Application Analysis of Mobile Block Section Based on ZigBee

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Abstract

As a number of commercial high-speed passenger rail lines are operated, such as Beijing-Tianjin intercity railway, Wuhan-Guangzhou high-speed railway, as well as the construction of Beijing-Shanghai high-speed railway and New Beijing-Shenyang special passenger transport item, China has really entered a high-speed railway era. In the era of high-speed railway, the cab can keep a top speed of 350 km/h or so. In this way, safe-running of cabs is especially important. On the basis of ensuring safe-running of cabs, using the "intangible" Mobile Block Section means can both shorten the interval between cabs and improve the efficiency of cab operation. Therefore, a set of wireless network systems based on ZigBee protocol is proposed. Between the cab and wayside equipments the WLAN constitutes a Mobile Block Section, which ensures the cab running safely, speedily and efficiently.

Keywords: ZigBee; WLAN; Mobile Block Section

1. Introduction

Presently, section signal blocking modes adopted in China`s railway are mainly semi-automatic blocking and automatic blocking [1]. When semi-automatic blocking is adopted, the evidence of that the cab occupy the section is the showing of outbound signal equipment or pass through signal equipment. It is controlled by semi-automatic blocking equipment. If only the section is free, after the procedure is transacted, the pass through signal equipment can be released. This can ensure there is only one cab on the same railway and in the same section to keep the safety of the cab. Signal machine is under the control of both block equipment and interlocking equipment. The automatic-blocking divides the length between stations into several parts, and the operating interval between two cabs can be realized through a certain quantity of blocking sections. This can make several cabs running on one railway in the same section at the same time, and also realize cabs tracing in the same section. However, no matter semi-automatic blocking and automatic blocking, according to standard, they belong to fixed blocking. There must be some free blocking sections between two cabs to be safety intervals. The control system cannot know the detail place of the cab, so the start point and the end point of cabs` braking are always on the boundary of a section. It affects the efficiency of the railway using greatly.

Mobile block can provide cab`s location real-timely and divides the block section according to this dynamic state. This can improve the efficiency of line`s using and railway`s transport greatly on the basis of ensuring cab`s safety.

2. Mobile Block

Mobile block [2] adopts radiolocation to realize the checking function of cab location and occupied track. Cab's tracing target is the cab's end in front of it. The cab's speed and location in the front is always changing, so the mobile block section is unfixed. Mobile block section is set by CTC according the location of the cab in the front dynamically. Wireless network nodes are installed on cabs and wayside. Cab A joins wireless network which is constitutes by terrestrial network nodes when it is occupying section. Terrestrial wireless network confirm cab A's speed, location and other information according to electromagnetic waves` strength sent by cab A through location algorithm. When cab B enters the present section, it also joins wireless network, and its running information is confirmed by wireless network, then mobile block interval between B and A is confirmed. After that, control information including mobile block interval and A's running information are sent to B, then B controls its running according to the information received. Mobile block system adopt curve of the distance mode (also called curve of once braking mode). As Figure 1.

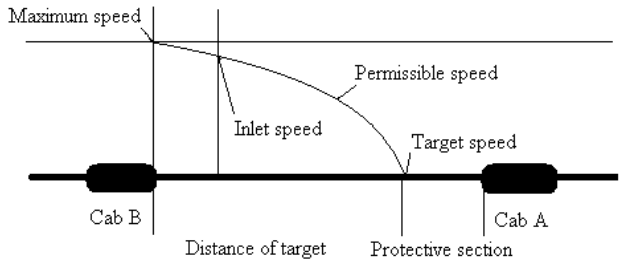

Fig. 1 Mobile Block diagram of the distance model curve

3. Wireless network based on ZigBee Technology

3.2.1 ZigBee Technical Features [3]

ZigBee is a kind of wireless network technology with high reliability, low complexity, MANET and strong anti-interference. It adopts IEEE 802.15.4 as technical standards to realize wireless group net communication. ZigBee network conveys data in a relay way efficiently.

