SWARM INTELLIGENCE – ANT COLONY TRAFFIC RULE OPTIMIZATION FOR OFFSHORE RESOURCE ALLOCATION AND PRIORITIZATION

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Abstract - Some animal's live and operate as colony, they are interdependent, self-organized and corporate amongst themselves for their survival, these types of social animal or insects like ant's colony has provided insights and solution to many human complex problems. With the increase in the complicated number of real-world problems or operations, organizations will have to always put on their thinking hats if they are to overcome these challenges to come out with better solutions each time, swarm intelligence has led to more efficient and better ways of coming up with smarter solutions. No wonder there has been lots of different study and application of swarm intelligence especially ant colony optimization (ACO) to solving complex problems. In this paper I will discuss related works of ant colony optimization for resource allocation and optimization like opportunity load balancing (OLB), minimum execution time (MET), etc. and then improve on the ant traffic rule and apply it to one of the real-world problems that is complex, complicated, and capital intensive, the harsh environment of the deep offshore drilling operations, because of the locations and conditions in the deep offshore environments it has becomes more and more difficult to get the drilling operations done in a safe, efficient and cost effective manner without running into complications. The modified ACO will be applied to the offshore helicopter operation and data transmission pathway selection to help proffer better solution to these two critical resources offshore, offshore logistics weather it is start or end of the project is very critical and important if not handled systematically this could cause a major delay in the takeoff or closure of a project. On the other hand drilling data transmission in and out of offshore location determines how efficient, the offshore location and office base location will work hand in hand to achieve the goal of completing the project in record time and safely.

Index Terms - Swarm Intelligence (SI), Offshore, Resource (OR), Self-Organized, Ant Colony Optimization (ACO)

1. INTRODUCTION

1.1 Background of the Study

Nature is full of inspirations and ideas, and some of these ideas are from natures smallest but self-organizing organisms and many others from nature leading us to what is now called swarm intelligence. Swarm intelligence have helped human solving real-world complex operations from ship building to remote locations like offshore operations to virtual world of computing there are complex operations that we humans have been battling with. The offshore operation are critical, complex and complicated, and most especially huge capital intensive. In the last few years the oil and gas industry have gone through serious resource allocation and prioritization challenge due mainly to very low oil price. Management at all levels have been asked to come up with better but cost effective ways of doing things while focusing on limited resources like reduced budgets, aging critical equipment's, reduced man power, etc.

Some of these inspirations and ideas that are needed in times like this can be seen if one takes time to study and observe the way and manner social insects like ants allocate limited resources and prioritize task if need be. One example of such is the ability of ants to use a chemical substance called pheromone which is a resource to allocate task and how they observe traffic rules to give way to inbound laden ants.

There are different ant colony optimization algorithms to get resource allocation and prioritization done, some of these algorithms are based on large scale and dynamic multi-agent scenario, cloud computing environment, etc. Social insects like ant colony behavior holds important information that can help us solve complex and complicated real-world problems and operations.

This paper will look at the how ant colony manage traffic in there very narrow and highly populated path, what rule or priority the naturally apply as they go in and out of their nest in search of food. Since ants are among the rare group of animals in which collective movements are predominantly bidirectional, ants carrying no food (task) moves aside for those carrying food (task) in the opposite direction [6]. There are lots of complex task that gets done offshore, and one of it is logistics, offshore operation depend heavily on logistics movement of material and personnel's to and fro offshore locations. If there is one thing that is problematic working offshore is task prioritization, manager's and supervisor's look for ways to prioritize logistics be it materials, humans, or even drilling operations so as not to cause delay or downtime to the operation.

Swarm intelligence (SI) is an aspect of artificial intelligence inspired by nature, for instance social insects like ants colony are self-organized and coordinated when it comes to task allocation, resource utilization and prioritization. According to Technopedia, (2019) "swarm intelligence is defined as the idea of coordinating massive numbers of individual technology entities to work together" Also swarm intelligence is the smart behavior of a group and collective and coordinated behavior of an enormous amount of independent agents. In nature, this is most usually used with reference to the colony-level conducts seen in social insects like ants.

Swarm intelligence has been applied by man to resolve complex and complicated task while studying how nature was able to resolve it complex and complicated situation. The case of ant colony has led to different algorithms applied to various needs of man and it has proven to be efficient and effective in proffering solutions.

