Design of Intelligent Bus Positioning Based on Internet of Things for Smart Campus

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ABSTRACT In order to improve the means of bus dispatch, improve the efficiency of bus operations, and implement a smart campus, the design of an intelligent bus positioning system, which is based on the Internet of Things, is studied. This article first discusses the location awareness of IoT nodes and the location awareness of multi-source positioning to achieve intelligent perception of the environment. Then the overall design of the intelligent bus system of IoT is carried out, and the design idea of the three-tier network hierarchy based on the perception layer, the network layer, and the application layer is given. The system uses RFID technology to track, locate, and monitor buses. The touch screens at bus stops can count the number of passengers waiting for each bus, and the electronic bus-stop boards can publish the arrival time of each bus and some other information. The Zigbee wireless network technology is used to achieve communication between the vehicle terminal, Platform system and dispatch monitoring center. Finally, the simulated annealing algorithm is used to achieve intelligent bus scheduling, improve the quality and efficiency of bus service to meet the travel needs of citizens.

INDEX TERMS Internet of Things; Intelligent Bus System; RFID; Zigbee; Simulated Annealing Algorithm

I. INTRODUCTION

Buses are the most popular means of transportation for the public, but several main problems—difficulty in waiting for and squeezing a bus, and the inaccuracy of bus arrival time, have always affected the bus ride experience. The scheduling of campus buses is basically carried out according to a fixed timetable, using the manual dispatching method of “fixed-point departure and two-headed points on time” [1], and the driver needs to call or manually report the station, so there exist the problems like leaving out, reporting wrongly etc. which have seriously affected the service quality and efficiency of campus bus passenger transportation. The intelligent bus system is a new generation of intelligence, environmental protection, digital bus stop kiosks and “Internet of vehicles” system, which has integrated the several big systems— the environmental protection and energy conservation, the bus supervision, and the public information release system. It is one of the key links of realizing the modernization of the traffic. With the development of Internet of Things, new technical support is provided for intelligent bus system.

Internet of Things, IoT, is an emerging field, as a result of the information industry developing into the 21st century [2]. It is expected to lead the third wave of the information industry revolution. In recent years, researches on the IoT and the related technologies have continued to flourish [3]. The information collected by the node during the application of the IoT is closely related to the location information of the node itself, which defines the location of the stop and the vehicle itself, clears the information, as the scheduled arrival time of buses, the arrival site, the passenger flow, etc. Thereby the comfort of passengers is improved.

In order to improve the service quality and efficiency of campus buses and the satisfaction of student passengers, the good node positioning of the Internet of
Things and the location awareness of multi-source positioning are applied to the environmental awareness of campus buses, and a campus intelligent bus system is designed to realize the real-time positioning of the campus bus, monitor the bus operation status, intelligently dispatch buses, and provide the station with the operation information of the bus in time.

II. INTERNET OF THINGS OVERVIEW

According to the burgeoning developing trend of research and application of IoT, the paper aims to summarize the location and location awareness technologies, and the related researches of the IoT. Referring to the layered characteristics of the IoT, the positioning and location perception are understood from three levels, as shown in Figure 1.

Figure 1 also lists the major issues related to the current IoT location and location awareness research. Starting from the heterogeneity and mobility of the IoT, the paper discusses the characteristics of location awareness and location, and introduces the signal system for wireless location of the IoT. Then two kinds of methods of position perception are discussed in detail: the range-based and range-free location. The network positioning capability and the localizability of the IoT are discussed. Then the location awareness method of multi-source positioning and information fusion is discussed, combining the status quo of research and application. Finally, we summarize the issue that the positioning of the IoT is worth of research. We also look ahead to the technical difficulties and application realization.

III. INTERNET OF THINGS POSITIONING CAPABILITIES AND POSITIONABILITY

A. NETWORK POSITIONING CAPABILITIES

The Internet of Things Location usually shows network [5]. From the perspective of perception and transmission layer, the IoT structure can be either “flat” self-organizing network or the “hierarchical” heterogeneous [6]. The Internet of Things Location, by the wide participation of hierarchical object nodes, is using the characteristics of network to complete the location and location awareness process.

