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

Submission Title: [Field trial of MHN system for high-speed train communications]
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Abstract: [This document presents field trials of MHN and MHN-E systems]

Purpose: [For discussion]

Contents

- Overview of MHN System
- Field trial of MHN system
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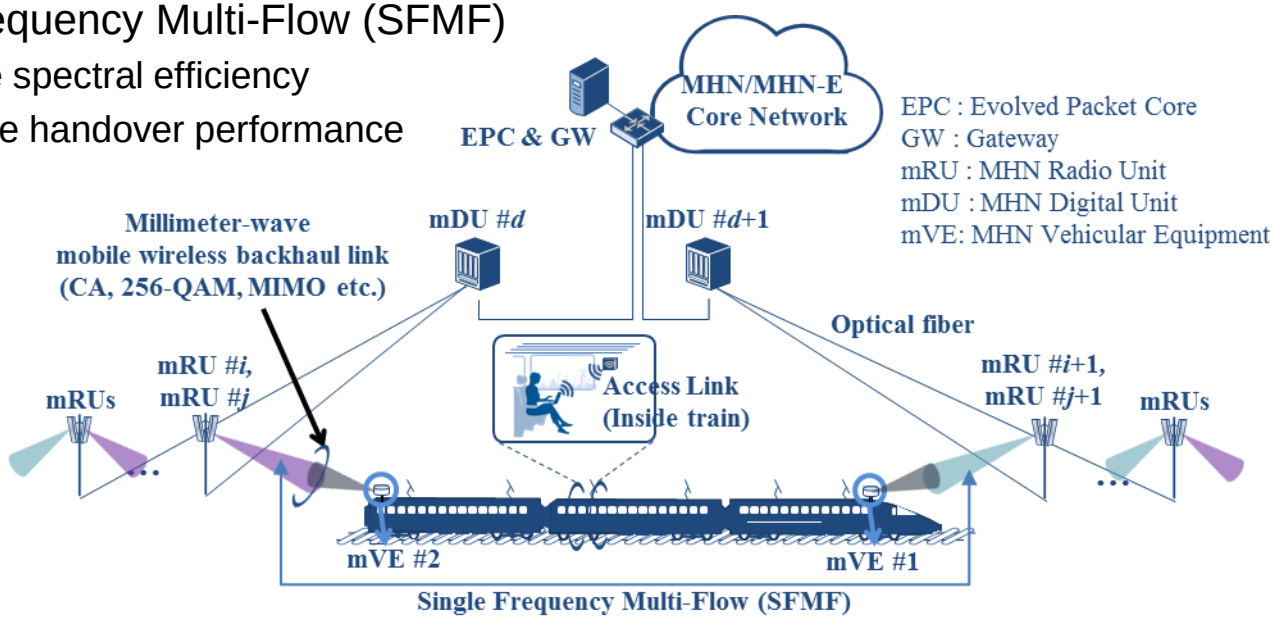
Overview of MHN System

- Basic System Architecture of MHN
  - MHN system for high-speed train (HST) communications
  - Hierarchical two-hop network
    - Mobile wireless backhaul (MWB) link outside using ***millimeter-wave***
    - Onboard access link
  - MHN*/MHN-E** system architecture[1]
    - Single Frequency Multi-Flow (SFMF)
      - Double spectral efficiency
      - Improve handover performance



*MHN : mobile hotspot network
**MHN-E : MHN Enhancement

Overview of MHN System

- Key Features of MHN-E System for HST Communications
  - High-mobility support up to 500km/h
  - A frame structure enabling effective neighbor cell search and high-performance handover
  - Carrier aggregation to attain a total transmission bandwidth of up to 1GHz
  - High-order modulation schemes (64-QAM and 256-QAM)
  - SFMF and MIMO using polarization antennas
  - Uplink-downlink duplexing : TDD
  - OFDM for both uplink and downlink transmissions
- MHN system VS MHN-E system