The rest of the paper is organized as follows. Section 2 gives a brief review and introduction to previous ACO-based algorithms and improvement on them. Section 3 describes in detail the proposed methodology using improved ant colony traffic rules to improve on two critical operations with limited resources, and the conclusion is drawn in Section 5.

1.2 Statement of the Problem

There is the need for a better and optimized algorithm like ant colony algorithm for resource allocation and prioritization in a complex and complicated remote environment's. Offshore locations are often in the remote areas, be it land or water and every resource available to them to carry out their job safely and efficiently has to be properly planned for. Planning the movement of materials and men in and out of the remote location becomes a complex and complicated one since there are lots of variables to take into consideration. Also when it comes to IT resource like bandwidth utilization inbound and outbound traffics has to also be properly allocated and prioritized considering the different applications that has to be processed.

The challenges in offshore resource allocation and prioritization is what this paper will try to solve and in doing so I will apply ant colony traffic rule optimization algorithm to the complex and complicated multiple operations that goes on simultaneously to help save time and to make efficient use of limited resources.

1.3 Aim and Objectives

The aim of this paper is to improve on resource allocation and prioritization using optimized ant colony traffic rule flowchart for better and efficient resource allocation and prioritization in a remote environment like offshore. The specific objectives are to:

i. Develop flowchart for offshore resource allocation and prioritization
ii. Optimization of ant colony traffic rule for offshore resource allocation and prioritization

1.4 Scope of the Study

This research is focused on finding a better option of allocating the limited resources and prioritize same for optimal and more uptime operation at remote locations like offshore using improved ant traffic rule flowchart. The work can be applied to different types of complex task and operation that requires proper planning and execution with little or no modification.

1.5 Significance of the Study

This research is very significant to the oil and gas sector and any other sector that operates in remote and harsh environment especially as it deals with limited resources allocation and prioritization

2. LITERATURE REVIEW

2.1 Overview

There have been many papers on swarm intelligence ant colony algorithm (ACO) for resource allocation and scheduling, these papers have improved or modified ACO algorithm from the original algorithm developed by Dorigo Marco in 1996 during his PhD thesis work. In their work reviewed many existing resource allocation approaches some of the techniques are: opportunity load balancing (OLB), Minimum Execution Time (MET), Minimum Completion Time (MCT), Max-Min, Min-Min, and ant colony based scheduling algorithm [1].

In his paper used ant colony algorithm for a large scale resource sharing and allocation with dynamic characteristics of cloud environment. The simulation results showed that ant colony algorithm can accomplish the task of sharing and allocating resource in a cloud environment effectively [23].

In "An ant based algorithm for task allocation in large-scale and dynamic multiagent scenarios", were able to show with their eXtreme-Ants algorithm that a model of ant like division of labour was used to decide whether or not to perform a particular task which allows the agents (eXtreme-Ants) to make efficient and coordinated decisions. Since the decision making is

probabilistic, it is fast, avoid time wasting, and required reduced communication and computational effort [17].

In the paper [24] they proposed that ant algorithm can be optimized by applying a local search algorithm to the output of the algorithm to find the optimal resource to schedule a job. They used two local search methods, Move-Top, Move-Minimum Completion Time Job First and Move-Maximum Completion Time Job First, focusing on the task completion time which is input to the algorithm. CPU workload, communication delay, QoS were not considered. From their result, the ant colony algorithm with local search algorithms performs 30% better than the algorithm without local search.

In paper [25] the authors came up with an ant colony algorithm to achieve the QoS. In their paper they proposed a two new types of pheromone updating rule, the first is that the pheromone value is inversely proportional to the execution time of the particular task on a selected resource and the second rule states that the pheromone value is inversely proportional to the total make span of the schedule and also the transition probability calculation formula is modified. The new improved rules showed that the overall makes pan and flow time improved.

Of particular interest is the research by [6] in their paper "Ant Traffic Rules" they showed that ants by nature observes a strict traffic rules which enables them to transport food to the nest in a very narrow path efficiently and without a traffic lock jam. While this work did very well in detailing social insect's behavior and how they overcome the challenge of congestions and collision by use of prioritized traffic rules the work did not come up with the ant traffic rule algorithm.

