

Thunderfield

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Abstract—Large-scale distributed deep learning workloads running on GPU clusters often suffer from energy inefficiencies caused by bursty inter-GPU communication. These short communication bursts increase network congestion, synchronization delay, and power consumption, leading to a higher Energy Delay Product (EDP).

In this work, we propose DL-AMCC, a learning based runtime controller that dynamically forms temporary GPU micro clusters during communication bursts. The system observes traffic and system telemetry and adjusts cluster behavior to reduce cross rack communication and improve energy efficiency.

We evaluate DL-AMCC in a large-scale GPU cluster simulator under realistic distributed training workloads. Results show that our approach reduces Energy Delay Product and communication overhead while maintaining overall training performance.

Index Terms—Deep Learning, Temporal Graph Neural Networks, Reinforcement Learning, GPU Clusters, Distributed Deep Learning, Energy Efficiency, Energy-Delay Product, Inter-GPU Communication, Runtime Optimization, Traffic-Aware Micro-Clustering

I. INTRODUCTION

Modern deep learning models are trained using *large scale* GPU clusters, where multiple GPUs work together to process different parts of the same model. In distributed training, each GPU computes gradients locally and then communicates with other GPUs to synchronize these updates. This communication is required to keep the model parameters consistent across all devices. Operations such as all reduce are commonly used for this synchronization process.

Although distributed training improves computational speed, it introduces heavy inter-GPU communication. These synchronization steps occur repeatedly during training and often create short but intense communication bursts. During such bursts, network traffic increases sharply, GPUs may wait for synchronization to complete, and power consumption can temporarily spike. As cluster sizes grow, these effects reduce energy efficiency and increase the Energy Delay Product.

Most existing cluster management systems make decisions at job launch time and do not adapt to runtime communication dynamics. As a result, systems cannot respond effectively to *burst driven* inefficiencies that arise during training.

To address this limitation, we present **Thunderfield**, an autonomous runtime framework for *burst aware* GPU clus-

ter control. Thunderfield is built around DL-AMCC, a deep learning based control mechanism that dynamically forms temporary GPU micro clusters during communication bursts. By observing traffic and system telemetry, Thunderfield adjusts cluster behavior in real time to reduce *cross rack* communication and improve energy efficiency without degrading performance.

The main contributions of this work are:

- Thunderfield, a *burst aware* runtime micro clustering framework for GPU clusters.
- DL-AMCC, a deep learning based controller that predicts and responds to communication dynamics.
- A *large scale* simulation study demonstrating improvements in Energy Delay Product while maintaining throughput.

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- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate

equations with commas or periods when they are part of a sentence, as in:

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- The word “data” is plural, not singular.
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- A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
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TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	<i>Table column subhead</i>	<i>Subhead</i>	<i>Subhead</i>
copy	More table copy ^a		

^aSample of a Table footnote.

Fig. 1. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

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