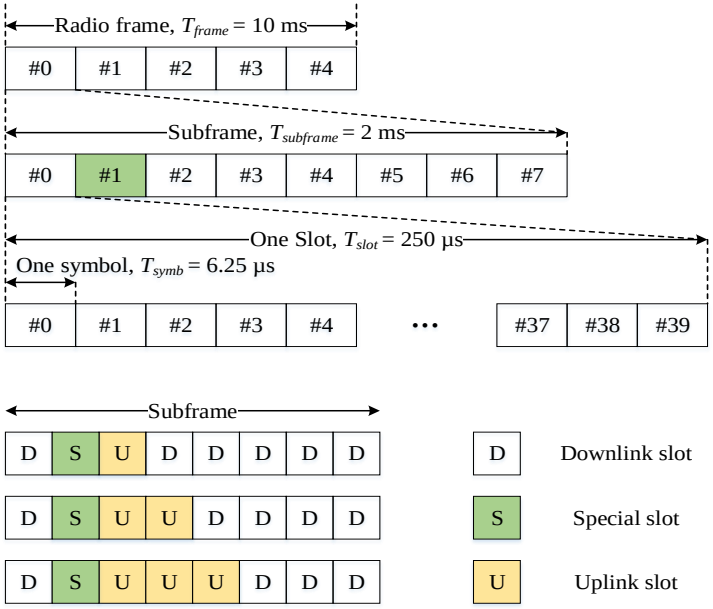
Design Parameters	Comparison	
	MHN-E	MHN
Frequency	25.5 GHz*	31.625 GHz
Bandwidth	1 GHz	< 500 MHz
EIRP	36 dBm**	42 dBm
Mobility support	Up to 500 km/h	Up to 400 km/h
Modulation order	QPSK, 16QAM, 64QAM, 256QAM	QPSK, 16QAM, 64QAM
Antenna configurations	2x2 SFMF, 2x2 MIMO	2x2 SFMF, 1x1 SISO
Maximum throughput	10Gbps	1Gbps

Overview of MHN System

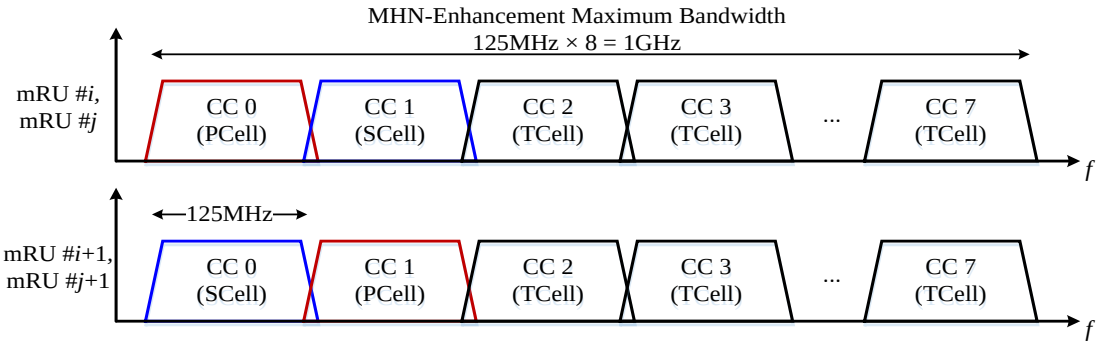
- Frame structure and numerology of MHN-E system

<Numerology of MHN-E system>

Subcarrier spacing	180 kHz
Sampling clock rate (MHz)	184.32
OFDM symbol duration, no CP (us)	5.56
CP duration (us)	0.69
CP overhead (%)	12.4
Number of symbols per TTI	40
TTI duration (ms)	0.25
Frame duration (ms)	10
Number of RBs in frequency domain	50
Number of subcarriers per RB	12
FFT size	1024