2.2 Types of Resource Allocation and Prioritization

There different types of resource allocation and prioritization methods that has been developed and put to use, some of them are:

2.2.1 First Come First Serve (FCFS)

This approach is same like First in First Out (FIFO) in this approach whoever comes first is served first, this approach does not take into account priority of the individual task once you come first your task will be scheduled for processing. As long as the queue is free jobs are cued and processed as they come. The downside here is that once the queue is full all other jobs have to wait, and if a job of urgent need it has to wait for it turn. This kind of approach is also applicable in controller area network (CAN). The only time there will be issue is if two task are sent in for processing at the same time then priority of task will be used to process the job. This is done without regard to which flow the packet belongs to or how important the packet is. This is sometimes called tail drop, since packets that arrive at the tail end of the FIFO are dropped [14]

2.2.2 Highest Priority First Serve (HPFS)

This is also same as Priority Based queue resources are allocated to task on priority base if the task at hand has the highest priority then resource will be allocated to it. Here it doesn't matter when the task requested for resource to be allocated or if two task requested at same time what will determine is the priority of the task. For instance in a computing environment if a task will impact only one user and task that will impact on many is to be processed the task that will impact many users will have the highest priority compared to the single user task. The problem with priority queuing, of course, is that the high-priority queue can starve out all the other queues; that is, as long as there is at least one high-priority packet in the high-priority queue, lower-priority queues do not get served [14]

2.3 Ant Colony Traffic Rules Optimization Algorithm

Ants have very limited resources in terms of pathway and pheromone to transport and locate food source to their nest, so they make very good use of the narrow pathway and pheromone by applying some basic rules that comes to them naturally. I will look at how ants are able to allocate and prioritize these two limited resource for efficiency during foraging. Figure 2.3 is the basic ant food search flowchart that will be improved on and applied to other real-world situations for better outcome.

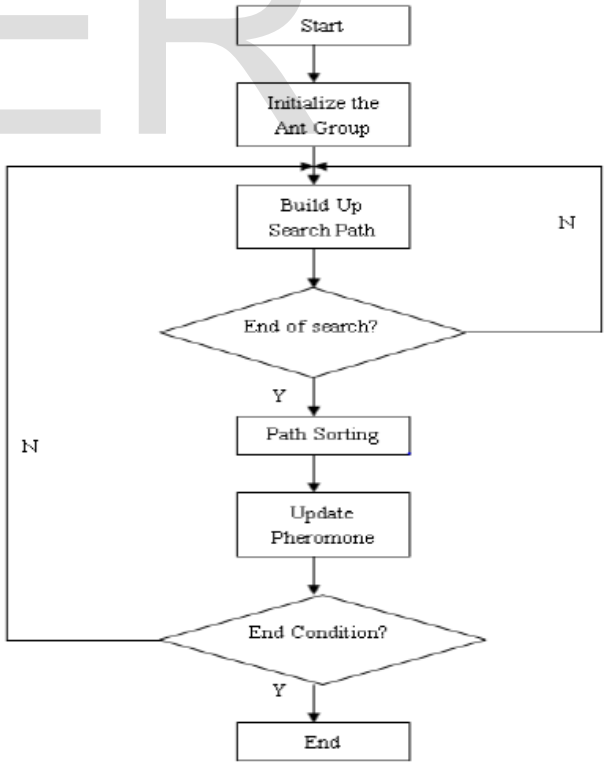

Figure 2.3: Basic Flowchart of Ant Colony Algorithm
Source: (J.P. Wang, Y. Gu, et al, 2012)

2.3.1 Pathway Resource Allocation and Prioritization

During their laboratory study of ants traffic [6] used a 50mm wide bridge installed between their nest and a box containing leaf material of the 15% inbound leaf cutting ants that returned to the nest with a leaf fragment, 94% traveled on the central part of the bridge while the ants carrying no leaf tend to travel most on the side of the bridge. Also for the outbound ants, 67% of them traveled on the central part of the bridge, and 80% of the times they gave way to inbound ants carrying leaf during head on encounters. This natural traffic rule behavior has helped ants to make good use of the limited resource been the 50mm wide bridge allocation while observing some pathway priority based resource allocation. See figure 2.3.1.

