CockroachDB cluster

Figure source: Taft et al., CockroachDB: The Resilient Geo-Distributed SQL Database, https://dl.acm.org/doi/pdf/10.1145/3318464.3386134

“At the time of writing, our largest Druid cluster deployment uses more than 100 nodes for Historical processes and about 75 nodes for MiddleManager processes. We ingest over three million events per second and respond to over 250 queries per second. We keep seven days of queryable data in Druid Historical nodes and two years of data retention in S3 deep storage.”

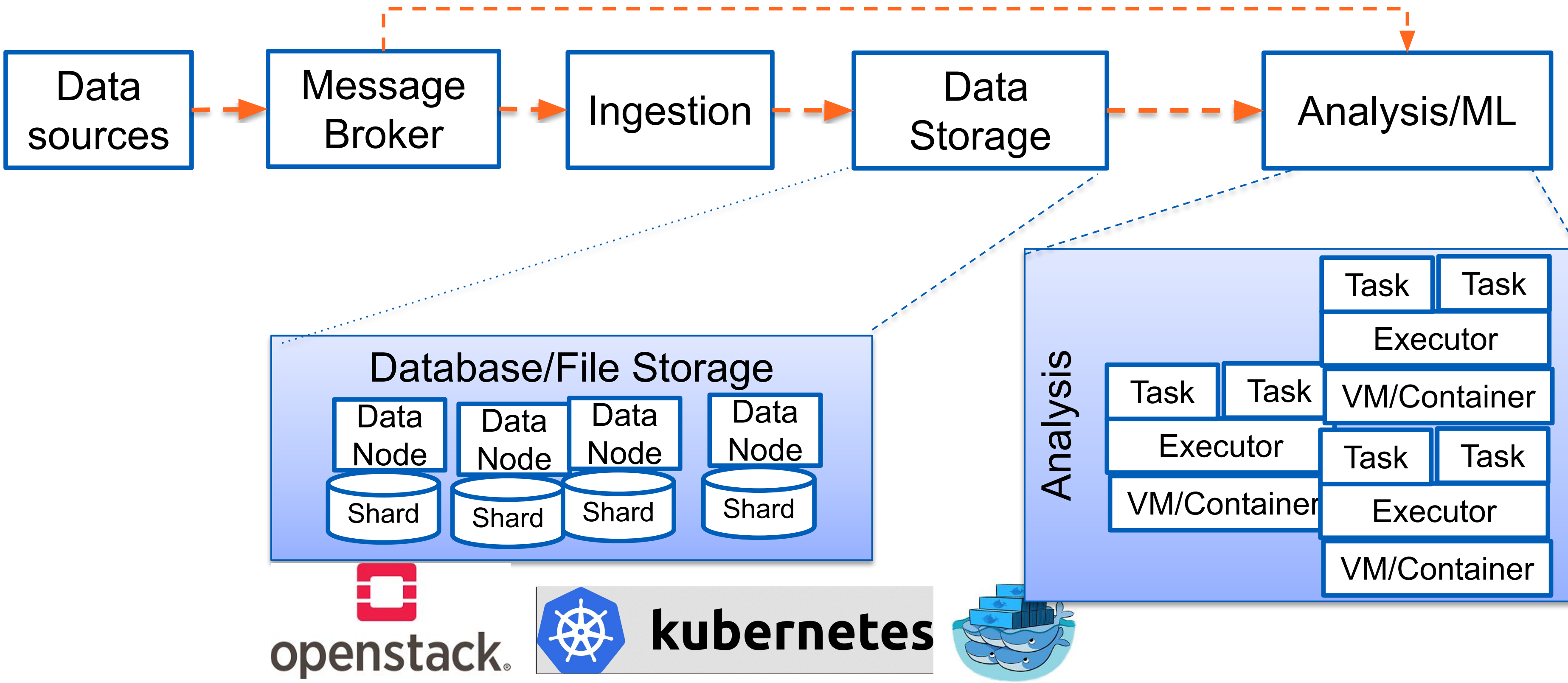
Source: *November 8, 2021, https://www.confluent.io/blog/scaling-apache-druid-for-real-time-cloud-analytics-at-confluent/*

We can create a lot of instances or we can create new services



Important states: how many services? How many instances? How many shards?

