MODELING AND SIMULATION OF THE AUTOMATIC TRAIN PROTECTION IN WLAN BASED CBTC SYSTEMS

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Abstract: The urban rail transit is playing a more and more role in the social and economic development, building a suitable ATP system in wireless LAN based CBTC system with low cost and high accuracy has become increasingly important. Based on the theories of wireless LAN-based CBTC and ATP system, this paper studies the general structure and modelling of ATP system in wireless LAN based CBTC system, and accordingly establishes the model of speed-distance brake curve for ATP system which is essential in optimal design of an ATP system. The model can realize a smooth train stopping and speed protection function. Meanwhile, strong wireless signal coverage improves the equipment reliability of internal communications. Comprehensive simulations on labVIEW platform verify the correctness of the model.

1 INTRODUCTION

In recent years, urban rail transit in various cities of China is developing rapidly. Along with the advance of computer technology, communication technology and control technology (generally called the 3C technologies), the latest train control system — CBTC (Communication Based Train Control) formed gradually. CBTC outcomes the shortcomings that information can only be transferred by trackside equipment when the train runs, and achieves real-time two-way communication between the train and the trackside equipment (Chen *et al.*, 2005). Safety is an important factor which restricts the development of CBTC in China. ATP (Automatic Train Protection) which is responsible for safe running of trains is the core component of CBTC on-board equipments. In CBTC, with the characteristics of wireless broadband, high speed and mobility, WLAN provides a more reliable medium in data communications on high-speed trains (Carr *et al.*, 2005). CBTC automatic train protection system based on WLAN can further reduce the amount of trackside equipment of signal system, and improve the ability of system upgrading and expanding. It has already become a new development direction of ATP system in urban rail transit.

In foreign countries, WLAN security technology has already reached the safety standards in CBTC system. CBTC system based on WLAN has been already widely used in urban rail transit (Wu, 2005). Automatic train protection system is an important problem to be solved on the way to establish a CBTC system with independent intellectual property in China. Due to the characteristics of CBTC system, the WLAN network performance under the condition of fast moving traffic on the road should be considered as a key issue. And we should pay attention to the problem of automatic train protection system in CBTC based on WLAN. To ensure the safety of operation and to improve the efficiency of transportation, it is urgent to equip advanced, safe and reliable train control system. Train control system currently used in China is mainly based on track circuit (Xu and Tang, 2007). This kind of system played an important role in the protection of traffic safety and efficiency. But some problems also exist, for example, real closed-loop control cannot be achieved due to the limited amount of information transmitted by track circuit, the stability of track circuits influenced by environment and large investment on repairing the track circuit. To overcome the shortcomings of train control system based on track circuit, more and more countries prefer to use CBTC which is a new generation of train control technology. Based on communication technology, CBTC achieves information exchanging with the station or the train controlling centre through on-board equipment and site communication

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equipment. There are many advantages when compared with TBTC, such as a shorter departure interval, less quantity of hardware, simple maintenance, more flexible, better security of the system and a better transmission mode. CBTC train control system will become a mainstream technology in the future.

Therefore China should speed up on the research of train control system, and develop train control technology with its own intellectual property. Although China has started the research of CBTC train control system technology, it is still in infancy period. Currently, WLAN based on the standard of IEEE802.11 has become the most widely used data communication method in urban rail transit (Grappone and Hubbs, 2007). ATP (automatic train protection system), which is responsible for the safe operation of trains, is the core component of CBTC equipment. Therefore, the study of urban rail transit ATP system based on WLAN is the main mission in the research of CBTC. The establishment on the model of urban rail transit ATP based on WLAN is a paramount and urgent research work. It is significant for ensuring the security and stability of CBTC system. Meanwhile it can help to reduce the project cost of CBTC systems.

