Framework of Urban Transportation Dynamic Perception and Parallel Management & Control

Gang Xiong，Wuling Huang，Lihao Jia，Hairong Dong，Fenghua Zhu，Qingming Yao，Feng Chen，Guoqing Zhang

Abstract: **ITS is considered as an effective way to relieve the traffic congestion and safety problem, which have drawn more and more attention all over the world. But ITS still exist several pending problems, such as lack of effective methods to detect large-scale urban traffic status in real time, so the existing intelligent transportation management & control system can't make its full use, especially when facing with traffic abnormal or emergency situations. In the paper, based on ACP approach, a complete novel resolution and its framework are proposed, where Internet of Things (IoT) and Cloud Computing platform are introduced to deal with the historical traffic data, real-time traffic data, and predict the coming traffic status with V-I and V-V connection. Parallel Traffic Management & control System (PtMS) is also introduced. Besides the traditional ITS, an Artificial Transportation System (ATS) is added into PtMS to improve traffic analyzing and decision making performance. ITS and ATS of PtMS interact with each other continuously to enhance the adaptive optimization ability of normal traffic management & control operation, and its ability to deal with different abnormal or emergency situations.**

Key Words: **Intelligent Transportation System, Transportation Dynamic Perception, Parallel System, Cloud Computing, Internet of Things**

I. Development of Urban Transportation Management & Control System

A. Urban Intelligent Transportation System in China

INTELLIGENT Transportation System (ITS) is considered as an effective way to relieve the traffic congestion and safety, which have drawn more attention from researchers, companies and government all over the world. Transportation perception is an important part of ITS. There have been some practical sensing technologies applied to collect traffic data, such as static cameras, infrared or laser sensors, pressure sensors and electromagnetic coil sensors. Among them, video-based method is more promising, and gradually becomes one popular replacement for the traditional technologies, for its rich content and intelligent sensing capacity, easy maintenance features.

Transportation management & control is another important part of ITS. From TRANSYT, SCOOT and SCATS, to RHODES system, their management & control methods are evolving from static off-line optimization, to online optimization and hierarchical control, and to hierarchical and dynamic optimization intelligent control. Recently, there are several traffic management & control systems developed in China, like GreenPass created by Chinese Academy of Sciences, and they are getting more and more applications. ITS R&D in China has made great progress in the last few years. It has been considered as one of the major and preferential development directions in Chinese "Information Technology Industry Development 'Eleventh Five-Year' plan and 2020 long-term planning framework". And Chinese ITS development strategy has also been jointly developed and executed by National Development and Reform Commission, Ministry of Science and Technology, Ministry of Transport, Ministry of Public Security, Ministry of Industry and Information Technology, General Administration of Quality Supervision, Inspection and Quarantine, and others. While 2008 Olympic Games, 2010 Asian Games and other world-class events also bring good opportunities to update the existing Intelligent Transportation Systems in China repeatedly. The organized researches and ITS pilot applications aim to promote ITS development, improve transportation efficiency and effectiveness, and gradually China will own the capacity of constructing complete ITS from the architecture design, equipment and devices manufacturing, ITS operation and management.

B. ITS's Existing Problems of Urban Transportation Management & Control in China

In China, ITS's existing problems of Urban Transportation Management & Control lie in several aspects. For the first, it lacks an effective solution of collecting large amount of traffic data in real time, and the collected data have not been effectively integrated into the management & control system for the detailed applications yet. The collection of traffic data usually concerns a subset of sensing technologies, including video based sensing, and other supplementation, such as GPS, microwave, mobile communications networks, radio frequency identification (RFID) tags, vehicle communication equipment (OBU), communication-based train control (CBTC) and other special data communication systems. This

Manuscript received August 15, 2011. This work was supported in part by NSFC 61174172, 70890084, 60921061, 61101220, 60904057 90920305; CAS 2F09N05, 2F09N06, 2F10E08, 2F10E10.

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kind of hierarchical sensing system provides complete urban transportation information sensing solution.

