computing@tanet.edu.te.ua
www.tanet.edu.te.ua/computing

International Scientific
Journal of Computing

ISSN 1727-6209

TRAFFIC CONTROL ASSISTANCE IN CONNECTION NODES[1]: MULTI-AGENT APPLICATIONS IN URBAN TRANSPORT SYSTEMS

Hakim LAПCHOUR[1], Salah MAOUCHE[2], Renй MANDIAU[3]

1) Ph.D. Student, Laboratoire d'Automatique I^{3}D (Universitй des Sciences et Technologies de Lille) Citй scientifique Bвtiment P2 59655 Villeneuve d'Ascq CEDEX France,
hl@i3d.univ-lille1.fr.
2) Professor, Laboratoire d'Automatique I^{3}D (Universitй des Sciences et Technologies de Lille) Citй scientifique Bвtiment P2 59655 Villeneuve d'Ascq CEDEX France,
sm@i3d.univ-lille1.fr.
3) Professor, LAMIH (Universitй de Valenciennes et du Hainaut Cambrйsis Le Mont Houy) –
B.P. 311 59304 Valenciennes Cedex France,
Rene.Mandiau@univ-valenciennes.fr

Abstract: *In this paper, we propose a model for the transport system based on a Hierarchical Multi-Agent System (HMAS). This model can be used in order to design a Decision-Support System (DSS) to facilitate the work of the regulator by proposing him various regulation actions in every connection node (SARC[2]: Systume d'Aide a la Rйgulation des Correspondances). An optimal organization of the connections is suggested, in normal or disturbed conditions, to avoid loss of time for the passengers. Our model includes a supervisor agent (interface), a connection agent (decision) for each connection node and an acquisition agent (perception) for each regulation station. In our research, we have used Multi-Agent Systems (MAS) which adapt themselves perfectly to the distributed systems as in the urban transport networks.*

Keywords: *Modeling, Urban Transport Network, Hierarchical Multi-Agent System, Connection Node and Supervision.*

1. INTRODUCTION

The exploitation of an urban transport network is more complex when the evolution of the means of transportation is strongly dependent on the conditions of traffic. The disturbances are numerous and entail important delays.

To respect best the theoretical schedules announced to the customers, the operator must insure a real time regulation in the network. The regulator is equipped with the Automatic Vehicle Monitoring system (AVM) which provides the data in real time of the network **[1]**. But the incidents are numerous and the regulator is sometimes overloaded with information which he can't treat due to the lack of time or experience. In front of numerous disturbances in the urban transport networks, the regulators find difficulties discovering the situations with problems (disturbances) and the relevant decisions to resolve these incidents.

Our objective is the minimization of the waiting times of the users of the urban transport networks in normal mode or in disturbed mode. We are interested particularly in the regulation of traffic in the connection nodes, the regulation isn't taken into account by the AVM system (Automatic Vehicle Monitoring).

The connection is a pole of exchange of passengers between two identical means of transport (bus/bus, train/train, …) or different means of transport (bus/tramway, bus/train,…). The connection is defined by a connection space and a connection time. The connection space is the place where the exchange of the passengers will be made. But the connection time is the date or the moment in which this exchange will be carried out. The connection is space-time by definition.

The main objective of our work is to elaborate a Decision-Support System (DSS) to facilitate the regulator work by proposing him various relevant regulation actions in every connection node.

The appearance of Multi-Agent System (MAS) paradigm have open serious perspectives to design and to build complex knowledge-based systems with best performances. Our research uses Multi-

[1] *Project financed by GRRT (Groupement Rйgional pour la Recherche dans les Transports) and the FEDER (Fond Europйen du Dйveloppement Et de la Recherche) entitled: "Improvement of the passengers movements quality in the urban transport network". Universitй des Sciences et Technologies de Lille (USTL).*
[2] *System of Assistance at the Regulation of the Correspondences.*

Agent Systems (MAS) which adapt themselves perfectly to the distributed systems as in the urban transport networks. An optimal organization of the connections is necessary, in normal or disturbed conditions, to avoid loss of time for the passengers when they should move from a station to the other by changing means of transport.

