New Database Table Design Program of Real Time Network for High Speed Train

Chang-Hee Cho*, Min-Kook Park*, Soon-Man Kwon*, Yong-Ju Kim*, and Sung-Shin Kim**
* Korea Electrotechnology Research Institute, Changwon, Korea
(Tel : +82-55-280-1473; E-mail: chcho@keri.re.kr)
**Department of Electrical Engineering, Pusan National University, Pusan, Korea
(Tel : +82-51-510-2366; E-mail: sskim@pusan.ac.jp)

Abstract: Real time control system such as in factory automation fields, defense field, aerospace, railway industries, financial trading and so forth, includes multiple computers on multiple nodes, and share data to process various actions and functions. This is similar to multitasking in a multiprocessor computer system. The task processing efficiency of such system is proportionally increased by process speed of each process computer. And also it is greatly influenced by communication latencies of each node. To provide proper operation of such real time system, a network that can guarantee deterministic exchange of certain amount of data within a limited time is required. Such network is called as a real time network. As for modern distributed control system, the timeliness of data exchange gives important factor for the dynamics of entire control system. In a real time network system, exchanged data are determined by off-line design process to provide the timeliness of data. In other word, designer of network makes up a network data table that describes the specification of data exchanged between control equipments. And by this off-line design result, the network data are exchanged by predetermined schedule. First, this paper explains international standard real time network TCN (Train Communication Network) applied to the KHST (Korean High Speed Train) project. And then it explains the computer program developed for design tool of network data table of TCN.

Keywords: TCN, KHST, Network, Database

1. INTRODUCTION

The network data table used for KHST prototype train is composed of various signals that were picked up from the CSS (Control System Specification) document. First network data is drafted by using Microsoft Excel® file and this worksheet is the base for generating the network data table. The table will be used for database of TCN in each network controllers. This file contains all essential fields of data for designing TCN network. It gives a clear view of the network signals transmitted by TCN.

As it was briefly mentioned in the introduction, for the design of the real time network, one has to have a proper tool not only for adding, deleting, modifying of this table, but also for selection, filtering, analyzing of the table data. The TCN data table design program was developed for these purpose, and give great help for the network system designer. And it also assists the onboard application programmer who uses TCN. Therefore gives a smooth development assistant for the entire network system of KHST prototype train.

1.1 TCN and KHST

Development project of KHST (Korean High Speed Train) was started in 1996. Goal of this government support research project is to develop the prototype of high speed train that has the maximum operation speed of 350 km/h. To achieve more speed than KTX (Korea Train Express, Seoul-Pusan), a lot of latest cutting-edge technologies were adopted. For example, to make the total weight of prototype lighter, aluminum compound material was used as a train body. And also to reduce the total number of the axle, articulated bogie type was selected. As a result total weight of bogie could be lessened. Although the articulated bogie has demerit such as the inconvenience in maintenance but KHST can make use of maintenance facilities of KTX. As for traction system, high power-small size induction motor was developed to make more power in the same space.

The brake system for the high speed train has various problems such as adhesion limit, heat emission, brake pressure limit. KHST uses both electrical (regenerative and rheostat) and frictional (disk and wheel) brake system. And it has additional non-contact type eddy current brake system. And by using brake blending unit, KHST can make the best combination of brakes according to the train speed and braking condition.

Although KHST will be operate with 11 or 20 vehicles in a commercial operation, the composition of first prototype train will consist of seven vehicles. In Fig 1, we can see that it has 2 power cars -locomotives- at both ends (TP1, TP2), 2 motorized cars is next to them (TM1, TM5), and 3 trailers is located in the middle of the train. (TT2, TT3, TT4)

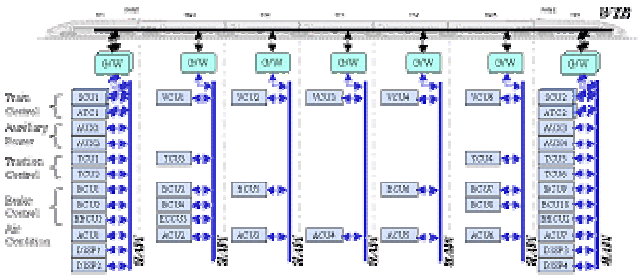


Fig. 1 Onboard controllers of the prototype KHST and constitution of the network devices

As the train of next generation, KHST has various characteristics and functionalities. One of the specific examples is the distributed control and diagnostic system that was realized by the large number of distributed onboard controllers and the train specific real time network that connects the entire system together.

