Interoperability test methodology for a train control system using interface channels

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Abstract

Train control system is the vital control equipment which is responsible for the operation of trains, and its functional safety must be validated through sufficient tests before actual use. Until now, most of them have gone through the interoperability testing stage with other devices by installing them at the railway site after performing validation on train control system developed by the simulator in a laboratory. In this process, more stringent validation on interoperability is required since interoperability for some cases is validated within the limited scope. This paper proposes a new interoperability test method and the tool to support it for the functional safety validation where the Ethernet and serial interface channel used by the actual train control systems are in common use.
Keywords: train control system, interoperability test, black-box testing.

1 Introduction

Train control system is the vital control system in charge of the very core for safe operation of train, and according to the latest development in computer and communication technology, existing mechanical and electric train control functions are replaced with computer software. One of the important matters in this technical development is considered to be the securement of interoperability among devices being developed. That is, from the aspect of individual train control device, since it is difficult to apply it to railway sites without guaranteeing interoperability with other devices, and in addition, it is difficult to interlock, expand and improve functions without guaranteeing the interoperability.

Interface protocols among train control devices are being standardized, and although this standardization plays an important role to secure the interoperability, it is our real state that sufficient interoperability is difficult to be secured actually

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due to the incompleteness and ambiguity, etc. of the standards. Moreover, interoperability validation stage is considered to be essential since standardization on the interface among train control devices are progressed for some cases only so far.

Up to now, validation on interoperability has been very difficult since national standards on the interface among train control systems are limited to some cases [1], and most of the interfaces are designed and applied by the manufacturer. In addition, it is our real state that a lot of time and efforts are consumed in the actual test run stage since interface specification by each manufacturer is usually incomplete for most cases.

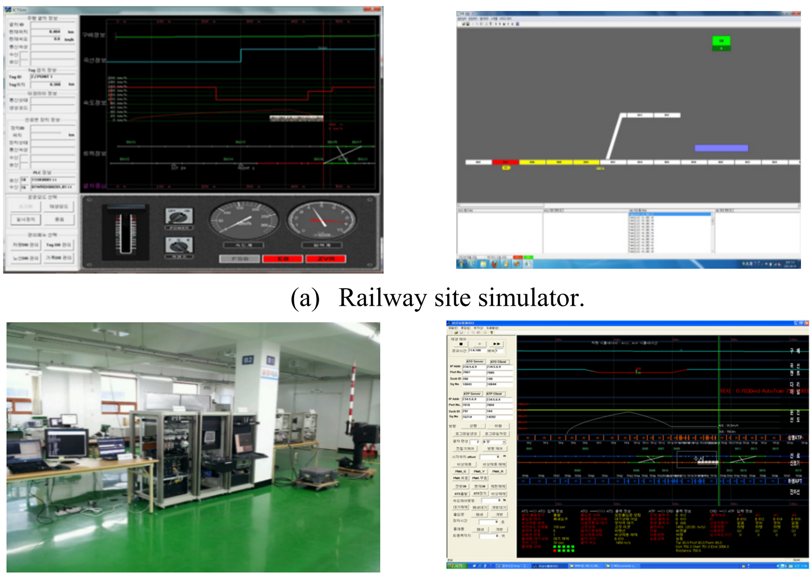
That is, interoperability is validated only within the extremely limited scope since validation on interoperability of train control system is conducted through the method by a simulator and that of test run at the actual applicable site, etc. Therefore, it is required to have a new method to validate interoperability sufficiently at the level of laboratory, and the system to support it is needed too [2–5]. This paper proposes a new method to validate interoperability from the aspect of validation on functional safety of this train control system and the testing tool to support it. The testing tool to test interoperability was based on the automated black-box testing tool developed through preceding research of the authors of this paper [4–7], and functions were added to support serial interfaces which are utilized in the actual train control device, although only Ethernet was supported by the existing development tool so that more substantial interoperability testing can be available.

2 Interoperability test for train control system

The test to check whether the interface is operated in the right way when two or more control devices are interfaced is the interoperability test, and it must be validated when developed devices are applied to the site. In case of the latest train control system, the size of interoperability test is growing bigger since it becomes a richer and more intelligent train control system as much more complex functions are performed due to the increased utilization of software and the functional distribution or combination with other devices is performed through communication.

