ATO Data of train control system based on Wi-Fi mesh telecommunication

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1. Abstract

Wi-Fi mesh telecommunication technology will be applied to ATO Data of train control system for driverless operation in Youngjongdo Urban Maglev project by SK C&C for the first time in the world. Although the application of the technology is restricted to ATO Data, non-vital area of train control system in this project, its application shall be extended to total train control system including vital items in the future based on commercial engineering backgrounds from the Youngjongdo Urban Maglev project by SK C&C.

2. Introduction

From Sep. 2013, Urban Maglev for the second time in the world will be moved in Youngjongdo, Incheon International airport based on the driverless operation, which can be actualized by train control system, the core part of train system. In case of most train control systems, track circuit, IL and AP telecommunication method have been applied.

By the way, Wi-Fi mesh telecommunication based ATO Data has been being developed for the Maglev project. Wi-Fi mesh telecommunication technology is general in the field of the telecommunication of railway, however, it has not been applied to train control regardless of its merits such as economic efficiency, self discovery & configuration, self healing, and fast roaming etc. Therefore, the Unrban Maglev project is the railway project where Wi-Fi mesh telecommunication technology will be applied to the train control system for the first time in the world. This can be regarded as an innovation event for train control system, which can be accomplished by only SK C&C keeping accumulated experiences based on abundant business records in the IT and telecommunication fields.

In 2009 the contraction of the Maglev project whose period is from 2009 to 2013 was made between KRNA(Korea Railway Network Authority) and SK C&C. In 2010, SK C&C provided wayside ATO Data facilities and got inspection approvals from KRNA. Therefore, this paper contains execution results of Wi-Fi mesh telecommunication based ATO Data during 2 years from 2009 to 2010.

3. Overview of Youngjongdo Urban Maglev train control system project

3.1 Project scale

As of May, 2011, a bridge 6.1km in length, 6 stations, 1 depot have been being constructed.

Fig. 1 : Project scale

3.2 Project schedule

As of May, 2011, project schedule is shown in the table 1 and can be changeable later because of work process of construction or rolling stock.

Table 1 : Project schedule

Time	Major event	Status
May, 2009	Conclusion of contract	Completed
Aug. 2009	Site test	
Nov. 2009	Approval of production design	
Dec. 2010	Provision and FAT of wayside equipment	
Dec. 2011	Provision and FAT of onboard equipment	Plan
Aug. 2013	Commissioning test	
Sep. 2013	Initiation of commercial operation	

3.3 SK C&C's execution field

SK C&C's major execution field is development of Wi-Fi mesh telecommunication based ATO Data.

4. Concept of ATO Data

4.1 Equipment configuration

Equipment configuration is as below Fig. 2 and its major features are as in the following.

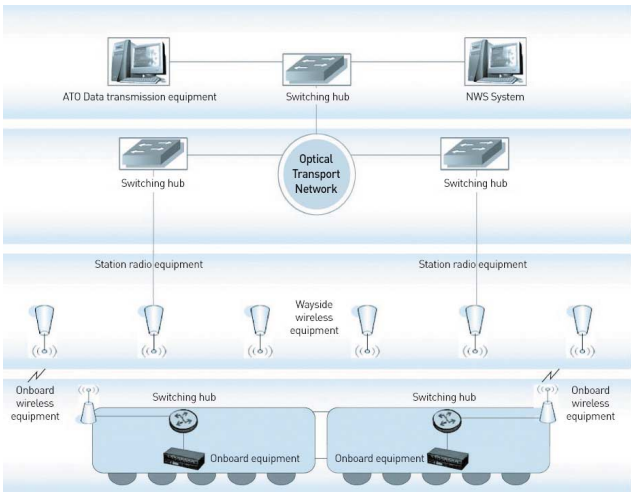

Fig. 2 : Configuration of ATO Data facilities

1) Wayside wireless equipment and onboard wireless equipment

Function of roamig in the ISM(5GHz) band is actualized for radio communication of ATO Data between AP(Access Point), wayside wireless equipment and moving onboard wireless equipment. In other words, if the distance between AP which is composed of directional antenna and onboard wireless equipment which consists of omnidirectional antenna is farther because of moving vehicle, roaming to the nearest AP is actualized. 29 sets of AP whose max. span is 380m are arranged based on electric field intensity.