The main character of Chinese urban traffic flow feature is the ternary mixture composed of motor vehicles, non-motor vehicles and pedestrians. Correspondently, the transportation management & control system should be conveniently customized to adapt for Chinese specific situation. However, current transportation management & control systems applied in China are mainly imported from the foreign companies, such as TRANSYT, SCOOT, SCATS, and RHODES, are all in passive control mode, have no analysis of whole city transportation, so is applicable to regional area only. The involved public transportation management departments, like Traffic Management Bureau, Municipal Commission of Transport etc., their ITS data are not shared each other, easily form an isolated data islands, so their responsibilities are difficult to become harmonized. It is difficult for any of them to detect whole urban traffic conditions in real time, and then hard to make accurate traffic prediction and management. Therefore, it is difficult to integrate all traffic data and information effectively, and provide one complete ITS solution of whole city. And it is also hard to build a closed-loop interactive processing platform from the traffic data collection and analysis, integration, to control modeling, traffic states forecast etc., so it is difficult to realize close-loop management & control.

Without effective assessment method of large-scale urban traffic sensing, any transportation management & control strategies will bring risk to the public transit. Currently it is still needs the experienced engineers and experts to manage individual subset of ITS and make the separated control decision. ITS' effectiveness depended mainly on how many experienced operators there are, ITS is not intelligent enough to deal with major sports activities, major holiday activities, traffic management under abnormal or emergency situations accurately and smartly.

In short, the independent original innovation is the only way to develop the China specific ITS for overcoming all kinds of urban traffic management & control challenges, and it is also urgent to introduce novel methods and theories, and develops new technologies, equipment for ITS.

II. Novel Solutions for Urban Transportation Management & Control

Novel technologies, such as Internet of Things (IoT) and Cloud computing technologies, makes it possible for the complete transportation perception in real time, and also help to build novel management & control system. Wireless sensor network, Vehicle to Infrastructure, Vehicles Networks and other kinds of IoT are used for traffic information collection. And the cloud platforms are used in real-time traffic data storage, analysis and mining, which provides better support and service for management & control system.

Based on the novel ACP approach (Artificial system, Computational Experiment, Parallel Control), we have proposed the ATS (Artificial Transportation Systems) and parallel control platform for the interactive processing of real and virtual transportation. We use ATS to promote the existing traffic simulation system, which is convenient to make more accurate management & control decisions, and more intelligent optimization and contingency plans. The whole system is based on the dynamic traffic perception by static or dynamic vision sensing, IoT and cloud computing platform that integrate and fuse the massive heterogeneous information, and active control of the regional coordination and parallel micro-simulation urban road networks. And this system is implemented in the semantic of multiple Agents, integrated with computational experiments and parallel control.

III. ACP Based Transportation Dynamic Perception and Parallel Control

A. Main contents of dynamic perception of urban traffic states and parallel management & control

Based on ACP approach, there are mainly three parts included in transportation dynamic perception, parallel management & control, which is shown in Figure 1. The first part is transportation perception, including "intelligent and dynamic perception of urban traffic", "traffic private cloud based on dynamic perception and specific Internet of Things", and "information fusion of urban traffic states based on the traffic private cloud". In this part, we develop the new technologies, devices and products based on the vision algorithms, the IoT integrated the information of traffic states, and the technologies of traffic private cloud and subsystems used for data storage and sharing, and finally the fusion methods and subsystems for building the intelligent space.

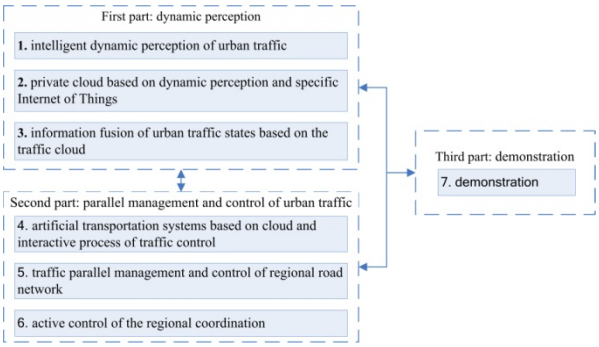

Figure 1. Main contents of dynamic perception of urban traffic states and parallel management & control

