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SYSTEMATIC REVIEW

Current trends in cloud computing

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Abstract

Objectives: This work reviewed the latest, state-of-the-art works in the area of Cloud Computing to help researchers, developers and stakeholders in decision-making. **Method**: The reviewed works are filtered after the rigorous process by using renowned indexing database of ACM and IEEE along with the subject based journals on Cloud Computing of international repute. These papers are further filtered by selecting papers published in last 4 years only. Our initial findings lead our reviews to five major areas of Cloud Computing including Load balancing, resource scheduling, resource allocation, resource sharing, and job scheduling. In this work we have limited ourselves to only technical aspects of cloud computing while excluding areas of security, privacy and economics (for example CapEx). We have presented our findings in the form of tables and graphs showing trends in Cloud Computing towards research community on the basis of five aspects as mentioned above. **Findings**: Our findings show that researchers are working in the area of Job Scheduling while low attention has been given in Resource Scheduling. Moreover, an open source robust framework for research community is needed covering all the aspects shown above for running experiments. Currently these features are available in commercial and proprietary frameworks including Amazon Web Service, Microsoft Azure, and Google Cloud Platform.

Keywords: Load balancing; resource scheduling; resource allocation; cloud computing; resource sharing; job scheduling

1 Introduction

Modern cloud computing has changed the computing paradigm with tools like i.e. Azure ML services, Amazon AWS, CV (Computer Vision) and DL (Deep Learning) services, Google Cloud, CV and DL services. In this work, we provide a survey of the latest research trends in cloud computing on the basis of factors involved in distributed systems. One of the factors include Resource Allocation that allows us to allocate cloud resources in dynamic environment effectively. Another factor on which we surveyed the existing systems is Load Balancing, which aims to optimize resource usage, maximize throughput while response time minimum, and avoid overloading of individual resource.

Parameters on Fault Tolerance including Reliability and Availability can be achieved through redundancy. Load balancing usually involves dedicated resources, as shown in[1] through a multilayer switch or a DNS server process. Resource Sharing and Scheduling are the two other factors on the basis of which we surveyed existing systems. Resource Sharing is the capability of cloud computing to share its resources on demand basis while Resource scheduling refers to the use of different algorithms to deliver and allocate different resources in a dynamic environment. The last factor is Job Scheduling, which is the process of prioritizing jobs for maximization of throughput, resource utilization, performance and availability[2]. The work in[3–5]and[6] surveyed workflow scheduling algorithms and highlighted major problems in workflow scheduling related to access of resources for workflows. They identify different issues in scheduling of tasks in light of constraints including deadline of task completion, budgetary issues, data intensive processing, energy aware power consumption, heterogeneity of resources, and deployment of infrastructure. Some of the surveys discuss and highlighted Workflow-as-a-service, QoS, and Visualization for Cloud based solution. Finally, literatures put some lights on taxonomy for cost-aware workflow scheduling[3]. Survey works presented in[7] and[8] discussed cloud computing from the perspective of Virtual Machines for load balancing and resource allocation. Moreover, literature also discussed a brief comparative study on existing challenges and algorithms for load balancing with expected future directions. The work presented in[9] surveyed job scheduling and load balancing algorithms based on MapReduce, Software Agents, etc. for application and network oriented environment over clouds with discussions on open issues and future direction. The survey only provided the detailed discussion on job scheduling problem along-with load balancing in Cloud Computing setting. Survey in[10] proposed a detailed discussion and comparison on resource scheduling algorithms along with resource distribution policies. This survey however only provided detailed insight on resource scheduling while rest of the factors of distributed computing were out of scope. Research in[11] provided comprehensive study along with the critical analysis on energy efficient resource allocation techniques and algorithms. Research in[12] and[13] compared as correlation between big data and green computing challenges. Authors investigated green computing challenges which are faced during deployment of Big Data lifecycle using two metrics namely effective energy efficiency and effective resource efficiency. Researchers also surveyed both areas and also highlighted future directions. Literature[14] discussed virtual machine migration, forecast methods, stability and availability in cloud environment. Moreover, literature[15] discussed pros and cons by providing taxonomy which includes resource adaption policy, objective function, resource allocation method, resource allocation operation and interoperability. In[16] discussed correlations between sustainable development goals (SGD) and information and communication technologies (ICT). Researchers concluded that IEEE and ACM research communities recognized SGD contribution. So in this research authors highlighted awareness for ICT which will add more value to SGD in near future. In[17] researchers deeply reviewed Cyber-Physical Systems (CPS). Authors also presented detailed taxonomy and different aspects which effect performance of CPS. Authors also discussed challenges of big data and green computing in contrast to CPS. Literature[18] discussed several issues that appear in cloud environment due to immature fault tolerance mechanism. Researchers also experimented fault tolerance with four different scenarios and on the basis of experiments they proposed a better algorithm which can deal with the highlighted issues. In[19] highlighted different theoretical and practical aspects of computer security and challenges for cloud based environment. In literature[20] presented a survey on challenges of IoT and cloud computing in contrast to security. Authors also highlighted the significance of cloud computing for IoT based systems. Researchers in [21] proposed a novel framework for managing permissions on Android device via Blockchain technology. Proposed framework utilizes two Blockchains namely (i) PERMBC and (ii) BTCBC both Blockchains handles different task. Literature [22] presents an optimized service broker routing policy for cloud environment. Proposed service uses different parameters for selecting datacenter for routing namely (i) minimum processing time, (ii) minimum response time and (iii) minimum cost. Authors also experimented with service by simulating it with known algorithms and shown better performance than prior solutions. Researchers in [23] proposed PBNM (Policy Based Network Management) to defend against DDoS attack while fulfill the quality of service policies. Researchers also performed two phase experiment and observed better performance with PBNM. Literature [24] presented different software architectures for Big Data processing and deployment platforms specifically in cloud environment. Authors also highlighted state-of-the-art practices for SLA based resource management and job scheduling. In this survey we considered load balancing, resource scheduling, resource allocation, job scheduling and resource sharing in cloud computing environment. In this survey we only considered literature from last four-year. Figure 1 shows the workflow for selection of published papers. First we shortlisted the papers which lie under the considered categories then after select papers that are most relevant to theme of this review.

