Enhancing Security in Cloud-Based VM Migration: A Trust-Centric Hybrid Optimization Approach

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Abstract: *Virtual Machine (VM) migration in cloud computing is essential to accomplishing various resource management goals, such as load balancing, power management, and resource sharing. Ensuring Quality of Service (QoS) is crucial while migrating VMs, which means that VMs must run continuously during the procedure. The dynamic nature of resource requirements in cloud computing, driven by "service-on-demand," poses security risks, even while live VM migration mechanisms help to maintain VM availability. This paper addresses changing resource requirements and improves overall system security by introducing a novel method for safe live VM migration. In this paper, a robust optimization approach has been proposed for live VM migration named the Gorilla-based Shuffled Shepherd Optimization Approach (GBSSOA). The proposed approach maximizes the number of fitness targets, such as migration time, QoS parameters, and job runtime. The method takes into account trust values in addition to the previously described performance measures, with a focus on security. Key performance indicators QoS as workload, migration time, trust, and GBSSOA-based secure live VM migration are taken into account during the evaluation. The obtained values of 0.141, 0.654, 342.254ms, and 0.569, respectively, show noteworthy accomplishments in the results. These results highlight how well the strategy developed may simultaneously improve performance metrics and strengthen the security of live VM migration in dynamic cloud computing environments.*

Keywords: *Virtual machine, migration, downtime, migration time, security, optimization algorithm, gorilla-based shuffled shepherd optimization approach.*

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1. Introduction

In the present technological era, cloud computing has reshaped the way users access data and other resources. Cloud computing is an emerging technology for providing services to clients irrespective of the location or time. Recently, cloud computing has found applications in many aspects of our day-to-day life including markets, business, industry, enterprise, and government. The services in the cloud are handled by a third party called a Cloud Service Provider (CSP) [22]. Cloud computing is a type of distributed parallel system that allows access to resources, processing tasks, data, centralized data storage, and servers that are available on remote servers [20]. The CSP offers services to the clients on a lease basis rather than buying it, thereby achieving reduced software cost [2]. Moreover, cloud computing utilizes remote computers for storage and retrieval of data rather than storing it in local computers [32]. Cloud computing normally utilizes public clouds which allow consolidation of numerous resources within a few PMs. The CSPs perform the process of handling the resources by scaling them based on the dynamic varying loads corresponding to the consumer needs [8]. Virtualization is the key aspect that allows multiple users to share the same resources by providing virtual computing resources and storage facility to the users. Virtualization helps in creating numerous instances of the Virtual Machine (VM) on a Physical Machine (PM) thereby enhancing the utilization of resources and enhancing the profits of the CSP [4]. Virtualization is done with the aim of managing the workload by transforming the conventional computing systems to make them economical, efficient, and scalable [15].

Virtualization facilitates the running of numerous Operating Systems (OS) on a single PM. A hypervisor controls every OS that runs on the VM. A key advantage of virtualization is the efficient management of the resources, which is accomplished by migration. The VMs at one PM (source) can be easily migrated to another PM (destination), and at the same time, the VM is kept operational throughout the process. By performing migration of VMs to the underloaded PMs from the overloaded ones, load balancing can be achieved [17]. The VMs constantly require extra resources during migration which impacts the efficiency of the currently running applications. thus, the migration process should be finished within a short span with the help of optimal bandwidth and a targeted server, thus improving the transparency and performance of the process [6]. VM migration can be carried out using two approaches, such as offline as well as live migration. If there is a delay or absence of active connections during

the migration, then the user may get disconnected from the services provided by the CSP. Thus, in order to avoid this kind of scenario, live migration is employed [18]. The VMs are migrated between the PMs by using dedicated or shared resources by the hypervisor with the help of live migration. As the VMs are migrated without interrupting the process during live migration, optimal utilization of resources is achieved. Further, the process ensures uninterrupted connectivity as well as helps to meet the Service Level Agreement (SLA) [6]. Live migration ensures that the CSP can provide a profitable way to access CPU and the other resources [21]. The study focuses on the methods and developments that enable smooth VM migrations in a live environment, resulting in better system performance and effective resource use [3].

Security is a key issue that must be addressed while the migration is carried out. In the case of a Wide Area Network (WAN), the transfer of VMs happens over heterogeneous links, which are shared thereby increasing the vulnerability of VMs. As the VMs contain sensitive information, like passwords, encryption keys, and so on, they must be secluded and protected during the process of migration [28]. Another major issue affecting the performance of the cloud system is resource allocation. The cloud must provide the customers with high quality resources in all scenarios for achieving maximum utility. Resource allocation is performed by mapping the VMs to the PMs and is done by using two processes, such as mapping and scheduling. Resource allocation offers the advantage of load balancing, minimal request execution time, and efficient bandwidth utilization. Normally, efficient VM resource provisioning ensures profit of CSP is enhanced by delivering the services corresponding to the varying user demands and minimizes the cost of CSP by reducing the energy consumed by the PMs [26]. Though virtualization effectively minimizes the hardware cost, the energy consumed during the process is high. Moreover, when the VM is overloaded, it won't be able to execute all services. Thus, efficient ways of allocating resources have to be considered for reducing the energy consumed [29]. Further, performing live VM migration with maximum Quality of Service (QoS) and minimal time is highly challenging, and the QoS and migration time depends on the bandwidth allocated. Several live VM migration algorithms have been proposed, such as Fast Transparent Migration (FTM) [16], Remote Direct Memory Access (RDMA) [9], multi-objective optimized replica placement approach [13], model-driven scheme [14], and so on.

This paper presents a Gorilla-based Shuffled Shepherd Optimization Approach (GBSSOA)-based secure live VM migration technique for providing security during live VM migration. Live VM migration is accomplished considering the workload of the PM computer depending on the QoS and migration time. Once the workload is computed, the value is compared with the threshold to determine if VM migration is required or not. If required, VM migration is performed with the presented GBSSOA, considering objectives, like migration time, run time of the task, and QoS. Further, the trust value is used to ensure security during the VM migration.

The key contribution of this study is listed below.

- Introduced GBSSOA for Live VM Migration: a new optimization algorithm named GBSSOA is devised for performing VM migration, wherein the GBSSOA is developed by adapting the exploration capability of the Gorilla Troops Optimization (GTO) in accordance with the Shuffled Shepherd Optimization Algorithm (SSOA) for improving the optimization process, based on objectives, such as run time of the task, migration time and QoS.

The rest of the study has the following organizational structure; the upcoming section details the related work in live VM migration; section 3 explains on the system model of the cloud, section 4 details the devised live VM migration scheme, section 5 elucidates the results obtained and the evaluation of the devised technique, and the research work is concluded in section 6.

2. Motivation

There has been a growing focus on cloud computing recently, with one of the major focuses on the service migration between the clouds. VM migration ensures the availability and reliability of the service provided by cloud computing. Though various approaches have been developed for achieving VM migration, the security issues associated with the live VM migration have been not much researched. This section details the prevailing schemes of VM migration together with their qualities and challenges, which enthused the formation of the devised scheme.

