Intelligent public transport cloud platform dispatching operation management system development

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Abstract. In recent years, with the rapid development of various cities, the operation and maintenance of the public transport system has become increasingly prominent problems, the development of the intelligent public transport system has been imperative. This paper takes the intelligent public transport system as the research object, using wireless network transmission technology, big data retrieval and processing, cloud computing platform and other technologies, analyzes the main requirements of the intelligent public transport system. This system adopts the classic three-layer architecture of the Internet of Things, namely, the perception layer, the network layer and the platform layer. Intelligent public transport dispatching system is the core system of intelligent public transport. The paper uses frog leaping algorithm as the dispatching algorithm to realize the function of public transport dispatching. Through the test, it can complete the task of adding or reducing vehicles according to the increase or decrease of passenger flow. The design and implementation of the cloud platform provides a strong support for the renewal and development of modern urban public transportation system, and has a certain guiding significance. As a complete system with more rapid and accurate management, more convenient and efficient operation, it improves the public transport dispatching ability and improves the travel experience of passengers, and has a cross-era significance for the development of urban public transportation.

Keywords: intelligent public transport system, cloud platform, dispatching, leapfrog algorithm.

1. Introduction

After implementing the policy of reform and opening up in our country, after decades of development, the level of development in all aspects of our country has been greatly improved. However, the rapid development of productivity has also brought about a negative effect, That is, the number of motor vehicles in our country is very large, which leads to bad traffic conditions in cities, huge exhaust emissions, air pollution is particularly serious and other problems. At the same time, it also brings about a lot of consumption of limited energy such as oil and natural gas. Therefore, public transportation as a clean and environmentally friendly way of travel has been vigorously promoted by the government.
The study of intelligent public transport dispatching system in foreign countries started earlier than that in China. Experts and scholars in the United States have realized real-time extraction and analysis of various bus operation information, and based on the analysis results, released information of public transport transfer, weather conditions, driving speed and other information to passengers [1]. Although Japan's research on intelligent bus started later than that of the United States, it is developing rapidly. Since Japan adopts a step-by-step approach in its development process, its development level is relatively solid and the error rate is lower [2]. Compared to Japan and the United States, continental Europe is a bit late to the research, in Europe, Germany was the first country to use GPS technology on buses.

The pace of China's research on intelligent public transport is a little later than that of other countries. In the 1980s, Chinese experts and scholars paid attention to the development trend of intelligent public transport abroad for the first time. In the 1990s, many domestic cities began to practice in the construction of intelligent public transport system, which successfully opened the prelude to the study of intelligent bus system in China. In 1997, Sun Fuling of Xi'an Highway Jiaotong University discussed several methods to determine the departure interval based on the survey data of some bus passenger flows in Xi'an [3]. In 1998, the first comprehensive bus ITS project in China was launched in Beijing. In 2008, Sun Chuanjiao first proposed the concept of co-scheduling regular buses and BRT buses. In 2009, Ning Guilan from Chongqing University proposed the APC and GPS based bus auxiliary scheduling system and related models [4]. In 2011, Zhang Qingyan put forward a series of effective rectification measures through investigation. In 2014, Wang Yan led other relevant experts to put forward for the first time the application of Internet of Things technology into the management system of urban intelligent bus, forming an effective solution. In recent years, with the efforts of experts, China's bus dispatch system has gradually caught up with the level of other countries. Some cities, such as Beijing, Shanghai and Shenzhen, have formed relatively perfect bus dispatch system, which is also at the leading level in the world. Chen Shenjin et al. used attractor propagation clustering algorithm to optimize passenger travel feature data set, and established a prediction model with support vector regression. Finally, deep learning technology was used to improve the scheduling optimization model, and the experimental results were both practical and reliable [5].

With the development of Internet cloud technology, the Internet era has entered a new era. By introducing the public transport system into the cloud, positioning, monitoring and dispatching can be achieved. Therefore, a perfect bus dispatching operation management system for the orderly operation of the bus has become a crucial link to attract people to take the bus. In this paper, an intelligent public transport dispatching operation management system is designed. The dispatching method is studied and tested. The specific design achieves the desired effect.