2. REPRESENTING OF A TRANSPORT SYSTEM

In our research, we succeeded in representing an urban transport network by a connected graph composed of a set of connection nodes connected by the lines of the urban transport system. Every line consists in a set of stations of three kinds: simple, regulation and terminal stations. The displacement of a node towards another is done directly or indirectly while passing at least by another node of connection.

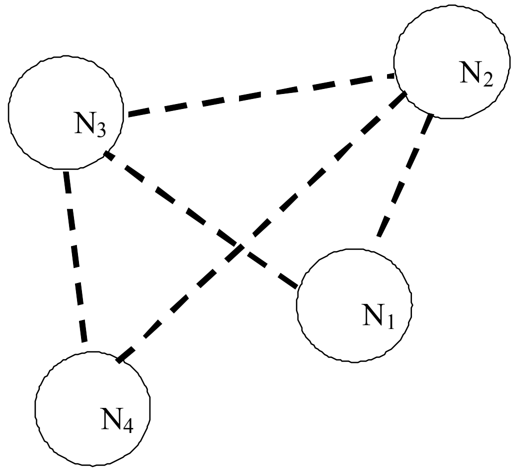


Fig.1 - *Representing of an urban transport network*

In the Fig.1, The N_i represent the connection nodes of the urban transport network. In this representation of the transport network, two kinds of regulation are considered:

– The micro-regulation: it consists in regulating the traffic at the level of a connection nodes (local regulation). The disturbance is resolved within a connection nodes to find it the relevant decisions (local decisions) without taking into account the whole network (others connection nodes).

– The macro-regulation: this kind of regulation, it take the relevant decisions found for the connection node perturbed in order to calculate its effects on the transport network.

The connection node is in fact defined as a point of the space. The buses bringing the passengers to this point represent the entrance stream and the taking buses form the exit stream.

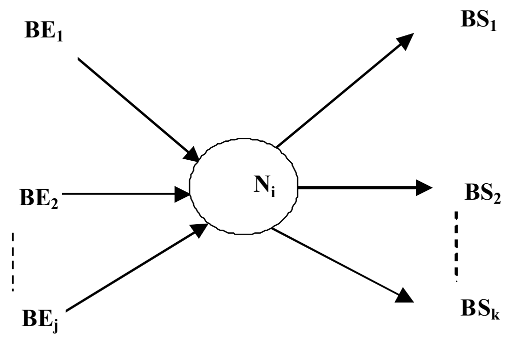


Fig.2 - *Representation of a connection node in the space*

In the Fig.2, we have one connection node N_i, the $BE_{1..J}$ represent the entrance streams and the $BS_{1..K}$ represent the exit streams.

Our System of Assistance to the Regulation of the Connection (SARC: Systиme d'Aide a la Rйgulation des Correspondances) is used, in case of disturbances, in order to propose to the regulator the relevant solutions and to keep the good functioning of the traffic within a connection nodes. This intervention will be realized exactly more in the lines bringing to the connection node.

The process of assistance to the regulation at the level of a connection node is based on the simulation of the functioning of the network to insure its supervision **[2]** and to foresee the disturbances (monitoring). To realize this simulation, the departure of every connection is advanced by some minutes. This anticipation (simulation) will allow to determine the state of the connection node at the actual moment of the departure of said connection. In case of disturbances, our system (SARC) determine and suggest a set of decisions to undertake to the regulator for the traffic control within the connection node. In the time, several simulations can be realized within a connection node with temporal windows on different horizons of some minutes because it can have several connections in a connection nodes anytime.

The simulation within a connection node allows the determination of the relevant actions in this node (local decisions) for the traffic control. The simulation within each a connection node allows to have local decisions and for each decision, it is necessary to determine its effects on the all network, in particular on the other connection nodes. In every simulation within a connection node, SARC determinates the state of the network by applying the decisions chosen for this connection node. The decisions and the state of the network are then presented to the regulator so that it chooses the decision which seems to him relevant.

