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Agent-based Clustering Approach to Transport Logistics

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Abstract - **Evolution of autonomous cooperation pulls away the traditional centralized approaches towards the decentralized approaches in logistic networks. In this concept, knowledge and decisions are distributed among the participants of the logistic process. Vehicles and goods become intelligent, interactive, and capable of deciding about how to achieve their aims. Software agent technology provides a means of bringing about autonomy by information sharing and decision-making capabilities. This paper presents the approach of integrating agent technology and knowledge management approaches like clustering techniques to ensure robust and efficient planning and scheduling in the transportation domain. Logistic entities are represented as software agents, where the objective is to cluster these entities which have common goals – like packages having the same destination, same type of packages, etc. The approach of autonomy through software agents and clustering techniques is expected to significantly decrease the communication demand imposed upon the logistic network for a set of required tasks to be performed. An enhanced clustering algorithm has been applied on a logistic scenario and compared with the original algorithm in terms of effective cluster formation with less iteration. This approach identifies challenges in the area of communication that arise from the distributed decision process and the interacting components.**

***Index Terms*— Agent based, Autonomous Cooperation, Clustering, Communication, Transport logistics**

I. Introduction

The high demand for customized products and their delivery at the right time and with the right quantity has imposed a greater dynamism in the logistic domain. *Autonomous Cooperation (AC)* can be seen as one of the possible approaches to cope with the rising complexity and dynamics involved within the logistic networks [1]. The paradigm shift of making the entities more autonomous and intelligent is facilitated by the availability of a wide range of information and communication technologies that can be utilized to devolve decision making down to the level of an individual item in the logistic chain. The distribution of planning and decision-making to autonomous components is a widely accepted promising solution to handle complex problems [2]. In addition software agent technology provides the *means* of creating autonomous, intelligent and social software entities that are assumed to be capable of supporting autonomous decision-making by effective coordination and information sharing on a continuous basis.

A. Role of Software agents in Logistics

The software agent's paradigm has much to offer in terms of dynamics involved within the logistic networks, refer Fig. 1. A logistic network in this context is a network of suppliers, factories, warehouses and distribution centers through which raw materials are acquired, transformed, produced and delivered to the end customer.