2. Overall structure intelligent transport system

With the increase of urban population and vehicles, urban traffic problems are becoming more and more obvious. Optimizing urban public transportation is one of the most effective ways to solve this problem. Therefore, the development of urban public transport system has become a necessary means to solve urban problems.

The content of this chapter first analyzes the specific needs of the current intelligent bus in China. Then, according to the requirements, the feasibility analysis and performance requirements are summarized, and finally the overall design of the bus management system is completed.

2.1. Demand analysis of intelligent public transport system

The main demand of passengers can be summarized as the optimization of their own travel experience.

1) Obtain bus and other related real-time dynamic information through electronic station boards
2) Through the way of the Internet, to get the bus line, waiting station service information

The main functions of the system should include vehicle location positioning system, video monitoring management system, real-time data query system, dispatching operation management system, information exchange management system and so on. Each system takes the Internet as the
carrier to realize data sharing and collaborative processing in different regions. Together set up a can be applied to the actual and meet the user needs of the complete system.

2.2. Feasibility analysis
1) The principle of practicality: The bus system can meet the needs of urban residents' travel requirements, to the overall system to have a detailed plan. Develop multiple programs for emergency needs and compare systematic planned and expected goals. For interface design, to be easy to operate, easy to use for the principle.

2) The principle of economy: On the basis of meeting the needs of public travel, we should seek the greatest economic and social benefits. This principle needs to be reflected not only in the design process, but also in the direction of future services and in reducing the cost of the system.

2.3. Performance requirements
1) Real time: The terminal equipment adopts 5G communication technology in the process of information collection, processing and transmission to ensure the real-time performance of data transmission.

2) Good control: The style of the terminal system is simple and easy to operate, which will not affect the normal driving of the driver. And, when the vehicle is not malfunctioning, the driver will not have the operation authority.

3) The reliability of communication: The on-board terminal equipment uses 5G network for data transmission. Due to the interruption of data transmission due to unforeseen reasons, the terminal equipment should be equipped with the function of automatic connection after link interruption.

4) Security: The database of the intelligent public transport system contains a large amount of information, so the security of the intelligent public transport system must be guaranteed to prevent the disclosure of personal identity information and business secrets and disrupt the market order.

5) Stability: In order to prevent the major consequences of traffic system breakdown, the public transport system has set up the necessary redundancy system to ensure the normal operation of the system in the case of failure.

2.4. Overall framework of intelligent public transport system
The overall framework of the whole intelligent public transport system draws lessons from the classic three-layer architecture design of the Internet of Things technology, namely, the perception layer, the network layer and the platform layer. As shown in Figure 1, the three layers can jointly complete all functions of the intelligent bus system. Specifically: As the perception layer, the vehicle position positioning system and video monitoring management system complete the collection of all kinds of driving data, including bus position collection, picture and video collection, train number data collection and line operation data collection, etc. The network layer sends all kinds of information collected by the perception layer to the platform layer through 5G, Internet and other network technologies. Professionals at the platform layer conduct in-depth analysis, processing and query on these data. According to the results of data analysis, it can better help the dispatcher make dispatching decisions and meet the profit needs of public transportation enterprises and the travel needs of citizens.
Figure 1. General framework of intelligent bus system

1) Vehicle position positioning system

The main function of the vehicle position positioning system is to realize the positioning of the target vehicle by using the precise positioning chip and its antenna of GPS or Beidou Satellite Positioning System located in the vehicle. To determine the latitude and longitude of the bus in the process of location information and speed information, and generate a replayable running track.

After the information is processed and analyzed by the system module, it is processed in two directions. One is to compare the station location information with the built-in bus information, and then decide whether to trigger the voice station announcement function. Second, the location and speed information of the vehicle is sent to the vehicle dispatching center in time so that the dispatcher can make dispatching decisions in time.

