Design of Urban Traffic Node Management Scheme Based on 5G Wireless Network Architecture

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Abstract. Effective management of urban traffic nodes can improve the order and efficiency of road traffic, and play a pivotal role in alleviating urban traffic congestion. To this end, a city traffic node management scheme based on 5G wireless network architecture is designed. This method first collects relevant traffic characteristic data, and then uses 5G cellular mobile communication technology to establish the connection between the control center and the on-board unit and roadside unit to realize real-time vehicle and road data transmission. Finally, it uses the algorithm based on dynamic programming to perform urban traffic node signal lights. Control and realize urban traffic flow scheduling. The results show that: under the application of the designed scheme, the number of vehicles in the queue is reduced, and the average delay time of vehicles is reduced, thus effectively improving the utilization efficiency of road traffic resources and alleviating the problem of urban traffic congestion.

Keywords: 5G wireless network architecture · Urban traffic node · Signal light management scheme

1 Introduction

Intelligent transportation system is the development direction of future transportation system. It effectively integrates advanced information technology, data communication transmission technology, electronic sensor technology, control technology and computer technology to the entire ground transportation management system, and finally establishes a It is a real-time, accurate and efficient comprehensive transportation management system that plays a role in a large-scale and all-round way [1]. The development of intelligent transportation is closely related to the development of the Internet of Things. Only when the Internet of Things technology continues to develop, the intelligent transportation system be more perfect. Intelligent transportation is a concrete manifestation of the high degree of materialization of road transportation.

As an important part of smart transportation, smart city traffic nodes can guide and divert traffic in time and space through the collection and transmission of traffic information, reduce congestion, and protect pedestrian safety. Because of the complicated traffic conditions of the traffic nodes, the large flow of people and vehicles, and the difficulty of

S. Liu and X. Ma (Eds.): ADHIP 2021, LNICST 417, pp. 40–50, 2022.
https://doi.org/10.1007/978-3-030-94554-1_4

optimizing control, it has become the primary problem to be solved in the establishment of an intelligent transportation system.

In this paper, under the support of 5G network, combined with the location, speed, route and other information of various target objects of traffic behavior, design an urban traffic node management plan. First collect traffic characteristic parameters, and then on the basis of traffic characteristic parameters, use part of the networked vehicle data to obtain the vehicle arrival matrix. At the same time, the NEMA dual-loop phase structure is introduced, and the phase duration and phase sequence are optimized by the dynamic programming method. The optimization model with the minimum delay as the goal realizes the real-time adaptive phase sequence traffic signal control at the traffic node. Through this research, it is hoped to provide reference and reference for the traffic scheduling problem of urban nodes and relieve the traffic pressure of traffic nodes.

2 5G Wireless Network and Urban Traffic

5G refers to the fifth-generation mobile phone mobile standard, also called the fifth-generation mobile communication technology. The 5G network has obvious advantages, which are mainly reflected in the transmission speed, bandwidth capacity, network delay and so on. According to related tests, the current fastest transmission speed of 5G network can reach 7.5–10.0 Gb/s, and according to the latest test of University of Salisbury, the fastest download speed of 5G network reaches 1 Tb/s. The 5G communication technology with super bearing capacity will surely open a new era of interconnection of all things [2]. The functional characteristics of the 5G network have a strong supporting role for the Internet of Things, making the high-quality and efficient networking of things and things, people and people, and things and people a reality, laying a good foundation for building a smart society with all things connected. The bandwidth capacity of the 5G network will be more than one hundred times that of the 4G network. The Internet of Things and mobile devices will no longer need to wait for access to the network, and fast and large amounts of information can be exchanged anytime and anywhere. The above-mentioned performance of 5G network is very beneficial to the operation of Internet of Things equipment, and will play a major role in traffic conditions, vehicle detection, unmanned driving, and intelligent transportation [3].

