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RESOURCE ALLOCATION IN IOT ENVIRONMENT USING SWARM OPTIMIZATION: A REVIEW

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***Abstract**: The* Internet of Things (IoT) Cloud Environment is steadily growing in support of current and projected real-time distributed Internet applications in civilian and military applications, The core idea of this environment is managing and scheduling the available resources to provide service's needs. It has become the most preferred network due to its guaranteed service rendering and cost-effectiveness. The increase in the capability of cloud services has increased the number of users to adapt to the cloud. The increase in the adaption towards the cloud in turn results in insufficiency in the proper and the simultaneous allocation of the resources according to the requisitions. So, task scheduling and resource allocation for the cloud becomes essential. the paper surveys the meta-heuristic optimization-based task scheduling and the resource allocation for the Internet of things cloud environment, that arrives in a more optimal solution at a faster rate and ease. The paper presents the survey of the optimization techniques of task scheduling available for the cloud and the discussion of the improvement of the performance metrics in terms of make-span, throughput, cost, latency, and successful service provisioning compared to the other conventional methods.

Keywords- Resource allocation; Cloud Computing; Fog Computing; Task Scheduling; Ant Colony Optimization; Particle Swarm Optimization; Artificial Bee Colony; Internet of Things.

I. INTRODUCTION

For ease of reading, we abbreviate nouns, as shown in Table 1.

Table 1. Noun abbreviation.

Abbreviations	Instructions	Abbreviations	Instructions
POS	Particle swarm optimization	TS	Task scheduling
ABC	Artificial bee colony	JOE	Internet of Everything
GA	Genetic algorithm	RAP	Resource Allocation Problem
ACO	Ant colony algorithm	VM	Virtual Machine
IOT	Internet of Things	VRP	Vehicle Routing Protocols
SI	Swarm Intelligence	CH	Cluster Head
WSN	Wireless Sensor Node	BOA	Butterfly Optimization algorithm

Resource Allocation on the Internet of Things Cloud has become increasingly complex during recent years. A wide range of organizations and companies that deal with cloud environments is facing this problem. This is because constraints and objectives encountered in practice are highly variable and vary for each setting. Since the resource allocation problem in IoT

Cloud Environment (1999) was introduced, performance has been the main constraint to focus on. But the problem is now more complex due to many other factors such as task execution time, task transferring, task execution cost [1], etc.

Task scheduling (TS) is one of the most famous combinatorial NP-complete tasks. The efficiency of TS directly affects system performance. Various researchers are proposing various algorithms for the efficient allocation and scheduling of resources in the cloud. This has been found in past comparative studies of various evolutionary and swarm-based methods to perform task scheduling of resources such as ant colony, bee colony, genetic algorithms, particle swarm, and simulated annealing. Various modified scheduling algorithms such as improved multi-objective particle swarm optimization, modified ant colony optimization, and genetic algorithms were also analyzed [2].

Internet of Things is the integration of many technologies sometimes called the Internet of Everything (IoE), Web-based components that collect, transfer, and the data they use from their ecosystem implanted sensors, processors, and communication hardware. IoT is projected to be the next big revolution Communication world. IoT aims to create a flawless network of billions of wireless devices that can communicate over the Internet. IoT ecosystem has millions of components with enormous diversity ranging from small sensors to large, powerful data center nodes, the dynamic execution environment, unambiguous nature of the data generated by smart objects, all these made IoT ecosystem as an atypical ecosystem. Acquiring physical data and transforming it into valuable information and/or services include many processes, such processes need a resource from the IoT ecosystem. For instance, some applications are latency-sensitive, and some need complicated processing like data and time series analysis [3].

IoT components like sensors have limited computing and energy resources, and they are not capable of storing large data and carrying out complicated tasks. So, there is a need for powerful components to carry out the transformation process required by IoT applications. Such components may be smartphones, gateways, and data centers. So, it is better to consider the IoT ecosystem with a cloud platform and some powerful devices like gateways, edge nodes. For example, some applications are latency-sensitive, and some require complex processing such as data and time series analysis [4].

