The proposed system architecture is using four communication ports, four communication lines and two switches, so the software for performance estimation should be able to support system architecture as the Fig 1. Approximately explaining the software, the message-generating routine creates an event of message generation to a slave message-sending routine when messages are generated. The slave message-sending routine which receives the event is constructed by the way of transmitting messages. The master plays a role to carry perfect data to application levels after copying the data entered individual received buffers and bring to voting routines, and comparing the data.

## 4. EXPERIMENTS OF THE PROPOSED METHOD

To verify the proposed network-based interface with redundancy architecture, we experimented on the bus redundancy which is to manage the conditions that some short circuits appear in cables by external causes from actual environments. Fig. 2 and 3 show the images that cables are cut, and the results achieved by the suggested system.

The experiment is to make 5,000 messages per 10 min., and the diagram shows the result got at a second (after about 39second, in the experiment) when the cables of slave whose IP address is 192.168.0.12 are cut. Up to the 3934th message, transmitting data per 10 min. in stations increases 1 gradually. Then there is no error and the final result value is normal. From the results, we can confirm that the error of only one bus is detected and correct result-value on bases of the others' bus value is recovered.

Transmission delay associated with the communication is a parameter which is the most importantly considered when we apply the network to the environments where the real-time proceeding is required. The time for detecting faults means the total time for sending messages from slave and analyzing them in masters. The fault detecting time covers transmission delay and propagation delay and also includes the processing delay which is for analyzing data in masters. The measured time of transmission delay is like the equation (1).

$$\text{Fault detection time}(D_T) = \text{Transmission delay}(Comm_T) + \text{Propagation delay}(Prop_T) + \text{Processing delay}(Proc_T) \quad (1)$$

As we can see the result from Fig. 4, the average transmission delay, which is measured from the traffic conditions where each 3 station (each has four ports) generates data a 10min, is about 770 sec. The fault detection time is within about 800 sec, because the faults are immediately identified without considering transient fault.

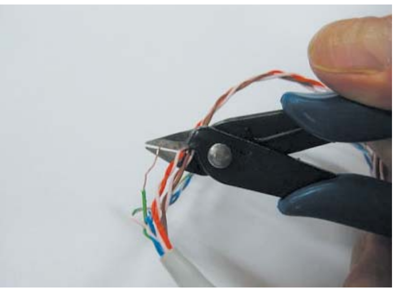

Fig. 2 Cutting cables

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2294 | Address: | 192.168.0.5 | Data: | 2293 | Delay: | 755.445 | us |
| 2295 | Address: | 192.168.0.5 | Data: | 2294 | Delay: | 759.56 | us |
| 2296 | Address: | 192.168.0.5 | Data: | 2295 | Delay: | 791.646 | us |
| 2297 | Address: | 192.168.0.5 | Data: | 2296 | Delay: | 793.284 | us |
| 2298 | Address: | 192.168.0.5 | Data: | 2297 | Delay: | 762.474 | us |
| 2299 | Address: | 192.168.0.5 | Data: | 2298 | Delay: | 759.282 | us |
| 2300 | Address: | 192.168.0.5 | Data: | 2299 | Delay: | 757.578 | us |
| 2301 | Address: | 192.168.0.5 | Data: | 2300 | Delay: | 759.205 | us |
| 2302 | Address: | 192.168.0.5 | Data: | 2301 | Delay: | 748.414 | us |
| 2303 | Address: | 192.168.0.5 | Data: | 2302 | Delay: | 772.204 | us |
| 2304 | Address: | 192.168.0.5 | Data: | 2303 | Delay: | 762.75 | us |
| 2305 | Address: | 192.168.0.5 | Data: | 2304 | Delay: | 758.755 | us |
| 2306 | Address: | 192.168.0.5 | Data: | 2305 | Delay: | 783.538 | us |
| 2307 | Address: | 192.168.0.5 | Data: | 2306 | Delay: | 791.097 | us |
| 2308 | Address: | 192.168.0.5 | Data: | 2307 | Delay: | 754.981 | us |
| 2309 | Address: | 192.168.0.5 | Data: | 2308 | Delay: | 773.953 | us |
| 2310 | Address: | 192.168.0.5 | Data: | 2309 | Delay: | 754.339 | us |
| 2311 | Address: | 192.168.0.5 | Data: | 2310 | Delay: | 755.835 | us |
| 2312 | Address: | 192.168.0.5 | Data: | 2311 | Delay: | 791.525 | us |
| 2313 | Address: | 192.168.0.5 | Data: | 2312 | Delay: | 755.354 | us |
| 2314 | Address: | 192.168.0.5 | Data: | 2313 | Delay: | 786.213 | us |
| 2315 | Address: | 192.168.0.5 | Data: | 2314 | Delay: | 758.315 | us |
| 2316 | Address: | 192.168.0.5 | Data: | 2315 | Delay: | 754.882 | us |
| 2317 | Address: | 192.168.0.5 | Data: | 2316 | Delay: | 751.895 | us |
| 2318 | Address: | 192.168.0.5 | Data: | 2317 | Delay: | 753.529 | us |
| 2319 | Address: | 192.168.0.5 | Data: | 2318 | Delay: | 759.869 | us |
| 2320 | Address: | 192.168.0.5 | Data: | 2319 | Delay: | 757.53 | us |
| 2321 | Address: | 192.168.0.5 | Data: | 2320 | Delay: | 761.359 | us |
| 2322 | Address: | 192.168.0.5 | Data: | 2321 | Delay: | 757.816 | us |
| 2323 | Address: | 192.168.0.5 | Data: | 2322 | Delay: | 774.907 | us |
| 2324 | Address: | 192.168.0.5 | Data: | 2323 | Delay: | 763.029 | us |
| 2325 | Address: | 192.168.0.5 | Data: | 2324 | Delay: | 771.608 | us |
| 2326 | Address: | 192.168.0.5 | Data: | 2325 | Delay: | 755.263 | us |
| 2327 | Address: | 192.168.0.5 | Data: | 2326 | Delay: | 752.094 | us |
| 2328 | Address: | 192.168.0.5 | Data: | 2327 | Delay: | 753.789 | us |
| 2329 | Address: | 192.168.0.5 | Data: | 2328 | Delay: | 765.081 | us |
| 2330 | Address: | 192.168.0.5 | Data: | 2329 | Delay: | 751.111 | us |
| 2331 | Address: | 192.168.0.5 | Data: | 2330 | Delay: | 752.815 | us |
| 2332 | Address: | 192.168.0.5 | Data: | 2331 | Delay: | 747.204 | us |
| 2333 | Address: | 192.168.0.5 | Data: | 2332 | Delay: | 762.798 | us |
| 2334 | Address: | 192.168.0.5 | Data: | 2333 | Delay: | 754.62 | us |
| 2335 | Address: | 192.168.0.5 | Data: | 2334 | Delay: | 763.461 | us |
| 2336 | Address: | 192.168.0.5 | Data: | 2335 | Delay: | 751.749 | us |
| 2337 | Address: | 192.168.0.5 | Data: | 2336 | Delay: | 756.933 | us |
| 2338 | Address: | 192.168.0.5 | Data: | 2337 | Delay: | 756.678 | us |