Fig. 3 : Antenna : L (direction) vs R (omnidirection)

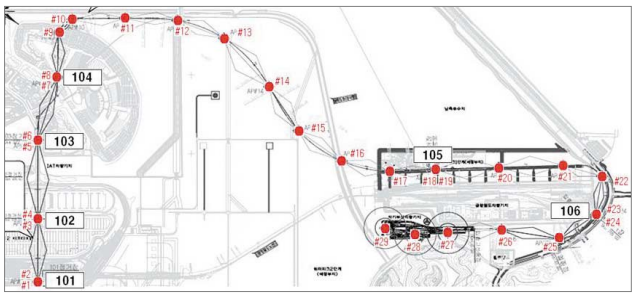

Fig. 4 : Arrangement of AP

2) Station radio equipment

Station radio equipment transmits ATO Data from AP to Switching hub after changing wireless data to wire data. Reversely it also transmits ATO Data from Switching hub to AP after changing wire data to wireless information.

3) Switching hub

Switching hub lies in station or OCC(Observation Control Center) for ATO Data communication between Station radio equipments.

4.2 Contents of ATO Data

Contents of ATO Data transmission between vehicle and OCC for 'Driverless operation' is divided as vehicle control information and vehicle condition information.

1) Vehicle control information

Vehicle control information such as 'reset' is transmitted from OCC(ATS) to vehicle(TCMS) though ATP/ATO Controller.

2) Vehicle condition information

Vehicle condition information confirmed by vehicle (TCMS) such as 'door open/close' is transmitted from ATP/ATO Controller to OCC(ATS).

5. Wi-Fi mesh telecommunication

5.1 Concept

Wi-Fi mesh telecommunication can transmit information to destination with safety through the most rapid route.

5.2 Major features

1) Self discovery and configuration

For wide rage network, although conventional telecommunication service needs cable networks between nodes, mesh telecommunication service is available only if power supply is fed to mesh nodes. Because of the feature of 'self discovery and configuration', mesh telecommunication service has been applied to the field of fire protection, disaster, military where existing infrastructure for telecommunication is inferior or automatic network is urgently required.

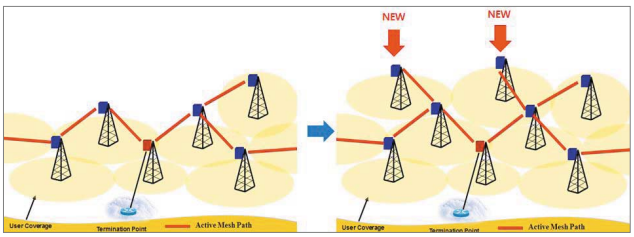

Fig. 5 : Concept of self discovery and configuration
(L : Before vs R : After)

2) Self healing

Mesh telecommunication service is not executed through the only sole route. So, it searches for alternative optimization route in case cut-off or overload on node happens. For self healing, all nodes scan optimization route periodically based on the calculation of traffic quantity and delay ratio.

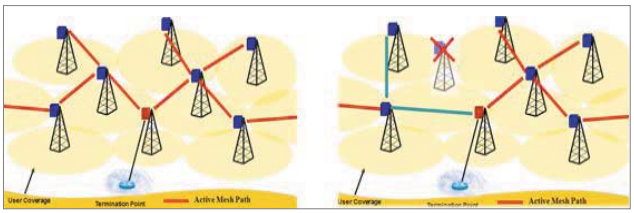

Fig 6 : Concept of self healing (L : Before vs R : After)

3) Fast roaming

Wi-Fi mesh telecommunication can guarantee fast roaming up to 200~300km/h.