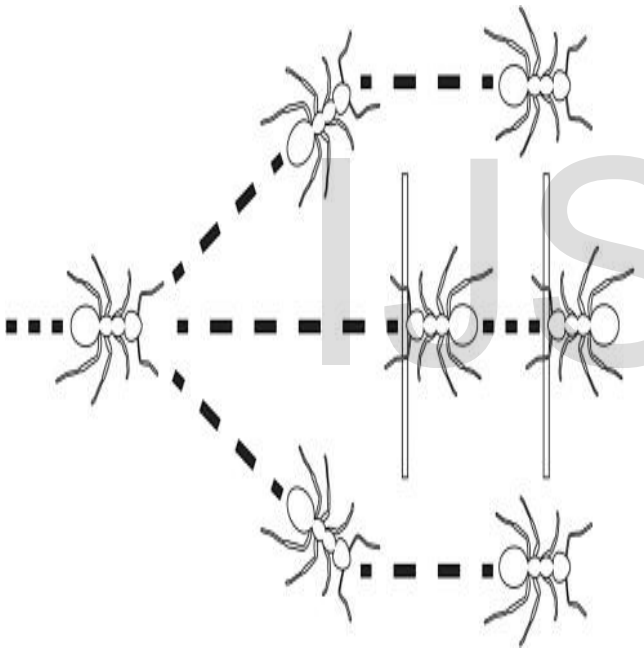

Figure 2.3.1: Ants Colony Traffic Rule Behaviour
Source: (T. Lenau, and T. Hesselberg, 2013)

2.3.2 Pheromone Resource Allocation and Prioritization

Pheromone is another resource the ants uses to communicate and recruit other ants for a task to be done reason why when ants go out in search of food source they leave pheromone as a means of leaving trial to where they are going in search of food when they find food on their way back they also leave more pheromone to reinforce the earlier dropped pheromone thereby leading others to the right location of the food source, but if they did not find any food they will not leave another pheromone on their back to the nest. This is a way of saving and using their resource prudently also the pheromone when reinforced helps leads ants to the shortest path of a food source, what the ants do is to compare the different distances to all food and priority by going with the shortest path making them get to the a food source on time

3. METHODOLOGY

Improved ant colony optimization traffic rule execution flowchart will be used to improve on offshore resources allocation and prioritization like limited VSAT bandwidth allocation and prioritization and crew change logistics in respect to helicopter seats allocation and prioritization.

Ant colony right of way priority will be employed to solve limited resource allocation, for offshore situation, allocation and the priority will be determined by a number of conditions like safety, operation, time sensitivity or non-critical operations, shortest path for data transmission, is path congested, what kind of traffic and set traffic priority, and all that.

3.1 Offshore Resource Allocation and Prioritization Using Improved Ant Colony Traffic Rule Flowchart

In this section I will apply the ant colony traffic rule on two critical offshore operations that has limited resources, one is the offshore crew change helicopter seats and the second is the bandwidth path allocation scheme. Both of these operations requires serious planning and strategizing to overcome the various complexities in them and because we can only do so much with so little. Figure 3.1 is the improved ant colony path search flowchart, it will be applied to both critical offshore operations for better outcome and decision making.

Flowchart in figure 2 took into consideration the ants leaving the nest in search of food, because if outbound ants meet or collide with an inbound ant carrying food (tasks) they are able to make a turn easily since they are not carrying any load their can move easily compared to ants with load [6]. When the system starts the ants are initialized from the nest, the search starts as they go along, the question, if the path is clear is for the outbound ants to note if there is an inbound ant, especially the ants carrying food, if yes the ant continues, but if no another question is asked if the inbound ant is carrying food(task), if no it continue on its path, but if yes the outbound ants will either turn left or right making way for the inbound ant with food. Then the ant check if there is pheromone on the path this would lead it the nearest food source, if no it starts search again, but if yes it updates the path, then if it finds no food it discards the path, but if it finds food the path is stored and if the search ends, the program stops, if not it continues searching for food.

By this they (ants) have given priority to the ants carrying food and have been able to manage their narrow path (bridge, helicopter seats, bandwidth or data traffic path) which is the resource that help them transport food to their nest easily.

