

# Measurement of Stragglers in Distributed Machine Learning Model Training

## 1 Alibaba PAI Production Cluster Data

### 1.1 Data from April 2, 2022

**Coefficient of variation of worker iteration time:** Coefficient of variation (CoV) is the ratio of the standard deviation to the mean. Figure 1 shows the CoV of five randomly selected machine learning (ML) jobs.

It can be observed that the CoV of the iteration time of job\_13 and job\_74 varies considerably between 0.1 and 2.4 over time and that of job\_15 and job\_81 ranges between 0.05 and 1. The CoV of job\_27 keeps stable from the beginning to the end. During the selected timeline, job\_13, job\_74 and job\_81 suffer from stragglers obviously all the way. The CoV of job\_27 is relatively stable, which means that it may not have stragglers. job\_15 experiences stragglers in the end of the timeline, while the straggling degree is not so significant compared to other jobs (except job\_27) for most of the time.

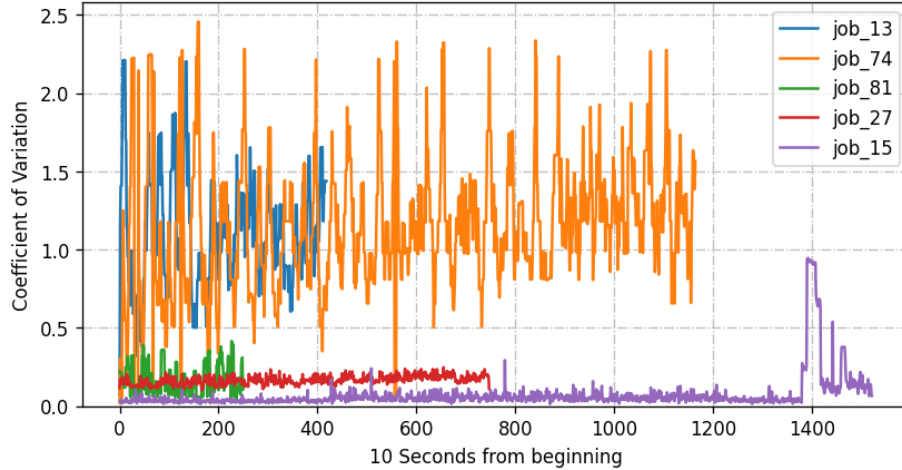


Figure 1: Coefficient of variation of the iteration times of a job.

Next, we show the iteration time of different workers of other 4 randomly selected jobs.

**Time series of job 1:** Figure 2 shows the worker iteration times of tracked job\_1 over time. The plan ratio of requested GPUs of each worker is 25%. The iteration time of workers except worker\_6 keeps almost the same from the beginning to the end. During the time between approximately 1800s-2000s, worker\_6's iteration time drastically by 150%, becoming a straggler.

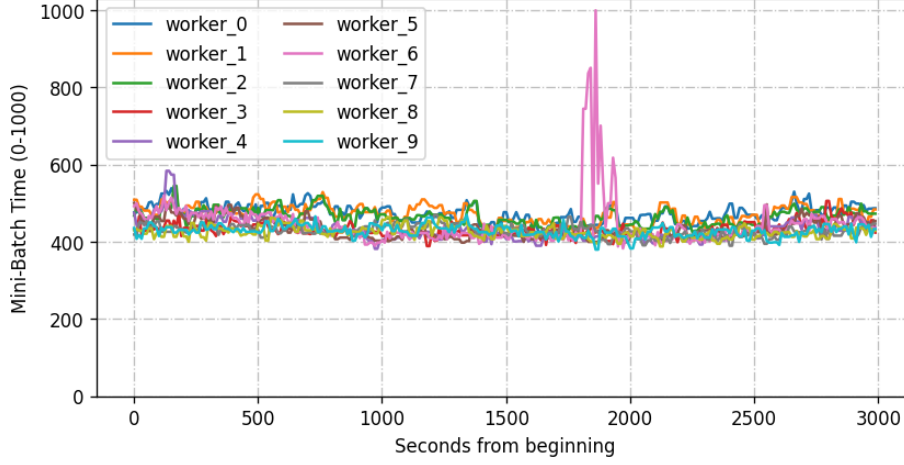


Figure 2: Time series of iteration times of the workers of job 1.

**Time series of job 2:** Figure 3 shows the worker iteration times of job\_2 over time. The plan ratio of requested GPUs of each worker is 20%. Even though the iteration time of each worker of job\_2 keeps relatively stable, different workers inherently have different iteration times. The job completion time of job\_2 is limited by the slowest worker, i.e., worker\_5. The relatively slow workers, worker\_3 - worker\_8, can be regarded as stragglers during the training.

**Time series of job 3:** Figure 4 shows the worker iteration times of job\_3 over time. The plan ratio of requested GPUs of each worker is 25%. Different workers of job\_3 have different iteration times. worker\_0 and worker\_1 are the two slowest workers during the training. From the beginning to approximately 2100s, the iteration times of all workers keep stable. After 2100s, the iteration time of worker\_6 - worker\_9 increase by approximately 50% and the iteration time variation among all workers becomes larger.