Fig. 3 Experimental of communication delay

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 192. 168. 0.9: | 3929 | 192. 168. 0.10: | 3929 | 192. 168. 0.11: | 3929 | 192. 168. 0.12: | 3929 | ***Result:*** | 3929 |
| 192. 168. 0.9: | 3930 | 192. 168. 0.10: | 3930 | 192. 168. 0.11: | 3930 | 192. 168. 0.12: | 3930 | ***Result:*** | 3930 |
| 192. 168. 0.9: | 3931 | 192. 168. 0.10: | 3931 | 192. 168. 0.11: | 3931 | 192. 168. 0.12: | 3931 | ***Result:*** | 3931 |
| 192. 168. 0.9: | 3932 | 192. 168. 0.10: | 3932 | 192. 168. 0.11: | 3932 | 192. 168. 0.12: | 3940 | ***Result:*** | 3932 |
| 192. 168. 0.9: | 3933 | 192. 168. 0.10: | 3933 | 192. 168. 0.11: | 3933 | 192. 168. 0.12: | 3966 | ***Result:*** | 3933 |
| 192. 168. 0.9: | 3934 | 192. 168. 0.10: | 3934 | 192. 168. 0.11: | 3934 | 192. 168. 0.12: | 3968 | ***Result:*** | 3934 |
| 192. 168. 0.9: | 3935 | 192. 168. 0.10: | 3935 | 192. 168. 0.11: | 3935 | 192. 168. 0.12: | 0 | ***Result:*** | 3935 |
| 192. 168. 0.9: | 3936 | 192. 168. 0.10: | 3936 | 192. 168. 0.11: | 3936 | 192. 168. 0.12: | 0 | ***Result:*** | 3936 |
| 192. 168. 0.9: | 3937 | 192. 168. 0.10: | 3937 | 192. 168. 0.11: | 3937 | 192. 168. 0.12: | 0 | ***Result:*** | 3937 |
| 192. 168. 0.9: | 3938 | 192. 168. 0.10: | 3938 | 192. 168. 0.11: | 3938 | 192. 168. 0.12: | 0 | ***Result:*** | 3938 |
| 192. 168. 0.9: | 3939 | 192. 168. 0.10: | 3939 | 192. 168. 0.11: | 3939 | 192. 168. 0.12: | 0 | ***Result:*** | 3939 |
| 192. 168. 0.9: | 3940 | 192. 168. 0.10: | 3940 | 192. 168. 0.11: | 3940 | 192. 168. 0.12: | 0 | ***Result:*** | 3940 |
| 192. 168. 0.9: | 3941 | 192. 168. 0.10: | 3941 | 192. 168. 0.11: | 3941 | 192. 168. 0.12: | 0 | ***Result:*** | 3941 |
| 192. 168. 0.9: | 3942 | 192. 168. 0.10: | 3942 | 192. 168. 0.11: | 3942 | 192. 168. 0.12: | 0 | ***Result:*** | 3942 |
| 192. 168. 0.9: | 3943 | 192. 168. 0.10: | 3943 | 192. 168. 0.11: | 3943 | 192. 168. 0.12: | 0 | ***Result:*** | 3943 |
| 192. 168. 0.9: | 3944 | 192. 168. 0.10: | 3944 | 192. 168. 0.11: | 3944 | 192. 168. 0.12: | 0 | ***Result:*** | 3944 |
| 192. 168. 0.9: | 3945 | 192. 168. 0.10: | 3945 | 192. 168. 0.11: | 3945 | 192. 168. 0.12: | 0 | ***Result:*** | 3945 |

Fig. 4 Experimental results of bus redundancy

## 5. CONCLUSION

The safety-critical systems, such as railway signaling systems, fault tolerance should be realized in the environment which requires high reliability when applying network. In this paper, we propose the network-based interface with redundancy structures and analyze the performing efficiency by using NIC with four modules. We verified the proposed schemes by experiments and error-recovery rates are very high in the situational cases when communication circuits are cut during the communication between slaves and masters. The fault detection time is also less than 1min.

The experimental results of proposed systems are equal to those of point-to-point communications in performance. For these reasons, we consider that the proposed system is safe enough to make it applied to railway signaling systems.

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SEPTEMBER, 2006 | Vol. 5 Publisher : CHAE, Namhee

"A New Engine for the Future of Railway Korea"

KRRI newsletter

# Korean Rail Technology

SEPTEMBER, 2006 I Vol. 5

Publisher : CHAE, Namhee

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# WHAT'S UP


President CHAE, Namhee is making a speech at WCRR 2006


## 1. KRRI PARTAKES IN WCRR 2006

The 7th World Congress on Railway Research was held in Montreal, Canada under the theme for "Progressing Together", where railway experts from about 40 countries got together around the globe between June 4 and 8. The President of KRRI, Chae, Nam-hee made a speech entitled "A Coalition of Railway Research in Asia" at a plenary session. A total number of 13 papers were presented by KRRI researchers for the event. In his speech, Chae introduced the tripartite technical meeting and their collaborated research activities between China Academy of Railway Sciences, Japanese Railway Technical Research Institute and KRRI which was initiated upon KRRI's proposal in 2001.