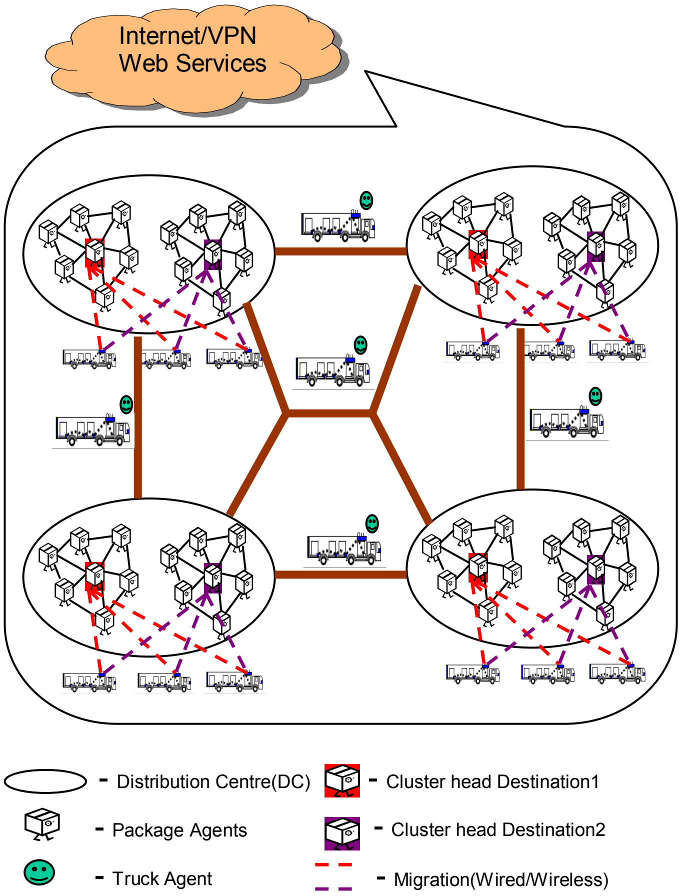

Fig. 1: Transport Logistics: Clustering of Logistic Entities

This dynamic process involves a constant flow of information and material across multiple functional areas both within and between different organizations. Several agent-based approaches have been proposed to deal with the dynamic optimization problems in transport logistics [3]. Agents represent a state-of-the-art approach for implementing autonomous systems. The motivation comes from the fact that the agent-based systems reflect the distributed nature and are able to deal with the dynamics of planning and execution on the near real-time settings [4]. For example, in transport logistics, this means that vehicles try to achieve aims such as cost efficiency, while goods aim to find a fast path to their destination. As the goods need to be transported by vehicles, there is an interdependence between the goods' and the vehicles' decisions. In order to deal with this interdependence, the "Distributed Logistic Routing Protocol" (DLRP) was proposed in [5]. In this protocol, information is retrieved by agents (packages, vehicles etc) using route request and route reply messages. In large networks, the route request and the route reply messages cause a significant amount of communication traffic. If goods with similar aims can be combined into a community with one "head-agent", a reduction of this traffic is expected. Thus, the idea of clustering logistic entities represented as agents is presented in this work.

B. Clustering

The term clustering means generating similar groups of entities such that the items within the group are more strongly related to each other than to those in different groups [6]. The key aspect of clustering is to reduce the communication volume, which may result in a large latency period to take decisions for mobile agents (packages etc). Logistic components may have common aims, for example there can be several goods that are at the same location and have the same destination.

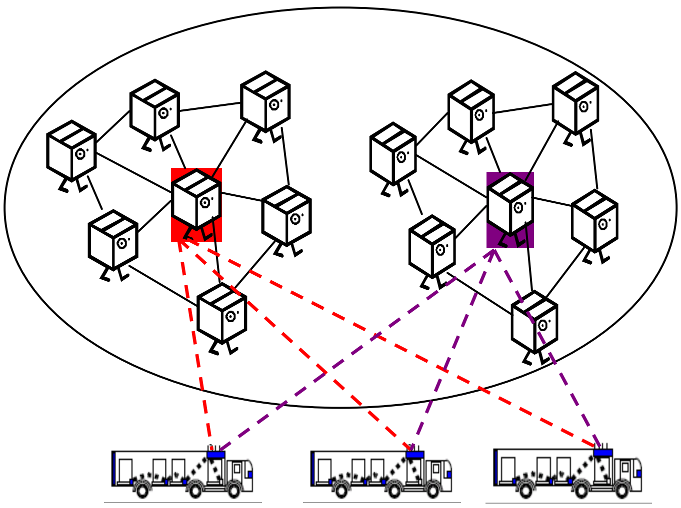

Fig. 2: Transport Logistics: Cluster-Head agent (Packages) communicating with the truck agents

In such a case, it can be sensible to form communities of those components and determine a community leader that acts on behalf of all members, refer Fig. 2. It is expected that thereby, the required communication among the logistic components can be optimized. As time plays the prime factor in logistics, it is important to take the right decision at the right time with large information exchange in less time. But at certain times redundant information may result in large latency and delay, which is not appropriate for the decision making at right time for any entity. For example, the information passed on by the vehicle agents about their availability, type of packages they carry etc. for large numbers of clusters or packages can result in information redundancy associated with a delay. Hence, the number of clusters formed and the size of the clusters play an important role in reducing the communication overhead and consequently the latency/delay in addition to the data aggregation.

II. APPROACH

Keeping in mind the above concepts, various clustering algorithms proposed for communication networks in literature can be modified and adapted to logistic scenarios. A good clustering imposes a regular, high-level structure on the network. This involves modeling the processes in a proper way and applying algorithms with logistic scenarios that represent a logistic world with integrated concepts for autonomous components. In this study reported here for logistic networks, the effects of the implementation of the algorithms proposed for clustering of sensor networks on the clustering of logistic entities is investigated using the software agent's framework. Each package is autonomous (represented as agent) enough to take decision by communicating (negotiating) and resulting in a cluster through the clustering process.

