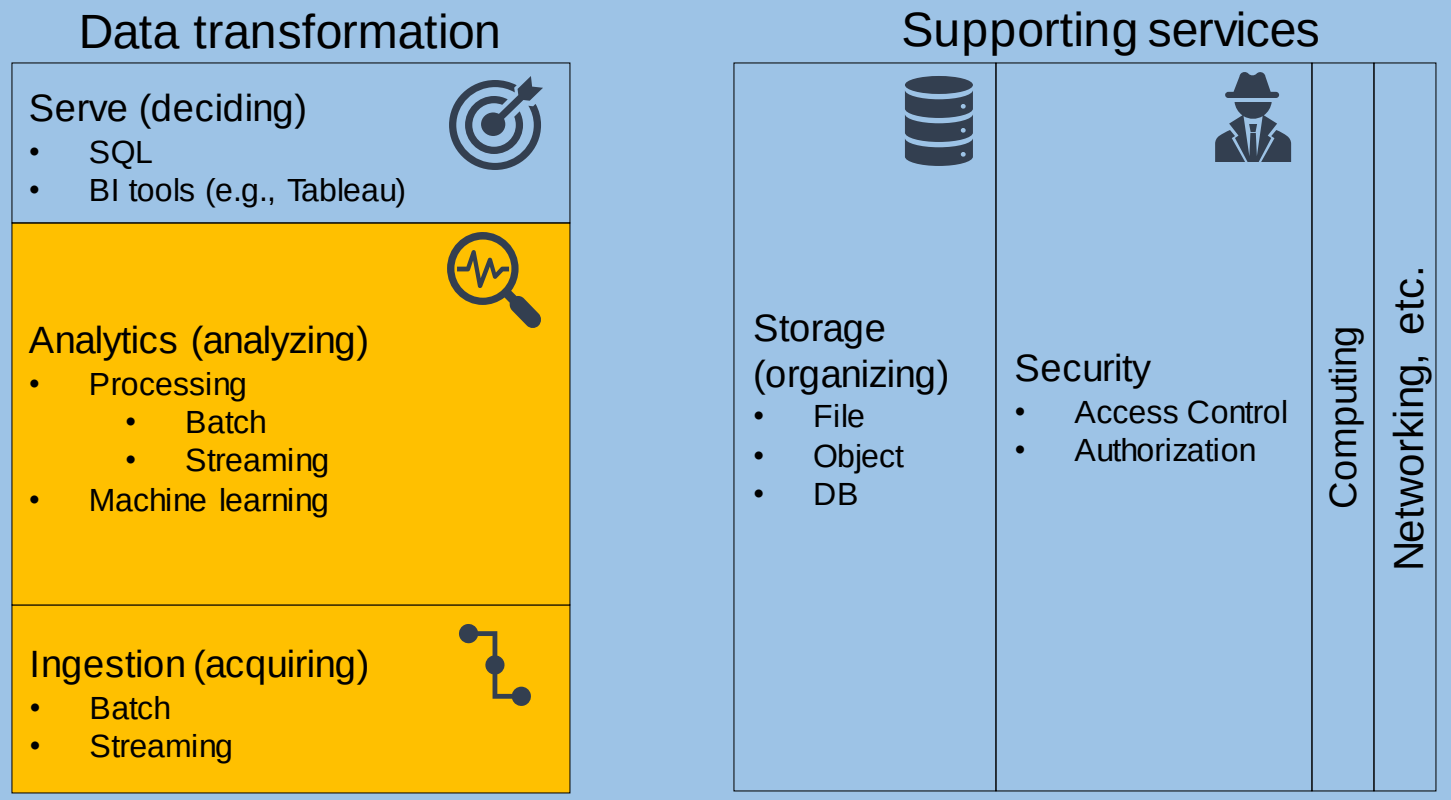
BIG DATA AND CLOUD PLATFORMS

Data pipelines on cloud (Streaming)


Data transformation
Serve (deciding)
• SQL
• BI tools (e.g., Tableau)
Analytics (analyzing)
• Processing
• Batch
• Streaming
• Machine learning
Ingestion (acquiring)
• Batch
• Streaming
Supporting services
Storage (organizing)
• File
• Object
• DB
Security
• Access Control
• Authorization
Computing
Networking, etc.

Batch vs. Streaming systems

What is a bulk processing system?

- High latency
- Exact results
- Process massive data at once
  - ... is this true?

What is a streaming system?

- Low latency
- Approximate result
  - ... is this true?
- Process data item by data item
  - ... is this true?

Batch vs. Streaming systems

What is a bulk processing system?

- An engine capable to handle processing on **bounded** datasets

What is a streaming system?

- An engine capable to handle processing on **unbounded** datasets
- Streaming is a superset of batch processing

Akidau, Tyler, Slava Chernyak, and Reuven Lax. *Streaming systems: the what, where, when, and how of large-scale data processing*. " O'Reilly Media, Inc.", 2018.

Ingestion: batch

Goal: moving data to the cloud

Moving data to the cloud

- 80TB of data to move,
- 1Gbps connection to the internet

How many days?

