An Implementation of Artificial Transportation Systems based on JXTA

Qinghai Miao, Zhixue Wang, Fei-Yue Wang, *Fellow, IEEE*, Shuming Tang and Feng He

***Abstract*—An artificial transportation system is a new type of traffic simulation software that employs agent modeling, distributed computing and concept of artificial societies to support the research and development in transportation. In this paper, models of vehicles, transportation infrastructures and a shopping center are described first, and the design and implementation of the basic ideas of artificial transportation systems based on a framework using P2P computing platform JXTA are stated in steps. Future work and issues related to operational mechanisms and strategies for such implementation are also addressed.**

***Index Terms*—P2P computing; multi-agent system; JXTA; artificial transportation system; artificial society;**

I. Introduction

With the improvement of CPU capacity and the popularization of Internet, P2P computing, as the new generation of distributed computing technology, becomes hot spot in IT field, and deeply affects our daily life. Software like MSN, Skype, Bitcomet, Emule, etc are all based on P2P computing. Besides these utilities we familiar with, P2P computing was born with the capacity to solve complex, large scale, distributed and computing intensive problems, and has been proved to be a powerful tool in many areas. For example, the famous SETI@HOME project, presided by University of California at Berkley, has called for thousands of volunteers from all over the world to find ET. Volunteers participate in the project as a P2P peer, download the data and terminal software, and run the program on his own computer, then turn back the result to the center. Such a computing style has been used successfully in other disciplines such as physics, biomedical and so on. We can see from the example that, in addition to the advantages of the abilities to solve distributed problems, P2P computing can provide us with a virtual experimental environment through which volunteers from all over the world can take part in our experiment. Such a virtual environment is an artificial system involving intelligent agents or real humans [1]. Developing from artificial life to artificial society [2], one of hot spots in artificial science is social computing: studying social problems based on computers and networks. This concept and method starts a new way to study complex systems [3, 4]. One of the pioneers in social computing is C.L. Barrett, who simulated the attack of smallpox to human society. The simulation was based on Agent modeling and studied how human intercourses influence the infection of smallpox. The result was regarded valuable to the health department [5].

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Transportation is an open, giant, complex system involving many aspects of our society. But, comparing to other systems like economy, it is relatively simple because all traffic elements are constrained to the rules and geometry of roads. So, it is the right field that the P2P and social computing can take advantages in simulations [6, 7].

Artificial Transportation System (ATS) is such a new type of simulation system, based on agent modeling, distributed computing and artificial societies [8]. We can use it to support the analysis, evaluation, decision making as well as put forward solutions for traffic emergency. Researches on ATS cover four issues, 1) modeling, how to employ the agent technology to model drivers, cars, roads and so on [9,10,11]; 2) computing, how to take the advantages of distributed computing to set up the structure of virtual traffic systems [12]; 3) experimenting, how to use methods of artificial societies, computing intelligence and parallel systems to run the simulation [13]; 4) decision-making, how to use metasynthesis to realize the interaction between real traffic system and ATS [14].

This paper introduces a primary implementation of ATS. First, the models based on Agent are described in detail. Then, as an emphasis, a P2P computing structure based on JXTA is set up and a simulation example is given to show its feasibility. Finally, problems and further work are stated.

II. Implementation of ATS based on JXTA

A. An Introduction to JXTA

The original goal of P2P computing is to rejuvenate the nature of Internet, or in another words, to return the control

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authority of information to the users. JXTA, a product of SUN, is such a P2P platform. JXTA is a set of open, generalized peer-to-peer (P2P) protocols that allow any connected device on the network — from cell phone to PDA, from PC to server— to communicate and collaborate as peers[15]. Using JXTA technology, developers can write networked, interoperable applications that can:

--Find other peers on the network with dynamic discovery across firewalls;

-- Easily share documents with anyone across the network;

-- Find up to the minute content at network sites;

-- Create a group of peers that provide a service;

-- Monitor peer activities remotely;

--Securely communicate with other peers on the network.

For the advantages on peer management and P2P communication, the ATS employs JXTA as the main structure of simulation system.

B. Models in ATS

This section focuses on the modeling in ATS. By employing Agent technology, we designed three types of models in ITS: Vehicle Agents, Infrastructure Agents and Transportation Related Agents.

1. Vehicle Agents

Vehicle Agents are primary elements in ATS. On the view of programming, we design an agent as an object oriented program, which has attributes and methods to describe features of different vehicles. For example, attributes of a vehicle may include: Type (car, bus, truck, etc.), performance (the state of the vehicle, old or new), driving style (rash or steady, skilled or beginner) and so on. All the attributes together decide the driving speed or actions of vehicle agent running in ATS. Besides, we also define some variables like ID, location coordinates, drying direction, lane number and so on, which are necessary in the identification and interaction of different vehicle agents in ATS.

