전자연동장치와 역정보전송장치간 인터페이스를 위한 데이터링크 프로토콜 성능해석

Performance Analysis of Data Link Protocol for Interface between EIS and LDTS

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Abstract

According to the computerization of railway signaling systems, the interface link between these signaling equipment is also replaced by digital communication channel, expecially communication link for interface between EIS and LDTS, but there are some problems in the present state of railway signaling. First of all, different communication protocol is applied to interface between above two signaling equipment although they have same functions. The other is that the communication protocol currently used in railway field has some unreasonable points such as structure, formation of byte, error correction scheme and etc. To solve these problems, the standard communication protocol for railway signaling is designed. The structure of designed communication protocol and the results of performance analyses are represented in this paper. It will be expected the increase of safety, reliability and efficiency of maintenance of signaling system by using of the designed communication protocol for railway signaling.

1. Introduction

A few years ago, most of the signaling equipment is composed of vital relay-based equipment to ensure safety of railway control system. However owing to the advance of computer and communication technology, these signaling equipment is computerized. According to this trend in railway signaling system, the interface link between these signaling equipment is also replaced as a digital communication channel and the importance of this communication link is increased.

And almost railway signaling are also operated under coarse environment such as terribly high and low temperature, vibration, EMI and etc. The railway signaling systems must be safely operated under these environments. Thus the very high reliable performance for safely operating has to be required for not only signaling equipment but also communication link between these equipment.

However the present state of railway signaling has some problems. First of all, the existing communication protocol for railway signaling has the different communication protocol to be applied to interface between signaling although they have same functions because they are offered from different manufacturers each other. So there are some difficulties in the maintenance of signaling communication equipment. The other is that the existing communication protocol currently used in railway field has some unreasonable points such as

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structure, formation of byte, error correction scheme and etc. To remove these difficulties and reduce corresponding costs, the standard communication protocol for railway signaling is deeply needed[1].

For the improvement of railway signaling reliability and standardization, various signaling operation characteristics and schemes - error correction methods, flow control methods, ARQ and data link control protocol, and etc. - have to be examined to apply at the railway signaling.

In this research, we have developed a simulation tool to analyze performance of data link control protocol for railway signaling. This is based on the Matlab/Simulink and can be easily regulated to various data link control conditions. The main purpose of data link control simulation is the analysis of link throughput, BER(Bit Error Rate) and FER(Frame Error Rate) under variation of communication link conditions such as signal type and propagation speed, physical link conditions, ARQ methods and etc.[2]-[5]. Generally the ARQ schemes used in data link control are Stop-and-Wait ARQ, Go-Back-N ARQ, Selective-Reject ARQ and Hybrid ARQ. The performance of data link control protocol for railway signaling is to analyze through this developed simulation tool. And we designed the communication protocol for railway signaling based on analysis of these simulated results.

This designed communication protocol was adopted as a Korea Railway Standard by KNR (Korea National Railroad). The structure of designed communication protocol for railway signaling and the comparative analysis results between existing and newly designed communication protocol for signaling equipment is represented.

2. Review of existing protocol

In this research, we have reviewed the existing communication protocol for interface between signaling equipment currently used railway field. First of all, we have surveyed the interface type between EIS(Electronic Interlocking System) and LDTS(Local Data Transmission System), which is representative signaling equipment in KNR.

The LDTS, which is located in the signaling equipment room, receives the commands from CTC (Centralized Traffic Control) for control of field signaling equipment such as point machines, signals and etc., then send them to EIS. And oppositely, LDTS transfers state information of field signaling equipment from EIS to CTC. EIS transfers the commands from LDTS to other field signaling equipment such as point machines, signals, and etc. If this link has some faults or errors, then lead to a severe accident because the interface link is essential hub-link for control and monitoring of railway signaling, so the interface link is significant link from the point of view of safety of railway signaling operation. Fig. 1 shows the configuration of LDTS and EIS.

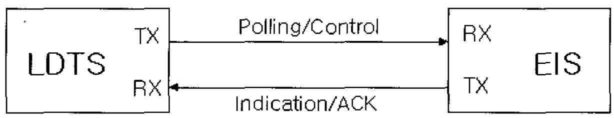


Fig. 1 LDTS and EIS configuration.

