



Fail-safe LAN for train control systems

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Abstract

A LAN (Local Area Network) applied to a train control system must absolutely be stable, precise, and valid in its inherent data transmission functions. Other facilities required include self-diagnostics for transmission conditions, easy status monitoring, and quick analysis of and recovery from faults and emergencies.

Recently, as new train control systems for the Tokaido Shinkansen have been constructed, a dedicated fail-safe transmission system was developed and incorporated, with innovative features that could not be achieved with a general-purpose transmission system.

1 Introduction

The Train Control System of Tokaido Shinkansen (552.6 km between Tokyo and Osaka) consists of three sub-systems, Automatic Train Protection(ATP), Electronic Interlocking (Ei) and Centralized Traffic Control(CTC).

The LAN consists of 3 kinds for the correspondence to each subsystem.

- LAN (ATP-LAN) for ATP control

This system is a LAN for ATP control of each section of about 20 km; ATP-LANs repeat each other and connect all sections of track.

- LAN (EI-LAN) for electronic interlocking control

This LAN performs route control for each station, and is connected to ATP-LAN.

- LAN (CTC-LAN) for CTC

This LAN centrally controls each section of about 40 km, and is connected to an interlocking LAN.

Fig. 1 shows the general configuration.

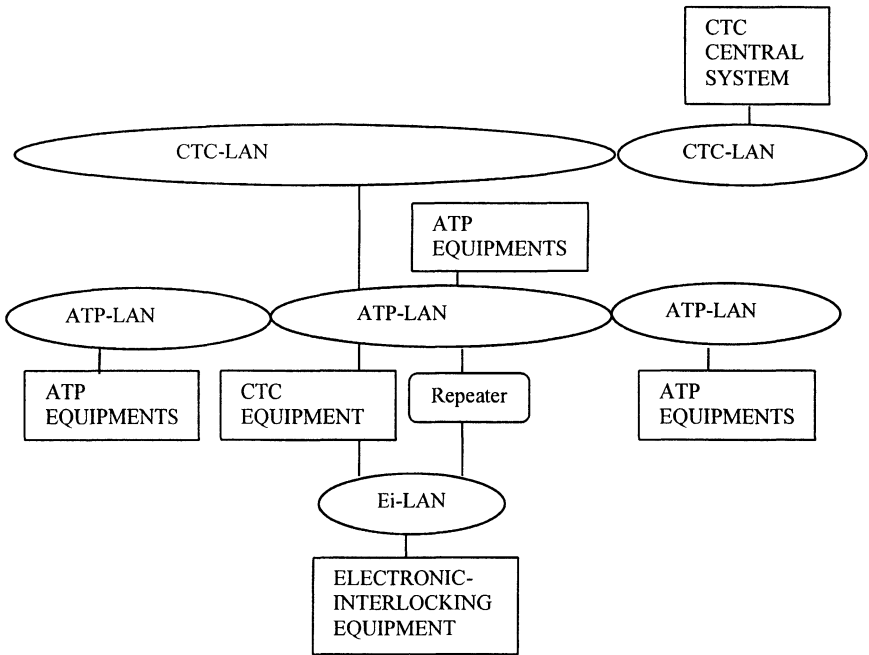


Fig. 1: General configuration and LAN

These three LAN systems are basically identical in their basic specifications and are configured under the same safety standard. The hardware in the transmission unit is also identical.

2 Fail-safe property

The fundamental components of a LAN consist of a transmission unit to achieve high-speed transmission, in which a transmission control unit ensures the fail-safe properties of transmitted information. In addition, an application unit (ATP, Ei, etc.), which performs a function unique to the system, and the transmission control unit asynchronously transfer data between each other.

The transmission control unit and the application unit are configured with fail-safe devices using a fail-safe Micro-Computer.

Similar transmission system was reported [1], but considered it as applied in broader subsystem.