2.1. Literature Review

Though several studies have addressed the issues of VM migration, we consider eight stat-of-art approaches in the analysis. Hu *et al.* [10] HMDC technique leverages hybrid memory copy and delta compression to enhance live VM migration performance. While demonstrably effective, limitations like increased CPU overhead and potential scalability challenges warrant further investigation for optimal application. Sun *et al.* [23] introduced Security Protection of Live Migration (SPLM) for providing security during migration using encryption and security policy transfer. The SPLM model was comprised of various modules, like Hypervisor Access Engine (HAE), VM Security Agent (SA), Virtual Security Gateway (VSG), and Centralized Management Platform (CMP), wherein the SA and CMP were responsible for providing security. The SPLM system was highly effective in handling huge

traffic while providing security during live migration, although the system suffered from high complexity and cost as the VM count increases. To minimize cost, Addya *et al.* [1], devised a Policy aware VM migration strategy for providing security during live VM migration in cloud federation. The cost associated during migration (down time and real migration time) and communication (request, reply, path establishment) was analyzed for parallel, serial, and enhanced serial techniques. Moreover, a technique for estimating the power consumed during the migration process was also developed. This scheme was effectively utilized for scrutinizing and identification of any abnormal incidents during the VM migration process, but it did not consider migration from one service provider to another. To overcome the drawback listed in [23], Zeb *et al.* [31], devised a Relative security metric model for securing VM migration. This framework utilized three quantitative security measures, like Cost/Benefit Measure (CBM), Performance Improvement Factor (PIF), and Attack Resiliency Measure (ARM) for estimating the effectiveness of the scheme. This enhanced security control scheme can effectively handle all attacks launched by Dolev-Yao (DY) model. However, it was vulnerable to some attacks, such as the ones produced by Key Compromise Impersonation (KCI) models. Attacks were effectively handled, where Torquato *et al*. [24] developed a Stochastic Reward Net (SRN) scheme for evaluating the security risk during the VM migration scheduling. The SRN model was implemented using three major modules, namely main node, VM and the standby node. This model effectively analyzed the tradeoff between security risk and availability during migration for Virtual Machine Monitor (VMM) rejuvenation by utilizing a security factor called Risk Score but was not suitable for multiple VMs.

Multiple simultaneous VM migration was considered, where Yang *et al.* [30] presented a Particle Swarm Optimization and Genetic Algorithm (PSO+GA) for allocating resources during VM migration. This method considered the constrained bandwidth allocation problem, while enhancing the QoS and satisfying the migration time. This scheme was highly effective in attaining an improved QoS with minimal migration time, although it failed to ensure enhanced performance as deadlines increased. This issue was overcome, where Deylami *et al.* [7] introduced a system named Kororā for providing security to the live VM migration process. Here, a virtual trusted platform was utilized for enhancing VM migration integrity and, VM migration was carried out using agents, like data organization, integrity analyzer, data plane, input/output, and Virtual Trust Platform Model (VTPM) agents. This scheme was efficient in providing trusted computing for migrating numerous VMs on the same platform, but it failed to improve the live VM migration integrity. The integrity was enhanced, where Huang *et al.* [11] proposed a Policy-Customized Trusted Cloud Service (PC-TCS) model for ascertaining the uniformity of customers' policies during VM migration. The PC-TCS scheme was implemented using two modules, namely the blockchain-based VM-migration and Attribute-Based Signature (ABS)-based remote-attestation approach. This approach was successful in performing validation of the VM migration in satisfying the security policy and also in reviewing the security of the request, although the approach faced limitations when applying it to the real-time clouds. This issue was overcome, where in Verma [25] devised a Dual Conditional Moth Flame Algorithm (DC-MFA) for performing load balancing in cloud environment. Here, the load balancing was achieved by minimizing the load of the servers by considering selection of one or more VMs for migrating, based on objectives, such as resource cost, migration cost, make span, security, CPU utilization, and migration cost. The DC-MFA was successful in minimizing the resource load and had a fast convergence but was unsuccessful in minimizing the energy consumption. In order to solve the current cloud storage security methods, Bhat *et al*. [5] offered the Probabilistic Public Key Encryption Switching (PPKES) protocol, which offers a single platform for both homomorphic and non-malleable cloud applications. For intermediate ciphertext connections, it presents a unique discrete chain bit pair function and contiguous chain bit pair encryption. The comparison various VM migration models are provided in Table 1.

Table 1. Comparison of various VM migration methods.

Parameter	Approach	Limitation
Security considerations	HMDC [10]	Lack of security
QoS and Load Balancing	SPLM Method [23]	Lack of consideration for QoS
Security Risk Evaluation	SRN Model [24]	Failure to consider various attacks
Integration of Agents	Kororā Scheme [7]	Inability to include agents like Libvirt and Go
Security Policy Guarantee	PC-TCS Model [11]	Failure to utilize optimization algorithms
Comprehensive Security Aspects	Prevailing Methodologies	Lack of consideration for security aspects

3. System Model

Cloud computing provides clients a means of accessing the shared pool of resources and computing devices regardless of their position and time. Virtualization is the key aspect of cloud, which enables in enhancing the availability of resources to the clients. Virtualization enables the cloud to create numerous instances of VM in single PM, wherein the VMs can be employed for processing distinct tasks. With the increase in user demands, the VMs has to be allocated with utmost care as inaccurate assignment of tasks can lead to poor performance as a result of underloading or overloading. The system model of the cloud is depicted in Figure 1.

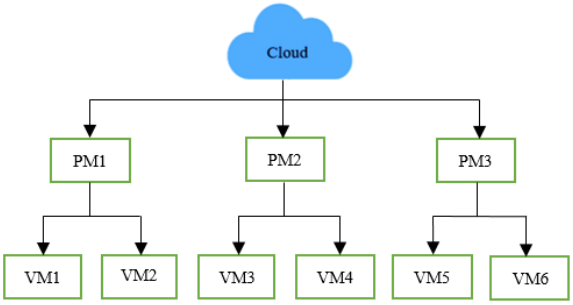


Figure 1. System model of cloud.

Consider a cloud system comprising of z PMs, and the set of PMs is expressed as PM={A_1, A_2, .., A_y, ..A_z}, where A_y signifies the y^{th} PM. Each PM is composed of a distinct number of VMs. Now, consider there are x number of VMs in the y^{th} PM and it can be represented as, $VM = \left\{B_1^y, B_2^y, .., B_x^y\right\}$. Each VM is composed of a set of parameters given by {CPU_b, M_b, BW_a, MT_b, QoS_b}, wherein CPU_b indicates the CPU of the b^{th} VM, M_b denotes the memory of the b^{th} VM, BW_b is the bandwidth of the b^{th} VM, MT_b specifies the migration time of the b^{th} VM, and QoS_b is the QoS of the b^{th} VM.

4. Devised GBSSOA based Live VM Migration Scheme

This section elaborates on the developed secure live VM migration in cloud depending on resource allocation. The introduced GBSSOA based live migration scheme is implemented using the following steps as in Figure 2.