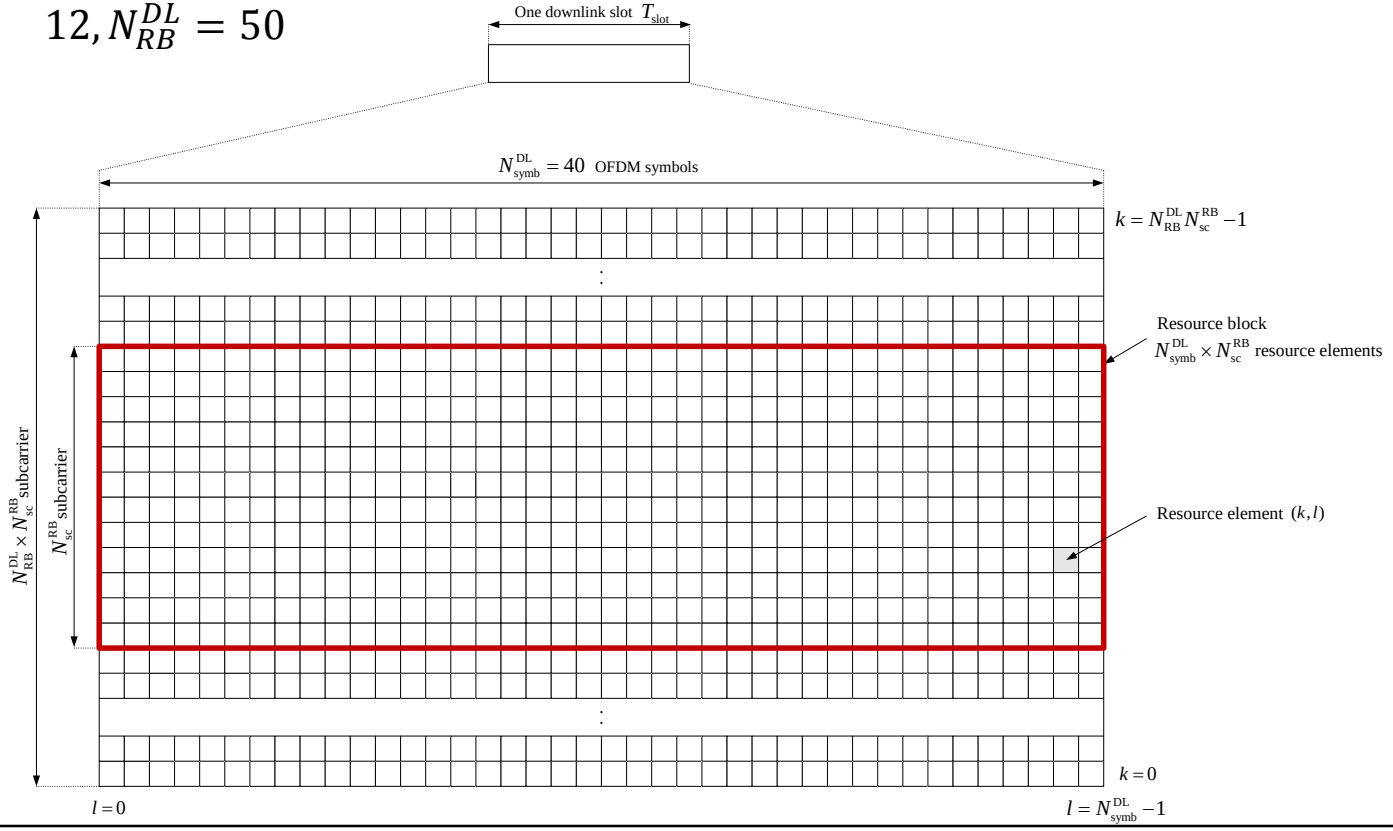
<TDD frame structure of MHN-E system>



<Carrier aggregation of MHN-E system(8×125MHz)>

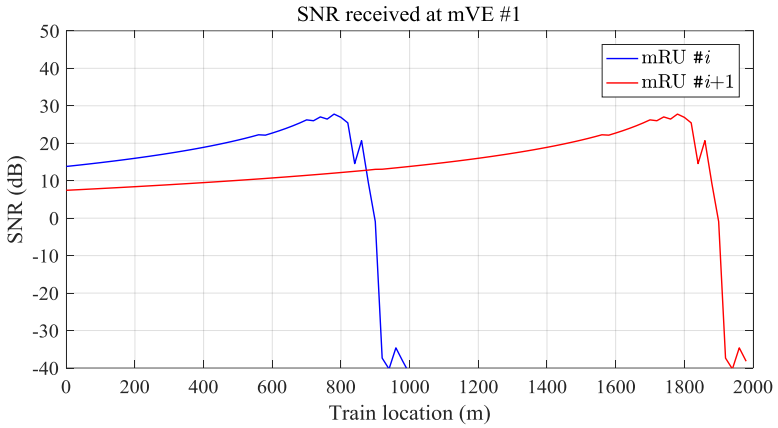
Overview of MHN System

- Frame structure and numerology of MHN-E system
  - Resource grid
    - 1 RB = 12×40 resource elements, $\Delta f = 180kHz, N_{symb}^{DL} = 40, N_{sc}^{RB} = 12, N_{RB}^{DL} = 50$

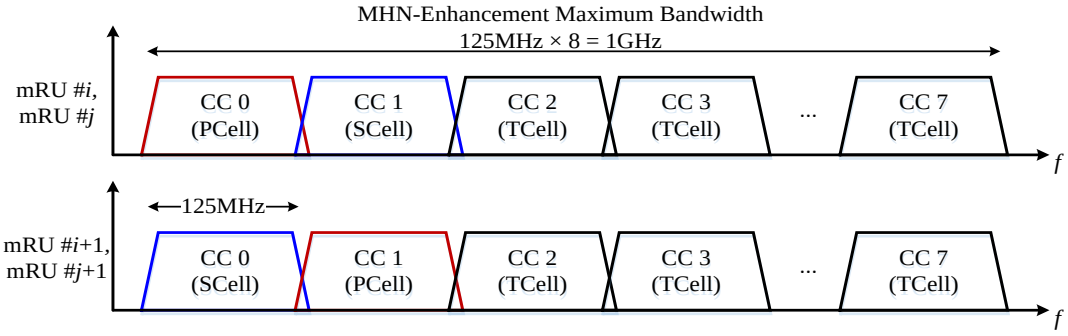


Overview of MHN System

- Frame structure and numerology of MHN-E system
  - A frame structure enabling CA, efficient neighbor cell search and high-performance handover
    - Different resource allocation
      - Primary cell (PCell)
      - Secondary Cell (SCell)
      - Tertiary cell (TCell)