The capability of the IoT positioning refers to the index improved by the characteristics of the network and related with the location, like whether the coverage area during the network positioning has certain real-time positioning capability, and whether it can use network structure characteristics to overcome the disadvantages of positioning, etc. The key problem can be attributed to how to mine the space-time characteristics of the IoT. Space-time collaboration in dynamic network is a relatively new view of collaboration: the use of network characteristics to complete the positioning from both time and space. Time Domain Collaboration is based on the node mobility model to help locate by state estimation. Spatial Domain refers to the use of relative positional relationships between nodes and topology properties to complete the positioning in each time slot or positioning interval. The space-time positioning covers multi-factors which affect the network positioning, such as topology structure, connectivity characteristics, wireless propagation environment, interference and network synchronization bias, etc. So the theoretical basis and
performance of network positioning can be explored from the principle [7].

B. LOCABILITY STUDIES
In the application of the IoT, the network structure will affect the localizability. The localizability of the network is discussed in detail by using graph theory and rigid theory. In general, the complete rigidity of the point is the necessary and sufficient condition of the localizability of the network, but the rigid graph can lead that two kinds of discontinuous deformation damage become completely rigid. As shown in Figure 2, Figure 2 (a) is the flip fuzzy, and unknown node X has two possible positions. Folding fuzzy is gotten through the continuous deformation process, as shown in Fig. 2(b). After removing the edges (B, C) and the graphics \{A, B, D, E\} for continuous deformation, find a position to make sure the length of the edges (B, C) does not change. Then add graphics (B, C) to get another graphics. Setting strict conditions ensures the rigidity of the network graph [8]. If unknown nodes need to maintain 3-connectivity, from graph theory, the above inferential basis is on the premise that accurate distance or position information can be obtained or that there is no error. Then the basic problem of node positioning is discussed: Under the specific network structure, how many object nodes can be located? Are there object nodes cannot be located? Through the theoretical analysis and experiments, the two questions are answered under the sparse and moderate IoT positioning, and the part of its results can be positioned as the gist of deploying object node when positioning is applied.

However, when the practical positioning is applied, the measurement of distance may not be always accurate, and the distribution of nodes also affect the positioning performance [9]. As shown in Fig. 3, it can be predicted that the final positioning error is smaller than the right image when the anchor nodes A, B, and C are distributed as the left diagram. Regardless of the range-based or range-free positioning method, the study of the distance error of nodes will occupy an important position in the research of the positioning ability and positioning performance of the IoT. To sum up, the existing researches mainly start from graph theory, rigidity theory and optimization theory to analyze positioning performance, eliminate localization ambiguity (positioning uniqueness), and discuss the localizability from different angles and different influencing factors.

C. IOT MULTI-SOURCE LOCATION AWARENESS
The current research of location awareness is based on wireless positioning, which is attributed to the dual advantages of wireless network technology used in communication and positioning. The IoT is widely used. The positioning technologies used are diversified, and the approaches to obtain positioning information tend to be heterogeneous and multi-sourced. As the rapid development of micro-systems and micro-sensing technology in the IoT [10], location-aware technology has gone beyond the scope of wireless positioning. Object nodes in the IoT are not limited to a single terminal. For example the widely used smart phones are equipped with a variety of sensing devices, most of which are low-cost and low-power microsensors. Table 1 shows some commonly used sensors without the aid of wireless positioning technology. These sensors can complete the sports tracker on the premise of knowing the initial position. And the typical application is the Dead Reckoning (DR).