The two types of communication protocols are currently applied to the above mentioned interface link between LDTS and EIS. One of them, I/O protocol, which is broadly called, is used widely in field. Thus it is only represented in this paper the structure and performance analysis of I/O protocol among existing protocol.

<table>
<tr><th>Flag</th><th>Bit 7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>1</td><td colspan="4">Destination Type Number</td><td colspan="4">Destination ID Number</td></tr>
<tr><td>0</td><td colspan="4">Source Type Number</td><td colspan="4">Source ID Number</td></tr>
<tr><td>0</td><td>Long/ Short Bit</td><td colspan="7">LONG : MESSAGE TYPE, BIT 0 - 6
SHORT : MESSAGE TYPE, BIT 0 - 6</td></tr>
<tr><td>0</td><td colspan="8">Long : Length of Message(including bytes 1-4)
Short : Termination Checksum</td></tr>
<tr><td>0</td><td colspan="8">Long : Data Byte 1 ... n</td></tr>
</table>

Fig. 2 Message Frame Format (EIS => LDTS).

We can find some uncommon points on this I/O protocol. The first is that byte formation is different type in comparison with generic one. One byte is generally consisted of 8 bits but one byte in this protocol is composed of 9 bits as shown in Fig. 2. This reason is that I/O protocol is called as a 9th communication protocol in railway field. As shown in Fig. 2, the 9th bit of first byte for message frame set to 1 and the 9th bit of residual bytes of message frame set to 0. The 1 set of 9th bit means the start of transmission message.

There is no need the meaning field with indication of message starting. This formation is useful but generic microprocessor cannot support this 9th bit formation, so this formation is not considered to design the standard communication protocol.

Another uncommon point for I/O protocol is the existing of Destination and Source Type/ID field. At a point-to-point communication protocol, there is no need these unusual fields for transmission message format as a practical sense. This malformation for transmission message frame is inheritance that existing protocol didnt convert to new protocol when conventional electric interlocking equipment, communicating multi-drop type to I/O board, has been replaced with new electronic equipment. That is, a LDTS still considers EIS as a relay-based electric interlocking equipment.

3. Performance analysis model

Elementary performance criteria of communication system are bit error rate (or bit error probability) which is the first calculation step for data link protocol simulation. Transmitted-bit error rate can be expressed as equation (1) [2].

$$P_b = Q\left(\sqrt{\frac{E_b(1-\cos\theta)}{N_0}} \right) \tag{1}$$

Where P_b: transmitted-bit error probability

E_b: signal energy of a bit

N_0: noise power per bandwidth

θ : angle between two binary signal vector

Q: cumulative standardized gaussian probability density function

In equation (1), if the two binary signal vectors are orthogonal (or unipolar), θ is zero and if the two binary signal vectors are antipodal (or bipolar), θ is negative one, so that antipodal signals have lower transmitted-bit error probability. Provided with the signal to noise ratio E_b/N_0, P_b is calculated according to the two signal types(unipolar and bipolar). With equation (1), frame error rate is obtained as equation (2) and (3).

$$\begin{aligned} P_c &= (1 - P_b)^n, \quad P_d = 1 - P_c - P_n \\ P_n &= 2^{(k-n)}\left[1+(1-2P_b)^n-2(1-P_b)^n\right] \end{aligned} \tag{2}$$

$$P_{fe} = P_n/(1-P_d) \tag{3}$$

Where P_c : no error probability

P_n : error detection probability

P_d : error detection probability by error detection code

P_{fe} : frame error probability

n : the number of code bit

k : the number of information bit

In equation (2), P_n is able to model some modified by error detection code such as parity check, check sum, CRC and etc. The above represented model, is in case of using of CRC code for transmitted-bit error detection.

The main purpose of data link control simulation for performance analysis is to verify throughput, FER or etc. under various link conditions such as signal type and signaling rate, E_b/N_o, physical link conditions, error control and ARQs. Generic ARQ schemes used in data link control are Stop-and-Wait (SAW) ARQ, Go-Back-N (GBN) ARQ and Selective-Reject (SR) ARQ.