The second part is parallel management & control of urban traffic, which consists of three parts, that is, "artificial transportation systems based on traffic private cloud and interactive process of traffic control", "traffic parallel management & control of regional road network" and "active control and coordination of the regional traffic network". Based on the perception of urban traffic, we develop ATS based on cloud platform, and interactive processing technologies and subsystems based on computational experiments. Based on cloud platform, we develop the

technologies of parallel management & control, and subsystem composed by parallel control of road network, regional coordination and induction, emergency control etc.
The third part is the demonstration of one typical pilot application. We integrate the contents of the aforementioned six techniques, devices, products and subsystems, apply them into specific areas of the pilot city roads, bus, subway, etc., to improve the entire ability of traffic state perception, collaborative optimization between road and vehicles, emergency management & control, and relieve the problems of urban traffic congestion, safety and pollution effectively.
We have developed the parallel systems for Taicang road Suzhou City in 2010. Based on these experiences and technologies, we further developed the public traffic management system for 2010 Asian Games in Guangzhou and achieved its success. After the Asian Games, parallel systems are extended to apply in the surrounding areas and BRT (Bus Rapid Transit).

B. Intelligent and Dynamic Perception of Urban Traffic Status

The dynamic perception methods of urban traffic status include data-driven intelligent sensing of traffic states, intelligent sensing of traffic states based on static vision, and intelligent sensing of traffic state based on dynamic vision. Urban traffic data of large-scale road networks can be collected by these methods, the overall block diagram is shown in Figure 3.

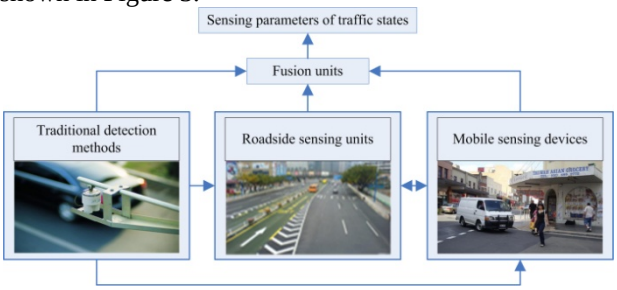

Figure 2. Block Diagram of Transportation Dynamic Perception Units

Roadside sensing units are used to detect the roadside traffic flow parameters such as traffic volume, speed, road share, traffic density, queue length and type of vehicle, and traffic anomalies or emergencies such as illegal parking, reverse driving, pedestrian invasion, speeding, pressing the yellow line, congestion. Nowadays, we usually adopt the roadside fixed cameras to detect the traffic status, that is, the detection and analysis of vehicle or pedestrian and get accurate parameters of vehicle flow, road sharing, averaged speed, traffic density, type of vehicle, length of queue, pedestrian counting, number of bus passenger who get on and get off, number of waiting passengers, density of passenger flow. While in the special environments, such as rain, snow, high-density mixed street traffic and cluttered background, we need develop more robust algorithms for vehicle or pedestrian detection and multi-target tracking.

Mobile devices are used for sensing the parameters of the location, time, direction, speed, acceleration of vehicle. To improve the detection accuracy of traditional means and enhance the perception of traffic incidents, we need research novel methods of the optimizing layout strategies, such as norms of sensor or sensor array, the micro-and macro-relational model of traffic states, data fusion of multi-source heterogeneous sensor data and micro-simulation-based verification methods. We mainly adopt the on-board equipments to achieve the mobile sensing of traffic information and compensate for the limitations of the roadside sensing units. For example, these on-board equipments can be fixed in public transport including bus, train, etc. and used to collect the flow of vehicle or pedestrian at key sites, which forms an effective complement to the method of intelligent sensing of traffic states based on static vision, and achieve the complete perception of urban traffic information in real time.

IV. TRAFFIC DATA FUSION BASED ON URBAN TRANSPORTATION CLOUD

A. Transportation Private Cloud

Transportation private cloud is made up of traffic information collection specific IoT, application middleware, and cloud computing platform. IoT consists of traffic detection WSN nodes, traffic information aggregation and transformation. Application middleware includes self-organized WSN, IPV6 protocol stacks, high speed transfer route and network access protocol for vehicles networks, mobile database access and intelligent mobile devices management software.