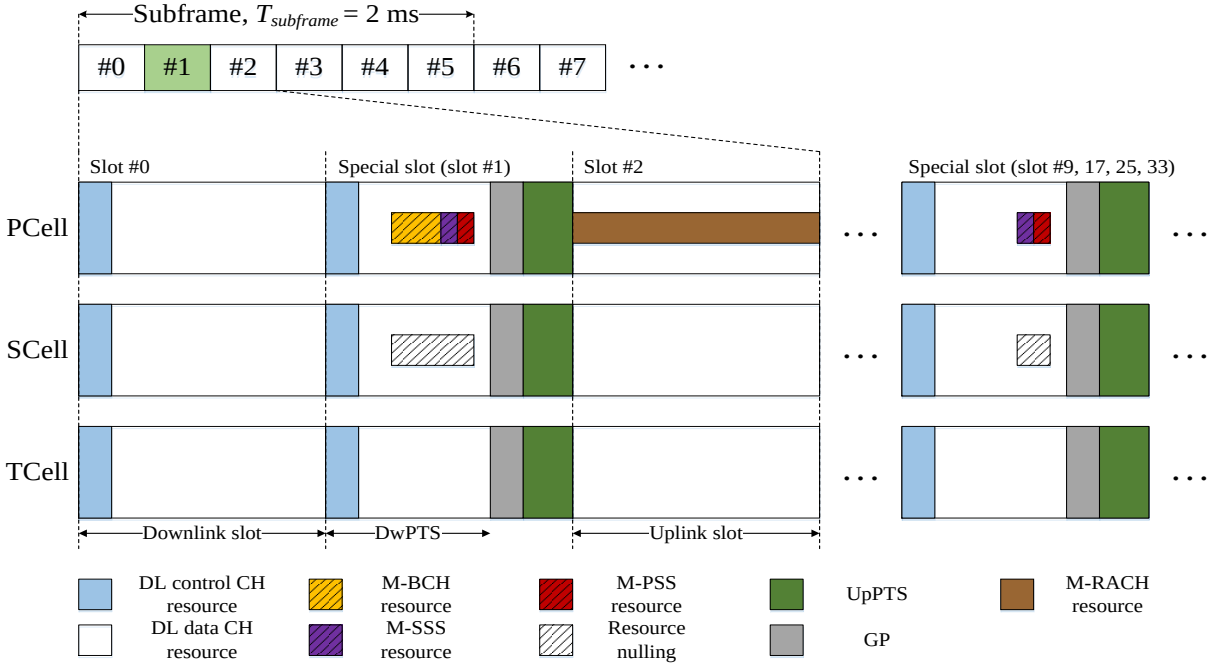
<Received SNR at mVE#1>



<Carrier aggregation of MHN-E system(8×125MHz)>

Overview of MHN System

- Frame structure and numerology of MHN-E system
  - A frame structure enabling CA, efficient neighbor cell search and high-performance handover
    - Resource nulling : SCell vacates the resources in order to detect target cell signal without interference from serving cell



<A new frame structure in MHN-E system>

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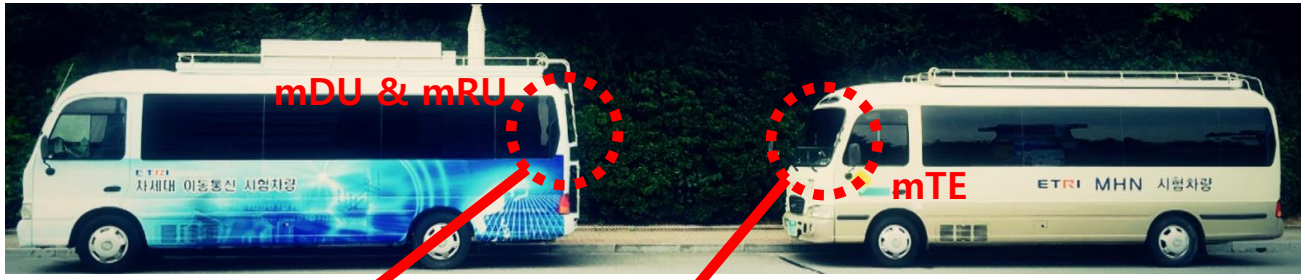
Field trial of MHN system

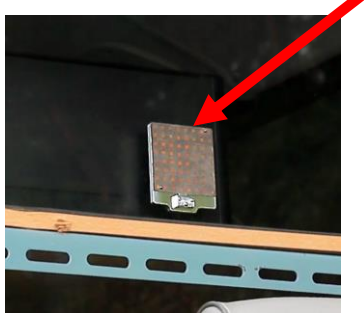
- Field trial of MHN system (completed)
  - Phase 1: field trial on the highway
  - Phase 2: field trial at Seoul subway tunnel
  - Phase 3: field trial at Seoul subway tunnel (upgraded testbeds)