IoT components like sensors have limited computing and Energy resources, and they are not capable of large storage to complete data and complex tasks. So, need Powerful components to complete the change process Required by IoT applications. May contain such components as Smartphones, Gateways, and Data Centers. So, it is better to Consider the IoT ecosystem with a cloud platform and more powerful tools such as gateways, edge nodes. Resources may vary from physical Resources to software resources. Physical resources are storage, processor, bandwidth, energy, and many more, software resources can be procedures to perform information fusion, virtualization function, etc. Identifying and analyzing such resources from the IoT ecosystem makes resource allocation a challenging task [4].

The IoT ecosystem consists of millions of heterogeneous devices that are connected through a network. Efficient resource management is required to increase the quality of services. Network diversity and diversity of IoT devices make resource allocation a challenging task, many efficient algorithms and techniques are being proposed and used to solve the resource allocation problem [5].

II. Optimization Techniques for Resource Allocation

2.1 Genetic Algorithm

A genetic algorithm is a technique of scheduling in which the tasks are assigned resources according to individual solutions (which are called schedules in the context of scheduling), which tells about which resource is to be assigned to which task. Several genetic algorithms have been developed to solve task scheduling problems. The main difference between most of these is the chromosomal representation used in the schedule. However, these existing algorithms are monolithic as they try to scan the entire solution space without considering how to minimize the complexity of the optimization.

The genetic algorithm (GA) was the first evolutionary method based on the laws of Mendelian inheritance and the principles of natural selection. GA offers several advantages over other methods for computationally intensive problems, provided appropriate adaptability functions and set operators are provided. GA defines a set of chromosomes (solutions) or sets of chromosomes called a population. This method then repeats the selection, mutation, and crossover operations until the stopping criteria are met. The result set is the solution set [6].

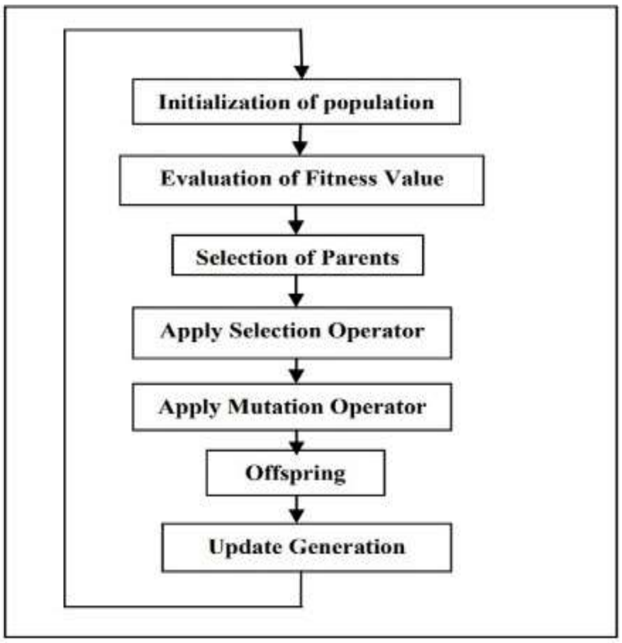

Fig.1: Working flowchart of Genetic Algorithm (GA)