<table>
<thead>
<tr>
<th>Method</th>
<th>Technology</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless</td>
<td>Global Positioning System</td>
<td>Range measurement</td>
</tr>
<tr>
<td>Non-wireless methods</td>
<td>Accelerometer</td>
<td>Acceleration</td>
</tr>
<tr>
<td>multi-sensors based localization</td>
<td>Gyroscope</td>
<td>Angular velocity</td>
</tr>
<tr>
<td></td>
<td>Barometer</td>
<td>Altitude/ height</td>
</tr>
<tr>
<td></td>
<td>Magnetometer</td>
<td>Heading direction</td>
</tr>
<tr>
<td></td>
<td>Camera</td>
<td>Environment aware</td>
</tr>
</tbody>
</table>

FIGURE 3. Different node distribution network positioning

FIGURE 2. Rigid discontinuous deformation
At present, multi-source positioning combined with wireless positioning and the multi-sensor is a highly potential location-aware strategy of the IoT. It is worth of noting that the assistance of geographic information (GIS) is also indispensable in many scenes \[11\], such as car navigation system, as shown in Figure 4. It cannot work, only relying on GPS and other positioning means without geographic information.

The key issue of location awareness based on multi-source location is information fusion. Figure 4 illustrates the role of location information fusion by taking vehicle tracking and intelligent traffic in IoT applications as an example. As shown in the figure, the vehicle obtains the distance information through GPS or cellular positioning, and the vehicle can form a VANET for non-ranging positioning. Vehicles can use various motion sensors, speedometers, gyroscopes to complete dead reckoning, and geographic information assistance to determine vehicle orientation and complete trajectory tracking.

In the application of the IoT location, multi-source location awareness and information fusion can best reflect its system characteristics. Through the following three examples that can be applied to location-awareness of the IoT, the research progress of multi-source location information fusion is discussed.

1) GPS ONE
GPS one is a comprehensive positioning platform that can provide the location-based wireless service and can be widely used in logistics management, personnel positioning and tracking in the IoT. GPS one integrates satellite positioning and cellular mobile positioning (mainly based on CDMA). The outdoor is mainly in virtue of GPS. In areas where GPS cannot receive, the success rate of positioning is ensured by the cellular base station. GPS one system integrates these two kinds of information sources \[12\]. As long as there is one satellite and one base station, positioning can be completed. This method mainly uses range-based location technology and it does not reflect the positioning cooperation between mobile nodes. By indoor maps and access to hotspots (like being provided by WLAN or Femtocell), the solution can also be extended to indoor navigation.

2) FIRST RESPONSE
Use EKF to obtain statistical positioning gains, integrate multiple sensors, and combine with UWB positioning to achieve fast-response IoT positioning. Coordinated positioning can be performed when nodes are in motion. 3D positioning can be completed, and various parameters, such as the position information, the speed, the azimuth, the accelerated speed and etc. can be described during the moving process. The motion sensor is wearable. Also, the person wearing the system can form a small-scale mobile ad hoc network, making full use of positioning information interaction, collaborative positioning and positioning information fusion.

3) USING WIFI SIGNAL CHARACTERISTICS AND LOCATION AWARENESS OF MULTI-SOURCE DATA.
Unloc is an indoor location and tracking solution that can realize non-supervision and is suitable for applications of IoT in indoor environments, such as clerk monitoring, factory industrial automation, etc. This system embodies the comprehensive use of multiple positioning methods. Use RFID to identify object nodes. Use the WiFi’s fingerprint matching algorithm to position. Use various inertial sensors, such as accelerometers and gyroscopes etc. in motion tracking. By studying the spatial relationship of the WiFi network RSS with the help of multi-data acquisition of smart phone terminals, and combining with node mobility characteristics, it is proposed to construct an indoor positioning system of a high-dimensional fingerprint space without prior knowledge of AP locations.
The above system applications all reflect the intelligent perception of the environment.

IV. MODEL DESIGN OF INTELLIGENT BUS SYSTEM BASED ON INTERNET OF THINGS

A. NETWORK LEVEL MODEL OF INTELLIGENT BUS SYSTEM

According to the three-tiered nature of the IoT, the network layer model of the intelligent bus system is mainly divided into three parts: bus data collection, bus data analysis and processing, and data information feedback and display\textsuperscript{[13]}, as shown in Figure 5.

