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Enhanced Vertical Handoff Using Hybrid Parallelized ACS – 3 Opt Local Search

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Abstract

Performing effective handoffs can greatly increase the reliability and the efficiency of any service provider. Performing these handoffs using conventional methods, though it provides accurate results, they usually take time, hence cannot be used in real time applications. A metaheuristic algorithm becomes the best option in this scenario. In this paper, we propose an efficient handoff decision making system using the metaheuristic based Ant Colony Optimization. The variants of ACO are analyzed along with their parallel counterparts. Best results were found to be exhibited by the 3-opt variant in terms of accuracy and time. This algorithm is then hybridized to provide better results.

Keywords: Vertical Handoff; Ant Colony Optimization; 3-opt ACS; Metaheuristic optimization

1. INTRODUCTION

The past decade has seen a huge increase in the number of users of the networked technologies. With the wireless and mobile networks converging into single entities, the number of users is bound to increase in future. In order to utilize the advantage of availability of varied interfaces, the vertical handover can be utilized. High speed wireless communications are available through diverse access technologies, such as WiFi, WiMAX and CDMA2000. From the operator's viewpoint minimizing the operational cost is of huge importance it is also required for them to accommodate maximum number of users in the network and provide mobility, while maintaining the required QoS. In a heterogeneous environment, the process of vertical handoff can enhance the mobility level and improve the overall experience for a user.

A number of techniques have been developed, that supports mobility in networks. Mobile IP [1], a network layer support for mobility, has led to an increase of several variants for optimization, including FMIP [4], MIP-RR [2] for localizing registration, HMIP [3] for reducing signalling delays, PMIP (proxy) [4] for absolving MN of signalling worries, F-HMIP [5] for reducing packet loss and localizing the signalling, PMIP(paging) [6] for economizing the battery power. Path extension [7] and multi-casting [7] approaches, have their own positives and negatives and have also been considered as viable options in case of heterogeneous networks.

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The Ant Colony Optimization (ACO) was proposed by Marco Dorigo [8]. This method was based on the behavior of ants during their search for food. Every ant moves through a path and finally finds the food source. On its way back, it leaves a pheromone trail marking the path it has travelled as one of the available paths for reaching the food source. This can be in simpler terms a graph traversal algorithm, finding optimal routes from a source to the destination. Trail intensity in a path (amount of pheromone deposited) and Visibility of a path (inversely proportional to the distance) plays a vital role in the selection of a path. In due course, the best trail that represents the shortest path prevails and the other paths tend to fade away due to the property of evaporation.

2. ANALYSIS OF ACO VARIANTS FOR ENHANCEMENT OF VERTICAL HANDOFF

Many meta heuristic algorithms exist in literature, that help in the process of optimization. From our previous study [15], it has been found that Ant Colony Optimization technique works best for the optimization of the channel selection process during a handoff. Several variants of ACO are available; hence the current paper performs analysis that determines the best variants for optimizing the process of handoff. The actual implementation of ACO, as proposed by Dorigo provides the algorithm to solve the Travelling salesman problem. Since our process of Vertical Handoff requires only a single length optimization, we use a modified form of ACO. Measurement of the evaporation rate is modified to suit the needs of the incorporated quality attributes.

2.1 ACO Variant Analysis and Parallelization

The basic three variants of ACO were proposed by Dorigo [8]. The original ACO algorithm was itself depicted in three varieties, Ant Cycle, Ant Quantity and Ant Density. Each of these variants differs in the way in which the pheromone deposition is calculated.

According to the Ant Cycle model, the pheromone update is calculated by

$$\Delta\tau_{ij}^{k}(t,t+1) = \begin{cases} Q/L_k & \text{if ant } k \text{ goes from } i \text{ to } j \text{ in its tour} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where, $L_k$is the total distance from the source to the destination nodes and Q is the total quantity of pheromone that can be deposited. The update calculation is actually performed after every complete cycle.

According to the Ant Density model, the pheromone update is calculated by

$$\Delta\tau_{ij}^{k}(t,t+1) = \begin{cases} Q & \text{if ant } k \text{ goes from } i \text{ to } j \text{ between } t \text{ and } t+1 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

The frequency of update is after the selection of every node.

