

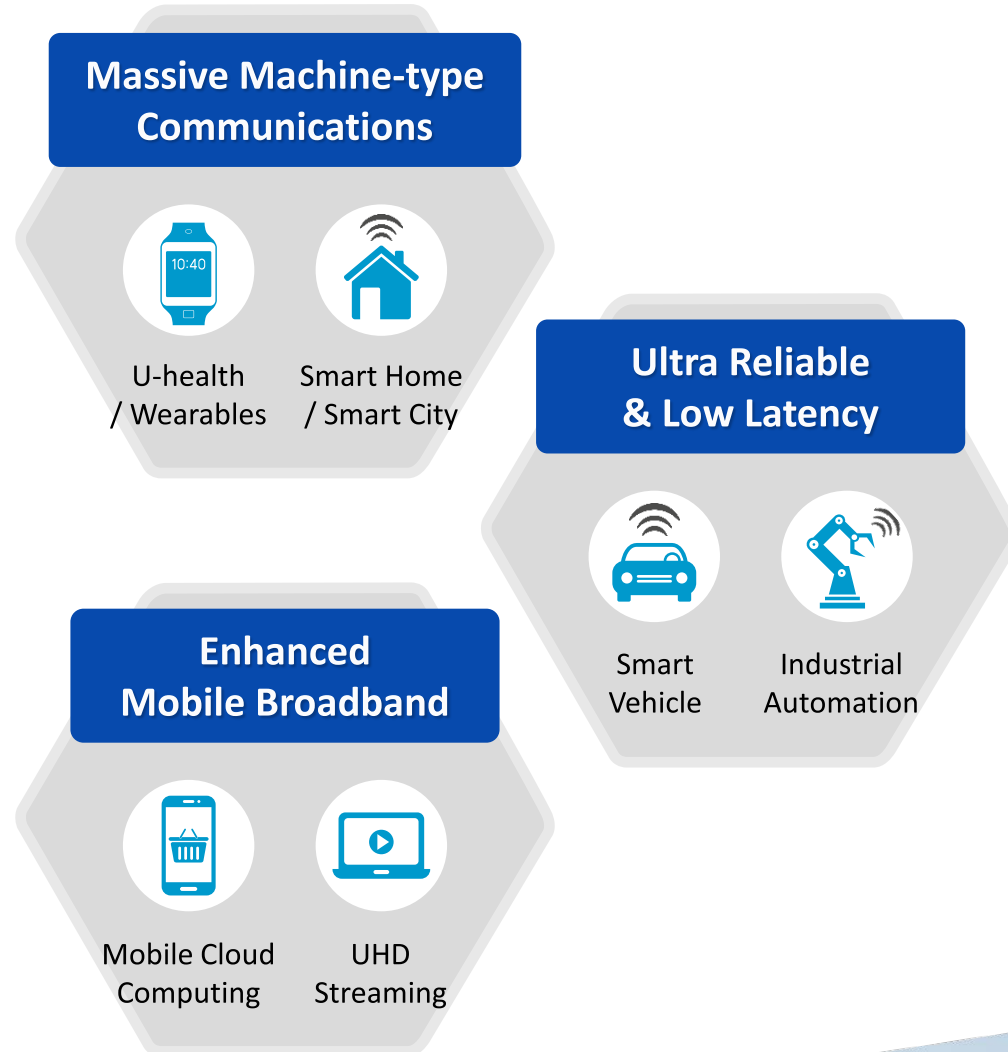
5G Trial and Field Test

Masao Akata

Vice President, Leader of SEJ-Technology Team
Samsung Electronics

5G Vision

Enabling New Services through Convergence



Innovation

2013 - 2014

Base Station



Mobile Station



World's 1st mmWave High Speed Test

(October 2014)