Runtime view of some components



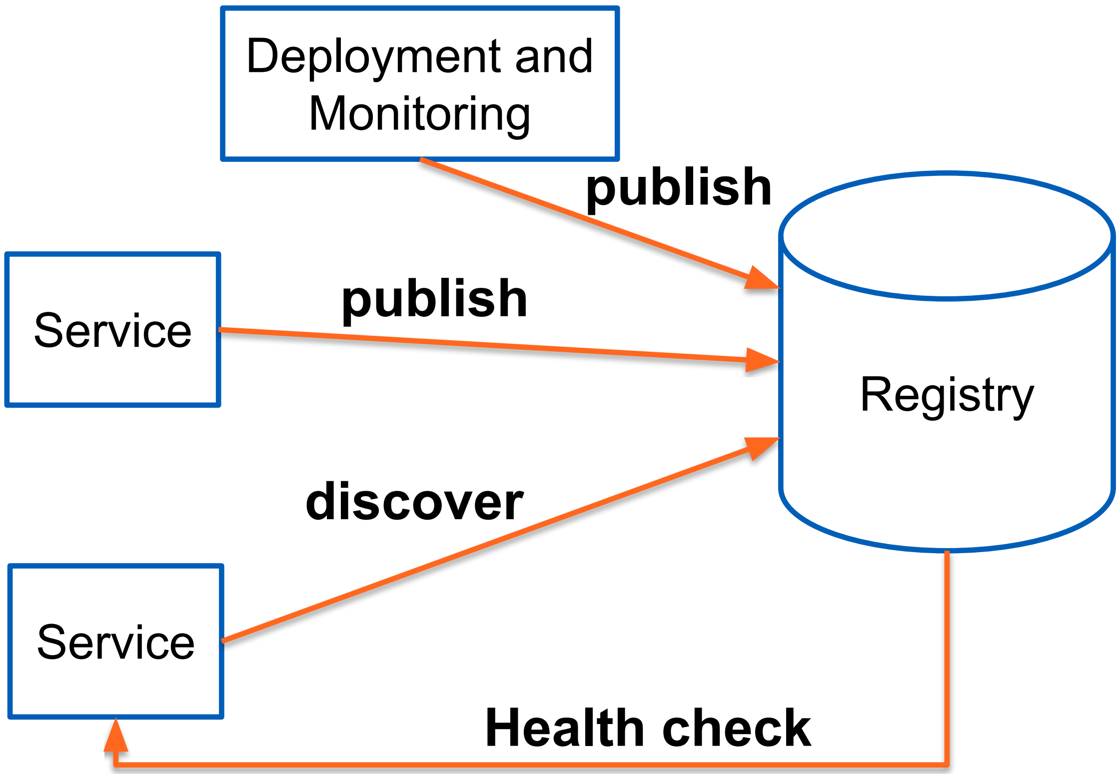
Multiple instances

- **A building block of big data platforms can have many services and a service can have many instances**
  - e.g., for replication and load balancing
  - a database service (e.g. MongoDB) has multiple data nodes, each responsible for a subset of shards/partitions
  - a processing engine (e.g., Spark or Airflow) can have many nodes, each executes different tasks of a process
- **The same component can have many instances deployed**
  - e.g., dedicated deployment of MongoDB for different customers

Service state management

- **Service information**
  - include states and other important configuration information
  - many instances
  - cross different infrastructures/data centers
- **Related components**
  - services themselves
  - monitoring component, deployment component, orchestration controllers
- **Lifecycle: very dynamic in elastic environments**
  - *Start, run, shutdown, restart, scale*

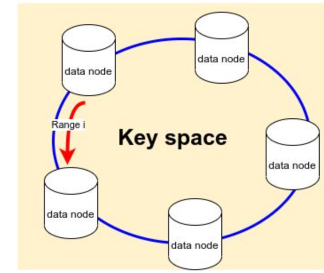
Service Discovery principle

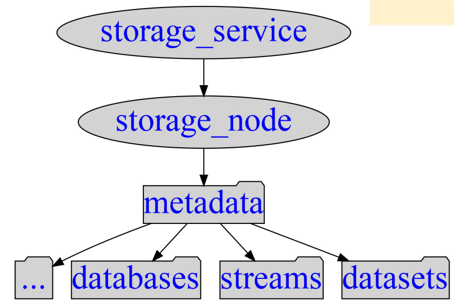


- **Key requirements**
  - fast
  - consistent
  - secure
  - cross data centers
  - simple APIs

But what about data discovery?

