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Parallel Public Transport System and Its Application in the Evacuation of Large-scale Activities

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***Abstract*—ACP (Artificial societies, Computational experiments, and Parallel execution) approach is adopted by our method to build parallel public transport system (PPTS). The framework of PPTS is proposed and some components are analyzed. Two key steps in building up PPTS are discussed. The first is growing up artificial public transport system from bottom up using agent-based technology. The second is implementing schedule plans of public vehicles using cloud computing. One specific PPTS is established for Guangzhou 2010 Asian Games. Its effectiveness is verified and illustrated by comparing the traffic parameters between before and after the employment.**

***Index Terms*—ACP approach, parallel public transport system (PPTS), computational experiment, agent,**

I. INTRODUCTION

With the rapid development of economic, more and more large-scale activities, such as sport games, vocal concert, exhibition, and so on, are held throughout the world, especially in big cities. Using China as one example, some most famous activities include Beijing Olympic Games in 2008, Shanghai World Exhibition in 2010, and Guangzhou Asian Games in 2010. To guarantee the success of these activities, public transport management for the evacuation is one of the priority problems to be addressed.

Public transport management not only serves for the demands of residents' daily activities, such as work and school, but also plays a very important role in special activities. When large-scale activities are conducted, massive pedestrian flows and vehicle flows will be abstracted in short time and into limited space, and comparing to daily traffic flows, there will be notable different characters. For example, the lasting time are short, i.e., the traffic flow are usually concentrated in the short periods before and after the activities, the categories and attributes of participants can be predicted according to the activity's type. Usually, private vehicles are prohibited in the surrounding area of the large-scale activity, almost all the participants must be evacuated by public transport in a short period of time.

Generally, Public transport management in large-scale activity should satisfy two folds of demands, the demands induced by the activity and the demands induced by the residents' daily activities. The latter has been explored for a long history and plenty of achievements have been reached [1-7]. However, there is still a lack of research about the former, which is the focus of our paper. In large-scale activity, there are various types of participants, which need different traffic services. How to keep the evacuation channel expedite, safe efficient and smooth, while provide pertinent service according to the needs of travelers, is the main goal of public transport in large-scale activity. Further considerations include balancing the benefit of passengers, transport companies and social environment, and maximizing the integrated benefit.

Most of research of the traffic management and control still use traditional theories and tools of transportation engineering and they are based on phenomena rather than based on essence, focusing on control rather than focusing on service, traffic-oriented rather than person-oriented. All these lead to three notable deficiencies of current transportation management and service, i.e., lacking efficient coordination and management of the planning and operation of different travel modes, lacking sufficient apperception and control of traffic elements, lacking optimal designing and execution of traffic service utilizing intelligent transportation systems (ITS). Therefore, there is an urgent need to study the people-oriented integrated management and service of intelligent transportation, which is usually on a further understanding of the travelers' behaviors.

Recent R&D advancements in complexity, complex systems, and the intelligence sciences have provided us an opportunity to look into new methods of conducting intelligent traffic control and management from new perspectives, at the system level with new tools, and an integrated approach. The ACP (Artificial societies, Computational experiments, and Parallel execution) approach was originally proposed in [8, 9], as a coordinate research and systematic effort with the emerging methods and techniques, for the purpose of modeling, analysis, and control

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of complex systems. Basically, this approach consists of three steps: modeling and representation with *A*rtificial societies; analysis and evaluation by *C*omputational experiments; and control and management through *P*arallel execution of real and artificial systems.

ACP approach differs from traditional methods and it integrates three research methods, which are theoretical study, scientific experiments and computational technologies. In this way, ACP approach can utilize both presentative and essential traffic information, give consideration to both control and service functions, and realize the people-oriented management of transportation. By adding the control and management functions of social elements, the implementation of ACP-based parallel transportation systems is of great significance that it can not only improve our cognitive competence of the dynamic formation and evolution mechanism of transportation systems, but also optimize the control and management process of the system in normal conditions as well as in abnormal conditions.