A new generation of intelligent transportation based on 5G wireless network consists of three parts: control center, vehicle terminal (vehicle user), and handheld terminal (pedestrian user). The control center is the core and brain of the entire intelligent intersection system, including 5G communication base stations, traffic lights, various sensors, cloud servers, etc. The 5G communication base station is used for large-capacity and high-speed information exchange between the control center and end users. The traffic signal receiving control center generates control instructions based on real-time traffic flow, and realizes the dynamic adjustment of the green light release time in each direction between the minimum green light time (to take care of pedestrians crossing the street) and the maximum green light time (considering traffic in other directions) to reduce green light loss Time, reducing red light waiting time, improving the efficiency of intersections, and reducing vehicle exhaust emissions [4]. Various types of sensors include video traffic cameras, radar speed measurement devices, illegal capture cameras, etc., which are used to obtain information on the number of vehicles and pedestrians in various directions and manage traffic violations such as speeding through red lights. The cloud server is the brain of the entire intersection. The number of users, location, speed, route and other information collected by various sensors are calculated and processed to issue corresponding control instructions to guide vehicles and pedestrians to efficiently and safely pass the intersection.

2.1 Collection of Relevant Traffic Data

OBU On-board Unit

The on-board unit includes on-board sensors, information processing modules, and communication modules. Vehicle-mounted sensors can collect vehicle information such as vehicle speed, position, lane change, etc., and then transmit it to other vehicles and RSU roadside units through 5G wireless network after processing by the vehicle-mounted information processing module [5, 6]. The structure diagram of the OBU on-board unit is shown in Fig. 1:

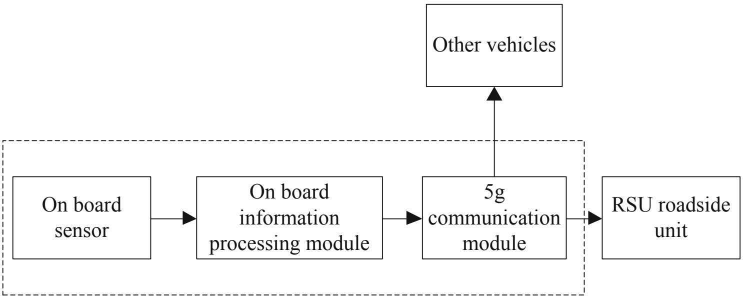

Fig. 1. OBU on-board unit

RSU Roadside Unit

The roadside unit includes a vehicle information receiving module, a data processing calculation module, and a communication module. The vehicle information receiving module receives the vehicle speed, position, status information and the current signal state of the road intersection sent by the vehicle unit through the 5G wireless network, and extracts the information for After calculating the real-time signal timing data, the data processing calculation module calculates the required timing plan according to the set calculation method and transmits it to the roadside signal machine for execution. The schematic diagram of the roadside unit structure is shown in Fig. 2.

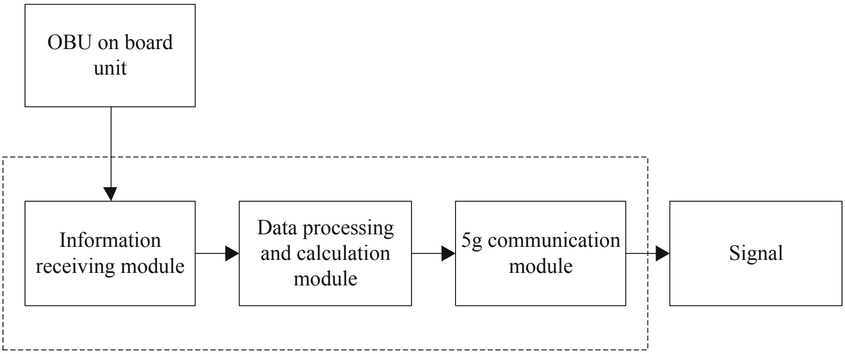

Fig. 2. RSU roadside unit

2.2 Data Transmission

The data transmission process is shown in Fig. 3, the system uses 5G cellular mobile communication technology to establish the connection between the vehicle and the roadside controller, and realizes the real-time vehicle road data exchange [7]. Data such as vehicle position and speed are directly applied to signal timing optimization control.

