Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Introduction to Taiwan High Speed Rail Broadband System

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Re: IG HRRC Discussion

Abstract: This contribution summarizes ITRI's work on Taiwan High Speed Rail broadband system.

Purpose: To share ITRI's experience on high speed rail communications at the IG HRRC meeting and to express ITRI's interest in participating in the activities of the IG.

Outline

- Background
- System Architecture for WiMAX
- Technology Breakthrough
- Achievements
- System Architecture for LTE
- Deployment and Handover Results
- Concluding Remarks

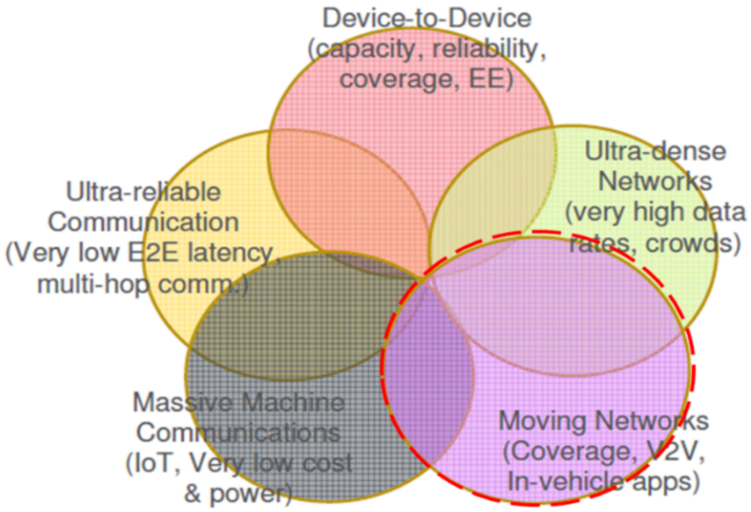
Why HSR Broadband Communication ?

From METIS FP7 to Horizon 2020

- Moving network is recognized as a high-potential scenario
- How to provide robust high-rate backhaul links for base stations is a major issue in high-mobility moving networks

Mobile applications on HSR will be a critical topic in the development of next-generation mobile broadband technologies

- High throughput (Gbps)
- Ultra-high mobility (500 km/h)



HSR: high speed rail

METIS FP7 Topics

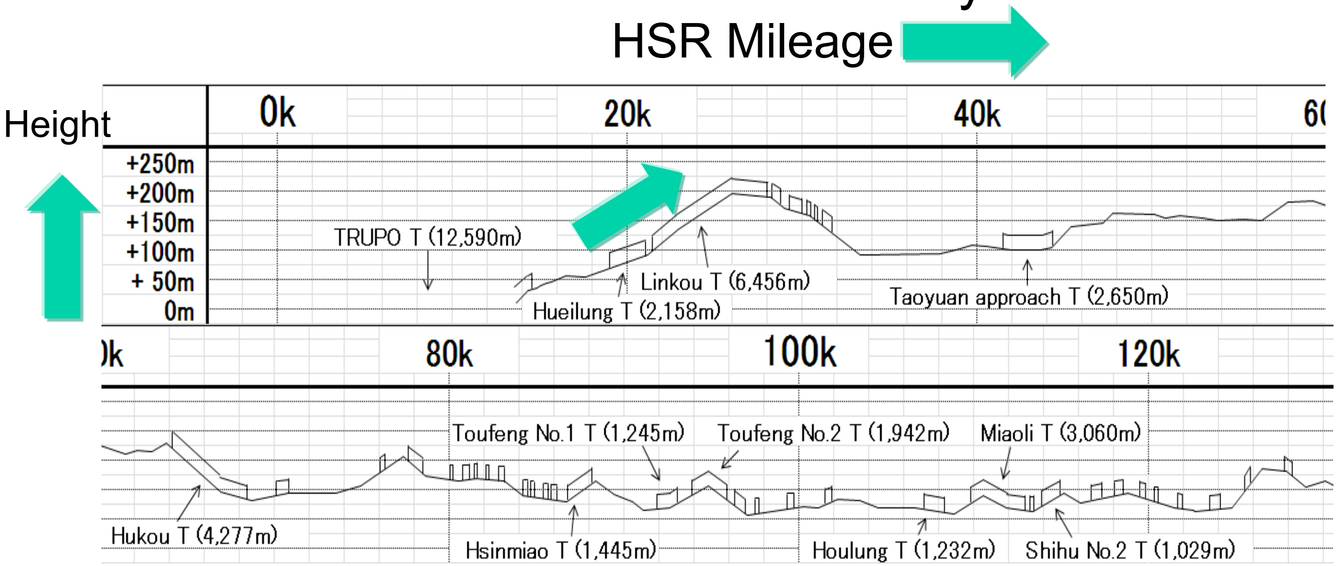
Challenges along THSR Track

Shadowing caused by the terrain

- Signal is blocked by hills, tunnels, or bridges
- Hard to find good locations to construct base-stations

Frequent handover and group handover

- Handover every 36 sec. (3 km distance, 300 km/hr)
- Over 1,000 users on one train to handover simultaneously