Up to now, pioneering works have been accomplished to promote the parallel transportation systems theory and verify its effectiveness in many areas, such traffic signal control, public transportation management, and so on. The focus of this paper is to present our works and results of applying ACP approach in the public transport management in large-scale activity, i.e., modeling and analysis of parallel public transport system (PPTS).

The rest of this paper is organized as the following: Section II propose the framework of parallel public transport system; section III introduce some details in the design process and section IV introduce how to implement the system on ITS clouds; section V verifies our method by illustrating one case study we carried out in 2010 Guangzhou Asian Games; section VI draws conclusions with some remarks on future works and directions.

II. The Framework of Parallel Public Transport System

Besides the schedule and monitor functions in daily operation, there are many advanced demands in public transport management. Those demands include evaluating

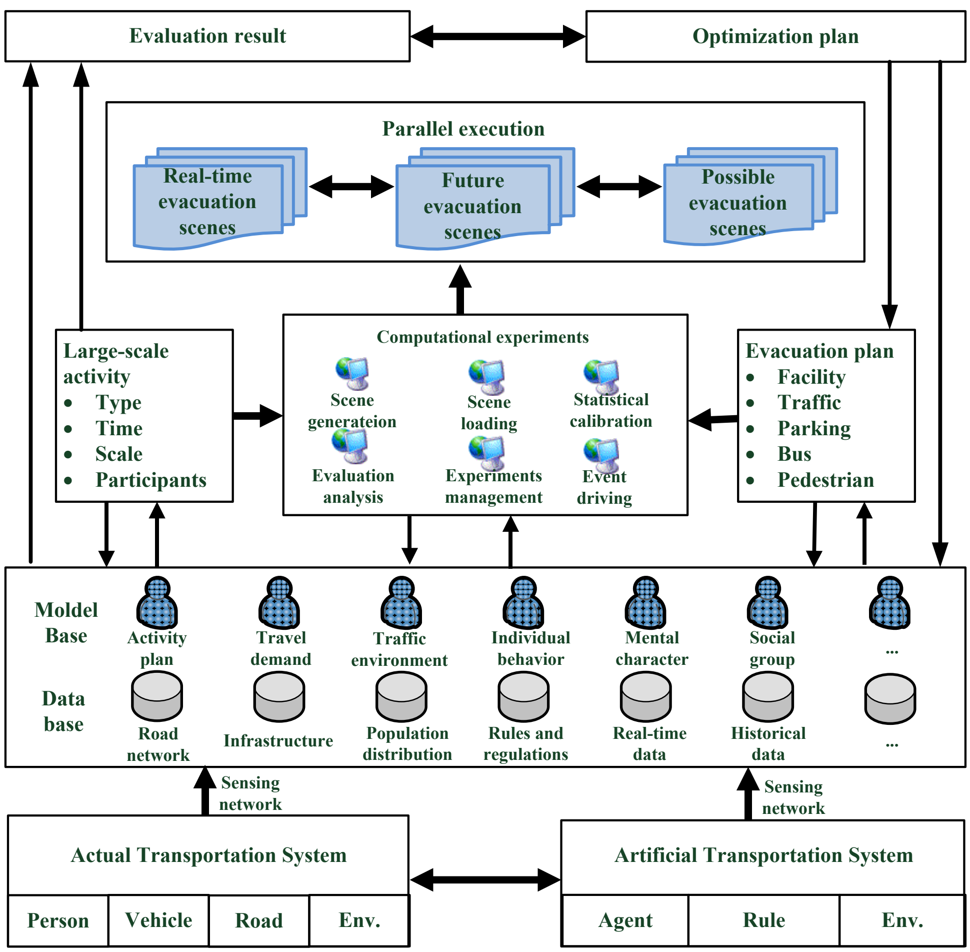

Figure 1. The framework of parallel public transport system

evacuation plan before actual operation, preparing emergency plans for possible incidents, and so on. To address those demands, many experiments need to be carried out, which are very costly and sometimes even impossible in real public transport system. Artificial public transports system (APTS) can "grow" live traffic processes in a bottom-up fashion and provide alternative versions of actual traffic activities, thus offer us a platform or a "living traffic lab" for public transport analysis and evaluation [11-14]. Base on APTS, we can carry out computational experiments of traffic signal priority plan and vehicle schedule plan. Furthermore, by integrating environmental factors, such as economic development, adverse weather, and so on, these experiments are designed and implemented from holism perspective, so reasonable results can be guaranteed [14]. This is the basic idea of parallel public transport system (PPTS).

Because there is no accurate mathematical model for transport system, PPTS that is composed of real transport system and artificial transport system, use agent-based technologies to establish artificial public transport systems, which are equivalent to real public transport system. Based on artificial public transport system, we can explore the evolution rules and interrelation among the elements in actual public transport system by carrying out corresponding computational experiments. Then, by connecting actual and artificial systems tightly and dynamically, we can compare and analyze the behaviors of the two systems in both normal and abnormal conditions, predict and consult the future status, and adjust their control and management methods [15,16]. Finally, parallel execution can be achieved using the explored rules. On one hand, the operation of public transport system can be optimized and the incidents can be reduced in normal conditions. On the other hand, in abnormal conditions, the system can come back to normal condition as soon as possible and the loss can be minimized. The framework of parallel public transport system is shown in Fig. 1.