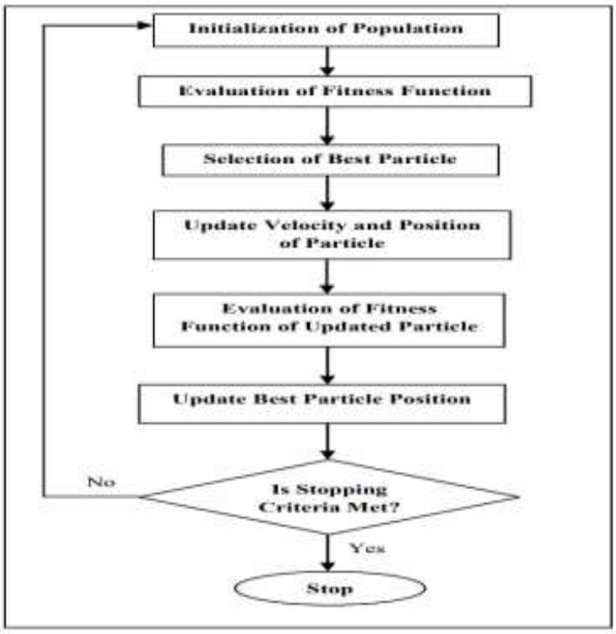

Fig.2: Working flowchart of PSO

2.2 Particle Swarm Optimization

Particle Swarm Optimization (PSO) has a heuristic approach that is applied to many large and complex problems such as power systems, data mining knowledge extraction, and task scheduling problems. PSO follows the principle of random search throughout the solution space using a large population depending on the problem area. Recently, PSOs provide better results than other well-known inefficient optimization solutions. Various methods applicable to task scheduling in this category include multipurpose task assignment using PSO, PSO-based heuristics for scheduling, PSO based on small position rules, and cost optimization using PSO.

2.3 Ant Colony Optimization

Ant colony optimization (ACO) is a meta-heuristic technique inspired by the cooperative food search model of ants. A set of agents is used to implement the colony behavior of real ants. Ants use pheromone trails to cooperate and communicate. Ants use the build graph to iteratively solve problems. Here, the edges represent possible partial solutions that the ant can make according to the rules of stochastic state transitions. Selecting a partial or complete solution triggers a pheromone update rule. This rule provides a reaction mechanism that speeds convergence and prevents premature stagnation of the solution. Due to the detailed properties of ACO, various algorithms based on ACO metaheuristics have been applied to many complex optimization problems [7]. The various methods used to schedule jobs in this category include ACO for load balancing and ACO for job matching.