Actions of a vehicle agent include car-following, turning direction, changing lanes, communication, and observation and so on.

1) Car-following. During the car-following, the driving speed is decided by the front car in the same lane. The driver tries to drive at expected speed while keeping a safe distance from the car in front. According to the distance between the two cars, there will be three driving states: a) full speed. The distance is much larger than safe distance, and the car can drive at expected speed or the speed limited by rules. b) car-following. The distance is critical safe distance, and the speed is decided by the car in front. c) stopping. When the front car stops, the following car must stop at a stopping safe distance, which is shorter than driving safe distance.

2) Lane changing. We suppose a car would change lanes in two modes: active and passive. A car changes lanes actively when the driver can drive faster but the front car is slow. On the other hand, a car must change lanes passively for the behind car that can run faster. In addition, a car needs to change lanes according to regulations when turning directions or exiting the road. A driver must assure safety before he takes actions. Whether a car can change lanes successfully is decided by the positions of cars around. Only when cars both in the same lane and in the destination lane are out of safe driving distance, can a car start to change to the other lane.

3) Turning. Turning actions include turn left, turn right, turn over and go ahead. According to the direction of the successive route, a car will take turning actions at a cross when the signal light is green. The cars turn right without signal light but must pay attention to the cars driving in the cross direction.

2. Infrastructure Agents.

Infrastructure Agents include roads, signal lights, detectors and guide signs.

1) Road Agents. In real transportation systems, road is a container of all vehicles and can collect traffic information with distributed detectors like inductive loop detectors and cameras. In ATS, we define a road as a two-dimension array to describe the geometric borders. All the coordinates of each vehicle must be constrained to this array. In addition, by employing the P2Pcommunication technology and embedding the virtual detectors, a road agent has all functions that a real road should have.

2) Signal Light Agents. We define two arrays to realize the functions of a group of signal lights. One is for the state of lights in four directions, the value of each element range from 0 to 2, which stands for green, yellow and red light respectively. The other is for the phase time, which can be adjusted according to different control schemes in different conditions.

3) Detector Agents. Detectors are distributed sensors that help us to get traffic information like flow, average speed and average delay time and so on. In ATS, we design a detector as a program that can be embedded into the road agent when needed. A detector can count the number of passing cars and generate the average speed and time-delay automatically.

3. Market Agent

Though a market is not a part of transportation systems, it affects the traffic significantly. In fact, if the location, open time, park size, and pedestrian way can not be planed appropriately, a market may cause traffic systems to run at low efficiency covering a large area. Supposed that arrival intervals and shopping time of each car are of independent exponential distribution, and then the process of entering the market can be regarded as a simple queuing model with N servers, M/M/N. In this paper, we mainly focus on the delay of traffic flow caused by cars entering and exiting the market.

C. Main Structure of ATS based on JXTA

The implementation of ATS is mainly based on JXTA technology. We take advantages of the peer management and P2P communication mechanism to organize all models as an entity to simulate the real traffic systems, as shown in Fig 1.

1. Peers Management

JXTA offers us a set of peer management methods, among which Peer Group and RDV Peer are most important for the construction of ATS [16].

1) RDV Peer. Rendezvous (RDV) Peer is a special peer that has more functions than edge peers. A RDV peer acts as the leader of a peer group. When a peer joins a group, it will search for RDV peer and register its information to this RDV. Each RDV maintains two lists, one for members of the local peer group, and the other for RDV peers of other groups [14]. In ATS, we define and configure a RDV as a supervisory agent for two uses. First, we use RDV as the top level Human-Machine-Interface, through which one can initiate, start and stop the ATS systems. In initiation procedure, RDV checks the connection status of each peer. After all peers have connected to become a virtual traffic net, the agents in ATS begin to run and the simulation starts. Second, RDV collects and broadcasts the real time traffic information. As the organizer of a peer group, a RDV can easily read the information of each vehicle agent from the list it maintains. At the same time, with the multicast mechanism within group, it is convenient to broadcast the traffic information to vehicle agents.

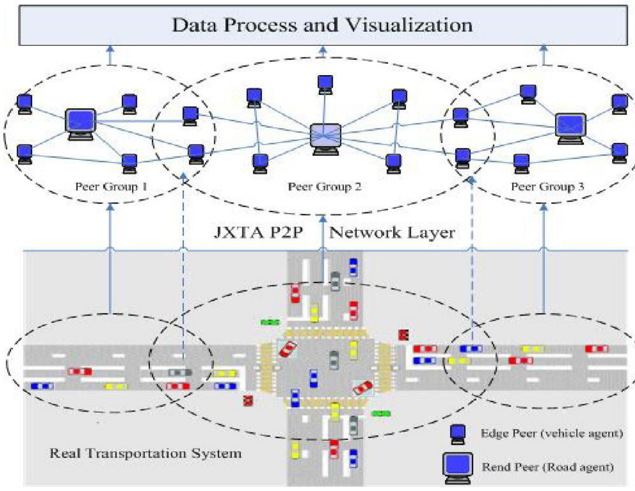

Fig. 1. The real traffic systems are mapped to the artificial transportation systems by employing JXTA technology.