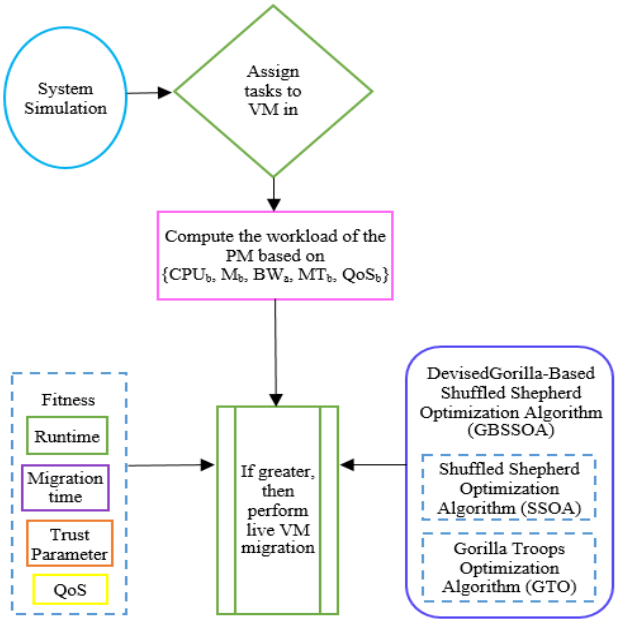


Figure 2. Schematic representation of the devised GBSSOA based secure live VM migration based on resource allocation.

Initially, the tasks are assigned to the VM in around robin manner. The workload of the PM is computed based on VM parameters, such as migration time, and QoS of the VM [30], wherein the migration time depends on the memory, bandwidth, and CPU. The workload estimated is then compared to the threshold, and if estimated workload is higher than the threshold, live VM migration is performed using the introduced GBSSOA. VM migration is carried out by moving the VM from the overloaded PM to the underloaded PM, based on objectives, like run time of the task, migration time and QoS.Here, the introduced GBSSOA is developed by adapting the GTO [27] in line with the SSOA [12]. Further, the security of the VM migration is ensured by considering the fitness considering the trust parameters of the VM, along with the objectives mentioned above.

4.1. Algorithmic Steps

The algorithmic steps of the live VM migration scheme are listed in Algorithm (1) below:

Algorithm1: GBSSOA TaskAssignment

Input: List of VMs, List of Tasks
Output: Task assignments to VMs using live VM migration if needed
Procedure:

1. *Assign tasks to VMs in a round-robin manner initially.*
2. *Initialize iteration counter to 0.*
3. *Repeat until all tasks are assigned:*
   Calculate the workload W_m of the Physical Machine (PM).
   If W_m > 0.9 (threshold), then perform live VM migration using GBSSOA scheme to the underloaded PM.
   Increment the iteration counter.
4. *End procedure.*

4.2. Prerequisites

The workload of the PM is computed based on VM parameters, such as migration time, and QoS of the VM, wherein the migration time depends on the memory, bandwidth, and CPU. The VM parameters, namely the QoS and migration time are detailed as follows:

- Migration Time: migration time of the VM denotes the time taken for performing migration of a VM from one cloud to another. The VM migration time is computed with the help of the pre-copy scheme and is represented as,

$$MT_P = \frac{M}{BW - D} \quad (1)$$

where P indicates the index of the live VM migration task, BW indicates the bandwidth of the network existing among the source as well as the destination hosts, M indicates the memory of the VM, and the dirty rate is specified as D. Dirty rate indicates the data rate of the VM while migrating and is dependent on the currently running application's QoS requirements.

- QoS: QoS is used to indicate the quality needed by the application running on the VM during migration. If an application needs higher QoS, then the VM

memory has to be restructured with high data rate while migrating. The data rate is also known as service rate or dirty rate. QoS depends on the resource allocation, which is given by,

$$RA = \max_{r_{p,q},D_{p,q},S_p} \frac{1}{P}\sum_{p=1}^{P}\left(\frac{1}{s_p}\sum_{q=1}^{s_p} C_{p,q}\right) \quad (2)$$

$$C_{p,q} = f\left(D_{p,q}\right)\ p = 1,2,..P; q = 1,2,..,P \quad (3)$$

$$\forall p \in [1,P]; \forall p \in [1,s_p], C_{p,q} \geq w \quad (4)$$

$$\forall p \in [1,P]; \forall p \in [1,s_p], C_{p,q} \geq w \quad (5)$$

$$\forall p \in [1,P]; \sum_{q=1}^{S_p}\left(r_{p,q} - D_{p,q}\right) * t = F_p \quad (6)$$

$$\forall p \in [1,P]; S_p \geq f_p \quad (7)$$

Here, $r_{p,q}$ and $D_{p,q}$ denotes the bandwidth allocated and dirty rate for the task P in time slot q,s_p indicates the actual migration time for task p, P signifies the live VM migration task count in the total time slots, t represents the length of the time slot, $C_{p,q}$ is the QoS of the task p in time slot q, w denotes the minimal QoS required for the VM migration task, E_q is the bandwidth of the network in the time slot q. E_q specifies the data transmission workload of the task p and is normally the VM memory size.

4.3. Workload Migration Using the Devised GBSSOA

Once the workload of the PM is computed, comparison of the workload is carried out with the threshold. If the computed workload of the PM is higher than the threshold then live VM migration is performed by migrating the VM from the overloaded PM to underloaded PM by using the devised GBSSOA. The process of live VM migration is detailed below.

- Solution Encoding: the solution of the devised live VM migration scheme is pictorially represented in Figure 3.

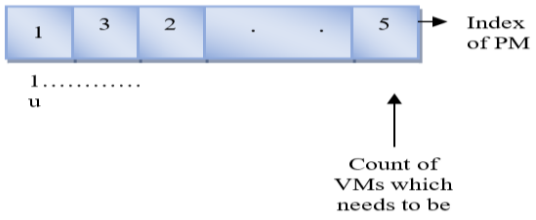


Figure 3. Solution encoding of the devised live VM migration scheme.

Here, solution indicates the PM where the VM needs to be migrated. Solution encoding refers to the pictorial representation of the solution of the devised scheme. The VM in the overloaded PM is migrated to the underloaded PM for balancing the load.

Here, u signifies the number of VMs which needs to be migrated to the PMs and the solution here, signifies the PM to where the VM migration is done. The optimal PM is determined depending on the fitness of the solution.

- Fitness: fitness is computed based on run time of the task, QoS, migration time and trust [19], wherein trust indicates the reliability degree of any data. It can also be considered the confidence level that a work assigned is executed in a specific time interval upon receiving a request. Trust is computed by considering the source PM and target nodes or the PM to which the VM has to be migrated [28]. The trust of a request is given by,

$$Trustij = c \times NewTrustij + \beta(1-c) \times OldTrustij \quad (8)$$

where, c represents the weight of the latest trust value and β is the ageing factor, with values in the range [0,1]. $NewTrust_{ij}$ and $OldTrust_{ij}$ denote the new and old trust value. The new trust value is obtained by using the following expression.

$$NewTrustij = gij + \alpha \times hij \quad (9)$$

Here, h_{ij} indicates the uncertainty count in forwarding, α specifies the relative atomicity parameter, and g_{ij} represents the belief of source node i in migrating the VM to j^{th} node and is given by,

$$g_{ij} = \frac{\gamma_{ij}}{\gamma_{ij}+\eta_{ij}} \times \left(1-h_{ij}\right) \quad (10)$$

where, the successful interaction count is represented by γ and η represents the unsuccessful interaction count. The value of disbelief is represented by,

$$e_{ij} = \frac{\eta_{ij}}{\gamma_{ij}+\eta_{ij}} \times \left(1-h_{ij}\right) \quad (11)$$