This paper will analyze on giving a model of the core algorithm formula on the speed-distance curve of the ATP system based on WLAN, and use modular design method to establish the model of ATP system and system maintenance and upgrading will benefit from it. To test the reliability of the model, the platform of Labview is selected and an integrated simulation system of ATP is established in this research. Then simulates this program and discusses the feasibility and accuracy of the proposed solution.

The paper follows the steps by question prompting, theoretical research, practical research, solution proposing and model establishing to check the solution. First, the paper points out the necessity and background of security problems in application of ATP system, and elaborates practical significance of this study. Second, the paper defines the basic theories, targets and principles of establishing models on applying WLAN to CBTC, and analyzes the advantages and disadvantages of current ATP systems, so that to find out the advantages of ATP system applied to CBTC based on WLAN. Then, applies WLAN technology based on IEEE 802.11 to the train control systems, builds the structure of the entire wireless communication system, and focuses on modeling the ATP speed-distance curve in mathematics and dynamics. Next, based on the established model, simulates the ATP system in CBTC based on WLAN and discusses the accuracy and feasibility of the proposed solution. Finally, summarizes the work on composing the paper.

2 RESEARCH FOUNDATION AND RELATED THEORIES

2.1 Problems Existed in WLAN

WLAN obeys an open channel standard. Therefore, it is hard to prevent attackers from eavesdropping deliberately, tampering and forwarding maliciously. Information of WLAN transmits in the air through radio waves. So attackers can receive, interfere, tamper, forward or even forge information as long as they have the same receiving equipment while the sender can't detect them. It's easier for attackers to camouflage to be legal users because users do not have to connect with the net actually. In addition, when the radio wave transmits in the air, the signal attenuates which leads to the missing of information for various reasons, such as barrier or shield. Radio coverage area is limited. Wave energy will become lower and lower when it spreads in the air. Besides, there may be some obstacles in the communication environment. When transmitting through the obstacles, the information may lose, causing data integrity problems.

When applied to urban rail transit CBTC, the WLAN's characteristics mentioned above will cause some specific security problems. When CBTC communicates by WLAN, as the environment is more complex, the speed of the train is fast and there are all kinds of interference such as signal reflection in the subway tunnel, shielding and signal temporarily blind areas, electromagnetic, signals, human destruction, etc [5]. Equipment processing capacity, network load capacity problems, communication equipment or media failure, may lead to insecurity data communication. Unauthorized users' accessing, eavesdropping, simulating base stations and other malicious behaviours are what we need to consider.

To solve these problems, there have been some related researches at home and abroad, for example, obtain the best AP density to ensure relatively redundancy by modelling and calculating to solve the problem of data loss. To carry out effective authentication, Message sequence number, Time stamp (Cai, 2000), Time-out, Source and destination identifiers, Feedback message, and Safety code

(Chen and Song, 2007) are used. Dynamic keys or random keys are used for data encryption.

Currently, there are some products which have been put into use in foreign CBTC system (Zhou *et al.*, 2009). However, the related domestic research has just started. As mature and open DCS communication security technology and products are still rare, related products are very expensive. Besides, the safety of urban rail transit is directly related to the security of life, property and social stability. Therefore, train operation control puts forward higher requirements for reliability, security and confidentiality of wireless transmission. These problems seriously affect and restrict the popularization and application of CBTC technology.

2.2 Characteristics of the ATP System in CBTC based on WLAN

ATP (He, 2005) system is an important subsystem of the automatic train control (ATC) system and a key facility to ensure the operation safety of trains. It is consisted of the trackside equipment and on-board equipment. With the advantages of its high accuracy positioning of trains, two-way high capacity train-ground data communication and on-board, the ATP system in CBTC based on WLAN (Zhang and Li, 2008) has become an important and indispensable part of the development of urban rail transit at home and abroad.

The main functions of ATP system in CBTC based on WLAN exists in following aspects: security parking point protection; speed monitoring and speeding protection; measurement of distance and speed to control the safe running of the train; gate controlling to prevent opening the door outside the station, opening the wrong door inside the station and preventing the train from starting with the door open in order to ensure the safety of passengers; interval controlling to prevent the train from rear collision.