**Time series of job 4:** Figure 5 shows the worker iteration times of job\_4 over time. The plan ratio of requested GPUs of each worker is 50%. For most of the time, the iteration time of each worker is relatively stable. Different workers have different iteration times. worker\_1, worker\_3, worker\_4 and worker\_9 are fast workers. Workers of job\_4 occasionally become stragglers during the training. There are more than one straggler and the straggling situation becomes better or worse over time. The iteration time of worker\_5 and worker\_6 significantly increases by 400% in the end of selected timeline and the straggling degree becomes extremely severe.

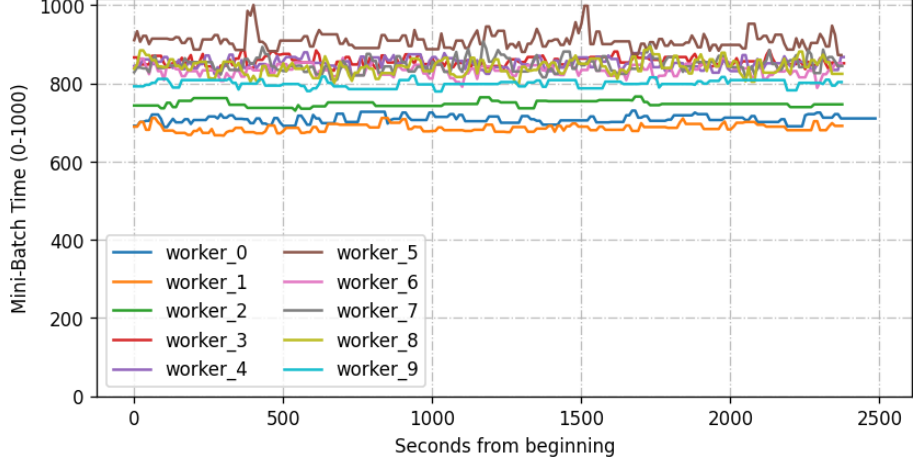


Figure 3: Time Series of iteration times of the workers of job 2.



Figure 4: Time series of iteration times of the workers of job 3.

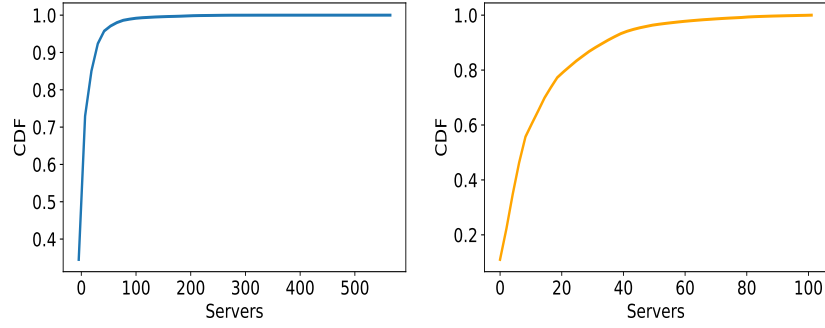
## 1.2 Trace Data from July to August of 2020

In the production cluster, the workers of a job are placed in different machines [1, 2]. We also conducted experiments to observe how the workers are placed in different machines using the Alibaba trace data [1]. Figure 6 shows the cumulative distribution function (CDF) of the number of servers that host the workers of a job of all the jobs occurs from July to August of 2020. Figure 6(a) demonstrates the CDF for all the jobs. We can see that the workers are placed across 100 servers for around 98% jobs. Figure 6(b) shows the CDF for the jobs whose workers are hosted by no more than 100 servers. Here, we can observe



Figure 5: Time series of iteration times of the workers of job 4.

that the workers are placed across 20 servers for around 80% jobs. This confirms that almost for all jobs, the workers are placed in multiple servers. Since the workers are placed in different servers, they tend to experience different resource contention, which causes some workers to run slower than other workers and thus result in stragglers.



(a) Worker distribution in all servers. (b) Worker distribution upto 100 servers.

Figure 6: CDF of the number of servers that host the workers of a job of all the jobs in the Alibaba trace.

## References

- [1] Qizhen Weng, Wencong Xiao, Yinghao Yu, Wei Wang, Cheng Wang, Jian He, Yong Li, Liping Zhang, Wei Lin, and Yu Ding. MLaaS in the wild: Workload analysis and scheduling in large-scale heterogeneous GPU clusters. In *19th USENIX Symposium on Networked Systems Design and Implementation (NSDI 22)*, 2022.
- [2] Wencong Xiao, Shiru Ren, Yong Li, Yang Zhang, Pengyang Hou, Zhi Li, Yihui Feng, Wei Lin, and Yangqing Jia. Antman: Dynamic scaling on gpu clusters for deep learning. In *14th USENIX Symposium on Operating Systems Design and Implementation (OSDI 20)*, pages 533–548, 2020.