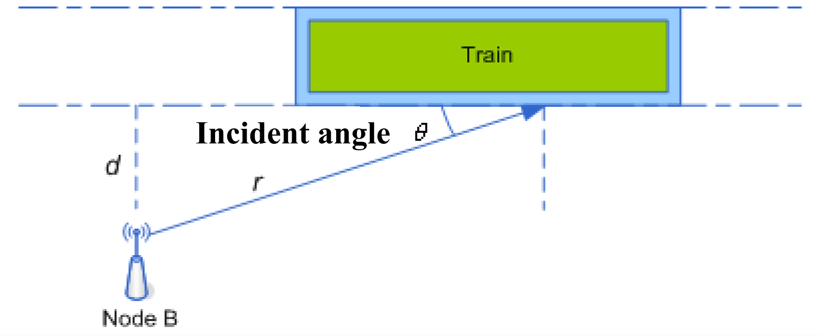


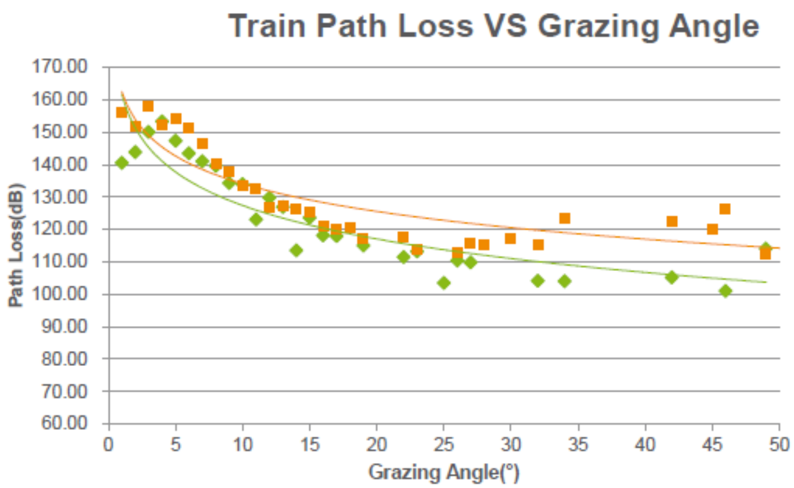
THSR: Taiwan high speed rail

Constraints of THSR Train

According to Ericsson's experiment, the signal attenuation and its incident angle have the following relations:

- The attenuation increases with the decrease of incident angle
- The attenuation at different locations in a car varies significant
- The attenuation close to and far from base station is 18 and 30 dB respectively in average, and the overall attenuation is about 25~30 dB

