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RESEARCH ARTICLE

Energy Efficient Data Transfer in Mobile Cloud Computing Environment Using Particle-Salp Swarm Optimization Technique

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Abstract – Mobile cloud computing (MCC) can request the service of cloud from the mobile appliance, such as mobile phones, laptops, palm tops and so on for data transfer in such a way to provide more beneficial applications. The consumption of energy is a major problem during the transfer of data in MCC that is needed to be optimized with the allocation of the tasks to mobile or cloud environment in an efficient manner. In order to deal this issue, a hybrid particle-salp (PS-SALP) swarm optimization technique is proposed in this research that incorporates the characteristic features of the particles and the salps leading to better convergence to enhanced solution in the resource allocation of data transfer. The main aim of this paper is to minimize the utility cost (UC) representing a better balance between energy consumption and the period of execution of the task. Initially, the local optimal solutions for each problem is found, followed by which the global optimal solution is obtained using the proposed PS-SALP optimization algorithm. The performance of the proposed technique of data transfer in MCC is analyzed in terms of the metrics, such as UC, energy consumption, and the task execution time. The results show the superiority of the proposed technique in energy efficient data transfer in the MCC environment.

Index Terms – Mobile Cloud Computing, Utility Cost, Optimization, Energy Consumption, Data Transfer, PS-SALP.

1. INTRODUCTION

Cloud computing is a technological advancement that involve in increasing the capability of IT systems by unifying how data is stored and processed [1]. It permits the consumers to access the request without first inaugurating them and increases access to private data over the cloud [2]. In addition, cloud computing possess the need for less expenses in developing the infrastructures of IT, and in attaining latest assets. The computers used in cloud computing service obtain the advantage of multitenant structure by preserving single application. It relies on the capability of using the resources of computer by way of mobiles. In the same way, mobile computing performs the completion of works that are customarily performed with general desktops. Generally, mobile computing is sustained using the important idea, like software, hardware, and communication [3]. Hardware comprise of devices, such as PCs, tablet, and mobile phones that are normally used as personal devices. Software comprises the applications modeled and designed to perform the works in a mobile platform. Finally, communication embraces the protocols and the networks that contain the ideas related to communication strategies [4]. The mobile computing strategy involves the following aspects. The first aspect is the term mobility that permits the nodes that can be fixed or movable to connect with the nodes of other devices in the environment of mobile computing using the Mobile Support Station (MSS). Next is the diversity of access varieties of network that leads the mobile nodes to communicate in the presence of different access networks each possessing varying bandwidths and overhead among the nodes of the mobile and the MSS.

Third is the disconnection of network frequently implying that the nodes of the mobile are not efficient to make reliable connection due to the limited resources of the nodes of the mobile, like energy in battery and communication bandwidth. Finally, due to the problem of poor consistency and safety, the signals of mobile node are subjected to intrusion in mobile networks [5]. The model of cloud computing contains most types of outsourcing of computing and hosting resources. According to NIST [6] the strategy of making efficient access to the resources of network with reduced time period and management attempt is termed as cloud computing. The grouping of wireless communications, cloud computing, mobile devices, mobile web, and so on for the efficient transfer of data is termed as mobile cloud computing that

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permits the clients to access unlimited computing resources and space for storage [7]. The shared issue among cloud computing and the mobile device acts a as a major issue in data transfer [8].

The most significant consideration for the transfer of data in conventional cloud computing is the cost and duration, whereas consumption of energy and communication are the important issues in MCC. Backup device is a functional service in case of small device and involve in moving increased rate of information. However, management of calendar and contact data, where the rate of moved data is more self-effacing, is a service commonly used [9]. The efficiency of energy is a critical factor for the mobiles and the significance keeps on rising. Progress of battery expertise is not capable of satisfying the requirements of power due to increased demand. The rate of energy, which can be saved in a battery is restricted and is rising only 5% per annum [10]. Larger batteries lead to the development of larger devices, but are not an advisable decision [11]. Improvements in the efficiency of energy may lead to other advantages, such as size of device, rate and R&D efficiency. Certainly, huge portion of the hardware strategy advancements have been dealt for programmability in the designs of the mobile phones [12, 13].

1.1. Motivation of the Research

The motivations of the proposed research are discussed as below:

- The major challenge associated with the data transfer in MCC environment is the long remoteness of proliferation from the mobile to a remote cloud that leads to extremely increased delay between the request of the mobile user and the response of the web application [5].
- Inadequate storage and computation at the edges of the network to enable mobile computing everywhere is another challenge in MCC [5].
- The limited convergence of the cloudlets on the network of mobile for the provision of data transfer does not maintain increased users of mobile for sharing the resources available, which is also a major challenge in MCC [5] [14].
- The problems, including limited storage and computing power, reduced bandwidth and inadequate existence of battery affect the accomplishment of mobiles. In particular, the inadequate life of battery limits the usage of smart phones in personal applications and business that need long running time [7].

1.2. The Important Contribution of the Paper is

- The main contribution of the proposed research is to develop a MCC system model, in such a way to reduce the utility cost of data transfer with the management of trade-off between the time of execution and the computation period of the work to be performed.
- The next contribution is to propose of a hybrid optimization technique called PS-SALP that inherits the features of two standard optimization techniques, such as PSO and SSA to obtain a global optimal solution with the objective of reducing the utility cost in data transfer.

The paper is organized as: Section 1 gives the prologue to data transfer in MCC. Section 2 deliberates the survey of number of conventional strategies of data transfer in MCC. Section 3 discusses the structure of the system with problem definition in data transfer model. Section 4 states the working principle of the proposed PS-SALP model in efficient data transfer. The results obtained using the proposed technique is analyzed in section 5 and the conclusion of the paper is given in section 6.

2. LITERATURE SURVEY

This section discusses the analysis of number of strategies of energy efficient data transfer in the mobile cloud environment with their limitations. The techniques related to energy efficient transfer of data in MCC is deliberted as; Mohammad Alkhalaileh *et al.* [5] developed a model based on mixed integer linear programming model that leads to optimized resource allocation in data transfer even with varying size of data and network bandwidth. However, this method takes long time for the production of suboptimal solution. Juan Li *et al.* [7] modeled a resource allocation strategy for work flow applications by partitioning the work into different local problems in such a way to find the global optimal solution using the Discrete Swarm Particle Optimization (DPSO) strategy from the developed local optimal solutions. However, finding the local optimal solutions for all the partitioned set of work is time consuming, which is the major drawback of this model. M Arumugam *at al.* [12] developed the Rivest–Shamir–Adleman (RSA) based data sharing concept in MCC that produced enhanced scalability and reliability in security. However, the tree structured access control is changed to make them suitable for MCC strategy that is a tedious process using this method. SajeebSaha and Mohammad S. Hasan [15] introduced the cloud migration decision making algorithm for evaluating the feasibility of executing data transfer on cloud rather than mobile device. However, the time needed for the transmission of data and the execution is high in this method. ManjinderNir *at al.* [16] designed the centralized broker-node based architecture that deals with the problem of task scheduling even with more number of mobile devices. However, the constraints corresponding to data rate may not be satisfied by most of the tasks. Amr S. Abdelfattah *et al.* [17] developed a Reliable strategy that handles the problem of time-out and attains consistent usage of service from web. However, the system may take certain duration to carry out

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the design of data on the middleware to maintain the data that is considered as the major drawback of this model. P. Nawrocki, and W. Reszelewski *et al.* [18] modeled a strategy to state that it is possible to optimize the usage of data in MCC by using the general concepts traditionally used in MCC, such as ”One User – One VM and Multiple Users – One VM approaches. However, the requests that cannot be processes instantly are enquired that lead to considerable variations in the response times.

3. STRUCTURE OF SYSTEM AND PROBLEM DEFINITION

This section deliberates the structure of the system and problem definition in the data transfer techniques in MCC.