2) Video monitoring management system

Video monitoring management system can real-time monitoring and video browsing, video storage and retrieval playback, picture capture. Relevant pictures and video images can be transmitted to the monitoring center through wireless network for real-time and unified management. When monitoring the passenger flow of the station, the corresponding scheduling strategy can be adopted according to the change of passenger flow, and the security situation of the station area can be monitored. Monitoring equipment includes in-car surveillance camera, front door camera, front car camera, rear car camera, vehicle travel recorder, forward ADAS device and electronic station status monitoring, etc.

3) Real-time data query system

Data query system can query the data. Vehicle scheduling center based on the results of the query, can better schedule the bus, to achieve the operation management of intelligent bus and solve emergency problems.

The main function of the data query system is to collect the information of passenger flow in a day and provide data support for the dispatcher to make dispatching decisions. Specifically, it mainly includes the following functions: collecting driving records, collecting line operation plans and other functions.

4) Dispatching operation management system

Bus dispatching operation management system has the most important function. It is mainly oriented to public transportation enterprises and their bus dispatching rooms, and realizes the bus enterprise dispatching and the on-site dispatching of the bus dispatching room. Each bus dispatching room can log in the bus dispatching operation management system, view the dynamic information of the bus operation in the city in real time, and implement the dispatching of the corresponding bus according to the running conditions of the lines under their jurisdiction. Managers can log in to the system at any time in order to view the citywide bus running dynamics in real time, can also grasp the citywide bus running conditions, operation data and other information in real time, can obtain the necessary support data management work.

5) Information exchange management system

The information exchange system includes two aspects: one is dispatching platform and bus station; the other is dispatching platform and bus station.

a) Dispatching platform and bus station: The bus background dispatching platform can send the text to the LED display of the electronic stop board of the designated station through the wireless network. And it can be flexibly set up on the electronic station board screen function partition. The screen supports the configuration of release frequency, release content, release route, release authority and other contents, and can set different levels of priority conditions to meet the different requirements of different management departments for information release.

b) Dispatching platform and bus station:

A voice intercom system was set up between the bus and the dispatch center, and the audio signals were transmitted over the Internet. When there is an emergency, it can dispatch in time, and can make remote emergency broadcast, etc., so as to timely inform the duty room staff, drivers and passengers in the center of the lower transportation hub.
3. Hardware design of intelligent bus system

The hardware structure of the intelligent bus system is shown in Figure 2. The intelligent bus positioning system is composed of GPS or the Beidou satellite, on-board front-end system, center management system and wireless network. The four parts coordinate with each other and constitute the whole intelligent bus system.

The vehicle-mounted front-end system is mainly responsible for the acquisition and collection of vehicle position information and surrounding road condition real scene information. Its equipment mainly includes the GPS antenna carried on the bus to receive the GPS positioning signal, and the dashcam to obtain and collect the real scene information of the surrounding road conditions. The information collected by GPS antenna and dashcam is sent or stored to the vehicle hard disk in real time via wireless network. In the process of bus operation and running, the on-board positioning system can obtain and collect positioning information such as location data and surrounding road condition information through the above series of on-board equipment. And these information through 5G or WiFi wireless network real-time transmission to the central management system, waiting for the bus command and dispatch center processing.

![Figure 2. Hardware structure diagram of intelligent bus system](image)

4. Intelligent Public Transport Dispatching method

At the present stage, it is difficult for residents to wait for the bus, transfer to the bus and slow driving speed. Dispatching system can maximize the capacity of the bus, but also can make up for the part of the line capacity and the actual passenger flow does not match the embarrassing problem, to meet the needs of passengers.

4.1. Influence factor

The travel of urban residents in China is characterized by two peaks, namely, the morning peak and the evening peak. As shown in Figure 3, the morning and evening peaks of residents' travel are from 7am to 8am and from 6pm to 7pm.