There have been some fixed necessary engineering data in the computer of ATP system such as route slope, length of track circuit, speed limit and so on. According to the existing data and operating conditions of the route, ATP computer follows a certain algorithm to calculate the maximum allowable curve of the train (Hong, 2006). Shown in Figure 1.

The information of the position or the danger point of the train ahead (named A) transmits to the follow-up train B which is running in the line interval through the wireless communication system. For train B, position of train A is a danger point. Train B calculates the maximum allowable speed to the danger point. With train A moving forward, the safe parking point of train B (stations do not belong to safe parking points) also changes. Train B calculates the speed-distance curve to the parking points at real-time. When actual speed exceeds the maximum allowable speed, the system alerts and requires the train to decelerate. If the train fails to decelerate to the maximum allowable speed within the given time, the system will implement emergency brake to ensure the safety of the train.

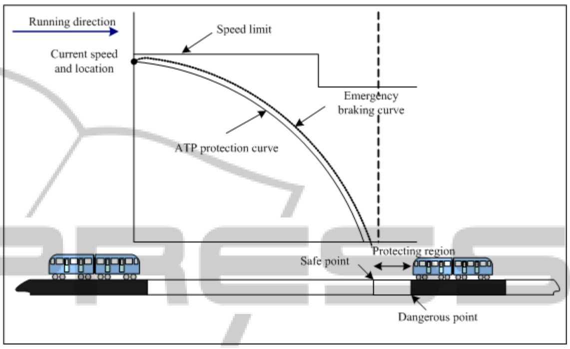

Figure 1: Operation principal of ATP system.

3 MODELING OF ATP SYSTEM STRUCTURE

3.1 The General Model of ATP System

Now build the model of ATP system according to section 2.2. The model mentioned in this paper takes WLAN which is based on the standard of IEEE802.11 to communicate between train and ground (Hu, 2002). Use the advantages of WLAN technology such as flexible using, convenient installation, economic, easy extension to connect ground equipment and on-board equipment through the information transmitting platform. We can achieve not only fast and real-time transmitting of high capacity information but also closed loop testing of train-ground information. The system will be more advanced when supplied by positioning and checking equipment (Chen *et al.*, 2007). The general model of ATP system in CBTC based on WLAN includes 3 parts: regional control centre, on-board equipment of the train and train-ground two-way transmitting system (Mirtchev, 2005). The general model is shown in Figure 2.

3.2 Design of Regional Control Centre

The regional control centre is established in the station where there is a bifurcation so that to interlock this station with neighbouring bifurcated stations and to control the ATP system. The control targets are turnouts, protective signal equipments and digital track circuits. The designed capacity of this centre is: controlling range ≤5km; system treatment cycle time200~250ms; the number collected by relay (digital input) ≤500points; the number controlled by relay (digital output) ≤500points (Lamborn and Thomas, 2005); the communication channel with neighbouring centres is redundant fiber channel; the number of centres whose interfaces can be connected ≤3. Communication mode: two-way serial communication; communication cycle time (transmission) 200~250ms (Wang *et al.*, 2005).

The wireless regional control centre which must be operated safely is the core part of the entire ATP system. Here redundant measurement, disperse and isolate measurement are carried out. Redundant measurement includes 3 levels (Xu and Tang, 2007): system redundancy, net redundancy and power supply redundancy. Disperse and isolate measurement distributes control to all I/O modules in order to reduce the burden on the host system by I/O modules intellectualization. Meanwhile board-level state testing and failure diagnosing are implemented.