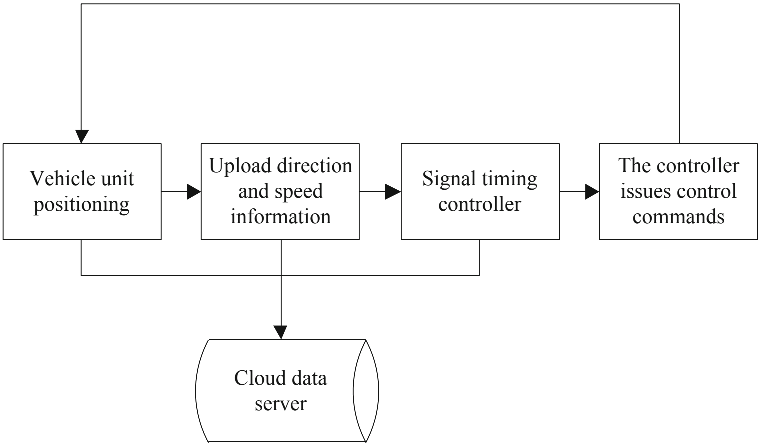

Fig. 3. Data transmission flow chart

2.3 Fuzzy Control of Traffic Node Signals

Traffic signal management of urban traffic nodes is the most basic form of urban traffic signal control, and it is also the basis of urban traffic signal management systems. Usually management methods are divided into timing control, induction control and adaptive signal control.

(1) Timing management is to formulate different timing plans according to several typical conditions based on historical traffic flow. This method is suitable for scenarios where the changing pattern of traffic flow is fixed, and the ability to adapt to changing traffic flow is relatively poor [8].
(2) Induction management detects the traffic demand arriving at the intersection through the vehicle detector, so that the signal timing can adapt to the control method of traffic changes. For intersections with large and irregular traffic flow, induction management has better results, but Induction management can only respond to the detected information of the arriving vehicles, and cannot truly respond to the traffic demand of each phase.
(3) Adaptive signal management uses the traffic flow information obtained by the detector to predict the arrival of vehicles and the length of the intersection queue in the short term, and find the optimal signal timing scheme according to the defined objective function, which is often compared to induction control Have better results. There are several popular adaptive signal management systems, including SCATS, SCOOT, OPAC, RHODES, etc.

In the current traffic signal management and control system, most of the data collection is provided by roadside inspection equipment, including coil detectors, video detectors, etc. There are two limitations to the use of these detectors. First of all, these detectors can only be detected when the vehicle passes the position of the detector. After the vehicle passes the detector, the state of the vehicle (including position, speed, acceleration, etc.) cannot be sensed; secondly, the roadside detection required by the system Equipment often requires high installation costs, and when one or more detectors have problems, the effect of the adaptive signal control system will be greatly reduced [9–11].

In the 5G network environment, the vehicle-road collaboration technology can obtain real-time networked vehicle information on the road, including the location, speed, acceleration, etc. of the connected vehicle, so as to accurately estimate and predict the arrival of vehicles at the intersection, which is real-time Adaptive signal control provides a good data basis. At the same time, based on the environment of vehicle-road collaboration, there is no need to spend a lot of money to arrange fixed-point detector equipment. Each connected vehicle is equivalent to a "mobile sensor", and when one or more connected vehicles have a communication failure, it is quite The coverage rate of connected vehicles is slightly reduced, and it will not seriously affect the effect of the adaptive signal control algorithm.

The research in this chapter is carried out in a 5G network environment. On the basis of 2.1 traffic characteristic parameter estimation, by estimating the information of unconnected vehicles, constructing a vehicle arrival matrix for a period of time in the future, and designing real-time adaptive signal management strategies. The adaptive signal management in this chapter draws on the COP algorithm in the RHODES system, and on this basis introduces the NEMA double-loop phase structure to increase the flexibility of phase sequence changes. This section specifically analyzes the signal control problems of the NEMA double-loop phase structure and uses dynamic programming methods to model and optimize [12–13].

