Key Technology and Open Test Method of Rail Train Field bus

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Abstract. With the continuous development of the rail transit field, the communication between trains and vehicles has received extensive attention. Therefore, various international organizations have studied and formulated various communication network standards. At present, the field buses used in rail transit at home and abroad (except Japan) are mainly TCN (Train Communication Network), WorldFIP bus and LonWorks bus. This article describes and compares these three types of field buses.

1. Introduction
Fieldbus refers to a variety of industrial communication protocols, usually used in real-time distributed systems, and is a way for manufacturing to connect instruments. Fieldbus usually adopts daisy chain, star, ring, branch and tree network topology in structure. Fieldbus technology was developed in the mid-1980s [1]. The main motivation for using fieldbus in distributed systems is to reduce the cost of equipment installation and maintenance without losing the reliability and availability of the automation system. The devices can be connected with a few cables and simple settings. With the field bus, data transmission and information exchange can be carried out between measurement and control equipment, between field equipment and remote computers. With the vigorous development of computer functions and microprocessors, prices have dropped, and computer networks have developed rapidly.

2. TCN(Train Communication Network)
TCN is an open working group named WG22 of the Ninth Technical Committee of the International Electrotechnical Commission (IEC) through studying existing protocols, such as Profibus, LonWorks, CAN, FIP, MIL1553 and MICAS, etc [2]. Communication system protocol. In June 1992, the working group passed the Commission Draft (CD) to various countries for comment. The CD draft is mainly composed of four parts, namely the overall structure, real-time protocol, multifunctional vehicle bus MVB, and twisted train bus WTB. From May 1994 to September 1995, the test team conducted a comprehensive TCN test on the car-couplings from Interlaken in Switzerland to Amsterdam in the Netherlands on Dutch NS, Italian FS, German DB, and Swiss SBB. In November 1998, at the annual meeting of the Ninth Technical Committee of IEC, the TCN protocol standard was formally adopted. In June 1999, IEC officially promulgated the draft TCN standard, namely IEC61375-1-1999. TCN is composed of two-layer buses, the twisted train bus WTB and the multifunctional vehicle bus MVB, both of which use the same real-time communication protocol RTP [3].
The transmission medium of the Wire Train Bus (WTB) is twisted pair, and the communication rate is 1Mbit/s. 32 devices can be connected without a repeater, which can transmit 860m. For the stable transmission of the entire network, WTB adopts dual medium redundancy. Unlike MVB, WTB can connect each node through initial operation and assign consecutive addresses to each node. The encoding method of WTB data is Manchester encoding.

The physical medium of Multifunction Vehicle Bus (MVB) is divided into electrical short-distance medium ESD, electric medium-distance medium EMD and long-distance optical fiber medium OGF [4]. ESD uses shielded twisted-pair wires and uses differential RS-485 differential signal transmission. Under the condition of no repeater, 32 devices can be connected within 20m [5]. EMD adopts shielded twisted wire cable and transmits in differential mode. Without repeaters, 32 devices can be connected within 200m. OGF connects optical links through active or passive star couplers to form a star bus fiber segment, and the distance between devices can be up to 2000m [6].

TCN is the most widely used train communication network in the world. The MITRAC train control system and the SIBAS train control system are formed on the basis of TCN, so many European countries have adopted the TCN communication network for rail transit. Since TCN has become a national and industry standard in China, it is also widely used in the domestic rail transit field.

3. WorldFIP
WorldFIP is derived from FIP fieldbus technology. FIP was developed by the FIP organization composed of more than 120 companies including ALSTON, CEGELEC, HONEYWELL, etc. In March 1993, FIP adopted IEC61158-2 and became WorldFIP (Factory Instrumentation Protocol of World). In February 2000, WorldFIP was transformed into the fieldbus Internet protocol FIP [7]. Manufacturers and users around the world, whether they are members of WorldFIP or not, can use WorldFIP fieldbus specifications.

The transmission medium of WorldFIP is shielded twisted pair or optical fiber. When using different transmission media, the transmission rate is different. When using shielded twisted pair cable, the transmission rate is 31.25Kb/s, 1Mb/s, 2.5Mb/s in the low-speed network segment; and when using optical fiber as the transmission medium, the transmission rate is 5Mb/s; 25Mb/s. The coding adopts Manchester coding. For topological structure, WorldFIP can adopt star, bus and free topological structure. The free topology structure greatly simplifies the network boundary, but the communication rate is lower, 31.25kbit/s. When the bus topology is adopted, the connections between the various sites are connected by twisted pair cables in a daisy chain manner. Each sub-segment of WorldFIP can have 32 connection points, and the entire network can use up to 3 repeaters and 4 connection sub-segments. The WorldFIP communication protocol uses a three-layer structure, namely the physical layer, the data link layer and the application layer. The media access control of the data circuit is bus arbitration, and the communication mode adopts the producer/consumer mode.

ALSTON company applied WorldFIP bus technology when developing AGATE train control system, which was successfully applied to TGV high-speed train. In China, Metro trains such as Shanghai Metro Line 3 and Nanjing Metro Line 1 all use WorldFIP bus. As shown in Figure 1, the communication network on the HXD2 high-power electric locomotive control system manufactured in China also uses the WorldFIP bus.
Figure 1. The appearance of HDX2 electric locomotive.

4. LonWorks
LonWorks (Local Operating Network) was launched by Echleon in 1991, and Echleon has already advanced the technology to the third generation. As an open control network platform technology, LonWorks is widely used in the connection of daily equipment [8].