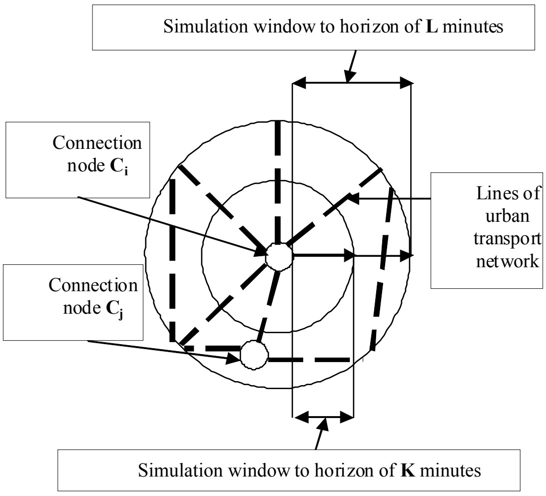


Fig. 3 - *The macroscopic representation of a connection nodes in the time*

3. MODELING AGENTS

The Distributed Artificial Intelligence (DAI) allows the construction of autonomous entities (called agents) collaborating in the resolution of problems.

An agent can be an autonomous entity able of acting on itself and on its environment **[3]**. The agent behavior is the consequence of their observations, their tendencies, their representations and their interactions with the environment and the other agents. The agents act and modify their environment by their actions. There are three kinds of agents: reactive, cognitive and hybrid. This last kind of agents combines the properties of the reactive agents and the cognitive agents. These three kinds of agents distinguish themselves by the structure of their knowledge. The cognitive agents are characterized by a strong or average structure, a model of representation of oneself and the others and a bigger capacity of reasoning. On the other hand, the reactive agents have of weaker structure, don't arrange model of the others. Their mechanism of reasoning is primitive often of the kind stimulus - answer.

The multi-agent approach is adapted to the urban problems of transport network management. The distributed and parallel character of paradigm multi-agent allows **[4]**:

– to describe the complexity of the evolution of a transport system, by structural analogy.

– to decompose a problem into simpler elements, easier to resolve (reduction of the complexity in a little formalized domain).

– to realize a better coupling of spatial systems in Geographic Information Systems (GIS).

– to insure the resolution of problems by a simulation.

The geographic distribution of a transport network allows a representation by a system multi-agent. We proposed (by basing itself on the representation of the network in the figure Fig.1) one modeling multi-agent organized into a hierarchy **[5][6]** (HMAS: Hierarchical Multi-Agent System). This modeling includes:

– a supervisor agent (interface) is charged of the dialogue with the regulator.

– connection agents, one by node.

– acquisition agents, one by regulation station.

Each agent has a role in this hierarchical multi-agent modeling.

The acquisition agents are responsible for the reception, which consists in recording the dates of buses passages in the regulation stations, as well as the different information concerning them (example: number of descending or rising passengers).

The connection agents ensure the follow-up of the functioning of the urban transport network in order to detect the eventual disturbances within a connection node. Each connection agent proposes a set of decisions in case of disturbances in order to keep the stability of the traffic within connection node. These decisions are validated by a cooperation (dialogue) between the concerned connection. The disturbances are detected by anticipating the connection departures of some minutes.

The supervisor agent is charged of the dialogue with the regulator.

In this modeling, the connection agents have two types of communication: horizontal and vertical communication. But the supervisor agent and the acquisition agents have only the vertical communication.

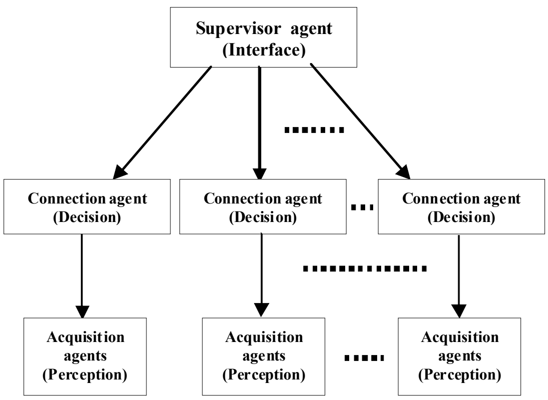


Fig.4 - *The modeling of the urban transport network by a Hierarchical Multi-agent System (HMAS)*

