future internet

MDPI

Article

Towards Efficient Resource Allocation for Federated Learning in Virtualized Managed Environments

Fotis Nikolaidis [1,*], Moysis Symeonides [2] and Demetris Trihinas [3]

[1] Institute of Computer Science, Foundation for Research and Technology Hellas, 70013 Heraklion, Greece
[2] Department of Computer Science, University of Cyprus, 1678 Nicosia, Cyprus; symeonides.moysis@ucy.ac.cy
[3] Department of Computer Science, School of Sciences and Engineering, University of Nicosia, 2417 Nicosia, Cyprus; trihinas.d@unic.ac.cy
* Correspondence: fnikol@ics.forth.gr

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

check for updates

Citation: Nikolaidis, F.; Symeonides, M.; Trihinas, D. Towards Efficient Resource Allocation for Federated Learning in Virtualized Managed Environments. *Future Internet* **2023**, *15*, 261. https://doi.org/10.3390/fi15080261

Academic Editors: Qiang Duan and Zhihui Lu

Received: 3 July 2023
Revised: 19 July 2023
Accepted: 25 July 2023
Published: 31 July 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

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

Western Agricultural Economics Association

Towards An Efficient Allocation:

Getting the books **Towards An Efficient Allocation** now is not type of inspiring means. You could not lonely going taking into account book gathering or library or borrowing from your links to door them. This is an entirely easy means to specifically acquire lead by on-line. This online statement Towards An Efficient Allocation can be one of the options to accompany you like having new time.

It will not waste your time. agree to me, the e-book will categorically publicize you new matter to read. Just invest tiny era to get into this on-line notice **Towards An Efficient Allocation** as competently as evaluation them wherever you are now.

https://ftp.thebrandexperience.com/About/virtual-library/HomePages/thunderbird_oconnor_duology_2vol.pdf

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

Towards An Efficient Allocation Introduction

Free PDF Books and Manuals for Download: Unlocking Knowledge at Your Fingertips In todays fast-paced digital age, obtaining valuable knowledge has become easier than ever. Thanks to the internet, a vast array of books and manuals are now available for free download in PDF format. Whether you are a student, professional, or simply an avid reader, this treasure trove of downloadable resources offers a wealth of information, conveniently accessible anytime, anywhere. The advent of online libraries and platforms dedicated to sharing knowledge has revolutionized the way we consume information. No longer confined to physical libraries or bookstores, readers can now access an extensive collection of digital books and manuals with just a few clicks. These resources, available in PDF, Microsoft Word, and PowerPoint formats, cater to a wide range of interests, including literature, technology, science, history, and much more. One notable platform where you can explore and download free Towards An Efficient Allocation PDF books and manuals is the internets largest free library. Hosted online, this catalog compiles a vast assortment of documents, making it a veritable goldmine of knowledge. With its easy-to-use website interface and customizable PDF generator, this platform offers a user-friendly experience, allowing individuals to effortlessly navigate and access the information they seek. The availability of free PDF books and manuals on this platform demonstrates its commitment to democratizing education and empowering individuals with the tools needed to succeed in their chosen fields. It allows anyone, regardless of their background or financial limitations, to expand their horizons and gain insights from experts in various disciplines. One of the most significant advantages of downloading PDF books and manuals lies in their portability. Unlike physical copies, digital books can be stored and carried on a single device, such as a tablet or smartphone, saving valuable space and weight. This convenience makes it possible for readers to have their entire library at their fingertips, whether they are commuting, traveling, or simply enjoying a lazy afternoon at home. Additionally, digital files are easily searchable, enabling readers to locate specific information within seconds. With a few keystrokes, users can search for keywords, topics, or phrases, making research and finding relevant information a breeze. This efficiency saves time and effort, streamlining the learning process and allowing individuals to focus on extracting the information they need. Furthermore, the availability of free PDF books and manuals fosters a culture of continuous learning. By removing financial barriers, more people can access educational resources and pursue lifelong learning, contributing to personal growth and professional development. This democratization of knowledge promotes intellectual curiosity and

empowers individuals to become lifelong learners, promoting progress and innovation in various fields. It is worth noting that while accessing free Towards An Efficient Allocation PDF books and manuals is convenient and cost-effective, it is vital to respect copyright laws and intellectual property rights. Platforms offering free downloads often operate within legal boundaries, ensuring that the materials they provide are either in the public domain or authorized for distribution. By adhering to copyright laws, users can enjoy the benefits of free access to knowledge while supporting the authors and publishers who make these resources available. In conclusion, the availability of Towards An Efficient Allocation free PDF books and manuals for download has revolutionized the way we access and consume knowledge. With just a few clicks, individuals can explore a vast collection of resources across different disciplines, all free of charge. This accessibility empowers individuals to become lifelong learners, contributing to personal growth, professional development, and the advancement of society as a whole. So why not unlock a world of knowledge today? Start exploring the vast sea of free PDF books and manuals waiting to be discovered right at your fingertips.