The uncertainty count in forwarding is computed in such a way that $g_{ij}+e_{ij}+h_{ij}=1$ and is given by,

$$h_{ij} = \frac{12 \times \gamma_{ij} \times \eta_{ij}}{(\gamma_{ij}+\eta_{ij})^2(1+\gamma_{ij}+\eta_{ij})} \times \left(1-h_{ij}\right) \quad (12)$$

Fitness function is given by,

$$Fit = \frac{1}{|PM||VM|}\sum_{i=1}^{|PM|}\sum_{j=1}^{|VM|}(G_{ij} * H_{ij}) \quad (13)$$

Here, $|PM|$ and $|VM|$ represents the count of PM and VM, and the terms G_{ij} and H_{ij} are expressed as,

$$Gij = RTij + MTij + QoSij + Trustij \quad (14)$$

$$H_{ij} = \begin{cases} 1 & ;if\ the\ i^{th}\ VM\ is\ assigned\ to\ the\ j^{th}\ PM \\ 0 & otherwise \end{cases} \quad (15)$$

Here, RT_{ij} indicates the run time of the task running in the i^{th} VM under the j^{th}PM, MT_{ij}, QoS_{ij} and $Trust_{ij}$ denotes the migration time, QoS and trust parameter of the i^{th} VM under the J^{th} PM.

4.3.1. Devised GBSSOA

Live VM migration is carried by using the developed GBSSOA, which is created by modifying the GTO [27] in line with the SSOA [12] for enhancing the performance of the optimization. The GTO algorithm is a gradient free optimization approach which is based on the way of life of gorillas. The gorillas live together as a group called troop that comprises of a silverback gorilla or a male along with multiple females with their offspring. The grownup male gorillas are referred to as silverbacks, and the smaller males are termed blackbacks. In GTO, exploration and exploitation are performed by using five operators. In exploration phase, the gorillas perform actions, like moving to an unfamiliar area, moving to a familiar region, and migrating towards other gorillas, whereas in exploitation they tag along the silverback and compete for the female gorillas. The GTO is highly efficient in attaining improved convergence and is effective in solving multi-objective optimization issues, although the stability of GTO reduces with highly complex optimization issues. The SSOA, on the other hand, is based on the inspiration of the intuition of a shepherd. Here, the sheep are divided into various groups called herds and, in every herd, a sheep is chosen as shepherd and the ones with the best objective is chosen as horses. The shepherd attempts to guide the sheep to the horse, and the sheep and horses are moved for attaining the new location of the shepherd and based on the shepherd's nature in the herd optimization is carried out. The SSOA is highly effective in attaining the best solution with minimal iterations and has high accuracy. However, the efficacy of the SSOA is highly oriented on the parameters. By combining the SSOA and GTO, the devised GBSSOA effectively overcomes the drawback of both and enhances the performance of optimization. The devised GBSSOA is implemented using the following steps.

1. Initialization: consider there are C number of gorillas in a search space of dimension K, then the population of gorillas can be initialized as,

$$LC \times K = rd(C,K) \times (up - low) + low \tag{16}$$

Here, rd is a matrix with dimension $C \times K$ with elements having arbitrary values in the range [0,1], up and lowdesignates the maximum and minimum bound of the search space.

2. Fitness evaluation: the optimal function is determined considering the fitness measure which is estimated by using Equation (13).
3. Exploration: generally, gorillas live in groups which are dominated by the silverback, which is responsible for the troop's movement and safety, mediating fights decision making, and leading the members to the food sources. In some scenarios, the gorillas tend to leave their group, where in such cases they may migrate into known or unknown territory, or they may shift to other groups. The male gorillas may create a new troop by drawing the female gorillas, which have moved from their groups in certain cases. All gorillas are assumed to be the candidate solution and based on the optimization the silverback is found by determining the best solution. The exploration can be modelled using the following equation considering the three approaches discussed above.

$$QL(t+1) = \begin{cases} (up - low) \times m_2 + low & m_1 < \lambda \\ \left(m_3 - R\right) \times L_\theta(t) + S \times T \times L(t) & m_1 \geq 0.5 \\ L(t) - S \times \left(S \times \left(L(t) - L_\varphi(t)\right) + m_4\left(L(t) - L_\varphi(t)\right)\right) & m_1 < 0.5 \end{cases} \tag{17}$$

where, λ is a constant that denotes the parameter for choosing the approach for migration to unfamiliar territory, t indicates the present iteration, $Q(t+1)$ denotes the candidate location of the search agents iteration t-1, $L(t)$ signifies the current position vector of the distinct gorilla, $L_\theta(t)$ and $L_\phi(t)$ designates the arbitrary chosen gorilla location.m_1, m_2, m_3, and m_4 are arbitrary numbers in the range [0, 1], T is the row vector with elements having value in [-R, R].

Here, R, T, and $T$are given by,

$$R = \left(\cos\left(2 \times m_4\right) + 1\right) \times \left(1 - \frac{t}{\max_t}\right) \tag{18}$$

$$S = R \times v \tag{19}$$

$$T = Y \times L(t) \tag{20}$$

Here, $\max_t$ denotes the overall iteration count, v signifies the arbitrary number with value in [-1, 1] and Y depicts the arbitrary value of the problem dimension in [-R, R].

Consider $m_1 \geq 0.5$ and assume $QL(t+1)=L(t+1)$, then Equation (17) can be rephrased as,

$$L(t+1) = (m3 - R) \times L\Theta(t) + S \times T \times L(t) \tag{21}$$

The temple solution vector of the SSOA is given by,

$$L_i^{t+1} = L_i^t + stepsz_i \tag{22}$$

where $stepsz_i$ is given by,

$$Stepszi = \chi \times rdo(Ld - L_i^t) + \delta \times rdo(Lj - L_i^t) \tag{23}$$

Here, L_j, L_d, and L_i^t indicates the solution vector of the sheep, horse and shepherd, respectively, rd is an random number with value in between 0 and 1, and the parameters χ as well as δ are given as,

$$\chi = \chi_0 - \frac{\chi_0}{\max_t} \times t \tag{24}$$

$$\delta = \delta_0 + \frac{\delta_{\max} - \delta_0}{\max_t} \times t \tag{25}$$

The term δ is initialized to δ_0 at the starting of the algorithm and increases to δ_{max} as the iteration progresses, χ is initialized to χ_0 and as the iteration increases, the value reduces to zero.