3.3 Construct of WLAN Communication System

3.3.1 Structure of WLAN Communication System

As the development of urban rail transit, data communication system based on WLAN will become the most widely used communication system in CBTC considering of the advantages of WLAN based on the standard IEEE802.11, for example, it can be applied to the situation that needs to connect with the net when moving and roaming; it supports distant data processing and uneasy wiring areas; its flexible using, convenient installation, economic, easy extension and so on (Xu and Li, 2006). The wireless data communication network consists of wired backbone network and wireless mobile network. Its network structure is shown in Figure 3.

WLAN communication system is the data transmission platform between different parts of ATP system (Zhang, 2007). The whole data communication system includes 3 levels: Core level, i.e., the backbone network. It's the central of data

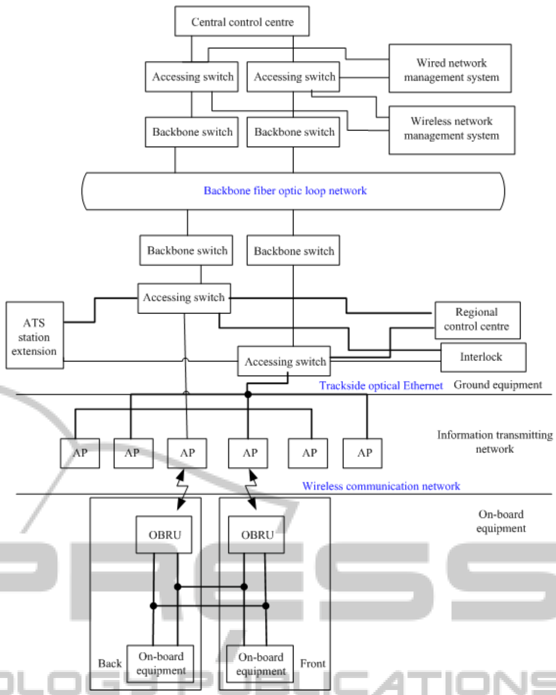

Figure 2: General model of ATP system.

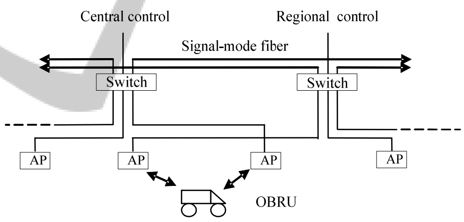

Figure 3: Schematic diagram of wireless data communication network.

communication system which is implemented by redundant optical network with the characteristics of high bandwidth and high reliability. Centre control system and regional control system access to the wired backbone optical network directly; Middle level, i.e., the trackside network. It connects backbone network and wireless network system. The network extents following the route by network switch which has accessed to the backbone network. In this way the trackside network formed. This network connects with wireless railside unit (WRU). Thereby, the wireless access point (AP) can access in it; Mobile level, i.e., the wireless network. This network supports train-ground two-way mobile communication. The trackside AP and on-board wireless units (OBRU) on moving trains communicate by wireless way. In this way, it constructs a link between ground and moving trains. One side of the wireless link is AP and the other side is on the train which connects with OBRU. WLAN communication doesn't mean totally wireless. There are wired fiber between different regional control centres. The equipment of whole communication system includes: optical backbone network, AP, wireless on-board equipment, interlocking centralized station, switch in control centre and router.

3.3.2 WLAN Ethernet Train-ground Communication System

(1)Trackside Wireless Unit
One side of the wireless link is AP and the other side is on the train which connects with OBRU. There is an identification gateway for every switch's ports and OBRU. This gateway certificates the identification of DCS message. To implement the redundant of wireless network, every port of every WRU connects with different switches. So a series of redundant local network is supplied to WRU.

The switch of trackside network connects with the supply chain of local WRU. This chain is consisted of fiber. Considering of technology demand and cost, multimode fiber is used generally. WRUs are installed following the route about 250 per meter. Actual distance depends on detailed survey, including terrain, tunnel structure, local standard, antenna type and so on. Every AP on WRU connects with Ethernet switches through local servo chains. Every AP has two directional antennas facing opposite directions.