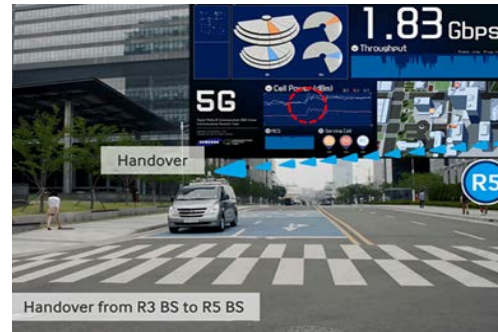


Record-Breaking
7.5 Gbps

• 7.5 Gbps at Stationary

• 1.2Gbps at >100km/hr

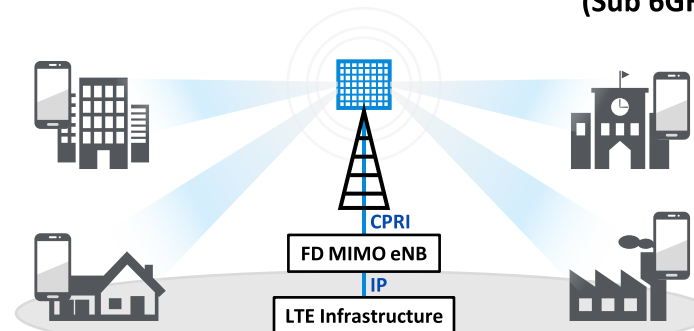
2015



• Avg. 1.7Gbps at 25km/hr

FD-MIMO with Massive Antenna Tech.

(Sub 6GHz)



2016

3.7Gbps peak using live commercial backbone NW

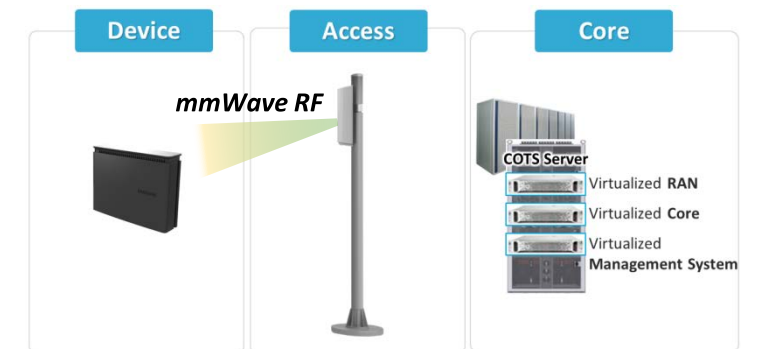


Here's what Verizon's 5G field test looks like (pictures)
[Read More](#) →
A big antenna for a big signal
A bulky antenna is mounted atop the van, which was created in partnership with Samsung. It makes for a conspicuous ride around the parking lot.

'Samsung Delivers on Gigabit Wireless Promise of 5G'

5G End-to-End Products

(Commercial)



Challenges and Opportunities

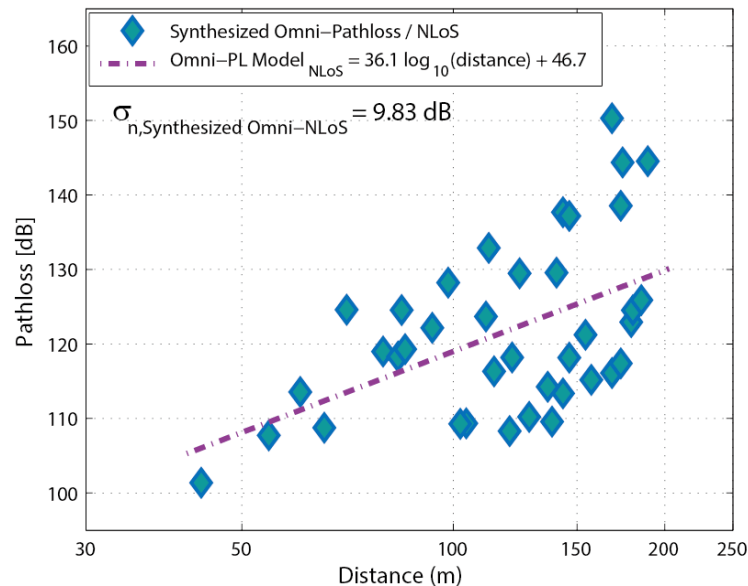
Challenges for mmWave

- Larger Path-loss
- Atmosphere loss, rain attenuation, foliage blocking
- Outdoor-to-indoor penetration loss
- Support of high-speed mobility