Meanwhile, KRRI opened a joint booth with Korean Railroad Corporation(Korail) and Korea Rail Network Authority(KRNA) to promote Korean railway technologies such as high speed train, light rail transit and tilting train systems. The biennial event was launched in Paris in 1994 and is now recognized as the most influential and authoritative event in the global railway industry. The prestigious railway conference has been contributing to international cooperation and technological exchanges between researchers by bringing railway organizers, rolling stock manufactures and researchers all together at a single event. The next Congress, WCRR 2008 is scheduled to be held in Seoul, Korea on May 18-22 in 2008.

## 2. KRRI ENTERS 5th UITP

Principal researcher Jang, Seky(second from left) is having a conversation with a visitor at UITP exhibition

KRRI took part in the Asia-Pacific Congress of the 5th Union Internationale des Transport Publique(UITP, International Public Transport Association) that was held at COEX, Seoul between June 20-23. Designed to share advanced technology related to public transport with improvement measures, the event attracted more than 500 transport experts from over 40 countries worldwide.

Accompanied the event was an exhibition at the Convention Hall, COEX where 74 organizations displayed their flagship items. KRRI drew a great deal of attention from outside railway experts with its technology show-offs that include an information maintenance system for urban rail, light rail transit and fuel cell-powered trams. Meanwhile, two KRRI researchers made a speech in a forum titled "Automatic distribution operation control system for high density areas" and "Technology development of Korean light rail transit, K-AGT" by Director of Railway Transport Research Team, Hong, Soon-heum and by Head of Urban Rail Technology Development Corps, Han, Seok-yoon respectively.

In the last leg of the event on June 23' the delegation headed by Secretary General of International Public Transport Association, Hans Rat went down to Gyeongsan, East Daegu for trial ride on the K-AGT.

## 3. KRRI MARKS DECADE


Shown is the KRRI's emblem on the occasion of its 10th anniversary

KRRI celebrated its 10th year on March 2 at its Green Court under the new slogan of "A new energy for the future railway of Korea". As many as 300 personnel were present at the ceremony including Head of Innovation Department of Ministry of Science Technology, Im, Sang-gyu and Railway Planning official of Ministry of Construction and Transportation, Chung, Duk-mo and President of Korean Institute of Science Technology Kim, You-seung along with other high-ranking government officials and industrial CEOs.

President Chae said, in his commemoratory message, that KRRI has made a giant leap in the Korean railway technology for the past 10 years with developments of high speed train, light rail transit and ensured the audience that KRRI will move forward to build even more convenient and reliable railways for another decade throughout its railway technology on the cutting edge. Timed with the anniversary, KRRI put a new face on its logo which was imaged with three different colors to represent technological innovation and environmentally-friendliness while imply the institute's ever growing improvement by the shape of parallel tracks with the two letters of R.

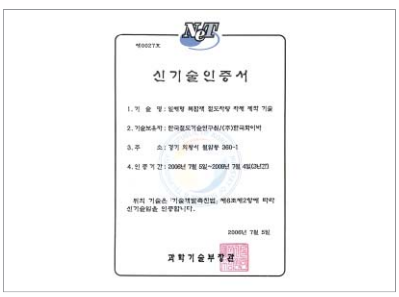
## 4. COMPOSITE MATERIAL WINS 'NET'

Korea Railroad Research Institute and Korea Fiber Glass Co. received an official mark entitled "New Excellent Technology(NET)" for their joint development of 'one-bodied composite material railway vehicles'. The report came on July 5th. The NET mark has been organized by Ministry of Science and Technology and is conducted by Korea Industrial Technology Association.

Supported by the Ministry of Construction and Transportation, KRRI has been leading the project of developing tilting train rolling stocks using the new composite material of honeycombed fiber class. The prototype of tilting train is expected to run Chungbuk railway line from January, next year.

The 23 meter-long structure is produced in one body in a large autoclave. As a sandwich structure made of the aluminum honeycomb core and the woven fabric carbon/epoxy face,


Vice President, Yang, Keun-yul(third from left) was awarded NET for development of composite material




The NET certificate issued by the Minister of Science and Technology

K-AGT is run on tests in Gyeongsan, East Daegu

it is the world's first attempt in the field railway industry. Compared to those vehicles made of stainless or aluminum using welding, the new technology boasts strengthened car body while the composite material reduces its weight by 40 percent. And also thanks to the lightened car body, the speed has improved given the same power on the existing ones.

This proves as much as US146,000 dollars can be saved annually in energy consumption as well as US42,000 dollars in rolling stock manufacturing per one train set, hinting at sea change in rolling stock manufacturing in high speed train, magnetic levitated train, and light rail train as well.

The manufacturing method of carbody with one-piece has not yet been actualized in advanced nations and those from Germany and Japan reveal keen interest in the manufacturing giving Korea a great opportunity of exports in the foreseeable future. The new technology has been applied to the development of Korean tilting train supported by MOTC and led by KRRI. Upon completion, the prototype is scheduled to kick off test run on Chungbuk line from January, 2007.

The awarding ceremony took place on July 5 at Korea Industrial Association building located in Yangjae-dong, Seoul. The fiber glass technology was one of 28 technology items awarded on the day.

### What is NET?

The New Excellent Technology is one of the two government-authorized systems along with New Excellent Products(NEP) which were integrated early this year out of 7 certificate systems; KT of Ministry of Science and Technology, NT, EM, EEC of Ministry of Commerce, Industry and Energy, IT of Ministry of Information and Communication, ET of Ministry of Environment, and CT of Ministry of Construction and Transportation. The awarded NET mark will be valid for three years upon receipt.

## 5. K-AGT TO SERVE PUBLIC IN 2009

Korea joined the nations with LRT systems followed France, Japan and Canada to be the fourth in its development. Upon completion of the 7-year project, MOCT and KRRI held a seminar where they announced the final results of the LRT development at Seoul Education & Culture Center on February 21 amid 200 people present.

Over 30 organizations from industry, academia and research institute participated in the LRT project that started in 1999 and 200 research personnel had been involved with USD51 million. Headed by KRRI, the project had Woojin Industries Company, POSCON, Hyundai Heavy Industries, Hyosung and Research Institute of Industrial Science and Technology. At the maximum speed of 70km, one vehicle of the train weighs 12 tons and can accomodate 57 persons(up to 100). The product employs local technology ranging from system design and manufacturing to core components as much as 90 percent which include rolling stocks, signalling control and track infrastructures.