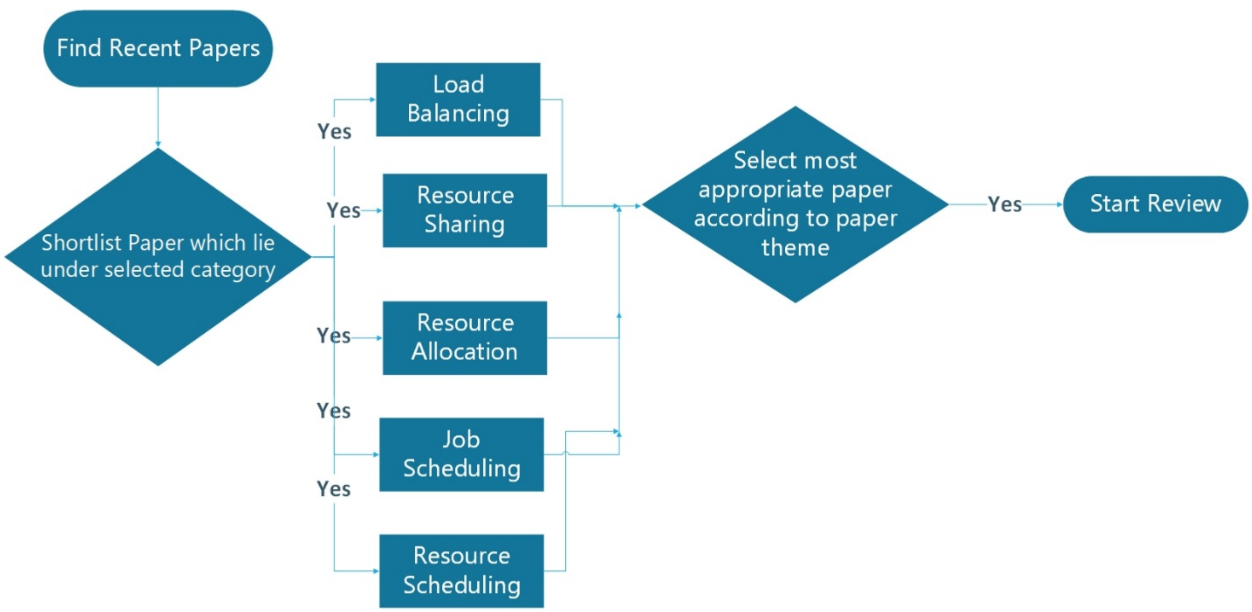

Fig 1. Workflow for paper selection

2 Resource allocation in cloud computing

Cloud computing facilitates its end users with great opportunities like scaling up and scaling down resources on the basis of usage dynamically. There are enough efficient algorithms out there that can take care of this crucial task and makes life easier for cloud users and providers based on their utility. Note that making changes as per user demand is one of the most crucial QoS (Quality of Service) stances of cloud computing itself. Due to heterogeneous nature of cloud computing elements i.e. (microprocessors, cores and VM (Virtual Machines) etc.), it is crucial for cloud providers like (Amazon, Google and Microsoft etc.) to maintain resource allocation properly but this becomes a bit challenging task when we have heterogeneous environment with different QoS standards and policies. Every cloud provider has its own set of rules and policies on which it works or sells its services which currently is out of scope for this study. Research in [25] proposed a metric for securing against co-resident attack in VM resource allocation. For mitigation, they proposed four steps i.e. define a metric for accessing attack, model metrics and compare its difficulty of achieving co-residence, design a new policy such that it can mitigate and also identify workload balance and low power consumption, implement test for prove of policy effectiveness. Literature [26] proposed novel model for static grid scheduling in cloud environment inspired from game theory using Imperfect Information StackelBerg Game (IISG) with hidden markov model (HMM). Due to heterogeneous and dynamic nature of cloud its critical to deploy such models which can benefit both provider and consumer. It used HMM for prediction of service provider current bid based of historical resource demand utility [26]. By the help of these predictions an IISG was established, as in game theory both opponents try to win and maximize its profits. IISG tries to predict optimal policy for resource provider which ultimately help out in getting maximum profit and effective resource utilization side by side. Furthermore, author also simulated results which gives proof of work that their proposed model provides incentive to both provider and user. Economical solution for resource allocation can help service provider such that they can provide better services. Research presented in [27] proposed a resource allocation technique using principle of coalition and uncertainty of game theory. It compares existing techniques with proposed technique which briefs betterment in resource utilization and consumer satisfaction. Energy effective resource allocation technique were discussed in literature [28]. In cloud environment VM's are not configured in standalone fashion instead they are configured in distributed fashion where they share resource and communicate with each other. Authors in literature proposed an energy efficient technique for network aware VM using famous optimization technique known as Ant Colony Optimization. Through simulation author claimed that there proposed techniques indicated better results than existing techniques. Research in [29] highlighted uncertain requirement of resource allocation i.e. VM and network bandwidth in cloud to answer this issue author proposed joint optimization technique that can help out service provider and reduce cases of under and over provisioning of resources. Proposed techniques used stochastic optimization integrated with tree reduction algorithm which enhances tractability of resources efficiently. Furthermore, author performed sensitivity analysis for optimal parameter values which can maximize cost-effectiveness for both user and provider. Literature article [15] proposed unique framework for resource management in cloud environment including allocation, scheduling etc. Proposed framework named SCOW (Smart Cloud-based Optimizing Workload) encompasses of CPS (Cyber Physical System) combined with heterogeneous cloud, for optimization. It introduces algorithms including WRM (Workload Minimization) algorithm, STA (Smart Task Assignment) algorithm and TMA (Task Mapping) algorithm. In [30,31] authors designed a module which does efficient resource allocation in network and human centric environment. Research presented in [32] claimed that recent proposals focused on job guaranteeing performance in network centric environment. These proposals lack in efficient cloud resource utilization or vice versa. In response they proposed DCloud which enables flexible and efficient resource allocation in cloud environment. DCloud implements time sliding and bandwidth scaling which guarantees effective resource utilization as a proof of work they also simulated DCloud with different testbed experiments which shows that DCloud can handle tenant resources more effectively than existing solutions which in result will increase service providers budget and individual cost. Authors of [33] proposed resource allocation technique using genetic algorithm. It enabled with number of novel ideas for resolving respective issue in cloud. In [14] research article authors studied performance limitation and cost effecting constraints and proposed novel approach named Cost-Aware Heterogeneous Cloud Memory Model (CAHCM). Proposed approach aims at high performance in heterogeneous nature of resource allocation. Authors proposed two algorithms for dealing with cost of memory

```
Require: B Table, N_mt, k, {M_mt(g)}
Ensure: DataAllocation
Input B Table
Initialize all availabilities of the cloud memories, N_mt, k,
  {M_mt(g)}
∀data, sort data by the values of (R_d(i) + W_d(i)) in a descending order
for ∀input data do
  Sort memory allocation costs in an ascending order
  /*According to B Table*/
  for ∀the cost for each data allocation manner do
    if The memory (M_mt(g)) is available then
      Allocate data to this memory
      /*D_i → M_mt(g)*/
      The number of this type of memory -1
    end if
  end for
end for
for i=1 to Constant do
  for j=1 to data.size do
    if (Cost_j (P lan_j )+Cost_j−1(P lan_j−1))>
    (Cost_j−1(P lan_j )+Cost_j (P lan_j−1)) then
      P lan_j ↔ P lan_j−1
      /*Switch the memory selections*/
    end if
  end for
end for
RETURN DataAllocation
```

Fig 2. Table for data allocation [14]

```
Require: D_i, N_d, R_d(i), W_d(i), M→−_ab, N_mt, M_mt(g), k, M_j ,
         S_d(i), C_r^β d(i), C_r^!β d(i), C_w^β d(i), C_w^!β d(i), β
Ensure: B Table
    Initialize all input data, D_i, N_d, R_d(i), W_d(i), M→−_ab,
    N_mt, M_mt(g), k, M_j , S_d(i), C_r^β d(i), C_r^!β d(i), C_w^β d(i), C_w^!β d(i), β
    for ∀data do
      for ∀memories {M_mt(g)} do
        Initialize Cost_temp ← 0
        if S_d(i) < β then
          Cost_temp ← Cost_temp + R_d(i) × C_r^β d(i)
          Cost_temp ← Cost_temp + W_d(i) × C_w^β d(i)
        else
          Cost_temp ← Cost_temp + R_d(i) × C_r^!β d(i)
          Cost_temp ← Cost_temp + W_d(i) × C_w^!β d(i)
        end if
        Cost_temp ← Cost_temp + M_ab
        Cost_temp ← Cost_temp + communication costs
        Data allocation cost to M_mt(g) ← Cost_temp
      end for
    end for
    RETURN B Table
```

Fig 3. Table for mapping cost against data allocation [14]

where as variable details are thoroughly mentioned in paper.

Algorithm mentioned in figure 3 is used as input for figure 2 algorithm. Literature [34] proposed a heuristic driven approach for dealing with resource allocation and job scheduling in cloud environment. Proposed literature combines five algorithms namely: modified analytic hierarchy process (MAHP), bandwidth aware divisible scheduling (BATS) + BAR optimization, longest expected processing time preemption (LETP) and divide and conquer. Authors also experimented and compared the proposed algorithm with its priors like BATS and improved differential evolution algorithm. Comparison shows that the proposed approaches surpass existing solutions at time and response metrics. In [35] authors proposed two phase approach for resource allocation and job scheduling. Proposed model uses social group optimization and shorts job first algorithms for completion of desired tasks. Further, authors also validated the proposed algorithms with self-generated data. In result the proposed algorithms improved make span time and throughput. Figure 4 shows the approaches proposed in recent literature for resource allocation. Last, not the least resource allocation should also take care of resource/ load balance as discussed in many literature which will be briefly discussed in upcoming section.