The architecture of PPTS is composed of four layers [17,18], basic components layer, data and knowledge layer, computational experiment layer and parallel execution layer. In basic components layer, distributed storage and computation of massive data are implemented on clouding computing platform. Multi-agent environment, which include agent management system, distributed directory server and agent communication channel, and so on, is also established in this layer. In data and knowledge layer, the models of participants, environment, rules and mechanism of public transport system are set up using agent-based technologies, and a dynamic or "living" ontology is created to represent and organize transportation knowledge, such as methods, algorithms, regulations, and case studies.

In computational experiment layer, scene generator is designed to support both real and virtual experiments. Event driving engine is implemented based on discrete event simulation technology, the interaction of agents is simulated dynamically, and algorithms analysis tools are developed on computational experiment platform. So the experimental processes and results can be analyzed, evaluated and optimized, and the knowledge base is renewed in real time accordingly. Two types of experiments are carried out in our implementation. One is traffic signal control optimization. By collecting public vehicle and social vehicle information and passenger information around the intersection using intelligent perception technologies, the optimized traffic control signal plan can be verified in real time, and the maximum traffic efficiency can be achieved. The other is the intelligent schedule of public transport vehicles. Based on the perceived and predicted position of public vehicles, the passengers in vehicles, the passengers waiting at bus stations, the departure frequency and schedule type can be optimized on GIS operating platform, thus intelligent management of public transport can be achieved.

In parallel execution layer, the experimental scene is generated base on real-time detected data. The software base and application protocols in higher level are designed. These protocols serve as the interface between the experimental platform and the terminal users and enable the users to manage and configure experimental conditions expediently. By monitoring and estimating the danger factors in experiment, the event security can be passively queried and the risk can be actively evaluated. Finally, the graphical visualization human-computer interface is designed, which can demonstrate the evolution process of both actual and artificial system and the interactions between the two systems.

III. MODELING PARTICIPANTS USING AGENT MODEL

Public transport systems are becoming increasingly complex, nearly incorporating all aspects of our society. As more and more facilities and activities are involved in transportation, the connections between transportation system and urban environment are also getting closer and closer [19-21]. All these make the top-down reductionism method of traditional simulation very ineffective and there is still no effective method to model and analyze public transport systems. However, since one is inclined to be agreeable with simple objects or relationships, it is useful to build agent models based on agreeable simple objects or relationships, then develop a bottom-up approach to "grow" artificial systems and observe their behaviors through interactions of simple but autonomous agents according to specified rules in given environments. In this context, ACP approach is proposed to grow holism artificial transport systems (APTS) from bottom up [22].