After more than 10 years of draft period, TCN was finally fixed as an international standard in summer of 1999. (IEC 61375, Electric Railway Equipment – Train Communication Network) TCN consists of 2 level hierarchical networks. One is a network for train bus called WTB (Wire Train Bus) that gives connections between vehicles, and the other is called as MVB (Multifunction Vehicle Bus) that connects equipments inside a vehicle. As a specialized network for railway application, TCN has following distinguishable features.

Inauguration is a function for WTB node. It is initiated when the composition of train has changed. After the inauguration process, each WTB node knows her network address, left/right direction, other vehicles information, and so forth.

And TCN is a real time network that gives a definite connection between equipment within a prescheduled time. Key of this real time feature is given by Source addressed broadcast scheme of the process data transmission. Source addressed broadcast is initiated by a bus master by sending a master frame over the network. When a bus master sends this frame to request transmission of certain variable as on prescheduled time table, a device that are to send the variable (Publisher) broadcasts a slave frame containing the variable. While, every device on the bus checks that slave frame, some devices that are designed to receive the variable (Subscribers) read the slave frame and copy it to their memory called the traffic store. While the process data is transmitted on the regular basis, the message data is transmitted on demand. It uses call/reply of the client/server concept, and each message packet is transmitted with the source and destination information.

TCN also has features for fault tolerant characteristics to increase the network availability. For example, the redundant concepts are used in bus medium (line) and bus administrator. And various software and hardware architecture exist for detect and recover from error. In addition to the features mentioned above, TCN has some specific features such like fritting, sink time supervision, check variables, TNM, and so forth.

2. NETWORK DATA TABLE

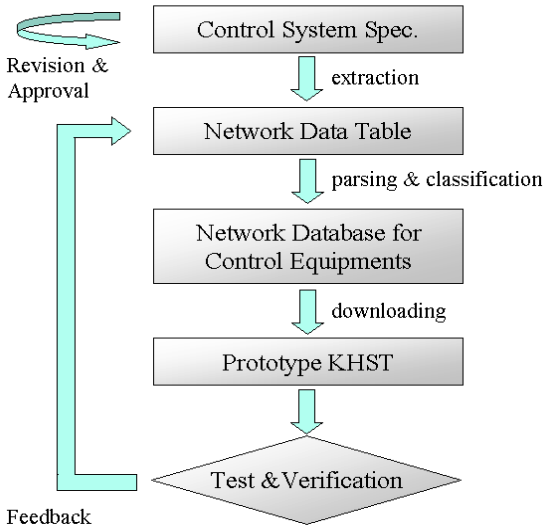
As mentioned in previous section, TCN is the real time network. Real time characteristic means that the specific data must be delivered to the designated devices within a pre-determined time. To satisfy this real time characteristic, we have to perform a precise off-line design of the network software as well as hardware. In the heart of this design process, there is the network data table. The network data table has whole information of network. By filling up, and by modifying the table content, a design of entire network is performed.

Before we make the proper network data table, we need the specification of requirements that describes the signal flow. That means we need to determine the information exchange between control equipments. We have to specify the signal type, how it is going to be transmitted (Network/Hardwire), where it is made or spent, when to transmit and so forth. Basic information of this kind can be collected in the Control System Specification.

2.1 Control System Specification (CSS)

Control System Specification (CSS) is a document that describes the functionalities of KHST control system. It defines basic definition of the functions, relationship between train equipments. It also contains the information regarding the conditions needed to operate this function, the process of function operation, input/output of signal, and some extra information. First draft of CSS was published in May. 2000. And currently CSS is revised as revision D.