The remainder of the paper is structured as follows: Section III gives the overview of research in the area of clustering mobile agents in various fields. For the purpose of clustering where logistic entities are represented as software agents, a simple scenario is introduced in section IV and algorithms applied to the scenario are presented in section V. In section VI, results are presented and in VII the conclusions drawn are presented with an outlook on future work.

III. STATE OF ART

Clustering has been studied in a variety of fields, notably statistics, pattern recognition and data mining. Clustering is also a research topic in communication networks like sensor networks, ad-hoc networks etc. For example multiple criteria clustering of mobile agents visiting a group of similar routers is presented in [7].

Potok and Ivezic analyzed grouping of spare parts for logistic optimization using multi-agent systems [8]. Knaak, Kruse and Page have presented an agent-based simulation of alternative logistic concepts for city courier services using some clustering concepts [9]. A cluster-based agent has also been used for routing of vehicles for transportation optimization in [10]. The TELETRUCK approach to order dispatching in the transportation domain is described in [11] where a holonic multi-agent approach is presented. The agents directly reflect the physical objects and form holonic agents composed of subagents acting in a cooperative way. In this approach proposed in the paper all the agents in the network assumed exhibit full autonomy when compared to the holonic MAS system where autonomy is handled only by one of the agents in the cluster.

The concept of sub-clustering applied in this work for a logistic scenario is the algorithm proposed by Chan and Perrig [12] termed the Algorithm for Cluster Establishment (ACE). The proposed algorithm incurs a small constant amount of communication overhead as each agent only communicates with a small set of neighboring agents in order to achieve the desired global objective of cluster forming and cluster-head selection. The algorithm proposed in [12] is presented in brief (termed ACE – I) and compared with the enhanced algorithms (termed ACE – IIa and ACE –IIb) in this paper. In this work the algorithm is mainly used for sub-clustering of packages which are already clustered within a Distribution Center (DC). The number of packages within a DC may be large in number, so the idea of applying a sub-clustering process evolved and the algorithm is applied for effective sub-clustering purpose.

IV. Scenario

A simple logistic scenario of various packages represented as software agents is depicted in Fig. 3. Packages are clustered within the Distribution Centers (DCs) with respect to their destinations, time, type, priority, etc. The links between the packages give the connection of the packages with respect to their destination. For example Package Agent2 (PA2) is highly connected to PA5 as they go to nearby destinations w.r.t. to each other compared to the PA6 which has a destination closer to PA4 but not with PA2 and so on. Once various clusters are formed, a cluster-head is selected for each cluster.

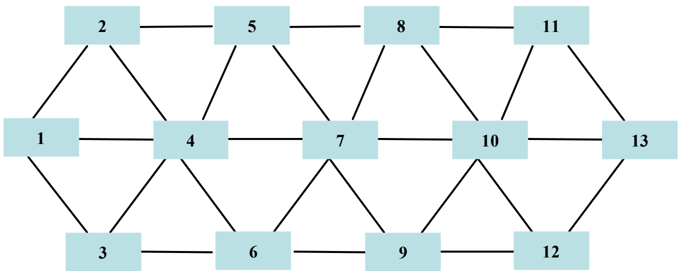

Fig. 3: Simple scenario: Sub-clustering with a group of packages

The idea of the cluster-head selection is that instead of all package agents communicating with the drivers/vehicles, packages going to the same destination can form a cluster and select a cluster-head which will then communicate/ negotiate with the vehicle-head (head of the cluster formed by vehicles) agent or if necessary with the distribution center. Thereby, the cluster-head would act as an information pool for the cluster members and the individual members can still take their own decisions. Cluster forming is thus considered flexible and advantageous in the sense that there may be a large number of packages stored within a DC and if all of the packages would communicate and negotiate with the vehicles or DC individually then it would increase the communication congestion enormously along with network load and latency associated with it.