- 80000GB / (1Gbps / 8) / 60 / 60 / 24 ~= a week without internet

Ingestion: batch

Batch/Bulk: move data from on-premises storage

Workflow

- Receive shipment
- Set up
- Transfer data
- Ship back (shipping carrier)

Ingestion: batch (AWS)

AWS Snowball

- 50TB (North America only) and 80TB versions
- Not rack-mountable

Throughput

- 1 Gbps or 10 Gbps using an RJ-45 connection
- 10 Gbps using a fiber optic connection

https://aws.amazon.com/snowball/

Amazon Snowmobile

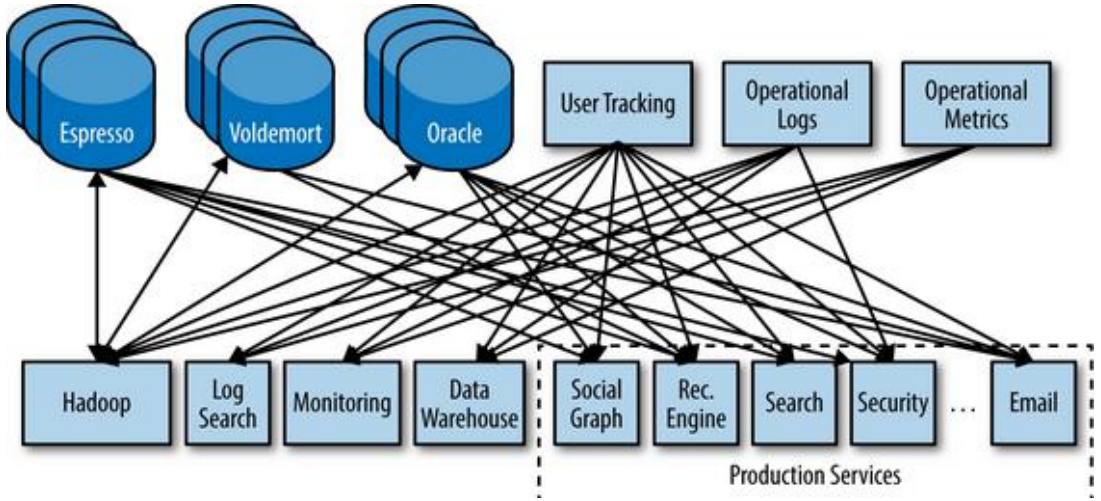
What if we have exabyte of data?

Value	Metric
10^3	KB (kilobyte)
10^6	MB (megabyte)
10^9	GB (gigabyte)
10^{12}	TB (terabyte)
10^{15}	PB (petabyte)
10^{18}	EB (exabyte)
10^{21}	ZB (zettabyte)
10^{24}	YB (yottabyte)

https://youtu.be/8vQmTZTg7nw?t=45 (2022-11-14)

Ingestion: stream

- Data (often) flows in both directions, storage systems are both sources and destinations for data transformations
- Two pipelines per application (data in/out)
  - Worst case (full connectivity): $O(N^2)$



Kreps, Jay. *I heart logs: Event data, stream processing, and data integration*. " O'Reilly Media, Inc.", 2014.

Ingestion: stream

Stream: real-time streaming data

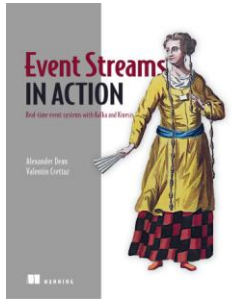
Event: anything that we can observe occurring at a particular point in time

Continuous streaming

- Illimited succession of individual events
- Ordered by the point in time at which each event occurred

Publish/subscribe (pub/sub): a way of communicating messages

- *Senders* publish messages associated with one or more **topics**
- *Receivers* subscribe to specific topics, receive all messages with that topic
- *Messages* are events



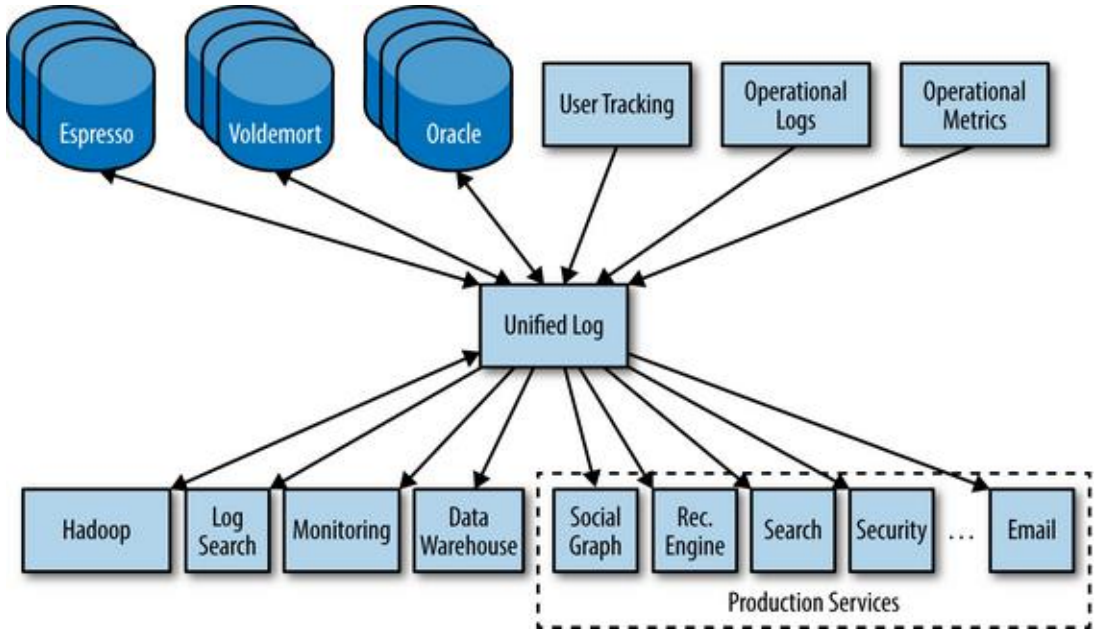
https://www.manning.com/books/event-streams-in-action

Ingestion: stream

Log

- Append-only data structure
- Each application only knows about the log, it ignores the details of the source
  - E.g., a data consumer is not concerned about whether the data came from a relational database or some application

The log acts as a messaging system with durability guarantees and ordering semantics



Kreps, Jay. *I heart logs: Event data, stream processing, and data integration*. " O'Reilly Media, Inc.", 2014.