The train sets can be formed from two to six train cars enabling flexible operation according to passenger demand. The driverless train is cost- effective in maintenance and construction, about 40~60% less than those of subway train. Another feature is the power supply device which is placed on the side not above the carbody using pantographs while rubber-tired wheels reduce much noise to fit urban environments.

In five years since the project kicked off, the prototype train was put to test in 2004 in north Kyeongsan province and has accumulated 35,000km as of this February without major glitch. Upon secured reliability and safety, as many as 2,000 government officials have visited the site from about 80 organizations.

Some of the notable events include achievement of KT mark in September 2005 from Ministry of Science and Technology for superior rolling stock system. The driverless AGT will be put to commercial subway line number three(Minam-Anpyeong corridor) of Busan from 2009.

MOCT and KRRI are to spur up their efforts to promote the system providing necessary support to local government authorities.

Turkey minister of transportation(6th from right) took HSR-350

## 6. TURKEY MINISTER TAKES HSR-350X

The minister of Transportation of Turkey, Binali Yildiri and his envoys had a ride on Korean High-speed train HSR-350x on May 24 which took them to West Daejeon station. While on board en route their destination, the delegates showed keen interest on the Korean high speed train system looking closely around the cabins for main systems and safety.
Headed by KRRI, the HSR project has been completed in consortium of 129 organizations in 2004. The bullet train boasts independent technology ranging from design to core devices like induction motor and control system.
An HSR test team was launched last February, composed of 50 railway experts from KRRI, Korail, Korea Rail Network Authority and ROTEM. The train has attained 142,000on test run as of July.

## 7. KOREA SEEKS BUSINESS IN VIETNAM

A Vietnamese official is opening intermediate meeting with Korean audience

The Vietnamese Ministry of Transportation held an intermediate meeting for "The Feasibility Study on building double-track gauge between Ho Chi Minh and Nha Trang" in Hanoi July 24. KRRI has been implementing the project assigned by Korea International Cooperation Agency (KOICA) in joint work with Chungsuk Engineering Co. The feasibility study initiated in the midst of Vietnamese government's effort to speed up the Hanoi-Ho Chi Minh railway line along with increased volume of capacity. As part of the Official Development Assistance or ODA, Korea jumped in the Vietnamese project.
Chaired by Deputy Director of Railway Administration of Vietnam, Tran Phi Thung, the meeting had around 60 attendants including the Vietnamese office head of KOICA, Kim, Seung-bum, government officials from Vietnamese Ministry of Transport, railway operators, engineers and journalists which followed a meeting with the Vice Minister of Transportation.
KRRI introduced, in the meeting, high speed train and tilting train in hopes of their technology application in Vietnam. Additional issues addressed in the meeting were Korean railway policy, analyzing methods, civil engineering and railway systems with the Vietnamese government officials and entrepreneurs. The event gave a ray of hope to Korea for prospective involvement in the process of the Vietnamese modernization of railway.

## 8. KRRI-SJU FORGE PARTNERSHIP

President Chae(third from left), and Vice President of SJU are shaking hands after signing MOU

KRRI signed a Memorandum of Understanding with Southwest Jiaotong University in Chengdu, China on April 24 upon the KRRI president Chae, Nam-hee's visit to the academy. The signed agreements state that both parties will collaborate in exchanging human resources, R&D papers and scientific materials and implementing joint research work.
The agreement ceremony came after a meeting between Jiang Ge-Fu, Vice president of SJU and president Chae, Nam-hee followed by KRRI delegation's lab tour for roller rig test facilities which are closely related to the KRRI's development of tilting train, set between 2002 and 2007 for speed improvement on conventional railway lines up to 200km/h.
In the course of KRRI's development of tilting train express, concerned researchers of KRRI reviewed dynamic performance of the tilting train bogies on the roller rig tester at SJU for over a three months' time that ended this January early this year.
The two organizations agreed on keeping up their efforts of joint research to yield high performance on their test based on sound partnership.

## 9. HSR-350X TO LAUNCH SERVICE IN 2009

HSR-350x is likely to serve public in 2009

A railway breakthrough in the Korean history, the high speed train (HSR-350x) is likely to be open to public via Honam and Cholla railway lines in 2009 and 2010 each.

The KRRI's one of the flagship projects of development "High-speed train" gained the upper hand in the Korea Railroad Corporation (Korail)'s purchasing bid for 100 cars of rolling stock that will be put to two of the major railway lines from 2009. The result came on June 9 after six months of negotiations between Korail and the rolling stock manufacturer ROTEM since HSR-350x was given priority in a bid December last year. Korail is planning to put six train sets in Honam line in 2009 and four train sets in Cholla line in 2010 respectively.

Korail announced that each car was priced at 3 million US dollars, compared to US3.2 million dollars of a KTX train car now in operation, amounting to a total price of around US306 million dollars for the whole 10 train units.

The bullet train offers the passenger all the amenities like family compartment, wireless internet service and satellite TV, etc. As opposed to KTX, the seats are installed toward moving direction and swivel to aid passengers with special needs. Especially, the car body made of aluminum extracts reduced noise while running and enhanced energy efficiency.

The development of HSR-350x was the fourth in the world followed by Japan, France and Germany and now Korea is scheming to forge into prospective markets abroad with its high speed train technology.


*A railway breakthrough in the Korean history, the high speed train (HSR-350x) is likely to be open to public via Honam and Cholla railway lines in 2009 and 2010 each.*

# KRRI R&D NOW

## Ⅰ. Personal Rapid Transit in Korea

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Train Control System Research Team
KIM, Yong-Kyu
SHIN, Kyung-Ho

### 1. INTRODUCTION

One of the reasons that cause traffic congestion in urban transit is the increasing number of cars. A study shows Seoul had ten million cars in 1997 and the number rose to fourteen millions in 2000. Frequent congestions on the road cost as much as eight hundred million dollars a year. Roads fell too short to cope with the ever increasing number of cars with merely 1.5 % expansion, which caused not only headaches in driving but environmental problems.