V. Algorithms

The ACE algorithm is applied to a general simple logistic scenario; wherein sub-clustering of various Package Agents (PAs) is done within a DC, as shown in Fig. 3. The algorithm in general can be applied to a more complex scenario but for simplicity the scenario presented here is exploited. The PAs are connected based on the destination they strongly share and sub-clustering is done based on the same. The algorithm used for clustering in general can also be used at a higher level for example in clustering DCs depending on the type of the goods they are storing and the destination where they are intended to be delivered which is discussed in the following in brief. The links between will have the weights to denote the distance between the DCs, and then a threshold is defined as a reference to identify the neighbors with respect to their link weights (distances). If the link gives a value less than the threshold value, then that DC will be assumed a good neighbor. The main advantage of this clustering approach is that the negotiation between various DCs is faster and additionally, the vehicles can efficiently decide which DCs to visit based on the information via the cluster-head which will give the information about how many packages need to be delivered to a common destination. This approach can be used to solve to the Vehicle Routing Problem to some extent. For example, vehicles can collect packages from all the DCs which are on their way, rather than going to some distanced DC and coming back to the area where they had been already, thus saving time and increasing their revenue.

A. ACE-I

In the initial step of the algorithm, the PAs are clustered within a DC. If the number of PAs going to the same destination is large in number to be handled in a vehicle there might be a difficulty in decision-making, cluster head selection or the information handling and sharing by the single cluster-head can be tedious. Hence a sub-clustering approach is simultaneously being proposed in this work. For sub-clustering it is assumed that the PAs are in three possible states: Ungrouped (not a part of any other sub-cluster (group)), Grouped (a part of a sub-cluster) or it may be a sub-cluster-head (Group-head). In the beginning of the algorithm it is assumed that all the PAs are ungrouped. During the sub-clustering process, out of all the PAs, one PA is randomly picked. Selected PA's available choice of actions depends on what state it is currently in.

If the selected PA is ungrouped, it polls its neighboring *group members* and counts the number of loyal followers, l (members which are still ungrouped and ready to be a part of the selected PA's sub-cluster (group)). If the selected PA finds that the count exceeds a certain *threshold* (l_min= 1, an assumption) it declares itself the group-head and then assigns its group-id to its followers, making them a part of its group (sub-cluster).

But in case the selected PA is already a group-head, the selected PA checks if its loyal followers have more loyal-followers themselves (if given a chance to be group-head) than itself. In that case, it will transfer its status of group-head to the loyal follower PA which has most loyal followers. Thus, the loyal-follower of selected PA with highest number of loyal-followers of its own becomes the new group-head and defines its group (sub-cluster) by assigning its followers its group-id.

When the members of the sub-cluster search for their possible loyal followers then they look for their ungrouped neighbors or neighbor members of the sub-cluster of which they are a member themselves. While checking for the better group-head the present group-head re-counts its own possible loyal followers since the last count, a new neighbor node might have come-up or an old loyal neighbor might not be there any more and so on.

B. ACE -IIa

In this enhanced algorithm (ACE-1 is enhanced), the procedure is the same with the introduced changes depicted in the steps below:

Step 1: It was observed that in ACE-I, the search for a better group-head was confined to the present group-head's sub-cluster only and was not extended to all its neighbors. So, the first idea was to extend the search to all the neighbors of the present group-head, irrespective if the neighbor was a part of its sub-cluster or not. Therefore, in this step if the Package Agent PA is already a group-head then it will poll all its neighbors, even those who are not part of its own group.

Step 2: If any of the polled neighbors have more loyal followers than the selected group-head, that neighbor announces itself as the candidate for the new group-head. Seeing this, the old group-head will abandon its position and make the polled neighbor with maximum loyal followers the new group-head. The new group-head would then announce itself to all its loyal neighbors as the group-head.

