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 cluster 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.

II. Prepare Your Paper Before Styling

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections II-A–II-E below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads—LaTeX will do that for you.

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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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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:

$$a + b = \gamma \tag{1}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(1)", not "Eq. (1)" or "equation (1)", except at the beginning of a sentence: "Equation (1) is . . ."

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Please use "soft" (e.g., `\eqref{Eq}`) cross references instead of "hard" references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don't use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

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An excellent style manual for science writers is [7].

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

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TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
copy	More table copy[a]		

[a]Sample of a Table footnote.

Fig. 1. Example of a figure caption.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

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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