The cooperation between the agents is realized by the mechanism of communication. The acquisition agents pass on the information about the passages of bus to the connection agents. The connection agents ask for information from the acquisition agents and supply the decisions taken to the supervisor agent. The supervisor agent pass on the connection agent decisions to the regulator and the supervisor agent pass on them the requests made by the regulator. This communication kind is called vertical cooperation. And the connection agents communicate between them to exchange messages of information and decisions in order to avoid possible conflicts. This communication kind is called a horizontal cooperation.

Our agent model is constituted of four parts:

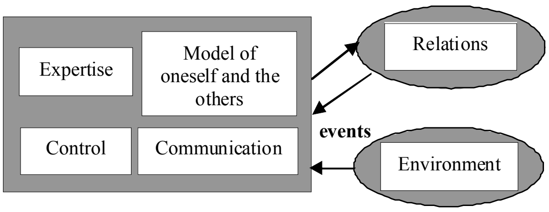


Fig.5 - ***The model agent***

– **Expertise:** This part concerns the domain of specification of the agent. Every agent has a set of methods or of rules which describe its behavior and how to realize its purposes (goals or decisions criteria), the treatment of the events, …etc. Only the connection agents have this part among others agents of model.

– **Model of oneself and the others:** An agent evolves in environment where exists also the other agents whom it doesn't know and which are called the relations. The agent has so a model of oneself and the others agents. This model allows it to represent its knowledge (its goals, its competence and its contextual information) and beliefs about the relations. This model evolves according to the messages which arrive in the agent and according to the changes of the system. Among these relations, some are static, the others are dynamic and evolve according to the context and the messages which arrive. The reagent agents (acquisition agents) do not arrange this part.

– **Communication:** The communication part allows to the agents to exchange information and results. It manages all the successful and emitted messages. In the reception of a message, the communication part warns the part controls of the arrival of new messages. As regards the emission of messages, the communication part takes care of messages to be emitted.

– **Control:** The control mechanism allows the agent to manage its internal activities. It has one limps with reception of the messages which result to it, either of the mechanism of communication (message emanating from sensors of the physical equipment or the relations), or from internal tasks which it launched.

4. THE DECISION-MAKING BASED ON SIMULATIONS

In our system SARC, various simulations **[7][8]** of the functioning of the urban transport system can be organized in every connection node: a local simulation (microscopic supervision), a simulation of departures (macroscopic supervision) and a learning simulation.

The local simulation is realized on different temporal windows fixed according to the density of the network and it allows a good local supervision of the connection node. One calls this kind of simulation microscopic supervision.

The simulation of departures allows an automatic detection of the delays, as well as a dialogue among a group of the concerned connection agents to reduce the delays. One calls this kind of simulation macroscopic supervision.

The learning simulation is realized after a request from the regulator and it can be used for the regulation learning and also training.

In this last kind of simulation, a regulation action can be simulated to determine its effects, in more or less long term, before being undertaken. The connection agent is endowed with a decision-support mechanism capable of proposing regulation actions at the level of every connection node in case of the problems.

The decision-making for the regulation, in SARC, is made at the level of the connection agents (local decisions). The decision-making is based on simulations **[9][10]**.

In the Fig.6, we represent the process the decisions-making within connection agents. In case of disturbances, the connection agents suggest the remedial decisions. Each remedial decision requires a projection in the future to determinate this consequences (prediction its effects of the transport network state). The connection agents concerned by the same disturbances communicate between them to resolve the possible conflicts **[11]**. The propagation a decisions to undertake allows the calculation of effects within a connection nodes.