The traffic dilemma gives the situation a quantitative point of view and calls for a certain form of innovation in public transportation for the passenger. This paper suggests a new concept for the public transportation Personal Rapid Transit(PRT) with illustrations of its trends in Korea.

### 2. BACKGROUND

A fundamental concept of the PRT system was introduced in the Individualized Automated Transit in the City in 1964. From late 1960's Aerospace Corporation, involved in US government, began the system analysis and development of the technical theory. The definition of PRT system is expressed by the several terminologies such as: vehicle management by on-demand, origin to destination with non-stop, completely unattended operation, 4-6 passengers per vehicle. It is not difficult to guess from the above terminologies that the system operational method for PRT is different from the operational method for the conventional railway train system. Table 1. shows comparisons between PRT system and conventional railway train system in operational point of view.

Table1. Comparisons between PRT and the conventional railway train

| | PRT System | Conventional Railway Train System |
|---|---|---|
| Operational control system | .Completely unattended operation<br>.Steering control from the vehicle<br>.Operations by on demand base | .Operation by driver<br>.Route control by switching machine<br>.Operations by time schedule base |
| Vehicle position detection | Needs special system to detect vehicle position such as GPS (Global Positioning System) or RFID (Radio Frequency Identification) because there is no track circuit | Train position detection by rail track circuit |
| Communication system | Wireless communication based information transmission system | Transmission the status information by rail track |
| Reliability Availability Maintainability Safety (RAMS) | The system has not been commercialized yet, thus RAMS activity should be performed from the conceptual design procedure | Completely commercialized |

### 3. TECHNICAL ISSUES

To solve the congestion problem in urban transportation it is possible to consider PRT system that has off line stations for non stop trip. In such system to maximize the ridership so as to increase the line capacity the average speed of the each vehicle should be maximized. For this all intermediate stops have to be eliminated by employing bypass tracks off the main guideway. And also, the off line stations are to be closely spaced in a network (shown in Fig. 1) of interconnected guideways that eliminate the need for passengers to transfer from line to line.

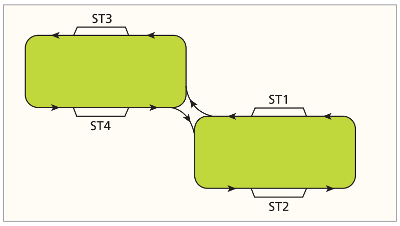


Fig. 1 Network configuration

For the implementation of the PRT concept the important technical issues may be a technology to detect a vehicle position and a strategy to control the vehicle operations. There are a few methods to implement these two technologies, which have been already reported in the literatures. In this section those methods are briefly introduced.

#### 3-1. VEHICLE DETECTIONS

There are two different kinds of technologies to detect a vehicle position. One is to use a conventional method such as the inductive loop type, the other one is to employ a modernized and advanced method such as GPS (Global Positioning System) or RFID (Radio Frequency Identification).

The principle of position detection by inductive loop is to obtain a high frequency signal according to the shape of the inductive loop that is located on the guideway in a shape of broaden line section and drawing line section alternatively: when a vehicle on which the antenna is contained moves on the inductive loop, the signal is obtained by alternating high frequency.

On the other hand GPS and RFID technologies are based on the wireless communication. Fig. 2 and Fig. 3 show the cases for GPS and RFID applications to detect a vehicle position depending on the different areas. The commercial GPS system still has approximately 10[m] error in detecting the vehicle position, RFID Tag is employed to back up the detecting error of GPS system. The higher resolutions can be achieved by employing DGPS (Differential Global Positioning System). DGPS is composed of GPS and the base station which has the reference position information. The base station receives signal from the GPS satellites and calculates the errors, then broadcasts the error correction data to the user GPS receiver so as to eliminate the error in the signal. RFID tags are able to detect the vehicle position without GPS, instead each tag should have a proper information indicating the tag location so that on board tag reader can read the information of the tag location.

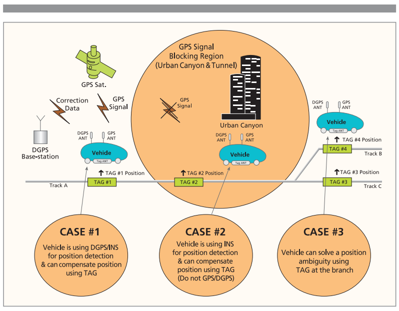


Fig. 2 Vehicle position detection by GPS

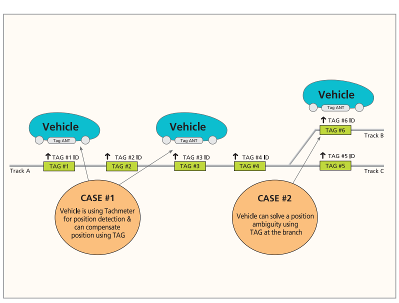


Fig. 3 Vehicle position detection by RFID

## 3-2. OPERATIONAL CONTROL

Once the vehicle location is detected the vehicle on the guideway should be controlled in a proper way that includes collision avoidance between two vehicles, origin to destination with non-stop, safe route control at switching point, etc. The most well known vehicle control principles among several control methods are point follower concept and vehicle follower concept. In the point follower concept each vehicle is assigned an virtually generated point which it follows along the guideway. Adjacent points are separated in time by the system headway. The point follower autopilot adjusts vehicle speed to minimize the position error between the vehicle and the moving point. On the contrary in the vehicle follower concept the relative position of the vehicles in the system is controlled by autopilot. Each vehicle looks down the guideway to detect the range to the nearest vehicle ahead. If the range is large the autopilot maintains some nominal value of line speed. At closer separations the autopilot adjusts vehicle range to satisfy some safety criterion. Table 2. shows the comparison of the two vehicle control concepts.