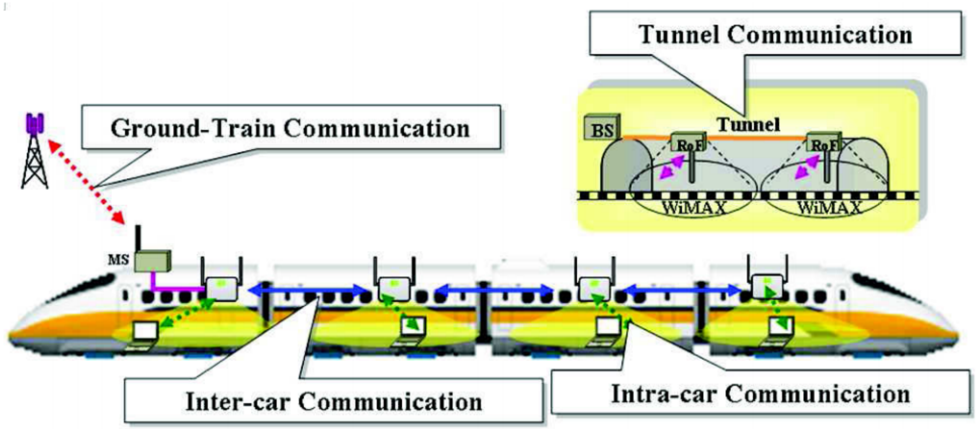




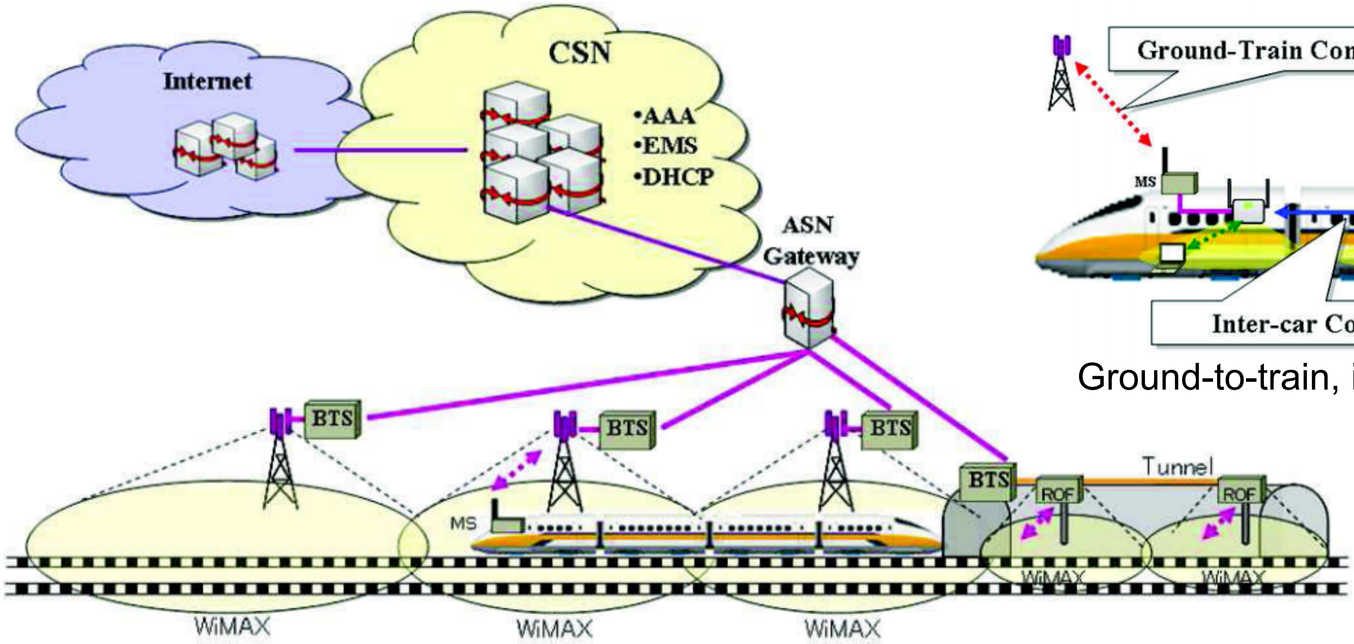
Incident angle

System Architecture for WiMAX

Core network: ITRI M-Taiwan WiMAX App. Lab. (MTWAL)
Ground-to-train communications: WiMAX in 2.5 GHz
Intra-car communications: IEEE 802.11b/g in 2.4 GHz band
Inter-car communications: IEEE 802.11a in 2.4 GHz band



Ground-to-train, intra-car and inter-car communications

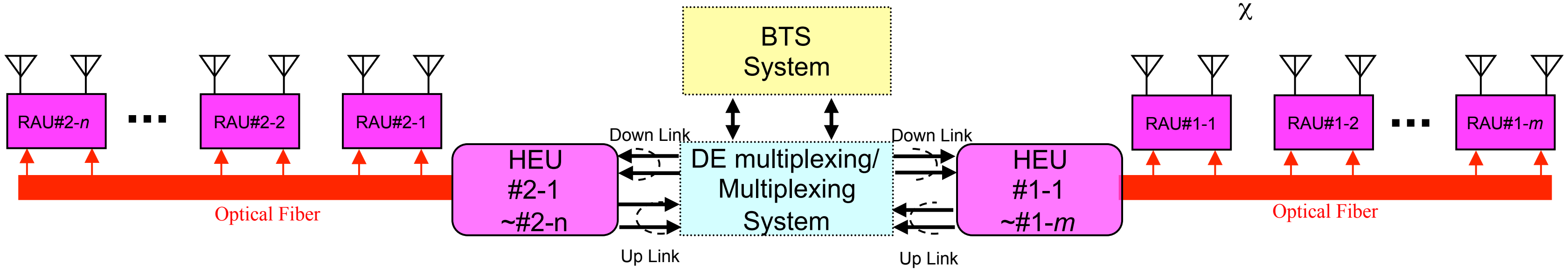


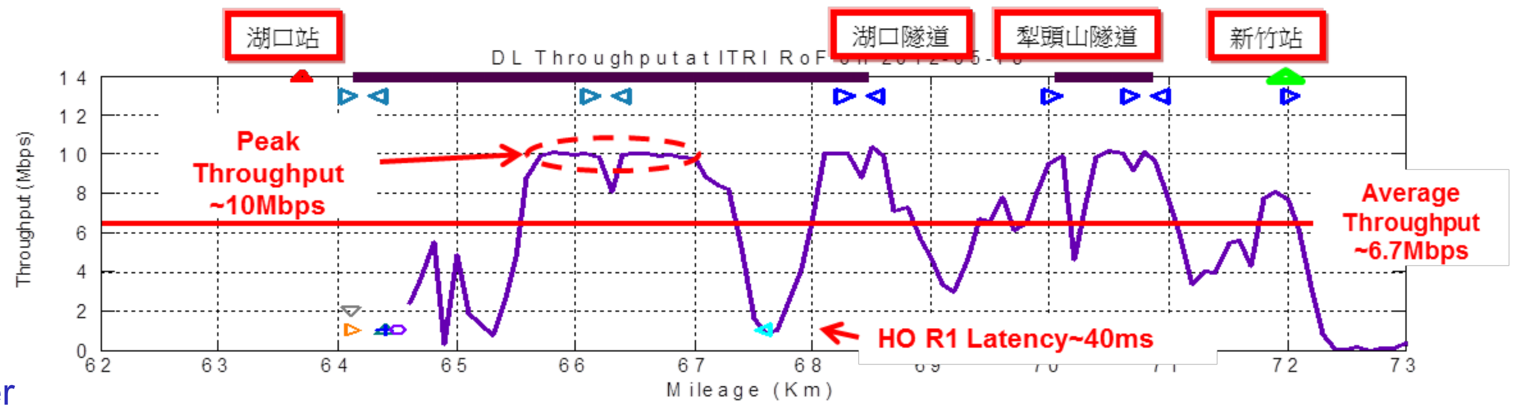
The ground network is based on ITRI MTWAL