2) Peer Group. A peer group is an organization of a number of peers that have common characteristics. A peer group must have at least one RDV peer. In JXTA, there is a default group called NetPeerGroup at the top level, and all peers belongs to it. In order to create an independent domain of traffic simulation, we define a specific peer group named ATSGroup in which we enforced a security police to protect our system from disturbance. By employing peer group mechanism, we can have the advantages to:

-- avoid time delay. For peers in JXTA can belong to different peer groups simultaneously, a vehicle agent can connect to the destination agent before it drives out of the local road agent. Consequently, time delay of setting up connection is avoided and the system can run smoothly.

-- create secure environment. With peer group, we can create a local domain of traffic simulation in which a specific security policy can be enforced.

-- create layered structure. The real traffic systems are managed at different levels like the whole city, residential areas and districts, from top to bottom in sequence. With the dynamic nested group mechanism, we define the ATS in two levels. The top level comprises supervisory agents and the other comprises basic vehicle agents.

-- create scalable structure. A peer group is autonomous and can communicate with other groups when needed. Thus, we implement the ATS beginning with several streets and dozens of vehicles. Gradually, we can add new groups to construct a big system simulating the real traffic at large scale.

2. Communication and Interaction in ATS

Communication and interactions between agents are important ways for artificial systems to get emergence [17]. We define two patterns of communication for different purposes: Blackboard within a peer and JxtaSocket between peers [18].

1) Blackboard. Blackboard is a common way used to share parameters among functions with high efficiency. The array representing the road geometric border is a typical blackboard for all vehicle agents to detect with each other and avoid crash. All actions of each running vehicle agent, including car-following and lane-changing, are based on the status of related elements in the road array. For example, when an agent observes whether the front car is in safe distance, it checks the array element with a smaller offset of index than the value of safe distance. If the value of any element is 1, there is a car within the safe distance; if 0, there is no car in front.

Signal light is another example of blackboard. When a vehicle agent drives approaching a crossroad, it need to observe the status of signal light before taking actions. This process is also accomplished by querying the signal light array.

2) JxtaSocket. JxtaSocket is a bidirectional and reliable communication mechanism developed from Java Socket [19]. JxtaSocket is based on pipe technology which enables us need not to pay attention to IP and Port configuration. What we need to do is to name a pair of JxtaSocket server and client, and then JXTA will generate a unique pipe ID using MD5 algorithm according to the name, and publish it in advertisement in the network. When an agent asks for connection, if the parameters are the same value as the server of target peer, JXTA will search for the matched ID and create the connection automatically.

The differences between each agent lie in their attributes, and their behaviors are almost the same. Thus, when a vehicle agent moves from one peer to another, it needs to send only parameters of attributes but not the whole entity. This can reduce the burden of network transmission comparing with the mobile agent. At the same time, the parameters are sent in binary format instead of XML documents. These two schemes help the system to get high communication efficiency.

3) Thread Pool Technology. The principle of P2P communication in JXTA is to configure a peer as both a server and a client. This is accomplished by employing a HTTP server and Java Servlet container, called Jetty. We set a pair of JxtaSocket S/C at each direction in one peer. When a vehicle agent drives in, the server in the corresponding direction will receive the data and call up a thread from the thread pool to run the agent locally. On the other hand, when a vehicle agent leaves for other peers, the corresponding client will connect to the destination and send the parameters. The running thread will be killed and return to the thread pool for next use, as shown in Fig 2.

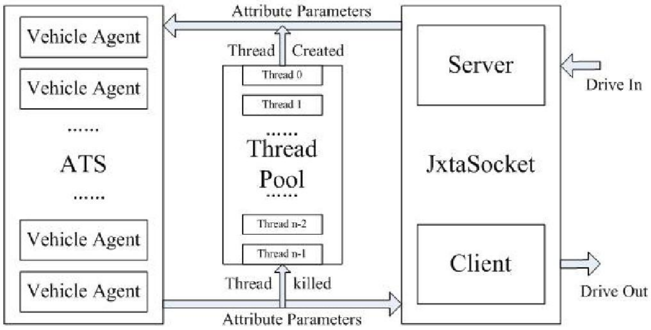

Fig. 2. The agent transport mechanism between peers supported by JxtaSocket and thread pool technology.