![Figure 3. Changes of passenger flow in different periods of time](image)
4.2. Public transport dispatching model definition

In this paper, the public transport dispatching model is defined as follows:

1) Let \( S \) be the set of all the bus stops on the route of a bus, denoted as \( S = \{s_1, s_2, \ldots, s_n\} \), where \( s_j \) represents a stop on the route.

2) Let \( T_0 \) represent the time matrix of a bus starting from the departure station, denoted as \( T_0 = (t_{ij})_{n \times n} \), as in (1). In the formula, \( t_{ij} \) represents the time taken for the bus to travel from \( s_i \) bus stop to \( s_j \) bus stop, and time \( t \) is the parameter. \( s_i \) and \( s_j \) are adjacent bus stations on the bus running route. If they are not adjacent, set \( t_{ij} = 0 \), that is:

\[
T_0 = \begin{pmatrix}
0 & t_{12} & \cdots & 0 \\
t_{21} & \ddots & \ddots & \vdots \\
\vdots & \ddots & \ddots & t_{n-1,n} \\
0 & \cdots & t_{n,n-1} & 0
\end{pmatrix} \quad (1)
\]

3) Set \( A \) as the initial passenger flow distribution matrix, denoted as \( A = (a_{ij})_{n \times n} \). \( a_{ij} \) in the formula represents the number of passengers who get on the bus from the bus stop \( s_i \) and get off at \( s_j \) as a function of time \( t \).

4.3. Model Building

The biggest contradiction between bus companies and passengers is that the bus companies want to have as few empty seats as possible on each bus, while passengers want to be able to sit down and enhance their travel experience when they get on the bus. Therefore, the needs of both sides should be taken into account when building the model. Based on the principle of minimizing the cost of both the bus company and passengers, the following bus dispatching model is established:

1) The travel cost of passengers includes the cost \( p \) of buying tickets and the time cost \( c \cdot W_i \) of waiting for a bus. Therefore, the total cost of a passenger traveling by bus is:

\[
P = \sum_{k=1}^{K} \sum_{i=1}^{I_k} [\alpha_1 \cdot c \cdot W_i + (1 - \alpha_1) p] \quad (2)
\]

In Formula (2), \( c \) represents the unit cost of each passenger per unit time, which can be determined by the quotient of per capita GDP and per capita working hours. \( W_i \) is the waiting time for the \( i \)th passenger; \( P \) is the price of a bus ride for a person; \( I_k \) represents the total number of passenger flows in the \( k \)th period of bus operation; \( \alpha_1 \) represents the weight between the passenger’s waiting cost and the cost of taking a bus.

2) For bus companies, the daily operation cost is the same as passenger travel cost, which also contains two parts: static cost and dynamic cost. The total cost \( H \) is shown in Formula (3):

\[
H = \sum_{k=1}^{K} \frac{T_k}{\Delta t_k} [\beta_1 E + (1 - \beta_1) \tau L] \quad (3)
\]

In Formula (3), \( T_k \) is the time span of the \( k \)th period, in minutes. \( \Delta t_k \) represents the departure interval in the \( k \)th time period, and the unit is minutes/car; \( E \) represents the static cost of each bus operating for one day; \( \tau \) represents the unit operating cost per kilometre of bus travel; \( L \) represents the total length of bus routes; \( \beta_1 \) is the weight between dynamic cost and static cost of bus travel; The quotient of \( \frac{T_k}{\Delta t_k} \) and \( \Delta t_k \) is the number of buses in the period \( k \).

Through the above analysis, it can be seen that the public transport dispatching problem is actually a multi-objective optimization problem to solve the minimum value, that is, the sum of the bus
company’s operating cost and passenger travel cost is the minimum objective function, and the formula is shown in (4).

\[ f = \min[\rho_t P = (1 - \rho_t)B] \] (4)

In addition, in order to balance the interests of passengers and the interests of the company, necessary constraints must be imposed on the departure interval, as shown in Formula (5).

\[ T_{\text{min}} < \Delta t_k < T_{\text{max}} \] (5)

In the formula, \( T_{\text{min}} \) represents the minimum lower limit of the bus departure interval (minutes/bus); \( T_{\text{max}} \) denotes the maximum limit (minutes/vehicle).