The optimization proposition is to optimize the evaluation index in the prediction time window T by optimizing the duration of each stage. Suppose there are P phase groups for signal phase at a single intersection, and each phase group is taken as a phase. Under the NEMA dual-loop phase structure, the number of phase groups P is 2, j is the phase group number, and j0 is the starting point for optimization Phase group number, i is the sequence number of the dynamic planning decision-making phase. In order to unify the phase group sequence number and the phase sequence number, definition $Y(i)$ means the phase group sequence number corresponding to phase i, and the phase group sequence number j and the decision stage number i satisfy:

$$Y(i) = (i + j_0) \bmod P \tag{1}$$

Define state variable s_i and decision variable x_i, take the time s_i from the start of the optimization to the end of the i-th stage as the state variable, and the phase group duration x_i allocated by the i-th stage as the decision variable. The relationship between state variables and corresponding decision variables at each stage is shown in Fig. 4.

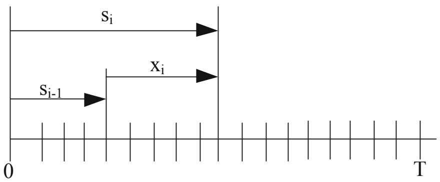

Fig. 4. The relationship between phases and states of the algorithm model

The state transition equation is:

$$s_{i-1} = s_i - x_i \tag{2}$$

When given a state variable s_i, there will be many possible decision values corresponding to it, and different state variable values will have different decision values. Define decision set $X_i(s_i)$:

$$X_i(s_i) = \begin{cases} 0, & \text{if } s_i < X_i^{\min} \text{ or } T - \sum_{k=1}^{i-1} X_k^{\min} < X_i^{\min} \\ 0, X_i^{\min}, \ldots, X_i^{\max}, & \text{if } T - \sum_{k=1}^{i-1} X_k^{\min} > X_i^{\max} \\ 0, X_i^{\min}, \ldots, T - \sum_{k=1}^{i-1} X_k^{\min}, & \text{if } T - \sum_{k=1}^{i-1} X_k^{\min} < X_i^{\max} \end{cases} \tag{3}$$

In the above formula, T represents the number of steps in the optimized time window; the unit time step is 2 s, $X_i(s_i)$ represents the decision set; $X_i^{\max}$ and $X_i^{\min}$ represent the maximum and minimum allowed by the i stage phase group, respectively.

The recursive formula and boundary conditions of the optimal index function are as follows:

$$\begin{cases} f_i(s_i) = \min\limits_{x_i \in X_i(s_i)} \left[v_i(s_i, x_i) + f_{i-1}(s_{i-1}) \right] \\ f_0(s_1) = 0 \end{cases} \tag{4}$$

In the above formula, $f_i(s_i)$ represents the optimal value function of a given state s_i, which represents the current state and the optimal index values of all previous stages; $v_i(s_i, x_i)$ represents the index function when the state variable of stage i is s_i and the decision is x_i, the specific evaluation index Function $v_i(s_i, x_i)$ is a sub-optimization problem, which will be expanded in the next section. The optimal value function here uses the forward recursion formula, after obtaining the optimal decision within the optimization step through the forward recursion, the optimal decision of each stage is recursively deduced in the reverse direction. The detailed forward recursion method is as follows:

Step 1: Initialization, $f_0 = 0$, $i = 1$;
Step 2: For $(s_i) = 0, X_i^{\min}, ..., T$, ask:

$$f_i(s_i) = \min_{x_i}\left[v_i(s_i, x_i) + f_{i-1}(s_{i-1})\right], x_i \in X_i(s_i) \tag{5}$$

The optimal decision of recording stage i in state s_i is $x_i'(s_i)$;
Step 3: If $i \geq P$ and there are $f_{i-k}(T) = f_i(T)$ for all $k < P$, then end the recursion, otherwise $i = i + 1$ go to step 2;

When considering the two adjacent phases $i-1$ and i, in the same state, more phases will allow more phase group changes, making the evaluation function value smaller, namely $f_{i-k}(T) \geq f_i(T)$, when $f_{i-k}(T) = f_i(T)$, it proves that the latter phase The phase group does not have a better effect on the index function, so it is considered reasonable to use $f_{i-k}(T) = f_i(T)$ as the end condition in the state T.