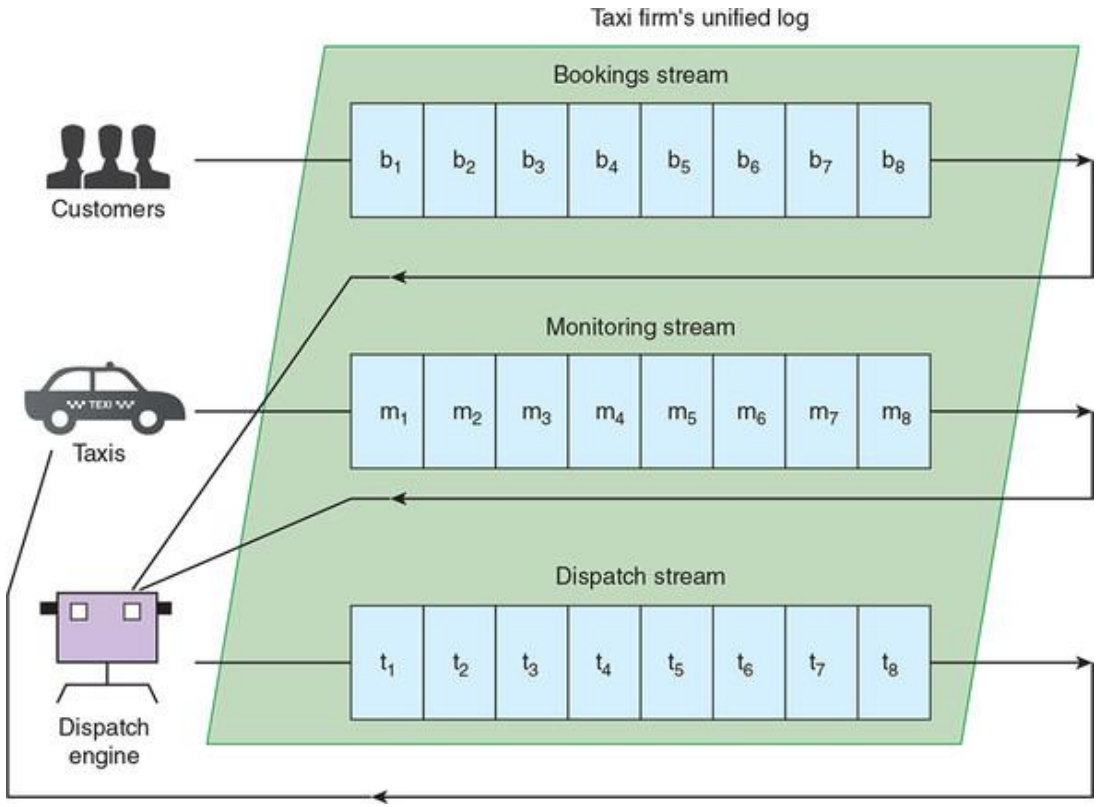
Ingestion: stream

General idea:

- Collect events from many source systems
- Store them in a unified log
- Enable applications to operate on these event streams

Unified log

- Unified, append-only, ordered, distributed log that allows the centralization of event streams



Ingestion: stream

Unified: a single log in a company with applications sending/reading events

- Log serves as central data backbone
  - It can contain many distinct continuous streams of events
  - Not all events are sent to the same event stream

Append-only: new events are appended to the unified log

- Existing events are never updated in place
  - If read the event #10, never look at events 1 through 10 again
- Events are automatically deleted from the unified log when they age
  - E.g., automatically remove events after 7 days

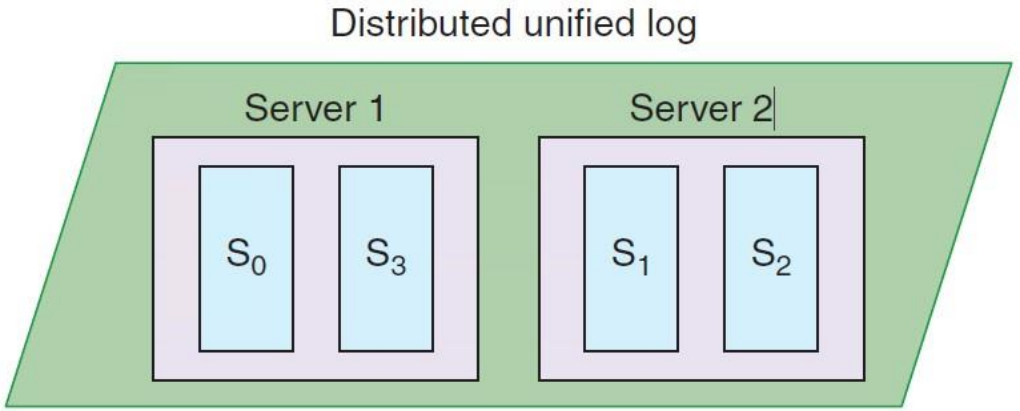
Ingestion: stream

Distributed: the unified log lives across a cluster of machines

- Optionally divide events into shards (i.e., partitions)
  Still, the log is unified since we have a single (conceptual) log