Special transmit condition at the channel bend and between distant stations should be considered when arranging AP antennas. We should install antennas according to the actual measured wireless covered range whether it is channels or outdoors. This way most factors that may influence signal transmission would be involved so that there won't be any gaps under the cross covering by wireless signals.

(2)OBRU
There's an OBRU with moving wireless radio (MR) station on each side of the train. In order to implement the redundancy between trackside and the train, these two OBRUs both connect with VOBC. In addition, to diverse the receiving mode of the signal, all MRs connect with 2 on-board antennas. Each MR can search out at least 2 AP signals at any time because of overlapping coverage. To enhance the signal strength and reduce the number of devices, these antennas are oriented.

3.4 On-board Subsystem

3.4.1 Structure of On-board Subsystem

ATP on-board equipment regard the information received from the ground as a basis and generate a speed Hijack curve to compare with the actual speed. If actual speed exceeds the speed control curve, on-board equipment will brake automatically. According to principles of ATP on-board subsystem and its mission, this paper refines it into different functional modules. The train can protect itself automatically by mutual coordination between all functional modules. Main processor is the central part to carry out different functional calculates. It calculates output according to the settings of application program and information from different modules and drive corresponding parts using these outputs.

3.4.2 Structure of Train Positioning Technology System

Real-time, precise train positioning technology is a premise to implement moving block urban rail transit and is the basis for ATP system. This model uses a technology called Wireless Spread Spectrum Communication Location to implement real-time, precise, train positioning and tracking under complex environment. This technology includes advanced wireless spread spectrum communication, pseudo code ranging and computer information processing technology. Wireless spread spectrum communication location system accord with the demand of ATP system based on WLAN. It can locate precisely and is a completely independent positioning system.

Set ranging base central controlling station on the ground along with the trackside radios. Install wireless spread spectrum communication transmitter on both sides of the train. The transmitter sends positioning information to the ranging base station on the ground; after receiving the information, the ranging base station calculates pseudo-range using digital signal processing technology and transmits to the central controlling station to precede data processing through wireless or wired links. The positioning result displays on e-maps and transmits to trains by wireless way. The position of trackside radio stations are fixed after accurate measurement. All the radio stations are synchronization accurately by synchronous clock. Trackside computers or on-board computers will calculate the position of the train according to the transmitting delay time of different radios.

A WLAN is constructed by distributed radio stations. Under most conditions, the area between different stations can be covered by wireless reliably and have redundancy. This kind of redundancy is a self healing structure. When a radio station fails to work, the system can rearrange and report the location or number of the failed radio automatically. So it won't influence communication and train controlling. Information of one radio station will be received by 2 or even 3 radios generally. Spread spectrum technology is design for military application initially. It has the ability to transmit under harsh electromagnetic environment. The position of a train can be tested every 0.5s and the positioning precision can reach to ±5m (Stadlmann, 2008).

4 MODELING OF ATP SPEED-DISTANCE BRAKING CURVE

After building the model of ATP structure, this section will research on ATP core algorithm modelling, speed-distance braking curve modelling. Train braking curve is the basis of over speed protection of ATP system in CBTC based on WLAN. The traction and braking force involved in this model is determined according to "Order of train traction calculation" (The Ministry of Railways of The People's Republic of China) promulgated by the PRC Railway Ministry.

4.1 ATP Protection Curve

The function of braking is to ensure the train to stop at a certain position or to limit the speed in a certain range, i.e., the so-called "rash advance protection" and "speeding protection". Rash advance protection is a special condition of speeding protection when the limit terminal velocity equals to 0. But there are some differences, for example, the result will be different when distinguishing the braking safety distance. In our design, all conditions are treated as "speeding protection" because moving-blocking method is used here. Expanse and adjust it to satisfy precise controlling of all parameters. The train braking distance formula after adjusting is shown as formula (1).

$$S_b = \frac{v_0 T_K}{3.6} + \sum \frac{4.17({v_0}^2 - {v_m}^2)}{1000\varphi_h \theta_h \beta_c + \omega_0 + i_j} \tag{1}$$

Where:
v_0, v_m—initial and terminal velocity of braking;
φ_h—conversion friction coefficient of brake shoes;
θ_h—conversion rate of train braking;
β_c—common used braking coefficient;
ω_0—unit basic resistance of the train;
i_j—additional slop thousandths at braking section.

