A Multi-Agent Information System Architecture for Multi-modal Transportation

Jihane LARIOUI
Laboratory LIMSAD, HASSAN 2 University Faculty of Science Ain Chock
Casablanca, Morocco
jihane.larioui@gmail.com

Abdeltif ELBYED
Laboratory LIMSAD, HASSAN 2 University Faculty of Science Ain Chock
Casablanca, Morocco
aelbyed@gmail.com

***Abstract*— Nowadays, we are witnessing a significant growth in terms of demand for public transport and the need for travel. This is due to an increase in population density, traffic congestion, lack of information and all the problems that the transport network is facing. Following the reasons cited, the movement of travelers is becoming increasingly difficult. Indeed, as soon as the trip requires the use of one or more services of a transport operator, the planning of the trip requires the traveler to collect the necessary information on the various websites of the transport operators concerned. The objective of this work is to develop an architecture of an information system for multi-modal transport, based on the notions of agents, in order to provide the users with the optimized route to follow and to avoid the consultation of several transportation websites to plan the trip. In addition to this, the system is based on the notion of multi-objective optimization to combine the different modes of transport and satisfy the different criteria such as minimization of the travel time and the number of correspondence between stations.**

***Keywords*— Information system, Multi-Agent system, Multi-Agent Architecture, Multi-modal itinerary, Multi-objective optimization, Trip planning.**

I. Introduction

In multimodal transport, users use at least two different types of transport to reach their destination. Therefore, multimodality refers to the optimal use of different modes of transport. Hence, the need to have a system providing information on departures, routes and traffic conditions before and during the journey in real time [2, 4].

The traveler wishes to have accurate information according to his personal criteria. He can search for this information himself, but it makes the traveler's orientation more complicated.

Several researchers and industrialists have been involved in the development of multimodal information services and systems not only to improve the comfort of travelers but also to encourage people to use public transport to preserve the environment from pollution and also to address the problems of traffic congestion and urban traffic.

The information system we present is based on a multi-agent architecture to associate user requests with information stored in database of transport operators. It chooses the modes of transport to be combined and provides itineraries responding the requests while optimizing travel time and number of correspondences. Our multi-agent architecture takes the paradigm of multi-agent systems [4] improving the association of transport operators, route calculation by a multi-objective optimization algorithm and the management of user preferences. The user will avoid consulting several transport Web sites to plan his personal trip [5, 8] since he can express his preferences between different modes of transport and define a decreasing order of priority with several criteria such as time, number of correspondence, cost and security.

II. Multi-Agent Information System : Adopted Strategy

In literature, agent-based information systems are commonly referred as Advanced Traveler Information Systems (ATIS) [10]. Indeed, traveler's information is by origin a complicated information. This information usually relates to the route itself and is always relative to the traveler. The latter plans his trip according to his own needs, criteria and preferences. As a result, the paradigm of multi-agent information systems for personalization, collection and integration is an effective way to address the problem of multimodal traveler information.

In order to create our multi-modal information system based on a multi-agent architecture, the system to be developed must reach different data sources and integrate the results generated by a multi-objective algorithm for route calculation. We suggest designing an agent-based information system that can find the source of information needed to meet the diverse users' requests. It should also be able to produce a real-time optimized multimodal information and calculate the itinerary.

It would be good to know that the exploitation of the multi-agent approach in information systems favors the collaboration of different entities in order to find the solution which is, in our case, the multimodal information to assist the traveler during his trip. In other words, an optimized multi-modal itinerary.

Our system must access the database of the different transport operators and integrate the results generated by different agents that make up the system to meet the demands of users. In this study, we consider a category of agents that refers to the same transport operator. In this category, each agent represents a transport line of a specific operator and uses his information. This approach will allow us to highlight the effectiveness of the algorithms used during the calculation. As a result, the problem of finding a itinerary between two stations belonging to different operators amounts to identifying the agents concerned and combining several itineraries sought by different operators.

Hence, our system will act on one side as a middleware connecting the client and the different data sources on the other side. It must be able to find the right source of information to query based on the queries of different users and collect information in a meaningful way to provide answers to these queries. It would propose the optimized itinerary to users through different linked agents to different lines of each operator. We are initially forced to find the shortest itinerary on the basis of a single criterion, which is time.

III. The Multi-Agent Information System: Suggested Architecture

The Figure Fig. 1. shows the architecture of the multi-agent system that we propose.

First, the user sends his request, specifies his departure and arrival stations, then, defines his preferences according to a descending order of priority with several criteria such as time, number of correspondence, cost and security.