3.1. Proposed System Model of MCC

Researches on MCC have observed tremendous development with the cause that mobiles are fetching as a very important requirement for human. It is movable and can be in all places for data transmission even at any of place and time. The introduction of MCC is an important aspect for the developers of mobile phones and computer science technology, as it can be used in various areas, including Electronic Mobile Commerce (EMC), Electronic Mobile Healthcare (EMH), and soon[12, 14, 15, 16, 17, 18].The system model of MCC is depicted in Figure 1.

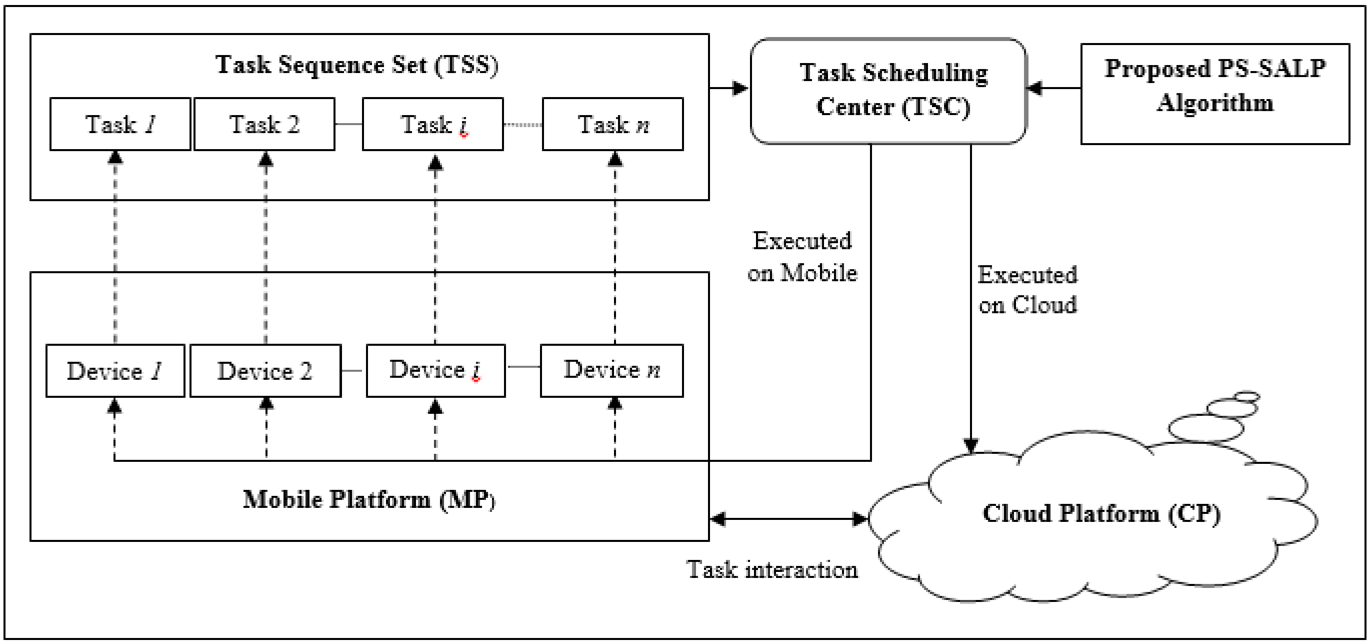

Figure 1 System Model of Mobile Cloud Computing

The models of resource allocation in data transfer is deliberated as:

3.1.1. Data Transfer Model

Data transfer in mobile cloud in the MCC is a practice that comprise of a set of works carried out either in parallel or in series and automated together. One of the significant characteristics of data transfer in MCC is that the user of the mobile may demand the data to be send to a preceding position from the current position.

3.1.1.1. Task of Mobile Cloud

A task of the mobile cloud in the MCC environment is a comparatively an autonomous computation element that is raised within a work flow and is carried out in the cloud server or in the mobile device. Every task accepts an input to be processed in such a way to produce an output. In this research, the task of the mobile is modeled as in equation (1),

$$T_{mob} = (A, Y, l) \tag{1}$$

Where, A represents the input, Y represents the output, and l is the size of the task to be performed.

3.1.1.2. Work Flow in Mobile Cloud

A task flow in the mobile cloud is a procedure that comprise of a set of tasks to be done in a definite array with the need to satisfy the request of the mobile user. The task flow of the mobile cloud can be modeled as in equation (2),

$$D = (W, R) \tag{2}$$

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where, $W=\{w_1, w_2, ...w_S, ..., w_x\}$ indicates the set of x number of mobile tasks, and $R=\{r(w_s, w_t); w_s, w_t \in w\}$ implying the relation among the tasks w_s and w_t with the condition stating that the completion of the task w_s is done before starting the task w_t.

3.1.2. MCC Model

The MCC model comprise of mobile device and the cloud server, among which the allocation of resources for data transfer takes place.

3.1.2.1. Mobile Device

A mobile is generally a portable device, which can be a mobile phone, laptop or any other movable device possessing admittance to internet and request for data sources from the cloud. In this research, the mobile device is modeled with four set of values as in equation (3),

$$S=\{u_m, p_i, p_l, p_{dl}\}; p_l >> p_{dl} \tag{3}$$

Where, u_m represents the frequency of operation in the mobile device while executing a task, and p_i indicates the idle power usage of the mobile device under idle state. Similarly, the term p_l is the power needed for uploading the information from the mobile and p_{dl} is the power required for downloading the data from mobile.

The power consumption of mobile can be expressed as in equation (4),

$$P_c=\beta u_m^{\eta} \tag{4}$$

Where, β and η are the constants correlated with the mobile device. The expression above represents that the consumption of power is directly proportional to square of the operating voltage and the frequency, with the condition that the operating voltage is proportional to frequency.

3.1.2.2. Cloud Server

The cloud server is an evaluating device that supplies service to mobile accessories. The frequency of cloud server can be denoted as u_c.

3.1.2.3. Section of Resource Allocation

The decision of the resource allocation is a vector of data transfer in the mobile cloud to evaluate the task either to be performed locally or remotely. This can be mathematically expressed as in equation (5),

$$K=\{k_1, k_2, ..., k_s, ..., k_x\} \tag{5}$$

The decision of offloading of the task w_s can be made using the variable k_s, representing the task k_s to be executed locally when $k_s=0$, and remotely when $k_s=1$.

3.1.3. Execution Time Model

The execution time of the task comprise of two divisions, such as computation time and the communication time. The execution decision is accountable for the computation time of the task w_s. On the other hand, the communication time of r_{st} relies on the decisions of the both the tasks w_s and w_t. Thus, the computation time of the task w_s is represented as $C_s^{cm}(k_s)$. Similarly, the communication time between the tasks w_s and w_t can be represented as $C_{ks}^{cm}(k_s, k_t)$, where k_s and k_t indicates the allocation decisions of tasks w_s and w_t, respectively.

3.1.3.1. Computation Time

When the work w_s is carried out on mobile, $k_s=0$, then the corresponding execution time can be evaluated as in equation (6),

$$C_s^{cm}(k_s=0)=z_s/u_m \tag{6}$$

On the other hand, when work w_s is carried out in mobile, $k_s=1$, the corresponding execution time can be evaluated as in equation (7),

$$C_s^{cm}(k_s=1)=z_s/u_c \tag{7}$$

3.1.3.2. Communication Time

When the tasks, w_s and w_t are equal and carried out either on mobile or cloud, then the communication time is zero. When the task w_s is done on mobile and the task immediate next to the task w_s is carried out on cloud, then the communication time is obtained as, $J^l{st}/U_l$. Similarly, when the task w_s is done on cloud and the task immediate next to the task w_s is carried out on mobile, then the communication time is obtained as, $J^{dl}{st}/U_{dl}$. This condition related to communication time can be summarized as in equation (8),

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$$C_{ks}^{cm}\left(k_s,k_t\right)=\begin{cases}0, & k_s=k_t=0\\ J^{l}{}_{st}/U_l, & k_s=0,k_t=1\\ J^{dl}{}_{st}/U_{dl}, & k_s=1,k_t=0\\ 1, & k_s=k_t=1\end{cases} \tag{8}$$

Where, $J^{l}{}_{st}$ is the data send from the mobile to the cloud, $J^{dl}{}_{st}$ represents the mobile getting information from cloud, and U_l and U_{dl} are the uploading and downloading rates, respectively.