Now, applying Equation (23) in Equation (22), we get,

$$L_i^{t+1} = L_i^t + \chi \times rd \circ \left(L_d - L_i^t\right) + \delta \times rd \circ \left(L_j - L_i^t\right) \tag{26}$$

Let us consider, $L_i^{t+1} = L(t=1)$ and $L_i^t = L(t)$, the Equation (26) can be rephrased as,

$$L\left(t+1\right) = L\left(t\right) + \chi \times rd \circ \left(L_d - L\left(t\right)\right) + \delta \times rd \circ \left(L_j - L\left(t\right)\right) \tag{27}$$

$$L(t+1) = L(t) + \chi \times rd \circ Ld - \chi \times rd \circ L(t) + \delta \times rd \circ Lj - \delta \times rd \circ L(t) \tag{28}$$

$$L\left(t+1\right) = L\left(t\right)\left(1 - \chi \times rd - \delta \times rd\right) + rd\left(\chi \times L_d + \delta \times L_j\right) \tag{29}$$

$$L\left(t\right) = \frac{L\left(t+1\right) - rd\left(\chi \times L_d + \delta \times L_j\right)}{\left(1 - \chi \times rd - \delta \times rd\right)} \tag{30}$$

Now, applying Equation (30) in Equation (21), we get,

$$L\left(t+1\right) = \left(m_3 - R\right) \times L_\theta(t) + S \times T \times \left(\frac{L\left(t+1\right) - rd\left(\chi \times L_d + \delta \times L_j\right)}{\left(1 - \chi \times rd - \delta \times rd\right)}\right) \tag{31}$$

$$L\left(t+1\right) - \frac{S \times T \times L\left(t+1\right)}{\left(1 - \chi \times rd - \delta \times rd\right)} = \left(m_3 - R\right) \times L_\theta(t) + S \times T \times \left(\frac{-rd\left(\chi \times L_d + \delta \times L_j\right)}{\left(1 - \chi \times rd - \delta \times rd\right)}\right) \tag{32}$$

$$L(t+1)\left(\frac{1 - \chi \times rd - \delta \times rd - S \times T}{1 - \chi \times rd - \delta \times rd}\right) = \frac{(m_3 - R) \times L_\theta(t)(1 - \chi \times rd - \delta \times rd) - S \times T \times rd(\chi \times L_d + \delta \times L_j)}{1 - \chi \times rd - \delta \times rd} \tag{33}$$

$$L(t+1)\left(\frac{1-\chi\times rd-\delta\times rd-S\times T}{1-\chi\times rd-\delta\times rd}\right) = \frac{(m_3-R)\times L_\theta(t)(1-\chi\times rd-\delta\times rd)-S\times T\times rd(\chi\times L_d+\delta\times L_j)}{1-\chi\times rd-\delta\times rd} \tag{34}$$

$$L\left(t+1\right) = \frac{\left(m_3 - R\right) \times L_\theta(t)\left(1 - \chi \times rd - \delta \times rd\right) - S \times T \times rd\left(\chi \times L_d + \delta \times L_j\right)}{1 - \chi \times rd - \delta \times rd - S \times T} \tag{35}$$

wherein, $L(t+1)$ indicates the position of solution at iteration t+1, L_j, and L_d designates the solution vector of the sheep, and horse.

4. Exploitation: while the troop is created by the silverback, it is most powerful and healthy and the remaining members follow the silverback. Eventually, the silverback becomes old and dies, and the younger blackbacks start fighting to establish dominion and mate with the adult females. These patterns are modelled in this phase, wherein follow of silverback and competition for mating is considered. The operation between these two patterns is switched over b considering a parameter Z. When $R>Z$, the silverback is followed by the other troop members and this is modulated as,

$$QL(t+1) = R \times V \times \left(L(t) - L_{Silverback}\right) + L(t) \tag{36}$$

where, $L(t)$ denotes the present position vector, $L_{Silverback}$ indicates the optimal solution attained till now, the term R is given by Equation (18) and the parameter V is represented by,

$$V = \left(\left|\sum_{i=1}^{C} L_i(t) \Big/ C\right|^{2^R}\right)^{\frac{1}{2^R}} \tag{37}$$

Here, C designates the population dimension, and $L_i(t)$ is the location vector of gorillas in the present iteration. If $R<Z$, then the blackbacks compete for mating the adult females and the process is modelled as,

$$QL(t+1) = L_{Silverback} - \left(L_{Silverback} \times Y - L(t) \times Y\right) \times X \tag{38}$$

where,

$$Y = 2 \times m_6 - 1 \tag{39}$$

$$X = \vartheta \times I \tag{40}$$

$$I = \begin{cases} C_1 & m_7 \geq 0.5 \\ C_2 & m_7 < 0.5 \end{cases} \tag{41}$$

Here, Y denotes the impact force, X represents the intensity of violence while competing, m_6 and m_7 are arbitrary integers in the range [0, 1], ϑ denotes a constant. If $m7 \geq 0.5$, then I will be an array of size $1 \times K$ with random number as elements following normal distribution, else, I will be a stochastic number following normal distribution, with K denoting the spatial dimension of the search space. Here, $L_{Silverback}$ denotes the best solution computed.

- Fitness re-evaluation: once the location of each gorilla is upgraded, the fitness of each gorilla is re-evaluated to find the best solution.

5. Terminate: the above procedure is kept repeated until the maximaliteration count is attained and the optimal solution is obtained by considering the position of the silverback. The pseudocode of the devised GBSSOA are depicted below in Algorithm (2).

Algorithm 2: Pseudocode of devised GBSSOA

Algorithm: GBSSOA (Gorilla Based Shuffled Shepherd Optimization Algorithm)
Input: Population size (C), Maximal iteration (maxt)
Initialization:
- *Initialize the population of gorillas (Li) randomly with size C.*
- *Compute the fitness of each gorilla.*
- *Set iteration counter (t) to 0.*

Optimization Loop:
- *While t < maxt do*
  - *Calculate R.*

– *Calculate S.*
– *For every gorilla Li, revise the gorilla position.*
– *Calculate the fitness of every gorilla.*
– *Keep the best solution as silverback (LSilverback).*
– *For every gorilla Li, if R >= Z then revise the gorilla position using one equation,*
else revise using another equation.
– *Revise the fitness of each gorilla.*
– *Revise the optimal solution (LSilverback).*
– *Increment the iteration counter: t = t + 1*
Output: Best solution (LSilverback).

The best solution is given by the position of the silverback $L_{Silverback}$ and by combining the SSOA with GTO; the exploration capability of the GTO is enhanced and thus achieving higher efficiency and achieving effective live VM migration.

5. Results and Discussion

The experimental results of the presented GBSSOA based secure live VM migration is elaborated in this section. The experimental set up, performance metrics, and comparative evaluation of the introduced approach are explained elaborately.

5.1. Experimental Set-Up

The experimentation of the developed GBSSOA based secure live VM migration is carried out by implementing it on a PC with intel core i-3 processor, 2GB RAM, and Windows 10 OS using Java with Cloudsim.

5.2. Evaluation Measures

The effectiveness of the devised GBSSOA based secure live VM migration is inspected in view of different parameters, like workload, QoS, migration time, and trust, and these metrics are shortly briefed below.

1) Workload: workload indicates the overall count of the requests received by the VM from various applications as well as users. The workload of the VM should be always kept low.
2) QoS: QoS parameter has already been elaborated in section 4.2. and is computed using Equation (2).
3) Migration time: migration time is discussed in section 4.2. and is calculated using Equation (1).
4) Trust: the trust parameter is elaborated in section 4.3.2. and is calculated using Equation (8).

