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Distributed Multi-Agent Based Approach on an Intelligent Transportation Network

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***Abstract*—**With the accelerating process of urbanization, the problem of urban road congestion is becoming more and more serious. Intelligent transportation system combining distributed and artificial intelligence has become a research hotspot. As the core development direction of the intelligent transportation system, Cooperative Intelligent Transportation System (C-ITS) integrates advanced information technology and communication methods and realizes the integration of human, vehicle, roadside infrastructure and other elements through the multi-agent distributed system. By analyzing the system architecture and technical characteristics of C-ITS, the paper proposes a distributed multi-agent C-ITS. The system consists of Roadside Subsystem, Vehicle Subsystem and Personal Subsystem. At the same time, we explore the scalability of the C-ITS and put forward incorporating local rewards in the centralized training decentralized execution paradigm, hoping to add a scalable value decomposition method. In addition, we also suggest introducing blockchain to improve the safety of the traffic information transmission process. The system is expected to improve vehicle capacity and traffic safety.

***Keywords*—**Distributed system, artificial intelligence, multi-agent, Cooperative Intelligent Transportation System.

I. Introduction

THE transportation industry has been one of the most popular fields of study in recent years. With the rapid development of modern cities, the traffic network is becoming more and more complex. How to effectively control the complex traffic system has become a great challenge. With the continuous development of distributed artificial intelligence technology, intelligent transportation systems based on multi-agent have become a promising method to solve complex transportation problems.

Intelligent transportation systems based on distributed multi-agent integrate information technology, wireless communication technology, sensor technology, computer technology, and other advanced technologies to realize the real-time dynamic interaction of traffic information between vehicles and between vehicles and roads, to form an efficient traffic management system. An intelligent transportation system regards the complex regional traffic as a distributed system composed of multiple agents of different sizes who cooperate, communicate, coordinate and control each other [1].

An intelligent transportation system is a complex large-scale system. After segmentation, it can form multiple subsystems with different sizes and functions. The subsystems can communicate with each other, to maintain the integrity of the whole regional transportation multi-agent system. At the same time, each subsystem also contains several agents. These internal agents can also communicate, cooperate and coordinate with each other to control the subsystem.

Lehmann presented a fully distributed scheme in which vehicles coordinate their maneuvers by using Vehicle-to-Vehicle (V2V) communication to exchange their plans and desired trajectories [2]. Correa proposed a Maneuver Coordination Message (MCM) based on the current V2V method to expand the current Maneuver Coordination Service (MCS) method, mainly by adding infrastructure [3]. Ahmed came up with a Predictive Road Traffic Management System (PRTMS) based on the VANET architecture. This work emphasizes the communication between vehicles and roadside units and shows how to realize traffic prediction in a distributed manner without using a central server [4]. Chen and Englund introduced the functional architecture of C-ITS (version 1) and the detailed description of each communication layer [5]. Fig. 1 is related to projects of the cooperative transportation system.

	Project	Region	Main content
1	Dutch C-ITS Reference Architecture (DITCM)	Netherlands	Developing a reference architecture for large scale C-ITS deployment
2	CONVERGE	Germany	Developing an open platform for service providers with focus on (V2X) systems network.
3	COMPASS4D	EU	Working with three C-ITS services such as Road Hazard Warning, Red Light Violation Warning and Energy Efficiency Intersection Service.
4	NordicWay	Nordic countries	A pre-deployment pilot project for C-ITS deployment.
5	US-ITS(ARC-IT)	USA	Defining a reference architecture that act as building blocks for small scale regional C-ITS projects in various regions of the USA.

Fig. 1 C-ITS reference architecture projects

Based on previous research and literature review, distributed multi-agent is an alternative tool and solution technique for solving some of the problems related to transportation networks [6].

In this paper, we would like to study the C-ITS. C-ITS is not only an important part of the intelligent transportation system but also the evolution direction of the intelligent transportation system. In 2017, the European Transport Security Council (ETSC) issued a briefing on C-ITS, pointing out the urgent need for new technologies with obvious road safety benefits [7]. C-

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ITS is a communication system that aims to allow road users to communicate with other vehicles and infrastructure. Its important feature is to connect various traffic elements and terminals through the new generation of communication, cooperate to solve various traffic problems and realize integrated services under the common goal. As a distributed multi-agent system, agents distributed in the traffic management center, road sections, road intersections, vehicles on the Internet, or wireless network in the C-ITS will make intelligent decisions based on the correct traffic information collected from the designated place at a specific time. Communication between vehicles and transport infrastructure enhances traffic participants' awareness of traffic conditions. The information sent between agents may include information about the location of vehicles, vehicle speed, traffic flow, accident information, and so on. This makes it important to verify messages to avoid publishing errors or malicious information in the system. Therefore, the security of communication information in C-ITS is very important. In addition, as a system with the structural characteristics of the distributed system, the scalability of C-ITS is also of great concern.