III. An Example Running on ATS

By now, we have the models and set up the ATS structure based on JXTA. In order to test the feasibility of the system, we carried out a simple experiment as an example.

A. Models.

In this example, models include vehicle agent, road agent, management agent and a Market Agent as introduced above. When programming in Java, we define them each as a class. The management class is in charge of configuring, starting and stopping the whole system as well as the data saving and supervising. In vehicle class, we set attributes and define the actions according to the driver style. All drivers in ATS are classified into types of slow, careful, middle, fast and hazardous with the ratio 10%, 5%, 65%, 15% and 5% respectively.

Market agent is a unique feature in our system. By involving such non-traffic systems, we can study traffic problems caused by them and testify the solutions. In this example, we define the market model as a simplified one that only considers the park size (30 sites) is considered and the influence of pedestrians is neglected.

B. Experiment.

To carry out the experiment, we use 7 computers in LAN of lab to set up the ATS. The topology of the small traffic district

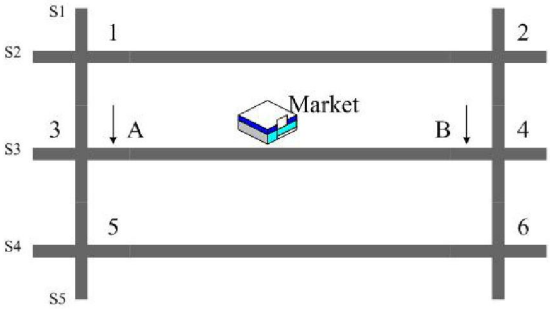

Fig. 3. The illustration of road topology with a market.

is shown in Fig. 3. Vehicle agents are generated from the source point s1-s5. The road is bidirectional 4 lanes with detectors at points A and B.

In order to compare the results, we run the system in three conditions, 1) a district without market, 2) a district with a market, and 3) a district with a market and road 3-4 only permits cars from point 3 to 4. After running for a specific period in each case, we got the data of traffic flow and average speed as shown in Fig.4 (a) and (b). The curves reflect the affections of market to the traffic systems. And we can also see

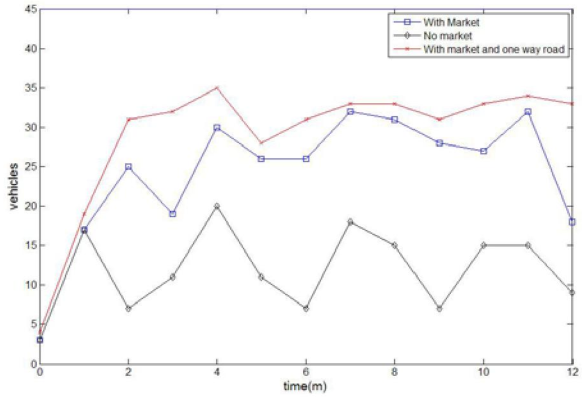

Fig. 4 (a). Traffic flow in three cases.

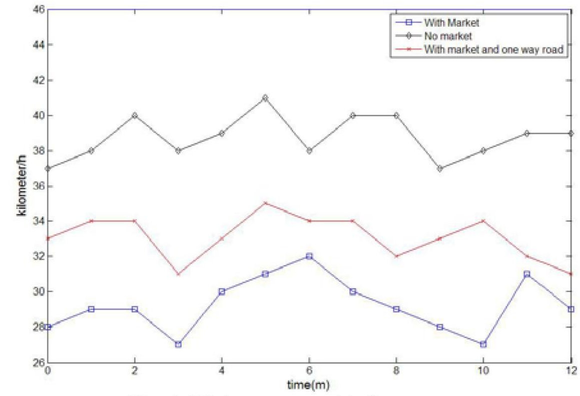

Fig. 4. (b) Average speed in three cases.

from the curves that, by changing the road 3-4 to one way only, the traffic efficiency is improved. The simulation experiment testifies that our system is feasible and worth further study.

IV. Problems and Future Work.

In this paper, the artificial transportation system is a primary implementation and far from developed. To let the ATS become more perfect, we need to do further work on three aspects: 1) Agent generation mechanism that answers the question when and where a vehicle agent emerges and which route it will choose. We will introduce the artificial population model to take place the traditional traffic flow prediction based on OD matrix. 2) Interaction mechanism of traffic system with subsystems likes economy, ecology, population and so on. We will abstract a number of variables in each subsystem, and make multi-resolution analysis on how they take effects in the whole artificial transportation system. 3) To run the ATS not only within a LAN but on ad-hoc networks in Internet. This is important for ATS to become societal by attracting volunteers over the Internet communities. To step over LANs, we must realize the functions offered by JXTA to penetrate Firewalls and NATs, and do a series of test to analysis the reliability.

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