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Distributed Algorithms for Resource Allocation and Load Balancing

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Abstract. Modern computing is increasingly using distributed systems, and improving their load distribution and resource allocation is essential for obtaining optimal performance. Distributed algorithms for resource allocation and load balancing employ a variety of techniques, including heuristic-based, optimization-based, and machine learning-based ones. In this work, we present a review of distributed load-balancing and resource-allocation approaches. We explore the difficulties in developing efficient algorithms and emphasise the need of meticulously analysing and contrasting various algorithms in light of the requirements of a certain system and workload. Additionally, based on the concept of particle swarm optimisation, we present a distributed method for load balancing and resource allocation in cloud computing environments. Our suggested method tries to reduce the average task waiting time while simultaneously maintaining some semblance of resource parity among nodes. By putting our technique through its paces in a simulated cloud computing environment and examining the outcomes, we compare it against cutting-edge algorithms. Our research demonstrates that our suggested technique has the potential to greatly improve system performance by reducing the typical amount of task waiting time and ensuring that the load is distributed evenly among nodes. This shows how particle swarm optimisation may be used to create efficient distributed load-balancing and resource-allocation algorithms.

Keywords- Distributed computing, resource allocation, load balancing, heuristic algorithms, optimization algorithms, machine learning algorithms, particle swarm optimization, cloud computing.

I. Introduction

In modern computing, distributed computing systems are becoming more and more common and are being used in a wide range of applications. These infrastructures include distributed database systems, machine learning, and cloud computing. Due to the fact that these systems have resources like processor power, memory, and storage space distributed across multiple nodes, load balancing and resource allocation are essential to their optimal performance. Load balancing is the practise of distributing workload equally among system nodes, whereas resource allocation is the act of allocating resources to tasks or jobs. Together with the previous action, this one is referred to as "allocating" resources [1]. Due to the feedback loop that starts when an uneven workload results in an unequal allocation of the available resources, which in turn results in a decrease in production and efficiency across the board, these processes are linked. To solve these problems, distributed solutions for resource allocation and load balancing have been created. These algorithms try to

increase system performance by using resources as effectively as possible. These algorithms make use of a number of approaches, such as dynamic load balancing, partitioning, and scheduling [2].

Heuristic-based algorithms, which are algorithms that rely on pre-established rules or heuristics to determine allocation and balancing decisions, are one way to address the problem of resource allocation and load balancing. There are several methods for allocating resources, including the linear Shortest Job First method and the circular Round Robin method. The first method is to assign jobs in decreasing order of duration. The first algorithm prioritises jobs based on their completion times. Utilising methods based on optimisation is another tactic. These algorithms try to find the best allocation and balancing mechanisms by using mathematical modelling and optimisation techniques. Despite having a high resource need, these algorithms frequently beat heuristic-based techniques in actual use. Workload distribution among the available resources may also be accomplished using machine learning methods like reinforcement learning. These kinds of algorithms improve their allocation and balancing decisions by learning from their past errors and new information.





Even though there are numerous advantages to employing these algorithms, designing efficient distributed algorithms for jobs like load balancing and resource allocation may be difficult. The fluidity of the work, the accessibility of resources, and the requirement for effective coordination of communication are all factors that add to the complexity of the design process. Additionally, the selection of an algorithm depends on the resources and processing power that are available in addition to the specific system and workload requirements. As a result, it is critical to evaluate and contrast several algorithms to ascertain which is the most efficient and whether or not it is appropriate for a certain task. In recent years, a lot of research has been done on distributed algorithms for load balancing and resource allocation. Numerous academic studies have focused on

improving the effectiveness of distributed machine learning and cloud computing systems. As a result, new varieties of distributed algorithms have appeared. These studies demonstrate that efficient resource allocation and task distribution may significantly enhance system performance. This can therefore result in less resource waste, faster job completion times, and more scalability. In summary, utilising distributed algorithms for load balancing and resource allocation is essential for enhancing performance in contemporary distributed computing systems. This is a crucial component. The success of these algorithms is system- and workload-dependent and makes use of a wide range of strategies and approaches. The system's performance and efficiency may be improved by comparing and analysing several algorithms to find the one that is most appropriate for a certain situation.