Technology Breakthrough (1/4)

RoF Distributed Antenna System

- Used to extend coverage, enhance reception, and improve frequent handover
- Over 8 km covered by RoF, we successfully conducted handover at 300 km/h with 40 ms latency, and achieved peak and average rate of 10 and 6.7 Mbps respectively



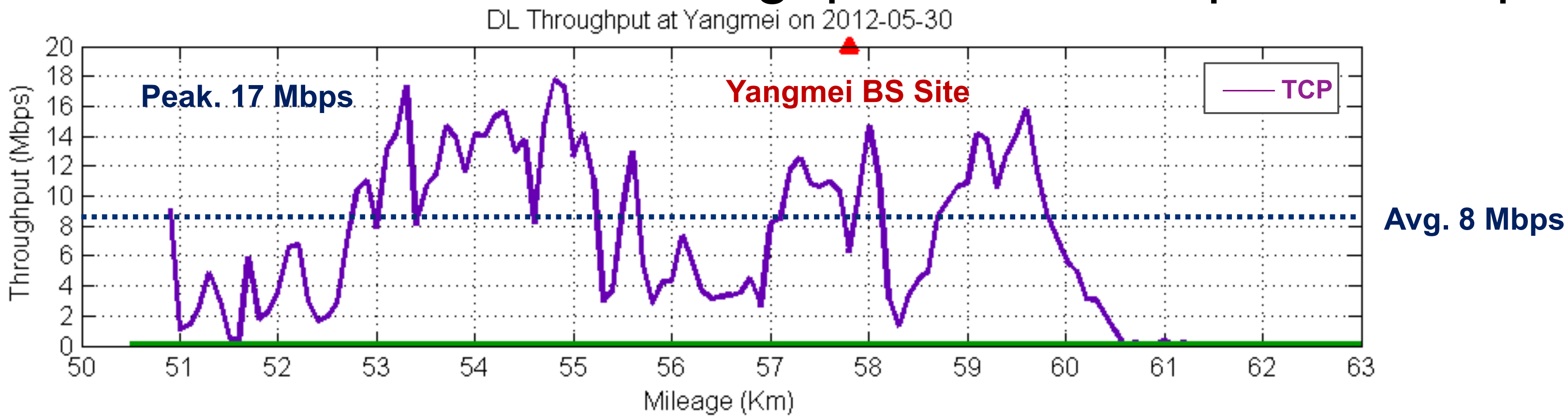


RoF: radio-over-fiber

Technology Breakthrough (2/4)

Adaptive power and MCS for high speed channel

- Improve reliability of intra-site handover
  - By limiting uplink MCS index
  - By improved power control convergence rate
- Increase downlink throughput
  - By offsetting MS channel quality estimation
  - By modifying rate control algorithm
- Achievement: increase throughput from 3 Mbps to 8 Mbps



MCS: modulation and coding scheme

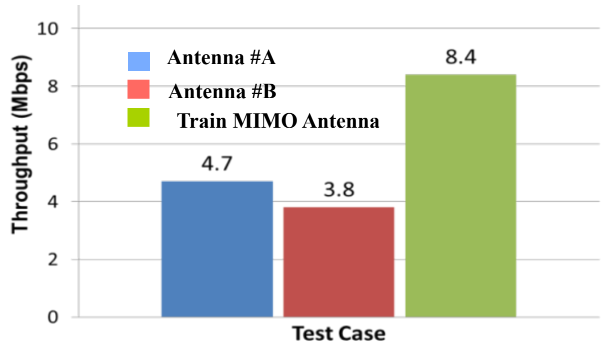
Technology Breakthrough (3/4)

Enhanced MIMO antenna design at train roof

- To fit in Kathrein radome
- Orthogonal polarization and new antenna pattern design
- Achievement: throughput is increased from 4.7 to 8.4 Mbps

WiMax Element	Type		Auden			
	Frequency Band		2500 MHz	2560MHz	2600 MHz	2690 MHz
	Peak Gain [dB]	Ant 1	0.02	0.14	1.35	1.98
		Ant 2	1.55	2.76	3.58	4.49
	Front-to-side ratio [dB]	Ant 1	7	8	8	7
		Ant 2	7	9	8.5	7
	Front-to-back ratio [dB]	Ant 1	1.02	1.14	1.5	2.98
		Ant 2	0.75	0.76	0.58	0.49
	envelope correlation coefficient ρ	Uniform	0.0005	0.0021	0.003	0.0044
		North-south	0.017	0.071	0.146	0.254
	Impedance		50 Ω			
	VSWR		Antenna 1 < 1.85, Antenna 2 < 1.828			
	Isolation [dB]		>-36.6			
	Polarization		Orthogonal			

MIMO antenna design spec.