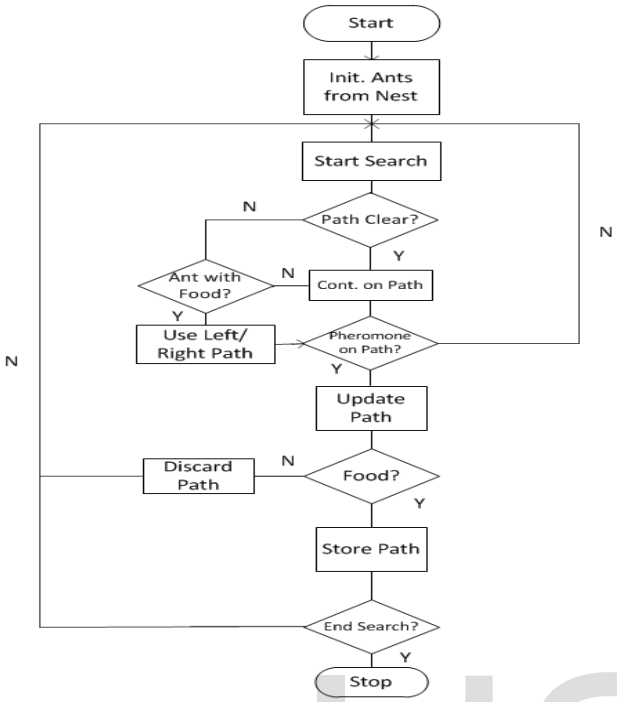

Figure 3.1: Improved Ant Colony Traffic Rule Flowchart

3.2 Offshore Helicopter Seats Allocation Using Ant Traffic Rule

Letter A side of figure 3 is painting a picture of how the ants carrying food to the nest are given priority to the narrow path, while the letter B side of figure 3 also showing ants with no food but inbound to the nest gives priority on the narrow path to outbound ants from the nest to look for food [6].

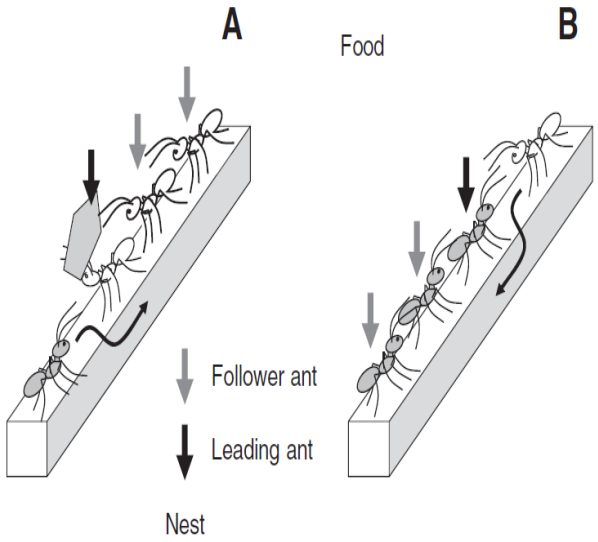

Figure 3.2: Leaf Carrying Ants on Central Path
Source: (V. Fourcassie, A. Dussutour, et al, 2010)

The same way offshore helicopter seats are allocated and prioritized, the seats available depends on the model of the helicopter, if for instance we are provided with one that has 12 seats and on a normal crew change day there are close to 20 people waiting to go offshore then the scheduler will have to apply the ant traffic rule to get the operation going smoothly. The drilling department crew are given priority they are like the inbound ants carrying leaf or outbound ants from the nest going in search of food, reason being that they are the core of the drilling operations so they get allocated seats first before any other departments. But if no drilling department personnel is left then the scheduler go by personnel's going home from offshore with early flights to catch against those going in normally. Just as the narrow ant path is the limited resource that must be properly planned for, allocated and prioritized to ants with higher priority so is the 12 seats on the helicopter has to also be allocated and prioritized properly for smooth operation, this way the company will not suffer any downtime or delay in critical drilling operation.

If we apply the outbound ants flowchart figure 2 to the helicopter crew change operation then it will be initiated on the crew change day from the ship, then search for passengers off signers start, and getting the all clear from the departmental heads, the next stage is prioritizing who leaves on first helicopter or second helicopter due to limited seats, if anyone is found on the first list and is not in drilling department or has a very critical operation is replaced by higher priority passenger.