However, in order not to cause the company to lose money, the company's ticket income must be greater than the operating cost, as shown in Formula (6).

\[ \sum_{k=1}^{K} \sum_{i=1}^{R_k} I_{ik} \cdot p > \sum_{k=1}^{K} T_k / \Delta t_k \cdot (\tau \cdot L + E) \] (6)

In summary, the objective function of the intelligent public transport dispatching model can be obtained, as shown in Equation (7).

\[
\begin{align*}
 f &= \min [\rho_t \sum_{k=1}^{K} \sum_{i=1}^{R_k} (\alpha_i \cdot W + (1 - \alpha_i) p + (1 - \rho_t) \sum_{k=1}^{K} T_k / \Delta t_k \cdot (\tau \cdot L + E))] \\
\text{S.t.:} & \quad T_{\text{min}} < \Delta t_k < T_{\text{max}} \\
& \quad \sum_{k=1}^{K} \sum_{i=1}^{R_k} I_{ik} \cdot p > \sum_{k=1}^{K} T_k / \Delta t_k \cdot (\tau \cdot L + E)
\end{align*}
\] (7)

4.4. Leap frog algorithm principle

Compared with other algorithms, leapfrog algorithm has the advantages of setting fewer parameters, simple idea, strong ability to find the optimal solution, easy to implement, so this paper chooses the leapfrog algorithm to study the problem of public transport dispatching.

As shown in Figure 4, the basic idea of the frog leaping algorithm is that there are a group of frogs living in a wetland. There are many stones scattered in the wetland, and the frog jumps to find the place with more food by looking for different stones. Information is exchanged between each individual frog through cultural communication. The culture of each frog is defined as a solution to the problem. The entire frog population in the wetland was divided into different subpopulations, each of which performed a local search strategy. Each individual in a subgroup has its own culture, which influences and is influenced by other individuals, and evolves as the subgroup evolves. When the subgroups have evolved to a certain stage, the exchange of ideas (global information exchange) between each subgroup will be carried out to realize the mixed operation between subgroups, until the conditions set are met.

![Figure 4. Schematic diagram of leapfrog algorithm](image-url)
4.5. Preferences

In view of the characteristics of leapfrog algorithm, the parameter selection of leapfrog algorithm is very important. The details are as follows:

1) Frog population size $F$

Because the ability of the algorithm to obtain the optimal solution increases with the growth of the population size, so the good or bad of an algorithm mainly depends on the selection of the population size, which is the basis of an algorithm.

2) The number of frog subgroups $m$

In the frog leaping algorithm, the frog subgroup is used to complete the local search task, so the frog population $F$ is decomposed into $m$ subgroup.

3) The number of iterations of each subgroup is $N$

The selection of subgroup iteration number $N$ is crucial, and the selection of $N$ should be comprehensively determined by the population size $F$, the number of subgroups $m$ and the number of frogs contained in each subgroup.

4) The number of global iterations of the population $M$

The choice of $M$ should be determined according to the actual problem of the required solution, and the value of $M$ should be directly proportional to the population size.

5) The maximum distance that each individual frog is allowed to jump $D$

The value of $D$ determines the search direction of the whole algorithm.

4.6. Specific process

The specific operation process of leapfrog algorithm includes six steps. The flow chart is shown in Figure 5:

Step1: Assign $F$ frogs to $m$ subgroup according to the number of $n$ frogs in each subgroup.

Step2: Initialize the position of each frog in the whole frog group, calculate the fitness value of each frog, rearrange all frogs according to the fitness value from the best to the worst, and write the frog with the best fitness value of the whole population as $p$.

Step3: Assign $F$ frogs to $m$ subgroup, and perform local iterative optimization.

Step4: Conduct local search on each subgroup.