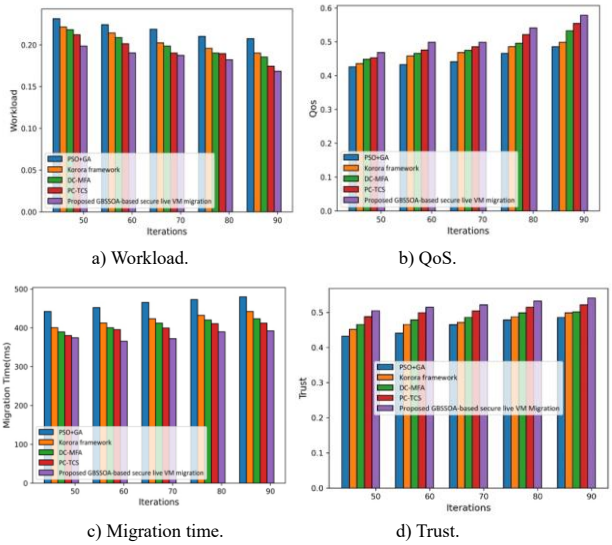
5.3. Comparative Techniques

The efficacy of the developed VM migration approach is inspected by comparing it with various schemes, like PSO+GA [30], Kororā framework [7], DC-MFA [25], and PC-TCS [11].

5.4. Comparative Assessment

The comparative evaluation of the devised GBSSOA based secure live VM migration is illustrated in this section. The introduced technique is assessed for its efficacy based on various metrics, like workload, QoS, migration time, and trust based on different task count.

- Assessment with Number of Tasks as 100: in Figure 4, assessment of the devised GBSSOA approach with task size as 100, considering different number of iterations. Figure 4-a) portrays the evaluation of the developed GBSSOA scheme considering workload. The workload computed by the introduced GBSSOA based secure live VM migration is 0.190 with 60 iterations, which is much lower than the value of workload attained by the prevailing methodologies, such as PSO+GA, Kororā framework, DC-MFA, and PC-TCS is 0.224, 0.214, 0.209, and 0.201. In Figure 4 b), the valuation of the GBSSOA system is depicted concerning the QoS parameter. For 70 iterations, the QoS measured by the existing approaches, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS and the devised GBSSOA approach is 0.441, 0.469, 0.475, 0.485, and 0.499, respectively. The devised technique is revealed to have attained a higher value of QoS, thus showing improved performance. Figure 4-c) depicts the evaluation of the proposed GBSSOA technique with regard to migration time. The proposed GBSSOA approach measured migration time of 389.658ms, which is lower that the migration time of the traditional methods, such as PSO+GA, Kororā framework, DC-MFA, and PC-TCS corresponding to 472.975ms, 432.259ms, 420.258ms, and 410.854ms, with 80 iterations. Figure 4-d) depicts the valuation of the presented GBSSOA technique in view of the trust. The trust achieved by the conventional approaches, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS, and the presented GBSSOA is 0.433, 0.451, 0.466, 0.488 and 0.505, respectively with 50 iterations.

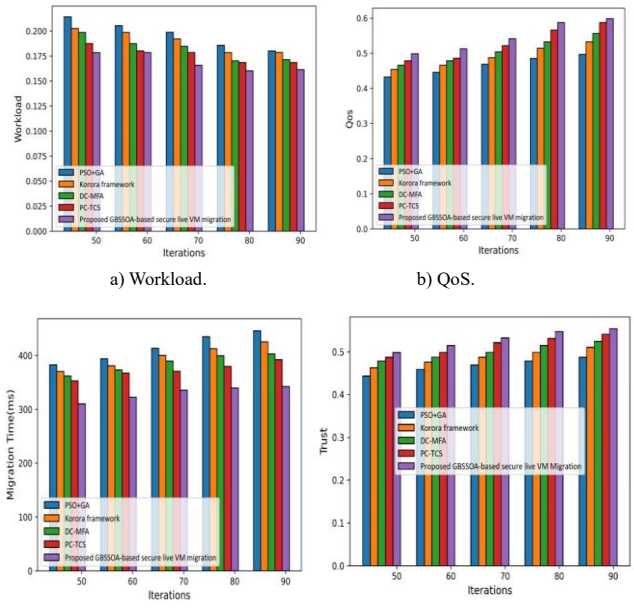


a) Workload. b) QoS.

c) Migration time. d) Trust.

Figure 4. Valuation of the introduced GBSSOA based secure live VM migration with task count as 100.

- Assessment with Number of Tasks as 200: the evaluation of the developed GBSSOA based VM migration is carried out with 200 tasks, considering various metrics and this is presented in Figure 5. In Figure 5-a), the workload-based analysis of the GBSSOA scheme. The workload measured by the proposed GBSSOA for 70 iterations is 0.166. On the other hand, the existing techniques, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS had higher workload of 0.199, 0.192, 0.185, and 0.179, correspondingly. Figure 5-b) portrays the assessment of the introduced GBSSOA method with respect to QoS. The conventional methods, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS achieved a low value of QoS at 0.485, 0.514, 0.533, and 0.566 with 80 iterations, when compared to the QoS of 0.587measured by the developed approach. The evaluation of the proposed GBSSOA based secure live VM migration based on migration time is illustrated in Figure 5-c). Considering a total of 50 iterations, the developed GBSSOA and the prevailing schemes, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS required migration time of 310.258ms, 382.587ms, 370.254ms, 361.855ms, and 352.875ms, respectively. In Figure 5-d), the evaluation of the devised secure live VM migration is displayed. The developed GBSSOA based live VM migration attained a trust value of 0.515, while the trust value measured by the approaches, 0.459 for PSO+GA, 0.476 for Kororā framework, 0.488 for DC-MFA, and 0.499 for PC-TCS, with 60 iterations.

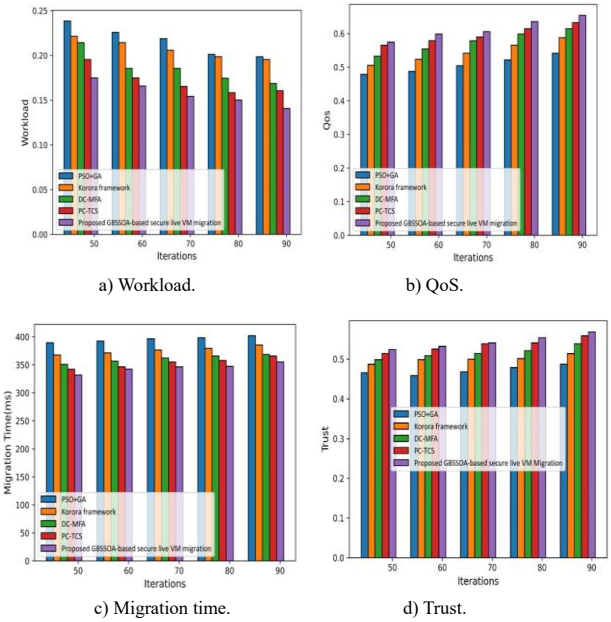


a) Workload. b) QoS.

c) Migration time. d) Trust.

Figure 5. The evaluation of the introduced GBSSOA based secure live VM migration with task count as 200.