FAQs About Towards An Efficient Allocation Books

1. Where can I buy Towards An Efficient Allocation books? Bookstores: Physical bookstores like Barnes & Noble, Waterstones, and independent local stores. Online Retailers: Amazon, Book Depository, and various online bookstores offer a wide range of books in physical and digital formats.
2. What are the different book formats available? Hardcover: Sturdy and durable, usually more expensive. Paperback: Cheaper, lighter, and more portable than hardcovers. E-books: Digital books available for e-readers like Kindle or software like Apple Books, Kindle, and Google Play Books.
3. How do I choose a Towards An Efficient Allocation book to read? Genres: Consider the genre you enjoy (fiction, non-fiction, mystery, sci-fi, etc.). Recommendations: Ask friends, join book clubs, or explore online reviews and recommendations. Author: If you like a particular author, you might enjoy more of their work.
4. How do I take care of Towards An Efficient Allocation books? Storage: Keep them away from direct sunlight and in a dry environment. Handling: Avoid folding pages, use bookmarks, and handle them with clean hands. Cleaning: Gently dust the covers and pages occasionally.
5. Can I borrow books without buying them? Public Libraries: Local libraries offer a wide range of books for borrowing. Book Swaps: Community book exchanges or online platforms where people exchange books.
6. How can I track my reading progress or manage my book collection? Book Tracking Apps: Goodreads, LibraryThing,

and Book Catalogue are popular apps for tracking your reading progress and managing book collections. Spreadsheets: You can create your own spreadsheet to track books read, ratings, and other details.

7. What are Towards An Efficient Allocation audiobooks, and where can I find them? Audiobooks: Audio recordings of books, perfect for listening while commuting or multitasking. Platforms: Audible, LibriVox, and Google Play Books offer a wide selection of audiobooks.
8. How do I support authors or the book industry? Buy Books: Purchase books from authors or independent bookstores. Reviews: Leave reviews on platforms like Goodreads or Amazon. Promotion: Share your favorite books on social media or recommend them to friends.
9. Are there book clubs or reading communities I can join? Local Clubs: Check for local book clubs in libraries or community centers. Online Communities: Platforms like Goodreads have virtual book clubs and discussion groups.
10. Can I read Towards An Efficient Allocation books for free? Public Domain Books: Many classic books are available for free as theyre in the public domain. Free E-books: Some websites offer free e-books legally, like Project Gutenberg or Open Library.

Find Towards An Efficient Allocation :

~~thunderbird oconnor duology 2vol~~
through my head
~~through unexplored texas~~
thurber country
tidningskungen lars johan hierta den ff rste moderne svensken
thy bread and water shall be sure
tick tock dont stop.
~~tides of passion~~
till murder do us part a marlow okelley mystery marlow okelley mysteries
tigre and other stories curley large prints
tickets a love story
tiempo nublado ensayo
tile indoors out every kind use
thunder of crude a

thrust signed limited

Towards An Efficient Allocation :