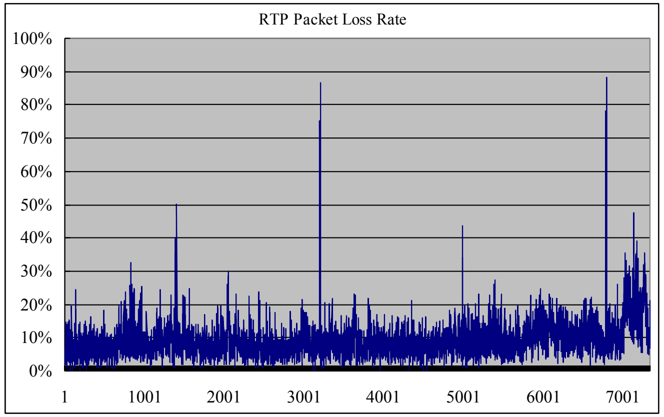
MIMO: multiple-input multiple-output

Technology Breakthrough (4/4)

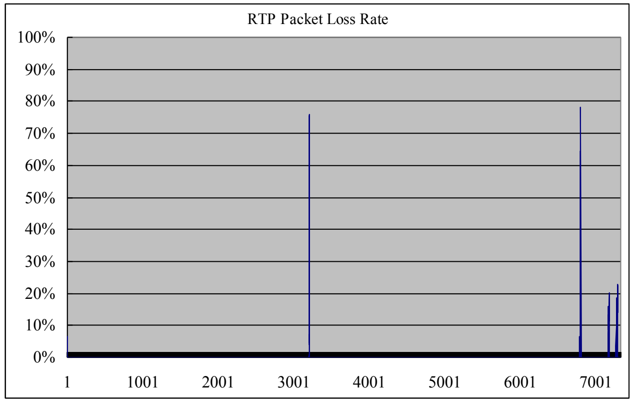
Live TV service based on Application-layer FEC (AL-FEC)

- Save Wi-Fi backhaul bandwidth usage and prevent congestion
- AL-FEC can eliminate 99% multicast packet loss and make multicast streaming service feasible on high speed trains

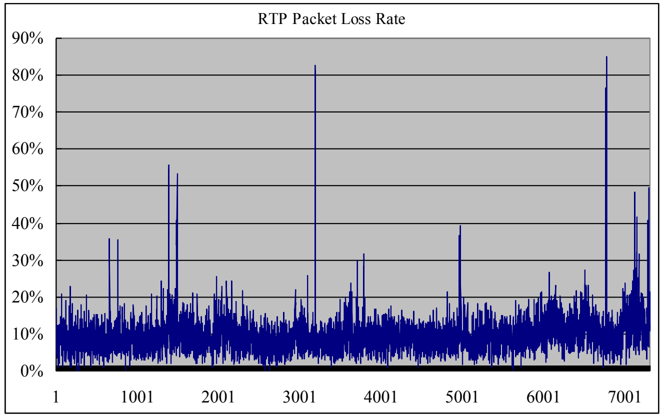
Android client (Asus Transformer)



After AL-FEC decoding



iOS client (iPad 3)



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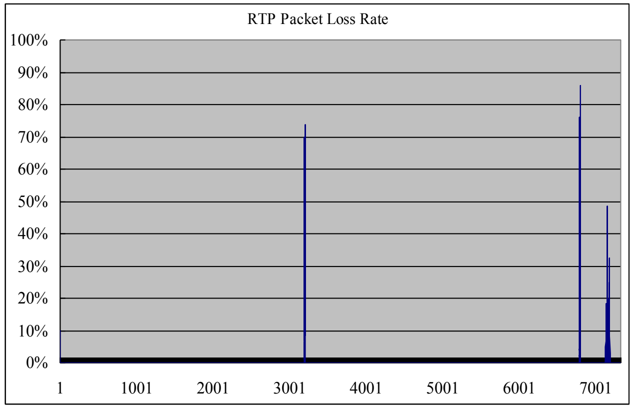