From several calculation steps under link conditioning parameters, link throughput values can be obtained as equation (4) in case of SAW ARQ.

$$\eta_{saw-0} = \frac{k}{T_D R_s} = \frac{k}{n+n'} \qquad (4)$$

where T_D : transmission delay time

R_s : symbol rate.

The above equation is able to obtain under the assumption of no error detection during message transmission. From this modeling we can find that the throughput, η_{saw-0}, is decreased by increase of T_D. If an error is detected within transmitted data at receiver, the average number of message retransmission is follows:

$$N_R = (1-P_d) + 2P_d(1-P_d) + 3P_d^2(1-P_d) + \cdots = \frac{1}{1-P_d} \qquad (5)$$

From equ. (4) and (5) throughput values can be obtained as shown equation (6) in case of SAW ARQ with existence of transmitted-bit error.

$$\eta_{saw} = \frac{k}{(T_D N_R) R_s} = \frac{(k/n)(1-P_d)}{n + n'} \qquad (6)$$

The similar modeling steps are able to apply to other schemes, such as GBN and SR ARQ, used in data link control. Link throughput for these two ARQ schemes is expressed as an equation (7) and (8) respectively.

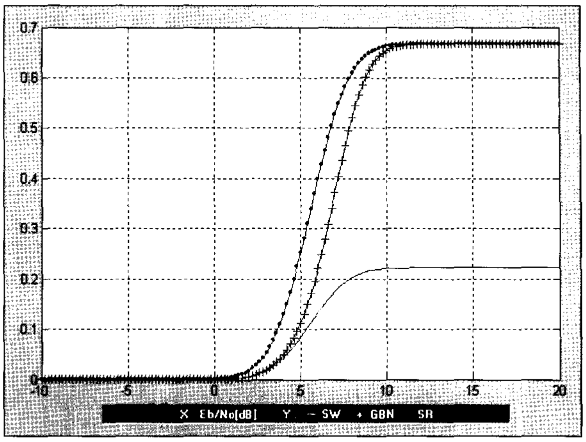


Fig. 3 Throughput with CRC 16 error detection code.

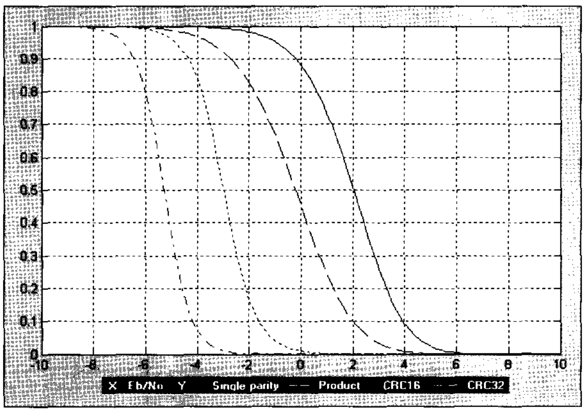


Fig. 4 Frame error rate for error detection scheme respectively.

[Go-Back-N ARQ]

$$\eta_{GBN} = \frac{(k/n)(1-P_d)}{1 + (n'/n) P_d} \qquad (7)$$

[Selective-Reject ARQ]

$$\eta_{SR} = \frac{k}{n}(1-P_d) \qquad (8)$$

The simulation for performance analysis of data link control protocol is carried out based on above modeling. Fig. 3 and Fig. 4 show simulated results under the conditions that message frame is composed of 6 bytes, transmission rate is 9600 bps, link distance is 10m and etc. Fig. 3 shows the throughput with CRC 16 error detection code and Fig. 4 shows the frame error rate for error detection scheme respectively. The appropriate data link control scheme is decided through these simulations by tuning of each data link control parameter respectively at this research.

4. Structure of designed protocol

As the mentioned above introduction section, the present state of communication protocol for railway signaling has some problems. That is, there are some uncommon points at protocol structure and different protocols are applied to interface link although these have same functions. The novel communication protocol is not expected to have these problems and also it is required the standardization of the novel designed protocol to improve the operation and maintenance ability.