According to the Ant Density model, the pheromone update is calculated by

$$\Delta\tau_{ij}^{k}(t,t+1) = \begin{cases} Q/d_{ij} & \text{if ant } k \text{ goes from } i \text{ to } j \text{ between } t \text{ and } t+1 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

Where, d_{ij} is the distance between nodes i and j. The frequency of update for this method is after the selection of every node, but the amount of pheromone to be deposited is divided according to the distance unlike the Ant Quantity model.

Other available variants of ACO are Elitist Ant System [9] where the global best deposits pheromone on every iteration, the Max-Min Ant Systems [10] where pheromone deposits are modified, Rank based Ant System [11] where solution ranking is performed on the basis of path lengths, Continuous Orthogonal Ant Colony [12] which provides enhanced global search capability and Recursive Ant Colony Optimization [13] using nested ant systems.

i. ACO with Three Opt Local Search

The three opt local search for ACO was proposed by Dorigo in [14]. All the other variants of ACO had very high probability of getting struck in local optima, in order to minimize this, the three opt local search was proposed. It contains a local and a global update method. It actually provides three updates; a state transition rule, a global update rule and a local update rule.

The state transition rule that was initially proposed was modified as

$$S = \begin{cases} \arg\max\{[\tau(r,u)][\eta(r,u)]^{\beta}\} & \text{if } q \le q_0 \text{ (exploitation)} \\ P & \text{Otherwise (biased exploration)} \end{cases} \quad (4)$$

Where q is a random number distributed in [0…1], q_0 is the parameter that determines if the system should perform exploration or exploitation. Hence by providing appropriate values for q_0 the probabilities for exploration and exploitation can be adjusted.

The global rule for pheromone update is given by

$$\Delta\tau(i,j) = \begin{cases} (L_k)^{-1} & \text{if } (i,j) \text{ belongs to the global best tour} \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

The pheromone level to be updated is the inverse of the total distance taken for the complete cycle. Hence, this rule performs the pheromone update after every complete cycle.

The local update rule is given by

$$\tau_{ij} = (1-\rho).\tau ij + \rho\, \Delta\tau_{ij} \quad (6)$$

This process is carried out after the selection of every node.

ii. Need for Parallelism

The Ant Colony Optimization algorithm is one of the available metaheuristic algorithms that are intrinsically parallel in nature. Hence by converting it to a truly parallel algorithm, it becomes possible to leverage the true power of ACO. In our previous implementation of ACO for the purpose of vertical handoff decision making, we have used the sequential implementation of ACO. In order to make it more efficient, we now use the parallel version of the ACO. According to this approach, the probability of selecting a channel is given by,

$$P^{k}_{ij}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{l \in J_k(i)}[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}, if & j \in J_k(i) \\ 0, & j \notin J_k(i) \end{cases}$$

Here,

P_{ij}^{k}(t)= Probability that an ant k will travel from I to j node in graph at time t.

This probability is dependent on several factors like,

$\tau_{ij}(t)$=Pheromone intensity at time t while travelling from node i to node j.

$\eta_{ij}(t)$= Pheromone visibility at time t while travelling from node i to node j.

α= Importance of pheromone intensity.

β=Importance of pheromone visibility

$J_k(i)$=Neighbourhood set of node I for ant k.

A modification is carried out in this approach by incorporating the QoS properties in determining the evaporation rate. The evaporation rate is usually constant, and is defined by the user. In our approach, the QoS properties of the user and the destination signal determine the evaporation rate.

The properties that determine the evaporation rate are, the type of traffic λ_{tt} (throughput sensitive or delay sensitive), speed of travel λ_s, direction of travel λ_d, time to drop λ_{td}, handoff count λ_{hc}, packet loss rate λ_{pl}, latency λ_l, throughput λ_{th}, packet drop probability λ_{pd}, out of order delivery λ_{od} and information priority λ_{prio}. Some of these properties correspond to the user's status, while others relate to the properties of the current being connected to the user. The next level of properties (signal based criteria) include cost of transmission λ_c, bandwidth λ_{bw} and availability λ_{avl}.