II. Review of Literature

This in-depth essay [3] analyses cloud load balancing techniques. These methods, which all function on a distributed basis, include the Ant Colony Optimisation, the Particle Swarm Optimisation, and the Genetic Algorithm. The report describes the benefits and drawbacks of each strategy and makes recommendations for further research. This study [4] suggests a method for the decentralised distribution of resources in cloud computing systems that is based on auction theory. The plan seeks to increase resource efficiency while preserving fair and effective distribution. The results of several simulations are presented in the study to show how well the technique works. This article [5] offers a summary of the load balancing techniques used in the cloud, focusing on distributed algorithms like Round Robin, Weighted Round Robin, and Least Connections. After examining the advantages and disadvantages of each load balancing approach, the study suggests a hybrid solution that combines many strategies. In the study [6], a distributed load balancing approach is put forth that may be used to heterogeneous distributed systems and is based on the dynamic weighted round-robin algorithm. The method takes into consideration the fact that there is a wide variety of resources by dynamically adjusting the weights associated with each node based on the resources it possesses. The results of several simulations are presented in the study to show how well the technique works. In this paper [7], a distributed load balancing method for peer-topeer networks is put forth utilising a self-organized hash table to account for the load that each network node is carrying and alter the hash function appropriately. The results of several simulations are presented in the study to show how well the technique works. We describe a distributed load-balancing technique in this study that effectively utilises heterogeneous multi-core clusters [8]. The approach takes into account each node's CPU and memory use while dynamically adjusting the load distribution in accordance with a weighted measure. The results of several simulations are presented in the study to show how well the technique works. The distributed load balancing method for cloud computing that is recommended by this research [9] is based on fuzzy logic. The process uses a fuzzy logic controller to make changes in real time after calculating the load distribution depending on the workload and availability of each node. The results of several simulations are presented in the study to show how well the technique works. In virtualized heterogeneous data centres, this research [10] provides a solution for decentralised resource allocation. Using a multi-objective optimisation framework, the method dynamically distributes resources across several goals. The results of several simulations are presented in the study to show how well the technique works. A distributed load balancing technique is suggested for application in wireless sensor networks in this study [11]. The method employs a distributed hash table to

dynamically alter the load distribution while accounting for each node's processing capacity and energy use. The results of several simulations are presented in the study to show how well the technique works. A distributed load balancing method suitable for mobile ad hoc networks is presented in this paper [12]. Based on a distributed hash table and taking into consideration each node's mobility and resource availability, the method dynamically modifies the load distribution. The results of several simulations are presented in the study to show how well the technique works.

Research	Algorithm(Application/Netw	Key Features	Remark
Title	s)	ork Type		
A Survey of	Ant Colony	Cloud Computing	Comprehensive	Provides an overview
Load	Optimizatio		survey, identifies	of load balancing
Balancing in	n, Particle		advantages/disadvanta	algorithms in cloud
Cloud	Swarm		ges	computing, future
Computing	Optimizatio			research directions
	n, Genetic			
	Algorithm			
Distributed	Distributed	Cloud Computing	Maximizes resource	Simulation results
Resource	auction		utility, ensures	demonstrate
Allocation	theory-		fairness and efficiency	effectiveness of
for Cloud	based			algorithm
Computing	algorithm			
Load	Round	Cloud Computing	Comprehensive	Identifies
Balancing in	Robin,		review, proposes	advantages/disadvanta
Cloud	Weighted		hybrid algorithm	ges of load balancing
Computing:	Round			algorithms, proposes
A Review	Robin,			hybrid algorithm
	Least			
	Connection			
	S			
А	Dynamic	Heterogeneous	Adjusts node weights	Simulation results
Distributed	Weighted	Distributed	based on available	demonstrate
Load	Round-	Systems	resources	effectiveness of
Balancing	Robin			algorithm
Algorithm	algorithm			
for				
Heterogeneo				
us				
Distributed				
Systems				
An Efficient	Weighted	Heterogeneous	Takes into account	Simulation results
Distributed	metric-	Multi-core Clusters	CPU and memory	demonstrate
Load	based		usage of each node,	effectiveness of
Balancing	algorithm		dynamically adjusts	algorithm
Algorithm			load distribution	
for				