Hence, the execution duration of a work is given as in equation (9),

$$C(K)=C_{y+1}^{final}=C_{y+1}^{cp}\left(k_{y+1}\right)+C_{s,y+1}^{cm}\left(k_s,k_{y+1}\right) \tag{9}$$

where, C_{y+1}^{final} is the completion time of the final task, C_{y+1}^{cp} is the duration of computation of final task, and $C_{s,y+1}^{cm}$ represents the communication time among the final and its predecessor task.

3.1.4. Power Consumption Model

Similar to execution time of the task, the power consumption model of the task also consists of two divisions, such as computation power and communication power consumption of arcs that is influence by the decision of resource allocation. The consumption of power with the execution of the task w_s with k_s is represented as $R_S^{cp}(k_S)$, and the power consumption of arcr r_{ks} with k_s and k_t is represented as $R_{ks}^{cm}\left(k_S,k_t\right)$.

3.1.4.1. Power Consumption During Computation

When the task k_s is carried out locally, the usage of power at computation is evaluated as, $R_S^{cp}(k_S=0)=P_cC_S^{cp}(k_S=0)=\beta u_m^{\eta-1}$. On the other hand, when the task is executed remotely, the consumption of power by the mobile is evaluated as, $R_S^{cp}(k_S=1)=P_iC_S^{cp}(k_S=1)=P_iz_S/u_C$.

This can be mathematically expressed as in equation (10),

$$R_S^{cp}(k_S)=\begin{cases}\beta u_m^{\eta-1}, & k_S=0,\\ P_iz_S/u_C, & k_S=1\end{cases} \tag{10}$$

3.1.4.2. Power Consumption at Communication

The usage of power at the time of communication relies on decisions of the allocation of resource for two works between the arc r_{ks}. When the task k_s is carried out on the mobile or cloud and its immediate next task k_t is proceeded on the same resource, then the power consumed equals zero. Conversely, when the task k_s is done on mobile and the immediate next task k_t is done on the cloud, then the power consumption is evaluated as, $p_lJ^{l}{}_{st}/U_l$. Similarly, when the task k_s is done on cloud and the immediate next task k_t is done on the mobile, then the power consumption is evaluated as, $p_{dl}J^{dl}{}_{st}/U_{dl}$. This condition related to communication power consumption can be summarized as in equation (11),

$$R_{ks}^{cm}\left(k_s,k_t\right)=\begin{cases}0, & k_s=k_t=0\\ p_lJ^{l}{}_{st}/U_l, & k_s=0,k_t=1\\ p_{dl}J^{dl}{}_{st}/U_{dl}, & k_s=1,k_t=0\\ 1, & k_s=k_t=1\end{cases} \tag{11}$$

Hence, the power consumption of a task can be expressed as in equation (12),

$$C(K)=\sum_{s,t\in W}\left(R_S^{cp}\left(k_S\right)+R_{st}^{cm}\left(k_S,k_t\right)\right) \tag{12}$$

where, C_{y+1}^{final} is the completion time of final work, C_{y+1}^{cp} is the time of evaluation of final task, and $C_{s,y+1}^{cm}$ represents the communication duration among the final and its predecessor task.

3.1.5. Data Transfer Model

As there is a contradiction between minimizing the time of execution of the task and the total consumption of energy, the aim is to reduce the total UC. Hence, the objective of the research is formulated as in equation (13),

$$Min\ U_C(K)=\frac{R(\Gamma)}{R(\Gamma_0)}\times\frac{C(\Gamma)}{C(\Gamma_0)}=\frac{R(\Gamma)}{\sum_{m=0}^{y+1}R_m^{cp}(\Gamma_0)}\times\frac{C(\Gamma)}{T_{y+1}^{cp}(k_{y+1})} \tag{13}$$

Where, $R(\Gamma)$ and $C(\Gamma)$ represents the total consumed energy and the time of execution, respectively of the mobile

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device, with Γ be the decision of resource allocation. The constraints associated with the optimization problem are divided into three conditions.

3.1.5.1. Condition 1

The entire time for executing a task must be less than that of the deadline execution of the task, and is expressed as in equation (14),

$$Min\ U_c(\Gamma) = \frac{R(\Gamma)}{\sum_{m=0}^{y+1} R_m^{cp}(\Gamma_0)} \times \frac{C(\Gamma)}{T_{y+1}^{cp}(k_{y+1})}; \quad C(\Gamma) \le C_{\max} \tag{14}$$

3.1.5.2. Condition 2

The uncertainty with the involvement of human involvement must be taken into care by considering certain constraints in partial execution time in such a way to complete the task in expected time. This formulation can be expressed as in equation (15),

$$C_s^{cp}(k_s) + \max_{r_{st} \in R} C_{st}^{cm}(k_s, k_t),\ \max_s(s, t \in [1, y]) \tag{15}$$

3.1.5.3. Condition 3

Some of the tasks of the mobile cloud can be performed only on the device or on the cloud without possessing any other possible way, and hence termed as fixed tasks. Consider N be the task that can be performed only on the mobile and I be the task that can be performed only on the cloud, which is expressed mathematically as in equation (16),

$$\text{For all } w_S \in N, k_S = 0; \quad w_S \in I,\ k_S = 1 \tag{16}$$

Hence, the optimization problem is developed as the minimization problem of utility cost during data transfer in MCC environment. Due to the drawbacks associated with the conventional methods of resource allocation in data transfer, a novel optimization technique is needed to be proposed in such a way to provide optimal data transfer with the satisfaction of the constraints, such as utility cost, energy consumption and execution time.

3.2. Problem Formulation

The mobile devices are embarrassed with the limitations of memory space, battery power, execution time and computation power due to which the tasks of the mobile phones are delegated to the cloud. When delegating a task to the cloud, there arise number of issues, related to quality of service, security, and mobile application development. The applications need complex computation, such as image processing, real-time computing, voice processing, and video streaming capabilities. Some of these tedious applications are difficult for the developers of mobile device application while executing the application for mobile devices. The issue of associated with the consumption of battery power and space in memory are increasing due to the increased need for mobile devices of small size, and hence these limitations are challenging in MCC [1]. Thus, it has turn out to be dominant to agree to the solutions for cloud computing in mobiles [19].

4. PROPOSED HYBRID PS-SALP SWARM OPTIMIZATION ALGORITHM FOR ENERGY EFFICIENT DATA TRANSFER

The execution capability of cloud server is generally more than that of mobile, and hence the time of execution van be enhanced with the tasks when performed on cloud. However, delegating the tasks to the cloud may take extra energy and time. Thus, there arise a disagreement with improving the execution time and saving the energy, and this disagreement is taken into consideration in the proposed energy-efficient data transfer methodology. In order to solve the conflict among the time of execution and the usage of energy, we consider utility cost as a constraint of time of execution and the usage of energy, and formulate the data transfer process as an optimization problem with the aim of minimizing the utility cost of the mobile device. The optimization problem is solved using the proposed PS-SALP optimization algorithm that incorporates the characteristic features of the standard optimization algorithms, such as PSO and SSA. The characteristic features of the PSO and SSA considered in the proposed research in order to enhance the solution quality. The robustness over the control parameters and the computational efficiency of PSO helps in achieving better solution. However, the low convergence rate with the use of PSO can be rectified with the SSA algorithm. The addition of SSA algorithm helps the solution not to get trapped in the local optima, leading a way to obtain the global solution.