Using this method, the evaporation rate is modified, since it is proportional to the probability of selection, we get

$$p_{ij}\alpha\frac{\lambda_{tt}.\lambda_s.\lambda_{hc}.\lambda_{th}.\lambda_{prio}.v_{bw}}{\lambda_{td}.\lambda_l.\lambda_{pl}.\lambda_{pd}.v_c}$$

From the bar chart (Fig 1) it can be observed that the time taken for the handoff decision making using the parallel versions of all the variants (except for Elitist) exhibit lesser delay than their sequential counterparts. The increase in time observed in the Elitist version can be attributed to a slightly increased processing overhead. The efficiencies of both the versions (parallel and sequential) have been observed to be approximately the same, hence it is not discussed here.

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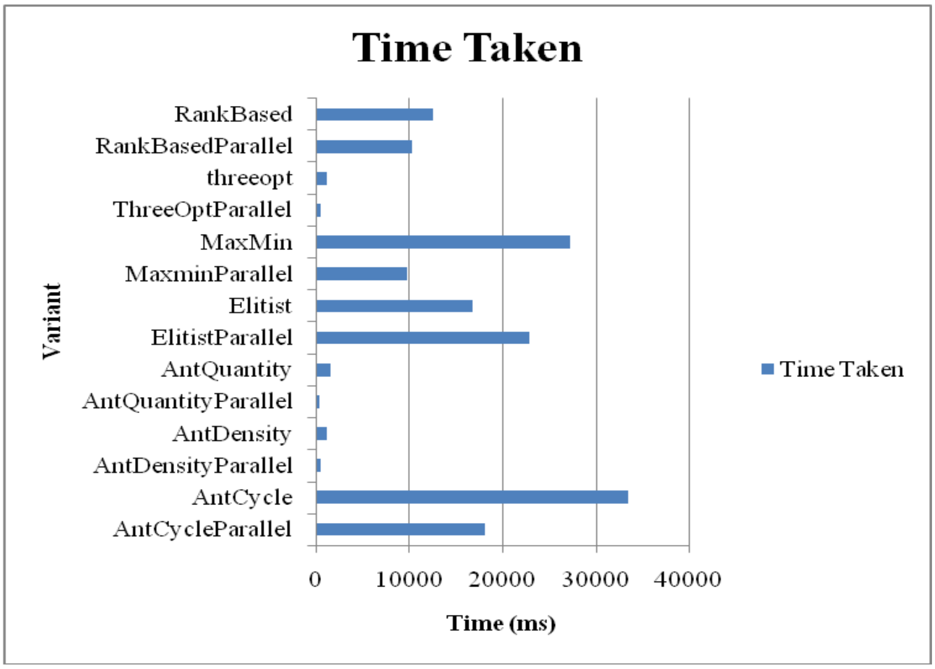

Fig1: Time Comparison (Normal Vs Parallel Versions)

iii. Parallel ACO : A Comparison of the Variants

On analysis of the parallel variants during the handoff decision making process, it has been found that the time requirement for the parallel variants is much lesser when compared to its sequential counterparts. A comparison has been made to analyze the variant that performs best in terms of time and accuracy.

All experiments were conducted in a framework with 50 nodes. All the available nodes for handoff (49 nodes) are considered while making a handoff decision. The handoff decision is dependent on two factors; the distance and the evaporation rate. Farther nodes have lower probabilities of being chosen. Best result is considered to be the node that has the least resultant value.