3 Load balancing in cloud computing

Previous sections discussed crucial considerations that cannot be underestimated in shifting our services, infrastructure or software in distributed cloud computing environment. This section is based on load balancing in distributed cloud computing environment which is another important aspect for cloud service providers. Researchers in [31] proposed multi-QoS load balanced resource allocation method (MQLB-RAM). In this methodology, load balancing is handled in real-time which results in better throughput, resource and load management across cloud. The work in [36] literature discussed role of load balancing in multi-user mobile-edge cloud computing. It adopted game theory approach using the mechanism of offloading for load balancing and resource sharing. Author formulated their approach as decision-making problem and observed that their approach possess Nash equilibrium. For Nash equilibrium resolution author designed offloading algorithm which can effectively tackle identified problem. Researchers in [37] literature proposed technique was also inspired by game theory, which proposed three tier architecture for load balancing and resource sharing. First layer was local tier of mobile nodes, second tier were collection cloudlets (nearby computing node) and third tier was remote cloud server. Proposed technique was greedy in nature where they considered mobile nodes for load balancing backed with cloud i.e. remote cloud and nearest computing node. For formal investigation author formulated their problem as Nash equilibrium and proposed distributed algorithm for its resolution. Here we have also included some mathematical details of model extracted from original paper.

$$R_{u,m} = \frac{\frac{1}{\mu_{u.m}}}{1 - \frac{x_{u,m}}{\mu_{u,m}}}, R_{u,clet} = \frac{1}{\mu_{u,w\ l}} + \frac{\frac{1}{\mu_{u,clet}}}{1 - \frac{1}{n_v}\frac{x_{v,clet}\lambda_v}{\mu_{v,clet}}} \tag{1}$$

$$R_{u,\text{cloud}} = \frac{1}{\mu_{u,w\ l}} + \frac{1}{\mu_{u,w\ n}} + \frac{1}{\mu_{u,clo\ ud}} \tag{2}$$

$$R_u\left(x_u, x_{-u}\right) = x_{u,m}R_{u,m} + x_{u,clet}R_{u,clet} + x_{u,clo\ ud}R_{u,clo\ ud} \tag{3}$$

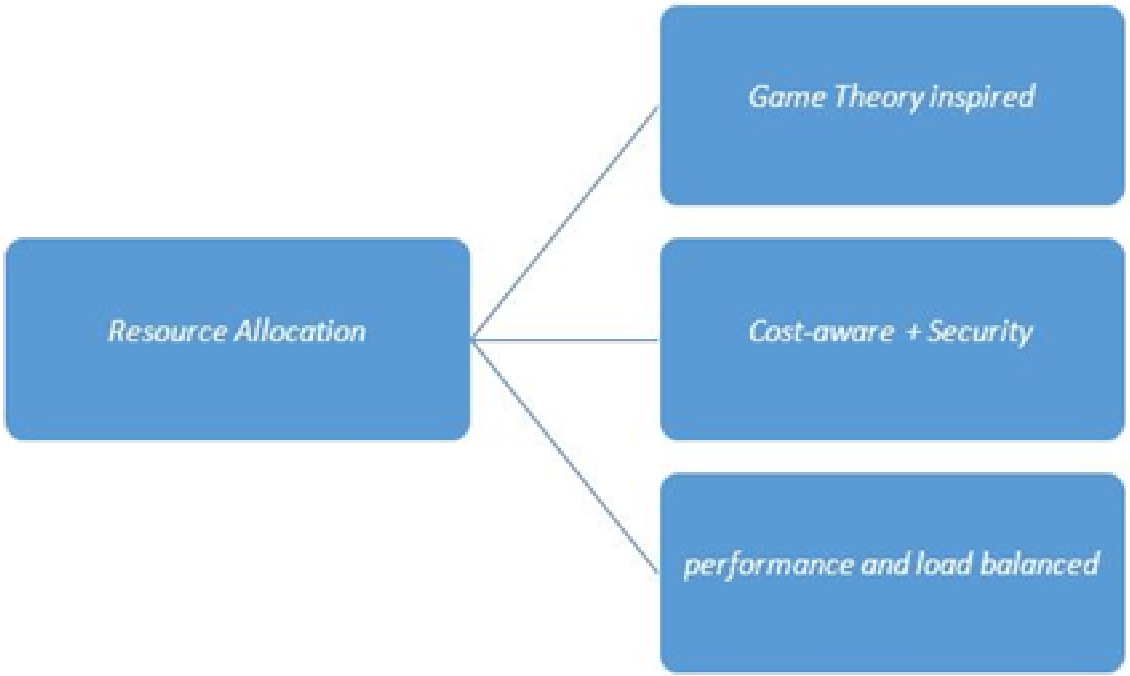

Fig 4. Techniques for resource allocation in cloud computing

Equations (1), (2) and (3) shows the formulation for calculating average response time (i) task wise and (ii) cloudlet wise. For further details, check corresponding literature article[37].

In research[38] authors investigated an effective use of mobile components in cloud environment where nodes are data-centric, resource-centric and need proper load balanced solution. Literature introduces a novel approach named EMOP (Energy-efficient Multisite Offloading Policy) using VIA (Value Iteration Algorithm) and found their solution as an effective alternate for multi-site partitioning problem. Further by numerical simulation author showed their policy was capable of distributing load with lower energy cost. The work in[39] literature focused on computation intensive application which requires an efficient load balancing. Author proposes a design pattern for on-demand load sharing/ balancing using cloud resources as backend and mobile devices as its front end for enabling better decision-making. Literature also discusses two real world implementations of proposed solution in which execution time was reduced to 6% from 96% and power consumption was also reduced to 60% from 96%[39] . Researchers in[8] proposed a novel load balancing algorithm based on estimation of service time deadline. Author claimed that proposed algorithm was effective for process and response time cycle. In[40] proposed novel technique for energy-aware load balancing in dynamic cloud environment. Proposed technique can help service providers in effective resource utilization by switching loads i.e. putting servers on idle, active and sleep states based on resource requirement. Researchers in[41] article addressed problem of ineffective load balancing in data-intensive environment moreover author focused their study to HDFS (Hadoop Distributed File System) and presented an effective replication policy for HDFS so that cloud can balance computational load effectively. The work in[42] presented a detailed survey on cloud brokering frameworks. Literature also presented taxonomy of cloud brokering techniques and discussed pros and cons of respective techniques. Finally, authors proposed a novel model for cloud brokering which addresses the identified challenges. Figure 5 shows the approaches proposed in recent literature for load balancing. As future work we can study different trade-offs between resources and loads when our environment gets more complex then what will happen is our latest techniques are enough capable of handling it? It is a crucial question which can further be explored. In upcoming section, we will explore how can we share our resources in a cloud environment?