Here the main idea of APTS is to obtain a deeper insight of traffic flow generation and evolution by modeling individual vehicles and local traffic behavior using basic rules and observing the complex phenomena that emerge from interactions between individuals. In the process of growing ACP-based APTS from bottom up, agent programming and

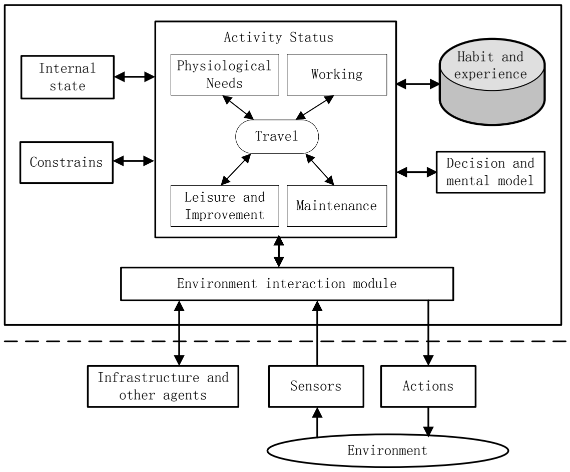

Figure 2. The structure of one agent in ATS

object-oriented techniques are extensively used for social and behavioral modeling. Fig. 2 is the structure of one agent that represents one person in APTS. Though there still hasn't a universally accepted definition about agent, it is widely accepted that an agent can be regarded as a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives.

Generally, travel is not undertaken for its own sake but rather to participate in an activity at a location that is separated from one's current location. After constructing activity plans for each member of a population, travel demand can be derived from the fact that consecutive activities at different locations need to be connected by travel. While one agent is carrying out its 24-hour activity plan, its autonomy is mainly reflected in two aspects, one is his habit and experience, the other is the decision process that is based on his decision and mental model. All these features formed the foundation of our activity-based travel demand generation method, which fit well into the paradigm of multi-agent simulation and provide us the feasible approach to generate individual's travel demand.

Based on the concepts and methods of artificial society and complex system, APTS differ from other computer traffic simulation programs mainly in two aspects. First, the objective of traditional traffic simulation is to represent or approach the true state of actual systems, while the primary goal of APTS is to "grow" live traffic processes in a bottom-up fashion and provide alternative versions of actual traffic activities. In sociologist Theodor Adorno's words, APTS reveals traffic properties based on the belief that "only through what it is not will it discloses itself as it is". Second, APTS must deal with a wide range of information and activities. Most of the current traffic simulation focuses on direct traffic-related activities alone, while APTS generates their traffic processes from various indirect facilities and activities, such as the weather, and legal and social involvements. More details about modeling transportation related system using ACP approach can be found in references [9,11,17,18].

It is worth to point out, besides providing feasible ways for modeling decision process of one agent, there are many other advantages of modeling transportation systems from bottom up. For example, both Cyber-Physical Systems (CPS) and Cloud Computing are natural and embedded in this approach. As a matter of fact, CPS, as well as Cyber-Physical-Social Systems (CPSS), is a special case of intelligent spaces and an extension of our Intelligent Transportation Spaces (ITSp), both were developed in our previous studies. As for cloud computing, it has already been used since late 1990s in our work on agent-based control and management for networked traffic systems and other applications under the design principle of "Local Simple, Remote Complex" for high intelligence but low cost smart systems.

IV. IMPLEMENTATION ON INTELLIGENT TRAFFIC CLOUDS

Agent-based parallel public transport systems can use the autonomy, mobility, and adaptability of mobile agents to deal with dynamic traffic environments. However, the large-scale use of mobile agents will lead to the emergence of a complex, powerful organization layer that requires enormous computing and power resources. To deal with this problem, we propose a prototype of public transport system using intelligent traffic clouds [23-25].