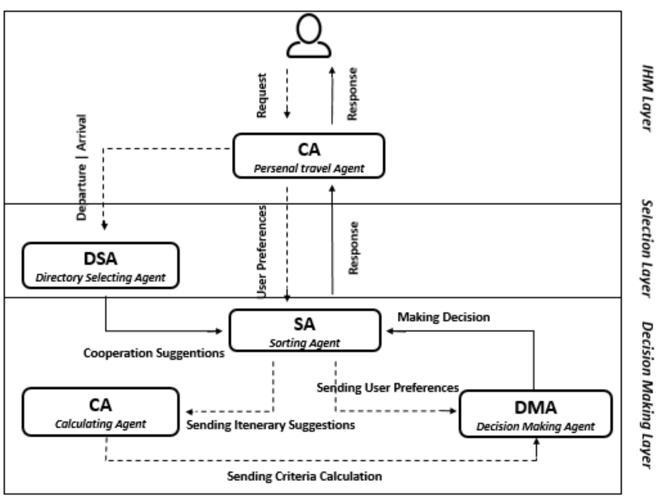

Fig. 1. Multi-Agent Information System Architecture

The PTA agent receives the request and splits it into two sub-requests: the first sub-query concerns only departure and arrival of the user, this one is sent directly to the DSA agent as for the second concerns his preferences, which is sent to the agent SA.

As soon as the DSA agent receives a request, it queries the different Category Agents to specify the IA agents that will work together to respond to the request of the user. Thus the Category agents return to the DSA agent the IA agents respectively corresponding to departure, arrival and correspondence stations. The DSA agent executes its selection algorithm based on Dijkstra's shortest path algorithm to form several agent groups. Each group is composed of IA agents linking the starting and the ending points. Then, he obtains a set of itineraries and transmits them to the agent SA. The latter bases these itineraries to calculate the final itinerary according to the preferences of the user. Indeed, the CA also calculates for each proposed itinerary the necessary parameters for making decision and sends them to the DMA agent. This one is based on the table generated by the CA agent to then apply the TOPSIS method finally choose the itinerary that satisfies user criteria.

The DMA agent then sends the response (the chosen itinerary) to the SA agent who will send the information to the PTA agent to finally respond to the use.

IV. Organization of the Multi-Agent Information System

In order to highlight our approach, we propose in this article a first conception of our multi-agent architecture. In this architecture, we have six types of agents.We present in the following the different types of agents that make up this architecture.

A. Personal Travel Agent (PTA)

Its main task is to accompany and assist the user, this collaboration and communication between the agent and the user makes it possible to better guide the execution of the different delegated tasks. Thus, we call it Agent PTA "Personal Travel Agent". The PTA makes it possible to better formulate the requests and consequently to better orient the field of research from the beginning.

This type of agent is adaptive and has a great learning ability. Based on a memorization of the behavior of the user facing the system, the query history of the latter and the set of preferences required for each connection, this agent manages to integrate into his own knowledge base a model of the user.

B. Information Agent (IA)

This agent is able to search, collect, integrate and manipulate information from different data sources. He can adapt his research techniques and criteria according to the needs of the user. Indeed, this agent shows a great autonomy. It is able to launch its research or information gathering activities in an autonomous way.

We have used this type of agent for several reasons, including the difficulty of accessing information from different transport operators, so it is better to have access to this information directly from our database.

Our approach is to create a category agent CA^mthat groups together several information agents (IA) and to associate each information agent (IA) with a carrier line of an operator particular.

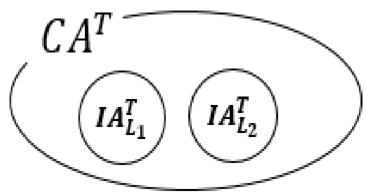

Fig. 2. Category Agent For Tramways Operator

For example, as we can see in Fig.2. , we have a category agent for Tramways CA^T that contains two information agents $IA^T_{L_1}$ and $IA^T_{L_2}$. The main role of the agent $IA^T_{L_1}$ is to extract the information relating to line 1 of the tramway, as for the agent $IA^T_{L_2}$ he deals with line 2 of the same operator.

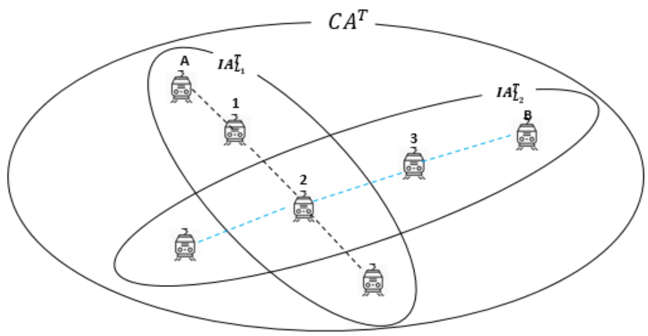

Fig. 3. Associated Information Agents in a Category Agent

Indeed, the IA has the protocols and functions that allow it to send requests and receive responses. The agent structure remains the same for all operators. In addition, each agent is responsible for his transportation network, otherwise he can respond to a request for a route if his place of departure and arrival are included in the area administered by the agent. He therefore has limited knowledge of the global network. Thus, in response to a request spread over several lines, the information agents responsible for the various operators involved must cooperate to provide the result.

C. Directory Selecting Agent (DSA)

The directory selection agent (DSA) has a complete and prior knowledge of all the IAs present in the global multi-agent information system.