CSS gives the fundamental rules for development of electrical equipment for control/diagnosis. And CSS gives the directives of software development as well as hardware. So it will be used in testing equipments of the prototype train after installation of equipments finished.



2.2 Design flow of the network data table

The signals used in CSS are transferred through hardwires, pneumatic tubes, or network. For the network configuration, the signals that are exchanged by network have to be extracted from CSS. The network signal table is the starting point of TCN network database generation.

Fig. 2 shows the development flow of the train network simulator. First CSS was written out and revised according to changing demands of the functions. From CSS, we extracted the signals that are to be transmitted by the network. Then, all the signals of the network table are assigned with properties that are needed for TCN communication. Such properties includes items such as, signal type (periodic or event data), transmission period, signal type, size, MVB port number, offset, source device, sink device, and so forth.

Next stage is to build the database file for each device of on board controllers respectively. To make the database, same sort of signals are parsed and classified by same properties.

After that, database files are downloaded device by device using serial service interface port, or ROMized to every devices. By taking several tests and verification of TCN communication, the designer can decide whether his work was suitable for user's demands or not. And by looping this development flow, suitable network data table, and finally TCN network system can be accomplished.

3. TCN DATATABLE DESIGN PROGRAM

3.1 The network data table design program

The TCN data table design program is a Microsoft Windows© application that consist of a single form of window. A form can be divided into upper and lower part. Upper part is consists of combo box, input box, some buttons for input of user. Lower part is a grid control that shows a data table that is a result of the user input. With the aids of desktop database, and DB access program with ADO (ActiveX Data Object), it has a basic function of input, delete, modifying of table. Data fields consist of several information such as identification, port number, signal name, source device, sink device, MVB (Multifunction Vehicle Bus) segment, period, and so forth.

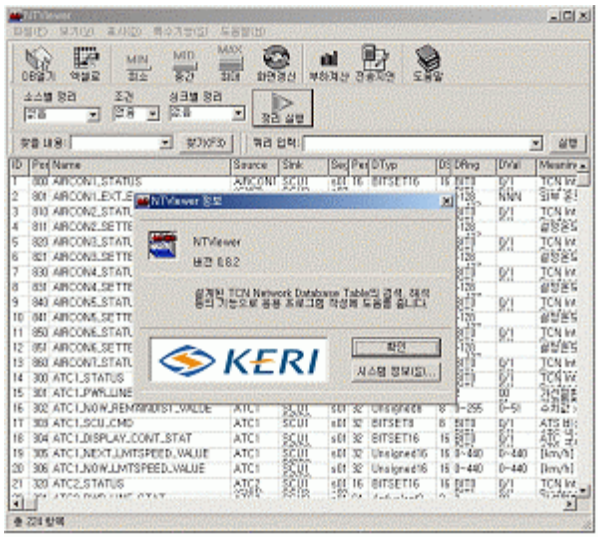


Fig. 3 Network data table design program

And next, as a one of the most important and most frequently used function, there is a data table extraction function. After data input has been finished. The network designers have to verify source and sink signal for a certain device, and they sometimes need the network data table to be arranged by MVB segment. In these cases, by using SQL query input, or predetermined combo box control, the design program can extract and sort the network data table very conveniently.

As mention in introduction, to provide timeliness of the real time system, data size, transmission period, number of data, etc are determined during the network design process. In this case, total amount of workload estimation is very important for the network designer. With the TCN workload calculation algorithm and graphical display of calculation results, the designers are able to estimate the real workload of each MVB segments.

TCN has two level of hierarchy. So when a network signal flows from source device to sink devices, data transmission delay corresponds to individual transmit period when they are in same MVB segment. However, when source and sink device are in different MVB segment, both network designer and application programmer have to know how much the maximum transmission delay will be. The new TCN data table design program calculate this delay automatically and generate visual display of results, and helps for designing and developing of TCN system.

3.1 Basic Functions

► *Install and Uninstall* 

As a Microsoft Windows application, this program is provided by installation program. Setup is done similar way as the other windows application program.

► *Input, Modify, and Delete*

As a fundamental design function, there are function of data input, modification, and deletion. First, the designer has to input the basic items to the network data table. Input items are as below.