The optimal transfer of data in the MCC environment with minimal utility cost, energy consumption and execution time to the users is done using the proposed PS-SALP optimization strategy, which is obtained using the combined characteristic features of the particles [20, 21] and salps [22]. The working principle of the proposed PS-SALP optimization strategy in MCC is depicted in Figure 2.

The advantages of using the characteristics of the particles is its uniqueness to be utilized in different fields of application with enhanced robustness, convergence to optimum within short period of time, and the skill to join with additional optimization algorithms for the enhancement of concert. In the same way, the benefits of choosing the characteristics of the salps is the purpose of attaining the global optima solutions in an improved manner, enhanced convergence in the evaluation of precise resolution for the objectives. The particles generally track a mutual way in identifying the prey, and each particle varies the search model depending on the learning behavior. The particles basically use the mode of swarm that creates the opportunity to identify the prey in most of the search space.

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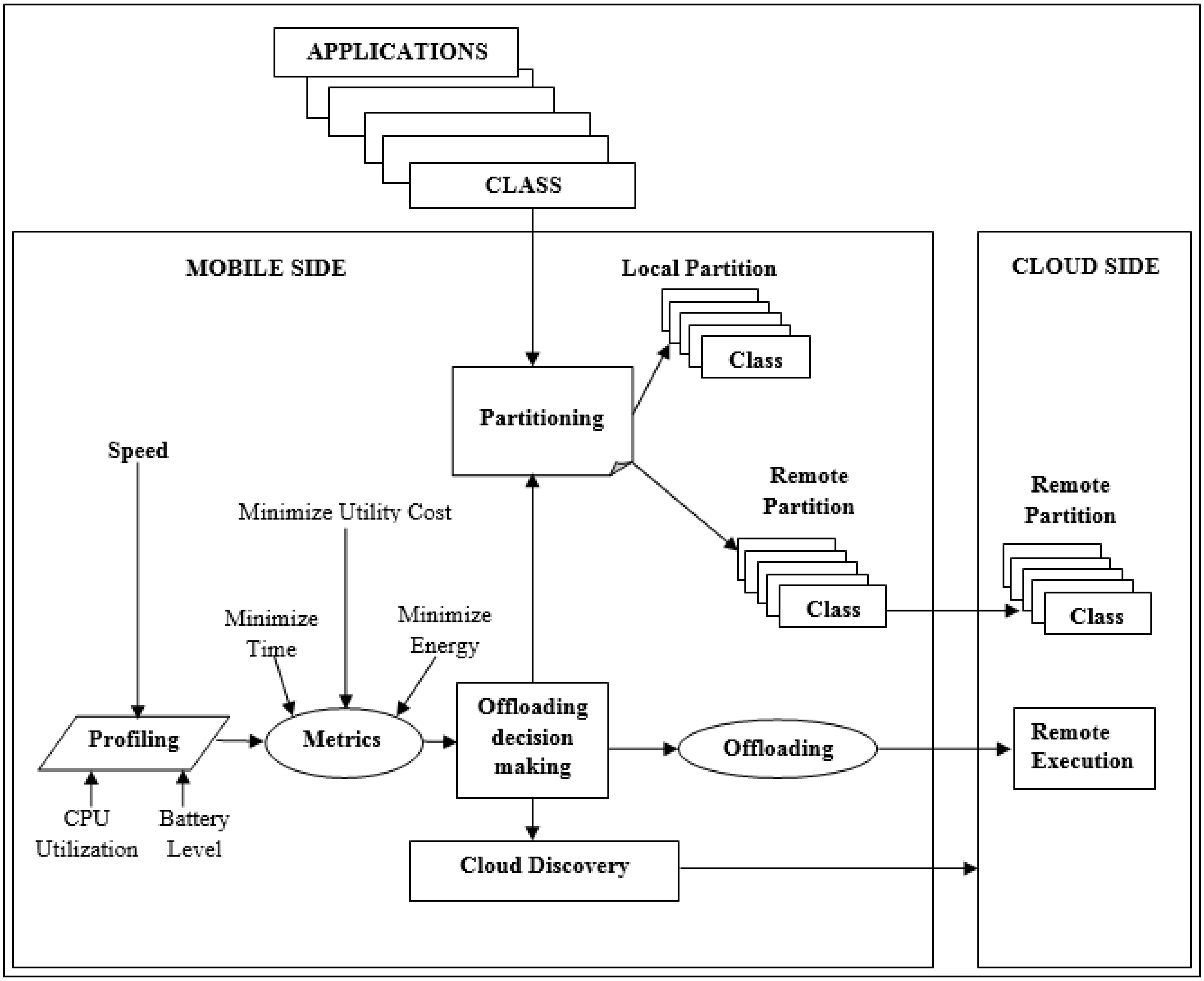

Figure 2 Working Principle of MCC with Proposed PS-SALP Algorithm

Diverse response, excellence, adaptability, nearness, and constancy are the major ideology pursued by the particles. The particles update the position and velocity in all iteration depending on the variation in surrounding. In addition, the particles do not stop the progress and keep on searching the optimal outcome incessantly in the given space of solution. The typical expression based on the position of particles is formulated as in equation (17).

The position of particles with the velocity, at

Which the particle move is expressed as in equation (18),

$$B^n_{a,g+1} = B^n_{a,g} + G^n_{a,g+1} \tag{17}$$

$$B^n_{a,g+1} = B^n_{a,g} + b * G^n_{a,g} + q_1 * rand * \left(M^n_{a,g} - B^n_{a,g}\right) + q_2 * rand * \left(M^n_{a,g} - B^n_{a,g}\right) \tag{18}$$

where, $B^n_{a,g+1}$ represents the location of particle a at $(g+1)^{th}$ iteration in the n^{th} dimension, $G^n_{a,g+1}$ is the velocity of the particle a, $M^n_{a,g}$ implies the optimal position, b is the inertia weight, q_1 represents the cognitive learning factor, and q_2 indicates the social learning factor.

Salps generally inherit the characteristics of the creatures, like flocks and herds in the earth. The salp models are utilized in

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resolving the optimization problems, and in case of numerical problem, the number of salps are partitioned as two divisions, such as leading salps and follower salp. The salps at the front site perform as the leading salp, and the rest of them perform as the follower salps. The entire group is instructed by the leading salp, and the follower salp tracks the rest. The location of the salps is accumulated in a space of two-dimension, and the food source or the target is assumed to be present in the search space. The typical expression based on salps is stated as in equation (19),

$$B^{m}_{a,g+1} = \frac{1}{2}\left(B^{n}_{a,g} + B^{n-1}_{a,g}\right) \tag{19}$$

Where, $B^{m}_{a,g+1}$ implies the a^{th} follower salp location in the n^{th} dimension, and $B^{n-1}_{a,g}$ is the a^{th} follower salp position in the $(n-1)^{th}$ dimension. From equation (18),

$$\begin{aligned} B^{n}_{a,g+1} &= B^{n}_{a,g} + b * G^{n}_{a,g} + q_1 * rand * M^{n}_{a,g} - q_1 \\ &* rand * B^{n}_{a,g} + q_2 * rand * M^{n}_{a,g} - q_2 * rand * B^{n}_{a,g} \end{aligned} \tag{20}$$

$$\begin{aligned} B^{n}_{a,g+1} &= B^{n}_{a,g}\left[1 - q_1 * rand - q_2 * rand\right] + \\ & b * G^{n}_{a,g} + q_1 * rand * M^{n}_{a,g} + q_2 * rand * M^{n}_{a,g} \end{aligned} \tag{21}$$

$$\begin{aligned} B^{n}_{a,g} &= \frac{1}{\left[1 - q_1 * rand - q_2 * rand\right]} \\ & \left\{ \begin{array}{l} B^{n}_{a,g+1} - b * G^{n}_{a,g} - q_1 * rand * \\ M^{n}_{a,g} - q_2 * rand * M^{n}_{a,g} \end{array} \right\} \end{aligned} \tag{22}$$