Traffic information collection specific IoT requires the standardized inter-platform interface and communication protocol, and shared transportation information and data mining technologies. Transportation private cloud consists of physical resource, uniform interface, IaaS (Infrastructure as a Service), PaaS (Platform as a Service), SaaS (Software as a Service). IaaS consists of traffic IoT and V-I networks, computing and storage resource, traffic information mining and states management uniform interface, secure and private uniform access interface to upper level. PaaS provides data fusion based on transportation cloud computing platform. SaaS provide application software for traffic management & control.

B. Traffic Data Fusion Based on Urban Transportation Cloud Computing Platform

Mass traffic data collection requires more bandwidth and storage. By optimizing the WSN sensors sample rate, data representation and compressed storage methods, the mass traffic data can be stored on the cloud and also the query response time is guaranteed.

To enhance the robustness of the data collection and the adaptability to the environment, it requires multiple resources, multiple dimensions, hyper-structure, multiple levels and erroneous sensing data fusion. Therefore, the WSN sensing rate strategy and data fusion methods are required. By semantic conformity check and cloud content distribution database technology, it provides a characteristic, user context aware data fusion services.

High performance and reliable transportation private cloud platform provides ATS and other simulation services, traffic control logic and algorithm, standardization specification, control methods evaluation and tests specification, intersections features and related control algorithms agents, and also meet those requests from traffic administrators, developers with different services.

V. Transportation Management & Control Interactive Procession with ATS Cloud Services

A. Transportation Cloud Computing Platform

Transportation cloud computing services make traffic management & control system an open and extensible system, new management & control algorithms can be easily applied, without updating the hardware, continuously optimizing the control agents performance and enhanced the performance. With the extension of the services in control algorithms, and data aggregation & sharing, the traffic management & control systems can be easily implemented. Transportation cloud computing platform consists of physical layer, uniform resource layer, platform layer and application layer shown as Figure 3.

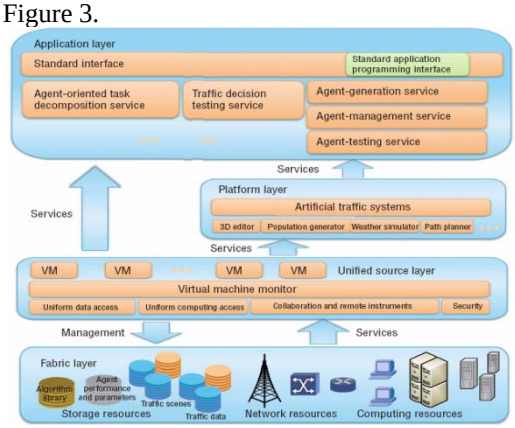

Figure 3. Transportation cloud computing platform architecture

B. Interactive Procession Platform based on Transportation Cloud Computing

With cloud computing and parallel control, real transportation system and ATS can interact with each other and evolve into parallel system. They share the data, compare and analyze the computing results, analyze and evaluate the traffic network with several intersections management & control resolution, and evaluate the optimized traffic management & control, fulfill the real time traffic dynamic prediction and induction, adjust traffic flow distribution, balancing the overloads of the traffic networks. Furthermore, with the traffic prediction services that ATS provides, the real transportation system can adjust its management & control methods, fix and apply specific management plan continuously.

According to computing experiment design method, ATS receives all kinds of management & control strategies and current situations and status, through ATS prediction functions to verify the resolution reliable and effective of the execution options. Taking advantage of the convenience of ATS execution and representation, it is easy to conduct the evaluation of the whole resolutions. And then the computing experiment and evaluation of real traffic and ATS can be executed. With ATS, when facing with traffic abnormal or emergency situation, it can focus on the resolution of constructible, computable management & control strategies.

VI. Regional Transportation Parallel Management & Control

A. Regional Transportation Parallel Management & Control

Adaption of real time multiple objective optimization, cooperative control strategies, and network traffic flow prediction are adopted specifically in regional transportation parallel management & control system.

Evaluation metrics, such as metrics evaluation, multiple resolution computing experiments, urban transportation simulation for area traffic network etc., are used in regional parallel management & control system.