Generally, conformance test is applied as one of the stages to validate interoperability. Conformance test is the method to test which development device is implemented to meet the requirement in the right way, and it is performed widely as the prerequisite to discover errors in implementation though it and to validate interoperability between each device. The research on conformance test was mainly conducted in the communication protocol conformance test field, and it is standardized by the recommendation from the ITU-T X.290 series [8]. Although there are some research cases similar to the conformance test in this communication protocol field in the train control device, they are not applied widely. In the field of train control system, the method which validates requirements by implementing a simulator simulating an actual railway site as its software or hardware within the laboratory and by connecting it to the developed train control device is applied as the conformance test in general [4–7].

Fig. 1 shows an example of simulator which simulated a railway site for conformance test of this train control device. (a) in fig. 1 shows the entire configuration for conformance test in the laboratory, (b) shows the simulator which simulated the rail, point machine, signals, track circuit and train, etc. for conformance test in the laboratory, and (c) shows the computer screen to analyze test results by the simulator. As shown in fig.1, in case of the railway train control device, although some of the single components such as point machines can be connected directly for the conformance test in the laboratory, most of railway sites are simulated by the simulator based on the software since all of the railway sites such as track cannot be simulated, and the testing to check whether required functions of validation target train control device have been implemented correctly is performed through it. Therefore, hereinafter, the functional validation test by simulator in this laboratory environment is referred to as the conformance test.



(a) Railway site simulator.

(b) Test environment in lab

(c) Test analyzer

Figure 1: Example of conformance test by simulator.

Although this conformance test in the laboratory is performed, actual other train control device interface implemented by the simulator can be different from the real one, and the validation on interoperability through conformance test by the simulator is performed in the limited scope only. Therefore, separate interoperability test is required.

The sharing or capability of sharing information by more than two control devices to perform a certain function or mission is called as the interoperability, and in case of the train control system whose dependence on the latest software is

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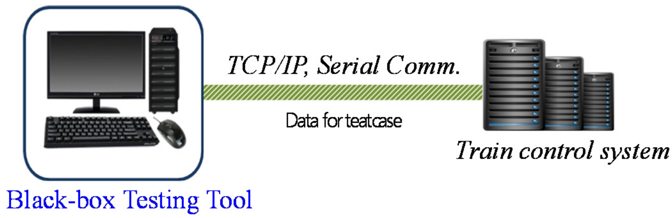
increased, this interoperability is increased also. Thus, validation on interoperability in the latest train control system must be validated before its application to the actual railway site. The level of interoperability can be considered largely at the specification level and from the implementation aspect, and this paper is targeted at the interoperability test which evaluates interoperability from the implementation aspect. As mentioned previously, this interoperability test is necessary because the problem of interoperability cannot be solved completely due to the incompleteness of requirement, or error in specification, or incompleteness of conformance test, etc.

Figure 2: Step for validation on interoperability.

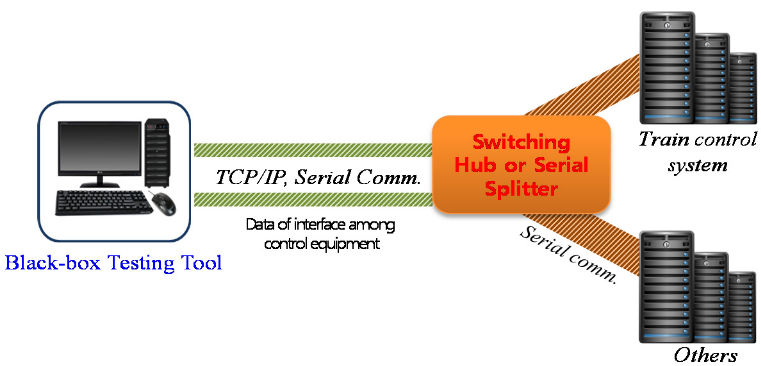
This paper proposes application methodology by step such as the primary validation through test via simulator in the laboratory as the method to validate interoperability of the train control system, and the secondary validation through conformance test by utilizing EUT (Equipment Under Test) and testing tool, and the third validation through interface with other device interfaced actually. Stage 1 validation method is the method to validate interoperability with other train control devices through simulator including modelling and operational scenarios for actual railway sites where train control devices will be operated by the simulator. Although this method is the one applied generally until now, there is a limit to validate interoperability with this method. Thus, to supplement stage 1 validation, stage 2 validation method is the method to test interoperability through test cases derived by connecting a testing tool to the actual interface communication channel which is operated through linkage to the EUT. In this case, test cases must be derived from interface protocol specifications among train control devices, and the testing shall be carried out in the manner that these derived test cases are mounted on the testing tool which is connected with the actual interface channel of EUT. That is, the testing tool which is connected separately by these test cases will substitute for other train control device to be interfaced actually during the testing period. In the research targeting at the actual train control device for this validation method, most of them are validated through the two-step validation method explained previously. However, three-step validation process is necessary since it is not to check operation linked to the actually interfaced train control device finally.