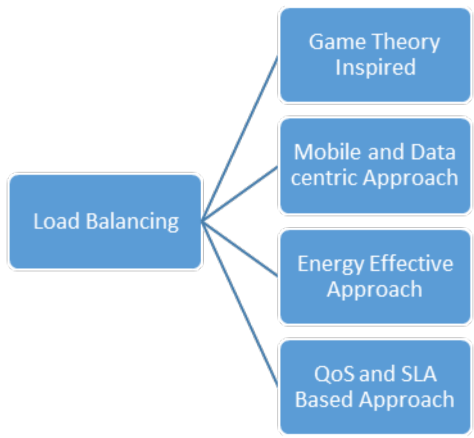

Fig 5. Load balancing in cloud

4 Resource sharing in cloud computing

Resource sharing belongs to balanced sharing of software, hardware or infrastructure. Resource sharing is critical for distribution cloud computing resources efficiently, and effectively. Cloud service provides public, and private community and hybrid solutions for end-consumers. In last sections, we already studied heterogeneous nature of cloud environment i.e. physical machines, servers, VM's etc. Due to heterogeneity, algorithm must share resources in a way that satisfy user's demands and utilize minimal cloud resources which becomes a challenge. The research article [25] was formally discussed in previous subsection on resource allocation four step policy for mitigation from co-resident attack in resource shared cloud environment was proposed. The work in [28] was also briefly discussed in previous sub-section on resource sharing in VM placement using ant-colony optimization technique. Resource sharing in cloud poses some network and physical node based constraints / limitations. This work came up with breakthrough to these limitations through the technique of ant-colony optimization. Research article [29] previously discussed in sub-section on resource allocation, it highlighted resource sharing for effective virtualization and resource provisioning in light of uncertainty due to dynamic requirements. It proposed a joint optimization technique through which service providers can tackle raised uncertainty through under and over resource provisioning efficiently without any hassle. Literature [36] was discussed in last sub-section where author proposed game theory inspired approach for resource sharing. Author formulated problem as Nash equilibrium and proposed effective approach for resource sharing in distributed environment. Research article [37] was also discussed in previous sub-section where it proposed multi-tier resource shared architecture and based on problem identification formulated Nash equilibrium and presented a distributed algorithm and tailored it to problem resolution with in-depth analysis. As future work more effective security policies and solutions should be proposed. The work in [43] literature highlighted cloud computing usage as HPC (High Performance Computing). For achievement of managed resources which guarantee optimized environment proposed two-level solution idea behind two-level solution was to employ share resources on-demand fashion and secondly ensure administer controlled secure environment through policies. Researchers in [44] literature presented resource sharing problem in versatile Dynamic Migration (DM) of VM's in cloud environment. Author proposed triple objective optimization model for DM-VM through energy consumption, inter-communication of VM's, migration cost and sub divided DM-VM problem into two dimension including grouping of VM's and optimal way to place VM onto physical nodes. Furthermore, authors proposed BGM-BLA (Binary Graph Matching-based Bucket-code Learning) algorithms which employs binary graphs for evaluating candidate nodes optimally and compared proposed algorithm outfitted performance with two existing algorithms including non-dominated sorting algorithm and binary graph based common-coding algorithm. Figure 6 shows the approaches proposed in recent literature for resource sharing.

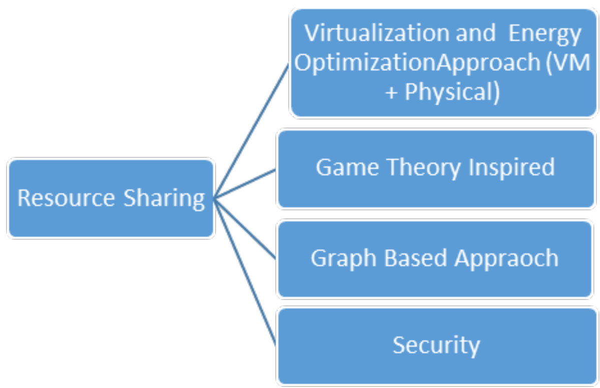

Fig 6. Resource sharing in cloud

5 Resource scheduling in computing

This article has now established some key notices that will help the researchers and practitioners in shifting to cloud computing. The current section briefly discusses resource scheduling in cloud. Resource scheduling becomes crucial when we have heterogeneous nature of computing resources especially virtualization of resources on user demands, optimally scheduling these resources is essential and critical. While [31] was extensively discussed in previous sub-section literature proposed multi-QoS load balanced resource allocation method for price effective cloud service provision. Researchers in [45] proposed an energy-efficient dynamic offloading and resource sharing (eDors) policy for reduction of energy resources and optimizes task completion time frame. The work formulated eDors into energy-efficiency cost (EEC) problem with exception of proper task scheduling constrained with given deadlines, for resolving identified problem author divided objectives into sub-algorithmic task through computational offloading selection, clock frequency control, and transmission power allocation. Furthermore, authors also identified problem dependency tasks and experimented their solution through different test beds. In [46] author also proposed genetic algorithm with strictly optimized constraints and compared performance of proposed algorithm with random, swarm optimization, heterogeneous finish time, and genetic algorithms. Moreover, author claimed better performance than formal techniques in large-scaled resource where 'N' is very large and workflow managed environment which is already proved to be a NP problem. Future research can be continued in achieving real-time scheduling, dynamic scheduling, large-scale scheduling, multi-objective scheduling, distributed and parallel scheduling and cloud scheduling for big data. The work in [47] proposed near-optimal dynamic priority scheduling (DPS) strategy for resource and job scheduling. Proposed algorithm was based on min-max heuristic and greedy algorithm. Moreover, author compared optimization of overall time of proposed algorithm with formal min-max and first come first serve (FCFS) algorithm. For benchmark authors used theoretical minimum execution time (MET). Researchers in [48] proposed an algorithm for balanced resource scheduling and workflow named as BaRRS (Balanced and file Reuse-Replication Scheduling). Algorithm was based on optimal scheduling approach in scientific application workflows. Proposed technique splits up large-scale workflow into sub-workflows so that it can balance resource utilization among complete job. Proposed work also use data reuse and replication technique for optimization enhancement although author focused their study on specific parameters including task execution, dependency patterns, and file sizes. Authors also evaluated and presented different trade-off for optimization of resource scheduling and compared their proposed approach with state-of-the-art scheduling algorithms. Literature [49] presented novel approach for resource scheduling in cloud VM based on auction mechanism. The work considered different factors which may affect performance of VM's in cloud. Algorithm uses deadline constrained approach for biding of available client machines and group these machines into groups. Furthermore, these groups are screened to corresponding VM's and by applying factor of minimum cost, it completes grouping and auctiond. Researcher in [50] proposed cost effective model named VoI (Value of information) for resource scheduling in cloud based environment where we have large-scaled application like weather forecasting, real-time financial analysis etc. for proposed approach integrity they simulated model with real-estate data. Author claimed using VoI-based approach service providers can minimize their computational cost effectively. Proposed mathematical model notations are presented in table 1. Literature discusses the scenario of investment opportunity for investor over single time point which are given in equation 4,5 and 6 respectively,

$$\mathrm{Pr}_{\mathrm{invest}} = V_{\mathrm{future}} - V_{\mathrm{cost}} - C_{\mathrm{cost}} \tag{4}$$

If investor declines to invest in opportunity, then $\mathrm{Pr}_{decline}$ is given by:

$$\mathrm{Pr}_{\mathrm{decline}} = R_{\mathrm{safe}} - C_{\mathrm{cost}} \tag{5}$$

then,

$$\triangle Pr' = Pr'_{invest} - Pr_{decline} = V_{est} - V_{\mathrm{cos}t} - R_{safe} \tag{6}$$

if $\Delta \mathrm{Pr}' > 0$ then investor will invest otherwise he would decline opportunity to safe the cost.