- ID ····· Index of database
- Port ····· Port Number of MVB Process Data
- Signal Name ····· Name of the Signal
- Source ····· MVB Source Device
- Sink ····· MVB Sink Device
- Segment ····· MVB segment where the signal belong to
- Period ····· Transmission Period
- Data Type ····· Type of the signal
- Data Size ····· Size of the signal
- Bit / Range ····· Bit for discrete / Range for analog
- Value ····· Actual transmitted value
- Meaning ····· Bit definition or meaning of contents
- Purpose ····· Object, Description of the signal
- CSS ····· CSS section number where the signal correspond

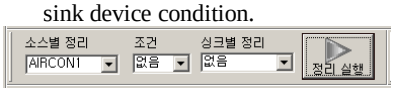
► *Size Control* 

Designer of network data table is able to find the result by referencing the data grid. Network signal of the data table usually contains a lot of information, so mostly a record occupies multiple lines. It means that the amount of information for a single grid page is limited by several records. In this case, designer is able to select size of grid by clicking the size control coolbar.

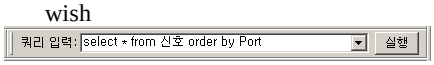
► *Data Selection*

Data selection function maybe the one of most valuable functionality of this program. After the input of data is completed, designer of the network has to do the works such as, checking the send/receive signal of the devices, choosing the network signal of the specific MVB segment, or data fraction according to individual transmit period of the signal. For these cases, this application program can satisfy the desires of the designer by providing the data selection function. User can extract the signals from the network data table database by two different data selection function as described below.

- Combo box and push button ····· predetermined source and sink device condition.



- SQL query input ····· Various SQL query statement as user wish



► *Sorting*

Sort is a function of data arrangement according to the specified order. Default sort of the network data table is done by the ID field. User can make use of this sort function by two methods. First one is to double click on the field name tag of the data grid. This will sort the entire data table grid by the alphabetical order according to that field. Second is by using 'order by' SQL statement. Users can do this by appending 'order by' statement when they input SQL query selection for selection of data.

► *Text Search* 

Text search is one of the most frequently used function. Users can use this function to find grid containing specified text. When the program find the text, result will be displayed in blue color.

► *To Excel Worksheet* 

As described above, users can perform various operations with the data table, and the result of works may be transmitted

to Microsoft Excel worksheet. Users may use advanced feature of Excel such like statistics, graph, report and so forth. Fig. 4 shows the example of Excel transmitted data table. The file contains 43 worksheet named by every device name. Each worksheet contains the network signal according to the source device. To help the programmer of onboard controller, the network data table is distributed as 6 Excel files as well as original data table database and the program.

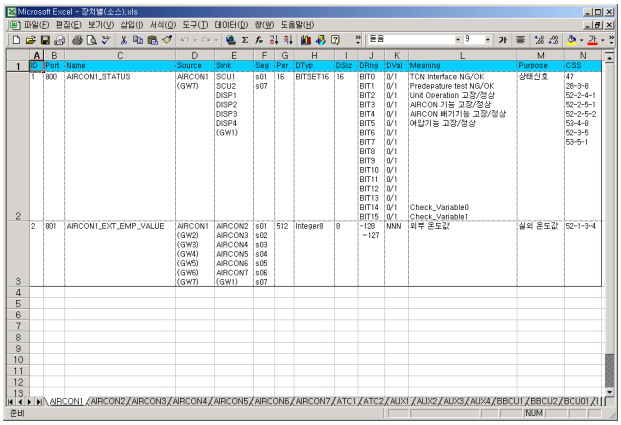


Fig. 4 Data table transferred to Microsoft Excel worksheet

► *HTML Help*

This program is provided with the user friendly HTML help. HTML help documents includes the information about brief introduction, user's guide regarding installation, function usage examples, and so forth It also has the function of index search.

3.2 Network Workload Analysis

There are two important factors in designing real time network. First one is the information regarding workload of designed network. Unlike the other network system, .in the real time network, the type and size of the transmitted data is determined by off-line design. Therefore, the estimation of total amount of workload that is to be allotted to each network is very important to the network designer.