Using intelligent traffic cloud, complex computing and massive data storage can be implemented on cloud site, and the high performance can be achieved with low cost. The implemented prototype is shown in Fig. 3. All services are put into intelligent traffic cloud. Besides transforming public

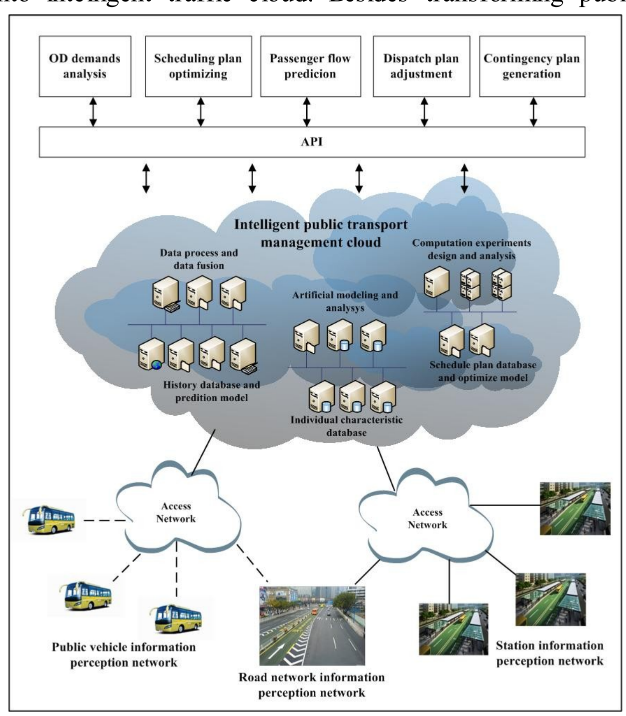

Figure 3. Parallel transport management system based on intelligent traffic clouds

vehicles schedule algorithms into schedule agents, the services also include agent performance test data and traffic detector data. Service consumer of intelligent transport cloud include transport manager, control algorithm developer and transport control center. According to the demands of service consumers, intelligent transport cloud can provide the following services [26]:

- User identity authentication and permission management services.
- Transform services from public vehicle schedule algorithms to schedule agents. The services use standard transform mechanism and universal API for traffic control algorithm developers.
- Performance test and evaluation services for vehicle schedule agent. Based on artificial public transport system, the operation results and performance of vehicle schedule agent can be tested and evaluated in various traffic flow status, using typical intersection and network.
- Storage management services for vehicle schedule agent. The services include vehicle schedule agent naming, redundancy, encryption, storage, and so on, and keep load balancing of the whole storage system.
- Storage services for operation data and detector data. The services record the running process of vehicle schedule agents and traffic flow data collected by various detectors.

With the support of cloud computing technologies, it will go far beyond other multi-agent traffic management systems, addressing issues such as infinite system scalability, an appropriate agent management scheme, reducing the upfront investment and risk for users, and minimizing the total cost of ownership.

V. CASE STUDY

The prototype of parallel transport management has been employed in the 16th Asian Games in Guangzhou, China. This Asian Games, which is unprecedented in both size and scale in the 59-year history of the quadrennial event, is the largest international events held in Guangzhou and provides an important chance to promote her international friendship, regional political, economic and cultural development.

More than 10,000 athletes from 45 countries and regions have participated in a record 42 sports ranging from Archery to Chess. Large number of contestants, spectators and visitors can make the current congested traffic in Guangzhou even worse. The safe and effective public transport is essential to assure the success of the games. One specific PPTS for 2010 Guangzhou Asian Games is established [10] and plays an important role in the evacuation of this Asian Games. The modeling area is surrounding Guangzhou Tianhe sport center, as shown in Fig. 4. The public transport facility include 30 bus lines, 28 bus rapid transit (BRT) lines and 4 Asian Game special lines, as shown in table I.