![Network Level Model of Intelligent Bus System](image)

**FIGURE 5. Network Level Model of Intelligent Bus System**

Thereinto, the bus information collection mainly collects the passenger flow distribution of each site at different time intervals and collects information on the operation of the bus system at the same time. The data information of bus is to analyze the collected data information through the functional bus management system. It can respond to the alarm information of abnormal conditions timely, dispatch bus lines uniformly, integrate the feedback of resource information effectively, and publish the position of the next bus, the predicting waiting time for passengers and the relevant information prompts through the prediction of the bus electronic bus-stop board or the display of the arrival information. These enable passengers to know various bus information on the way. Therefore the service level of the bus is enhanced.

The intelligent bus system is an integrated system including multi-subsystems with different functions. In the intelligent bus system based on the IoT, on the one hand, it is necessary to collect and transmit data information such as passenger information, bus position information and so on. On the other hand, it is needed to integrate, summarize and prioritize the collected various information and make corresponding responses and solutions. For the main functions of the intelligent bus system, a detailed description of the design of the system is provided according to the Hierarchical Networking Model of the intelligent bus system.

1) PERCEPTUAL LAYER

In Figure 5, the bottom layer is the perception layer, which is also the basic application level of the IoT technology in the intelligent bus system. It basically completes the collection of basic data and provides the most primitive data information for the entire intelligent bus system. Data acquisition mainly uses Wireless Radio Frequency Identification technology to identify, and the intelligent vehicle speed achieves the information acquisition--- the bus information, the passenger information, the arrival information and other data information by terminals and wireless communication equipment.

The bus information is mainly realized through RFID technology. The RFID tag is embedded in the bus body, and then a reader is installed at the bus stop to read the vehicle information. When buses exit, arrive, and return, their information will be identified, combining with the GPS. The vehicle information can be located at any time, and then the information can be sent to the Bus Dispatch Center. The bus can be dispatched reasonably through the intelligent bus system. At the same time, the information of public vehicles can be sent to the electronic bus-stop boards to provide the real-time and dynamic bus information for passengers so as to facilitate passengers to make reasonable choices.

Statistical Information of passengers are also mainly implemented through the RFID, the instrument of passenger flow statistics and smart vehicle terminals. The tag is embedded in the bus card, and when the card is swiped, the vehicle reader RFID reads the passenger's identification, and then the instrument of passenger flow statistics counts the number of passengers on the bus. Upload the information to the vehicle terminal and send it to the Information Center for processing. After the data is transmitted back to the Bus Dispatch Center, the intelligent bus system is used to optimize the allocation of bus lines according to the passenger flow, and change the frequency of bus departures dynamically according to the flow of passengers, so as to achieve reasonable dispatch of bus.

2) NETWORK LAYER

The network layer mainly completes the information transmission between the Bus Dispatch Center and each bus, as well as the information transmission between the Bus Dispatch Center and the electronic bus-stop boards. It realizes the networking function, mainly through the basis networks such as the mobile communication network, Internet, satellite communication and so on. This can basically meet the requirements of IoT bus information transmission.

3) APPLICATION LAYER

The application layer filtrates, classifies, and analyzes the information transmitted from the perception layer and the network layer, and then makes corresponding processing. This layer can be divided into two aspects: the feedback control and the service. The feedback control is mainly based on the data information provided by the perception layer and the network layer. The intelligent bus system need provide corresponding feedback, control and processing. The service mainly provides the traffic information including the vehicle information.
information, the road condition, the passenger flow information and so on on electronic bus-stop boards. Therefore, the intelligent bus system consists of the subsystems such as the Intelligent Dispatch Subsystem, Intelligent Bus Positioning Subsystem, and Communication Management Subsystem to complete the management of the intelligent bus, to provide service support for realizing the automation of dispatching for bus companies and the intelligent management of bus operations.

Among them, the Intelligent Dispatching Subsystem is responsible for intelligently adjusting the departure time through the collected vehicle information, passenger information and road condition information, combined with the operation schedule. The Bus Positioning Subsystem mainly uses satellite positioning technology to locate the bus's operating position, traveling speed, and trajectory, and compares it with the site information to realize the electronic reporting bus stop. The Communication Management Subsystem is mainly responsible for sending and receiving data information.