FEC: forward error correction

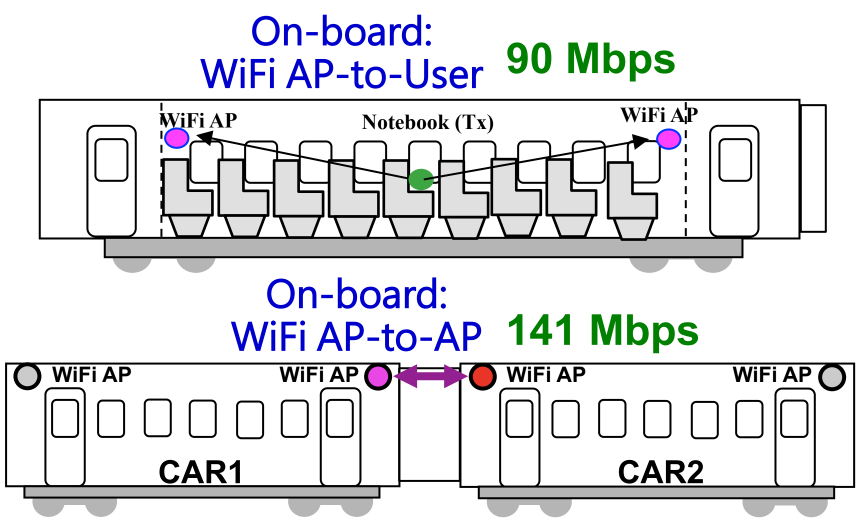
Achievements

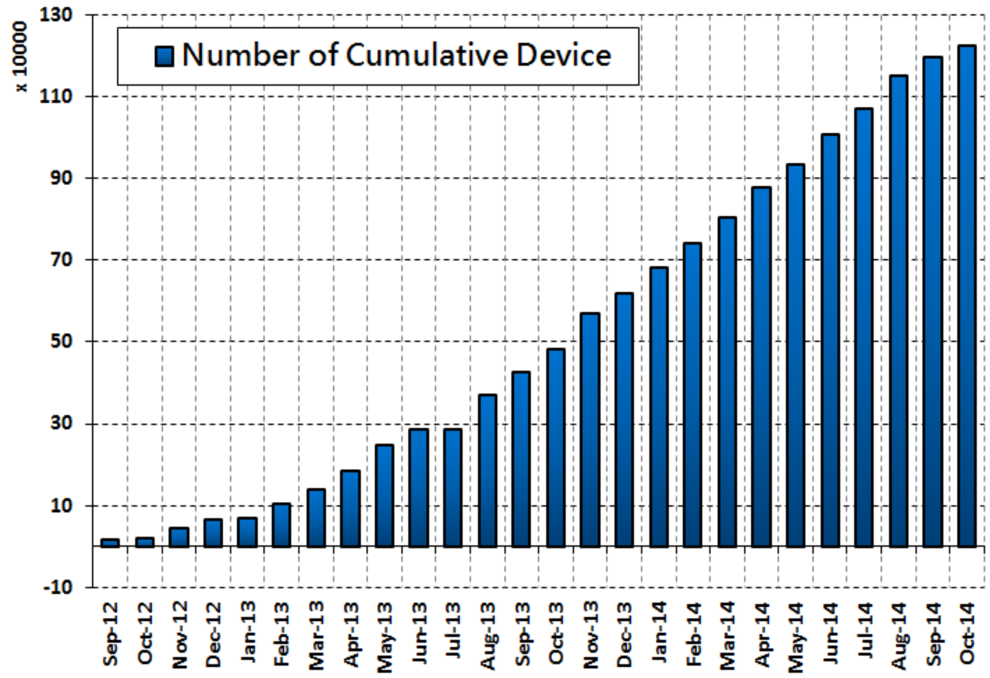
Two trains have been providing broadband services since Sep. 2012

The radio access technologies and bandwidth used :

- ground to train: WiMAX backhaul (~8.4Mbps)
- on-board : Wi-Fi access (~90Mbps)

The accumulated number of accesses of the Wi-Fi network is over 1 million





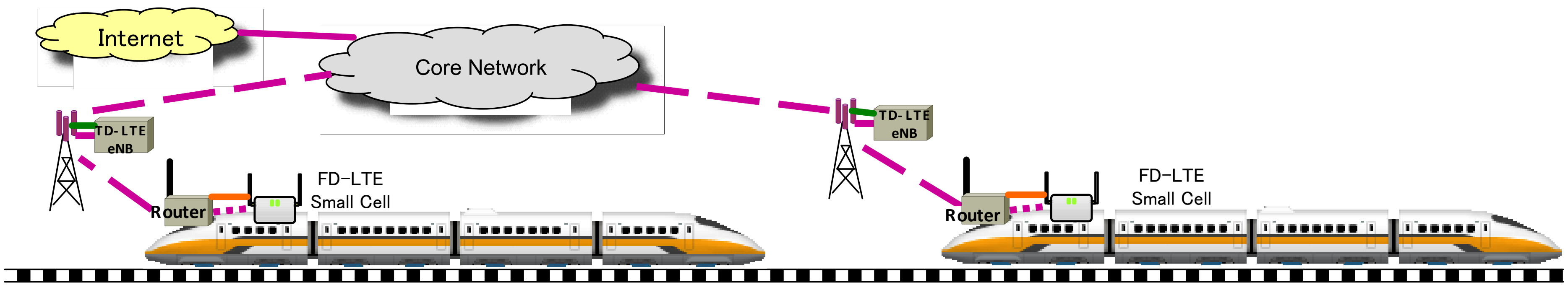
System Architecture for LTE

Two-hop architecture is exploited

- UEs on train use FD-LTE small cells
- The FD-LTE small cells use TD-LTE wireless backhaul to connect core network

The advantages of two-hop architecture:

- Reduced power consumption for UE
- Simpler processing and signaling overhead for eNB