Table 1. VoI mathematical notations [50]

Notation	Definition
V_{cost}	The purchase cost of investment
V_{future}	The future value of investment
V_{est}	The estimated future value of the investment
R_{safe}	The safe return on investment
C_{cost}	The amount of computation analyzing the investment
Pr_{invest}	Profit if investing
$\mathrm{Pr}_{decline}$	Profit if not investing

highlighted formal faulted techniques for scheduling which does not consider energetic-cost / energy awareness into account for evaluation so in this literature author proposed an energy-aware real-time dynamic scheduling scheme for distributed resources in cloud. Proposed algorithm minimizes multi-objective function which combines energy-consumption and execution time according to available resources. Algorithm was tested on different DAG (Directed Acyclic Graph) generated randomly and proved to be suitable for run-time scheduling. Researchers in [51] proposed novel algorithm, presented algorithm use fuzzy-based multidimensional resource scheduling model. Researchers also simulated proposed model and achieved 7% and 35.5% efficiency and response time respectively then prior approaches. In [52] literature proposed a security framework for dynamic edge-cloud environment namely COP (CORAS-based Object-oriented Petri-net). Proposed framework combines the added benefits from CORAS modelling and Object-oriented Petri-net theory. Finally, authors validated proposed model which reveals COP is capable to deal with dynamic and complex security events. Literature [53] review the latest research progress in using deep learning for development of wireless communication. Researchers highlighted the key technological innovations under the umbrella of deep learning like end-to-end communication, signal processing, compression etc. Authors also shed light on potential challenges like baseline, opportunities like improved CSI feedbacks, data augmentation, and future trends. Researchers in [54] presented a review on cloud computing characteristics like resource scheduling. Literature discussed different models from the perspective of virtualization, E-governance, data recovery etc. which can aid individuals and organizations to implement/ utilize cloud computing services. Figure 7 shows the approaches proposed in recent literature for resource scheduling.

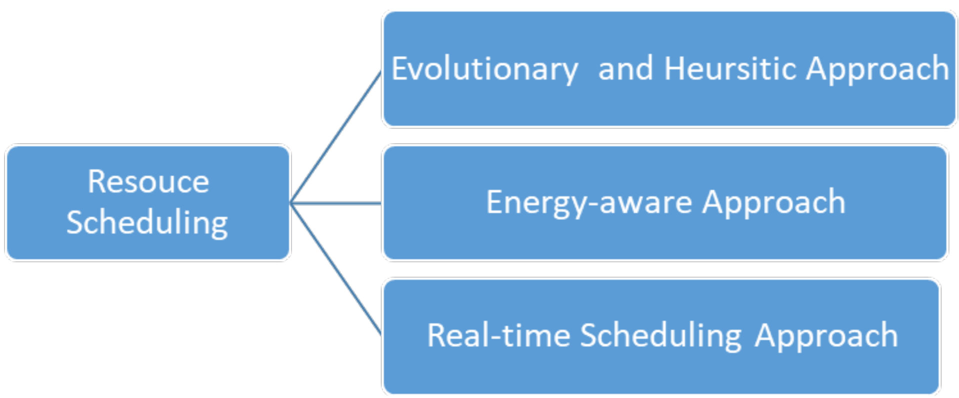

Fig 7. Resource Scheduling in Cloud

6 Job scheduling in cloud computing

In this section we will discuss some aspects of job scheduling in distributed cloud environment. With drastic changes in technology and data generation velocity it is now becoming obvious to enhance your architecture that is where current cloud capabilities help out industry and data revolution in providing such workflow mechanism that can entertain them in a scheduled and balanced manner. Job scheduling also known as workflow is a critical for service providers as it enables them to provide resources on-demand fashion. WFS is mainly concerned with the automatic assignment and management of dependent tasks where jobs on shared through resources managed by workflow resource scheduler. Managing single task is quite easy and there is no extra need for any scheduling mechanism but complexity arises when we have multiple tasks dependent on each other. Such situations need a mechanism for handling the flow for smooth execution of our desired tasks. As previously studied in cloud environment we are dealing with heterogeneous nature of hardware and software, it becomes a challenge to maintain a proper balance between both cost and resource. Research presented in [32] was previously discussed in previous sub-section detailing resource allocation. Job schedulers are enforced to handle conflicts and their resolution among resources. Authors proposed deadline constrained approach for effective job scheduling and resource allocation in uncertain distributed environment. By leveraging resources DCloud guarantees effective job scheduling through deadline management, network bandwidth management, VM management etc. as discussed in literature. The work in [38] was briefly discussed in previous sub-section. Authors proposed a novel approach for data-centric and computation-intensive applications using DTMC and MDP, offloading of mobile resources and load requires balance which is ensured by job scheduler specifically when energy-aware load balancing is required as previously discussed. Literature [45] was discussed in previous sub-section where authors proposed eDors policy for effective resource and job/task scheduling. The proposed policy was capable enough of handling ECC, deadline constraints, data-intensive task scheduling for robustness in eDors that was tested with SMD (Smart Mobile Device) and DVFS (Dynamic Voltage and Frequency Scaling). Literature [46] was discussed in previous sub-section, that proposed evolutionary algorithms and claimed better performance for scientific workflow scheduling which is an emerging area. Researchers in [47] proposed multi-step workflow model for cloud based instance-intensive environment, due to multi stepping workflow scheduling that was incorporated and proposed favourable results using MET as a benchmark. The work in [48] literature highlighted a balanced approach named BaRRS as discussed in previous sub-section which is suitable for large-scale workflows. The proposed algorithm split up large-scaled workflow into multiple sub-workflows via parallelism and then utilized resources effectively to acquire targets. Moreover, approach was compared with formal scheduling techniques and proved to be a better technique as shown by presented results. In [55] literature discussed an analytical comparison for balanced VM's in dynamic cloud environment which throwback service providers into broken SLA's and policies. Authors introduced broker policy for distribution of workflow among heterogeneous nodes in cloud environment. Proposed approach was evaluated by simulating it on Cloud-Analyst simulator and results proves that technique was successful in finding the best combinations for workflow scheduling. Researchers in [56] highlighted complexity of job scheduling cloud environment and proposed game theory and mathematics inspired technique for task scheduling in dynamic circumstances. Another major focus of technique was energy distributed effective in on-demand manner, using game theory algorithm was capable of balancing/ scheduling jobs. The work in [57] introduced a novel energy-aware multi-job scheduling model which was based on MapReduce technique. Authors considered handling variations of energy-aware events which often occur in cloud environment. This model also considered network fluctuation and data placement policies. For handling aforementioned problems author formulated a bi-level programming model and tends to optimize proposed model. In [58] authors proposed a dynamic task scheduling algorithm inspired by genetic algorithm. Proposed algorithm improved throughput of cloud computing and enhanced task scheduling approach whilst reducing execution time in cloud environment. This algorithm is an improved version of genetic algorithm which outperforms formal algorithm in job scheduling task in cloud based environment. The work in [59] literature proposed a novel cloud-based workflow scheduling (CWSA) policy for multi-tenant and computer-intensive residing in cloud environment. Proposed policy can help service providers in minimization of overall job completion time, tardiness, cost of job execution and utilization of idle resources in cloud. Furthermore, proposed algorithm was compared with stat-of-the-art algorithms including FCFS, MCT (Minimum Completion

Time), EASY Backfilling algorithm and their experimental results showed scalability and effectiveness of CWSA. The work presented in [60] addressed job scheduling problems and proposed an optimized algorithm for edge based cloud computing. The work in [7] presented DAG for task precedence and proposed MSLBL (Minimizing the Schedule Length using the Budget Level). Authors discussed formal literature and modelled edges in DAG as the minimum cost assignment for each task (as nodes) and then applied MSLBL technique. Moreover, identified problem was divided into two by satisfying budget constraints and applying heuristic scheduling for resolve jobs in relaxed time complexity. Mathematical cost model proposed in literature is discussed below with equation no 7 and 8 and table 4. Whereas table 2 shows the mathematical notations extracted from literature.

$$\cos t_{i,k} = \cos t_{(n,pk)} = w_{i,k} \text{ price}_k \tag{7}$$

$$\text{cost}(G) = \sum_{i=1}^{|N|} w_{if(i)} \times \text{price}_{f(i)} \tag{8}$$

Table 2. Mathematical notations of MSLBL [7]

Notation	Definition
$\mathbf{w_{i,k}}$	execution time of task n_i running on processor p_k
$\mathbf{c_{i,j}}$	communication time between n_i and n_j
f (i)	index of the processor assigned to task n_i
price $_k$	unit price of processor p_k
cost$_{i,k}$	cost(n_i , p_k), cost of task n_i on processor p_k ,
cost(G)	total cost of the application G

The work in [61] presented a comparison of Spark a big data cluster based framework with COMP superscalar framework. For experimentation researcher considered three algorithms namely (i) Wordcount, (ii) Kmeans and (iii) Terasort. Comparison shows that COMP outperformed Spark framework. Open area for researchers in job scheduling are system architecture challenges based on intensity, data-intensive application in cloud environment, and time-complexity. Figure 8 shows the approaches proposed in recent literatures for job scheduling.

