Traffic controlling in unpredictable environment using multi agent systems

DMNCS Dissanayake[1#], ADAI Gunasekara[1] and B Hettige[1]

[1] General Sir John Kotelawala Defence University, Sri Lanka
[#] DMNCS Dissanayake; niroshanac@gmail.com

Abstract— *With the developments taking place in every area, life has become fast-paced journey making time is one of the most important factor. Transport sector has not been left behind on this scope of development. Technologies used in transport have been of great assistance to human kind, but have generated their own challenges. Traffic jam, accidents, congestion and pollution are some of the economic losses due to those challenges. When considering the challenge of road congestions, the intersection traffic management, contribute critically to this phenomenon. Almost all the intersections in Srilanka are operated through pre-timed electronically controlled traffic lights. These pre-timed traffic lights operating from one intersection, perform their duties at that specific intersection; and yet, their coordination to the corresponding traffic lights in a neighbouring intersection is very ineffective, thus leading to the deployment of traffic police officers to regulate the traffic. It will be a wastage of manpower as well as considering a dynamic situation as static. This project use multi-agent based framework to model the situation as dynamic in nature, to resolve this unpredictable traffic congestion situation. Project has been designed and implemented as a framework, which serves to monitor the changing traffic situation and copes the traffic according to density and wait time of vehicles. This framework tries to compare wait times, compare traffic density of lanes and release each lane accordingly. Project uses JADE development framework and Prometheus methodology in forming the agent based solution. It offers stage-by-stage requirement for the system design and code guidelines to make sure system specifications are met. This framework offers features of observe-think-and-act model. It ensures coordination of traffic during the complete process of movement. If the system is fully implemented, seeks to benefit the road users that, thereby increasing the uptake of agent technology in giving solutions to complex and dynamic matters.*

Key Words- Agents, Multi-Agent Systems, Traffic Congestion, Intersections.

I. INTRODUCTION

In recent years, the transport industry has been facing challenges in respect to time spent waiting on the roads. This could be a result of the situations like unfavorable weather conditions, busy hours, road maintenance accidents or incidents etc., leading to congestion of vehicles on the roads. Over the years, growth in population and economic prosperity in urban areas has resulted increased purchase of automobiles in urban areas. Hence increasing the number of vehicles on the roads. The United Nations Population Foundation published in its technical report (UNFPA, 2007) that, more than half of total population of the world lives in urban areas. Therefore, drivers and passengers spend major percentage of their day locked in traffic. The technical report published by Texas Transportation Institute (Schrank, D. et al., 2012) exposed that in 2011 traffic congestion cost a $121 billion annual drain on U.S. economy, of which 5.5 billion hours of extra time and 2.9 billion gallons of fuel spent in the traffic. A massive amount of time that could be spent on productive actions is wasted on the roads, resulting into enormous costs on fuel among other challenges.

For efficient managing of the traffic at intersections according to the varying traffic conditions, this project put forward a multi-agent approach for traffic light control in two traffic intersections. It aims to introduce agents at each intersection to control traffic and replace the pre-timing of the traffic lights. The aim is to reduce waiting time at each intersection. This goal is to be attained by an agents observe-think-act process. That is, the agent constantly observes the prevailing traffic condition by gathering traffic data, and the data is then used for reasoning with the traffic-light-control rules by the agent's inference engine to decide how a signal will be altered on each traffic light at each intersection, so that the traffic can be controlled in most efficient and effective way.

A number of cities have come up with interesting approaches to reduce traffic congestions. One way is to make the traffic control mechanisms more intelligent, and let them cope with the complexities of managing the traffic control instrument to the prevailing situation. Additionally, several studies have been carried out on intelligence control of transportation traffic over the years. It is therefore beneficial to come up with better-automated and

intelligent means that are responsive to the varying conditions that in effect, make better use of the existing infrastructure to deliver efficient flow of traffic.

II. METHODOLOGY

In the development of multi agent systems, different set of methodologies followed. According to (Giorgini and Henderson-Sellers, 2005), the methodologies include ADELFE, Tropos, PASSI, Prometheus, MAS-CommonKADS, Gaia, MESSAGE, RAP, INGENIAS, and MaSE. All of the mentioned methodologies provide unique and valuable approaches, viewpoints and contributions to support in the development of agent based applications. Therefore, this project is to be built using Prometheus, which is one of the above mentioned Agent Development Methodologies.