Substitute equation (22) in equation (19), we get

$$B^{m}_{a,g+1} = \frac{1}{2}\left(\begin{array}{c} \dfrac{1}{\left[1 - q_1 * rand - q_2 * rand\right]} \\ \left\{ \begin{array}{l} B^{n}_{a,g+1} - b * G^{n}_{a,g} - q_1 * rand \\ * M^{n}_{a,g} - q_2 * rand * M^{n}_{a,g} \end{array} \right\} + B^{n-1}_{a,g} \end{array} \right) \tag{23}$$

$$\begin{aligned} & B^{m}_{a,g+1} - \frac{1}{2}\left(\frac{B^{n}_{a,g+1}}{\left[1 - q_1 * rand - q_2 * rand\right]} \right) \\ &= \frac{1}{2}\left(\begin{array}{l} B^{n-1}_{a,g} - \\ \left(\dfrac{b * G^{n}_{a,g} + q_1 * rand * M^{n}_{a,g} + q_2 * rand * M^{n}_{a,g}}{1 - q_1 * rand - q_2 * rand} \right) \end{array} \right) \end{aligned} \tag{24}$$

$$\begin{aligned} & B^{m}_{a,g+1} - \frac{1}{2}\left(\frac{B^{n}_{a,g+1}}{\left[1 - q_1 * rand - q_2 * rand\right]} \right) = \\ & \left(\frac{B^{n-1}_{a,g}}{2} - \left(\frac{b * G^{n}_{a,g} + q_1 * rand * M^{n}_{a,g} + q_2 * rand * M^{n}_{a,g}}{2\left[1 - q_1 * rand - q_2 * rand\right]} \right) \right) \end{aligned} \tag{25}$$

$$\begin{aligned} & B^{m}_{a,g+1} = \left[\frac{2\left[1 - q_1 * rand - q_2 * rand\right]}{1 - 2q_1 * rand - 2q_2 * rand} \right] \\ & \left(\frac{B^{n-1}_{a,g}}{2} - \left(\frac{b * G^{n}_{a,g} + q_1 * rand * M^{n}_{a,g} + q_2 * rand * M^{n}_{a,g}}{2\left[1 - q_1 * rand - q_2 * rand\right]} \right) \right) \end{aligned} \tag{26}$$

Hence, equation (26) is used in the minimization of utility cost of the data transfer in MCC, which relies on the location and the rapidity of the particle, cognitive learning factor, and the position of salp.

4.1. Algorithmic Flow of PS-SALP Technique in MCC

The flow of execution of proposed PS-SALP strategy is deliberated as below,

Step 1: Initialization

The population representing the number of salps is initialized in this step as, F_h with $h = \{1, 2, \ldots, \delta\}$, where h represents total salps.

Step 2: Initialization of parameters:

The parameters involved in the optimization process, such as inertia weight b, cognitive learning factor q_1 and the social learning factor q_2 are initialized at this step.

Step 3: Evaluation of fitness

The fitness of the optimization problem relies on the UC during the transfer of data in MCC environment. The fitness measure in this research can be evaluated using equation (13).

Step 4: Update of position

The position of the salp can be updated using equation (26) for all the salps in the population depending on the fitness measure.

Step 5: Stopping criteria

The algorithmic steps are continued till obtaining the optimal solution, and once when the optimal solution is found, the process is terminated. The pseudo code of PS-SALP algorithm is depicted in Algorithm 1.

Hence, the proposed PS-SALP algorithm is used for the obtaining a better trade-off between execution time and the computation time with the minimization of the utility cost that acts as the major objective of this research.

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Position estimation using PS-SALP Algorithm

Input: Vector representing the solution $\rightarrow F_h$ with $(h = 1,2,...,\delta)$; h is the total number of salps.

Output: Better outcome $\rightarrow M^{n}_{a,g}$

Begin

Initialization of Parameter:

Constants $\rightarrow b, q_1, q_2$

Input the position of salp

If (termination criterion is not fulfilled)

Evaluate fitness measure for population using equation (13)

For each F_h

position update using equation (26)

Stop

Sort the population in terms of leading point

Output $M^{n}_{a,g}$

Terminate

Algorithm 1 Algorithm of PS-SALP Algorithm

5. RESULTS AND DISCUSSIONS

To analyze the effectiveness of the PS-SALP data transfer strategy in MCC, simulation experiments are carried out. The setup is executed in PYTHON with the PC set up with Windows 10 OS with 4GB RAM.

The results thus obtained are matched with the traditional methods using the performance metrics, such as utility cost, consumption of energy and the time of execution for data transfer.

5.1. Performance Metrics

The performance metrics plays a major role in analyzing the efficiency of the PS-SALP strategy. The metrics used for evaluation are:

- Utility Cost.
- Energy Consumption.
- Computation Time.

5.1.1. Utility Cost

MCC is a profitable representation, where the charge is proportional to the rate of information and service utilized. Thus, the services in MCC are charged in terms of utilization of resources from cloud that in turn relies on the consumption of energy and the time of execution of the request [23].

5.1.2. Energy Consumption

Energy consumption is the entire power taken in performing a task or request both at cloud and mobile level. Lower consumption of energy reduces the cost and the better complementary of tasks at cloud may reduce the lower of work at the server that speed up the process to reduce the consumption of energy.

5.1.3. Computation Time (CT)

The term computation time is termed as the time duration taken by the mobile to perform a work using cloud or mobile level. Reduced time of execution is necessary for the cloud and the user for enhanced efficiency. Computation time possess influence on the usage of resource, energy, and the effectiveness of the method in the execution of task.

5.2. Performance Analysis of Proposed PS-SALP Swarm Algorithm

This section deliberates the performance of PS-SALP swarm algorithm in executing a task with respect to mobile and cloud.

5.2.1. Performance of Mobile and Cloud Using Wi-Fi and 3G

Initially, the experiment is carried out for the cloud in the presence of Wi-Fi and mobile to analyze the effectiveness of the PS-SALP swarm optimization algorithm as depicted in Figure 3. It is identified that the proposed strategy performs the work on mobile only up to the array size of 500. After this, it gives up the work to the cloud to be performed.

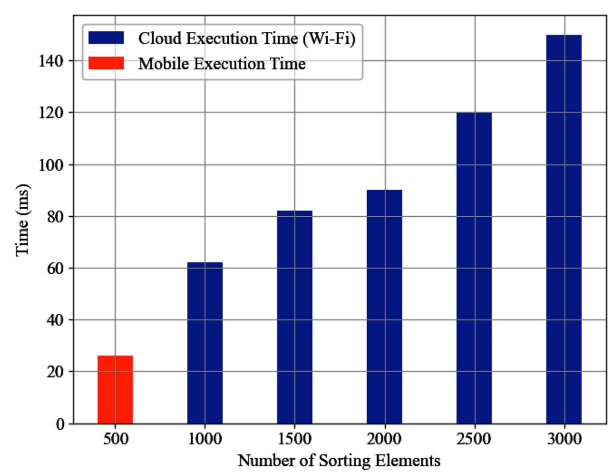

Figure 3 Execution between Mobile and Cloud with Wi-Fi Connection

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Similarly, the experimentation between the cloud with 3G connections and mobile is depicted in Figure 4. It is identified that the proposed strategy performs the work only on mobile for the size of array up to 500. Once the mobile completes its role, the cloud server performs the task after the array size of 1000.