Step 3: If any of the polled neighbors which was a part of any other sub-cluster and does not become the new group-head then, this particular neighbor node is allowed to become a part of the group whose group-head polled this neighbor node i.e., the neighbor node *can change its loyalty* and become a part of another group (sub-cluster). The reasoning can be that the polled neighbor was given a chance to be the new group-head and hence it repays by becoming that loyal follower (a member) of the group.

C. ACE IIb

This algorithm is same as ACE IIa except for the only change in the third step. If the polled neighbor is part of another group and is not the new group-head, then the neighbor is not allowed to change its group (sub-cluster) i.e., *no change of loyalty*. This approach can be seen as something in between ACE-I and ACE-IIa with much better performance as would be shown in the section VI.

D. Description by flow charts

The description of the Algorithm for Cluster Establishment (ACE) on the whole is presented in Fig. 4, 5 and 6. In Fig. 5 and 6, the differences of ACE IIa and ACE IIb to the original ACE I are written in red color.

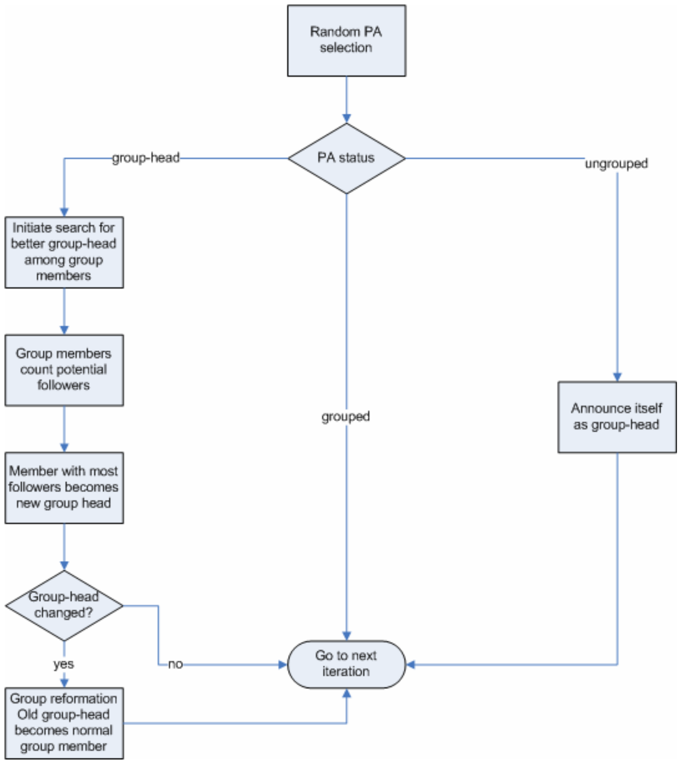

Fig. 4: ACE-I algorithm

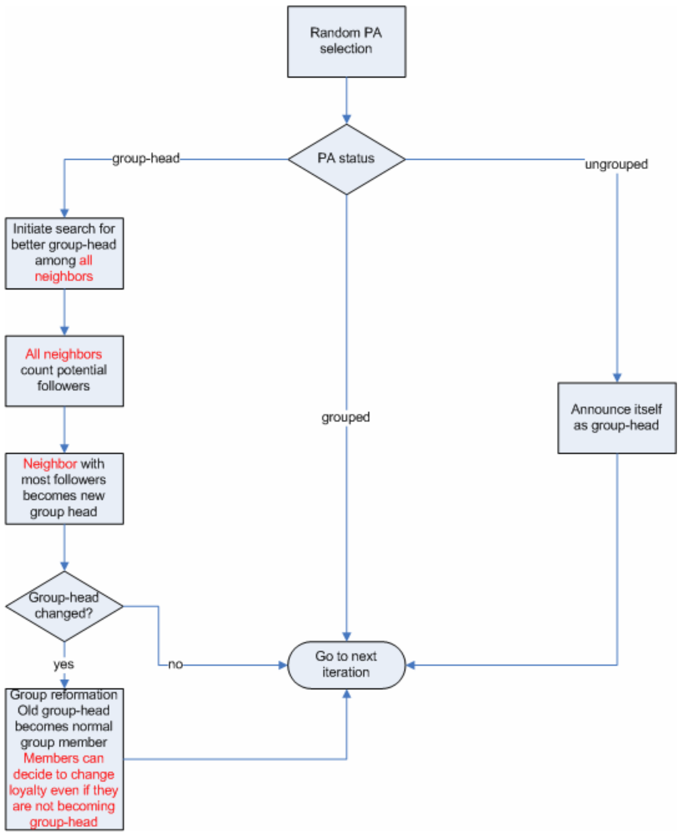

Fig. 5: ACE-IIa algorithm

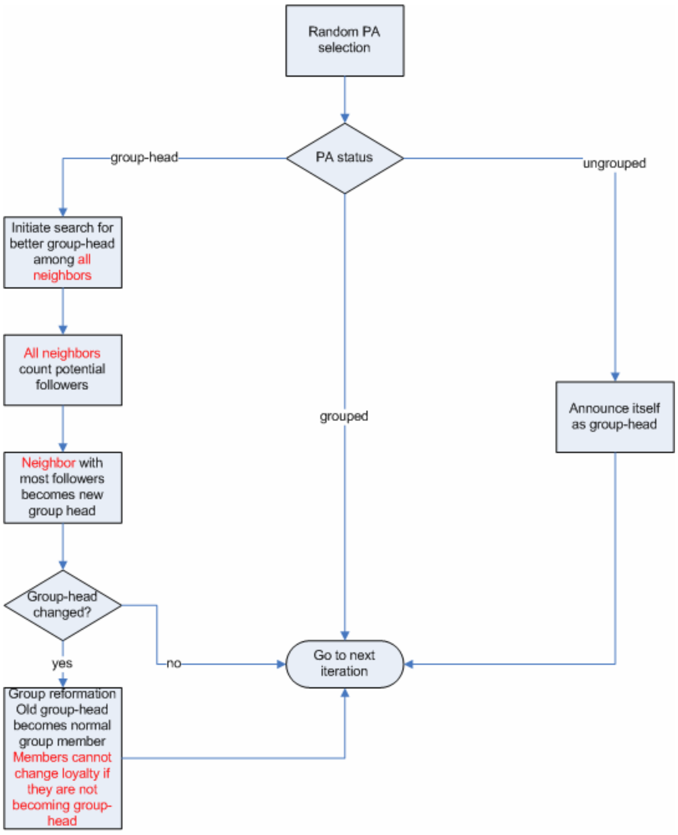

Fig. 6: ACE-2b algorithm

VI. RESULTS

The figures 7, 8 & 9 depict the resultant sub-clusters formed by the respective algorithms. The dark colored PA implies group-heads (sub-cluster-heads) and the light colored as their loyal members.

As observed the resultant groups (sub-clusters) formed by ACE-I are three groups with one PA remaining ungrouped, refer Fig. 7 whereas the algorithms ACE-IIa and ACE-IIb result in two groups (same) but the number of action points/computations in ACE-IIb is one more compared to ACE-IIa, as shown in Fig. 8 and 9.