The application layer includes the electronic bus-stop board, which displays the arrival and departure of the bus and displays the distance from the bus stop to the next. The passenger can choose the appropriate bus. The electronic bus-stop board can also display information related to travel information such as the weather condition and the noise decibel.

### B. MAIN FUNCTIONAL MODULES OF INTELLIGENT BUS SYSTEM

Main functional modules of the intelligent bus system:

1) **RFID BUS MONITORING**

Radio Frequency Identification (RFID) technology is a wireless, non-contacting automatic identification technology. RFID technology can locate, track and monitor buses. The RFID system consists of a reader, an antenna, and an electronic tag. Because the bus lines are relatively fixed, and each stop has different vehicles with multiple lines parking. RFID readers are installed at each site and RFID tags are attached to buses. When the bus approaches the site, the reader can read the corresponding bus data, then the microwave sensor collects the traffic parameters of the bus and associates the address information of the bus stop, the bus information, and the arrival time together.

2) **ZIGBEE WIRELESS COMMUNICATION**

Zigbee has the characteristics of low power, low consumption, low cost, low-speed in short-distance, short delay, high capacity, and high security. It is suitable for the application of the intelligent bus system. Zigbee wireless network technology connects the vehicle-mounted terminal, the platform system and the dispatch monitoring center together. The Zigbee transceiver chip transmits the collected bus information and the information of the waiting passengers to the Bus Dispatching Management Center via the wireless sensor network. The center can adaptively conduct the dispatch in time and the dynamic monitoring of buses according to the passenger flow and bus information.

3) **ON-BOARD SUBSYSTEM**

The Onboard Subsystem realizes the functions of automatic positioning of buses, automatic voicing stop, automatic recording of driving information, fault alarm and so on. When approaching the stop, the wireless data receiver passes the received geographical information signal to the main control microprocessor for analysis and processing. Then obtain a corresponding reaction signal. The signal reaches the audio control chip via the serial interface, and the chip drives the audio frequency and the process according to the signal. Through the external voice output speaker, achieve automatic voicing stop and warm prompts at the same time. The chip of the liquid crystal display system processes the signal transmitted through the main control microprocessor to drive the display driver. There shows the names and pictures of the corresponding sites, as well as simple scrolling prompts on the screen. It can also be used to broadcast tendentious slogans, public service ads, and nearby attraction information. In some holidays, you can insert festive elements to increase passengers' entertainment. When the bus encounters a traffic accident or a vehicle fault occurs, the driver can send a fault signal to the dispatch center by the set button to request help.

4) **PLATFORM SUBSYSTEM**

The platform subsystem realizes the estimation of the bus arrival time of each route and the statistics of the number of waiting passengers. And the bus that is about to pass the bus stop is stored into the memory of the microprocessor in the form of code. When the passenger arrives at the bus stop, the number of ride can be selected by touching the screen B. The main control microprocessor will read the code in the memory. After analyzing and processing, on the one hand, the main control microprocessor drives the high-frequency transceiver to release the corresponding data signals without intervals in the transmittable range; on the other hand, the main control microprocessor transmits the data signal to the display control chip. When the corresponding bus enters the wireless signal range, the onboard subsystem will feedback the corresponding data signal to the platform subsystem and eliminate the number of waiting passengers through the display control device after the bus receives and verifies the information. It reverts to the initial state and shows that “Bus is about to arrive, please make preparations” on the screen.

### C. INTELLIGENT BUS SYSTEM HARDWARE SYSTEM

1) **VEHICLE SUBSYSTEM**

The onboard subsystem consists of a main control microprocessor, a high-frequency transceiver chip, a wireless receiver chip, a voice control chip, a liquid crystal display, a touch screen, and a memory module, as shown in Figure 6.
2) PLATFORM SUBSYSTEM
The platform subsystem consists of a main control microprocessor, a high-frequency transceiver chip, a display control chip, a memory, and a touch screen module, as shown in Figure 7.