Furthermore, we manipulate regional cooperative technologies, such as Vehicles to Infrastructure (V-I) and Vehicle to Vehicles (V-V), Vehicles Networks to realize more active regional transportation management & control.

B. Regional Cooperative Inducement Technology

Transportation dynamic conception results are transferred to the ATS and real transportation system in real time. ATS pre-run and performance evaluation metrics and get the output, after comparing several outputs of different resolution and choosing the highest quality one. Then through the V-I platform send the characterized and inducted information out.

In the abnormal situation, it needs to achieve people evacuation and emergency management, inducing people to choose the evacuation traffic networks routes. To implement this function, co-action model and strategies, evaluation metrics and methods, simulation optimization and the output can be used to achieve traffic flow coordinative control with multiple mode.

C. V-I Cooperative Safety Voluntary Control

By using those devices installed on vehicles and infrastructure, the vehicles and pedestrian can be detected and traffic event can be recognized. By using V-V and V-I cooperative sensing technologies, vehicles driving status and behavior can also be recognized. Through V-I and V-V multiple modes wireless network, vehicles intelligence can be easily and highly enhanced.

By using intelligent vehicle behavior and adaptive speed mode control, private status sensing, pedestrian-vehicle and V-V safety control, vehicle safety like collision avoidance can be implemented. V-I and V-V cooperative system can be integrated to realize multiple scale traffic safety voluntary control.

It is proposed to use traffic scenery vector transform, micro and macro traffic flow quantities and qualities representation methods to realize large scale traffic network simulation, driver-vehicle properties presentation and behaviors modeling, vehicle gas remission and traffic pollution diffusion modeling, multiple modes actuator virtualized, self

organized Ad Hoc network and wireless route protocols and channel simulation.

VII. The System's Technology Roadmap

The system's technology roadmap consists of three steps. The first step is to develop urban transportation status sensing technology. Using IoT vehicles terminal and infrastructure devices to realize multiple scale V-I cooperation application traffic safety control and reduce the traffic accidents, using traffic cooperative and vehicle parallel control to realize traffic network balance and reduce the traffic delay, pollution and cost.

The second step is to construct all kinds of virtual interaction in traffic sensing and parallel management & control system. Using rolling optimization functions of parallel control to optimize network coordination and self organization abilities, to increase the traffic capacity. Using parallel emergency traffic management functions to improve the emergency handling ability and cut down the cost of its impact.

The third step is to testify the former two parts by typical pilot, to verify its application and form a full intelligent resolution plan. Its pilot can be arranged in the area of Guangzhou's BRT route. Based on the breakthrough of the core technologies, urban traffic sensing networks can be built, including more than 50 intersections, 200 sensing nodes of video and micro wave technologies, more than 50 aggregation and routing nodes. Management & control center can provide traffic signal optimization in real time, traffic inducement information broadcast, and automatic emergency transaction plan creation. The expected effect includes: increasing vehicles average speed up to 8%, reducing intersection waiting queue length by 10%, average bus waiting time decreased by 10%, providing an effective plan for releasing the traffic jam of urban downtown.

VIII. Conclusion

The IoT and cloud computing platform can be introduced to store the historical and real time traffic status, and predict the coming traffic status, with V-I and V-V connection. We also need parallel management & control system which is based on ACP approach. Besides the traditional ITS, an Artificial Transportation System (ATS) is added into PtMS to improve traffic analyzing and decision making performance. ITS and ATS of PtMS interact with each other continuously to enhance the adaptive optimization ability of normal traffic management & control operation, and its ability to deal with different emergency situations.

On the one hand, transportation IoT and private cloud can extend the application scope of parallel system, from current road signal control and bus management of specific areas, to BRT, Taxi and subway public transportation of whole city. On the other hand, the implementation of Parallel Transportation Management & Control System (PtMS) can improve the existing ITS applications' intelligence levels.

Acknowledgments

We are thankful to the guide of Prof. Feiyue Wang and Hong Qiao from Institute of Automation, Chinese Academy of Sciences, and Prof. Bin Ning from Beijing Jiaotong University, and the participation and support of Dr. Sheng Liu, Yisheng Lv, Zhenjiang Li and Xisong Dong.

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