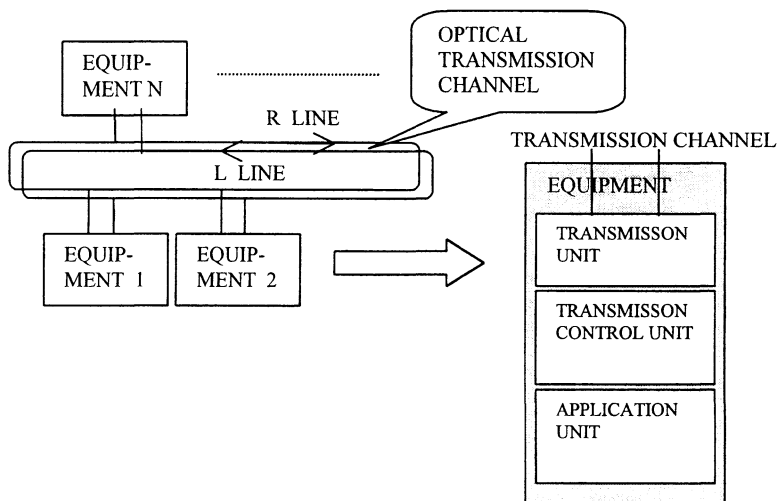


Fig. 2: Configurations of transmission channel and interior of the equipment

2.1 Basic transmission

When length of unit data, number of unit data, transmission intervals, etc are set according to the application of a LAN, a data frame is transmitted from a specific transmission unit (called boundary unit). Other transmission units regenerate and repeat the frames received. If no frame is received during a preset time, the transmission unit generates and transmits a new transmission frame.

When data are specified by the transmission control unit, in a data frame received, the data are copied from the frame and sent to the transmission control unit. When transmission data are set in the transmission control unit, the data are placed at the location specified in the data frame.

When specific data (unit data) in the data frame circulate the transmission unit at the outgoing transmission unit, the data are erased in the next transmission unit at the outgoing side.

Transmission of data only with a transmission unit cannot assure the data (information).

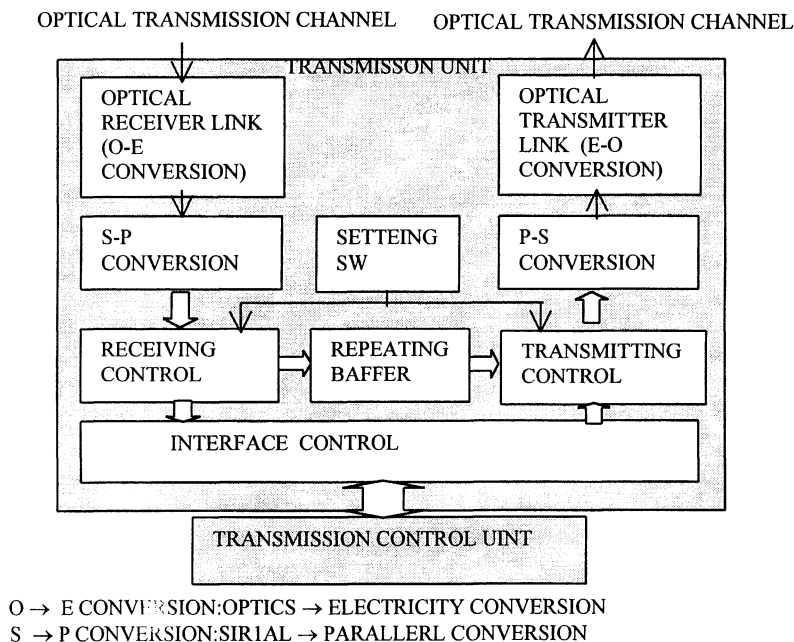


Fig. 3: Internal configuration of transmission unit

2.2 Transmission data frame

A transmission data frame consists of frame header data, specified number of unit data, and frame end data. The maximum designed length of data frame is 32 Kbytes.

The data frame configuration is shown in Fig. 4.