D. INTELLIGENT TRANSIT SYSTEM SOFTWARE SYSTEM
The software of the IoT-based intelligent bus system encapsulates the functions of the bottom layer (Zigbee, RFID, etc.) through the network layer, and provides a unified call interface for the upper GUI interface [18]. The functional block diagram is shown in Figure 8. The underlying driver layer and physical hardware layer are encapsulated by the operating system layer (network layer), providing an interface for upper API functions to connect user applications.
1) **EMBEDDED LINUX DEVELOPMENT PROCESS**

1. Establish the development environment, install the Fedora® system as a host environment in the virtual machine, and install the GCC cross-compiler [19].
2. Configure the development host. Configure serial port terminal software parameters, configure NFS network file system, configure SMB service, establish boot loader BOOTLOADER.
3. Download the transplanted Linux operating system. After downloading, add drivers for hardware such as RFID, Zigbee, and LCD to debug and modify.
4. Create a root file system, download from www.busybox.net and use BUSYBOX software to perform function reduction, generate a most basic root file system, and add other programs according to your application needs.
5. To create a flash disk partition for an application, use the JFFS2 or YAFFS file system, and provide the driver for these file systems in the kernel. You need to plan the flash partitioning scheme according to the application.
6. Development applications can be downloaded to the root file system, or they can be placed in the YAFFS and JFFS2 file systems.
7. Write the kernel, root file system, and applications.

2) **NETWORK SERVICE LAYER**

Implementing (Socket Communication) Socket is the most widely used inter-process communication mechanism on Linux. What different it from other Linux communication mechanisms is that it can be applied to the inter-process communication within various machines as well as to the single one. However, since Socket itself does not support simultaneous wait and timeout processing, it cannot be directly used for real-time communication between multiple processes [20].

This article uses the event-driven library libev to build a "question and answer" server model. Socket server side Libev is a high-performance event loop/event-driven library. Libev has faster speed, smaller size, functions and other advantages. Libev starts with void ev_loop(ev_loop* loop, int flags) uses the ev_loop structure loop body to detect if an int flags) uses the ev_loop structure loop body to detect if an event is generated. Because the actively terminated connecting mechanism is not designed, each connection can be maintained at any time, and the client can freely choose the exit timing. The above model can accept any number of connections and provide completely independent question and answer services for each connection. With the event loop/event-driven interface provided by libev, the above models have the opportunity to have the features of high efficiency, low resource consumption, good stability, and simple writing that other models cannot provide.

The main implementation process of the server is as follows: first a Zigbee background thread (bottom layer) is started to listen to server call information, then a receive thread is started using ev_io_start (loop, & ev_io_watcher) , which is specifically used to receive the command information sent by the client, and then follow the corresponding protocol. Parse, jump to the corresponding interface, further use the bottom layer- Zigbee and other information and send the correct information to the client. The client program is used to interact with the server to provide an encapsulated interface for the upper GUI.

3) **QT/E GUI INTERFACE DESIGN**

QT is a cross-platform C + + graphical user interface (GUI) toolkit, the design of the host computer interface software uses QT/E4.6 as the interface development package, the general process is to first call the network client Api_GetConnect (port) interface function, connected to the server's port port, and then open a thread (zigbeetopo.cpp) to call the network client's Api_Cliect_GetRfidId() interface to obtain the card number read by RFID [21].

V. SCHEDULING APPLICATION OF INTELLIGENT BUS SYSTEM BASED ON SIMULATED ANNEALING ALGORITHM

A. **MATHEMATICAL MODEL OF BUS SCHEDULING**

The bus scheduling problem is essentially a multi-objective optimization problem. The objectives considered are mainly the interests of both passengers and bus companies. Passengers want to wait as short as possible and the bus company operates as efficiently as possible [22-24].