- Assessment with Number of Tasks as 300: Figure 6 displays the analysis of the developed GBSSOA approach for secure live VM migration considering 300 tasks. In Figure 6-a), the analysis of the developed GBSSO approach is carried out considering the workload. The workload of the devised GBSSOA based approach is 0.150, which is lower than the workload of the conventional schemes, like PSO+GA, Kororā framework, DC-MFA, and PC-TCS at 0.201, 0.199, 0.175, and 0.158, respectively, for 80 iterations. The developed GBSSOA scheme is evaluated considering QoS and this is portrayed in Figure 6-b). The QoS of the existing approaches, such as PSO+GA, Kororā framework, DC-MFA, and PC-TCS, and the developed GBSSOA is at 0.504, 0.541, 0.578, 0.590, and 0.605, considering 70 iterations. In Figure 6-c), the analysis of the proposed GBSSOA based secure live VM migration considering migration time is illustrated. With 60 iterations, the migration time required by the approaches is 392.554ms for PSO+GA, 371.541ms for Kororā framework, 356.587ms for DC-MFA, 346.585ms for PC-TCS, and 342.326ms for GBSSOA based secure live VM migration. Figure 6-d) exhibits the valuation of the developed GBSSOA technique considering trust. For 50 iterations, the value of trust computed by the live VM migration schemes is 0.466, 0.487, 0.499, 0.515, and 0.524, respectively for PSO+GA, Kororā framework, DC-MFA, PC-TCS, and the established GBSSOA.



a) Workload. b) QoS.

c) Migration time. d) Trust.

Figure 6. Assessment of the introduced GBSSOA based secure live VM migration with task count as 300.

5.5. Comparative Discussion

This section details the comparative evaluation of the proposed GBSSOA based secure live VM migration scheme. The efficacy of the devised technique is investigated considering different parameters, like workload, QoS, and migration time considering different number of tasks by varying the iteration count.

Table 2. Comparative discussion of the introduced GBSSOA based secure live VM migration scheme.

Number of tasks	Metrics	PSO+GA	Kororā framework	DC-MFA	PC-TCS	GBSSOA-based secure live VM migration
100	**Workload**	0.207	0.190	0.185	0.175	0.169
	QoS	0.485	0.499	0.533	0.554	0.578
	Migration time (ms)	479.954	442.253	423.256	412.258	392.256
	Trust	0.486	0.499	0.501	0.521	0.541
200	**Workload**	0.180	0.179	0.171	0.169	0.161
	QoS	0.497	0.533	0.556	0.587	0.599
	Migration time (ms)	445.854	425.258	402.854	392.255	342.254
	Trust	0.487	0.510	0.525	0.541	0.554
300	**Workload**	0.199	0.195	0.169	0.161	**0.141**
	QoS	0.541	0.587	0.614	0.633	**0.654**
	Migration time (ms)	402.258	385.541	368.541	365.854	355.254
	Trust	0.488	0.514	0.539	0.559	**0.569**

Table 2 depicts the comparative discussion of the introduced GBSSOA based secure live VM migration and the values are portrayed corresponding to the iteration count of 90. It can be deduced from the table that the devised GBSSOA scheme achieved a minimal value of workload and migration time of 0.141, and 342.254ms, and a maximal QoS of 0.654 and maximum trust of 0.569. The high value of QoS and trust are achieved owing to the utilization of the presented GBSSOA technique for the optimization of the migration process. Further, minimal workload and migration time is ensured by the allocation of the VM in a round robin manner. Thus, compared to existing approaches, GBSSOA exhibits both lower workload and superior QoS during live VM migration. Notably, it achieves the fastest migration times and highest trust values, indicating efficient resource utilization and reliable service guarantees. This suggests GBSSOA's potential as a leading method for high-performance live VM migration.

6. Conclusions

Live VM migration is the process of migrating an operational VM from a server to other servers by ensuring that the application services are provided uninterruptedly during the migration process thereby ensuring QoS. A new method for providing security during the process of live VM migration is developed using hybrid optimization in this paper. Initially, the tasks are assigned to the VM using a round robin manner. After task allocation, the workload on the PM is computed based on migration time and QoS. The computed workload is equated with the threshold to determine if VM migration is needed. If the workload is greater than the threshold, live VM migration is performed using the introduced GBSSOA, based on fitness objectives, such as run time of the task, migration time and QoS. Moreover, the security of the VM migration is ensured by considering the trust value along with the above-mentioned parameters. The developed GBSSOA-based secure live VM migration is evaluated using measures, such as workload, QoS, migration time, and trust and is revealed to have achieved values of 0.141,0.654, 342.254ms, and 0.569 correspondingly. Future direction of this research comprises inclusion of other objectives, such as cost and power consumption for enhancing the migration process.

References

[1] Addya S., Turuk A., Satpathy A., Sahoo B., and Sarkar M., "A Strategy for Live Migration of Virtual Machines in a Cloud Federation," *IEEE Systems Journal*, vol. 13, no. 3, pp. 2877-2887, 2019. DOI:10.1109/JSYST.2018.2872580

[2] Ahmad O., Haij L., Shukur H., Zebari R., Abas S., and Sadeeq M., "Comparison among Cloud Technologies and Cloud Performance," *Journal of Applied Science and Technology Trends*, vol. 1, no. 2, pp. 40-47, 2020. https://jastt.org/index.php/jasttpath/article/view/19/8

[3] Alqam S., Alzeidi N., Touzene A., and Day K., "Live Virtual Machine Migration in Fog Computing: State of the Art," *The International Arab Journal of Information Technology*, vol. 20, no. 6, pp. 977-995, 2023. https://doi.org/10.34028/iajit/20/6/14

[4] Bhardwaj A. and Challa R., "Virtualization in Cloud Computing: Moving from Hypervisor to Containerization-A Survey," *Arabian Journal for Science and Engineering*, vol. 46, no. 11, pp. 8585-8601, 2021. https://doi.org/10.1007/s13369-021-05553-3

[5] Bhat R., Sunitha N., and Iyengar S., "A Probabilistic Public Key Encryption Switching Protocol for Secure Cloud Storage Applications," *International Journal of Information Technology*, vol. 15, no. 2, pp. 675-690, 2023. https://doi.org/10.1007/s41870-022-01084-8

[6] Choudhary A., Govil M., Singh G., Awasthi L., Pilli E., and Kapil D., "A Critical Survey of Live Virtual Machine Migration Techniques," *Journal of Cloud Computing*: *Advances, Systems and Applications*, vol. 6, no. 23, pp. 1-41, 2017. DOI:10.1186/s13677-017-0092-1

[7] Deylami H., Gutierrez J., and Sinha R., "Tailoring the Cyber Security Framework: How to Overcome the Complexities of Secure Live Virtual Machine Migration in Cloud Computing," *arXiv Preprint* arXiv:2110.04457, 2020. https://doi.org/10.48550/arXiv.2110.04457

[8] García-Valls M., Cucinotta T., and Lu C., "Challenges in Real-Time Virtualization and Predictable Cloud Computing," *Journal of Systems Architecture*, vol. 60, no. 9, pp. 726-740, 2014.

https://doi.org/10.1016/j.sysarc.2014.07.004

[9] Huang W., Gao Q., Liu J., and Panda D., "High Performance Virtual Machine Migration with RDMA over Modern Interconnects," *in Proceedings of the IEEE International Conference on Cluster Computing*, Austin, pp. 11-20, 2007. DOI:10.1109/CLUSTR.2007.4629212