According to (Padgham, L. and Winikoff, M., 2004), Prometheus methodology has been developed over the last few years in partnership with Agent Oriented Software (OSA). Prometheus is detailed and complete in the way of covering all steps required in developing intelligent agent systems. The key reason for using Prometheus in this project is that it varies from existing methodologies in the ways such as it backs the development of intelligent agents, which are using goals, beliefs, plans, and events. In contrast, most of other methodologies consider agents as simple software processes those who interact with each other to accomplish an overall system goal, it delivers 'start -to- end support' (specification to detailed design and implementation) and a detailed process, it also provides hierarchical structuring mechanisms allowing design to be implemented at multiple levels of abstraction. Such mechanisms are critical to the practicality of the methodology on bulky designs and at last it uses an Iterative process instead of a linear 'waterfall model', therefore can involve a combination of activities from different stages with a changing focus.

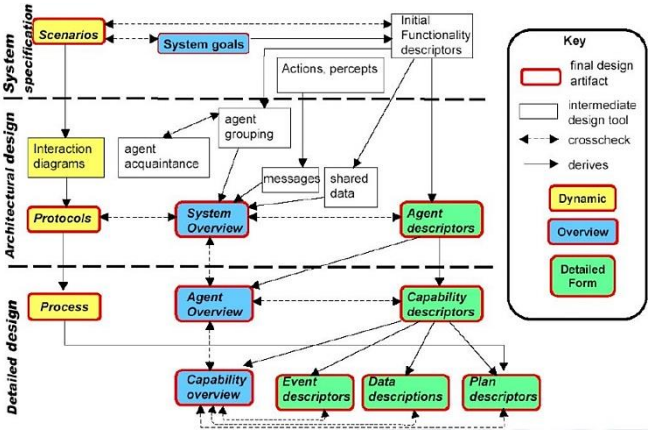

Figure 1. The Prometheus Methodology

The Prometheus methodology contains three major steps: System specification phase, architectural design phase and detailed design phase. system specification phase focuses on identifying the basic functionalities of the system, alongside the inputs (percepts), outputs (actions). It forms the system's environment model, recognizes the objectives and defines key use case scenarios. Architectural design phase utilizes the outputs from the earlier phase to decide the agent types, design the general system structure, and define the interaction between agents. Detailed design phase is the final phase. It analyzes the internals of each agent, and how it will undertake its tasks inside the system. This step emphasizes on defining internal events, capabilities, plans and detailed data structure. In verification, testing and results justification phase, it discusses system agent's verification and validation testing, generating data based on the test scenarios. The testing action has been separated into two different steps: the first test is to verify the pre-timed traffic lights performance with regards to the vehicular density on roads and the second test is to verify agent controlled traffic lights performance with regards to the vehicular density.

III. EXPERIMENTAL DESIGN

Implementation of the Multi Agent System has been achieved through the creation of seven models obtained by performing twelve iterative and sequential activities. They are discussed in the section below. The conceptual model of the proposed solution is as below; the model comprises the Agent A and B: In charge for monitoring the queue length and waiting time of the roads joining the intersection; Share traffic data; change traffic lights. Intersections A and B consists of traffic lights, which emit Red/Yellow/ Green lights to provide direction to vehicles.

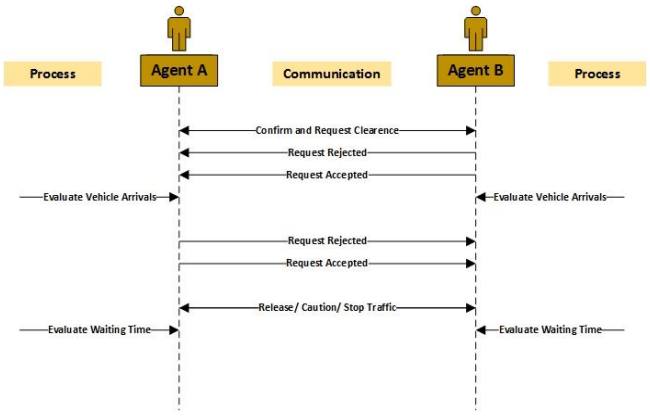

Figure 2. Conceptual Model of the System

Implementation of the Multi Agent System has been achieved through the creation of seven models obtained by performing twelve iterative and sequential activities. They are discussed in the section below. The conceptual model of the proposed solution is as below; the model comprises the Agent A and B: In charge for monitoring the queue length and waiting time of the roads joining the intersection; Share traffic data; change traffic lights. Intersections A and B consists of traffic lights, which emit Red/Yellow/ Green lights to provide direction to vehicles.