ZigBee`s workable frequency now are 2.4GHz(Global) ,

868 MHz (Europe) and 915 MHz (USA). Transmission rate on these three frequency are respective-ly 250Kbps、20 Kbps、40Kbps. Distance between network nodes can be extended to 5km from standard 75m. Advantages of ZigBee technology [4] are:

- High reliability. It adopts CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) mechanism, and reserving special slot for communication services which need fixed bandwidth. It avoids competitions and conflicts when sending data. There is self-forming net function among node modules, and information in the whole ZigBee net is conveyed in an automatic routing way, therefore it ensures the reliability of information`s transmission.
- Short delay. The delay of activate dormant for ZigBee node modules is 15ms, and delay for nodes joining channel is 15ms.
- Safe, high security. ZigBee provides data integrity check and authentication function, and it adopts 64-bit serial number and supports general AES-128 encryption algorithm.
- Large network capacity. It can support 65000 nodes.
- MANET and strong self-healing capabilities. On no need of manual interference, network nodes can perceive the existence of other nodes then confirms the connection relationship and constitutes structured net. ZigBee network can add, delete and move nodes, when nodes are in malfunction; they can self-heal without manual interference to keep the whole system running normally.

3.2 Protocol stack and Network topology

From bottom to top, ZigBee protocol stack constitutes with physical layer, data link layer, network layer, application convergence layer and layer of high-level application specification. Thereunto, protocol above network layer are set by ZigBee alliance. IEEE is in charge of standard for physical layer and link layer.

ZigBee relies on every independent node, it constitutes star-shaped, tree-shaped or mesh network through wireless connection. Most nodes in the system are sub-nodes, in the network communication group; they are only a subset of their function, which is called RFD. And there are some other nodes, they are in charge of communicating with sub-nodes under their control, pooling data and releasing control, or functions as communication routers, call FFD. Diagram of ZigBee mesh network topology. As Figure 2.

Every independent network has an only identifier and a PAN. Using PAN, network equipments communicate by 16-bit short address code, and also activate communication among network equipments. There is an only coordinator in every network; it has managing ability for its network.

Full function nodes can act as router, coordinator and terminal node. But semi-function nodes can be used only by terminal nodes. In mesh network, full-function node has a routing function, semi-function nodes only communicate with full-function nodes near them.

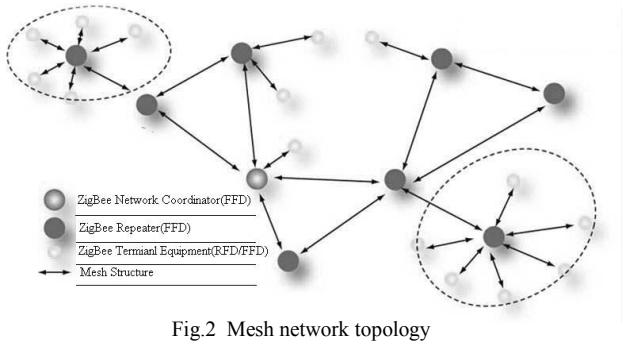

Fig.2 Mesh network topology

4. Frame of Mobile Block Network

4.1 Basic constitution and working principle of the system

Mobile block system based on ZigBee mainly indicates wireless network formed by wireless module, including cab node and ground node. The basic structure of the system is shown in Figure 3.