Table 2. Comparison of the vehicle control principles

| | Point Follower Concept | Vehicle Follower Concept |
|---|---|---|
| Maintenance of the safety distance | Moving slot system | Non- slot system |
| Control type | Centralized control (Speed profile is generated by central computer) | Decentralized control (Speed profile is generated by on board computer) |
| Stability & Headway | Guarantee the safety distance | Guarantee the minimum headway |
| Communication | Not allowed the communication between vehicles | Allowed the communication between vehicles |
| Merging control | Simple merging control by the reservation control concept | Communication based merging control between vehicles |
| Control range | Wide | Limited |

## 4. PRT IN KOREA

As to Korea, since the PRT system has been introduced in early 1990's a great effort has been invested for the development of the system and for commercialization. The three major leading groups, PRT Korea, Vectus Ltd., Korea Railroad Research Institute have developed a computer simulation models and have constructed the test line. Especially Vectus Ltd. has a plan to construct a test track in Uppsala, Sweden. However the most active research group among those three leading groups is KRRI (Korea Railroad Research Institute). KRRI has finished the conceptual design procedure for the development of the PRT system that can move 2-6 passengers per vehicle by the rotary motor type propulsion system.

KRRI is focusing on practical system development for the public convenience. A successful implementation of the project will entail a network operation control algorithm, fault tolerant communication system, unattended system, propulsion system, inductive power transformer system, and vehicle system. RAMS(Reliability, Availability, Maintainability, Safety) activity will also be required, according to international standards, for the test and demonstration of the safety and the reliability of the whole system.

## 5. CONCLUSIONS

PRT system can be a solution to solve the congestion problems in urban transit system by employing off line stations for non stop trips. In the process of the project implementation, it is necessary to develop a vehicle position detection technology and vehicle operational control algorithm. KRRI tries to develop the core technologies for PRT system which are the network operational control algorithm and inductive power transformer system.

# Ⅱ. A Review of Real Scale Fire Test for Rolling Stocks

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## 1. INTRODUCTION

As to assessing fire safety, we used to check on materials if they met the standards prescribed for each material. This conventional method has been used for ages. However, safety checks now rely on performance-based engineering technology; computational fire simulation model and real scale tests. The comparison data of real scale fire tests from a numerical calculation brought cost effectiveness replacing expensive fire tests. The up-to date fire tests also are applied to various fire control equipments for certification such as the automatic fire suppression system.

Large scale fire tests require substantial costs and time. Since real fire tests should be limited for actual performance, the test must be carefully designed. In a related move, Korea Railroad Research Institute plans to build an exclusive Fire Test Facility for rolling stocks. We have reviewed real scale fire tests of rolling stocks performed by other research organizations especially National Institute of Science and Technology (NIST, USA), Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) with the mock-up tests conducted in Korea after the Daegu Fire Accident.

## 2. REAL SCALE FIRE TEST CASES

Fig. 1 Fire test in a mock-up train(KORAIL)

Fig. 2 Fire spreads in 3 minutes after ignition(CSIRO)

In summer of 1999, an Amtrak Amfleet-I vehicle denoted by Amtrack to Federal Railroad Administration (FRA, USA) for research program was tested by BFRL team. The details of the test are described in the report NISTIR 6563, Fire Safety of Passenger Trains; Phase III, published in 2004.

One of the most important factors of fire analysis is heat release. We should use the calorimetric equipment and calculation technique to get the heat release rate, obtained by measuring the oxygen consumption without gas loss during the combustion. However, in case of train, it is almost impossible to guide all the fire gas into one way for measurement of oxygen consumption because the length of the train is longer than the common measuring facilities. To overcome this limit, the Calorimeter Exhaust Stack was specially used for the test, which, in practice, had uncontrolled gas leak throughout the vehicle. In spite of the unfortunate performance, it was still a meaningful trial. EUREKA project in June 1991 suggested more practical way to get the total heat release from passenger train by the fire test in tunnel.

In Australia, they used the Duggan calculation with the data of cone calorimeter for the safety evaluation of rolling stock. The full scale Fire experiment on passenger train in Brisbane in 2003 was a different approach in fire scale. The object of the test was to understand how large and fast fire develops and how the fire performance was linked with flammability of the inner materials. Since they allowed the fire to be fully developed, they could find out the facts that the fire spread over the ceiling, and the flashover time was about 140 seconds after ignition. Some of the test results were reported by Nathan White and Vince Dowling (CMIT, CSIRO) in the proceeding of IAFSS 2005.

The high speed of fire development obtained from this experiment help us to understand the Daegu Fire in Korea, for the similarity of interiors with that of Daegu subway carriage. Investigators assumed the fire was fully developed in less than 10 minutes.

We recently had train fire tests with mock-up vehicles. However we had to face some problems in the course of conducting the test because the mock-up fell short to simulate the real carriage in length. The test was focused on ensuring fire resistance of new interior designed car in Korea. Polyester FRP, Polyethylene Foam insulator, PVC gangway and floor covering and Urethane Foam Seat Cushion were replaced by AL Panel or Phenol Composite Panel, Glass Wool Insulator, Rubber gangway and floor covering, and Anti-vandal Seat Cushion. 4 liters of gasoline was used for the fire source like the Dague Fire Accident case.

KRRI got involved in the fire test of Daegu Metropolitan Subway Corporation and the temperature measurement of Seoul Metro Mock-up test. From the Mock-up Fire Test of a tilting train, we could practically try to increase the equality between test conditions and real carriage fire. At first, we preheated the car body at 20~25°C with a heating blower to compensate the heat loss to the cold air. The tilting car body made of epoxy-carbon Fiber composite panel was tested at Hankuk Fiber Glass Co., Ltd. in Milyang of Korea in January 2006. The test was conducted, as the scenarios by pouring 4 liters of gasoline over the walls and seats in the cabin and casting gasoline bomb on the outside walls. We used the thermocouple, video camera and heat picture camera for temperature measurement. We liked to see the temperature of the interior skin to the time variance and fire size for the comparison with their ignition temperature. At first, we just attached the thermocouple to the skin of the interior and the results seemed to be mixed with the gas temperature. We drilled small holes from the outside of the car body and fit the hole with the thermocouple in the next step. The result of the next trial gave better data. The skin temperature of the phenol sandwich wall went up to 140°C at its highest.

## 【3. PLAN OF FIRE TEST FACILITY OF ROLLING STOCK】

KRRI plans to design exclusive fire test facility for rolling stocks. In the process, the length should be basically in much consideration for proper tests to fit the long train carriage. The facilities should have repeatability and cost effective advantage in order to produce data which can be compared to the simulation model study. They also need to comply with the performance test for certificate of fire controllers like fire detector and suppression system.