Step5: After withdrawing from local search, mix all the frogs in the population, sort the position of each frog from the best to the worst according to the adaptive value, and update the frog with the best adaptive value.

Step6: If the optimal solution satisfies the actual conditions, exit the loop; otherwise, return to Step3.

```
Start

Meet the termination condition

The fuel consumption of the bus and the number of waiting passengers were determined, and the population was randomly initialized according to the actual situation of the dispatching (A successful dispatching scheme)

Calculate the cost of each bus to travel a certain route and rank it by fitness

Subpopulation partitioning: Divide $F$ individuals into $m$ populations according to certain rules, and carry out local iterative optimization for each subgroup

Individuals jump, sort, and merge in each subgroup

Mixing all the subgroups to form a complete population

Yes

No

Output the optimal solution

End
```

*Figure 5. Flowchart of leapfrog algorithm*
5. System test
The system test mainly includes hardware test and software test. The software test specifically carries out the functional test of the traveling record and dispatching system.

5.1. Driving record function test
After logging in the query system, the manager selects the track playback function to query the driving record of a certain vehicle. Look for the vehicle, click query, the track of the vehicle will be displayed in the interface.

5.2. Dispatching system functional tests
After logging in the dispatch center to log in the system, the actual direction and linear simulation diagram of the buses in operation will be displayed on the screen. The linear simulation diagram is a simplification of the actual trend diagram, which is more conducive to the dispatcher to understand the actual situation of bus operation.

This test included two buses, 101 and 102, and the dispatcher could see the number of departing and returning vehicles of each bus in the interface of the linear simulation diagram. The number of vehicles waiting to depart can also be seen at the starting station of the running line, while the number of vehicles parked at the terminal station can be seen.

In addition to dispatchers can schedule vehicles according to the simulation diagram displayed, the starting and ending stations of each line can be seen on the right side of the display. And has the special event inquiry function and the travel record playback function. When dispatching, the dispatcher can see the serial number of each vehicle in the line, And the dispatcher usually only calls the serial number of the other party through the voice cluster dispatching system, which is more convenient and fast. In addition, the system sets the optimal departure time for each vehicle based on the optimal solution obtained by the intelligent algorithm and displays it on the screen. On the right side of the set time, the system records the actual time of the driver's departure, which is compared with the optimal departure time obtained by the intelligent algorithm.

Moreover, if a bus line often needs temporary additional vehicles, then it is proved that the buses in the line according to the actual needs of the line; On the contrary, if the bus load rate of a certain line often fails to meet the operating requirements, the operating vehicles of the line should be reduced. When a new vehicle is added, in order to supervise and manage the vehicle, the dispatcher needs to fill in the license plate number of the new vehicle, as well as the vehicle information such as the brand and model, and describe why the new vehicle is added.

6. Conclusion
Public transport system is an essential part of people's life in the city, which provides considerable convenience for People's Daily travel. However, in recent years, with the rapid development of various cities, the scale of the city continues to expand, the population continues to increase, the operation and maintenance of the bus system and other problems are increasingly prominent. It is imperative to develop intelligent bus system based on many disadvantages of traditional bus system.

This paper takes the three-layer architecture of the Internet of Things as the basic framework, and designs the vehicle location positioning system and video management system as the perception layer. As the scheduling operation management system and data query system of the application layer, data transfer is realized between the perception layer and the application layer through the network layer. In this paper, the scheduling system is the core, using leapfrog algorithm, the establishment of a bus scheduling model for the benefit of the Bus Company and residents, to achieve the maximization of the interests of both sides. The linear simulation diagram of 101 and 102 buses is established to facilitate the management of dispatchers. And according to the number of passenger flow, the paper scheduling system also designed the function of increasing or decreasing vehicles, to achieve distribution according to demand.
Although the new technology of intelligent bus system has been widely used in foreign countries, but China has also independently designed and manufactured the intelligent bus system suitable for China's urban conditions and put into use. It is believed that in the near future, the urban intelligent bus system with its own characteristics will be popularized in various large and medium-sized cities in China.

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