The validation method in the third stage proposed in this paper is the method to test interoperability through confirmation of data to be interfaced between the train control system to be validated and the other control device connected to the train control system actually, and to perform the functional safety validation on software of the EUT simultaneously. That is, this stage is the method validating interoperability in the highest level, and it is the method utilizing interfaces for actual inspection to validate interoperability of the train control system. It will check if the interface between two devices is correct by using the method where snooping of interface data exchanged mutually is available by inserting a testing tool in the middle of interface media between actual train control devices and will check the interoperability through it.

A separate testing tool is necessary in stages 2 and 3, and to support it. The preceding research of this paper can utilize the developed testing tool. This testing tool was designed and developed so that it can be applied to stages 2 and 3 identically. There is a difference in the connection method with EUT only, and it is possible to utilize the same tool. However, the test case for validation by each stage must be input into the derivation and testing tool separately. Testing tool can be utilized as the two-step configuration form for conformance test where test data are injected and fed back by connecting the testing tool with an interface channel of EUT directly in the actual application, and the configuration form for three-step validation by snooping method by connecting the testing tool with an interface medium in the middle of other control device that is interfaced with EUT actually. (a) of fig. 3 shows the configuration for validation in 2-step, and (b) shows the configuration for validation in 3-step. Explanation about this tool is described briefly in the next clause.



(a) Configuration of 2-step validation



(b) Configuration of 3-step validation

Figure 3: Configuration of 2 and 3 step connection for validation on interoperability.

3 Testing tool for interoperability

To validate 2 and 3 step interoperability of the train control system explained in the previous clause, the appropriateness of interface among train control devices being operated actually by connecting with each other must be verified. However, although validation on interoperability in the low level has been progressed until now by the method such as the test by simulator or conformance test, etc., for the validation in the higher level, this paper utilized the tool developed through preceding research that supports validation via connection with interface channels of train control device used actually [4–7]. This is a method utilizing interfaces for actual inspection to validate interoperability of the train control system, and this will check if the interface between two devices is correct by using the method where snooping of interface data exchanged mutually is available by inserting a testing tool in the middle of interface media between actual train control devices and will check the interoperability through it.

Fig. 4 is a figure showing the connection method of testing tool conceptually to test interoperability through connection with this interface media used actually. Test cases derived through analysis on interface protocol between two devices are stored in the testing tool connected in the middle, and the level of interoperability is measured by comparing interface information gathered through snooping with these test cases derived in advance.

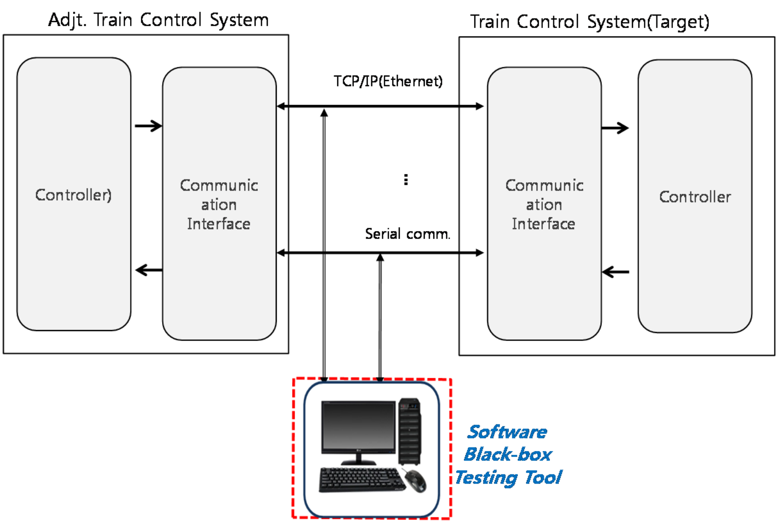


Figure 4: Configuration of interoperability testing tool.

In this tool, test cases prepared on the basis of TTCN-3 which is the international standard language in relation to testing are input basically, and it is made so that the tester can modify some of the test cases in the tool [9–11]. Although TTCN-3 based test case is consisted of the script language as international standard language basically, it has the function to convert a MSC

(Message Sequence Chart) language, which is one of the graphic languages, into the TTCN-3 language automatically if it is input since there may be users not familiar with this script language. And the testing result will be output in the script language and the MSC based graphic language simultaneously as shown in the fig. 5. Fig. 6 shows the main window of testing tool to support validation on interoperability. Testing tool to support an interoperability test used in this paper is explained in details in [4–7], and the detailed explanation is omitted in this paper.