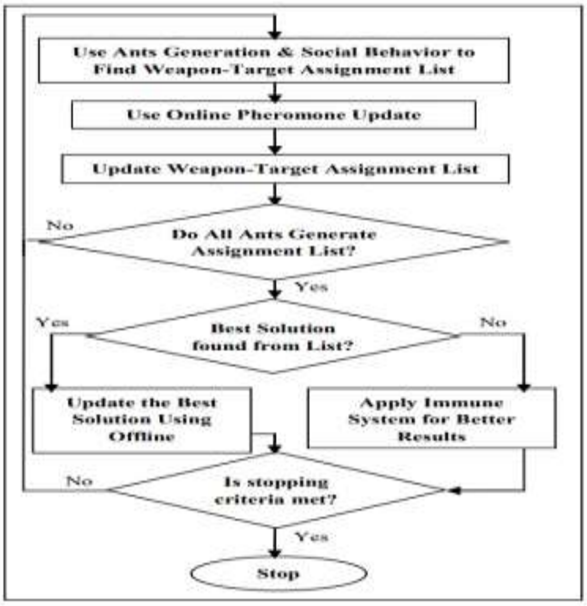

Fig.3: Working flowchart of ACO

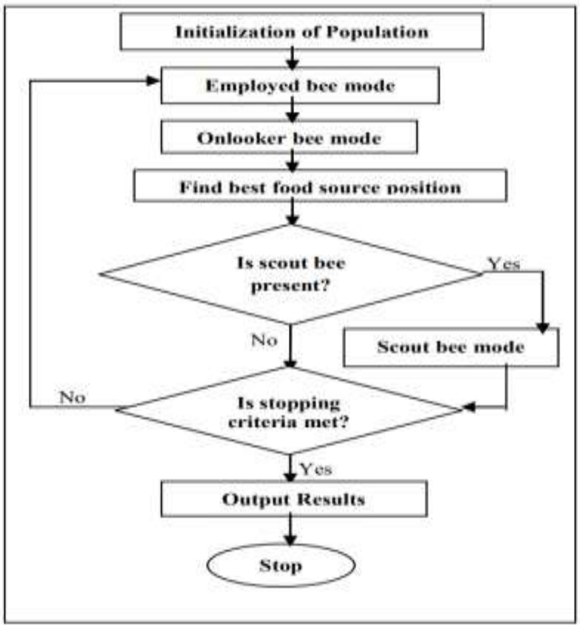

Fig.4: Working flowchart of ABC

2.4 Artificial Bees Colony Optimization

The Artificial Bees Colony (ABC) is based on bee's activity when exchanging information with other bees in search of nectar. There are three types of agents: Employed Bees (EB), Reflective Bees (RB), and Scouts Bees (SB). EB live far from food sources and remember their surroundings. The audience receives this data from jobs and selects one of the food sources. Meanwhile, the scouts work to find a new honey source [8]. Various methods applied to job scheduling in this category include modified bee lifespan algorithms and bee lifespan algorithms.

III. INTERNET OF THINGS CLOUD ENVIRONMENT

Recently, the Internet of Things (IoT) has become one of the major revolutions in the information and communication technology industry. With IoT, an Internet connection to cater to many different applications and services such as traffic control, medical treatment, from traditional smart devices such as smartphones and tablets to devices and things (machines, sensors, vehicles, etc.) Spans a wide range. Energy Management, Health Care, Vehicle Network, etc. It produces a large amount of data that needs to be processed, stored, and analyzed to obtain valuable information to meet the user's goals and needs. In addition, the number and scale of applications and services are growing rapidly, requiring processing capabilities that most powerful smart devices cannot meet at this time.

The cloud environment, known as a large resource hub, that allows users to share and flexibly provides resources, supports IoT development. Time-consuming and resource-intensive tasks can be minimized on powerful computing platforms such as cloud computing while leaving simple tasks to handle smart devices. However, when IoT and cloud computing is combined, new problems arise.

3.1 Cloud Computing

Cloud computing is the next-generation computing paradigm. It is a new computing technology that is increasingly integrated into the on-demand future of distributed computing [9] [10].

Cloud computing is becoming an important pillar for various Internet companies using virtualization principles. Several computing platforms have been proposed for big data storage and multiple parallel computing in cloud computing [11].

3.2 Fog Computing

Fog Computing [4], first proposed by Cisco, represents a new model of cloud computing, which can transform a network edge into a distributed aging infrastructure capable of implementing IoT applications. The concept of cloud computing is to bring cloud computing closer to IoT devices that generate and use data, which in turn brings processing and storage resources closer to users. Rather than moving all processing operations to the cloud, fog computing aims to handle part of the workload produced by applications on devices close to the network to users, called fog servers or fog nodes. These devices can be deployed anywhere from network connectivity: factories, commercial centers, on electric poles, next to railways, inside vehicles, etc. Any device with computing, storage, and network capabilities can be considered a fog node: controllers, switches, routers, embedded servers, surveillance cameras, etc. Placing resources at the edge of the network reduces the time it takes for data to a processing station can be reached in a shorter time, so applications can be optimized for transmission time. However, the processing capability of a fog node is restricted, thus processing requests with small tasks or small delays will be preferred to process over the fog computing infrastructure, while delay-tolerant and large-scale tasks will still be pushed into cloud layers. Ultimately, fog computing complements the cloud to create a new computing paradigm, cloud-fog computing.

IV. LITERATURE REVIEW

An extensive literature survey has been done to understand the resource allocation problems, the existing methods that have been applied to solve RAPs in a better and more efficient way. It is found in past studies that the exact methods such as Genetic Algorithm, PSO, ACO, and BCO have a size limit and fail to deal when the dimension and the complexity of the problem increases. The findings are discussed below:

Internet business (e-business) is becoming one of the best business models today. To meet the needs of Internet-connected businesses, computing becomes a model that includes services implemented and delivered, such as traditional utilities such as water, electricity, and gas. Many computing paradigms promise to provide such service computing without regard to where is the host or how they provide a service [12].