Indeed, it has a list of different information agents detailing their crossing stations with other operators. Therefore, this agent has the different possibilities of cooperation between the different information agents Fig. 4.

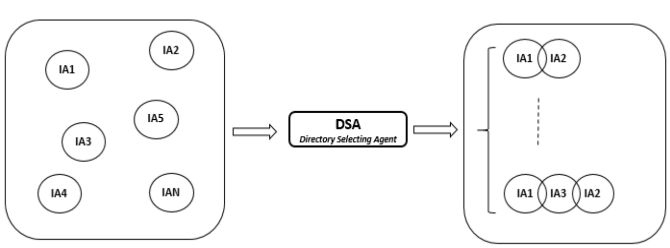

Fig. 4. Set of associated IAs made by the DSA

The main role of this agent is to define the search domain by specifying the end agents according to the request of the user (Start / Arrival) and then to suggest a set of groups of agents who will cooperate together to help a selection algorithm based on the shortest path algorithm (Dijkstra). The Fig. 5. explains the process of the DSA agent in the constitution of cooperative IA agents. Hence, each proposed group is a group of agents representing the path from the departure station to the arrival station.

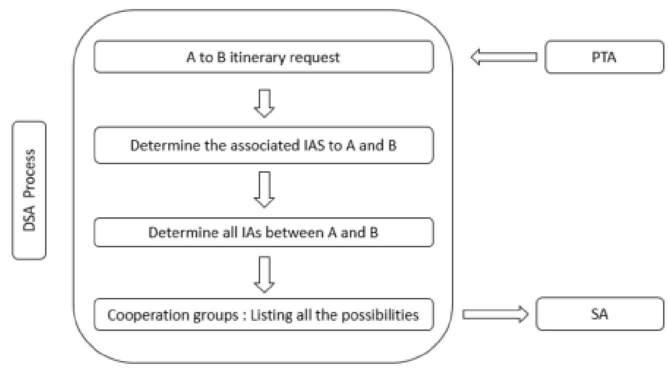

Fig. 5. Directory Selecting Agent Process

D. Sorting Agent (SA)

The main role of this sorting agent is to examine the different routes proposed by the DSA and to decide how to treat them according to user preferences. For this, the SA delegates the route calculation part to the CA agent and the decision-making part to the DMA agent and then sends the response to the PTA agent.

E. Calculating Agent (CA)

This Calculation Agent (CA) is based on the different itineraries that have been proposed by the DSA to calculate the final itinerary based on user preferences.

Indeed, the CA agent calculates for each proposed itinerary the corresponding travel time, the number of mode changes made, the cost to pay and the security rate, to finally generate a table Table 1 and send it to the DMA agent.

TABLE I. TABLE GENERATED BY THE CA BETWEEN TWO STATIONS A AND B

Itinerary	*Time*	*Cost*	*Number of mode changes*	*Security*
Case 1	30 min	8	2	2
Case 2	45 min	5	1	3
Case 3	17 min	13	3	1

After having received all the possible IA agent cooperations, the CA agent lists them in the form of several cases and examines for each case the travel time, the number of mode changes, the cost and the security.

Indeed, security is a very important criterion to which the traveler is very interested. We opted for a rating of this criterion under an evaluation scale Table 2. However, in the real world, there are modes of transportation and areas in the city that are much safer than others are.

Thus, according to the modes of transport used and the geographical location of the different stations that compose the route in each case, the CA agent gives a note for the security for each route.

TABLE II. SECURITY SCALE

Scale	*Mentions*
1	Very Good
2	Good
3	Not Good

Finally, the CA agent generates a table Table 1. that contains the various parameters calculated for each criterion and route and sends them to the DMA agent.

F. Decision Making Agent (DMA)

This decision-making agent is based on the table generated by CA to then apply the TOPSIS "Technique for Order of Preference by Similarity to Ideal Solution" method as a MCDM method to facilitate decision-making and ultimately to choose the itinerary that will satisfy the user's preferences.

TABLE III. TABLE GENERATED BY DMA AGENT

Itinerary	*Time*	*Cost*	*Number of mode changes*	*Security*	*Results*
Case 1	30 min	8	2	2	**60%**
Case 2	45 min	5	1	3	**10%**
Case 3	17 min	13	3	1	**30%**

The results are interpreted in the table above Table 3. as a percentage. Thus, the itinerary with the highest percentage is the most satisfying user's preferences.

V. CONCLUSION

Using a multi-agent technology for the development of an intelligent information system for urban mobility was our approach in this article to address the problems of passenger travel.

The proposed multi-agent architecture is efficient, flexible, designed to easily be adapted and to manage disturbances in the transport network.

In this context, our architecture remains open to include new modules to develop other interesting aspects and can be improved in our future work.

However, this work points the way towards a very promising research perspective, especially, the study of the selection algorithm used by the DSA agent to build the set of information agents that will cooperate, the calculation of the itinerary used by the CA agent as well as the MCDM method used by the DMA agent. These lines of research will be the subject of a rather deep study in our next scientific contributions

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