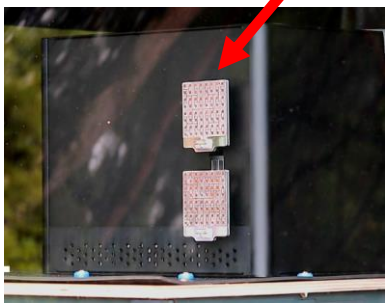
- Field trial/demonstration of MHN-E system
  - Phase 1: preliminary test in the lab (completed)
  - Phase 2: field trial using a vehicle with low mobility (being prepared)
  - Phase 3: field trial at Gangneung IoT street with a vehicle running at a speed of up to 60km/h (being prepared)
  - Phase 4: field trial with subway train (TBD)

Field trial of MHN system

- Phase 1: field trial on the highway
  - MHN testbeds installed in two moving vehicles
    - The speed of mTE vehicle was up to 80km/h
    - Demonstration of point-to-point communications showing a peak data rate of 500Mbps

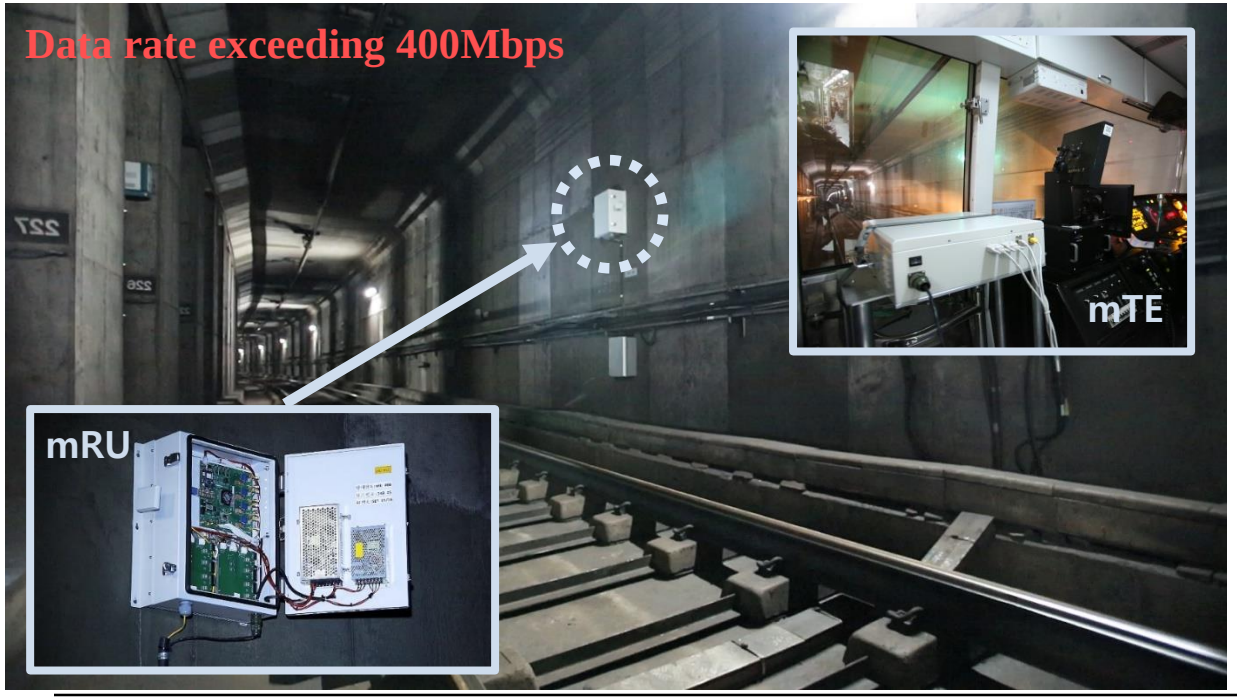






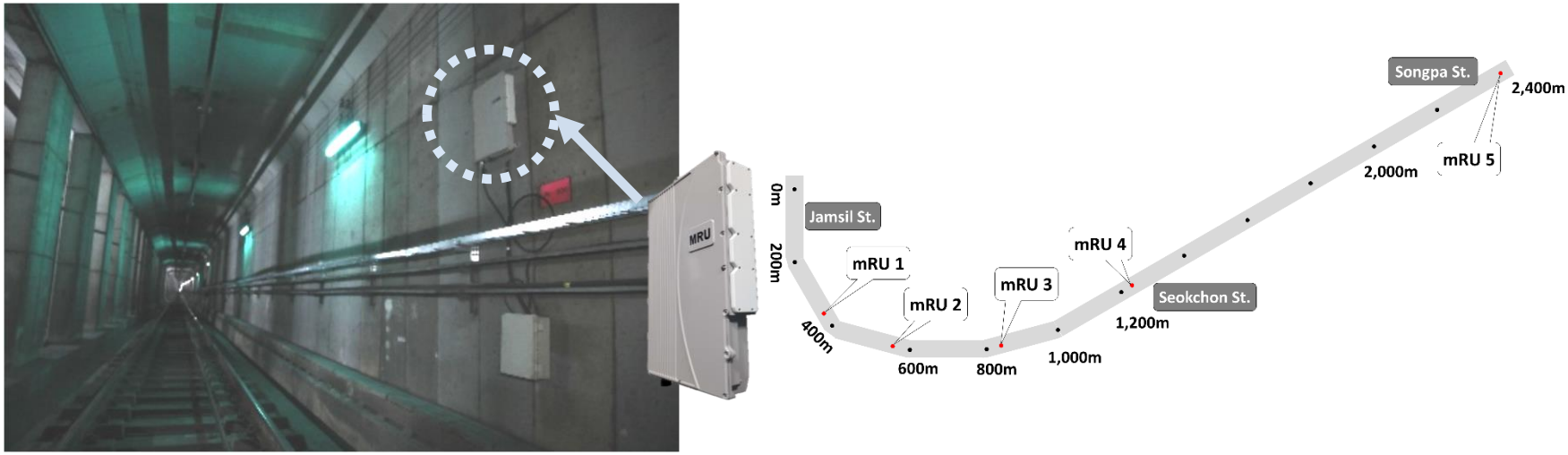
Field trial of MHN system

- Phase 2: field trial at Seoul subway tunnel[2][3]
  - MHN Test Bed Installation along Seoul Subway Line 8
    - Installation of mRU testbed and mTE testbed
  - Demonstration of the MHN system in the moving subway (Jan. 2016)



Field trial of MHN system

- Phase 3: field trial at Seoul subway tunnel (upgraded testbeds)
  - Reinstallation of the upgraded MHN system prototype
  - A field trial along 2.4 km long railway line through three stations of Seoul Subway Line 8 (Feb. 2017)