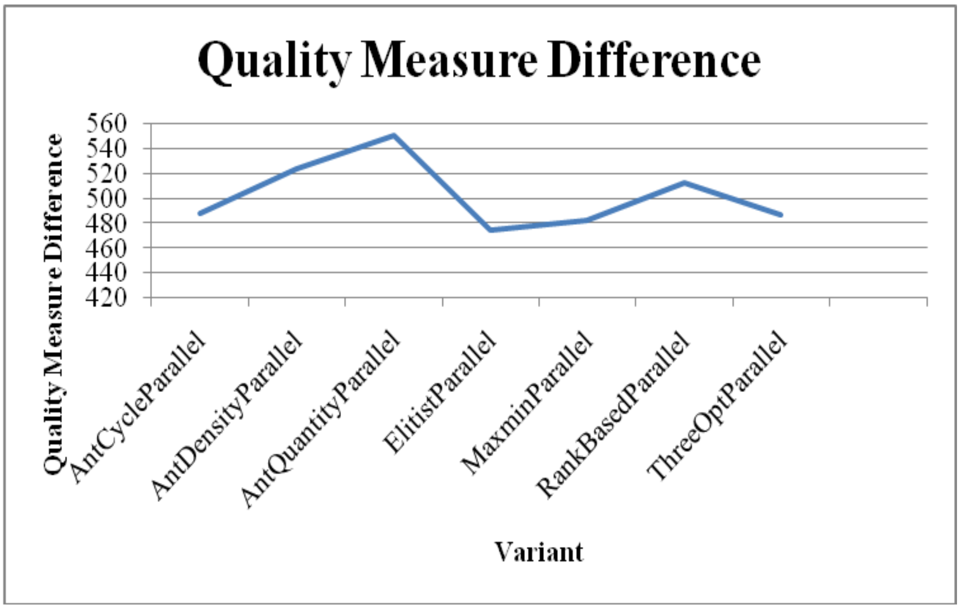

Fig 2: Quality Measure Difference Comparison

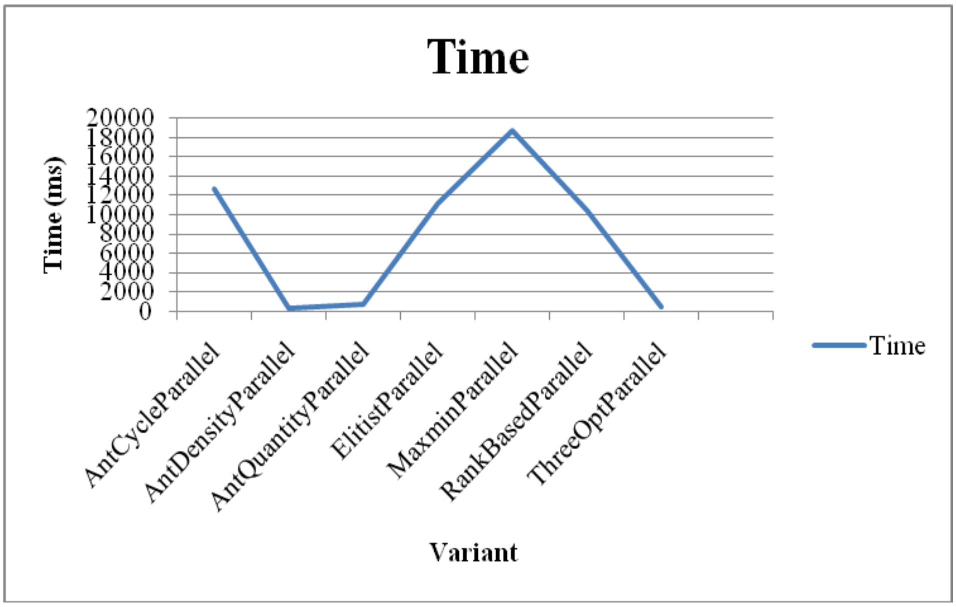

Fig 3: Time Comparison

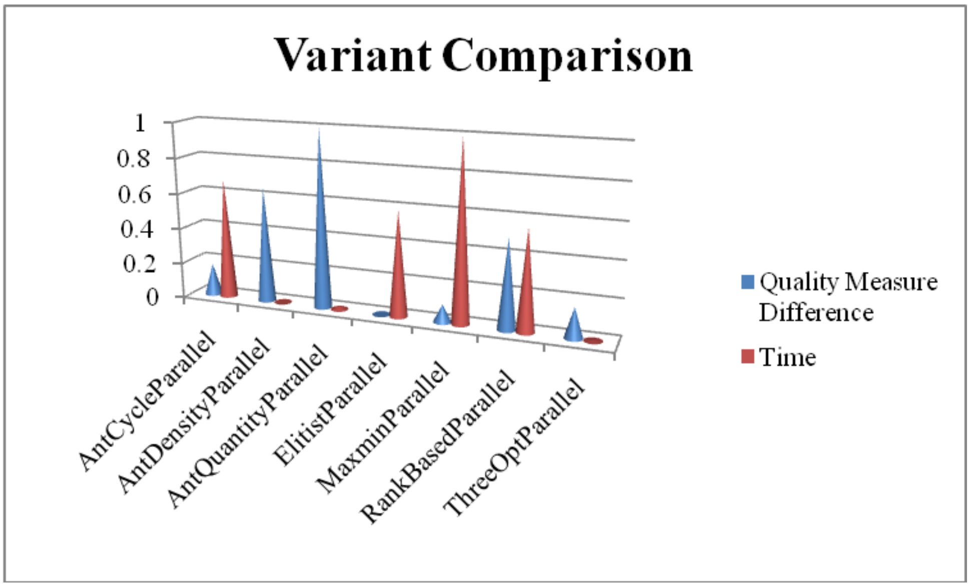

Fig 4: Variant Comparison

Variant comparison was performed and the results were normalized. It has been found that the parallel versions of most of the variants, exhibit huge variations in terms of time and the final result, a tradeoff which cannot be adjusted. The requirement for a handoff is the best result in the lowest time. This is satisfied by the rank based and the three opt versions of ACO. On closer analysis, the three opt variant exhibits a much better result in a shorter time, hence we choose the three opt version of the ACO for performing the process of hybridization.

b. Hybridized ACO

The process of hybridization is performed for two reasons; to perform efficient single pass optimization, and to perform fast and efficient local update. From the comparison of the parallel models, it has been found that the three opt version of the Ant Colony algorithm works best in the process of handoff, hence it has been chosen for the process of hybridization. Hybridization is carried out by incorporating a Tabu List and optimization of local search is carried out using Simulated Annealing. In [15] an analysis of the efficiency of Ant Colony Optimization algorithm in the process of handoff decision making was discussed. [15] applies ACO on all the available networks that are currently accessible, but the downside of this approach is that ACO being a probability based optimization mechanism, can also return the current channel that is being used, which tends to trigger the handoff mechanism in the very near future. This results in an overhead. To avoid this, we incorporate a Tabu List in our process. A Tabu List stores the recent channel that has been used, which helps avoiding them in the near future. The size of the Tabu List determines the exploration rate. A smaller Tabu list will reduce the rate of exploration, while a larger list tends to push the algorithm to deep into exploration. Since the requirement for our mechanism is limited to the channel that is currently being used, we maintain a small Tabu List.

i. Comparison

The three-opt local search tends to perform both exploration and exploitation depending on the value q_0 defined by the user. This method of local search is replaced by Simulated Annealing. Simulated Annealing is a global optimization method that tends to overcome the problem of getting caught in the local optima. Hence this becomes a good choice for replacing the local update method, which tends to be the base for the global update. Further, the advantage of the Simulated Annealing approach is that it tends to work well on discrete and large search spaces.