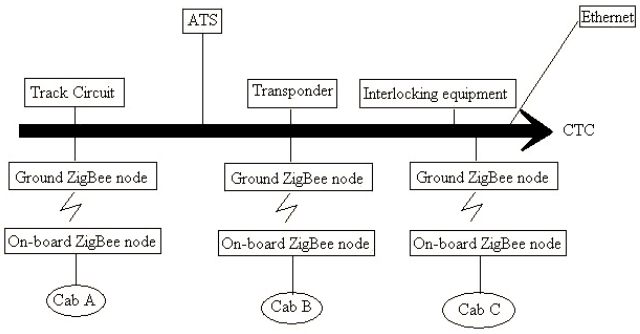

Fig.3 Diagram of mobile block section system based on ZigBee

Ground ZigBee module is paved at wayside and each node constitute wireless network. The whole network, track circuit, turnout and transponder constitute ground cab control system. Cab control system, ATS and interlock equipment connect to the schedule central system through Ethernet.

Cab ZigBee node, as a sub-node in ZigBee network, joins ground ZigBee wireless network and keeps continuous two-way communication. Cabs transmit information about its mark, direction and speed to ground network continuously, then ground network calculates and confirms cab`s mobile block section according to information and signal strength sent by the cab, and transmits related information to the cab and the cab after it in order to ensure cab`s safety.

4.2 Cab locating principle and algorithm

4.2.1 Locating principle

This system adopts technology of RSSI (Received Signal Strength Indication). RSSI measures signal strength accepted on the receiver, and it calculates the distance between transmitter and receiver according to free-space electromagnetic wave propagation model. Therefore, it can realize cab location.

Free-space electromagnetic wave propagation model:

$$L=32.45+20\lg f+20\lg d \quad (1)$$

In formula (1), L indicates Propagation loss, its unit is dB; d indicates the distance between receiver and transmitter, its unit is km; f indicates working frequency, its unit is MHz.

$$L=P_t/P_r \quad (2)$$

In formula (2), P_t indicates trnsmit powear, its unit is mW. P_r indicates received power, its unit is mW.

4.2.2 Locating algorithm

When working frequency of electromagnetic wave-f and transmit power- P_t are fixed, calculate cabs` distance d according to Received power-P_r. After the cab node joins ground wireless network, in order to locate the cab, network automatically choose 3 ground nodes, which can receive the strongest signal. Diagram of principle for locating algorithm is shown in Figure 4.

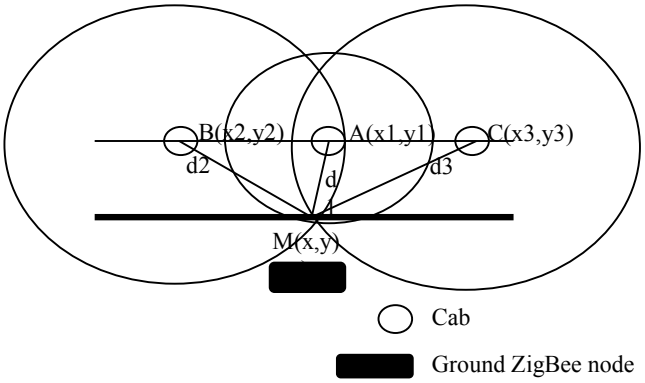

Fig.4 Diagram of principle for locating algorithm

Suppose cab node M`s coordinates are （x, y）, coordinates of the three nodes receive the strongest signal-A、B、C are (xl,y1),(x2,y2),(x3,y3) ,Using formula（1）,（2） to calculate d1,d2,d3. Take A,B,C three receiving node as center of the circles respectively, and d1,d2,d3 as radius respectively to draw circles. The three circles intersect at M. Finally, locate cab`s approximate coordinates M by formula (3).

$$(x-x1)^2+(y-y1)^2=d_1^2$$

$$(x-x2)^2+(y-y2)^2=d_2^2$$

$$(x-x3)^2+(y-y3)^2=d_3^2 \quad (3)$$

4.3 Planning and Simulation of Mobile Block System

Core module of the system adopts TI company`s ZigBee great power long distance transmission module-CC2430. Technical parameters of this module are as follow:

- Output power: 50mW(17dBm)
- Outdoor transmission distance: 1.6km
- Data transfer rate:250 Kbps
- Working frequency: 2.4 GHz
- Receiving sensitivity: -102 dBm
- Type of spread spectrum: DSSS
- Network topology :Mesh
- Encryption: 128-bit AES

