A Milestone for FaaS Pipelines, Object Storage- vs VM-Driven **Data Exchange**

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Serverless functions provide high levels of parallelism, short startup times, and "pay-as-you-go" billing. These attributes make them a natural substrate for data analytics workflows. However, the impossibility of direct communication between functions makes the execution of workflows challenging. The current practice to share intermediate data among functions is through remote object storage (e.g., IBM COS). Contrary to conventional wisdom, the performance of object storage is not well understood. For instance, object storage can even be superior to other simpler approaches like the execution of shuffle stages (e.g., GroupBy) inside powerful VMs to avoid all-to-all transfers between functions. Leveraging a genomics pipeline, we show that object storage is a reasonable choice for data passing when the appropriate number of functions is used in shuffling stages.

KEYWORDS

serverless computing, function-as-a-service

PROBLEM STATEMENT AND GOALS.

Serverless computing platforms (such as AWS Lambda, IBM Cloud Functions, etc) provide on-demand scalability and fine-grained resource allocation. This means that a developer can leverage massive levels of parallelism in just a few seconds to build applications with rapid horizontal scaling. Along with their ease-of-use, these platforms have been recently used to execute serverless workflows composed of a sequence of execution stages, which can be represented as a directed acyclic graph (DAG). DAG nodes correspond to serverless functions and edges correspond to the flow of data between dependent stages.

Unfortunately, serverless functions do not support point-to-point communication. As a result, the standard practice for passing intermediate data between serverless functions is through remote object storage (e.g., IBM COS). If care is not taken, however, I/O-bound stages that require all-to-all data transfers between functions (such as GroupBy and OrderBy) can end up bottlenecking the system. This typically occurs due to the limited throughput of object storage services (e.g., IBM COS only supports a few thousand operations/s).

On the positive side, object storage is cheap and an "always-on" service, requiring little intervention from the user. It is therefore the most comfortable option for programmers and data analysts, despite its higher latency and lower throughput compared to other alternatives such as AWS ElastiCache. For this reason, some practitioners prefer to run I/O-bound stages inside large-memory virtual machine (VM) instances to minimize data transfers. Nevertheless, these solutions do not exploit the huge aggregated bandwidth offered by object stores.

The objective of this demo is to show the practical utility of a pure serverless implementation for workflows. That is, we demonstrate that object storage performs well when the appropriate number of functions is used in I/O-bound stages. To do so, we run a genomics pipeline in two manners. One way that is "purely" serverless using object storage, and the other when the shuffle operation runs inside a powerful VM. In this way, we qualitatively evaluate the pros and cons of each strategy for serverless workflows.

RESEARCH AND TECHNICAL APPROACH.

Pipeline Description.

We employ METHCOMP [1], a compression method for DNA methylation annotation files, as an evaluation workflow, since it is habitual in the genomics community. For instance, the ENCODE project repository contains bisulfite data for more than 500 samples. Unfortunately, raw data in structured BED format can amount to tens of GBs. METHCOMP presents a compression method tailored to methylation data that yields about 10x better compression ratio than gzip. Particularly, this method operates in two consecutive stages. A first sort stage that entails all-to-all data transfers between functions, and a second stage that is embarrassingly parallel (encoding). For the purpose of this demonstration, we port the METHCOMP pipeline to serverless.

Pipeline Implementations.

We use Lithops [3], an open source² Python framework for serverless analytics. Lithops allows the parallel execution of analytics workflows on top of cloud functions. Moreover, it supports the provisioning of heavyweight VM instances to run computations, which gives us the chance to seamlessly run different incarnations of the same pipeline. We use IBM Cloud as the cloud provider for both scenarios. IBM COS is used as data passing mechanism in both pipelines.

Our first implementation is VM-based (Figure 1, A). Thanks to Lithops VM provisioning, we execute the sort stage within a VM with sufficient physical memory, while resorting to cloud functions only for the encoding stage.

Our second implementation is purely serverless (Figure 1, B). For the sort operation, we use Primula [4], an extension of Lithops that optimizes all-to-all transfers between functions. Along with a number of I/O optimizations for serverless all-to-all communication, Primula finds the optimal number of functions for a given shuffle data size "on the fly". For I/O-bound tasks, using the optimal number

¹ https://www.encodeproject.org/data-standards/wgbs/

²https://github.com/lithops-cloud/lithops

Table 1: Performance of METHCOMP pipeline in terms of latency and cost for a 3.5GB input.

Configuration	Latency (s)	Cost (\$)
"Purely" serverless	83.32	0.008
VM-supported	142.77	0.010

of functions in terms of remote storage resource utilization is crucial for good performance [4].

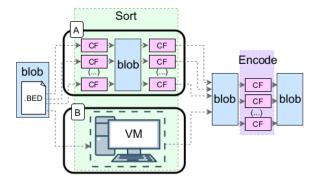


Figure 1: Purely serverless (A) and hybrid implementations (B) of the genomics compression pipeline.

2.3 Experiment setup and results

In the demo, we will evaluate both configurations in the us-east region using the 3.5GB dataset: ENCFF988BSW³. We will allocate 2GB of memory to cloud functions, and use a bx2-8x32 IBM Virtual Server Instance as our VM for the sort stage.

Table 1 shows our results in terms of end-to-end latency and cost for a parallelism degree of 8 workers. End-to-end latency includes startup times. Cost subsumes the following charges: the cost of cloud functions, storage requests, and the VM expenses — i.e., execution time and storage volume. While both configurations deliver similar costs, the "purely" serverless architecture significantly outperforms the hybrid pipeline in terms of latency. This shows that the execution of DAGs over a serverless infrastructure can be superior to a VM-based, "serverful" infrastructure thanks to a better exploitation of the aggregated bandwidth offered by object storage when sharing intermediate data.

2.4 User Interface and Configuration.

As our main objective is to show the feasibility of executing work-flows using a pure serverless architecture, we found it imperative to provide a declarative programming interface to represent work-flows. To this end, we augmented Lithops with a module to create pipelines from JSON configuration files. Further, we also developed a IPython interface for job tracking in real time, which displays the workflow progress and breaks the cost down at each stage.

3 RELATED WORK

Research on serverless analytics systems is gaining attraction in the last few years. Lithops [2] is an open-source, general-purpose tool for serverless analytics. Lithops is now multi-cloud [3] and for legacy support, it also enables the execution of Python code as is inside VM instances. To improve the performance of all-to-all data transfers through object storage, Lithops integrates Primula [4].

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³https://www.encodeproject.org/experiments/ENCSR515MHO/