The connection agent activating the simulation communicates its decisions to the others connection agents concerned in order to check the validity of these decisions. Each connection agent (receiver) simulates with the decisions received by an other connection agent to validate or refuse this decisions at the level of the sender connection agent. We This process is repeat until The deci-

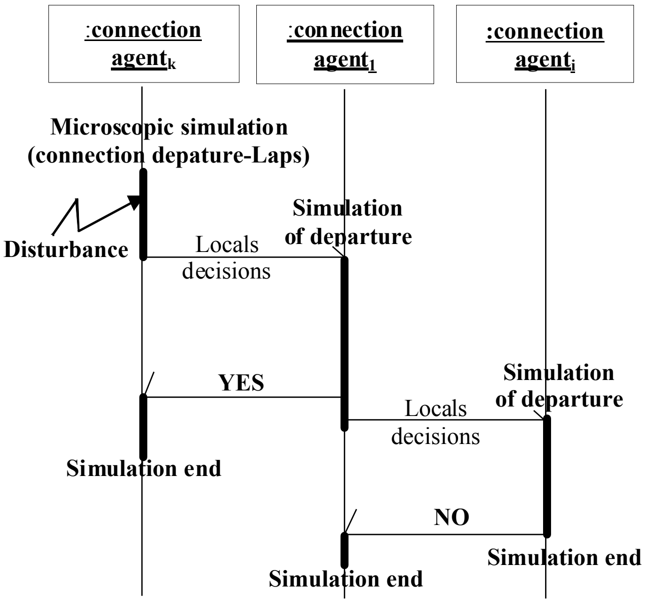


Fig.6 – *The process sequences diagram of the decisions-making within the connection agents*

sions to undertake in connection nodes, in case of validity, are communicated to the regulator through the supervisor agent.

Our agent model enable to implement three different dynamics:

– The dynamic of states bound to the agents, in particular the connection agents.

– The dynamic of the interactions or the communication between the agents.

– The global dynamic which allows the auto-organization or the forming of agents' blocks co-operating in the resolution of a program by progressive adaptation to the environment.

The agents don't all participate to the elaboration's of the decisions. Their participation depends on the kind of disturbance, the geographic place and the time. The microscopic supervisions (locals) and the macroscopic supervisions associated to a communication between connection nodes concerned allow to absorb at least, to limit, the effects of the disturbances.

5. CONCLUSION

The multi-agent approach exploits the natural distribution as well as the distribution of the knowledge and the control within the network. Therefore three reasons are gathered in the multi-agent modeling: an incomplete vision, distributed data and different treatments. The using of this approach is adapted to modeling an urban transport network.

The new aspect of our work is the prediction of the incident within connection nodes before its occurrence. Then, in order to prevent the evolution of the disturbance, the regulator can chose the appropriate decision among the proposed solutions by our decision-support tool.

The determination of the decisions is based on the thresholds of delays authorized by the regulators as well as the waiting at stations of the buses. Our system takes into account the automatic control and the diagnosis of the disturbances.

The future work on this system (SARC) go in order to improve the decision-making part in a connection agents. Various methods can be employed to conceive the decision-making process among them multi-criteria approaches and fuzzy systems.

According to the real conditions of transport, the SARC will have to allow at the regulator to simulate different decisions which he can undertake in order to calculate its effects on the transport network. This method allows to show the disturbances situations at the regulator before their production. The best decisions only and their effects on the transport network will be displayed.

The implementation of SARC is under development. We are using the C++ language for the realization. In order to validate our system, the simulations will be based on scenarios provided by the transportation company SEMURVAL[3].

6. REFERENCES

[1] M.Rizzi and A.Saporito. Systume d'information objet pour l'exploitation des rŭseaux de surface. Internal documentation of the RATP Department buses, Methods and Operational Systems. Paris, 1997.

[2] M.-K.Allouche, C.Sayettat, and O.Boissier. Towards a multi-agent system for the supervision of dynamic systems . Proceedings of the Workshop "IEEE International Symposium on Autonomous Decentralized Systems (IEEE ISADS'97)". 1997.

[3] J.Ferber. Les systumes multi-agents : vers une intelligence collective. Edition Inter Editions. 1996.