We have deduced a performance analysis model of data link control protocol. The performance of data link control protocol for railway signaling is analyzed through this simulation tool to design new protocol. And the communication protocol for railway signaling has been designed from these simulated resulted. The designed communication protocol was adopted as a Korea Railway Standard by KNR. In this section the designed communication protocol for railway signaling is going to describe concisely.

The designed protocol has been improved structure and mechanism by removing drawbacks of existing protocol. Thus the existing 9th communication scheme is changed to generic one byte of 8 bits. And STX and ETX fields are added to designed frame format. This added fields have a same role of existing 9th scheme. STX field means the start of transmission frame, and ETX does the end of one. That is, the unusual 9th scheme is replaced to STX and ETX fields. And also the uncommon frame format at conventional one, Destination and Source Type/ID files, has been removed at designed protocol.

To improve the error detection performance during transmission of message frame, BCC error detection code is transferred to CRC 16 error detection code. The application of this error detection code is expected to contribute the decrease of frame error rate during communication. The simulated results for those will be represented to next section. The designed transmission message format is as follows:

Table 1 Message format

STX	Data Length	Sequence No.	Message Type	Data	CRC	ETX
1 byte	1byte	1 byte	1 byte	N byte	2 byte	1 byte

Where

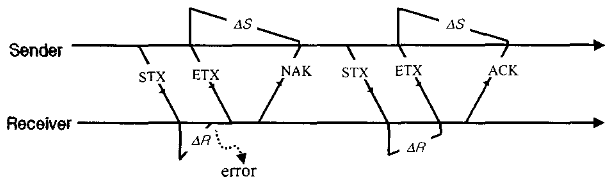
- STX: start of frame,
- Data Length : message length from Sequence Number to ETX (maximum 255 bytes),
- Sequence No. : 0x00 ~ 0xFF,
- Message Type : transmitted message types,
- Data : variable according to information,
- CRC : CRC-16($X^{16}+X^{15}+X^2+1$),
- ETX : end of frame.

SAW ARQ scheme is applied to error correction based on CRC 16 error detection code and ACK/NAK control message is used to error correction and flow control. And a message has to be retransmitted in case of error detection. Follows are description of retransmission mechanism.

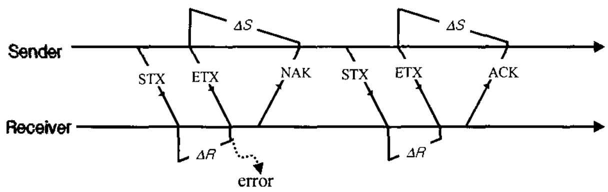
(a) If the following cases were occurred to sender, the same message has to be retransmitted to receiver and the retransmission is permitted 3 times.

① Reception of NAK message at sender

Case I : Error detection in transmission frame by error detection code and fault of sequence number at receiver(NAK message transmission to sender)



Case II : No reception of ETX message at receiver in spite of expiration of receiver timer setting time ΔR(NAK message transmission to sender)



② If sender could not receive any response message from communication receiver such as ACK or NAK, even though sender timer was expired, then previous message retransmits to destination.

(b) Even though the identical message was sent 3 times, sender could not receive any response from destination, sender regards as a communication link error. Therefore, sender discards the transmission message and link error process is executed. Then the sender periodically transmits polling message with 0x00 sequence number to receiver for identification of link restoration.

5. Performance analysis of communication protocol

To verify the designed protocol performance on data link control, the simulation is performed on two protocols for railway signaling interface described in section 2 and 4 respectively under the same conditions.

The performance of data link control is simulated based on performance analysis model presented in section 3 and frame error probability and link throughput are considered as a performance metric. These two metrics are very useful for data link control protocol. Table 2 shows the simulation conditions for this comparative performance analysis.