The workload calculation of TCN is done with the periodic data that is transmitted cyclically. The periodic data does not mean the event data or supervisory data that is transmitted on demand. In TCN, periodic data transmission is done by the process data that is transmitted regularly. The single transmission of process data is comprised by one master telegram and following slave telegram, as seen in Fig. 5. The master frame contains total 33 bits of SB (Start Bit), MSD (Master Start Delimiter), CS (Check Sequence). The slave frame contains SB, SSD (Slave Start Delimiter), SFD (Slave Frame Data). Because the size of SFD is variable according to the port size, the size of slave frame is 33 bits for minimum, or 297 bits for maximum. Time gap from the end of master frame to the start of next slave frame is called T_ms, and T_sm for

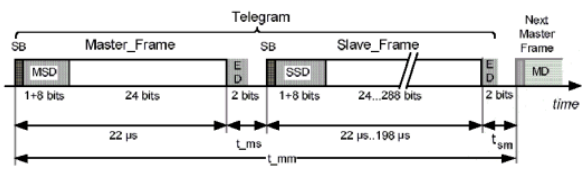


Fig 5 Structure of the transmitted master/slave telegram

vice versa.

The process data of TCN is transmitted periodically by every individual period. Individual period is different to each process variable, and is one of $T\_bp \times 2^n$ (n=0~10). The percent workload of each individual period can be calculated by dividing the time sum of every master, slave frame time, and time gap of that individual period by entire time sum of that individual period (periodic phase, excluding sporadic phase) and multiplying 100. And by the same way, the total workload of TCN can be calculated by percent calculation of entire process data time sum against entire time sum.

By referencing network data table, the network data table design program can calculate the amount of master and slave frames of given MVB segment, and can calculate the total workload of the network. Fig. 6 shows the graphical report of workload of the actual KHST prototype train. Each train constitutes a single MVB segment, it can calculate workload of the 7 individual segment. The figure shows the workload of the individual period as well as total workload of the first locomotive of the prototype train (TP1). In table 1, you can see the workload of the entire train. In the table, you can see the number of onboard controllers, number of the network signals, and total workloads. It is not hard to find that number of devices, signals and by the result total workload is much higher at both end locomotives.

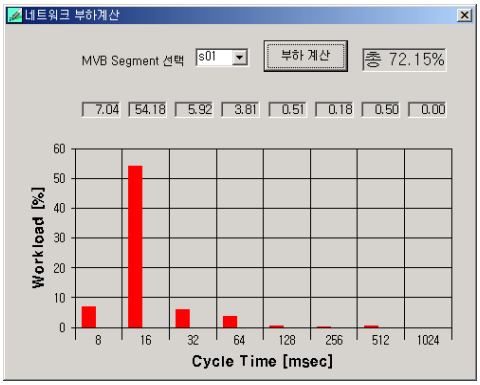


Fig. 6 Network workload calculation

Table 1 Workload analysis results for each MVB segment

MVB segment (Vehicle)	Number of devices	Number of signals	Workload [%]
S01 (TP1)	13	181	72.15
S02 (TM1)	7	112	40.22
S03 (TT2)	4	69	20.09
S04 (TT3)	3	64	17.72
S05 (TT4)	4	65	17.74
S06 (TM5)	6	105	36.00
S07 (TP2)	13	180	72.00

3.3 Transmission Delay Analysis

Second important factor in designing real time network, is a information about transmission delay. Because TCN has two level of hierarchical network, time required from transmission to reception of the network signal can be different from its individual transmission period. If the sender and receiver is located in the same MVB segment, transmission delay of data is equal to its individual transmission period. However, if they exist in the different MVB segments, then the transmission of

signal need to go through WTB network. Fig. 7 shows the flow of the network signal transmission. You can see the difference of the signal flow between in same segment and in different MVB segments.

In the figure, ① and ⑤ represents transmission delay according to MVB transmission. ② and ④ represents delay caused by the gateway transit. And ③ represents data delay caused by WTB transmission.

