

Article

Towards Efficient Resource Allocation for Federated Learning in Virtualized Managed Environments

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Abstract: Federated learning (FL) is a transformative approach to Machine Learning that enables the training of a shared model without transferring private data to a central location. This decentralized training paradigm has found particular applicability in edge computing, where IoT devices and edge nodes often possess limited computational power, network bandwidth, and energy resources. While various techniques have been developed to optimize the FL training process, an important question remains unanswered: how should resources be allocated in the training workflow? To address this question, it is crucial to understand the nature of these resources. In physical environments, the allocation is typically performed at the node level, with the entire node dedicated to executing a single workload. In contrast, virtualized environments allow for the dynamic partitioning of a node into containerized units that can adapt to changing workloads. Consequently, the new question that arises is: how can a physical node be partitioned into virtual resources to maximize the efficiency of the FL process? To answer this, we investigate various resource allocation methods that consider factors such as computational and network capabilities, the complexity of datasets, as well as the specific characteristics of the FL workflow and ML backend. We explore two scenarios: (i) running FL over a finite number of testbed nodes and (ii) hosting multiple parallel FL workflows on the same set of testbed nodes. Our findings reveal that the default configurations of state-of-the-art cloud orchestrators are sub-optimal when orchestrating FL workflows. Additionally, we demonstrate that different libraries and ML models exhibit diverse computational footprints. Building upon these insights, we discuss methods to mitigate computational interferences and enhance the overall performance of the FL pipeline execution.

Keywords: federated learning; machine learning; edge computing; Internet of Things



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1. Introduction

Federated Learning (FL) is transforming the field of Artificial Intelligence (AI) by allowing collaborative training of statistical models in decentralized environments [1]. It enables multiple devices or entities to contribute their local data for training a shared model without requiring the raw data to be transferred to a central server [2]. Instead, the models are trained locally on each device, and only the model updates, which are lightweight and privacy-preserving, are exchanged with a central server or coordinator [3]. This approach ensures data privacy, as sensitive information remains on the local devices, and it also addresses challenges associated with data silos and data transmission costs. FL is particularly useful for organizations operating in collaborative and cross-border settings, such as health and financial institutions, as they are subject to regulatory and legal frameworks like the EU's General Data Protection Regulation (GDPR) [4]. These frameworks mandate strict data governance policies for managing, processing, and exchanging data among different administrative sites [5].

Towards An Efficient Allocation

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Table of Contents Towards An Efficient Allocation

1. Understanding the eBook Towards An Efficient Allocation
 - The Rise of Digital Reading Towards An Efficient Allocation
 - Advantages of eBooks Over Traditional Books
2. Identifying Towards An Efficient Allocation
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Towards An Efficient Allocation
 - User-Friendly Interface
4. Exploring eBook Recommendations from Towards An Efficient Allocation
 - Personalized Recommendations
 - Towards An Efficient Allocation User Reviews and Ratings
 - Towards An Efficient Allocation and Bestseller Lists
5. Accessing Towards An Efficient Allocation Free and Paid eBooks
 - Towards An Efficient Allocation Public Domain eBooks
 - Towards An Efficient Allocation eBook Subscription Services
 - Towards An Efficient Allocation Budget-Friendly Options
6. Navigating Towards An Efficient Allocation eBook Formats

- ePub, PDF, MOBI, and More
 - Towards An Efficient Allocation Compatibility with Devices
 - Towards An Efficient Allocation Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Towards An Efficient Allocation
 - Highlighting and Note-Taking Towards An Efficient Allocation
 - Interactive Elements Towards An Efficient Allocation
 8. Staying Engaged with Towards An Efficient Allocation
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Towards An Efficient Allocation
 9. Balancing eBooks and Physical Books Towards An Efficient Allocation
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Towards An Efficient Allocation
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Towards An Efficient Allocation
 - Setting Reading Goals Towards An Efficient Allocation
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Towards An Efficient Allocation
 - Fact-Checking eBook Content of Towards An Efficient Allocation
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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