Table 2 Simulation conditions

E_b/N_o	-10 ~ 20 [dB]
Signal type	Bipolar
Data field	100 [Byte]
Physical link distance	100 [m]
Effective noise temperature	27[℃]
Media propagation speed (copper)	2×10^8 [m/s]
ARQ scheme	SW ARQ

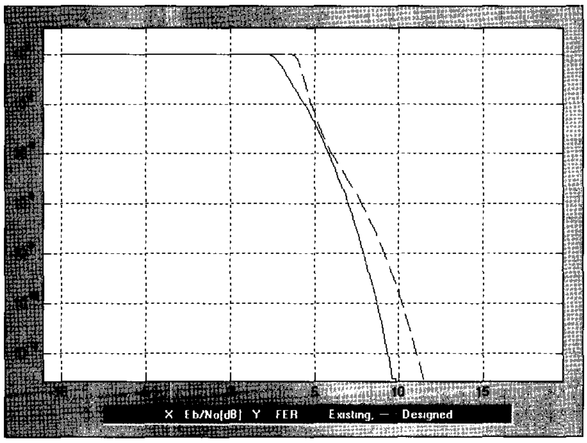


Fig. 5 Comparison of frame error probability.

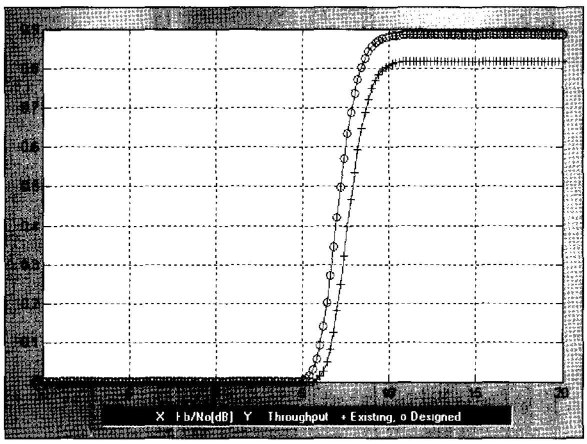


Fig. 6 Comparison of throughput.

With parameters shown Table 2, simulation has been showing performance characteristics of designed protocol. Fig. 5 shows the frame error probability characteristics by the designed communication protocol and the existing one. Comparison of these results shows that the frame error performance of designed protocol is superior to conventional one. Fig. 6 shows the link throughput characteristics by two protocols, and also link throughput is improved greatly in case of designed protocol than existing one. These two figures demonstrated that the designed protocol has good performance by comparing conventional one. It can be seen that designed protocol has good performance on error probability and throughput characteristics.

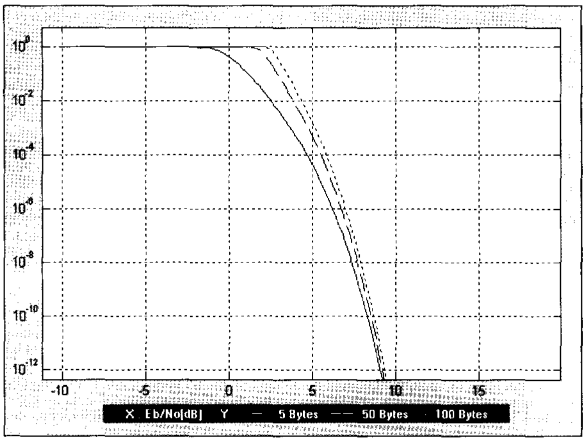


Fig. 7 Frame error probability of designed protocol.

Fig. 7 shows the performance characteristics of the designed protocol. Fig. 7 is the frame error probability characteristics and the result is given for different values of data field length of message frame. It is generally expected that an error probability of transmitted data is influenced on several factors such as message frame length, error control scheme, flow control scheme and etc. However the results of Fig. 7 illustrated that the frame error probability dependent upon transmitted message frame length but the effects for designed protocol is low. An error probability of transmitted message is more essential metric than link throughput because of requirement of high reliability for railway signaling. Therefore, variation scheme of data field length for novel protocol is well fitted to protocol scheme of railway signaling.

6. Conclusion

This paper describes the designed communication protocol structure for interface between EIS and LDTS and its performance analysis results. The existing communication protocol has some problems, but the novel communication protocol is designed to solve these problems. To verify the designed protocol performance on data link control, the simulation is performed on existing and novel protocols under the same conditions. From the performance analysis, it is verifies that the novel designed protocol has the good performance and also some problems are eliminated at designed protocol formation and mechanism. It will be expected the increase of safety, reliability and the efficiency of maintenance of signaling system by using of the designed communication protocol for interface between two equipment.

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