Distribution ensures

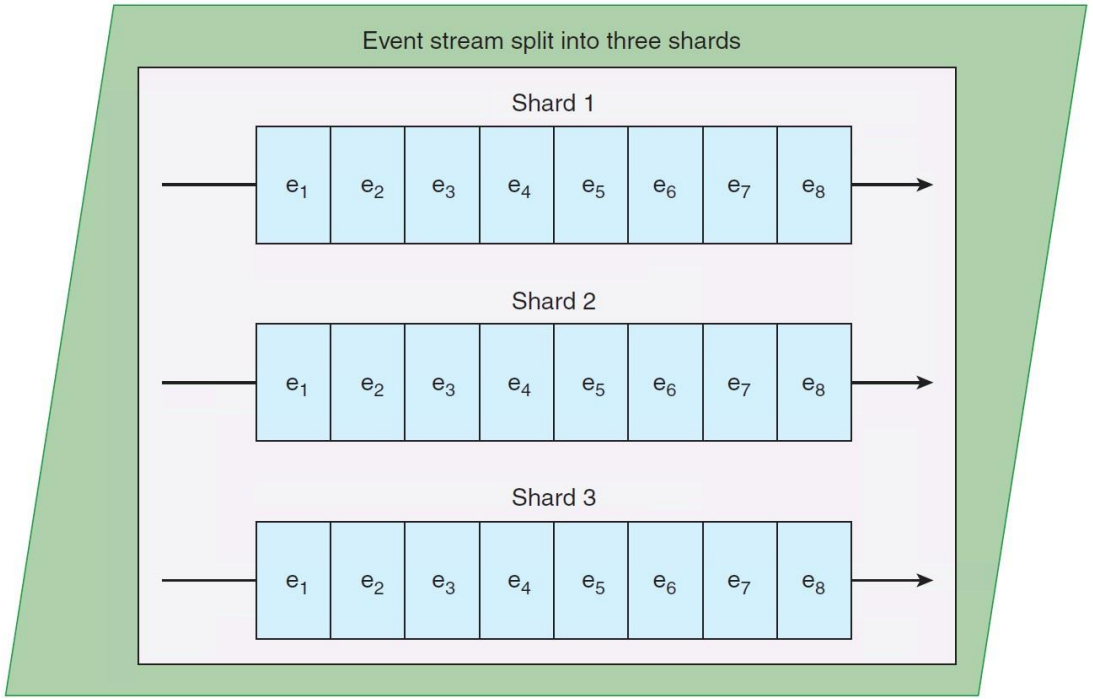
- Scalability: work with streams larger than the capacity of single machines
- Durability: replicate all events within the cluster to overcome data loss
- Using a log as a universal integration mechanism is never going to be more than an elegant fantasy if we can't build a log that is fast, cheap, and scalable



Ingestion: stream

Ordered: events in a shard have a sequential IDs (unique in a shard)

- Local ordering keeps things much simpler than global ordering
- Applications maintain their own cursor for each shard

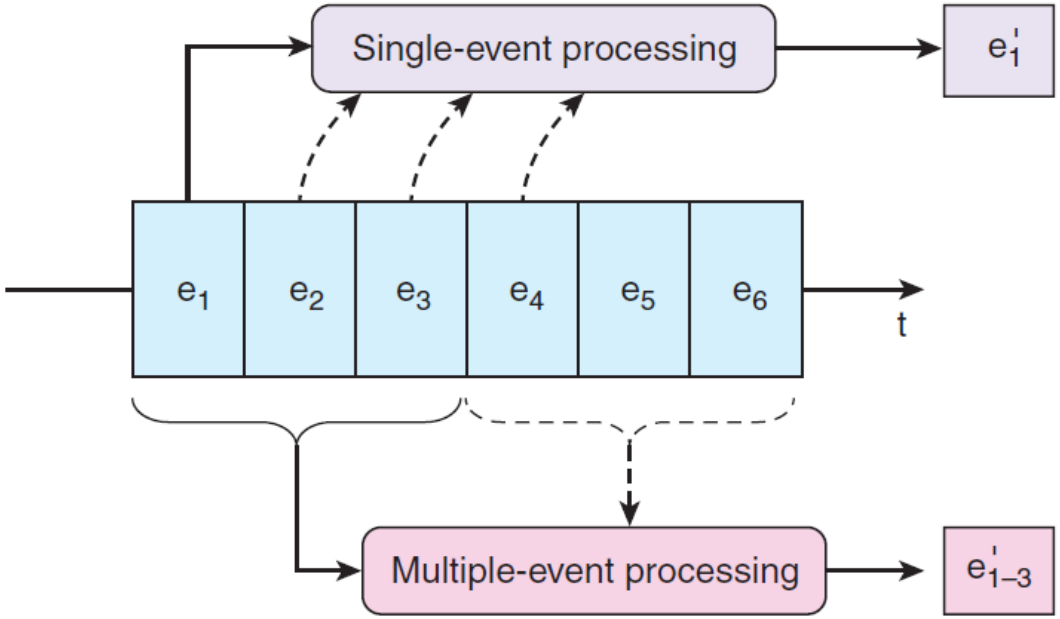


Lamport, Leslie. "Time, clocks, and the ordering of events in a distributed system." *Concurrency: the Works of Leslie Lamport*. 2019. 179-196.