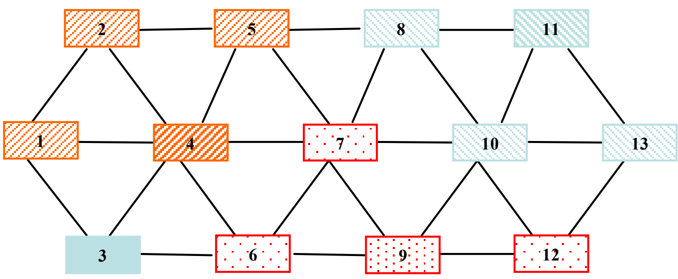

Fig. 7: Simple scenario: ACE – I

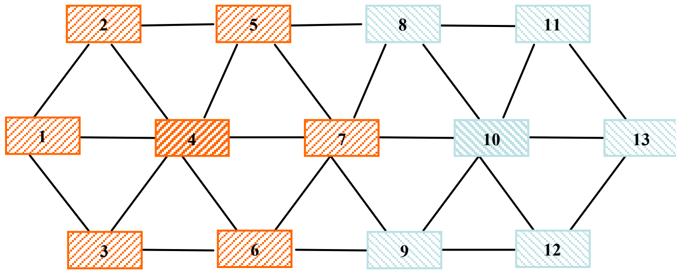

Fig. 8: Simple scenario: ACE – Iia

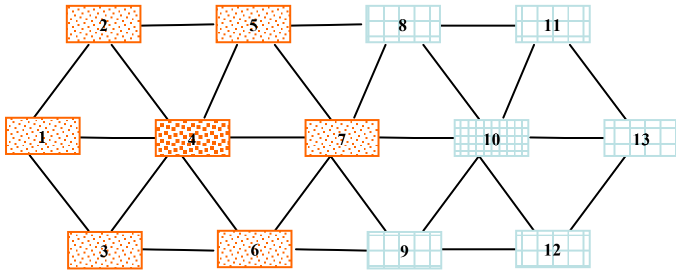

Fig. 9: Simple scenario: ACE - IIb

The random sequences in which the PAs are selected in each case are presented in Table 1. It can be observed that the action is only taking place for those selected package agents, which are group-heads or ungrouped. These package agents are represented in bold font in Table 1. For ACE-I the number of action points (selected PAs) are 11 and for ACE-IIa and ACE-IIb the number of action points is 8 and 9 respectively.

Thus, to speed up the process, PAs should be selected from the set of ungrouped or group-head PAs only rather than from the complete set of PAs. Hence, it can be concluded that the proposed algorithm performs better to the original algorithm.

TABLE I
SEQUENCE OF SELECTED PACKAGE AGENTS (SPA)

ACE –I	**SPA‘s Sequence:** **2 11 9** 5 8 **9 2 6** 3 3 5 12 12 **11** 8 3 13 7 8 **10** 6 2 8 10 **9** 8 **4 6** 13 4 (30 iterations)
ACE – IIa	**SPA‘s Sequence:** **2 11 9** 5 8 **9 2** 6 3 3 5 12 12 **11** 8 3 13 7 8 **10** 6 2 8 10 9 8 **4** 6 13 4 (30 iterations)
ACE – IIb	**SPA‘s Sequence:** **2 11 9** 5 8 **9 2 6** 3 3 5 **12 12 11** 8 3 13 7 8 10 6 2 8 10 9 8 4 6 13 4 (30 iterations)

VII. Conclusion and Outlook

The method of clustering logistic entities can be advantageous in many folds. The selected cluster-head acts as an information pool for its cluster and hence brings the information near the package agents, reducing the latency and bandwidth demand. The optimal selection of the cluster and cluster-head goes a long way in reducing communication as well as transport costs on the whole. Though in the initial stages of cluster formation, there is a need of substantial communication, once the clusters are formed and a cluster-head is selected, there will be a reduction in the amount of communication as the logistic autonomous entities like vehicles only need to communicate with the cluster-head instead of all the individual packages.

The method of clustering can increase the profit margin of the organization due to the planned organized movement of vehicles for load collection based on the knowledge of clusters of packages formed for different destinations. This can also aid the routing problem giving a better option for the vehicle to take an appropriate route based on the clustering done. On the way, the vehicle can pick and drop packages as well if the packages and vehicles negotiate in an optimal way. The algorithm presented offers a method of effective clustering with limited communication overhead.

This study of clustering logistic entities along with software agents presents a demonstration of integration of knowledge management approaches with multi-agent systems in research related to logistic distribution and transportation.

The future research will be focused on extending the deployment of clustering algorithms based on criteria such as type, priority, lifetime, etc and thereby handling more dynamics like the cluster-head migration based on the transportation of the package. This approach will be investigated by simulation in the near future in close relevance with the transport routing problems, expecting a significant improvement in communication efficiency by improving the communication between the different transport logistic entities through the deployment of software agents. More of the future work would also be justifying the efficiency of this approach with some quantitative analysis.

Acknowledgement

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