2.3 Transmission control

The transmission control unit is provided to assure fail-safe, high-speed transmission of data (information). The transmission control unit uses a bus-synchronized duplicate Micro-Computers operating in a two-out-of-two configuration, in which completely independent dual-circuit computers are operated in synchronism. If a data disagreement or a memory check error occurs, CHR drops away and trips the power supply to the buffer memory in the transmission unit. If a check error occurs in transmitted data, as described later, the contents of the data are set, thus fail-safe processing is accomplished to transfer data between the transmission unit at an application unit at the safe side.

Transmission control unit and transmission unit are integrated into a fail-safe transmission control unit for fail-safe operation.

The concept of the hardware in the transmission control unit and the transmission unit is shown in Fig. 5.

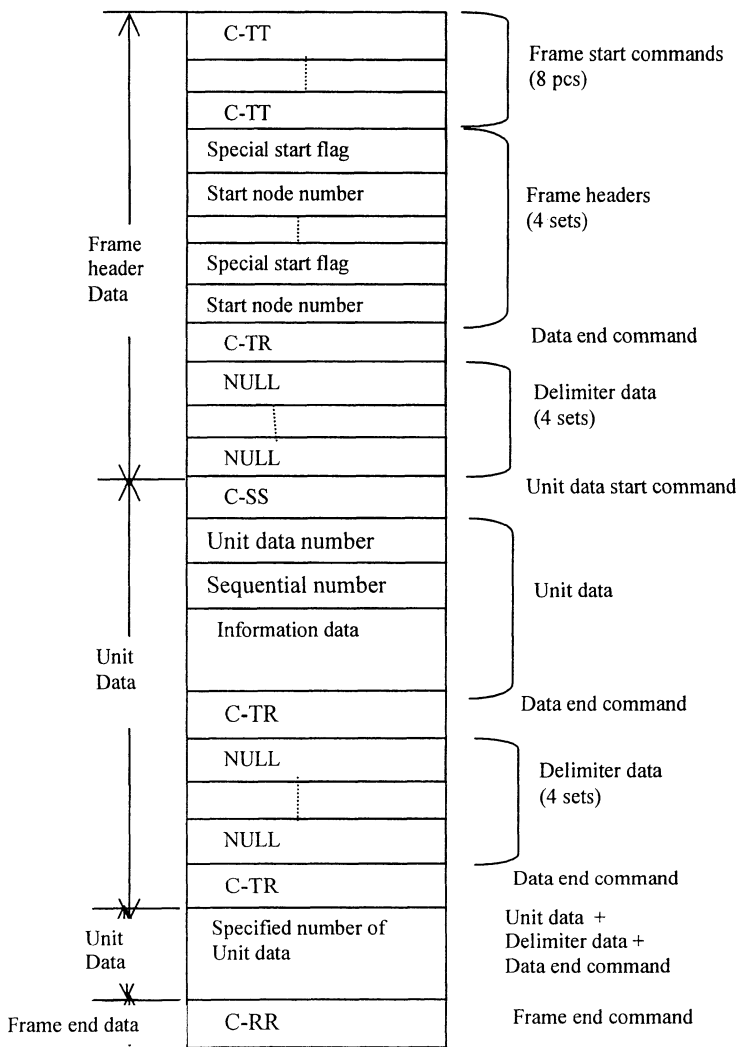


Fig. 4: Configuration of data frame

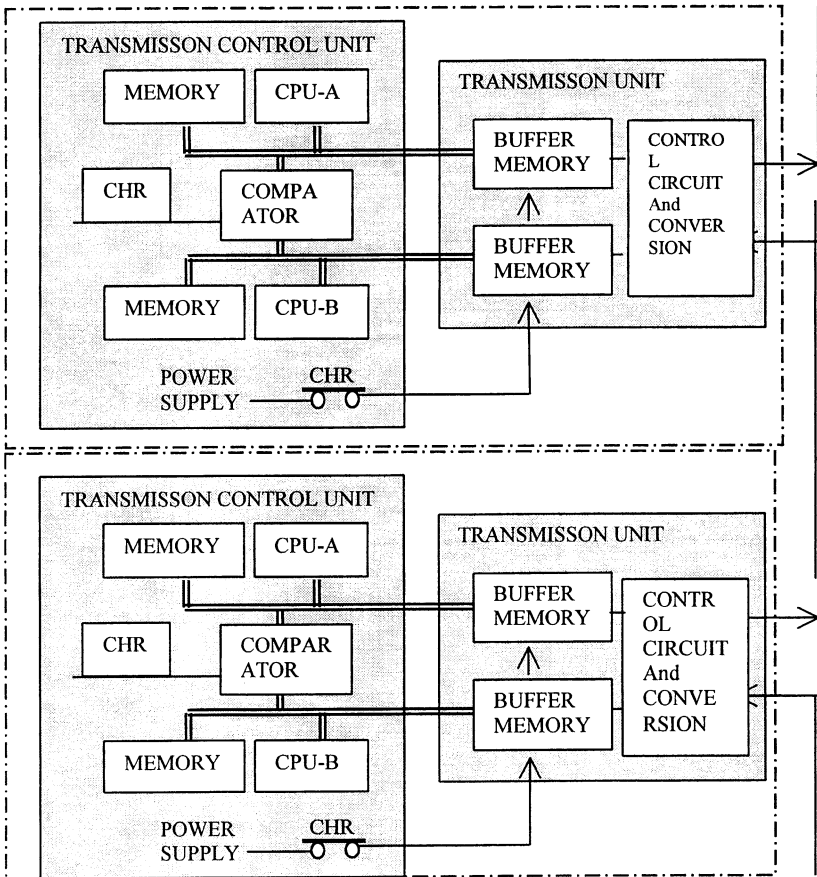


Fig. 5: Connection between transmission unit and equipment

2.4 Definition of fail-safe LAN and its application.

2.4.1 Definition

- LAN for assuring data transmitted
- LAN for assuring verify of data received
- LAN for eliminating unassured LAN data
- LAN for assuring transfer of LAN data in defined data format if equipment fails or data are abnormal

2.4.2 Practical methods for ensuring fail-safe LAN

A fail-safe LAN is assured as follows. Fig. 6 shows items and correlation.

- (1) Data transmitted are refreshed and transmitted periodically.