[4] F.Balbo. A Multi-Agent System for fault detection in public transportation. Proceeding of the workshop "Group Decision and Negotiation (GDN'2000)". Glasgow, 3-7 July 2000.

[1] Name of urban transport company of the Valenciennes, town in the north of France.

[5] N.Bensand and P.Mathieu. A Hybrid and Hierarchical Multi-Agent Architecture Model. Proceedings of the workshop "Practical Application of intelligent Agents and Multi-agent Technology (PAAM'97)". London-United-Kingdom, 21-23 April 1997, pp.145-155.

***[6]** N.Bensand and P.Mathieu. A Framework for Cooperation in Hierarchical Multi-Agent Systems. Mathematical Modeling and Scientific Computing. 1997.*

***[7]** M.Ben-Akiva, M.Bierlaire, H.N.Koutsopoulos, and R.Mishalani. DynaMIT: a simulation-based system for traffic prediction and guidance generation. Proceeding of the workshop "TRISTAN III'98". 1998.*

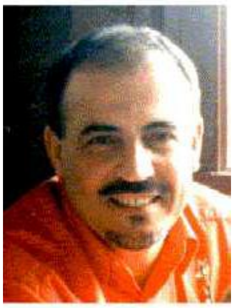
***[8]** J.C.Soulie and P.Marcenac. Environmental Simulations Using Multi-agent Systems. Proceeding of the workshop "IEEE International Conference on Information Intelligence and Systems (IEEE ICIIS'99)". 1999.*

***[9]** R.Ikni and J.M.Toulotte. Les agents et la simulation de systumes automatisůs : une nouvelle approche. APII-JESA (Journal Europŭen des Sytumes Automatisůs) Vol. 34, Number. 1, p. 63-90. February 2000.*

***[10]** K.Fisher, B.Chaib-draa and al. A Simulation Approach based on Negotiation and Cooperation between Agents: A case Study. IEEE Tans. on Systems, Man, and Cybernetics. Vol. 29, Number. 4, p. 531-545. 1999.*

***[11]** R.Mandiau and S.Piechowiak. Conflict Solving in Multi-agent Distributed Planning. Proceeding of the workshop "IEEE International Conference on Systems, Man and Cybernetics (IEEESMC'98)". 1998.*

Hakim LAПCHOUR was born in Algiers, Algeria in 1971, he obtained the Engineer diploma in Computer Science from INI (Institut National d'Informatique) of Algiers, Master degrees in Automatic Control and Computer engineering at University of Science and Technology of Lille (France) in 1998. He is currently Ph.D. student at University of Lille (Automatic Control Laboratory I3D -Interaction, Image et Ingŭnierie de la Dŭcision - FRE-CNRS-2497) in the domain of Decision-Support for the Traffic Control Assistance in Correspondence Nodes (Urban Transport Domain), using Multi-Agent Systems and the Multi-Criteria Approaches (MCA).



Dr Salah MAOUCHE was born in Algeria in 1952. He is Engineer graduated from ENPA (Ecole Nationale Polytechnique d'Alger). He obtained the Ph.D. thesis in Automatic Control of the university of Lille in 1982 and his DSc of the same university in 1995. He is currently professor at UST Lille (Universitŭ des Sciences et Technologies de Lille) in Automatic Control (France) and he is responsible of the Decision Engineering group of the automatic control laboratory I3D (Interaction, Image et ingŭnierie de la decision) of the university of Lille. His research deals with optimization and decision making and he attempts to apply to transportation and conformal radiotherapy problems.

Dr Renŭ MANDIAU is professor of University in Computer Sciences at LAMIH (Laboratory of Human and Industrial Automation and Mechanics), University of Valenciennes (France). His research deals with multi-agent systems. He attempts to apply its principles on the transportation problems and administrative process. He has received the Ph.D. Thesis in 1993 and his HdR (French diploma for becoming Professor of University) in 2001. The Ph.D. Thesis aims to study BDI (multi-modal logic for Beliefs-Desires-Intentions) models for cooperating agents; the HdR works speak about the models of multi-agent (re-)organizations.