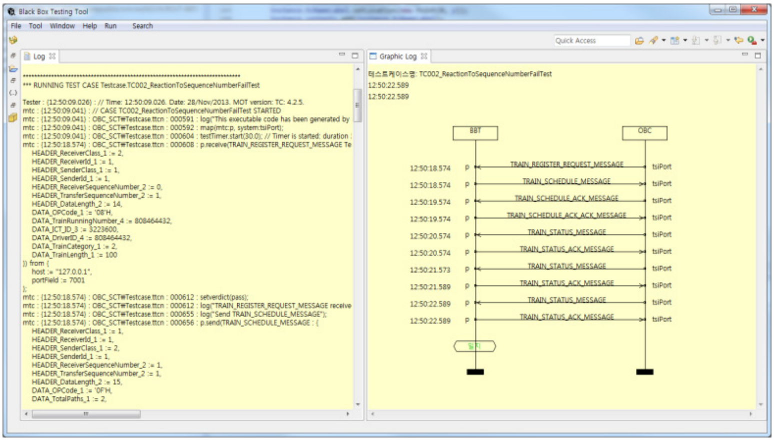


Figure 5: Testing result screen to be output in the script and graphic languages.

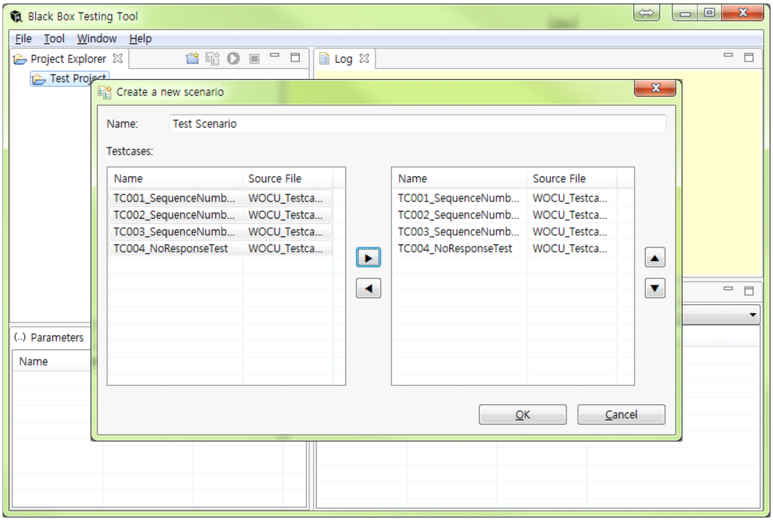


Figure 6: Interoperability testing tool screen.

Testing tool developed through preceding research supported interfaces in the Ethernet method only. However, since not only Ethernet but also serial communication methods are applied a lot to the interface between actual train control devices, this study added a serial interface method to the Ethernet support method in the existing tool. It is the method to be connected between two train control devices through serial splitter to support serial interfaces and to snoop data to be interfaced.

Fig. 3(b) is a figure showing the connection configuration of testing tool to validate interoperability utilizing serial interfaces which are applied to many of the train control devices in general, and the testing tool is directly connected with a serial splitter. Information interfaced between two devices will be snooped through serial splitter with EUT or other train control devices, and it was made to verify the appropriateness of interface in other modules explained in the previous clause and to create test results by using data acquired through it.

4 Conclusion

This paper proposed a testing methodology by step to validate interoperability of the train control system, and explained main features and necessary contents by each step. Especially, for the validation in stages 2 and 3 proposed in this paper, we proposed a plan to utilize the software testing tool developed through preceding research. This testing tool is made to enable test cases created and input on the basis of TTCN-3 script language basically, and made to enable train control devices intended to be validated utilize actual interfaces. Although only Ethernet communication method could be supported in the existing tool, this paper changed and developed this testing tool so that the serial interface using a serial splitter can be supported since interfaces by serial method are utilized a lot in the actual train control device. And the method of connection with EUT for the validation by each step utilizing this testing tool was explained. Currently, the testing tool to apply interoperability validation methodology by step proposed in this paper was developed, and applicability tests in stages 2 and 3 were performed. As a result, it was verified that the validation on interoperability in the higher level proposed in this paper was possible such that errors in the interface protocol specification, and errors in the implementation of protocol, etc. which were not verified in the performance of the validation in the first stage only were verified in the higher level, etc.

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