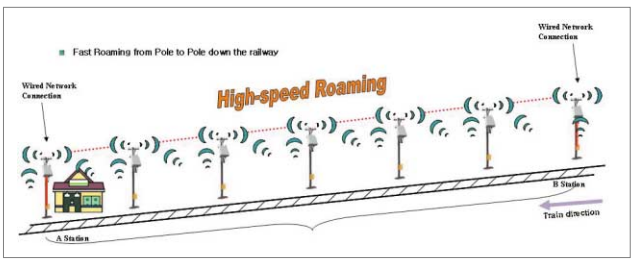

Fig 7 : Concept of fast roaming

5.3 Comparison between Wi-Fi mesh telecommunication and AP

In case of current RF-CBTC(Communication-Based Train Control system) system, data transmission is not Wi-Fi mesh telecommunication but AP. Although AP requires all cables between all Access Points and main equipment, Wi-Fi mesh telecommunication doesn't. Therefore Wi-Fi mesh telecommunication is superior to AP regarding extension work, safety, economic feasibility, construction and maintenance.

5.4 Applied instances in railway

Actually applied instances of Wi-Fi mesh telecommunication in railway is North Country Transit District, Amsterdam, and North East Railway Corridor etc. By the way, their examples not train control but telecommunication. Therefore, Youngjongdo Urban Maglev project is the first project in the world where Wi-Fi mesh telecommunication to be applied to train control system despite ATO Data, one of Non-Vita fields.

6. Test and verification

6.1 Site test

1) Overview

For safe and exact transmission of ATO Data even in moving condition whose highest velocity is 110km/h, telecommunication circumstances in the site between wayside wireless equipment and onboard wireless equipment were checked. Since the site test was executed in 2009 when bridge construction was not initiated, van instead of Maglev vehicle ran on the road route which is the most similar to original one for the test.

2) Test methodology

Measurement of radio wave and survey of wireless LAN use status as well as measurement of radio mesh were executed.

- Measurement of radio mesh
  - Purpose

    Possibility of exact transmission and reception for ATO data between APs on the basis of Wi-Fi mesh telecommunication was tested even in the moving condition of max. velocity 110km/h.
  - Test execution

    In the 1.5km test section where the Maglev will speed up to 110km/h in actual route, total 4 sets of wayside wireless equipment were installed at regular interval of 500m. For mesh network, Root Mesh was linked to a computer and Outdoor A, B, C were linked to omnidirectional antenna.

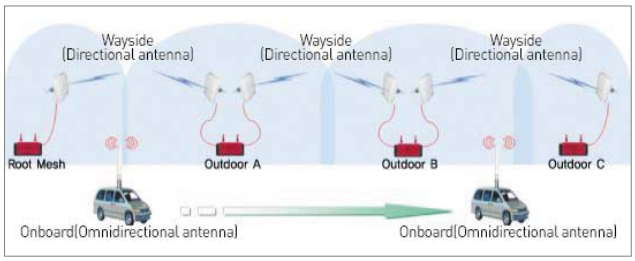

Fig. 8 : Configuration of wayside wireless equipment

While the van equipped with omnidirectional antenna ran with 110 km/h from Root Mesh to Outdoor C, application acceptance and roaming performance were measured.

- Measurement of radio wave and survey of wireless LAN

use status

· Purpose

For minimization of frequency intereference against ATO data, measurement of radio wave and survey of wireless LAN use status in the site were executed.

· Test execution

For the total 6.1km route and depot, radio waves whose range is between 90kHz and 8GHz were scanned by spectrum analyzer and wireless LAN use status in the ISM(5GHz) band were surveyed by wireless laptop analyzer.

Fig. 9 : Measurement of radio wave

Fig. 10 : Survey of wireless LAN use status

3) Test results

• Measurement of radio mesh

· Traffic application

Since test results showed verified frequency bandwidth was min. 6.8Mbps even in the worst case, traffic application of ATO Data in moving condition of 110km/h is surely guaranteed considering the bandwidth of ATO Data is planned as 20kbps.

Table 2 : Result of traffic application

Case	Tested point	First test	Second test
Case 1	Root Mesh	15.4Mbps	11Mbps
Case 2	Outdoor C	8.1Mbps	6.8Mbps

• Roaming test

Since test results showed ping loss did not happen, exact roaming through Wi-Fi mesh in moving condition of 110km/h was surely guaranteed.

Table 3 : Result of Roaming test

Case	1st test	2nd test	3rd test
No. of Ping Loss	Zero	Zero	Zero

• Measurement of radio wave and survey of wireless LAN use status

· Measurement of radio wave

Since frequencies whose band was under 3 GHz were detected in all tested points, frequency interference will never happen if ATO Data is transmitted in ISM(5GHz) band.