- **Approach 1**
  - pre-defined mapping: e.g., using consistent hashing
- **Approach 2**
  - discover relevant services and then ask relevant services about metadata about data
- **Approach 3**
  - use a dedicated data discovery service and ask the service for metadata about data





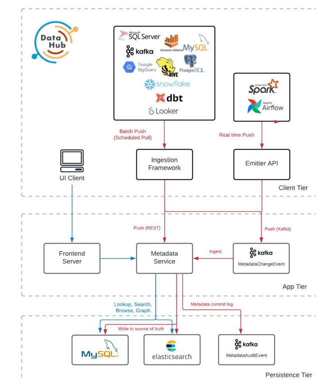


Figure source: https://datahubproject.io/docs/architecture/architecture

Example:

https://github.com/rdsea/bigdataplatforms/tree/master/tutorials/servicediscovery

Consensus for big data platforms

- **Consensus is about to agree on something**
- **Very important for replication and fault tolerance in big data platforms**
  - distributed lock, master selection
- **Scope**
  - platform level and service component levels
  - single data center or cross-data center
- **We will have to deal with them in several frameworks for big data, e.g. Apache Spark, Hadoop and Kafka**

Distributed coordination

- **A lot of algorithms, etc.**
  - Paxos family
- **Well-known in the cloud**

TABLE 4. PATTERNS OF PAXOS USE IN PROJECTS

		Usage Patterns								
Project	**Consensus System**	**SR**	**LR**	**SS**	**BO**	**SD**	**GM**	**LE**	**MM**	**Q**
GFS	Chubby			✓				✓	✓	
Borg	Chubby/Paxos	✓				✓		✓		
Kubernetes	etcd						✓		✓	
Megastore	Paxos		✓							
Spanner	Paxos	✓								
Bigtable	Chubby						✓	✓	✓	
Hadoop/HDFS	ZooKeeper	✓						✓		
HBase	ZooKeeper	✓		✓			✓		✓	
Hive	ZooKeeper			✓					✓	
Configerator	Zeus								✓	
Cassandra	ZooKeeper					✓		✓	✓	
Accumulo	ZooKeeper		✓	✓					✓	
BookKeeper	ZooKeeper						✓		✓	
Hedwig	ZooKeeper						✓		✓	
Kafka	ZooKeeper						✓	✓	✓	
Solr	ZooKeeper							✓	✓	✓
Giraph	ZooKeeper		✓		✓				✓	
Hama	ZooKeeper				✓					
Mesos	ZooKeeper							✓		
CoreOS	etcd					✓				
OpenStack	ZooKeeper					✓				
Neo4j	ZooKeeper			✓				✓		

Notes from the paper: “server replication (SR), log replication (LR), synchronization service (SS), barrier orchestration (BO), service discovery (SD), group membership (GM), leader election (LE), metadata management (MM) and distributed queues (Q)”

What if they do not fit into your big data platforms?

Source: Ailidani Ailijiang, Aleksey Charapkoy and Murat Demirbasz , Consensus in the Cloud: Paxos Systems Demystified, http://www.cse.buffalo.edu/tech-reports/2016-02.pdf

What you should do this week

- Look at the list of data sources and start think which data sources you will use for your study
- Lambda and Kappa architecture styles
- Check and play with basic ingestion: simple queue, MQTT/AMQP (from the cloud background)
- Brush up patterns for scaling and failure handling
- Look at how service discovery and consensus are implemented in big data systems

Note: *materials/links are in our git and slides*

Thanks!

Hong-Linh Truong
Department of Computer Science

rdsea.github.io