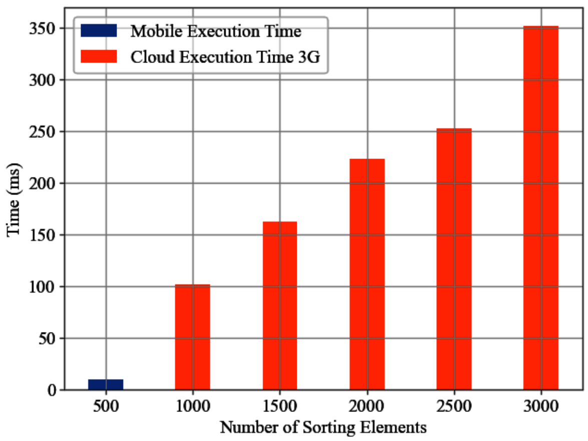

Figure 4 Execution between Mobile and Cloud with 3G Connection

5.2.2. Performance Analysis in Terms Small Array Size

The time required for the execution of task using mobile, cloud in the presence of Wi-Fi and cloud with 3G are depicted in Figure 5. It is noted from the graph that the time required for completing a task increases with the increase in size of the array. For the size of array up to 500, the task completion using mobile is better as compared to cloud, and vice versa.

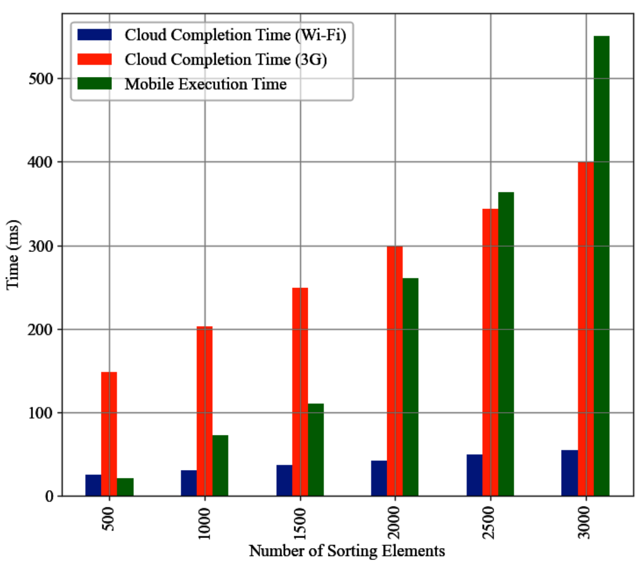

Figure 5 Task Completion Time for Small Arrays

It is also noticed that when the array size increases, the period of communication rises due to increased transfer of data. The result depicting the relation of communication time in case of small number of arrays is shown in Figure 6.

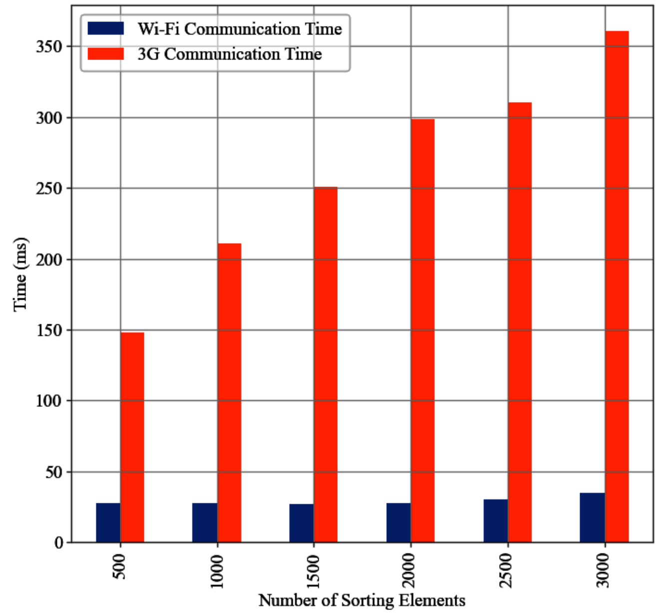

Figure 6 Communication Time for Small Arrays

The computation time in case of smaller size array is depicted in Figure 7. It is noted that the mobile device possess better result till the cutoff of 500 and 2000, after which the cloud migration takes place.

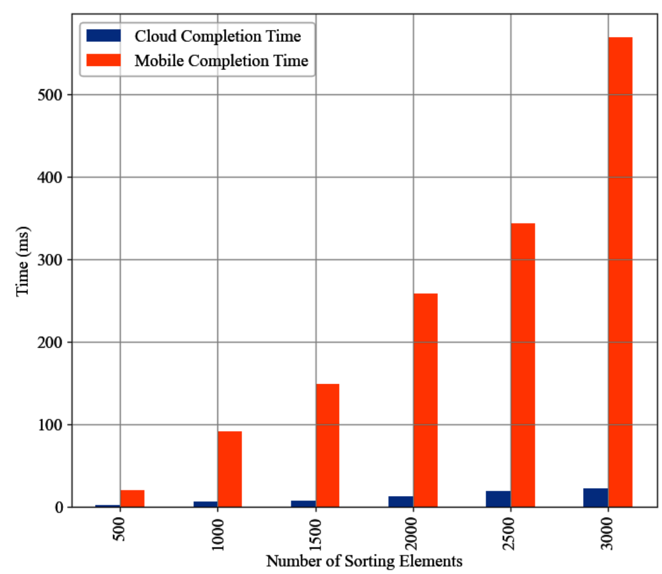

Figure 7 Computation Time for Small Arrays

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5.2.3. Performance Analysis in Terms Larger Array Size

The time required for the execution of task using mobile, cloud using Wi-Fi and cloud with 3G are depicted in Figure 8. The period of completion rises slightly for cloud when the array size increases, whereas it increases quickly for the execution of task using mobile.

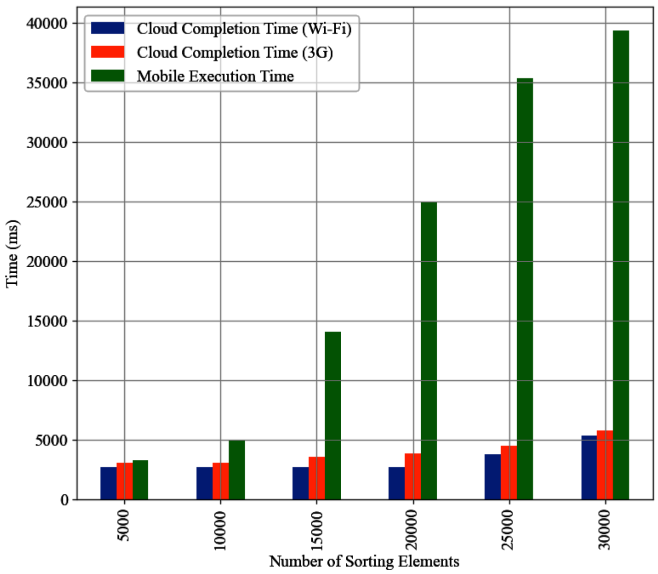

Figure 8 Task Completion Time for Large Arrays

It is also noticed that as the number of array size increases, the period of communication also increases with the increased rate of transfer of data. The result depicting the relation of communication time for large array size is shown in Figure 9.