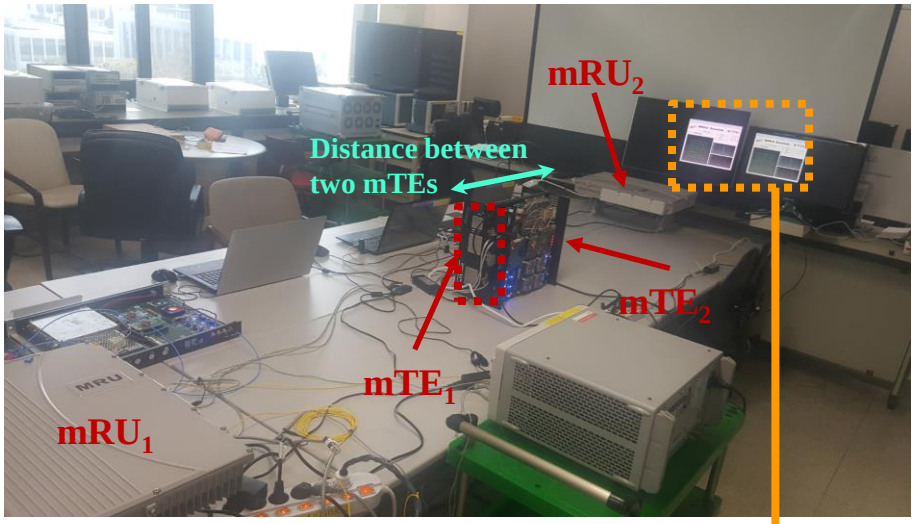


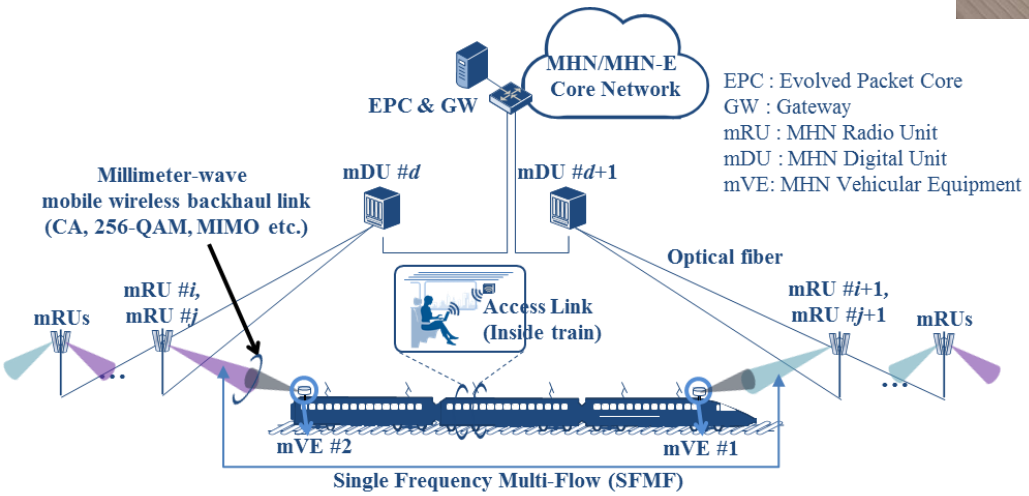
Field trial of MHN system

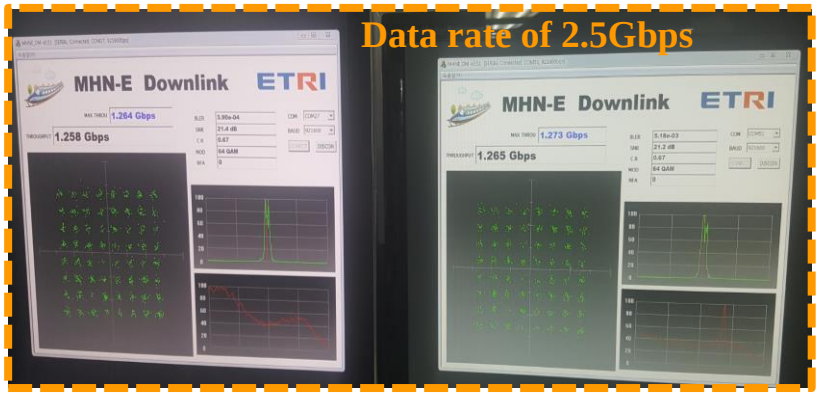
- Phase 3: field trial at Seoul subway tunnel (upgraded testbeds)
  - Peak data rate of downlink was 1.2Gbps
    - Much higher than that of previous field trial[2][3]
  - Peak data rate of uplink was 110 Mbps
    - Ratio of downlink to uplink time duration = 7:1
  - Handover test
    - 4 handover points : mRU 1 ~ 4

Field trial/demo of MHN-E system

- Phase 1: preliminary test in the lab (Feb. 2017)
  - Feasibility validation of SFMF transmission technique
  - Data rate of 2.5Gbps was achieved