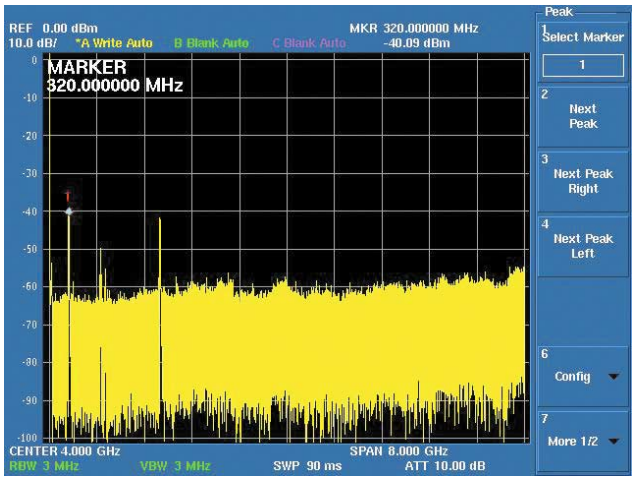

Fig 11 : Result of measurement of radio wave

· Survey of wireless LAN use status

On the basis of the test results, the frequency channel of ATO Data will be made after avoiding currently operating channel in the 5GHz band. On the other hand, since TRS and Bluetooth are executed in MHz band, frequency interference against ATO Data will never happen.

Table 4 : Result of survey of wireless LAN use status

Tested point	Channel	Frequency	Output
AP5~6	161	5.805GHz	-45dBm
AP9~10	36	5.180GHz	-80dBm
	40	5.200GHz	
AP20	149	5.745GHz	-80dBm
AP21	149	5.745GHz	-80dBm
AP22	149	5.745GHz	-80dBm
AP23~24	153	5.765GHz	-85dBm

6.2 FAT (Factory Audit Test)

Major items in FAT of Dec. 2010 are introduced as belows.

1) Smart frequency selection

- Overview

  If frequence interference happens, current frequence channel should avoid to different channel automatically.

- Test execution

  While 157 channel(5.785GHz) were used for communication between onboard wireless equipment and wayside wireless equipment 3, frequence interference as the same 157 channel between wayside wireless equipment 1 and 2 happened.

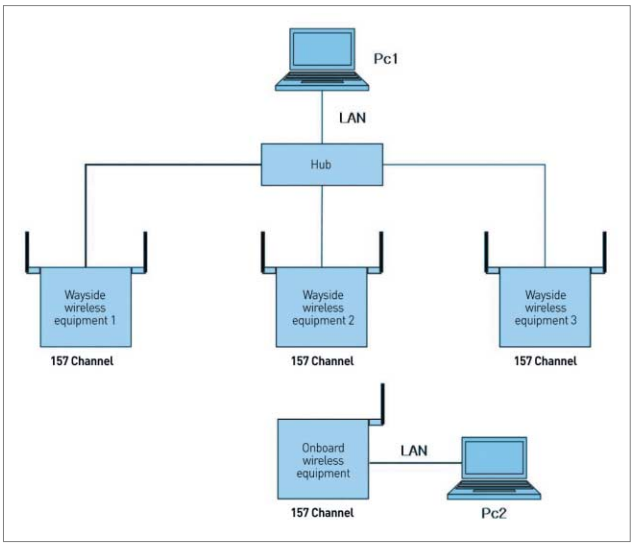

Fig. 12 : Configuration of smart frequency selection

- Test result

  By Smart Frequency Selection, channel of wayside wireless equipment 3 were converted to 149(5.745 GHz) automatically to avoid the initial 157(5.785 GHz).

Fig. 13 : Setting of Smart Frequency Selection

2) Self healing

- Overview

  If a communication route in the radio system breaks down, ATO Data should be transmitted through different route automatically by self healing.

- Test execution

  In case of normal condition, communication route is between Pc2(onboard wireless equipment) and Pc1(wayside wireless equipment) is Pc2 → AP1 → AP3 → switching hub → Pc1.