Refer to specifications of CTCS-3 cab control system which is applied at the Wuhan-Guangzhou high-speed railway, in order to satisfy requirements of operating speed up to 300km/h or above and cab tracing running in 3 minutes, this mobile block system division is usually designed according to no more than 2000m. Therefore, it should be ensured that in one block section there are two to three wireless nodes. Cab`s maximum design speed is 350km/h, Maximum Doppler shift Δf can be calculated by formula (4), Δf=0.778 KHz.

$$\Delta f=\frac{v}{c}\cdot f \quad (4)$$

In the formula, v indicates rain`s speed－350km/h; c indicates speed of light−m/s; f indicates working frequency of wireless node−2.4GHz.

Cab`s Maximum Doppler shift Δf=0.778 KHz, it is 7 magnitudes less than the working frequency of wireless node (2.4GHz). Cab`s speedy running requires a very high transmission rate of the system, and the max transmission rate of ZigBee is 250Kbps. According to the two points above, we can draw the following conclusion: Adopting a 2.4GHz`s working frequency can reduce Doppler effects which are caused by speed running of the cab effectively. Also, it provides a channel to the system for the high speed data transmission.

Both ground and on-board wireless node adopt 120° directional antenna to realize signal`s full coverage to the railway.

In order to ensure that there are two to three wireless nodes in one mobile block section, distance between nodes in ground wireless module should be 500-1500m. Equipments which are less than 500m have very high cost in paving, and also equipment using rate is low; if distance is too long, modules cannot work. The max transmission distance of module can reach 1600m, and in the real

paving there should be some amount of surplus. Matlab simulation diagram of distance between ground wireless nodes as shown in Figure 5.

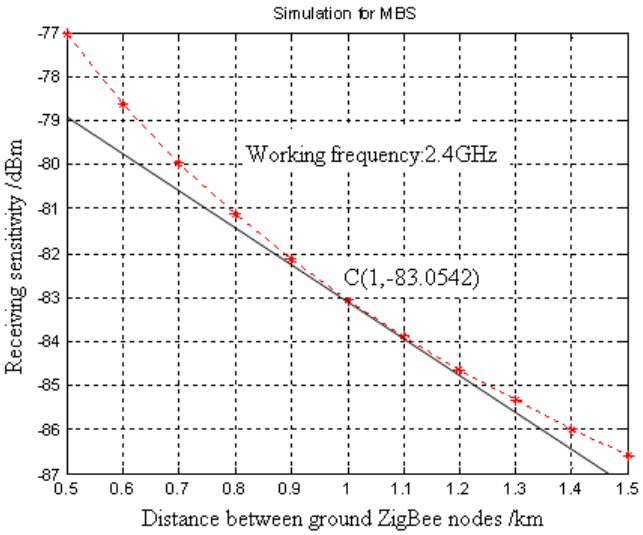

Fig. 5 Matlab simulation diagram of distance between ground wireless nodes

From simulation diagram, we can see that the tangent point of curve locates at C （1,-83.0542） . CC2430`s receiving sensitivity is -102dBm,-83.0542dBm, which totally fulfills requirement. Therefore, we can draw the following conclusion: the reasonable distance between ground modules is 1km.

5. Conclusions

With the coming of high-speed railway era, mobile block technology based on ZigBee will become mainstream. After mobile block is adopted, central control system can calculate maximum braking distance of cabs according to cabs` real-time speed and location, and distribute safe section dynamically. Because of the assurance of the safe distance in front and back of the cab, two mobile block sections nearby can go forward at the same time with a very short interval. This makes cabs running with a high speed and short interval, therefore, transportation efficiency is improved. At the same time, ZigBee technology stands itself out from many wireless technologies because of its unique feature. Wireless mobile block technology based on ZigBee will have a very broad prospect.

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