3.3 Data Transmission Pathway Selection Using Ant Shortest Path to Food

Ant pheromone represent the procedure or way of carrying out a task using task risk assessment (TRA) after the task is done we

debrief and lesson learned discussions are updated on the TRA for improved way of doing same task and stored for the next group of people that might do same task in the future or creating different paths for routing data off the ship to onshore destination. Bandwidth is the pathway for all data from the ship, figure 3.3 shows a sending router and the various path available to it, primary path for sending data is, path 1 V240 dish, 4MB link and the secondary path 2 V130 dish, 2MB link. There may be criteria set to make a path primary some of the criteria maybe bandwidth size, packet size, shortest or quickest path, etc. So every data for transmission will also follow the primary learned path if for instance the primary path has bigger bandwidth and would transmit the data faster in the shortest time automatically every data would take that path even though they know and have details of the other paths. This is how ants use their pheromone to communicate to others of the shortest path to a food source even though there are other food sources ants would always follow the shortest path to a food source.

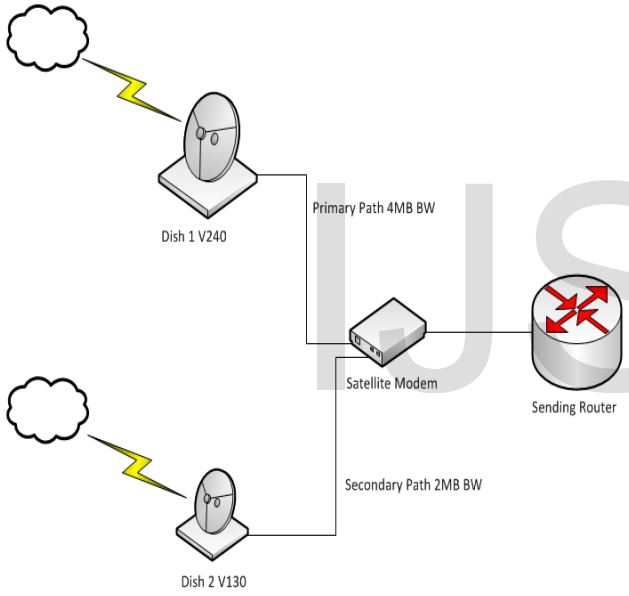

Figure 3.3: Data Transmission with Path Allocation and Prioritization

For offshore operation VSAT bandwidths are very expensive, to get a decent bandwidth of say 4MB or less companies have to be ready to pay from $20,000 per month and drilling contractors try as much as they can to reduce IT resources cost since IT department does not generate money or is not their core business. Typically offshore traffics is categorized and prioritized into four different types they are: telemedicine (medical), remote support (for drilling, and marine equipment's), corporate (company PC, and devices), and guest or crew (internet café, and personal devices) network. It becomes very important to make sure data traffic is properly allocated the required resources and priority. Following the order of data traffics mentioned so is their importance to offshore operation. So if we have all four traffics contending to be transmitted the priority set give all medical or telemedicine traffics upper hand since it deal with human health and life, followed by remote support for drilling and marine equipment's, then corporate traffics before public internet (café) for the crew member.

We also have a setup of multiple paths and traffics use one as the primary and the other as secondary path because the primary has a more bandwidth space to send out data quicker and faster, by default all traffic uses the path after learning from the routing table that the primary path is the shortest path to their destination just like the ant would learn of the shortest path to a food source from the pheromone of other ants.

4. CONCLUSION

In this paper I have been able to discuss the inspiration gotten from social insects like ants in solving real-world complex and complicated problem which is call swarm intelligence, in particular ant colony optimization (ACO) is one of the popular swarm intelligence that has been applied to solving many problems from combinatory, to multi-task and multi-robot task allocation and optimization taking a leap from the first problem (travelling sales man problem) solved using ACO.

In this paper a careful study was done on how ant traffic rule was used to share used resource that is limited their narrow pathway. This pathway is very narrow compared to the number of ants using but yet they are able to keep moving and no traffic lock jam of any kind making it easy for them to keep going for more and more food to the nest.

An improvement on the ant traffic rule was suggested and applies to two critical resources offshore logistics for crew change helicopter seat and bandwidth for data transmission, these are limited resources which if not carefully allocated and prioritized would impact negatively on the drilling operation.

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