After the forward recursion is over, assuming that stage I is the final decision-making stage, the optimal decision value in the predicted time window T is obtained, and then reverse recursion to obtain the optimal decision sequence in the time window T, the steps are as follows:

Step 1: Let $S'I - (P - 1) = T$;
Step 2: For $i = I - (P - 1), ..., 1$, read the optimal decision value $x_i'(s_i)$ under the optimal state S_i' of this stage, and obtain the optimal state $s_{i-1}' = s_i' - x_i'(s_i)$ of the previous stage according to the state transition equation, and then obtain the optimal decision sequence by analogy.

3 Simulation Experiment Analysis

In order to verify the dynamic trunk line coordination control algorithm, this section builds a simulation road network on the SUMO simulation platform, uses C# secondary development to implement the algorithm, and accesses the GAMS/CPLEX solver to assist in the solution of the optimization model. The experimental diagram of the urban traffic road network simulation system is shown in Fig. 5.

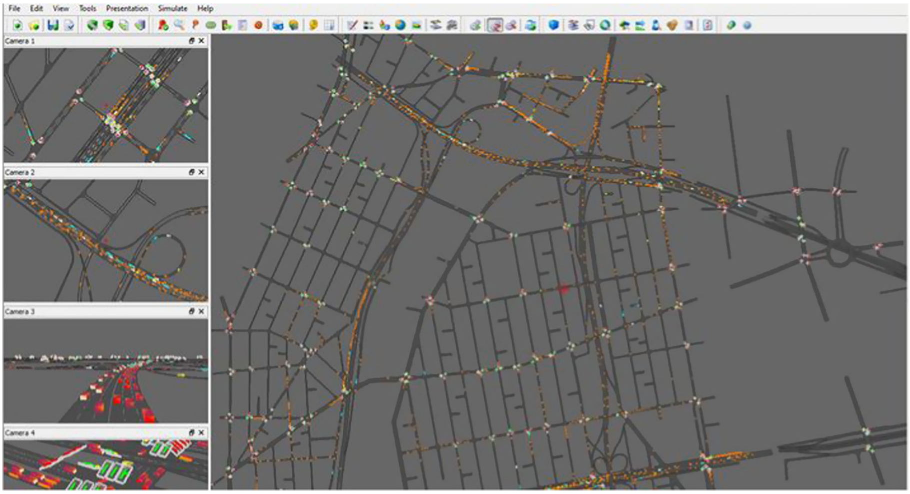

Fig. 5. Urban traffic road network simulation system

3.1 Simulation Tools

(1) NS-3 is a relatively novel simulation tool compared with GloMoSim, OPNET and other network simulation software. Its powerful functions bring great convenience and help to experimental research. In fact, NS3 is not the next generation software of NS2, but a brand new discrete event simulation software. In NS3, the simulator is all written in C++, with only selective Python language binding. Therefore, the simulation script in NS3 can be written in C++ or Python. Because NS3 can generate pcap package trace files, it can also be used in combination with other simulation tools to analyze the simulation process by importing trace files generated by other software.

(2) SUMO (Simulation of Urban Mobility) simulation platform is a microscopic, continuous road traffic simulation software, mainly developed by the German Aerospace Center. SUMO came out in 2000. The main purpose of SUMO as an open source, microscopic road traffic simulation is to provide traffic research organizations with a tool to implement and evaluate their own algorithms. There is also to achieve complete traffic simulation without involving all the necessary components and equipment, such as setting traffic network commands and realizing traffic control.