In this paper, a bus of a certain line is taken as the research object. The statistics of the number of people getting on and off at each station in each time period have been investigated, and we have optimized the starting schedule of the line in the upward direction. The line has a total of 13 stations in the upward direction. The first bus departure time is set at 5:00 am and the last bus is at 24:00 pm. All-day passenger traffic is known, with the goal of setting a full-day departure schedule and maximizing the target needs of passengers and bus companies, reducing passenger waiting time. The statistics of the number of people getting on and off at each stop of the bus at each time are shown in Table 2.

<table>
<thead>
<tr>
<th>Platform</th>
<th>A13</th>
<th>A12</th>
<th>A11</th>
<th>...</th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00-6:00</td>
<td>Get on</td>
<td>360</td>
<td>67</td>
<td>52</td>
<td>...</td>
</tr>
<tr>
<td>Get off</td>
<td>0</td>
<td>9</td>
<td>14</td>
<td>...</td>
<td>84</td>
</tr>
<tr>
<td>6:00-7:00</td>
<td>Get on</td>
<td>1004</td>
<td>470</td>
<td>321</td>
<td>...</td>
</tr>
<tr>
<td>Get off</td>
<td>0</td>
<td>253</td>
<td>739</td>
<td>...</td>
<td>836</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>23:00-24:00</td>
<td>Get on</td>
<td>15</td>
<td>4</td>
<td>3</td>
<td>...</td>
</tr>
<tr>
<td>Get off</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>...</td>
<td>20</td>
</tr>
</tbody>
</table>

1) **OBJECTIVE FUNCTION OF PASSENGERS’ INTERESTS**

$s$ indicates satisfaction. $T$ means waiting time. $t$ indicates the time from the departure of the first bus (The unit is minutes). $t_0$ is the first bus departure time (5 am means the same as 300 minutes). Passenger satisfaction is described as the number of triangle ambiguities in waiting time, and satisfaction decreases as the waiting time increases [25].

In the morning and evening peak hours, that is, $420 \leq S + t_0 \leq 540$ and $960 \leq S + t_0 \leq 1080$, there are 26
\[ s(t, T) = \begin{cases} 
1 & 0 \leq T \leq 2 \\
-\frac{1}{3}T + \frac{5}{3} & 2 < T < 5 \\
0 & T > 5 
\end{cases} \quad (1) \]

The non peak satisfaction function \( s(t) \) is

\[ s(t, T) = \begin{cases} 
1 & 0 \leq T \leq 6 \\
-\frac{1}{4}T + \frac{5}{2} & 6 < T < 10 \\
0 & T > 10 
\end{cases} \quad (2) \]

Passenger satisfaction \( s \) is related to waiting time and bus arrival time. \( R(i, j, T) \) is used to express the waiting time at moment \( t \) and the waiting time at station \( j \) is \( T \) passengers. Then there are

\[ F_i(X) = \int_0^{T_i} \sum_j T_j \int_0^T (R(t, j, T) \cdot s(t - T, T))dT \] \( dT \) (3)

The constraints of the decision variables are as follows

\[ x_i \in \mathbb{Z} \text{ and } x_i \geq 0, i = 1, 2, \ldots, m \]
\[ x_1 = 0, x_m = 1080 \]
\[ x_1 < x_2 < \cdots < x_n < \cdots < x_m \]

Among them, \( F_i(X) \) represents the sum of all passenger satisfaction of the car throughout the day; \( X_m \) represents the time of the \( m \)th car departure time from the start time.

2) OBJECTIVE FUNCTION OF BUS COMPANY'S INTERESTS

Let \( p_k \) denotes the number of passengers on board during the journey from station \( k \) to station \( k+1 \). Then the vehicle satisfaction of any number of trains running between two stations is \([27-28]\)

\[ s'(p_k) = \begin{cases} 
0.012p_k & 0 \leq p_k \leq 50 \\
0.008p_k + 0.2 & 50 < p_k < 100 \\
1 & 100 \leq p_k \leq 120 
\end{cases} \quad (5) \]

The company's total satisfaction is the sum of all vehicle satisfaction within one day.

\[ F_2(X) = \sum_{i=1}^{k_0} \sum_{k=1}^{k_0} s'_k(p_k) \] \( (6) \]

3) OPTIMIZATION OBJECTIVE OF BUS DISPATCHING

According to formula (3) and formula (6), we can get the optimization objective of bus dispatching.

\[ F(X) = \max \{ F_1(X), F_2(X) \} \] \( (7) \]

Taking \( F(X) \) as the goal of bus dispatching, it takes both passenger satisfaction and bus company satisfaction into account. It conforms to the needs of today's society and is conducive to realizing the common interests of passengers and bus companies. It is a multi-objective optimization problem \([29]\).