Frontend interfaces include client devices such as thin clients, sophisticated clients, and mobile devices. Clients need specific interfaces and applications to access cloud computing systems. The server part consists of various servers and data storage systems. A central server is used to manage the cloud system. A central server monitors overall traffic and responds to user requirements in real-time. The main goal of a cloud computing environment is to make the best use of available computing resources. In the optimization process, Scheduling algorithms play an important role. Therefore, user tasks should be scheduled using an efficient scheduling algorithm. Scheduling algorithms are typically aimed at maximizing utilization by distributing the load across the available processors and minimizing the overall execution time [1].

Task scheduling (TS) is one of the most famous combinatorial NP-complete problems [13]. The main goal of scheduling is to schedule tasks in the correct order that can be performed given certain constraints [14].

One of the greatest technology revolutions is undoubtedly the Internet of Things (IoT). Due to the potential of IoT, daily objects can be programmable (called smart devices) and consciously work in harmony with optimized performances [15] [16]. Therefore, IoT is changing the way how daily objects (such as phones to smartphones, TV to smart TV, etc.) work in our life. Regularly, the number of IoT-capable devices is increasing. The number of smartphones and tablets for 2013 passed one billion and the expected number for 2017 is almost two billion. However, the expected number of IoT device units in 2020 is 20 billion [17].

As the number of Internet-connected devices increases, today’s technology is not ready to fully bring the power of IoT in our daily life because a huge amount of data, which is generated by many Internets connected devices, is required to be analyzed. On the other hand, the powerful data management of cloud computing allows IoT to make the revolution in our life. The simplicity of usage, the flexibility of data access, ease of maintenance, time, and energy efficiency, and pay-as-you-go policy have already increased the usage of cloud computing over traditional computing [18] [19].

Fog computing [20], first proposed by Cisco, represents a new model of Cloud computing, which can transform a network edge into a distributed computing infrastructure capable of implementing IoT applications.

Zhao, Liu, Zhang, Hu, and Xi [3] presented GA-based optimizations for segmentation and offline task scheduling, with different computing and storage requirements for heterogeneous systems with heterogeneous computing and communication resources. Adapts to present a computing algorithm.

Ge and Wei [21] have developed a new scheduler that uses GA to make optimization and scheduling decisions by evaluating an entire group of jobs in a job queue.

Guo-Ning, TingLei, and Shuai [22] developed a simulated GA annealing-based algorithm that considers the QoS requirements of different types of consumption operations, which correspond to the operation characteristics of cloud environments.

Zhu, Song, Liu, Gao, and Cheng [23] demonstrated the benefits of a multiagent genetic algorithm (MAGA) over traditional GA by developing a load balancing model based on virtualized resource management.

Xiaoli and Yuping Wang [24] proposed an improved two-step multi-objective evolutionary algorithm that accelerates convergence using a modified operator and local search method. This algorithm generated multiple scheduling plans and improved server efficiency through data placement policies and job scheduling strategies.

Chang-Tian and Jiong [25] considered power consumption, performance criteria, and user QoS as targets, and used Dynamic Voltage Scaling (DVS) for two types of ETU_GA (Time Unify Genetic Algorithm) power consumption and Time Double Fitness Genetic power consumption. We have proposed several algorithms. Algorithm (ETDF_GA) - Balances performance and energy.

Jang, Kim, Kim and Lee [26] demonstrated a job scheduling model in which the scheduler calls a GA scheduler function on each scheduling ground and generates a series of schedules ranked according to user satisfaction and virtual machine (VM) availability.

Junwei and Yongsheng [27] presented an improved GA considering the average task completion time, total task completion time, and cost constraints.

Liu, Luo, Zhang, Zhang, and Li [28] have proposed a multi-objective genetic algorithm (MOGA) scheduling algorithm, considering the revenue and energy consumption of access providers. This allows you to dynamically select the appropriate scheduling based on the user's real-time needs.

Pop, Cristea, Bessis, and Sotiriadis [29] used a reputation-based genetic planning algorithm for independent work to increase benefits and minimize costs.

Pandey, Wu, Guru, and Buyya [30] used PSO-based heuristics to schedule workflows in a cloud environment, consider not only the cost of execution but also the cost of transferring dependent data.