3.2 Simulated Road Network

Before the NS3 simulation simulation, the SUMO tool was used to generate an effective mobile mode. The simulation scene used a simulation area of 2000×2000 m^2 and used the main street layout of the urban area. The city simulation area includes 32 two-way roads and 17 road intersections, as shown in Fig. 6. Vehicle nodes are randomly released above the road and start movement in two directions at the same time. The intelligent driver model manages the movement of vehicle nodes on the road. Table 1 summarizes all the basic simulation parameters. The simulation results shown below are the average of several simulations.

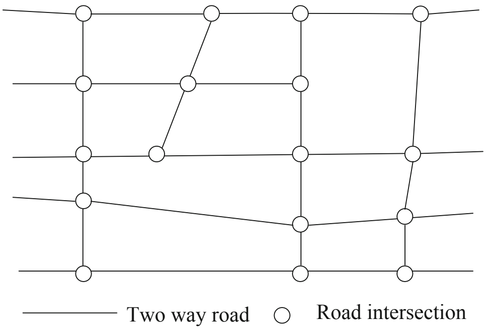

Fig. 6. Simplified model of urban traffic node routes

Table 1. Simulation parameter settings

Parameter name	Parameter settings
Simulation area	2000 m × 2000 m
Number of intersections	17
Transmission range	265 m
Number of vehicle nodes	75–250
Number of roads	32
Vehicle speed	30–60
MAC	Layer protocol
Channel capacity	2 Mbps
Business model	CBR
Packet size	128
Weight coefficient size(α and β)	0.5

3.3 Result Analysis

This article mainly calculates the average delay time of vehicles at the intersection as the evaluation index. The vehicles are equally distributed to different time periods to form the number of queues in Table 2, and it is assumed that the vehicles arrive at the intersection evenly. Under the signal control strategy in this article, the maximum green light time for traffic flow in the straight direction is 50 s, and the maximum green light time for traffic flow in the left turn direction It is 30 s, and the average headway of vehicles passing through the intersection is 2 s. The saturated flow rate is both 2000 pcu/h, and the average delay time of the vehicle under the fixed period signal is about 23.10 s. Under this signal control strategy, through the proper combination and optimization of the sub-phases, the priority phase rotation order can be obtained; by calculating the time each time the vehicle passes through the intersection, the total vehicle delay time is obtained, and the average vehicle delay time is calculated to be about 17.34 s. Numerical results show that the use of the traffic node management strategy based on this paper can reduce the average delay time of vehicles.

Table 2. Number of vehicles queued in different periods

Period	East	West	South	North
8:04–8:05	4	6	6	6
8:05–8:06	3	4	7	5
8:06–8:07	5	3	5	4
8:07–8:08	3	5	5	5
8:08–8:09	5	4	4	8
8:09–8:10	2	8	5	4
8:10–8:11	6	6	8	7
8:11–8:12	5	4	4	5
8:12–8:13	3	6	5	5
8:13–8:14	5	5	6	6
8:14–8:15	4	3	4	8
8:15–8:16	3	4	5	5
8:16–8:17	4	6	5	4
8:17–8:18	3	5	7	5
8:19–8:20	4	6	6	6

Since the simulated road network scene area is large enough, the layout of the main streets in the urban area can be simulated more accurately. The nodes of the designed vehicles are randomly released on the road and start to move in two directions at the same time, which ensures the randomness of the simulation. In summary, all the basic simulation parameters are summarized with high reliability.

4 Conclusion

In the era of mobile Internet, traditional traffic signal control concepts and technologies have gradually been unable to meet the needs of urban traffic development. For this reason, an urban traffic node management scheme based on 5G wireless network architecture is designed. The experimental results show that the method in this paper can reduce the number of vehicles in line and reduce the average delay time of vehicles, thereby effectively improving the utilization efficiency of road traffic resources and alleviating urban traffic problems.

The design method in this paper can effectively realize the management of traffic nodes and reduce the average delay time of vehicles. In future research, the goal should be to improve the efficiency of node management, improve the urban traffic node management plan, and further improve the level of urban traffic management.

Fund Projects. Guangxi High School Young Teachers Improve Scientific Research Ability Project in 2019 "The Research of Nanning Rail Transit Emergency Pre-warning System" (2019KY0935).

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