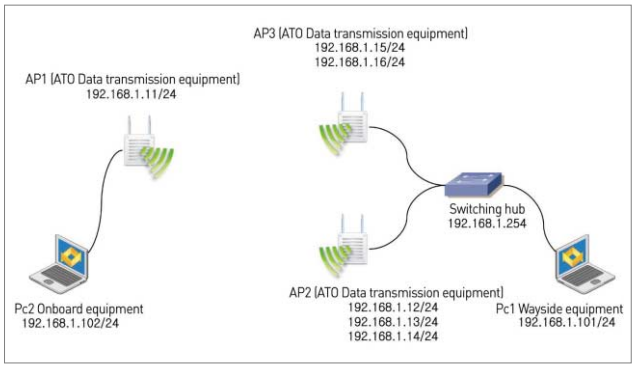

Fig. 14 : Configuration of Self healing test

While ping test was executed from Pc2 to Pc1, ping loss was checked in case of Case 1(AP3 Ethernet cable problem) and Case 2(AP3 itself problem).

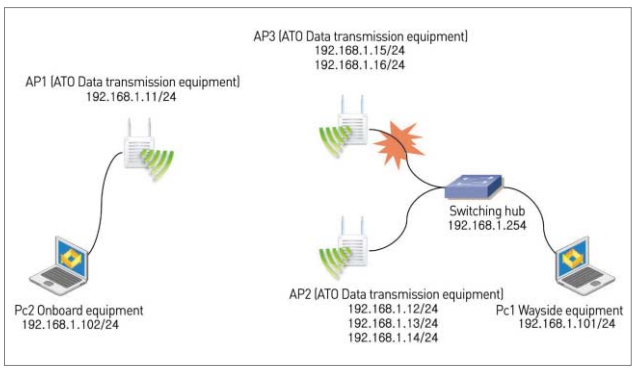

Fig 15 : Case 1 (AP3 Ethernet cable problem)

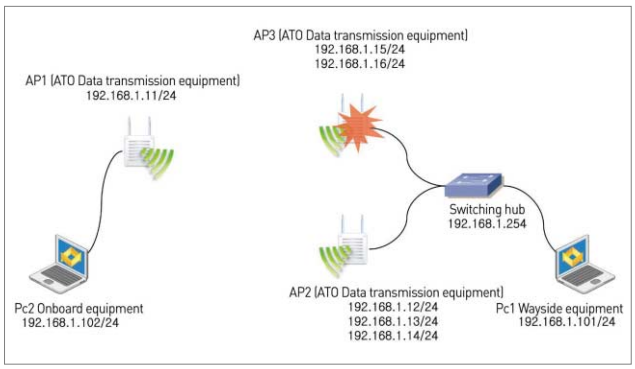

Fig. 16 : Case 2(AP3 itself problem)

- Test result

  Since max. number of ping loss occurrence was 2, all of test results were under 3 of max. standard value.

Therefore, when AP3 broke down, communication route between Pc2 and Pc1 were automatically revised to Pc2 →AP1 →AP2 →switching hub → Pc1 by self healing.

Table 5 : Test result of self healing

Case	No. of ping loss	
	Pc1	Pc2
Case 1	1	2
Case 2	1	1

3) Transmission test of ATO Data information

- Overview

  Transmission of ATO Data information between ATS simulator and ATP/ATO Controller simulator were tested.

- Test execution

  · Vehicle control information

  If a Vehicle control information is set up in ATS simulator, it should reach ATP/ATO Controller simulator exactly.

  · Vehicle condition information

  If a Vehicle condition formation is set up in ATP/ATO Controller simulator, it should reach ATS simulator exactly.

- Test results

  Every information between the 2 simulators was transmitted exactly trough Wi-Fi mesh telecommunication.

6. Conclusion

Site test in 2009 and FAT for wayside wireless equipment of ATO Data in 2010 were successfully completed. Therefore, SK C&C has strongly confirmed that Wi-Fi mesh telecommunication should be successfully applied to ATO Data for the first time in the world although it is non-vital.

7. Future plan

Until Dec. 2011, FAT for onboard wireless equipment of ATO Data will be completed, and Commissioning test is planned to execute until Aug. 2013. Therefore, excluded test items in this paper because of timing inconsistency will introduced next time.

SK C&C will challenge to application of Wi-Fi mesh telecommunication for total train control system in the future based on enough verification from ATO Data in this Urban Maglev project.