[10] Hu L., Zhao J., Xu G., Ding Y., and Chu J., "HMDC: Live Virtual Machine Migration Based on Hybrid Memory Copy and Delta Compression," *01-Applied Mathematics and Information Sciences*, vol. *7*, no. 2L, pp. 639-646. 2013. DOI:10.12785/amis/072L38

[11] Huang C., Chen W., Yuan L., Ding Y., Jian S., Tan Y., Chen H., and Chen D., "Toward Security as a Service: A Trusted Cloud Service Architecture with Policy Ustomization," *Journal of Parallel and Distributed Computing*, vol. 149, pp. 76-88, 2021. https://doi.org/10.1016/j.jpdc.2020.11.002

[12] Kaveh A. and Zaerreza A, *Studies in Systems, Decision and Control*, Springer, 2023. https://doi.org/10.1007/978-3-031-25573-1_2

[13] Li C., Wang Y., Tang H., and Luo Y., "Dynamic Multi-Objective Optimized Replica Placement and Migration Strategies for SAAS Applications in Edge Cloud," *Future Generation Computer Systems*, vol. 100, pp. 921-937, 2019. https://doi.org/10.1016/j.future.2019.05.003

[14] Lichtenthäler R., "Model-Driven Software Migration towards Fine-Grained Cloud Architectures," *in Proceedings of the 11th ZEUS Workshop*, Bayreuth, pp. 35-38, 2019. https://ceur-ws.org/Vol-2339/paper7.pdf

[15] Malhotra L., Agarwal D., and Jaiswal A., "Virtualization in Cloud Computing," *International Journal of Computer Science and Mobile Computing*, vol. 3, no. 8, pp. 745-749, 2014. https://ijcsmc.com/docs/papers/August2014/V3I8201499a19.pdf

[16] Nelson M., Lim B., and Hutchins G., "Fast Transparent Migration for Virtual Machines," *in Proceedings of the USENIX Annual Technical Conference*, California, pp. 391-394, 2005. https://www.usenix.org/legacy/events/usenix05/tech/general/full_papers/short_papers/nelson/nelson.pdf

[17] Noshy M., Ibrahim A., and Ali H., "Optimization of Live Virtual Machine Migration in Cloud Computing: A Survey and Future Directions," *Journal of Network and Computer Applications*, vol. 110, pp. 1-10, 2018. https://doi.org/10.1016/j.jnca.2018.03.002

[18] Pal S., Kumar R., Son L., Saravanan K., Abdel-Basset M., Manogaran G., and Thong P., "Novel Probabilistic Resource Migration Algorithm for Cross-Cloud Live Migration of Virtual Machines in Public Cloud," *The Journal of Supercomputing*, vol. 75, no. 9, pp. 5848-5865, 2019. https://doi.org/10.1007/s11227-019-02874-x

[19] Salehi M., Boukerche A., Darehshoorzadeh A., and Mammeri A., "Towards a Novel Trust-Based Opportunistic Routing Protocol for Wireless Networks," *Wireless Networks*, vol. 22, no. 3, pp. 927-943, 2016. DOI:10.1007/s11276-015-1010-4

[20] Saraswathi A., Kalaashri Y., and Padmavathi S., "Dynamic Resource Allocation Scheme in Cloud Computing," *Procedia Computer Science*, vol. 47, pp. 30-36, 2015. https://doi.org/10.1016/j.procs.2015.03.180

[21] Seo D., Jeon Y., Lee S., and Lee K., "Cloud Computing for Ubiquitous Computing on M2M and IoT Environment Mobile Application," *Cluster Computing*, vol. 19, no. 2, pp. 1001-1013, 2016. https://doi.org/10.1007/s10586-016-0573-x

[22] Shukur H., Zeebaree S., Zebari R., Zeebaree D., Ahmed O., and Salih A., "Cloud Computing Virtualization of Resources Allocation for Distributed Systems," *Journal of Applied Science and Technology Trends*, vol. 1, no. 3, pp. 98-105, 2020. https://www.jastt.org/index.php/jasttpath/article/view/31/14

[23] Sun D., Zhang J., Fan W., Wang T., Liu C., and Huang W., "SPLM: Security Protection of Live Virtual Machine Migration in Cloud Computing," *in Proceedings of the 4th ACM International Workshop on Security in Cloud Computing*, Xi'an, pp. 2-9, 2016. https://doi.org/10.1145/2898445.2898446

[24] Torquato M., Maciel P., and Vieira M., "A Model for Availability and Security Risk Evaluation for Systems with VMM Rejuvenation Enabled by VM Migration Scheduling," *IEEE Access*, vol. 7, pp. 138315-138326,2019. DOI:10.1109/ACCESS.2019.2943273

[25] Verma G., "Secure VM Migration in Cloud: Multi-Criteria Perspective with Improved Optimization Model," *Wireless Personal Communications*, vol. 124, no. 5, pp. 75-102, 2022. https://doi.org/10.1007/s11277-021-09319-w

[26] Wang W., Jiang Y., and Wu W., "Multiagent-Based Resource Allocation for Energy Minimization in Cloud Computing Systems," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 7, no. 2, pp. 205-220, 2017. DOI:10.1109/TSMC.2016.2523910

[27] Xiao Y., Sun X., Guo Y., Li S., Zhang Y., and Wang Y., "An Improved Gorilla Troops Optimizer Based on Lens Opposition-Based Learning and Adaptive β-Hill Climbing for Global Optimization," *Computer Modeling in Engineering and Sciences*, vol. 131, no. 2, pp. 815-850, 2022. https://doi.org/10.32604/cmes.2022.019198

[28] Xie X., Yuan T., Zhou X., and Cheng X.,

"Research on Trust Model in Container-Based Cloud Service," *Computers, Materials and Continua*, vol. 56, no. 2, pp. 273-283, 2018. https://doi.org/ 10.3970/cmc.2018.03587

[29] Yang C., Chen S., Liu J., Chan Y., Chen C., and Verma V., "An Energy-Efficient Cloud System with Novel Dynamic Resource Allocation Methods," *The Journal of Supercomputing*, vol. 75, no. 1, pp. 4408-4429, 2019. DOI:10.1007/s11227-019-02794-w

[30] Yang L., Yang D., Cao J., Sahni Y., and Xu X., "QoS Guaranteed Resource Allocation for Live Virtual Machine Migration in Edge Clouds," *IEEE Access*, vol. 8, pp. 78441-78451, 2020. DOI:10.1109/ACCESS.2020.2989154

[31] Zeb T., Yousaf M., Afzal H., and Mufti M., "A Quantitative Security Metric Model for Security Controls: Secure Virtual Machine Migration Protocol as Target of Assessment," *China Communications*, vol. 15, no. 8, pp. 126-140, 2018. DOI:10.1109/CC.2018.8438279

[32] Zeebaree S., Jacksi K., and Zebari R., "Impact Analysis of SYN Flood DDoS Attack on HAProxy and NLB Cluster-Based Web Servers," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 19, no. 1, pp. 505-512, 2020. https://ijeecs.iaescore.com/index.php/IJEECS/article/view/20515/13894

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