820008M Super Nova Airless Paint Sprayer - Graco Inc. The strain reliefs help protect the hose from kinks or bends at or close to the coupling which can result in hose rupture. TIGHTEN all fluid connections ... 820007M Electric NOVA Airless Paint Sprayer Liquids can be injected into the body by high pressure airless spray or leaks – especially hose leaks. Keep body clear of the nozzle. Supernova airless paint sprayer graco protected url .pdf Jun 28, 2018 — Technical Report Implementing TWI Thomas Register of American Manufacturers and. Thomas Register Catalog File House Painting Inside & Out ... Ultra 395 PC Electric Airless Sprayer, Stand - Graco Inc. The performance and versatility of the Ultra 395 PC has made it Graco's most popular sprayer. SmartControl 1.0 pressure control delivers a consistent spray fan ... Graco TC Pro Airless Handheld Paint Sprayer - YouTube Preparing to Spray with Your Graco Sprayer - YouTube My First Time Using The Graco Airless Paint Sprayer Outside ... How to set up an airless sprayer - Graco GXff - YouTube Graco NOVA 390 PC Electric Airless Sprayer The 390 PC Hi-Boy is a solid workhorse built for the professional just “starting out.” Durable and portable, it's easy to move on and off the jobsite. Graco 390 PC Electric Airless Paint Sprayer, Stand - 824505 Volume 141 Catalog Page: 859 · Catalog Item · Ideal sprayer for residential jobs · Lightweight and portable at only 30 Lbs · Rugged steel Frame withstands rugged ... Guide de survie pour les enfants vivant avec un TDAH Un livre sympathique pour enfant, plein d'astuces et de trucs pour mieux s'organiser à l'école, à la maison et avec les amis quand on vit avec un TDAH. Guide de survie pour les enfants vivants avec un TDAH Ce livre a été écrit spécialement pour toi - mais tu peux le lire avec tes parents ou avec un adulte en qui tu as confiance. Parle de ce que tu vis, expérimente ... Guide de survie pour les enfants vivant avec un TDAH Mar 20, 2012 — Il ne va pas résoudre tous tes problèmes, mais il va certainement te donner plusieurs trucs pour mieux t'organiser à l'école, à la maison et ... Guide de survie pour les enfants vivant avec un TDAH Tu y trouveras plusieurs activités à réaliser afin de découvrir tes forces et de mieux actualiser ton potentiel.. ... Biographie de l'auteur. John F. Taylor, Ph. Guide de survie pour les enfants vivant avec un TDAH Ce petit guide plein d'idées va permettre aux enfants de mieux comprendre le TDAH, afin qu'ils s'approprient des stratégies pour développer leurs pleins ... Guide de survie pour les enfants vivant avec un TDAH Feb 24, 2014 — Annick Vincent, médecin spécialiste en TDAH, auteure et maman. John F. Taylor, Ph. D. Un guide pratique, sympathique et amusant ! Guide de survie pour les enfants vivant avec un TDAH - Benjo Guide de survie pour les enfants vivant avec un TDAH. Editions Midi Trente. SKU: 0978292382723. Guide de survie pour les enfants vivant avec un TDAH. Guide de survie pour les enfants vivant avec un TDAH Guide de survie pour les enfants vivant avec un TDAH · Lecture en tandem · Catalogue de bibliothèque. Pour aller plus loin : Faire une ... Guide de survie pour les enfants vivants avec un... - John F ... Guide de survie pour les enfants vivants avec un TDAH de Plongez-vous dans le livre John F. Taylor au format

Grand Format. Ajoutez-le à votre liste de ... Teaching Literacy to Learners with Dyslexia: A Multi- ... It offers a structured, cumulative, multi-sensory teaching program for learners with dyslexia, and draws attention to some of the wider aspects of the learning ... Teaching Literacy to Learners with Dyslexia Jun 8, 2022 — This bestselling book for teaching literacy to children and young people aged 4–16 years with dyslexia and other specific literacy ... Teaching Literacy to Learners with Dyslexia This bestselling book for teaching literacy to children and young people aged 4–16 years with dyslexia and other specific literacy difficulties has been fully ... Teaching Literacy to Learners with Dyslexia Teaching Literacy to Learners with Dyslexia: A Multisensory Approach · Student Resources · The resources on the site have been specifically designed to support ... Teaching literacy to learners with dyslexia : a multisensory ... The second edition of this bestselling book provides a structured multi-sensory programme for teaching literacy to children and young people from 5-18 with ... Teaching Literacy to Learners with Dyslexia: A Multi- ... It offers a structured, cumulative, multi-sensory teaching programme for learners with dyslexia, and draws attention to some of the wider aspects of the ... Teaching Literacy to Learners with Dyslexia This bestselling text offers theoretical detail and depth alongside a programme of activities to implement in practice which can improve literacy levels and ... Teaching Literacy to Learners with Dyslexia 3rd edition Teaching Literacy to Learners with Dyslexia: A Multisensory Approach 3rd Edition is written by Kathleen Kelly; Sylvia Phillips and published by Corwin UK. Teaching literacy to learners with dyslexia : a multisensory ... Provides a structured program--including strategies, activities, reproducible resource sheets, and downloadable materials--for teaching literacy skills to ... Teaching Literacy to Learners with Dyslexia: A Multi- ... Mar 26, 2016 — The Second Edition of this bestselling book provides a structured multi-sensory programme for teaching literacy to children and young people ...