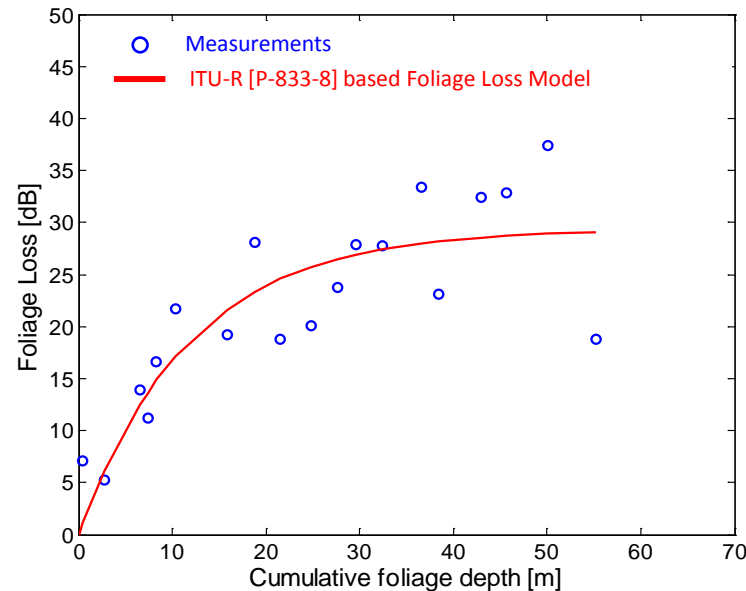
Realizing 5G mmWave

Samsung developed the World's 1st mmWave Prototype to verify the feasibility of mmWave mobile communications

Path Loss Model in Urban Environment



Foliage Loss Model



Field Test



mmWave Channel Modeling (2011~)

Leading Channel Modeling Activity toward Outdoor Cellular Deployment

Measurement and Simulation

Measurement Campaign



NYU campus



2018 Winter Olympic Resort

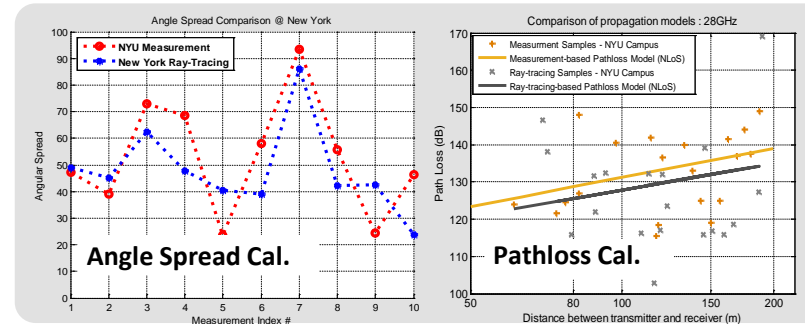
28 GHz
Channel
Sounder
[TX]

[RX]