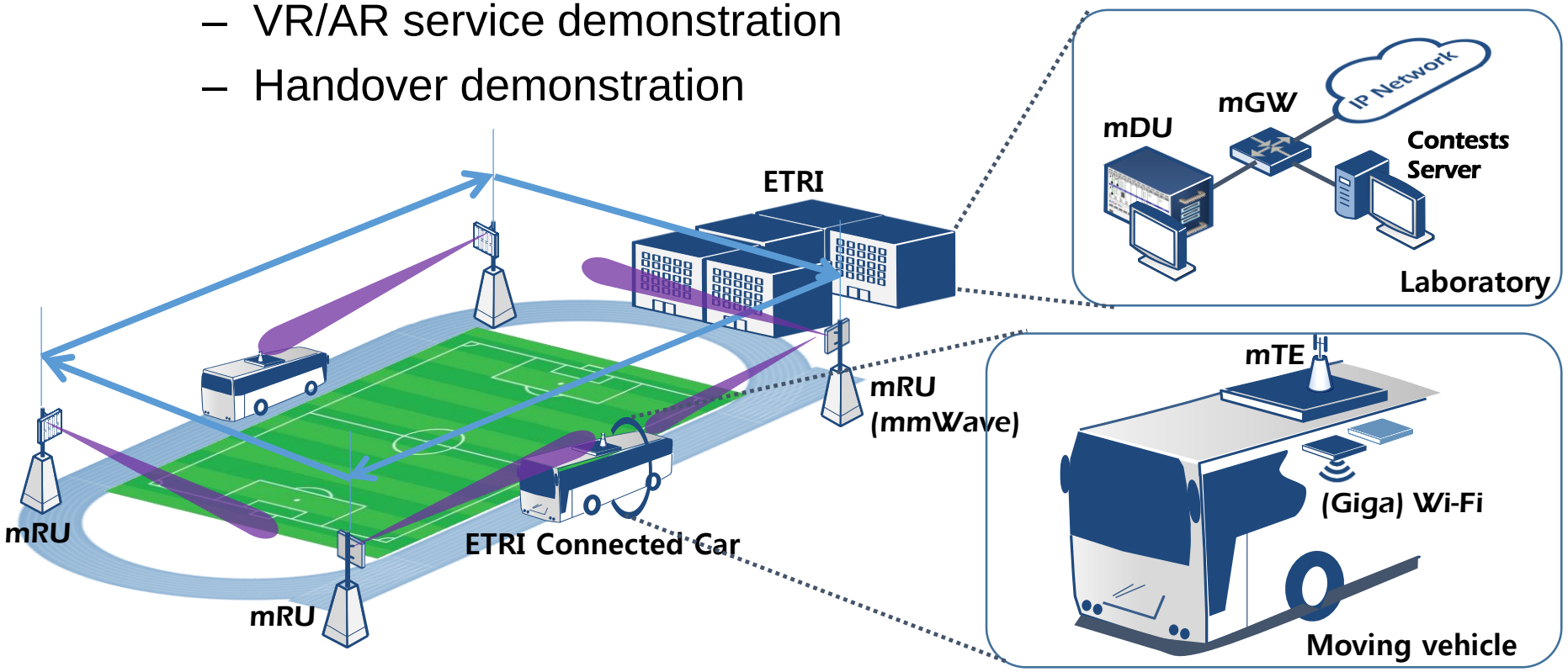






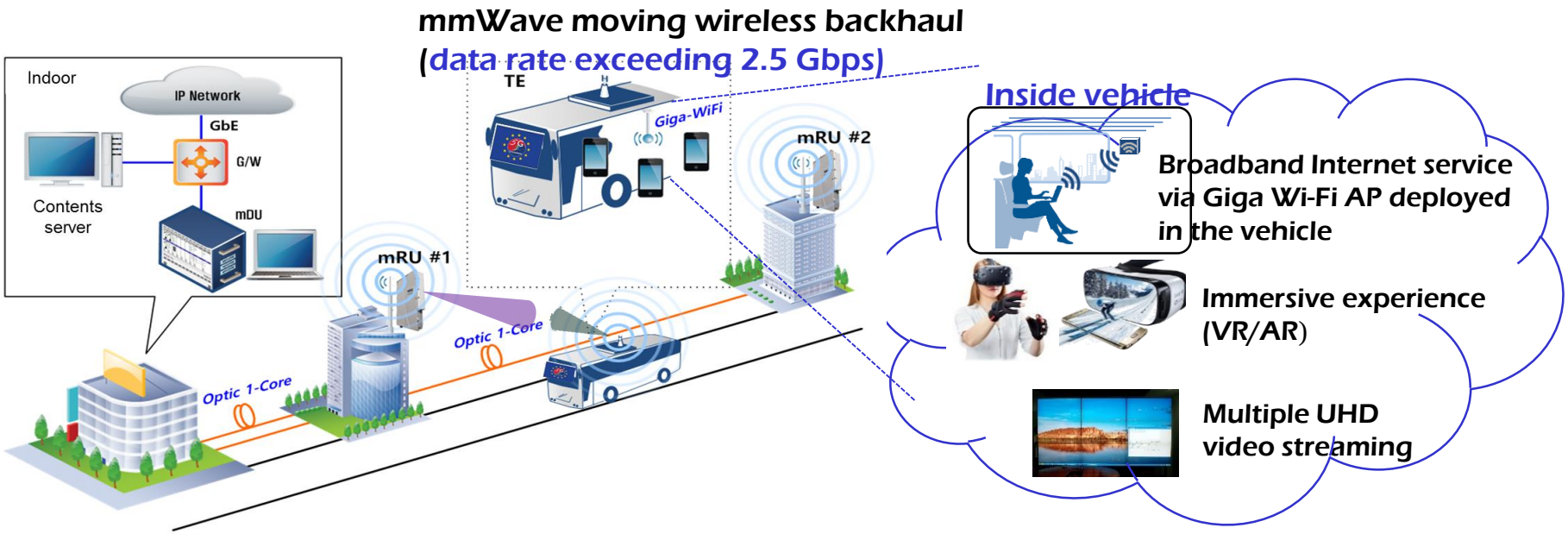
Field trial/demo of MHN-E system

- Phase 2: field trial using a vehicle with low mobility (being prepared)
  - Demonstration of a peak data rate exceeding 2.5Gbps
  - VR/AR service demonstration
  - Handover demonstration



Field trial/demo of MHN-E system

- Phase 3: field trial at Gangneung IoT street with a vehicle running at a speed of up to 60km/h, which is scheduled for Feb. 2018



- Phase 4: field trial of MHN-E system with subway train (TBD)

References

[1] J. Kim, H. S. Chung, S. W. Choi, I. G. Kim and Y. Han, "Mobile Hotspot Network Enhancement System for High-Speed Railway Communication," *EuCAP 2017*, March 2017.

[2] S. W. Choi et al., “Performance Evaluation of Millimeter-wave-based Communication System in Subway Tunnels”, IEEE 802.15-16-0185-01-hrrc, Mar. 2016

[3] S. W. Choi, H. Chung, J. Kim, J. Ahn, and I. Kim, "Mobile Hotspot Network System for High-Speed Railway Communications Using Millimeter Waves," *ETRI Journal*, vol. 38, no. 6, pp. 1042-1051, December 2016.

Thank you