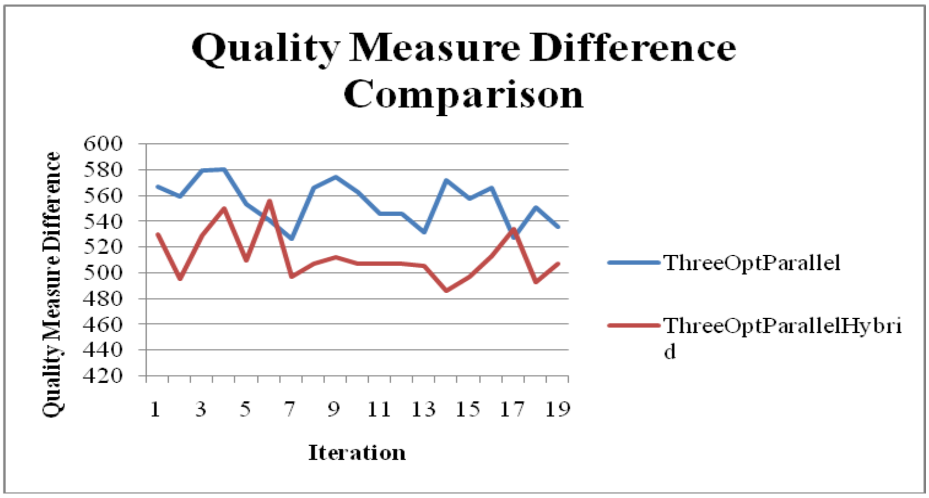

Fig 5: Result Comparison

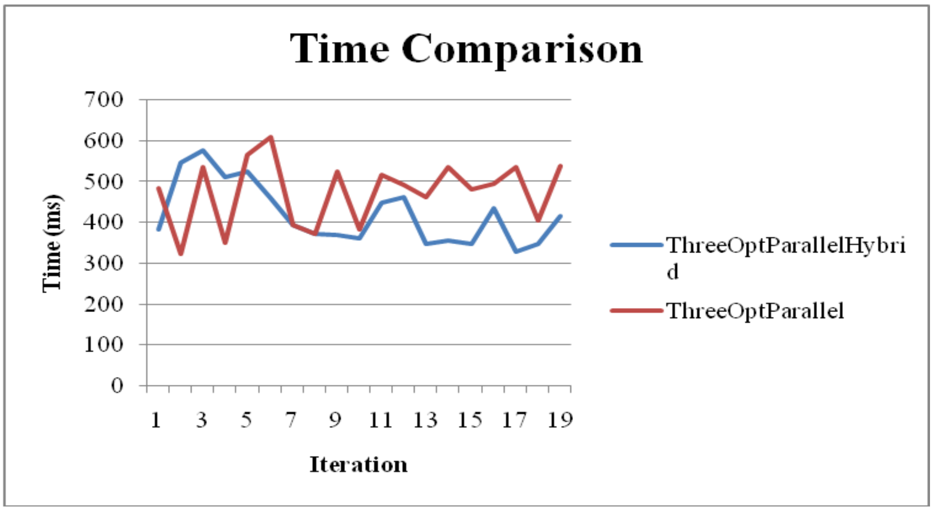

Fig 6: Time Comparison

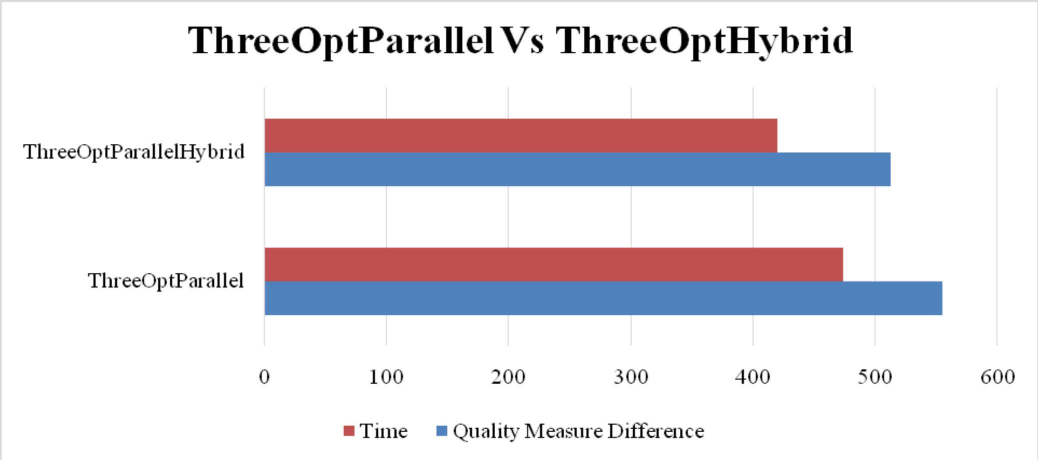

Fig 7: Time and Distance Comparison

From the graphs it can be found that the three opt hybridized parallel variant of ACO performs well in terms of distance and in terms of time. A consolidated comparison of the average values is shown in Fig 7. By experimental analysis, it can be proven that the Three Opt Hybrid Parallel version of the Ant Colony Optimization algorithm works best on the Vertical Handoff Problem.

3. CONCLUSION

Vertical Handoff decision making is a major process that is to be performed by any network provider. The efficiency of the handoff being performed is determined by the handoff decision making algorithm. Our current paper is concentrated on analyzing the parallel variants of ACO and to determine the best variant that handles the handoff process effectively. The three opt variant of ACO was determined to work effectively. Further, we have also performed the process of hybridization to determine the efficiency of a hybrid algorithm, rather than its naïve parallel counterpart.

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