Netjinda, Sirinaovakul, and Achalakul [31] used the PSO method to transform real particle data into an integral representation of the result to optimize cost, show potential performance in terms of total cost and convergence, and provide various alternatives, get information about changes in user behavior.

Guo, Shao, and Zhao [32] formulate a multi-criteria work allocation model and desc the PSO algorithm in the cloud to optimize time and cost.

Guo, Zhao, Shen, and Jiang [33] developed a model that uses the PSO algorithm based on small position rules, which is faster and saves processing time.

Chiang, Lee, Lee, and Chou [34] proposed an algorithm that adopted tribe ACO-TMS with new state transition rules that reduce the time needed to find satisfactory planning results, along with local search procedures that help improve planning results.

Li, Xu, Zhao, Dong, and Wang [35] proposed based on the Load Balanced Ant Colony Optimization (LBACO) algorithm, the cloud job scheduling policy aims to stabilize the overall workload along with optimizing the scope of the worksheet configuration. It also applies to dynamic cloud systems and provides better load balancing on the system.

Mizan, Masud, and Latip [36] modified Combining this algorithm with the desired method, we get optimistic service cost in hybrid cloud, get a positive response from the user side, and deploy a resource in ad hoc mode. This section introduces different types of evolutionary and swarm algorithms, as well as different approaches for each category applied to job scheduling in cloud systems, as can be seen in the history of research. These methods are further presented in tabular form with their characteristics and benefits in the following sections. Each table represents a method available in an algorithm of a particular class.

Our department's research group which is involved in research in Nature Inspired Swarm Intelligence Techniques has been working on Swarm Intelligence techniques and implementing them on problems such as Multicast routing, Multi-Processor/Job-shop scheduling, graph coloring, Knapsack problem, Timetabling problem, etc [37] [38] [39] [40]. This group has so far worked successfully on serial and parallel implementations of single depot multiple objective VRPs [41] [42] [43], where SI techniques such as ACO, PSO, and IWD were used. This gives away and motivation to extend that work onto the serial and parallel implementation of SI techniques to the Multiple Depot VRPs.

V. APPLICATION OF SWARM INTELLIGENCE IN IOT ENVIRONMENT

No.	Authors	Problems	Swarm Intelligence techniques	IoT areas
1.	[44]	Cluster Head Selection Problem and Resource allocation in IoT cloud.	ABC	Cluster Head in IoT
2.	[45]	The problem of reliable data gathering in IoT systems.	ABC	IoT Cloud
3.	[11]	Efficient Cluster Head Selection	ABC PSO	Cluster Head Selection for IoT
4.	[46]	Efficient sensor node selection	PSO	Wireless Sensor Node
5.	[47]	Multicast Routing problem in Network	Micro-ABC	MANET (mobile ad-hoc network)
6.	[48]	Efficient Communication problem within IoT Network	ACO	IoT Network
7.	[49]	Efficient Resource allocation or selection in IoT Cloud	GA PSO	Resource selection in IoT Cloud
8.	[50]	Effectively manage and integrate a large amount of data in the IoT Cloud.	GA PSO	Virtual machine selection in cloud IoT
9.	[51]	Data Security in IoT Cloud	GA PSO	IoT Environment
10.	[52]	Load scheduling in IoT Cloud	PSO	IoT Cloud

VI. CURRENT SITUATION AND DEVELOPMENT TREND

6.1. Current Statuses

In this section, we conduct statistical analysis in two aspects. On the one hand, we analyze the number of related literature using PSO, ABC, and GA in WSN and IoT Cloud the past four years (2017–2020) and further analy the specific applications of the four algorithms in WSNs. On the other hand, we analyze the measures considered by these SI algorithms in optimization. Figure 7 presents related works where SI algorithms (PSO, ABC, and GA) are applied in IoT Cloud applications in the past four years (2017–2020).

Fig.5

Fig.6

Fig.5: No. of related literature using PSO, ABC, GA, with IoT Cloud in past 4 years (2017-20)

Fig.6: No. of related literature using PSO, ABC, GA, with WSN in past 4 years (2017-20)

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