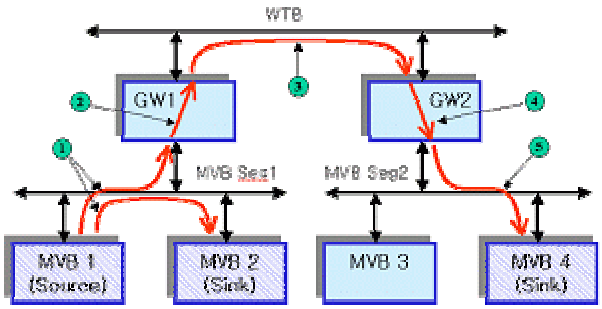


Fig. 7 Flow of the network signal transmission

In MVB transmission delay, the minimum delay corresponds to the time needed for master and slave frame transmission. It depends on the size of the port data but it is usually several tens to hundreds of micro seconds. On the contrary, the maximum delay corresponds to the individual transmission period of the port data. (1~1024 msec)

The delay caused by the gateway transit is due to the process called as the process data marshalling. The process data marshalling is a internal task of the gateway. It holds the major key of the gateway action. It exports the process variables from MVB to WTB, or vise versa. And for intelligent networking, it also has some other functions such like arithmetic/numeric calculation, internal marshalling, overriding of variable, and so forth. The process data marshalling is a cyclic task. Therefore, a process variable needs to take some time to go up or down to next hierarchy of network.

Because MVB and WTB uses same transmission topology (Source addressed broadcast), the delay caused by WTB transmission can be calculated identically as in MVB's case. The minimum delay is the time from start of WTB master frame to end of the WTB slave frame. The maximum delay corresponds to some multiple of WTB basic period (25 msec) according to the total number of WTB nodes (Gateway). The number of WTB master and slave frame that can be covered in a single WTB basic period can be calculated as follows. The maximum time space between a WTB master frame to the next master frame can be considered as the worst case of WTB master timeout time. This timeout value can be calculated when maximum WTB port bits, worst case of bit stuffing, maximum lag in media transmission, maximum responding time of the slave device and this result is 1820μ sec. This maximum value can be converted to maximum WTB master/slave frames that can be transmitted in a single basic period. Because periodic phase of WTB is 60% (15 msec) of its basic period, you can see maximum of 8 WTB master and slave frames can be transmitted in a single basic period. Therefore the prototype KHST consists of 7 vehicles, the maximum delay caused by WTB transmission can be considered as 25 msec.

By this way, the data table design program calculates the transmission delay of the user specified network signal. If the network designer select one signal and press calculate button, design software calculate the transmission delay from source device to every sink devices. Fig. 8 shows the result of transmission delay calculation. The report form includes intuitive visual report of worst transmission delay value. Therefore, time required for each stage should be added for calculating entire transmission delay.

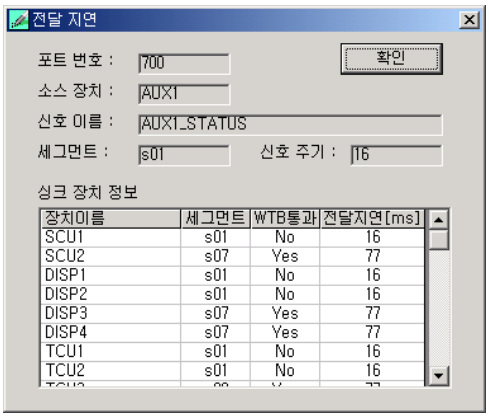


Fig. 8 Transmission delay calculation

5. CONCLUSION

In this paper, TCN data table design program was presented. This program helps the network designer of KHST prototype train. As the real time network, TCN is designed precisely by off-line design process. This program was developed as a design aids program for network system designer, as well as a network assistant program for the programmers of onboard equipments. Characteristics and special feature of this program was explained briefly. Distinctive characteristics of TCN were also introduced so as to help the reader's comprehension. Currently, it is used in development project of Korean High Speed Train. First network table was developed in 2001 and several tests were conducted to verify the TCN system. Presently, prototype KHST that consists of 7 vehicles is on its way of test drive with the real time network installed.

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