# Ⅲ. Railroad and Climate Change Convention


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## 【1. INTRODUCTION】

We have been experiencing some unusual weather conditions such as enormous floods and snowstorm across the world caused mainly by the global warming. In an effort to reduce the greenhouse gas (GHG), EU and Japan have discussed a lot of measures. Since the Kyoto protocol took effect in February 2005, the GHG emissions have been under legal control. Until now, Korea is not upon the entry into force in Kyoto protocol. Nevertheless, Korea may join the secondary parties of the pact because total $CO_2$ emissions of Korea is among the top ten in the world. Thus, Korean government has established many policies to reduce the GHG emissions. Railroad is considered an environment-friendly transportation because its $CO_2$ emissions per traffic volume (passenger_km or ton_km) is much lower than that of other modes. However, railroad has emitted a great amount of $CO_2$ in the process of energy consumption. This study touches upon various strategies on Climate Change Convention in railroad. Total $CO_2$ emissions in Korean railroad were investigated and several methods were brought up to cut down on $CO_2$ emission.

## 【2. CLIMATE CHANGE CONVENTION】

The Climate Change Convention is an overall framework for intergovernmental efforts to solve global warming problems caused by the increase of energy consumption. The Convention entered into force on March 1994 and 189 countries were joined. Especially, the article 4 of the Convention gives the duty of the parties, which is classified into common and special duty (Table 1). Under the Convention, governments share information on GHG emissions, national policies and best practices.

Table 1. Main contents of Climate Change Convention

| Article | | Contents |
|---|---|---|
| Objective (article 2) | | Stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system |
| Principles (article 3) | | . Equity: common but differentiated responsibilities considering the special circumstances of developing country Parties<br>. Efficiency: prevention, all relevant sources, cooperative implementation<br>. Economic: sustainable development, open international economic system |
| Duty | Common | . National GHG inventory, implementation of policies (article 4-1)<br>. Research and systematic observation (article 5), education, training and public awareness (article 6) |
| | Specific | . Stabilization of GHG emission at a level in 1990 (article 4-2)<br>. The provision of financial resource and the transfer of technology (article 4-3~4-5) |
| Organization and institution | Organization | . Consideration of special situations of developing countries (article 4-8~4-10)<br>. Conference of the parties (article 7), secretariat (article 8), subsidiary body for scientific and technological advice (article 9), subsidiary body for implementation (article 10), financial mechanism (article 11) |
| | Institution | . Pledge and review (article 12): national report submission and review by conference of the parties<br>. Resolution of questions regarding implementation (article 13), settlement of disputes (article 14) |

## 【3. STRATEGY ON CLIMATE CHANGE CONVENTION IN RAILROAD】

### (1) INTERNATIONAL RAILROAD

In EU, railroad companies have set various policies to solve global warming problems. VR (Finland) will increase the percentage of rail traffic electrically powered up to 80% of all rail traffic by 2012 because diesel-powered trains produce 71% of all $CO_2$ emissions from rail traffic even though 25% of rail traffic is diesel-powered. Also, high eco-efficiency in transport is achieved by increasing train capacity utilization, train sizes and axle loads. DSB (S-tog, Denmark) sets out strategic target for reduction of $CO_2$ emission per passenger_km by 40% between 1999 and 2007 (Fig. 1). Energy consumption efficiency has been enhanced through the increase of new S-trains with lower energy consumption, upgraded buildings, more efficient lighting management system at stations, etc. DB (Germany) approved its "Climate Protection 2020" program in 2003. This program aims to reduce $CO_2$ emissions by 15% in 2020 compared to 2002 levels from transport performance.

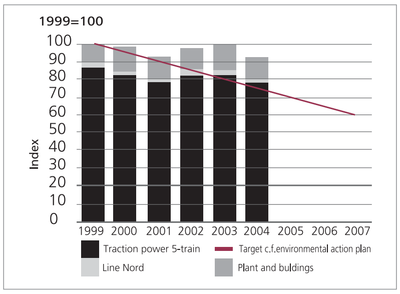


Fig. 1 Change of $CO_2$ index per passenger_km in DSB

JR east (Japan) has succeeded in reducing overall $CO_2$ emissions by 16% since 1990, which was due to the increase of energy efficiency. Energy consumption in train operations decreased by use of energy-saving railcars equipped with the regenerative brakes and VVF inverter controls. The fuel cell powered-NE train has been developed as the first hybrid railcar system to reduce energy consumption by 20%. In addition, JR East is working to reduce $CO_2$ emissions of the entire transportation system by the promotion of intermodal transportation integrating rail with other modes of transportation (Fig.2).

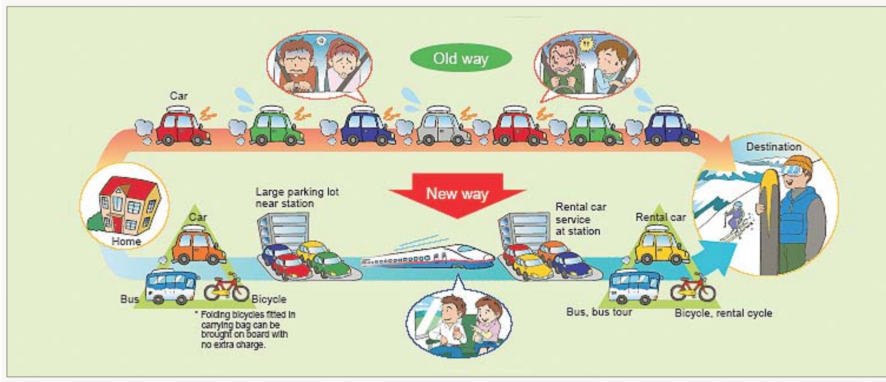


Fig. 2 Intermodal transportation system (JR East, Japan)

## (2) DOMESTIC RAILROAD

- Figure 3 shows total $CO_2$ emission in Korean railroad including the operation of trains and the energy consumption at stations. In 2004, total $CO_2$ emission was 1,560 thousands $CO_2$_ton/yr. The increase of $CO_2$ emission was nearly 3% per year compared to 1990 level. Most of $CO_2$ was emitted from the operation of trains and more than 50% of total $CO_2$ emission was caused by diesel consumption as a fuel source. $CO_2$ emission from diesel-powered trains decreased significantly in 2004 by the introduction of electric-powered KTX.