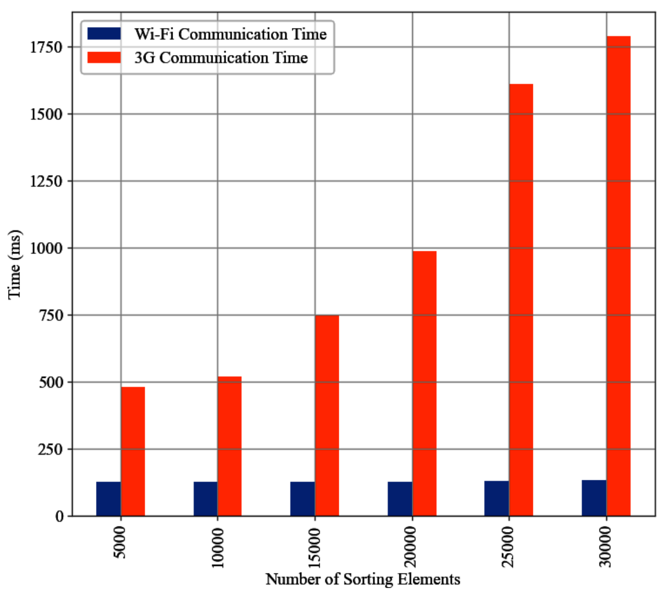

Figure 9 Communication Time for Large Arrays

The computation time in case of large size array is depicted in Figure 10. The period of communication does not possess any considerable effect on the complete performance gain and ruins a number of times greater than the execution period of the mobile device.

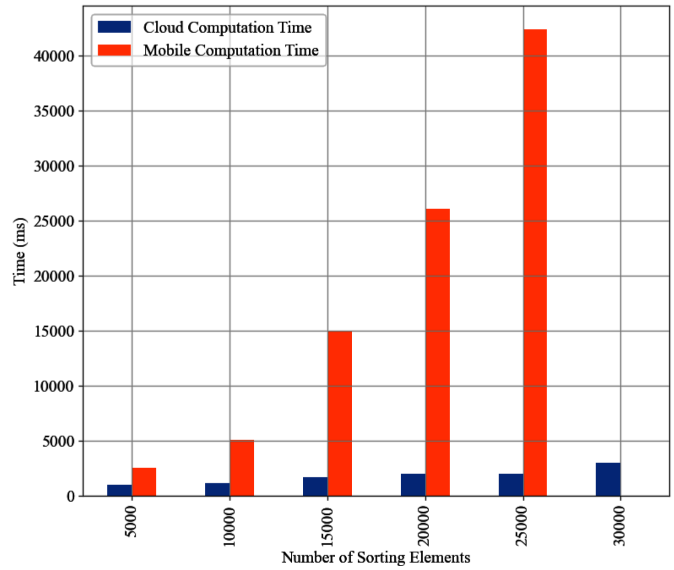

Figure 10 Computation Time for Large Arrays

5.3. Comparative Analysis of Proposed PS-SALP Algorithm

The comparative analysis is made in this research in such a way to analyze the effectiveness of the proposed PS-SALP algorithm. The comparative methods taken for consideration are PSO algorithm [21], SSA optimization technique [22] the local search algorithm [24], Genetic algorithm [25], and the proposed PS-SALP optimization algorithm.

5.3.1. Comparative Results in Terms of Utility Cost

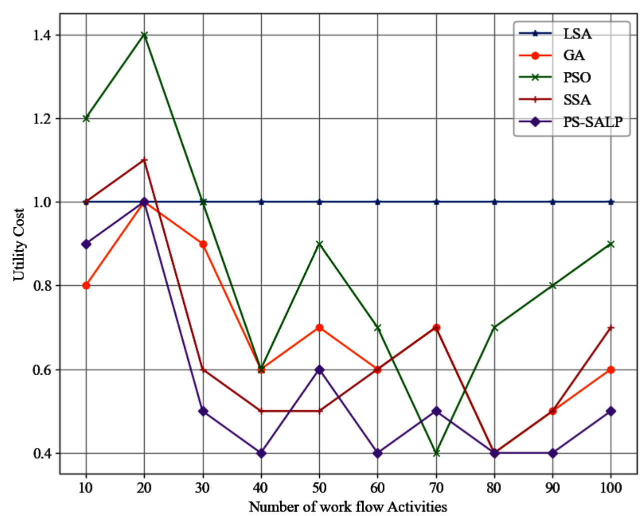

Figure 11 Work Flow or Data Transfer Activity in Terms of Utility Cost

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The work flow activity of the proposed PS-SALP method and the comparative methods in terms of utility cost is shown in Figure 11. The utility cost of LSA remains constant and is equal to 1 while completing the tasks form 10 to 100. The minimum utility cost of GA is 0.4 and the maximum utility cost of GA is 1. The minimum utility cost of PSO is 0.4 and the maximum utility cost of PSO is 1.4.The minimum utility cost of SSA is 0.4 and the maximum utility cost of GA is 1.1. However, the utility cost of the proposed PS-SALP method produces reduced utility cost as compared to other comparative methods. The minimum utility cost attained using the proposed PS-SALP method is 0.4 at the execution of 40 tasks, which is the least value obtained throughout the iterations. The maximum utility cost of the proposed PS-SALP method is 1.

The work flow deadline of the comparative methods in terms of utility cost is shown in Figure 12. The utility cost of LSA remains constant and is equal to 1 while completing the tasks form 10 to 100. The minimum utility cost of GA is 0.2 and the maximum utility cost of GA is 0.5. The minimum utility cost of PSO is 0.4 and the maximum utility cost of PSO is 1. The minimum utility cost of SSA is 0.1 and the maximum utility cost of GA is 0.5. The minimum utility cost attained using the proposed PS-SALP method is 0.01 at the execution of 40 tasks, which is the least value obtained throughout the iterations. The maximum utility cost of the proposed PS-SALP method is 0.2.

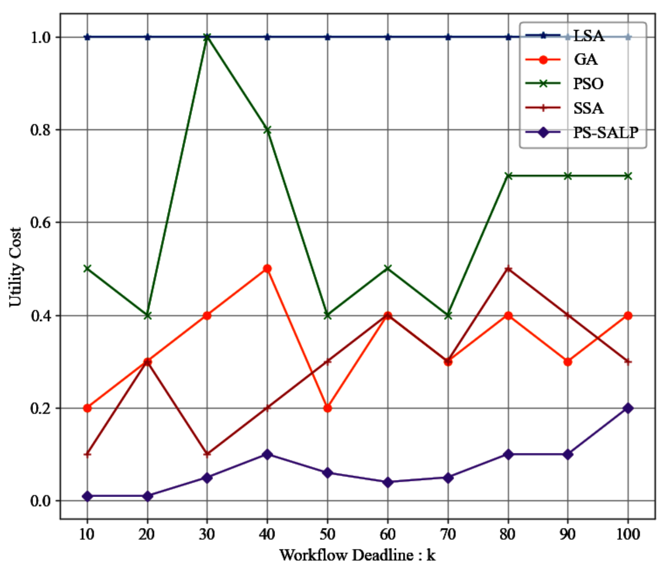

Figure 12 Work Flow Deadline in Terms of Utility Cost

5.3.2. Comparative Results with Respect to Energy Consumption

The flow of tasks by the proposed PS-SALP method and the comparative methods with respect to consumption of energy is shown in Figure 13. From figure, it is evident that the proposed PS-SALP method consumes reduced energy as compared with the conventional techniques. At the task 100, the energy consumed by the methods, such as LSA, GA, PSO, SSA, and the proposed PS-SALP method are 11Wh, 10Wh, 9Wh, 8Wh, and 7Wh, respectively. Hence, the overall performance is high only for the proposed PS-SALP algorithm.