Figure 4. The modeling area of PPTS

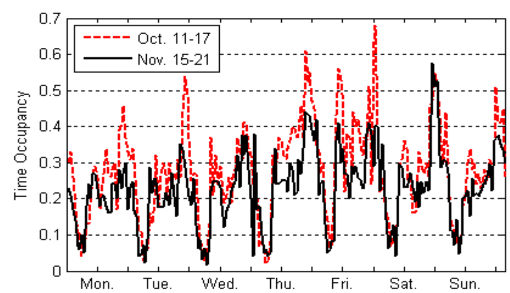

Figure 5. Time occupany comparion between before (Oct. 11-17) and after (Nov. 15-21) the employment of PPTS

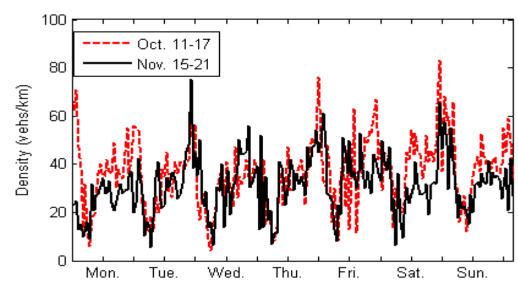

Figure 6. Space density comparion between before (Oct. 11-17) and after (Nov. 15-21) the employment of PPTS

Table I Public Transport Facility In the Surrounding Area of Tianhe Sport Ceneter

Type	No. of lines	Names
Bus	30	78, 89, 133, 540, 551, 810, 810A, 22, 39, 45, 54, 62, 136, 813, 195, 233, 263, 280, 41 (short line), 43, 130, 191, 283, 298, 302, 302A, 504, 547, 15(rush hour rapid line), 28 (rush hour rapid line)
BRT	28	B1, B2, B2A, B3, B3A, B3B, B3C, B4, B4A, B4B, B4 (rapid line), B5, B5 (rapid line), B6, B9, B10, B12, B13, B14, B21, B21 (rapid line), B25, B27, B16, B17, B19, B20, B23
Special	4	B10, B2, B5, B6 (special line)

Here we use average time occupancy and space density as two examples to illustrate the results. Fig.5 and Fig.6 are the comparison results between before the employment (from October 11 to October 17, 2010) of PPTS and after the employment (from November 15 to November 21, 2010) of PPTS. In Fig. 5, the average value of time occupancy drops from 27.8% (before the employment) to 22.6% (after the employment), decreased about 18.8%. In Fig. 6, the average value of space density drops from 36.2 vehs/km to 31.3 vehs/km, decreased about 13.5%. Both results show clear improvement of traffic status after the employment. It should be pointed out that most the improvement intervals fall in the periods when traffic demand are high. For example, the improvement in morning and evening rush hours are particularly notable. These phenomena mean parallel public transport system posses adaptive ability and can adjust its parameters accordingly when traffic demand varies.

VI. CONCLUSIONS

Public transport system plays a very important role in the evacuation of large-scale activities. However, there are still many problems in the modeling and analysis of the system, as transportation system is both too huge and too complex to be modeled using traditional methods.

ACP approach is adopted by our method to build parallel public transport system. Some details of the modeling process are represented, including growing up artificial system using agent-based technology and implement the schedule plan based on intelligent traffic clouds. One case study is carried in Guangzhou 2010 Asian Games, and the effectiveness of PPTS is verified by comparing the traffic parameters between before and after the employment.

This paper is only the initial step of our plan to improve public transport management in Guangzhou. Currently, one PPTS that covers the whole city is under constructing. Besides Asian Games, the employed PPTS will be used widely by the operators in their management work, such as peak transport in the Spring Festival Season, transport in the China Import and Export Commodities Fair, and so on.

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