→ At the receiving side, the cycle time for transmission is controlled, and stability and regularity are monitored. If transmitted data are interrupted for a preset time, regulated default data are used.

(2) Data transmitted are numbered by transmission sequence.

→ The receiving side monitors data transmitted for missing data and errors. With a continued numbering error, regulated default data are called up.

(3) CRC check data computed from data transmitted are suffixed to the data.

→ Validity of data is checked by CRC computed from data received and CRC in data transmitted. If the result is abnormal, the data are discarded.

(4) A number unique to the equipment is added to data transmitted.

→ A unique equipment number circulated is checked at the receiving side, and the integrity of the line and interference with other devices are monitored. If there is an error, default data are fixed, and an emergency alarm is output.

(5) Data transmitted to and received from the transmission unit and the application unit are checked, and self-diagnostics are performed. Once an error is detected, data transmission to the transmission unit is stopped, and default data are output to the transmission control unit, while an alarm is issued.

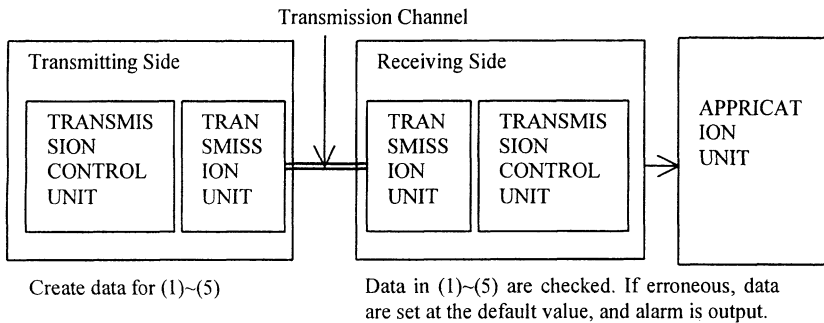


Fig. 6: Principles of fail-safe transmission

3 High reliability

The data transmission system is a very important information system, acting like a nervous system, in which high reliability as well as fail-safe properties are included as necessary conditions. This section describes the high-reliability methods used in the system.