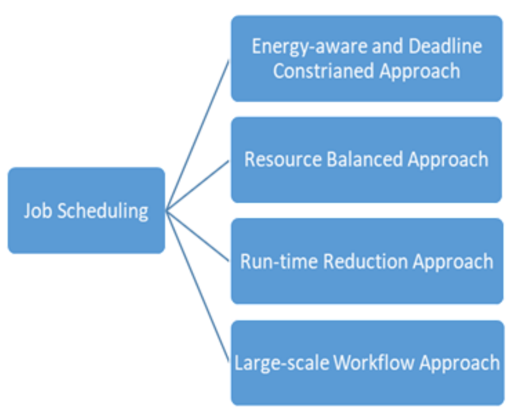

Fig 8. Job scheduling in cloud

7 Comparison of latest trends in cloud computing

This section compares the latest research trends in cloud computing. Table 3 beneath represents papers to corresponding area.

Table 3. A comparison of latest trends in cloud computing

Papers	Resource Allocation	Load Balancing	Resource Sharing	Resource scheduling	Job scheduling
(7)	No	No	No	No	Yes
(8)	No	Yes	No	No	No
(12)	No	No	Yes	No	No
(13)	No	No	Yes	No	No
(14)	Yes	No	No	No	No
(15)	Yes	No	No	No	No
(18)	No	Yes	No	No	No
(25)	Yes	No	Yes	No	No
(26)	Yes	No	No	No	No
(27)	Yes	No	No	No	No
(28)	Yes	No	Yes	No	No
(29)	Yes	No	Yes	No	No
(30)	Yes	No	No	No	No
(31)	Yes	Yes	No	No	No
(32)	Yes	No	No	No	Yes
(33)	Yes	No	No	No	No
(36)	No	Yes	Yes	No	No
(37)	No	Yes	Yes	No	No
(38)	No	Yes	No	No	Yes
(39)	No	Yes	No	No	No
(40)	No	Yes	No	No	No
(41)	No	Yes	No	No	No
(42)	No	Yes	No	No	No
(43)	No	No	Yes	No	No
(44)	No	No	Yes	No	No
(45)	No	No	No	Yes	Yes
(46)	No	No	No	Yes	Yes
(47)	No	No	No	Yes	Yes
(48)	No	Yes	No	Yes	Yes
(49)	No	No	No	Yes	No
(50)	No	No	No	Yes	No
(62)	No	No	No	Yes	No
(51)	No	No	Yes	No	No
(55)	No	No	No	No	Yes
(56)	No	No	No	No	Yes
(57)	No	No	No	No	Yes
(58)	No	No	No	No	Yes
(59)	No	No	No	No	Yes
(60)	No	No	No	No	Yes
(61)	No	No	No	Yes	Yes

Figure 9 shows area wise comparison of papers published in recent years. Comparison shows that in recent years research community is working towards job scheduling approaches. Whilst load balancing is on second place and resource allocation is on third place respectively. Last not the least resource scheduling and resource sharing are on fourth and fifth spot.

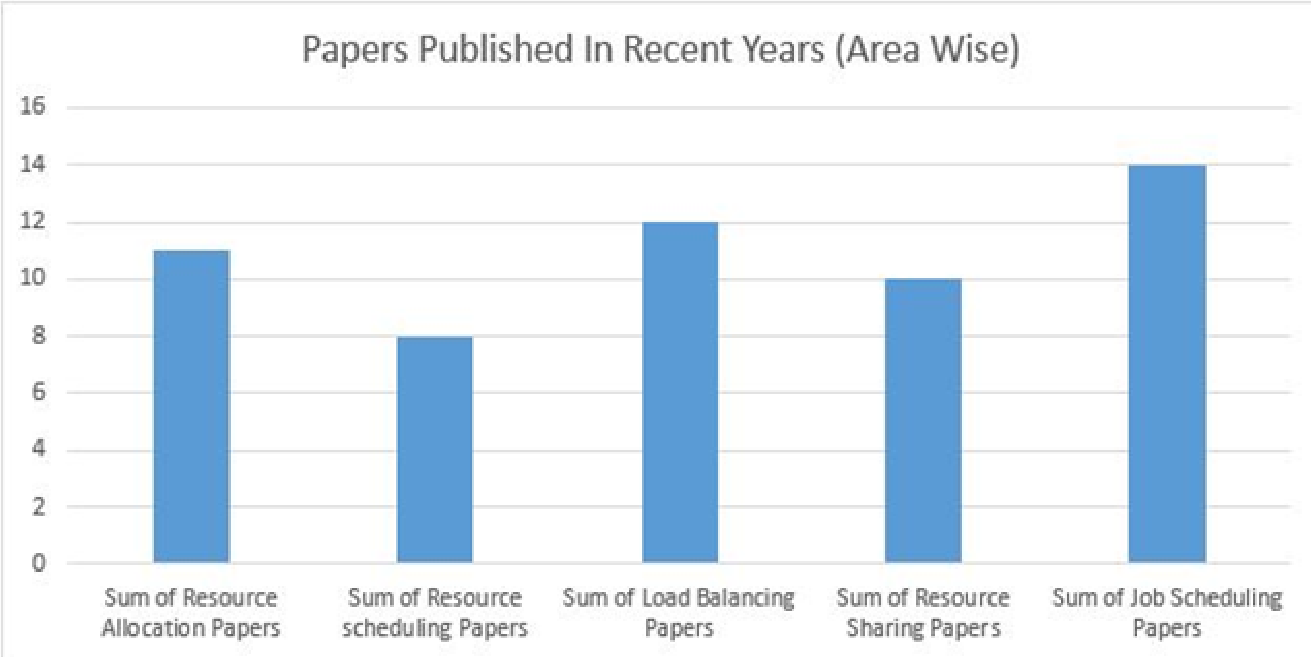

Fig 9. Comparison of published articles area wise

8 Conclusion

In this paper, we presented a comprehensive review of Cloud Computing. The analysis of different models based suggests that exiting research and development of Cloud Computing are focused on Resource Sharing and Allocation. Recently, Resource and Job Scheduling are receiving attention.

It has been found that robust models including IISGE (using Hidden Markov Model), CAHCM, and BGM-BLA (using Binary Graph based Sorting Algorithm), and SCOW (using CPS, Workflow Management, STA and TMA) are working towards resource allocation and sharing. Load balancing are adequately addressed by MQLM-RAM, and EMOP (using Value Iteration Algorithm). Extensive coverage with good results have been provided by eDors (keeping in view Energy-Efficienct Cost), DPS (using Heuristically Greedy Algorithms), BaRRS, VoI, CWSA, and MSLBL in resource and job scheduling.

This review attempts to provide researchers an insight into different types of techniques provided in Cloud Computing for Scheduling, Allocation and Sharing of Resources including infrastructure, platform and software. It provides the set of different open problems that are required to be solved. Previous works provide review on combination of 2-3 metrics while ignoring others. This work provides robust insight considering 5 different parameters.

References

1) Wikipedia . 2018,. Available from: https://en.wikipedia.org/wiki/Load_balancing_(computing.
2) Dave YP, Shelat AS, Patel DS and Jhaveri RH. Various job scheduling algorithms in cloud computing: A survey. In: and others, editor. International Conference on Information Communication and Embedded Systems (ICICES2014) . 2014,. Available from: https://doi.org/10.1109/ICICES.2014.7033909.
3) Alkhanak EN, Lee SP and Khan SUR. Cost-aware challenges for workflow scheduling approaches in cloud computing environments: Taxonomy and opportunities. *Future Generation Computer Systems*. 2015;50:3–21. Available from: https://dx.doi.org/10.1016/j.future.2015.01.007.