A. Problem

The growth trend of the urban population brings great pressure to urban traffic. By 2050, urban traffic, which accounts for 64% of all traffic, is expected to be three times higher than it is today [8]. The increase of vehicles will increase the density of vehicles on the road, which will easily cause traffic congestion.

Traffic congestion may bring many problems. First of all, it will increase the probability of traffic accidents. Globally, more than 3500 people die on the road every day, and road traffic injuries are the main cause of death for children and young people aged 5-29 years. As things stand, they are estimated to kill 13 million people and injure 500 million others over the next decade [9]. In addition, vehicles will start and stop frequently on congested roads, which will lead to more fuel consumption and more exhaust emissions, resulting in environmental pollution and energy waste. The website of the U.S. Office of Energy Efficiency and Renewable Energy states that the total amount of excess fuel consumed due to congestion has been on a steady upward trend, peaking at nearly 3.5 billion gallons in 2019 [10]. At this point, the urban transportation system urgently needs to make changes to solve these problems and improve the mobility of vehicles.

B. Objectives

Through the analysis of the current transportation system, we can find that there are many disadvantages. The study will focus on the C-ITS based on distributed multi-agent. The objectives of the study are listed below:

1) To study the Cooperative Intelligent Transportation model or framework based on distributed multi-agent.
2) To determine that the C-ITS can meet the requirements of urban development.

C. Research Questions

1) How can the agents of the C-ITS communicate with each other?
2) What influence may C-ITS have on the urban transportation industry?
3) How to improve the scalability of the distributed multi-agent C-ITS?

II. Framework

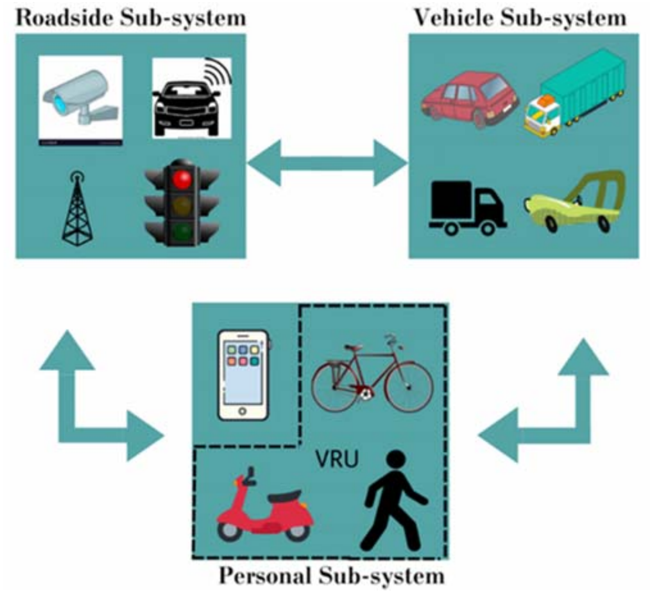

Fig. 2 C-ITS Model Based on Distributed Multi-agent

Fig. 2 shows the framework of a local C-ITS network based on distributed multi-agent and reflects the information exchange between modules. C-ITS consists of several subsystems, including the roadside subsystem, communication service subsystem, vehicle subsystem, and so on. These subsystems are essentially independent systems with their functions and objectives. These subsystems with different owners and functions are connected in a distributed environment to work together in a network of collaborative intelligent transport systems [11]. The three main subsystems will be explained in more detail below.

A. Roadside Subsystem

The main functions of the roadside subsystem are realized by the roadside sensing and positioning system. The system uses cameras, sensors, and other traffic detectors to accurately capture and identify the road traffic operation status, and then uses roadside computing devices to analyze the collected original sensing data, and uses other road infrastructures to respond to this. Traffic lights are very important traffic infrastructures. The roadside subsystem senses and collects relevant traffic data through the intersection controller and camera and calculates a more appropriate signal control time and steering configuration scheme. In addition, the roadside subsystem can also transfer the processed data to other subsystems in the distributed system. For example, it can exchange information with the personal subsystem. If an accident or excessive traffic is detected, it can send information to mobile phones to help users obtain road information and decide the driving route as soon as possible.

B. Vehicle Subsystem

The vehicle subsystem provides traffic safety, traffic efficiency, and information services for vehicles. With the support of Vehicle-to-Everything (V2X) communication technology, vehicles can quickly obtain detailed road information and the driving intention of passing vehicles to support the dynamic planning of vehicle driving path, improve traffic flow and realize local coordination of traffic. The vehicle subsystem can conduct two-way information exchange with the roadside subsystem. On the one hand, the sensing device on the vehicle can collect the traffic information and gather it to the roadside subsystem in real-time through V2X technology to fuse with the information directly perceived by the roadside. On the other hand, vehicles can identify traffic participants or abnormal road conditions that are not within their perception range and make correct driving decisions in advance.