Ingestion: stream

Two types of processing

- **Single-event:** a single event produces zero or more events
  - Validating "Does this event contain all the required fields?"
  - Enriching "Where is this IP address located?"
  - Filtering "Is this error critical?"
- **Multiple-event:** multiple events collectively produce zero or more events
  - Aggregating, functions such as minimum, maximum, sum
  - Pattern matching, looking for patterns or co-occurrence
  - Reordering events based on a sort key

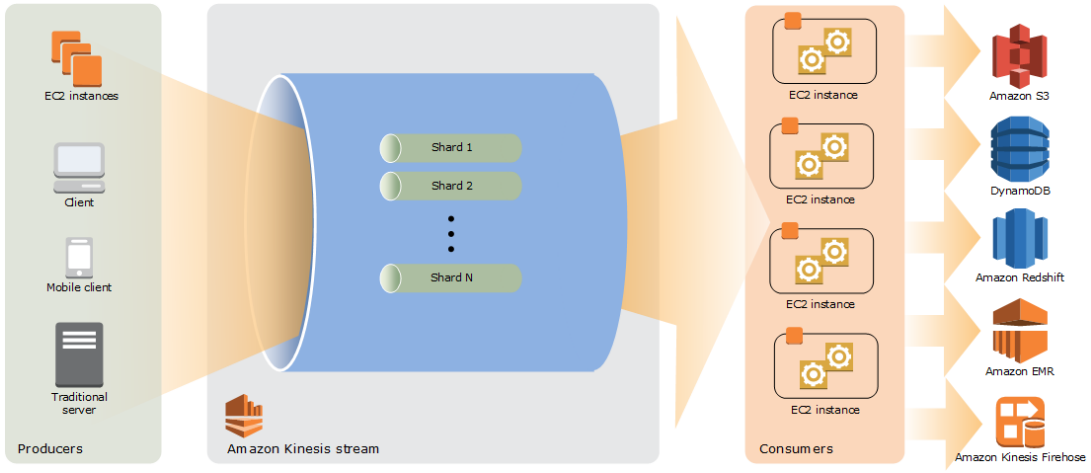


Ingestion: stream (AWS)

Amazon Kinesis Data Streams

- Created and provisioned by shard
  - Each shard provides 1 MBps and 1000 data puts per second
- A data record consists of
  - User-supplied partition key to balance records across shards
  - Incremental sequence number added by the shard
  - A data blob
- Consumers get records by shard
  - Records are sorted by partition key and sequence number
  - Ordering is not guaranteed across shards
- Records are retained for 7 days at maximum

https://docs.aws.amazon.com/streams/latest/dev/key-concepts.html



Ingestion: stream (AWS)

Re-sharding (i.e., scaling)

- Split a shard into two, or merge two shards
- Users must scale shards up and down manually
  - Monitor usage with Amazon CloudWatch and modify scale as needed
- Avoid shard management by using Kinesis Data Firehose

Kinesis is a regional service, with streams scoped to specific regions

- All ingested data must travel to the region in which the stream is defined

Costs

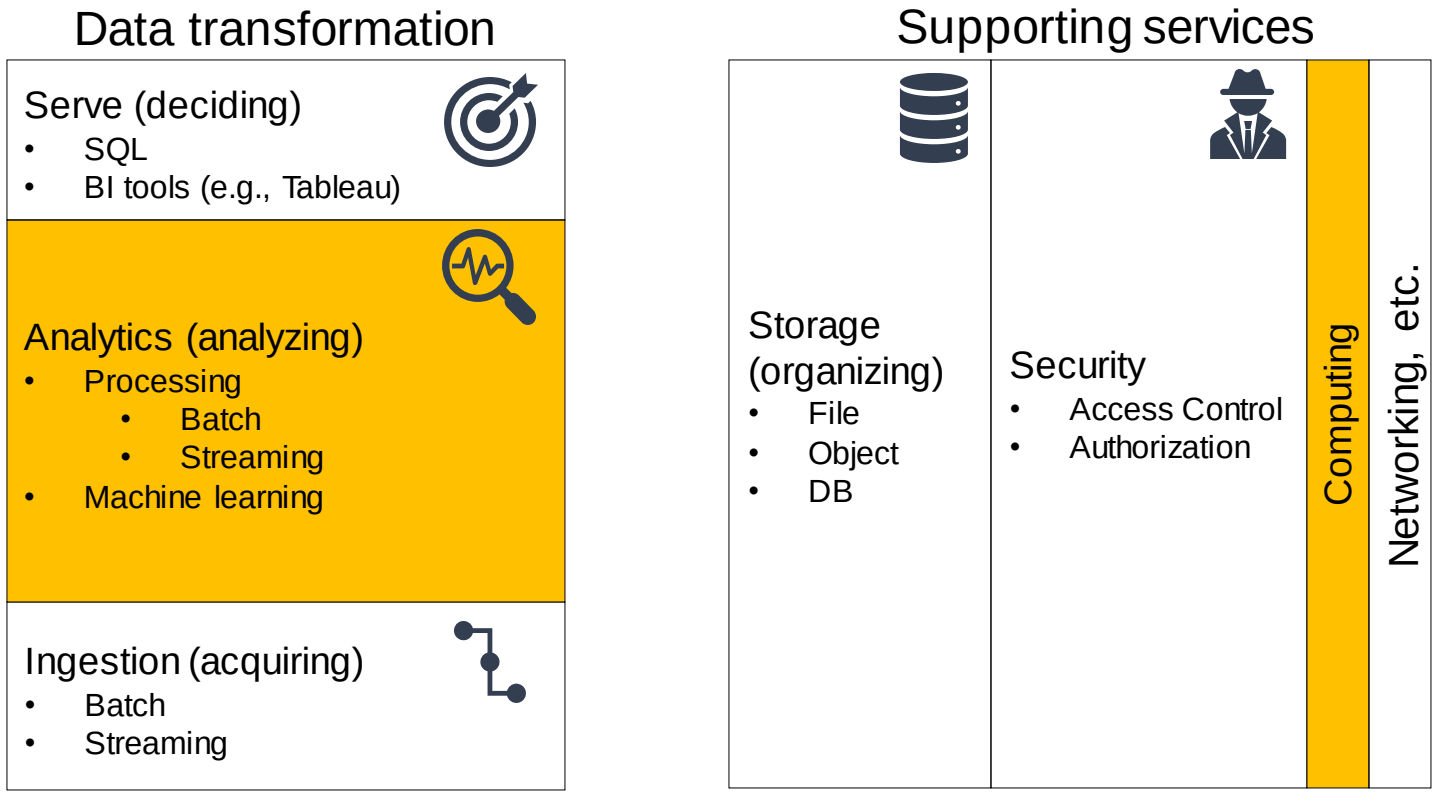
- Priced by shard hour, data volume, and data retention period
- Pay for resources you provision (even if not used)