4) Masdari M, ValiKardan S, Shahi Z and Azar SI. Towards workflow scheduling in cloud computing: A comprehensive analysis. *Journal of Network and Computer Applications*. 2016;66:64–82. Available from: https://dx.doi.org/10.1016/j.jnca.2016.01.018.
5) Rodriguez MA and Buyya R. A taxonomy and survey on scheduling algorithms for scientific workflows in IaaS cloud computing environments. *Concurrency and Computation: Practice and Experience*. 2017;29(8). Available from: https://dx.doi.org/10.1002/cpe.4041.
6) Wu F, Wu Q and Tan Y. Workflow scheduling in cloud: a survey. *The Journal of Supercomputing*. 2015;71(9):3373–418.
7) Chen W, Xie G, Li R, Bai Y, Fan C and Li K. Efficient task scheduling for budget constrained parallel applications on heterogeneous cloud computing systems. *Future Generation Computer Systems*. 2017;74:1–11. Available from: https://dx.doi.org/10.1016/j.future.2017.03.008.
8) Chien NK, Son NH and Loc HD. Load balancing algorithm based on estimating finish time of services in cloud computing. In: and others, editor. 18th International Conference on Advanced Communication Technology (ICACT) . 2016,. Available from: https://doi.org/10.1109/ICACT.2016.7423340.
9) Ghomi EJ, Rahmani AM and Qader NN. Load-balancing algorithms in cloud computing: A survey. *Journal of Network and Computer Applications*. 2017;88:50–71. Available from: https://dx.doi.org/10.1016/j.jnca.2017.04.007.
10) Singh S and Chana I. A Survey on Resource Scheduling in Cloud Computing: Issues and Challenges. *Journal of Grid Computing*. 2016;14(2):217–264. Available from: https://dx.doi.org/10.1007/s10723-015-9359-2.
11) Dave A, Patel B and Bhatt G. Load balancing in cloud computing using optimization techniques: A study. In: and others, editor. International Conference on Communication and Electronics Systems (ICCES) . 2016,. Available from: https://doi.org/10.1109/CESYS.2016.7889883.
12) Wu J, Guo S, Li J and Zeng D. Big Data Meet Green Challenges: Big Data Toward Green Applications. *IEEE Systems Journal*. 2016;10(3):888–900. Available from: https://dx.doi.org/10.1109/jsyst.2016.2550530.
13) Wu J, Guo S, Li J and Zeng D. Big Data Meet Green Challenges: Greening Big Data. *IEEE Systems Journal*. 2016;10(3):873–887. Available from: https://dx.doi.org/10.1109/jsyst.2016.2550538.
14) Gai K, Qiu M and Zhao H. Cost-Aware Multimedia Data Allocation for Heterogeneous Memory Using Genetic Algorithm in Cloud Computing. *IEEE Transactions on Cloud Computing*. 2016;(99):1–1. Available from: https://dx.doi.org/10.1109/tcc.2016.2594172.
15) Gai K, Qiu M, Zhao H and Sun X. Resource Management in Sustainable Cyber-Physical Systems Using Heterogeneous Cloud Computing. *IEEE Transactions on Sustainable Computing*. 2018;3(2):60–72. Available from: https://dx.doi.org/10.1109/tsusc.2017.2723954.
16) Wu J, Guo S, Huang H, Liu W and Xiang Y. Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives. *IEEE Communications Surveys & Tutorials*. 2018;20(3):2389–2406. Available from: https://dx.doi.org/10.1109/comst.2018.2812301.
17) Atat R, Liu L, Wu J, Li G, Ye C and Yang Y. Big Data Meet Cyber-Physical Systems: A Panoramic Survey. *IEEE Access*. 2018;6:73603–73636. Available from: https://dx.doi.org/10.1109/access.2018.2878681.
18) Goundar S and Bhardwaj A. Efficient Fault Tolerance on Cloud Environments. *International Journal of Cloud Applications and Computing*. 2018;8(3):20–31. Available from: https://dx.doi.org/10.4018/ijcac.2018070102.
19) Gupta BB, Computer C and Security . 2017,. Available from: https://www.researchgate.net/publication/318941164_CFC_Computer_and_Cyber_Security_Principles_Algorithm_Applications_and_Perspectives.
20) Stergiou C, Psannis KE, Kim BG and Gupta B. Secure integration of IoT and Cloud Computing. *Future Generation Computer Systems*. 2018;78:964–975. Available from: https://dx.doi.org/10.1016/j.future.2016.11.031.
21) Ouaguid A, Abghour N and Ouzzif M. A Novel Security Framework for Managing Android Permissions Using Blockchain Technology. *International Journal of Cloud Applications and Computing*. 2018;8(1):55–79. Available from: https://dx.doi.org/10.4018/ijcac.2018010103.
22) Manasrah A, Aa A and Gupta BB. An optimized service broker routing policy based on differential evolution algorithm in fog/cloud environment. *Cluster Computing*. 2019;22.
23) Dahiya A and Gupta BB . 2019,.
24) Gupta BB and Agrawal DP . 2019,.
25) Han Y, Chan J, Alpcan T and Leckie C. Using Virtual Machine Allocation Policies to Defend against Co-Resident Attacks in Cloud Computing. *IEEE Transactions on Dependable and Secure Computing*. 2017;14(1):95–108.
26) Wei W, Fan X, Song H, Fan X and Yang J. Imperfect Information Dynamic Stackelberg Game Based Resource Allocation Using Hidden Markov for Cloud Computing. *IEEE Transactions on Services Computing*. 2018;11(1):78–89. Available from: https://dx.doi.org/10.1109/tsc.2016.2528246.