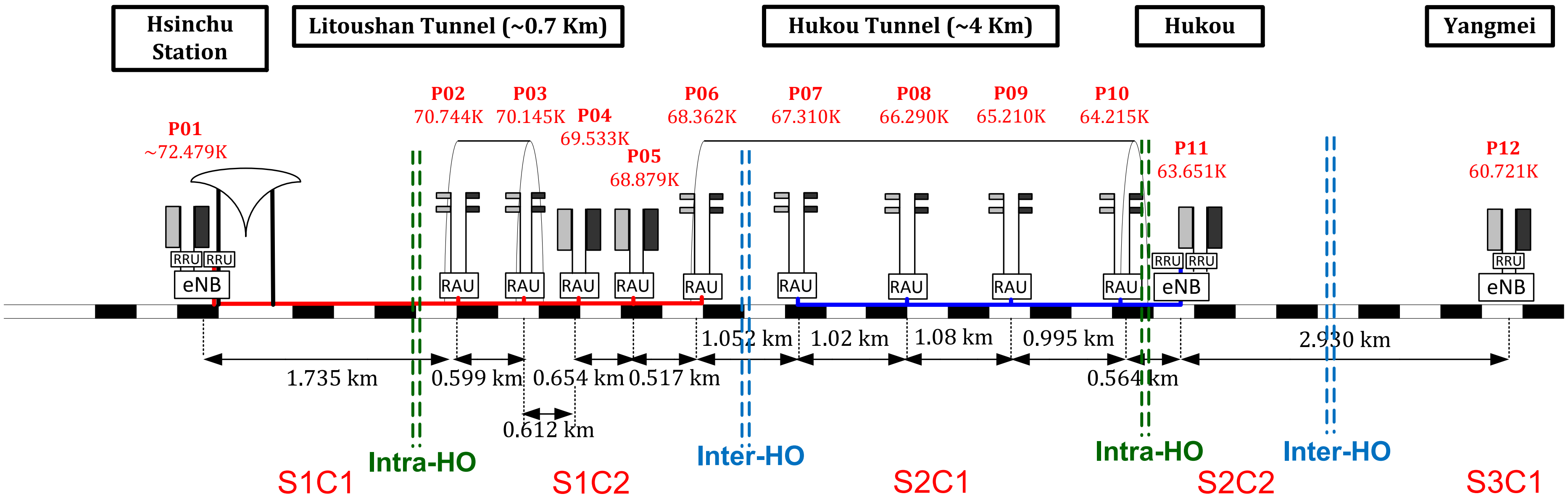
UE: user equipment

Field Trial Deployment

Handover (HO) performance was investigated

3 eNBs (P01, P11,P12) are deployed, where RoF systems with five RAUs (P02~P06) and four RAUs (P07~P10) are connected to P01 and P11, respectively, for signal coverage extension in two tunnels (Litoushan Tunnel 0.7 km, Hukou Tunnel 4 km).

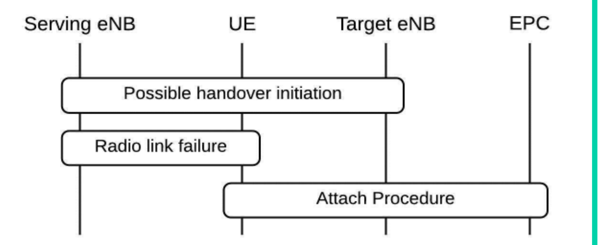
The handover is classified as intra handover (intra-HO) and inter handover (inter-HO)



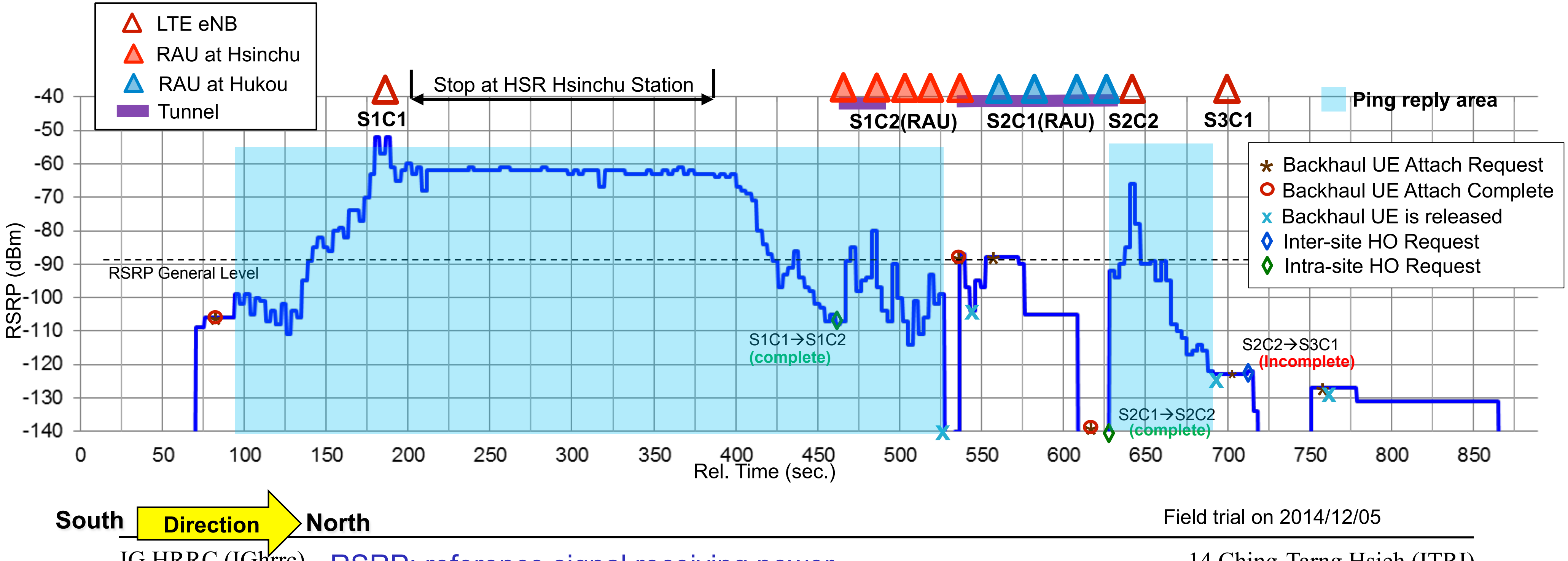
 RoF: radio over fiber; RAU: remote antenna unit