ATP system of urban rail transit monitors the speed continuously to prevent from speeding. Firstly, ATP system works out the maximum allowable speed of the train at any time, i.e., the safe running speed. If actual speed exceeds this speed, ATP system will brake so that the actual speed can decrease to safe speed in given time. In this process, ATP speed-braking curve model is a most important basis for speeding protection.

4.2 Algorithm to Determine the Maximum Allowable Speed

There have been some fixed necessary engineering data in ATP system such as route, slope, length of track circuit, speed limit and so on. On-board ATP equipment stores basic data about the train such as mass and performance characteristics. First, determine the position of the train by on-board positioning system. On-board wireless equipment transmits information including position code to regional control centre through track WLAN. Then regional control centre sends fixed engineering data of the train position to on-board ATP equipment through WLAN. On-board ATP computers work out the maximum allowable speed curve based on this model algorithm.

4.3 ATP Speeding Protection Process

After calculating the maximum speed and generating the maximum allowable speed curve, on-board ATP computers monitor the running speed and position of the train. If actual speed curve exceeds the maximum speed protection interface, ATP system will cut off the train traction power immediately to carry out protection braking.

The maximum allowable speed varies as the train position changes. On-board ATP equipment makes real-time and two-way communication with regional control centre through WLAN. So ATP speeding protection system is dynamic and real-time. This is just the advantages of ATP system based on CBTC.

5 SIMULATION OF ATP SYSTEM OF CBTC BASED ON WLAN

In Section 3 and 4 we've built the models of ATP system and ATP braking curve. The combination of them can implement the main function of ATP system, i.e., designated parking, speed monitoring, speeding protection, distance and speed measuring, gate controlling and interval controlling. Now build a simulation platform based on LabVIEW to verify the effect of this model.

5.1 Function of ATP System based on WLAN

According to the main function of ATP system in CBTC based on WLAN, this paper designs it into 4 functional modules:

(1)Basic data input subsystem

It is mainly used to set basic parameters for the entire ATP system including 2 parts: structure of route data and train data. Structure of route data includes slop segment data, curve data and speed limiting data. Structure of train data includes traction braking characteristic curve data, mechanical property data of the train and parameters.

(2)Speed controlling subsystem

It is used for speed monitoring, distance and speed measuring and speeding protection. This subsystem can prevent the train from speeding and ensure the actual speed lower than allowable speed which is determined by route, turnout, train and safe controlling curve so that the train can run safely.

(3)Position testing and interval controlling subsystem

It is used to protect the safe parking point and control the running interval. This subsystem can check running state of the train automatically and generate a corresponding curve according to the route environment so that the train can stop at safe regions and rear collision can be avoided.

(4)Gate protection subsystem

It is used for protecting the safety of opening or closing the door. This subsystem controls the platform screen doors and safety doors to ensure the security of passengers when the train stops or leaves.

5.2 Input and Output Design for ATP System based on WLAN

Input and output design includes speed controlling, position testing and interval controlling and gate protection subsystem. The following example shows the speed controlling subsystem.

5.2.1 Function Description

Speed controlling subsystem involves basic data input system and speed controlling sub module. Here is the train speed controlling sub module simulation-IPO (Input-Process-Output) diagram, as is shown in Figure 4.