Referring to the numbers shown in Fig. 7, the following methods are used.

(1) The transmission line is configured as a dual system, in which data are transmitted in reverse directions so that individual units of apparatus do not stop functioning at the same time.

(2) The transmission unit check the basic transmission cycle time, and when transmission is stopped, the frame under transmission is transmitted for back-up.

(3) An application unit is connected to the transmission unit via the transmission control unit to protect transmission functions from damage caused by an error in the application unit.



- (4) To protect transmission functions from adverse effects if the transmission control unit fails, only data transmitted by the faulty unit are cut, and overall operations are maintained normally.
- (5) Power supplies for the transmission control unit and the transmission unit are separated, to reduce the effects caused by an abnormality in the power systems.
- (6) Each apparatus and device is configured individually in dual systems.

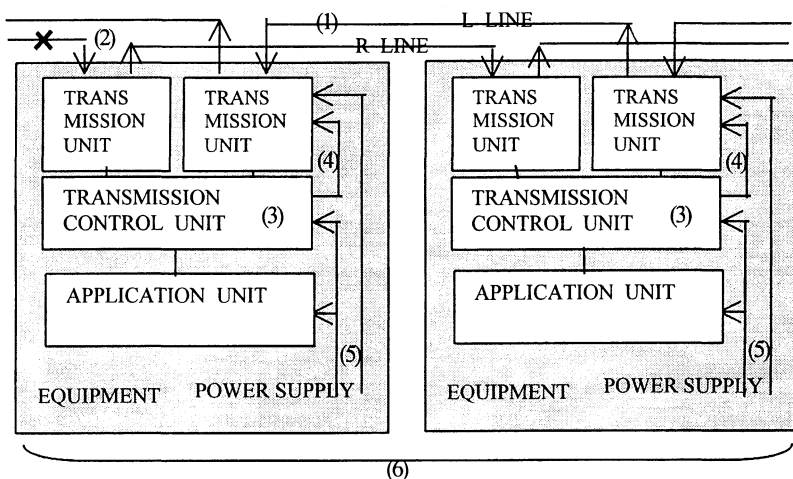


Fig. 7: High-reliability methods

4 Transmission characteristics

Table 1 shows the Transmission characteristics

Table 1. Transmission characteristics

ITEM	CHARACTERISTICS	NEWS
Transmitting Power	-15.0 ~-8.0dBm	
Receiving Power	-28.0~-8.0dBm	
Fiber Optic connector	Dual-SC Type	
Optic Fiber	Single mode	
Optic Wavelength	1.3 μ m	
Transmission Speed	125Mbps	
Transmission Cycle	Maximum 20ms	Variavle
Number of node	Maximum 255	Variavle
Number of unit data	Maximum 255	Variavle
Length of unit data	Maximum 2048byte	Variavle
Transfer delay time	Maximum 6 μ s	
Transfer buffer Memory	32kbyte	



Transmitting buffer	Device	DP-RAM	
	Volume	30kbyte	
	Number of Section	Maximum 255	
Receiving Buffer	Device	DP-RAM	
	Volume	30kbyte	
	Number of Section	Maximum 256	
Operating Temperature		-20°C ~ +70°C	

5 Conclusions

The train control systems for the Tokaido Shinkansen, the biggest railway artery in Japan, have introduced LANs. The basic principles for system configuration include to achieve high safety and reliability, as well as an easy-to-operate configuration during normal operations and emergency actions. We are convinced we have successfully developed and supplied LAN systems that can satisfy all these requirements.

References

- [1] Maruyama,K.M.,Seto,M.S.,\$ Murakami,Y.M.,Fail-Safe LAN at the Higher Rate for Railway Signalling, *Technical Report of IEICE*,FTS96-55,pp.57-63,1996