LonWorks supports a variety of communication media, such as power lines, twisted pairs, optical cables, etc [9]. Its core LonTalk communication protocol is solidified in the neural chip. Compared with other field buses, the characteristics of LonWorks are mainly manifested in three aspects, namely system interoperability, neural chip and LonTalk communication protocol [10].

Neuron neuron chip is the core of LonWorks technology. It provides the first 6 layers of the ISO/OSI communication protocol model. Developers only need to program and parameterize the application layer. The neural chip has a unique 48-bit identification code, which not only has input, output and control capabilities, but also manages communications. The neural chip has three pipelined CPUs inside it, namely the media access CPU, the network CPU and the application CPU. The media access CPU is responsible for processing the first to second layers of the seven-layer protocol, driving the communication subsystem hardware and executing the MAC algorithm. The network CPU is responsible for processing the third to sixth layers of the LonTalk protocol. It will process the authorization, background diagnosis, authorization authentication, etc., and control the network communication port. The application CPU will call the operating system commands according to the code written by the user in Neuron C language and the user code.

The LonTalk protocol is the network communication protocol of LonWorks. Different from other fieldbus communication protocols, the LonTalk protocol provides all seven-layer services of the OSI reference model. The LonTalk protocol uses something similar to the "Carrier Sense Multiple Access" (CSMA) algorithm used by Ethernet, which provides a medium access protocol on the basis of CSMA. LonTalk supports a variety of media, including twisted pair, infrared, power line, radio frequency, coaxial cable and optical fiber, etc., and twisted pair and power line are commonly used. Different data encoding and decoding are used for different communication media. Generally, power lines use spread spectrum, differential Manchester encoding is used for twisted pair cables, and frequency shift keying is used for wireless communication. Compared with other network communication protocols, the messages sent by LonWorks are very short data, generally only a few to dozens of bytes; the nodes on the network generally use low-cost single-chip microcomputers; the LonWorks communication protocol uses multiple nodes and multiple communication media; high reliability and real-time performance.

LonWorks has a wide range of applications in the North American railway industry. The New Jersey Light Rail Comet IV project in the United States, the San Francisco Bay Area Subway (BART) brake system monitor and automatic train control system, and the Canadian BOMBARDIER have all
adopted LonWorks. In addition, in Europe, ALSTON's traction system and German Railways (DB) heating, air-conditioning control system and lighting are also applied LonWorks. In China, as shown in Figure 2, internal combustion EMUs such as “Shenzhou”, “Golden Wheel” and "New Dawn" have adopted the LonWorks bus. A comparison of bus types, as shown in Table 1.

![Figure 2. Appearance of "new dawn" Diesel Multiple Units.](image)

| Fieldbus | Transmission speed | Transmission medium | Encoding | Verification method |
|----------|--------------------|---------------------|----------|---------------------|
| TCN      | WTB 1 Mbit/s       | Shielded twisted pair| Differential Manchester Coding | 16-bit CRC |
|          | MVB 1.5 Mbit/s     | Shielded twisted pair, optical fiber | Differential Manchester Coding | Multiple 8-bit CRC |
| WorldFIP | 31.25Kbit/s 1Mbit/s (ordinary railway) | Shielded twisted pair, optical fiber | Differential Manchester Coding | 16-bit CRC |
|          | 2.5Mbit/s 5Mbit/s (optical fiber transmission) | | | |
| LonWorks | 1.25 Mbit/s        | Twisted pair, power line, wireless | Twisted pair: differential Manchester coded; power line: spread spectrum; wireless: FSK | 16-bit CRC |

5. Open Test Platform for Subway Network

The integrated platform for integrated testing and certification of urban train interoperability realizes the study of system interoperability by simulating the operation of trains, and realizes the simulation of the whole process and all working conditions of the traction performance of urban rail trains, with different gauges, different wheelbases and different Standard power supply for urban rail train starting characteristics, traction characteristics test, urban rail power supply system network voltage fluctuation, network voltage sudden change, network voltage interruption simulation and interoperability detection, urban rail train electrical drive system research test and other functions. The network interface of integrated platform is shown in Figure 3.
The integrated platform simulates the operation of the train on an infinitely long straight track through the track wheels, realizes the traction operation and control through the ground traction equipment on the wheel-to-side side, provides the load through the equipment on the track wheel side, simulates the running resistance of the train, and simulates the train movement through inertia. In the integrated platform of urban train interoperability comprehensive testing and certification, MVB is used to connect CCU, BCU, EDCU, VOBC, DCU and ACU, so as to realize the realization of functions and the transmission of messages. Figure 4 shows the DCU in an integrated platform. MVB interface on BCU and ACU is shown in Figure 5.
6. Conclusion

This article elaborates on the three field buses of TCN (Train Communication Network), WorldFIP bus and LonWorks bus which are widely used in the field of rail transit. Fieldbus is one of the hotspots in the field of automation today. Its application is not limited to the field of rail transit. It is widely used in various industries such as national defense, manufacturing, and process industries. There are many types of fieldbuses, and there are nearly 200 kinds of fieldbuses currently in use. The above descriptions are only those that account for a large number of fieldbuses in the rail transit field.

In recent years, in the field of fieldbus, industrial Ethernet has developed rapidly, and a new generation of industrial automation has begun to focus on Ethernet. Industrial Ethernet has become a current technical hotspot. Industrial Ethernet is undoubtedly a future development direction of industrial control. The development trend of the field bus is that every bus will transition to Ethernet until it is finally connected to the Internet.

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