B. APPLICATION OF SIMULATED ANNEALING ALGORITHM IN BUS DISPATCHING

1) BASIC IDEAS AND STEPS OF SIMULATED ANNEALING ALGORITHM

The basic idea of the simulated annealing algorithm is to start from a given solution, using the generator and the receiving criteria, to constantly change the solution of the current structure into the solution of the adjacent structure \([30]\).

The general steps of a simple simulated annealing algorithm can be described as follows:

Step1 Selecting an initial solution \( x_0 \). Setting the number of iteration steps \( k=0 \), the initial temperature is \( T_0=t_{\text{max}} \).

Step2 If the internal circulation stop condition is reached at this temperature, proceed to Step3. Otherwise, randomly selecting \( x_j \) from the neighborhood \( N(x_i) \), calculating \( \Delta f_j = f(x_j) - f(x_i) \); If \( f_j \leq 0 \), then \( x_j = x_i \) Other wise accepting \( x_j \) with probability \( \exp(-\Delta f_j/T_k) \); repeat Step2.

Step3 \( t_{k+1} = \Delta t_0 \), \( k = k+1 \). If the stop condition is satisfied, the calculation is aborted; Otherwise, return to Step2.

2) INTELLIGENT CAMPUS BUS SCHEDULING SCHEME BASED ON SIMULATED ANNEALING ALGORITHM

The mathematical model established in the VI.A section, the initial temperature is set to 1000, and the cooling function is \( T_k = T_0 \times 0.9^k \). \( K \) is an evolutionary algebra. The operation process is optimized according to the simulated annealing algorithm.

Simulation results are obtained.
morning and evening peak hours, and the scheduling is reasonable [31].

FIGURE 10. All-day departure frequency map

The departure frequency has formed two distinct peaks, and there are very obvious “peaks” and “valleys”. This corresponds to the peak hours of the passenger flow in the morning and evening, fully reflecting the interests of passengers, further indicating that the simulated annealing algorithm has better efficiency. At the same time, it also shows that the established bus scheduling model reflects the actual situation and is feasible.

VI. CONCLUSION

This paper studies the application of IoT node location and multi-source location awareness in the campus intelligent bus system to improve the intelligentization of campus bus scheduling, and integrates RFID technology and Zigbee wireless network technology into the intelligent bus system. The design scheme of intelligent bus system based on Internet of Things is proposed. The main functional modules of the intelligent bus system are discussed from the aspects of vehicle monitoring and dispatching, vehicle terminal, electronic station sign and communication network. The design framework and flow of the hardware and software of the system are given. Taking a bus of a certain road as an example, the simulated annealing algorithm was used to simulate the dispatching, and good expected results were obtained. Based on this, the bus scheduling table was given. The system can locate and monitor the bus running status in real time, provide the bus running information to the station in time, and improve the quality, efficiency and satisfaction of the bus service.

VII. SYSTEM APPLICATION PROMOTION

Although this paper only studies the location of the campus bus based on the Internet of Things, and gives the design of the intelligent bus system, it still has some inspiration for the development of the urban intelligent bus system. The construction of the intelligent bus system based on the Internet of Things will promote the standardization of urban bus industry management, automation of operation supervision, scientific decision support, rationalization of command and dispatch, integration of information services, and improve the service and management level of urban bus transportation. Comprehensively enhance the attractiveness of urban buses and the share of travel, and promote the construction of a comprehensive urban transportation system that is safe, convenient, efficient and green.

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