A. systems specification model

The systems specification model includes four different activities and produces a description of the functionalities necessary from the system and division of them according to the agent pattern. Different activities are defined as use case description- in this case, we demonstrate the functionality of the solution by means of a conventional use-case diagram. System goals- system goals starts from the use-case diagram of the previous step.

B. Architectural design model

The architectural design model determines the various functional areas of the road intersection and then decide the value of the relationships between each function. Protocols offers a planning to each of the agents to evaluate proposals and generate counterproposals. As stated by the FIPA architecture, an Agent Interaction Protocol is used for each communication.

C. Detailed Design

The detailed design phases contain the internal structure of each and every agent. It also concentrates on the implementation of the functionalities contained in the internal modules. The requests/proposals are obtained from the adjacent agent; evaluation of the request/proposal is done by monitoring its events. The agent has an ability to initiate its main activities. Events which are mentioned in the detailed design are actions (affecting the environment in some way that is accept/reject), percepts (knowledge receiving from the available environment, that is wait time and queue length), and messages (to other agent and from other agent that is proposal/request).

Agent processes like the processes illustrated in the above diagram can be implemented by using plans. Plans comprise a set of instructions for taking decisions, new events and generate/receive messages. Also, plans are triggered by events. For instance, arriving messages or events generated by other plans. Agent overview then shows interaction among plans, shared data and events. Main abilities of these agents are represented together with data produced or used, communication messages and agent inner events. Following capabilities represent the grouped processes, events and data:

- Traffic monitoring: This will check the state of traffic. That is queue length and wait time.
- Manage traffic environmental information: This capability is related with objective of maintaining up-to-date info on traffic movement. Plans for this ability capture information on stopped roads, rate of exit and rate of arrival of vehicles.

D. Implementation

The executable model contains entities that have been developed in the detailed design phase (i.e. agents, plans, data, capabilities, message and events). For code generation, we have thought to use JADE platform, since it is among of the most extended multi-agent platforms, delivers FIPA standards structure for inter-agent communications and to manage distributed agents software. JADE agents have been built centered on behaviors instead of plan-based design. Algorithm implementation of the traffic model has been done by showing the processes for functionality. The key algorithms implemented in the solution contains:

- Monitor algorithm
- Send message algorithm
- Compare algorithm

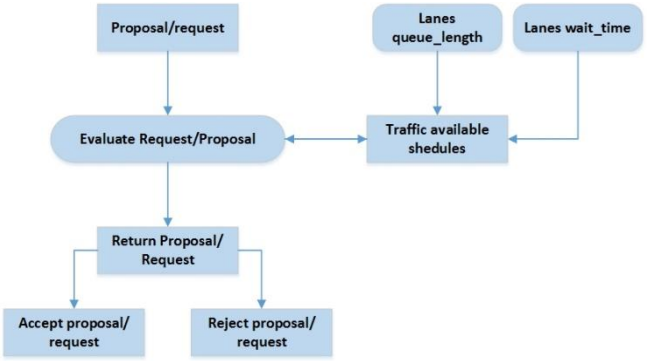

Figure 3: Agent internal communication

E. System verification and testing

In here, the verification and testing have been done as a series of different tests. The initial test is the verification of pre-timed traffic lights with respect to:

- The amount of vehicles handled through the intersections at specific amount of time.
- The wait time of vehicles gathered at the intersections based upon the intersections throughput.

The second test is the verification of the agent-based traffic lights control with regard to:

- The amount of vehicles handled through the intersection at specific amount of time.
- The waiting time of vehicles at the intersections based on the intersection throughput.

IV. Results

The figure expressed below shows the simulation screen shot of system: pre-timed control system and agent-based control system both follow similar simulation interface.