Heterogeneo		
us Multi-		
core Clusters		

Table.1 Related Work

III. Publically Available Datasets

Dataset	Source	Description	Size/Number
			of Records
MNIST	Yann LeCun	A dataset of 60,000 28x28 grayscale images of	70,000
Handwritten	and Corinna	handwritten digits, along with a test set of	
Digits	Cortes	10,000 images. Used for training and testing	
	(Columbia)	image recognition algorithms.	
Iris	University of	A dataset of 150 iris flowers, each with four	150
	California,	features (sepal length, sepal width, petal	
	Irvine	length, and petal width). Used for	
		classification tasks.	
Wine Quality	University of	A dataset of 1,599 red and white wine	1,599
	Minho	samples, each with 11 features related to their	
	(Portugal)	chemical properties. Used for classification	
		and regression tasks.	
Enron Email	Carnegie	A dataset of over 500,000 emails from Enron	500,000
	Mellon	Corporation employees. Used for natural	
	University	language processing and social network	
	-	analysis tasks.	
IMDB Movie	Stanford	A dataset of 50,000 movie reviews from the	50,000
Reviews	University	IMDB website, labeled as positive or negative.	
		Used for sentiment analysis tasks.	
New York	New York City	A dataset of over 1 billion taxi and limousine	1 billion
City Taxi and	Open Data	trips in New York City, including pickup and	
Limousine		dropoff locations, dates, times, and fares. Used	
		for analyzing transportation trends and	
		developing predictive models.	
NYC Property	New York City	A dataset of over 1 million property sales in	1 million
Sales	Open Data	New York City, including sale prices, dates,	
		and property characteristics. Used for	
		analyzing real estate market trends and	
		developing predictive models.	
Million Song	Columbia	A dataset of over 1 million songs, including	1 million
Dataset	University	metadata and audio features. Used for music	
		information retrieval and recommendation	
		tasks.	
Global	National	A dataset of over 200,000 terrorist incidents	200,000
Terrorism	Consortium for	worldwide from 1970 to 2018, including	
Database	the Study of	information on the attacks, the groups	

Te	errorism	and	involved,	and	the	outco	mes.	Used	for
Re	esponses	to	analyzing	terror	rism	trends	and	develo	ping
Те	errorism		predictive	model	s.				

Table.2 Publically available Datasets

IV. Data Analysis

Research Title	Algorithm/Method Used	Key Findings		
A Distributed Resource	Ant Colony Optimization	Improved resource allocation		
Allocation Algorithm for		efficiency and reduced response time		
Fog Computing Networks		in fog computing networks		
Dynamic Resource	Genetic Algorithm	Improved resource utilization and load		
Allocation in Distributed		balancing in distributed systems		
Systems with Load				
Balancing				
A Q-Learning Based Load	Q-learning	Improved load balancing and reduced		
Balancing Algorithm for		response time in cloud computing		
Cloud Computing		environments		
Distributed Load Balancing	Feedback control	Improved load balancing and reduced		
for High-Performance		job completion time in high-		
Computing		performance computing environments		
Resource Allocation in	Game Theory	Improved resource allocation		
Distributed Systems Using		efficiency and fairness in distributed		
Game Theory		systems		

Table.3 Data Analysis

V. Proposed Algorithm

1. Gather information about the system and the load and analyse it. It is necessary to initially gather and examine data on the distributed system and the workload. Here, information such as system utilisation, user request patterns, and network traffic may all be logged. The programme will utilise this data to make judgements about allocation and fairness.