https://aws.amazon.com/cloudwatch/
https://aws.amazon.com/kinesis/data-firehose

Ingestion: stream

Feature	AWS Kinesis	Google Pub/Sub
Unit of deployment	Stream	Topic
Unit of provisioning	Shard	N/A (fully managed)
Data unit	Record	Message
Data producer/destination	Producer/Consumer	Publisher/Subscriber
Data partitioning	User-supplied partition key	N/A (fully managed)
Retention period	Up to 7 days	Up to 7 days
Pricing	Per shard-hour, PUT payload units, and optional data retention	Message ingestion and delivery, and optional message retention

A tentative organization



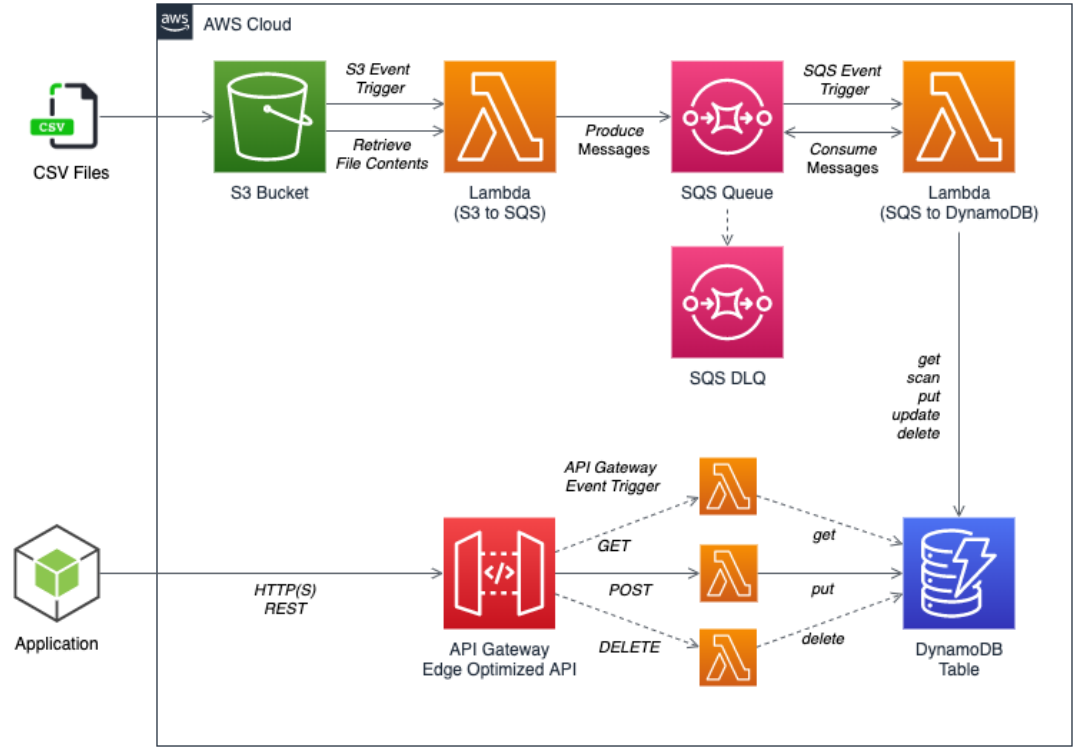
Serverless computing/processing

AWS Lambda: compose code functions in a loose orchestration

- Build modular back-end systems
- Event-driven and push-based pipelines

With Lambda, you are responsible only for your code (Lambda function)