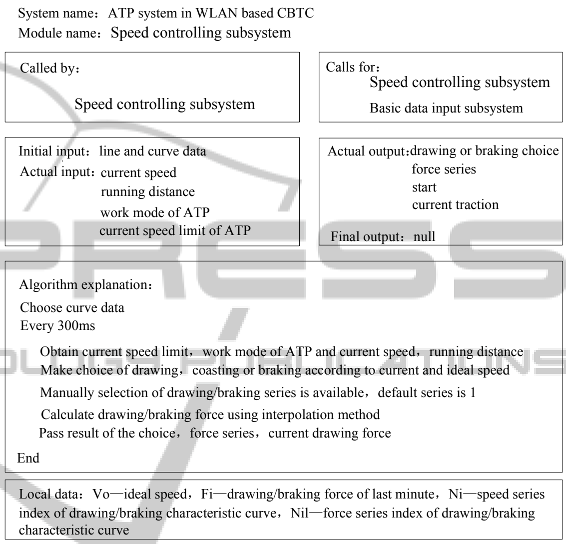

Figure 4: IPO diagram of speed controlling subsystem.

5.2.2 Algorithm Explanation

Use interpolation method to calculate traction/braking force: assume (V_1, F_1) and (V_2, F_2) are two known points on the traction curve. Point (V_X, F_X) is a point whose speed is known but force is unknown and should be worked out.

When $V_1<V_X<V_2$:

$$F_X = F_1 - \frac{(F_1 - F_2)(V_X - V_1)}{V_2 - V_1} \tag{2}$$

Where:

F_X—traction/braking force of the unknown point (KN);

V_X —current speed (km/h).

5.3 System Simulation and Calculation

5.3.1 Simulation Environment

Use LabVIEW virtual instrument development platform of NI to develop the system. LabVIEW

(Zhang and Zhang, 2007) is currently a unique worldwide graphical programming environment based on data flow. According to the program of simulation and test, this paper chooses LabVIEW PDS, Measurement Studio, Signal Express and LabVIEW add-on tools in NI Developer Suite.

ATP system of CBTC based on WLAN includes initial parameter setting, speed controlling, position testing, and interval controlling and gate protection. Speed controlling is the central module of the entire ATP system. It generates fixed or temporary speed limit curve after inputting basic train information and route information. It can also generate braking curve according to the information from the control centre.

The train and route parameters of this simulation come from Rail Transit Line 2 of the straddling monorail train and line data in Chongqing and are simplified according to the model. Here, a section of 1.2km is chosen to simulate. In order to better reflect the logic of the model all speed limits are attributed to one parameter-interval speed limit which is set as 85km/h. In order to reflect the ability of the model to adapt to various situations, all input data involved in the software, including interval speed limit, can be manually set to facilitate the testing of the system.

5.3.2 Simulation Result

Initial state: the train ahead runs under a constant speed 85km/h and stops smoothly at 1.1km. The distance between the train behind and the train ahead is 0.5km. The train behind regards the front train as target distance and target speed to adjust the protection curve. The simulation result is shown in Figure 5.

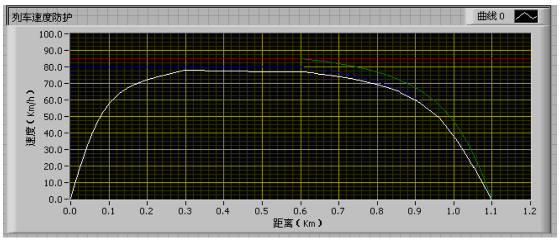

Figure 5: Braking curve of the train.

In this figure the red curve represents for interval speed limit data. It's obtained from reading data which is set before the software runs. The green curve represents for protection curve. It's generated by the model of ATP system. The blue curve represents for target speed. It's obtained by decreasing the speed of protection curve by 3-7km/h.

This paper compared the simulation result with actual auto protection curve obtained in the test phase of Rail Transit Line 2 of the straddling monorail train in Chongqing. Sampling point is chosen as every 0.1km. The comparison result is shown in Table1 and Table2.