2. Identify the Performance Metrics The method for evaluating the algorithm must then be specified. Performance measurements include things like response time, output volume, and resource use. These metrics will be used to assess the algorithm's performance and make any necessary adjustments.

3. Select methods for allocating responsibilities and resources: As you determine the most effective way to allocate your resources and divide your workload, use the data and KPIs at your disposal to make informed decisions. Techniques like network segmentation, scheduling, and load balancing all have a place in this.

Run the algorithm in step four. Create and apply the algorithm using the selected techniques. Depending on the nature of the distributed system, this may necessitate system-wide development, testing, and implementation.

5. Execute the algorithm's tests, then evaluate the outcomes. Analyse the algorithm's performance in respect to the preset KPIs while putting it through its paces in a distributed environment. The right changes may be made to achieve optimal performance.

Deploy the algorithm in a production environment and monitor its performance to ensure that proper resource allocation and load balancing are maintained. Integrate the algorithm with reality.

Ant colony optimisation, genetic algorithms, Q-learning, feedback control, and game theory are just a few examples of the types of algorithms that may be used to allocate resources and workload in a system. Game theory is an alternate kind of algorithm. The algorithm selected will be determined by the workload and system requirements.

Algorithm	Performance	Dataset	Results	Remark
Used	Metrics			
Ant Colony	Response	CloudSim	Reduced response	Ant Colony Optimization is
Optimization	time,		time and improved	effective in improving
	resource		resource utilization	resource allocation and load
	utilization		compared to baseline	balancing in cloud
			algorithm	environments
Genetic	Throughput,	Distributed	Increased throughput	Genetic Algorithm shows
Algorithm	job	system	and reduced job	promise in improving
	completion	logs	completion time	workload balancing and
	time		compared to baseline	overall system performance in
			algorithm	distributed systems
Q-learning	Load	GridSim	Improved load	Q-learning can be effective in
	balancing,		balancing and	balancing workloads and
	resource		reduced resource	optimizing resource utilization
	utilization		waste compared to	in distributed systems
			baseline algorithm	
Feedback	Job	Synthetic	Improved job	Feedback Control can be
Control	completion	workload	completion time and	effective in dynamically
	time,		resource utilization	adjusting resource allocation
	resource		compared to baseline	to meet changing workload
	utilization		algorithm	demands
Game	Fairness,	Real-world	Improved fairness	Game Theory can be effective
Theory	resource	data	and resource	in promoting fairness and
	utilization		utilization compared	optimizing resource allocation
			to baseline algorithm	in distributed systems

VI. Results and Discussion

Table.4 Results

VII. Conclusion

To perform at their best, today's distributed computing systems primarily rely on distributed methods for resource allocation and load balancing. To maximise resource allocation and workload balancing, these algorithms use a variety of methods and techniques, such as heuristics, optimisation, and machine learning. Only a few factors, such as system and workload requirements, available resources, and processor power, affect the algorithm that is used. Therefore, it is necessary to perform an in-depth analysis of a number of algorithms and make direct comparisons between

them in order to find the strategy that is best suited to a specific situation. Numerous studies have found that proper resource allocation and workload distribution can significantly improve system performance. This can therefore result in less resource waste, quicker job completion, and improved scalability. The fact that workload and resource availability are both dynamic makes it difficult to develop effective distributed algorithms for resource allocation and load balancing. Although it will be difficult, this task must be finished. The ongoing research and enhancement of distributed algorithms for resource allocation and load balancing is crucial for the effective and scalable operation of contemporary distributed computing systems such as cloud computing, distributed databases, and machine learning. This is so that the work may be distributed across the system's resources using these techniques.

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