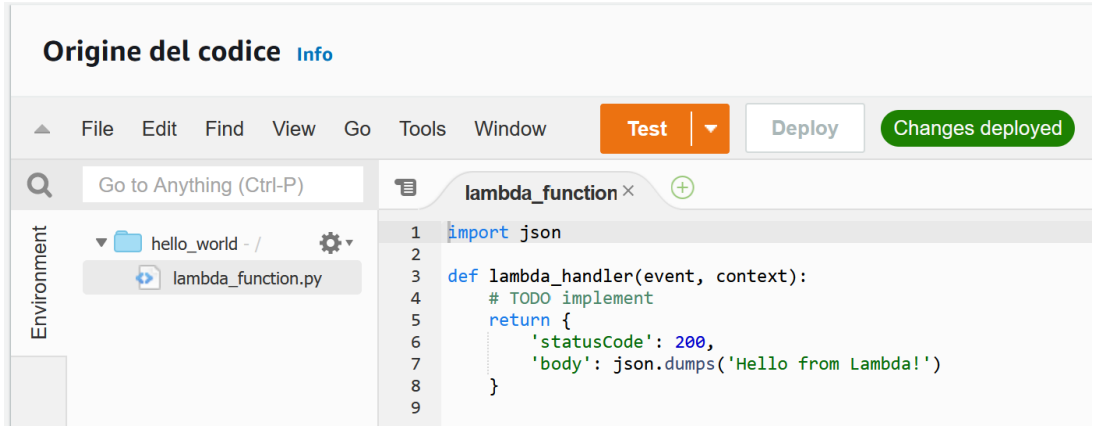
- Lambda manages the compute fleet that offers a balance of memory and CPU
- Lambda performs operational and administrative activities on your behalf
  - Provisioning capacity, monitoring fleet health, applying security patches, etc.



Serverless computing (AWS Lambda)

AWS Lambda

- A Lambda function is a granular service
- The Lambda runtime invokes a lambda function multiple times in parallel
- Compute service that executes code written in JavaScript/Python/C#/Java
  - Elastic Compute Cloud (EC2) servers run the code (e.g., a Linux server)
- A function is `code + configuration + dependencies`
  - Source code (JARs or DLLs) is zipped up and deployed to a container
- Invocation supports push/pull events



Serverless computing (FaaS)

FaaS: write single-purpose stateless functions

- Keep the single responsibility principle in mind
- A function that does just one thing is more testable and robust
- A function with a well-defined interface is also more likely to be reused
- Code should be created in a stateless style
  - Statelessness allows scalability
  - Local resources or processes will not survive along sessions
- Functions that terminate sooner are cheaper
  - E.g., pricing is based on #requests, execution time, and allocated memory

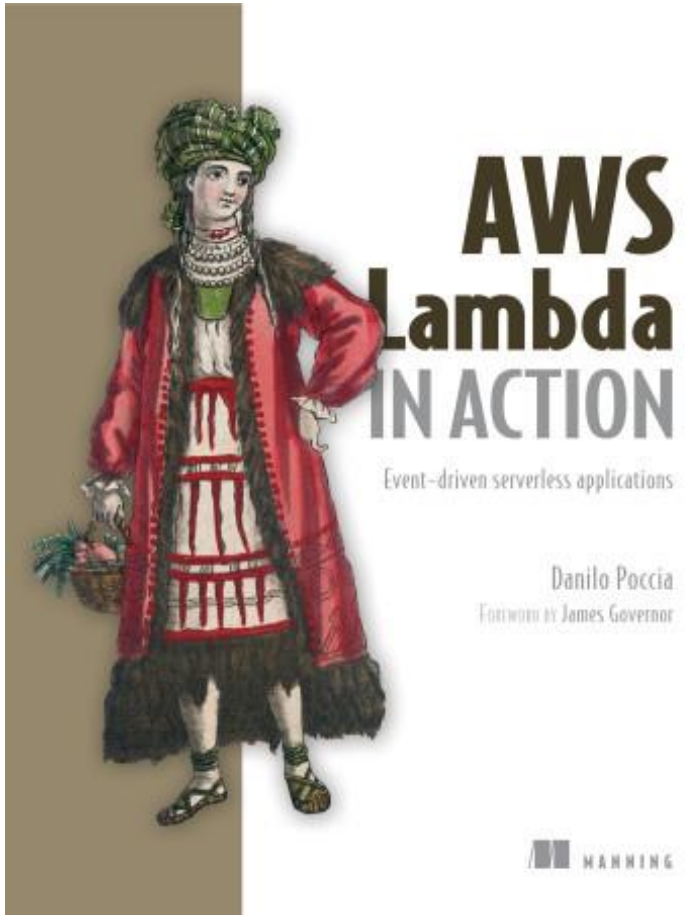
Patterns for data pipelines

Patterns are architectural solutions to problems in software design

- A (design) pattern is a general, best-practice reusable solution to a commonly occurring problem within a given context in software design
- It is a template for how to solve a problem in many different situations

Patterns for serverless data pipelines

- Command pattern
- Messaging pattern
- Priority queue pattern
- Pipes and filters pattern