C. Personal Subsystem

The personal subsystem shall provide ITS application for the person and mobile devices. A person can also be regarded as a vulnerable road user here, which can be understood as road traffic participants such as pedestrians or cyclists. The personal subsystem can exchange data with the roadside subsystem, for example, integrate pedestrian traffic into the signal stage optimization, pedestrians can control the waiting time of traffic lights through buttons to realize more intelligent traffic lights by monitoring the flow of Vulnerable Road Users (VRU) to improve pedestrian safety and balance the traffic between vehicles and VRU. Most VRUs use mobile devices to participate in C-ITS. The personal subsystem can receive the information sent by the roadside subsystem to obtain real-time traffic information.

To develop a general and efficient C-ITS framework, we analyze the existing C-ITS reference frameworks and projects in order to find the gaps that can be improved. Through research, comparison and analysis, we draw three directions that the current framework still needs to be paid attention to and can be improved, including increasing the scalability, ensuring the security of transmitted data and data storage and backup. We solve the above problems one by one through targeted transfer learning. The following part is the specific problems we found and detailed suggestions.

III. Findings & Discussion

From the above discussion, we can conclude the influence of C-ITS implementation on our daily life mainly from three aspects: safety, mobility, and environment [12]. Here we come into detail with the framework of the C-ITS.

From the point of safety, the roadside subsystem can detect the forward speed of the personal subsystem and vehicle subsystem and send prompt messages to agents of the two systems asking them to speed up, slow down or increase their attention, so as to reduce the possibility of collisions and ensure the safety of drivers and pedestrians. What is more, mobility is also the point of our concerns. C-ITS roadside subsystem analyzes the real-time information sent by the other two subsystems and sends the most efficient path to the surrounding agents to save travel time. In route planning, distance, time, energy consumption and other factors will be taken into consideration then the shortest, the most effective path comes out. On the other hand, the road subsystem and the personal subsystem can control the traffic lights to save travel time. When the system detects that the traffic flow at the intersection is small, it can reduce the time of red light and green light according to the actual situation of the intersection, to improve the transportation rate. When the traffic flow is smaller than the value set by the system, the roadside subsystem opens the traffic light control permission, and pedestrians can switch traffic lights by pressing the button on traffic lights to reduce waiting time. Lastly, the implementation of C-ITS also has a good effect on the environment. As we all know, the longer a vehicle waits, the more exhaust it emits, and the more pollution it causes to the atmosphere [13]. Therefore, C-ITS has a positive impact on the environment by reducing vehicle waiting time at intersections and reducing exhaust emissions.

Although we have identified many advantages of C-ITS, there are still some areas for improvement in C- ITS, which are still in the early stages of development. For example, the scalability is low which means if there are large enough vehicles it may cause network problems. Nowadays, the communication among the vehicles is mainly based on the digital certificates. But it is a waste of money, as it should calculate the demand and verify the period. Finally, C-ITS needs to handle large amounts of data, which is a huge challenge for the system's data processing and storage systems.

As one can see from the findings, C-ITS has its drawbacks, but it is very useful for linking the current state of the transport system.

IV. Recommendations

In the above section we have already mentioned some of the current shortcomings of C-ITS, so in this section, we will propose corresponding improvements based on the problems we have identified with C-ITS.

For further improvement, we suggest incorporating local rewards in the Centralized Training Decentralized Execution Paradigm to improve the scalability. It is an important way to realize effective learning systematically. Let's visualize it by taking work as an example. If one employee makes a mistake, it is more effective to send punitive feedback directly to him than to the entire company. Because if feedback is sent to the entire company, the person who made the mistake does not know they did it and will not change, which wastes resources. We hope to add a scalable value decomposition method that may improve the allocation of the credit by using it. At the same time, it can also achieve the goal that to cooperate with each agent. Also providing a direct decomposition method for finding local rewards when only a global reward is provided.

What is more, we think it is a good way to add blockchain technology to the C-ITS-based distributed multi-agent system.

We hope to add the blockchain to trace each vehicle's certificate. The blockchain technology is an appropriate tool for transforming information [14]. Because it provides instant, shareable information that is guaranteed to be accessible only to authorized users [2]. This can speed up the information exchange between agents and provide data confidentiality between agents.

Lastly, we all know the communication among multi-agent system mainly depends on the transformation of the data. As a result, it is a big problem to back up a huge amount of data. We suppose to obtain clouding technology to set up the traffic data cloud for the transportation department. This facilitates data classification and review.

V. Conclusion

In this paper, C-ITS based on distributed multi-agent is studied. This report analyzes some problems of the current traffic system: heavy traffic pressure, frequent traffic accidents, and resource pollution caused by traffic jams. Secondly, we describe the communication framework between the roadside subsystem, vehicle subsystem, and personal subsystem in C-ITS. And we have analyzed the impact of safety mobility, and efficiency of C-ITS on real life. Finally, we put forward our suggestions based on the current C-ITS: incorporating local rewards to improve the scalability of C-its, adding blockchain technology to speed up the exchange of the data, and providing access to obtain clouding technology for backing up the data.

Although C-ITS has not been fully popularized yet, it can be seen from our research that it conforms to the development trend of the current society and has great development potential. And there are great expectations for C-ITS. It is believed that C-ITS will be widely used around us soon.

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