These trends will remain according to a plan of KORAIL related to the introduction of new trains and the disuse of old trains. As diesel-powered trains are substituted to electric-powered trains, total $CO_2$ emission will go down. However, energy efficiency should be improved because $CO_2$ emission increases continuously by the consumption of electricity in electrically powered train. First, energy efficiency can be enhanced by the development of lightweight rolling stocks. As the carbody material of electric motor unit is exchanged to aluminum instead of mild steel and stainless steel, the weight of rolling stock is reduced by 30%. From the development of new materials such as composite, the weight of rolling stocks will be lightened increasingly. Although the cost of rolling stocks increases due to the introduction of new material, the decrease of their weight is intimately associated with energy efficiency. In addition, it is essential to decrease the energy consumption in the interior air-conditioning and heating, the opening and closing of gate, and light system. Indoor temperature must be controlled constantly to enhance the efficiency of air-conditioning and heating. The use of lighting can be reduced by brighter interior. From these methods, energy efficiency will be enhanced cutting down on $CO_2$ emission.

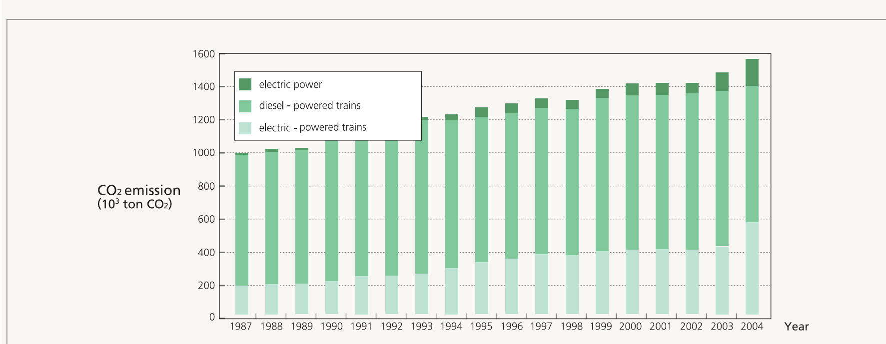


Fig. 3 Total $CO_2$ emission in Korean railroad

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# Ⅳ. Safety Guarantee Method of Network-based Interface for Signaling Systems

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## 1. INTRODUCTION

The links between controlling equipments for railway signaling have some problems on maintenances and repairs because the way of linking is a point-to-point communication. Advanced countries study and develop the way of linking signaling systems by networking them. To apply industrial networks to railway signaling systems, the network needs to be developed by Ethernet-based protocol. Ethernet application to industrial controlling systems was impossible because the real-time requirements were not satisfied due to the random characteristics, but the recently advanced switched Ethernet makes the Ethernet technology applicable to the industrial controlling systems . In this paper, we confirm performance efficiency of the proposed network-based interface with redundancy architecture including the algorithms for detecting faults and its recovery.

## 2. ETHERNET VS. SWITCHED ETHERNET FOR SIGNALING SYSTEMS

Ethernet is the basis of a physical layer and a data link layer of the office communication. The communication procedure of the CSMA/CD is the media access control method of Ethernet. The more collisions occur, the more delays the transmission by waiting for the random backoff time during the collisions. It is impossible to directly apply these Ethernet to the railway signaling systems. The problem of the Ethernet applications is solved by bringing the switching technologies whose trials for applying to industrial networks are increasing, as their generalization and cost decrease.

The switched Ethernet differs from its conventional one. In the switched Ethernet, collisions between other stations are prevented because of the dedicated virtual circuits between the stations, which communicate through switches. Collisions do not occur in the cases of which many stations transmit simultaneously because the switches send frames only to the determined destination stations when the source stations transmit frames. Also any collisions do not occur before the frames are not received because full duplex method is used in switched Ethernet, which performs sending and receiving by each line.

## 3. NETWORK-BASED INTERFACE SCHEME

In this paper, we study the methods of developing switched Ethernet reliability to apply them to railway signaling systems in which the safety is critical. Switched Ethernet satisfies the real-time requirements, but the reliability can not be guaranteed when each component is broken down because system components are related with each other such as Network-Interface Card (NIC), switch hub, and communication lines. To solve this problem, we propose a multiple architecture of which each component is duplicated, and estimate its performance.

### SWITCH HUB

In the beginning stage of switching hub, unavoidable collisions occur as traffics are gradually increasing because the hub which never buffers total packets has just destination addresses and takes the way to transmit. Most of the currently realized switching hubs do not bring any collisions excluding queue delay in switches, because they have independent queues more than two in every port, and store the whole data in the way of Store & Forward, and then transmit the data after confirming destination addresses.

### MULTIPORT NETWORK INTERFACE CARD

Fault tolerant system is designed not to disturb system operations even in case of faults in some modules or components. Even when a module has some faulty data, fault recovery can keep fault tolerance giving no influence on other systems. We embody the redundancy system by using NIC which has four Modules. The fault tolerance goes through three steps (1. fault detection, 2. fault diagnosis, 3. fault recovery). These stages are progressed and linked with running application software.

### SYSTEM ARCHITECTURE WITH FAULT TOLERANCE

As mentioned above, the fault tolerant system needs multiple communication ports and communication lines for construction. And also module redundancy should be embodied using multiple NIC, and redundancy in switches should be realized by linking switch hubs doubly. If only one switch is installed, obstacles of total systems occur when faults are made in switches even though the redundancy in modules is guaranteed. The following Fig. 1 is the system architecture which meets those requirements.

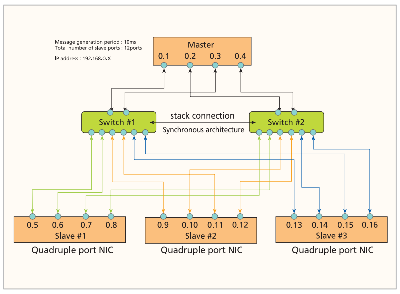


Fig. 1 Overview of System Architecture