RSRP and Attach Performance (1/2)

- Radio link failure (RLF) occurred at 525 sec
- It corresponds to the location of the first inter-HO in the long tunnel (Hukou tunnel)
- Attach was complete at 625 sec, followed by another RLF before 700 sec



HO procedure



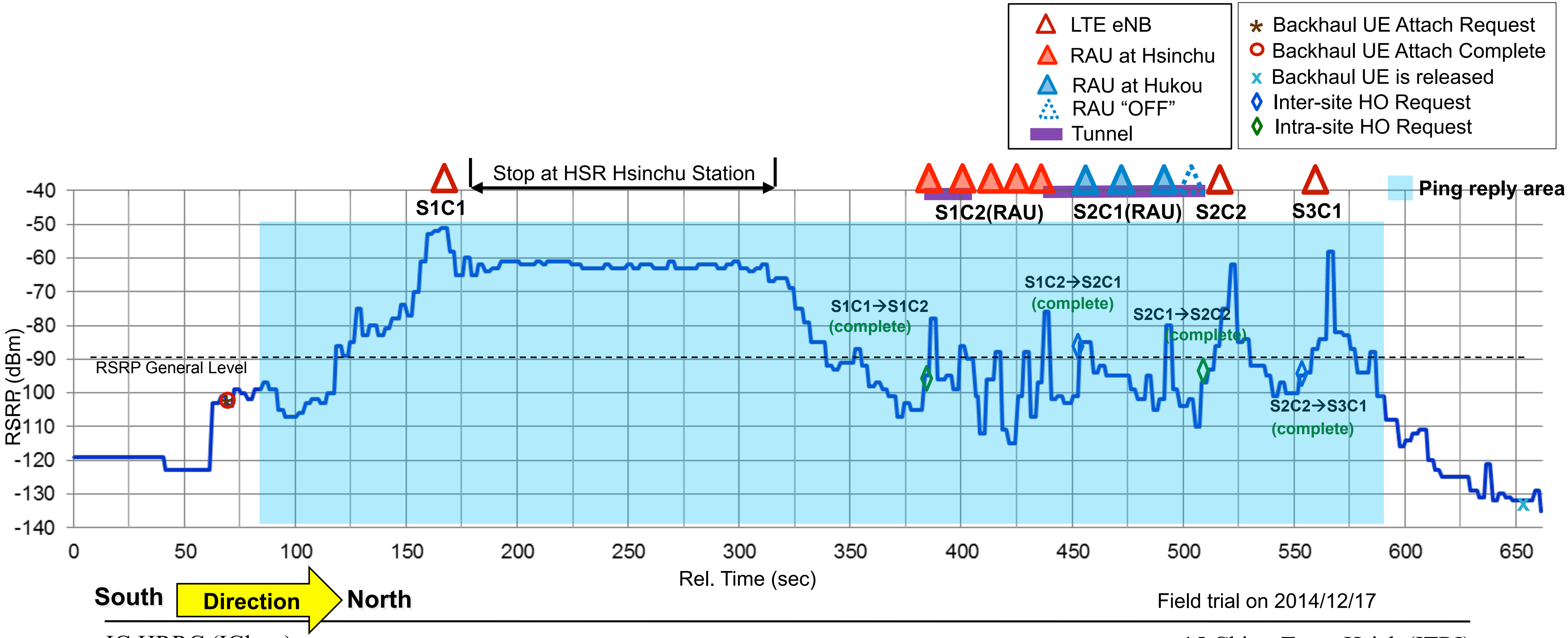
Field trial on 2014/12/05

RSRP: reference signal receiving power

RSRP and Attach Performance (2/2)

To solve the RLF issue during inter-site HO, one RAU (P10) was shut down and some eNB parameters were further adjusted

2 intra-HO and 2 inter-HO were executed successfully without RLF (continuous ping reply without interruption)



Concluding Remarks

ITRI is cooperating with Ericsson to build a LTE HSR test-bed as the foundation for next-generation moving network research.

There is on-going effort to improve the throughput performance, including enhanced MIMO antenna design, load balancing with wireless backhaul diversity, etc.

ITRI looks forward to participating in the IG and cooperating with other parties to share our knowledge as well as expand our vision and visibility.

thank you!

LTE System Parameters

Cell	S1C1 at Hsinchu South	S1C2 at Hsinchu North (RoF)	S2C1 at Hukou South (RoF)	S2C2 at Hukou North	S3C1 at Yangmei
State	ON	ON	ON	ON	ON
Physical CID	303	304	308	306	310
Sync. Dev.	<= 10 us	<= 10 us	<= 10 us	<= 10 us	<= 10 us
Tx. Mode	2	2	2	2	2
Bandwidth	15 MHz	15 MHz	15MHz	15 MHz	15 MHz
EARFCN	37875	37875	37875	37875	37875
Power PUCCH	-107 dBm	-107 dBm	-107 dBm	-107 dBm	-107 dBm
Power PUSCH	-93 dBm	-93 dBm	-93 dBm	-93 dBm	-93 dBm

EARFCN: EUTRA Absolute radio-frequency channel number