5.3.3 Simulation Result Analysis

The braking curve, i.e., the speed-distance curve indicates that if the train wants to stop at a certain safe parking point with a certain initial speed, it should start braking at a certain position to ensure the train arriving right there according to braking curve.

Table 1: Comparison of simulation speed and actual data.

Sampling points (km)	Protection speed (km/h)	Target speed (km/h)	Simulation speed (km/h)	Actual speed (km/h)
0	85	80	0	79.52
0.1	85	80	57.61	78.98
0.2	85	80	72.09	78.76
0.3	85	80	77.94	78.03
0.4	85	80	77.47	77.57
0.5	85	80	76.89	77.08
0.6	85	80	77.00	76.65
0.7	82.17	76.44	74.13	76.12
0.8	77.19	71.05	69.38	73.78
0.9	67.23	60.19	59.97	68.43
1.0	45.86	38.61	38.54	45.57
1.1	0	0	0	0.01
1.2	—	—	—	—

Table 2: Comparison of simulation stopping distance and actual data.

ATP stopping distance(m)	Target stopping distance(m)	Simulation stopping distance(m)	Actual stopping distance(m)
1100	1098	1097.8	1098.5

Figure 5 shows that this model of ATP system can implement the function of smooth parking and speed protection. It can be found from Table1 that the simulation speed is always lower than the target speed and changes smoothly. The goal of controlling the train to be safe and satisfying the comfort requirement is able to achieve. At the point of 0.8km, the actual speed is 73.78km/h. Although this speed hasn't reached ATP protection speed 77.19km/h, it has exceeded target speed 71.05km/h already. As soon as the actual speed exceeds the target speed, the train will start to brake. It's easy to cause emergency brake. Thus, it doesn't satisfy with the comfort requirement. However, ATP system in CBTC based on WLAN in this paper improved the situation that actual speed exceeds target speed when the train runs because of transmission delay or equipment limits. Table2 shows that this system is able to satisfy the function of designated parking and rash advance protection.

We can conclude after comparing the train operation diagram and data:

(1)ATP system in CBTC based on WLAN applies WLAN to CBTC so that it can communicate wirelessly. It overcomes the disadvantages of traditional ATP systems such as one-way transmission, high cost and hard maintenance.

(2)The model build in this paper can calculate the data of protection curve at real-time according to two-way communication of WLAN and display directly.

(3)ATP speed protection model, working as a speed monitor, controls the train to run according to the target speed curve. Running curve and protection curve fits well.

(4)Under the monitor of ATP protection model, the train meets the demand of protected parking. If the train exceeds the parking section when entering the station parking circle range, ATP system will carry out full brake and monitor the train to ensure it parking in front of the parking spot.

(5)This system takes hardware redundant of key modules to satisfy with the reliable designing requirements of single unit equipment. It also takes advanced WLAN technology to implement strong covering of wireless signals and improve the reliability of internal communication.

(6)This system takes distributed network structure, standard communication protocol, typical division of module function and other measures to improve equipment expansibility. It can meet some special functional requirements of urban rail trains.

6 CONCLUSIONS

The research of CBTC based on WLAN has been a research focus in the entire rail transit industry. In this paper, we mainly focus on modelling of ATP system in CBTC based on WLAN and propose related frame structure and principle model according to the study of ATP system and WLAN technology combining with private ideas and literature summary. We also focus on ATP speed-distance curve modelling in detailed mathematics and dynamics. Finally, we make simulation on the ATP system in CBTC based on WLAN. The functional modules of simulation, data structure and IPO were designed for implementation of simulation. And we also focus on simulation of speed controlling module and analyze the simulation result to verify the correctness of the model.

There are still imperfections that need further study for the simulation of ATP system in CBTC based on WLAN. A research of simulation on channel establishment of the entire wireless communication system in ATP has not been given yet. Meanwhile, the signal security and system stability problems are not solved. These are to be researched for the next step.

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