27) Pillai PS and Rao S. Resource Allocation in Cloud Computing Using the Uncertainty Principle of Game Theory. *IEEE Systems Journal*. 2016;10(2):637–648. Available from: https://dx.doi.org/10.1109/jsyst.2014.2314861.
28) Gao C, Wang H, Zhai L, Gao Y and Yi S. An Energy-Aware Ant Colony Algorithm for Network-Aware Virtual Machine Placement in Cloud Computing. *IEEE 22nd International Conference on Parallel and Distributed Systems (ICPADS)*. 2016;2016:13–16.
29) Chase J and Niyato D. Joint Optimization of Resource Provisioning in Cloud Computing. *IEEE Transactions on Services Computing*. 2017;10(3):396–409. Available from: https://dx.doi.org/10.1109/tsc.2015.2476812.
30) Taneja M and Davy A. Resource aware placement of IoT application modules in Fog-Cloud Computing Paradigm. In: and others, editor. 2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM) . 2017,. p. 8–12. Available from: https://dx.doi.org/10.23919/INM.2017.7987464.
31) Liu L, Mei H and Xie B. Towards a multi-QoS human-centric cloud computing load balance resource allocation method. *The Journal of Supercomputing*. 2016;72(7):2488–2501. Available from: https://dx.doi.org/10.1007/s11227-015-1472-2.
32) Li D, Chen C, Guan J, Zhang Y, Zhu J and Dcloud YR. Deadline-Aware Resource Allocation for Cloud Computing Jobs. *IEEE Transactions on Parallel and Distributed Systems*. 2016;27(8):2248–60.
33) Lin YK and Chong CS. Fast GA-based project scheduling for computing resources allocation in a cloud manufacturing system. *Journal of Intelligent Manufacturing*. 2017;28(5):1189–201.
34) Gawali MB and Shinde SK. Task scheduling and resource allocation in cloud computing using a heuristic approach. *Journal of Cloud Computing*. 2018;7(1). Available from: https://dx.doi.org/10.1186/s13677-018-0105-8.
35) Praveen SP, Rao KT and Janakiramaiah B. Effective Allocation of Resources and Task Scheduling in Cloud Environment using Social Group Optimization. *Arabian Journal for Science and Engineering*. 2018;43(8):4265–4272. Available from: https://dx.doi.org/10.1007/s13369-017-2926-z.
36) Chen X, Jiao L, Li W and Fu X. Efficient Multi-User Computation Offloading for Mobile-Edge Cloud Computing. *IEEE/ACM Transactions on Networking*. 2016;24(5):2795–808.
37) Cardellini V, Personé VDN, Valerio VD, Facchinei F, Grassi V, Presti FL et al. A game-theoretic approach to computation offloading in mobile cloud computing. *Mathematical Programming*. 2016;157(2):421–449. Available from: https://dx.doi.org/10.1007/s10107-015-0881-6.
38) Terefe MB, Lee H, Heo N, Fox GC and Oh S. Energy-efficient multisite offloading policy using Markov decision process for mobile cloud computing. *Pervasive and Mobile Computing*. 2016;27:75–89. Available from: https://dx.doi.org/10.1016/j.pmcj.2015.10.008.
39) Liu Z, Zeng X, Huang W, Lin J, Chen X and Guo W. Framework for Context-Aware Computation Offloading in Mobile Cloud Computing. In: and others, editor. 2016 15th International Symposium on Parallel and Distributed Computing (ISPDC) . 2016,. Available from: https://dx.doi.org/10.1109/ISPDC.2016.30.
40) Paya A and Marinescu DC. Energy-Aware Load Balancing and Application Scaling for the Cloud Ecosystem. *IEEE Transactions on Cloud Computing*. 2017;5(1):15–27. Available from: https://dx.doi.org/10.1109/tcc.2015.2396059. doi:10.1109/tcc.2015.2396059.
41) Dai W, Ibrahim I and Bassiouni M. Improving Load Balance for Data-Intensive Computing on Cloud Platforms. *IEEE International Conference on Smart Cloud (SmartCloud)*. 2016;.
42) Chauhan SS, Pilli ES, Joshi RC, Singh G and Govil MC. Brokering in interconnected cloud computing environments: A survey. *Journal of Parallel and Distributed Computing*. 2019;133:193–209. Available from: https://dx.doi.org/10.1016/j.jpdc.2018.08.001. doi:10.1016/j.jpdc.2018.08.001.
43) Vázquez-Poletti JL, Moreno-Vozmediano R, Han R, Wang W and Llorente IM. SaaS enabled admission control for MCMC simulation in cloud computing infrastructures. *Computer Physics Communications*. 2017;211:88–97. Available from: https://dx.doi.org/10.1016/j.cpc.2016.07.004.
44) Tao F, Li C, Liao TW and Laili Y. BGM-BLA: A New Algorithm for Dynamic Migration of Virtual Machines in Cloud Computing. *IEEE Transactions on Services Computing*. 2016;9(6):910–925. Available from: https://dx.doi.org/10.1109/tsc.2015.2416928.
45) Guo S, Xiao B, Yang Y and Yang Y. Energy-efficient dynamic offloading and resource scheduling in mobile cloud computing. In: and others, editor. IEEE INFOCOM 2016 - The 35th Annual IEEE International Conference on Computer Communications . 2016,. p. 10–14. Available from: https://dx.doi.org/10.1109/INFOCOM.2016.7524497.
46) Liu L, Zhang M, Buyya R and Fan Q. Deadline-constrained coevolutionary genetic algorithm for scientific workflow scheduling in cloud computing. *Concurrency and Computation: Practice and Experience*. 2017;29:e3942–e3942. Available from: https://dx.doi.org/10.1002/cpe.3942.
47) Xu R, Wang Y, Huang W, Yuan D, Xie Y and Yang Y. Near-optimal dynamic priority scheduling strategy for instance-

intensive business workflows in cloud computing. *Concurrency and Computation: Practice and Experience*. 2017;29(18). Available from: https://dx.doi.org/10.1002/cpe.4167.

48) Casas I, Taheri J, Ranjan R, Wang L and Zomaya AY. A balanced scheduler with data reuse and replication for scientific workflows in cloud computing systems. *Future Generation Computer Systems*. 2017;74:168–178. Available from: https://dx.doi.org/10.1016/j.future.2015.12.005.
49) Kong W, Lei Y and Ma J. Virtual machine resource scheduling algorithm for cloud computing based on auction mechanism. *Optik*. 2016;127(12):5099–5104. Available from: https://dx.doi.org/10.1016/j.ijleo.2016.02.061.
50) Bölöni L and Turgut D. Value of information based scheduling of cloud computing resources. *Future Generation Computer Systems*. 2017;71:212–220. Available from: https://dx.doi.org/10.1016/j.future.2016.10.024.
51) Priya V, Kumar CS and Kannan R. Resource scheduling algorithm with load balancing for cloud service provisioning. *Applied Soft Computing*. 2019;76:416–424. Available from: https://dx.doi.org/10.1016/j.asoc.2018.12.021. doi:10.1016/j.asoc.2018.12.021.
52) Li Q, Yin X, Meng S, Liu Y and Ying Z. A security event description of intelligent applications in edge-cloud environment. *Journal of Cloud Computing*. 2020;9:23–23.
53) Wu H, Li X and Deng Y. Deep learning-driven wireless communication for edge-cloud computing: opportunities and challenges. *Journal of Cloud Computing*. 2020;9:21–21.
54) Rashid A and Chaturvedi A. Cloud Computing Characteristics and Services A Brief Review. *International Journal of Computer Sciences and Engineering*. 2019;7(2):421–426. Available from: https://dx.doi.org/10.26438/ijcse/v7i2.421426. doi:10.26438/ijcse/v7i2.421426.
55) Mesbahi MR, Hashemi M and Rahmani AM. Performance evaluation and analysis of load balancing algorithms in cloud computing environments. *Second International Conference on Web Research (ICWR)*. 2016;2016:27–28.
56) Yang J, Jiang B, Lv Z and Choo KK . 2017,. Available from: https://doi.org/10.1016/j.future.2017.03.024.
57) Wang X, Wang Y and Cui Y. An energy-aware bi-level optimization model for multi-job scheduling problems under cloud computing. *Soft Computing*. 2016;20(1):303–320.
58) Ma J, Li W, Fu T, Yan L and Hu G. A Novel Dynamic Task Scheduling Algorithm Based on Improved Genetic Algorithm in Cloud Computing. In: Q-A Z, editor. Wireless Communications, Networking and Applications: Proceedings of WCNA 2014. Springer . 2016,. p. 829–864.
59) Rimal BP and Maier M. Workflow Scheduling in Multi-Tenant Cloud Computing Environments. *IEEE Transactions on Parallel and Distributed Systems*. 2017;28(1):290–304. Available from: https://dx.doi.org/10.1109/tpds.2016.2556668. doi:10.1109/tpds.2016.2556668.
60) Zhao T, Zhou S, Guo X and Niu Z. Tasks scheduling and resource allocation in heterogeneous cloud for delay-bounded mobile edge computing. *IEEE International Conference on Communications (ICC)*. 2017;.
61) Conejero J, Corella S, Badia RM and Labarta J. Task-based programming in COMPSs to converge from HPC to big data. *The International Journal of High Performance Computing Applications*. 2018;32(1):45–60. Available from: https://dx.doi.org/10.1177/1094342017701278. doi:10.1177/1094342017701278.
62) Juarez F, Ejarque J and Badia RM. Dynamic energy-aware scheduling for parallel task-based application in cloud computing. *Future Generation Computer Systems*. 2018;78:257–271. Available from: https://dx.doi.org/10.1016/j.future.2016.06.029. doi:10.1016/j.future.2016.06.029.