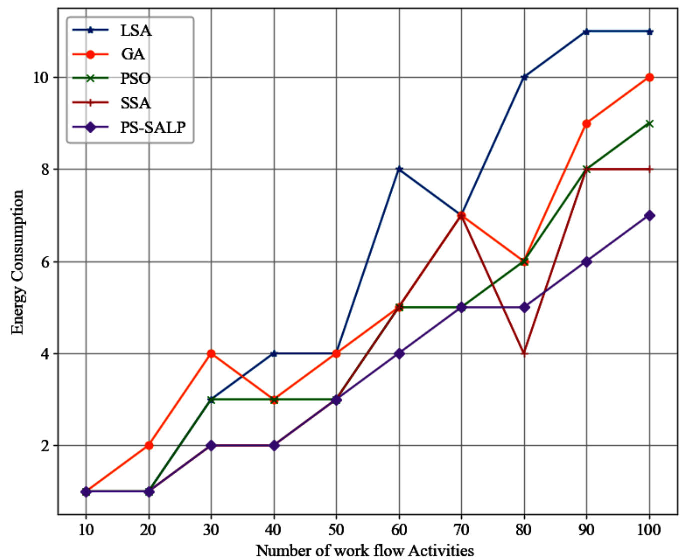

Figure 13 Work Flow or Data Transfer Activity in Terms of Utility Cost

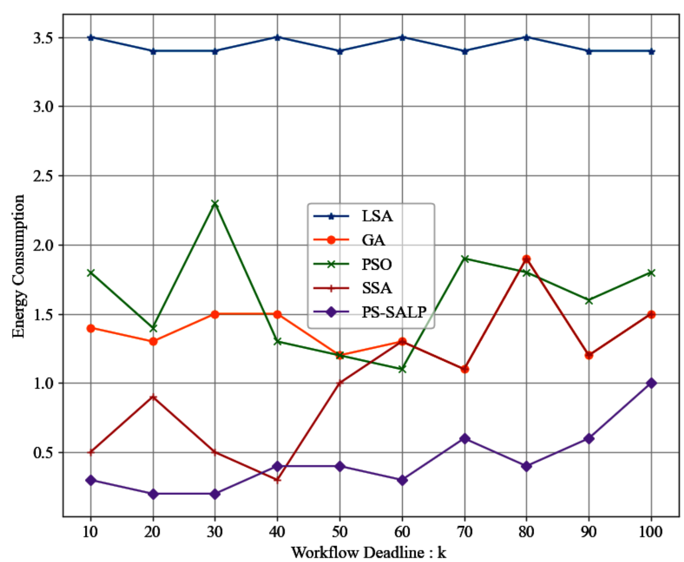

Figure 14 Work Flow Deadline in Terms of Utility Cost

The work flow deadline of the comparative methods with respect to the consumption of energy is shown in Figure 14. From the analysis, it is evident that the proposed PS-SALP optimization algorithm consumes reduced amount of energy when compared with the traditional strategies. The proposed PS-SALP optimization algorithm outperforms all the other techniques, when performing the tasks at its deadline. At the task 100, the energy consumed by the methods, such as LSA, GA, PSO, SSA, and the proposed PS-SALP method are 3.4Wh, 1.5Wh, 1.8Wh, 1.5Wh, and 1Wh, respectively.

5.3.3. Comparative Results in Terms of Execution Time

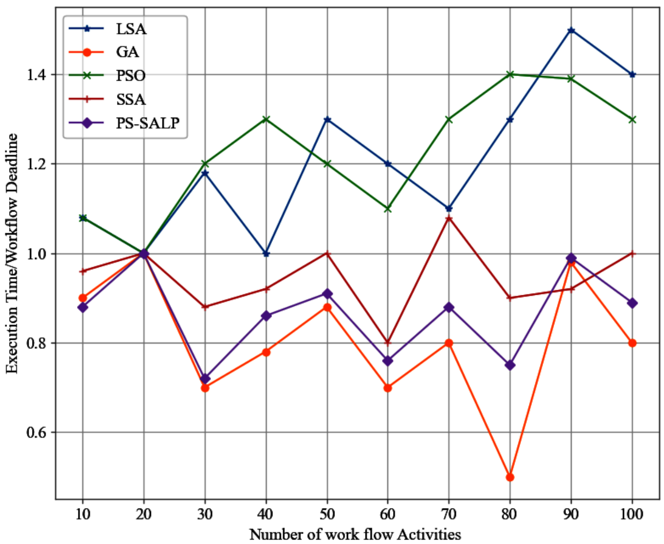

Figure 15 Work Flow or Data Transfer Activity in Terms of Utility Cost

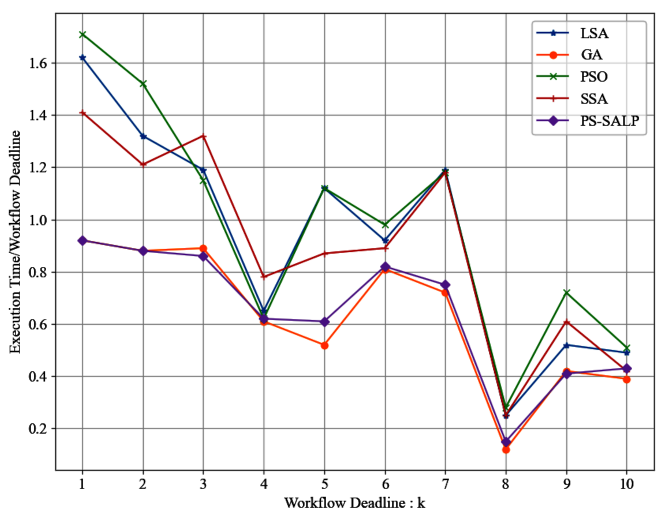

Figure 16 Work Flow Deadline in Terms of Utility Cost

The work flow activity of the proposed PS-SALP method and the comparative methods in terms of execution time is shown in Figure 15. At the task 100, the execution time of the methods, such as LSA, GA, PSO, SSA, and the proposed PS-SALP method are 1.4ms, 0.9ms, 1.3ms, 1ms, and 0.89ms, respectively. Hence, the proposed model is seems to complete the task within short duration as compared to other methods.

The work flow deadline of the comparative methods in terms of execution time is shown in Figure 16. At the task 100, the execution time of the methods, such as LSA, GA, PSO, SSA, and the proposed PS-SALP method are 0.49ms, 0.39ms, 0.51ms, 0.42ms, and 0.38ms, respectively. The execution time for the proposed PS-SALP technique is less while executing most of the tasks. From the analysis, it is evident that the proposed PS-SALP optimization algorithm experiences reduced execution time as compared to the conventional methods.

The table representing the comparative analysis of the methods in terms of utility cost, energy consumption, and execution time are tabulated in Table 1.

Metrics	Methods				
	LSA	GA	PSO	SSA	PS-SALP
Utility Cost	1.0	0.4	0.7	0.3	0.2
Energy Consumption (Wh)	3.4	1.5	1.8	1.5	1
Execution Time (ms)	1.4	0.9	1.3	1	0.89

Table 1 Comparative Analysis of the Methods in Terms of Utility Cost, Energy Consumption, and Execution Time

Thus, from the tabulation, it is clear that the proposed PS-SALP is effective in attaining enhanced performance in MCC in terms of utility cost, energy consumption, and execution time.

6. CONCLUSION

In this research, a novel hybrid PS-SALP optimization algorithm is proposed for performing an effective data transfer in the MCC environment. The aim of the research is the reduction of the UC by maintaining a better balance among the consumption of energy and the task execution time. The proposed PS-SALP incorporates the characteristic features of the basic algorithms, such as PSO and SSA in such a way to produce the global optimal solution by avoiding all the possible local optimal solutions. The effectiveness of the proposed PS-SALP technique of data transfer in MCC is analyzed in terms of the evaluation indices, namely utility cost, energy consumption, and the task execution time. The outcomes indicates the effectiveness of the proposed PS-SALP algorithm over other comparative methods in terms of the evaluation indices, and it is proved to be an efficient

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method of data transfer in MCC environment. In future, intelligent technique can be used for effective data transfer in MCC environment, with the consideration of some other performance metrics, like delay, transmission rate, packet loss, and so on.

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