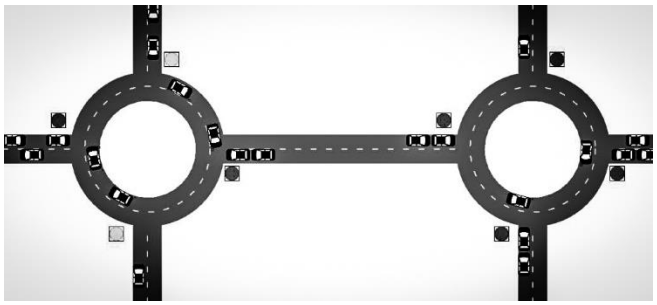

Figure 4: Sample traffic network behaviour

A. *Test environment*

The test environment comprised of the following:

- Software consisting of:
  - Java environment.
  - JADE
  - Windows 8
- Hardware consisting of:
  - Laptop (all of the above software installed)

V. Discussion

A pre-timed traffic light system and an agent controlled traffic light system have been developed to handle the movement of the vehicles with relative to the density on different lanes.

From the two developed systems, following observations were made: Vehicles counter at pre-timed system indicates smaller values; Vehicles counter at agent coordinated system indicates larger values; A pre-timed traffic light system is experiencing more notable amounts of stops as depicted on the system; The intersection with agent-based system are constantly experiencing steady movement of vehicles in all lanes, with fewer notable stops. In agent-based control, on every occasion vehicles' density rises in a certain lane, the agent is able to assess that lane in terms of wait time and vehicle density with other lanes in the same intersection, liaise with the next agent, and then it handles the situation based on that evaluation. These results so, presents an averagely higher output on the intersections managed by the agent-based controlled traffic system. The performance of agent-based traffic light control has proven to be rolling more efficiently than the pre-timed traffic light intersection.

VI. Conclusion

As for the ending this section presents achievements of the project, challenges, limitations, recommendations and conclusions.

A. *Achievements*

In circumstances of intersection controls, more complex the system becomes, the more several details can be accomplished in the model developed. Although the model presented is a simple one, from this research, it is noteworthy how agent technology and associated applications are increasingly being useful in complex scenarios to offer efficient solutions.

The following specific objectives were achieved:

- Able to come up with the prototype of a pre-timed traffic light system and measure its performance;
- Able to design and implement a multi-agent based traffic light controlled model to provide a platform for lifting the performance of traffic lights at the intersections;
- Able to simulate the effectiveness of an agent-based approach in handling road traffic issues;
- The results delivered, showed the effectiveness of an agent-based approach in handling traffic as opposed to the pre-timing in a dynamic situation.

B. *Project challenges*

Making the choice on the agent methodology that could be the best for the project proved to be a great challenge, since most of the things were problematic to understand in one area or the other. Setting up the project designs to apply with the Prometheus methodology was challenging as well. However, this was solved later studying most of the agent methodologies, and getting to know further about Prometheus methodology and its advantages compared to others.

C. *Project limitations*

The design is mainly focused on agents interacting among themselves and managing the traffic lights infrastructure, which does not cover the whole scope of road models that comprise of traffic police officers, vehicle breakdowns on the road creating more congestions therefore, does not reveal the broad picture. Secondly, the project has

assumed tests using the two systems running on a computer, therefore does not show the comparative performance of the systems fixed on the real environment. Lastly, the solution implemented is so basic and has not been designed to fit in mechanisms of fault tolerance inside a large network.

D. *Recommendations and future work*

It is witnessed that it is not obvious to expect effective movement of vehicles at the intersections based on traffic lights only. There need to be correct and effective management of those lights to ensure maximum throughput. More research must be done in the field of intersection traffic management, to enable the efficiency of road users. E.g., giving main concern to emergency road users like ambulances and allocating time for pedestrians. The research can also be stretched to a wider area, to include more than two intersections in multiple-lane road network, to test the scalability of a capable system. Therefore, there is no doubt that this research has affected positively towards additional absorption and adoption of the agent technology.

ACKNOWLEDGMENT

This research project would not have been possible without the support of many people. First and foremost, I would like to thank, Mr. ADAI Gunasekara and Mr. B Hettige for their valuable guidance and advice. They inspired me greatly to achieve the best in this project. And I would like to extend my gratitude to my colleagues at the university and outside who supported in making this project a success.

References

Giorgini, P., Henderson-Sellers, B., 2005. Agent-oriented methodologies: an introduction. Agent-Oriented Methodol. 1–19.

Padgham, L., Winikoff, M., 2004. Prometheus: A Methodology for Developing Intelligent Agents. RMIT University.

Schrank, D., Eisele, B., Lomax, T., 2012. TTI's 2012 URBAN MOBILITY REPORT Powered by INRIX Traffic Data.