https://www.manning.com/books/aws-lambda-in-action

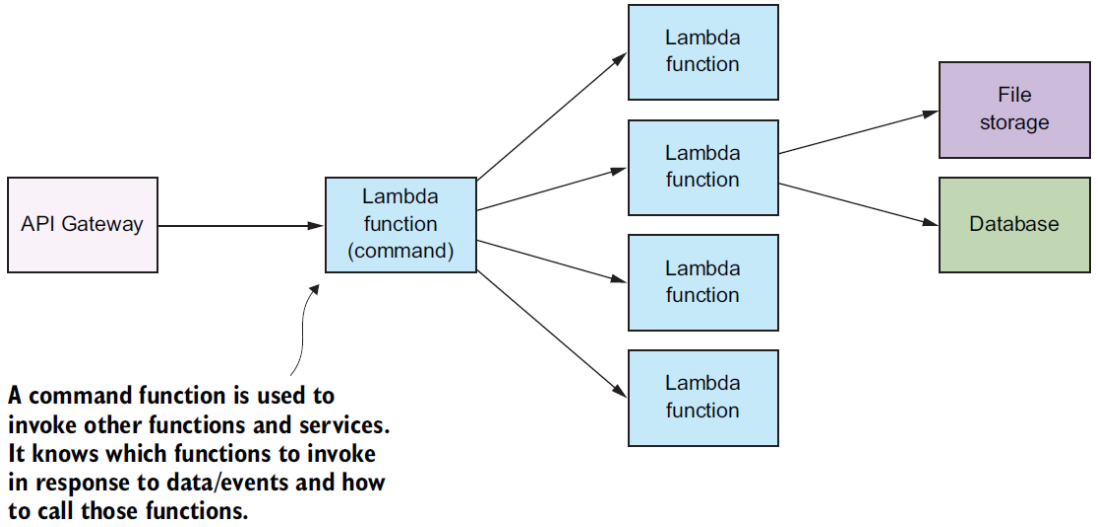
Command pattern

Command pattern

- A behavioral design pattern in which an object is used to encapsulate the information needed to perform an action or trigger an event

Encapsulate a request as an object

- Issue requests to objects without knowing anything about the operation being requested or the receiver

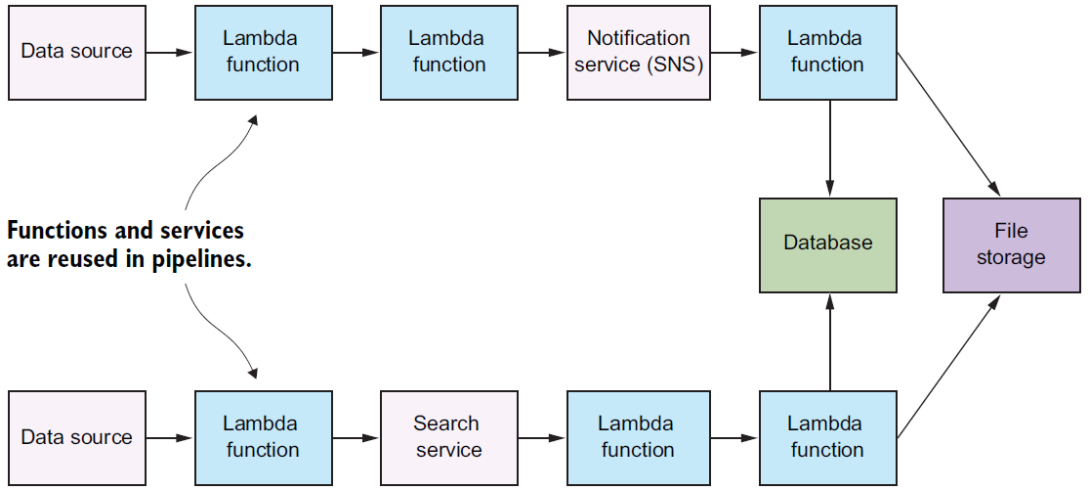


https://aws.amazon.com/api-gateway

Pipes and filters pattern

Decompose a complex processing task into a sequence of manageable services

- Components designed to transform data are referred to as filters
- Connectors that pass data between components are referred to as pipes



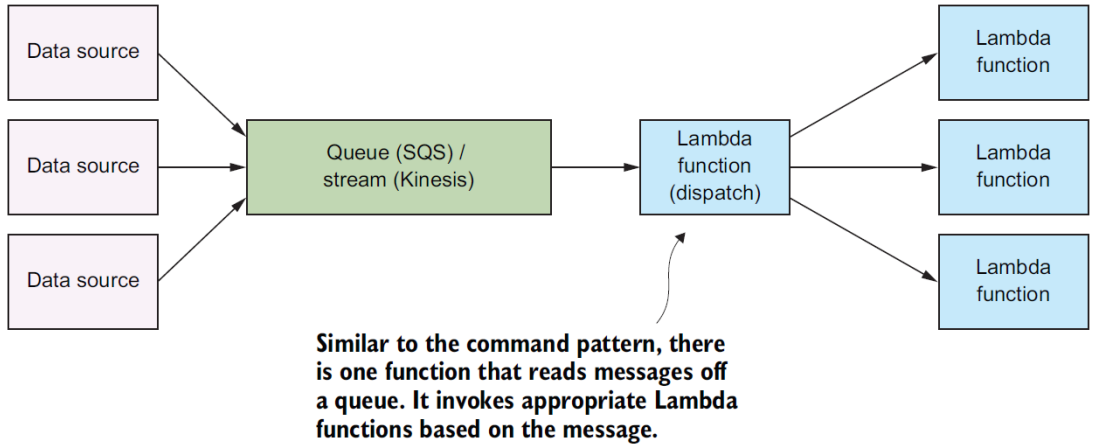
Messaging pattern

Messaging pattern

- Describes how two different parts of a message passing system connect and communicate with each other

Decouple services from direct dependence and allow storage of events in a queue

- Reliability: if the consuming service goes offline, messages are retained in the queue and can still be processed
- A message queue can have a single sender/receiver or multiple senders/receivers



Priority queue pattern

Decouple and prioritize requests sent to services

- Requests with a higher priority are received and processed more quickly than those with a lower priority
- Useful in applications that offer different service level guarantees

Control how and when messages are dealt with

- Different queues, topics, or streams to feed messages to your functions
- High-priority messages go through expensive services with more capacity