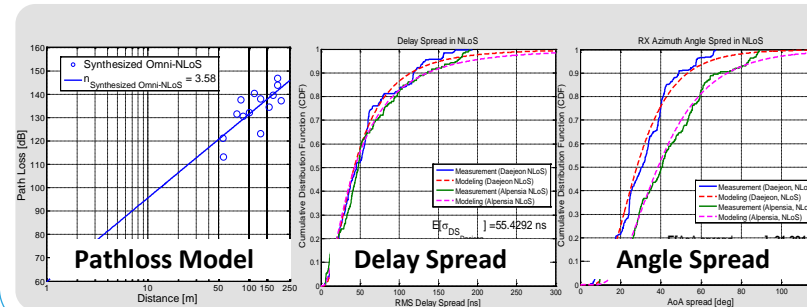


Channel Modeling

Calibration



Channel modeling



Samsung's Activity on Channel Modeling

Universities & research centers

- NYU, USC, KAIST

Research projects

- 5G PPP mMAGIC, COST IC1004

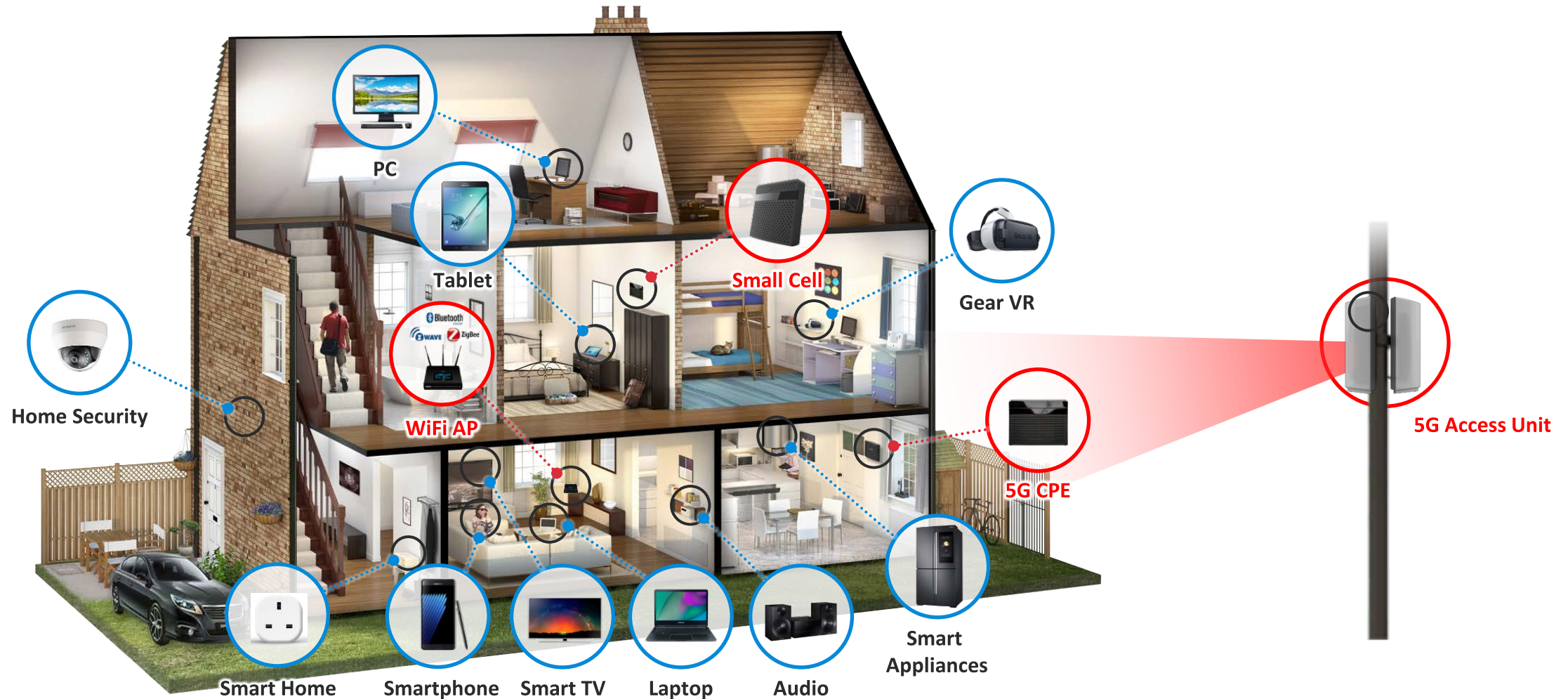
Standard

- Rapporteur on 3GPP 5G Channel Model SI for > 6GHz



Fixed Wireless Access as First 5G Use Case

| An Alternative to Fiber for Delivering 5G Broadband to Homes and Offices



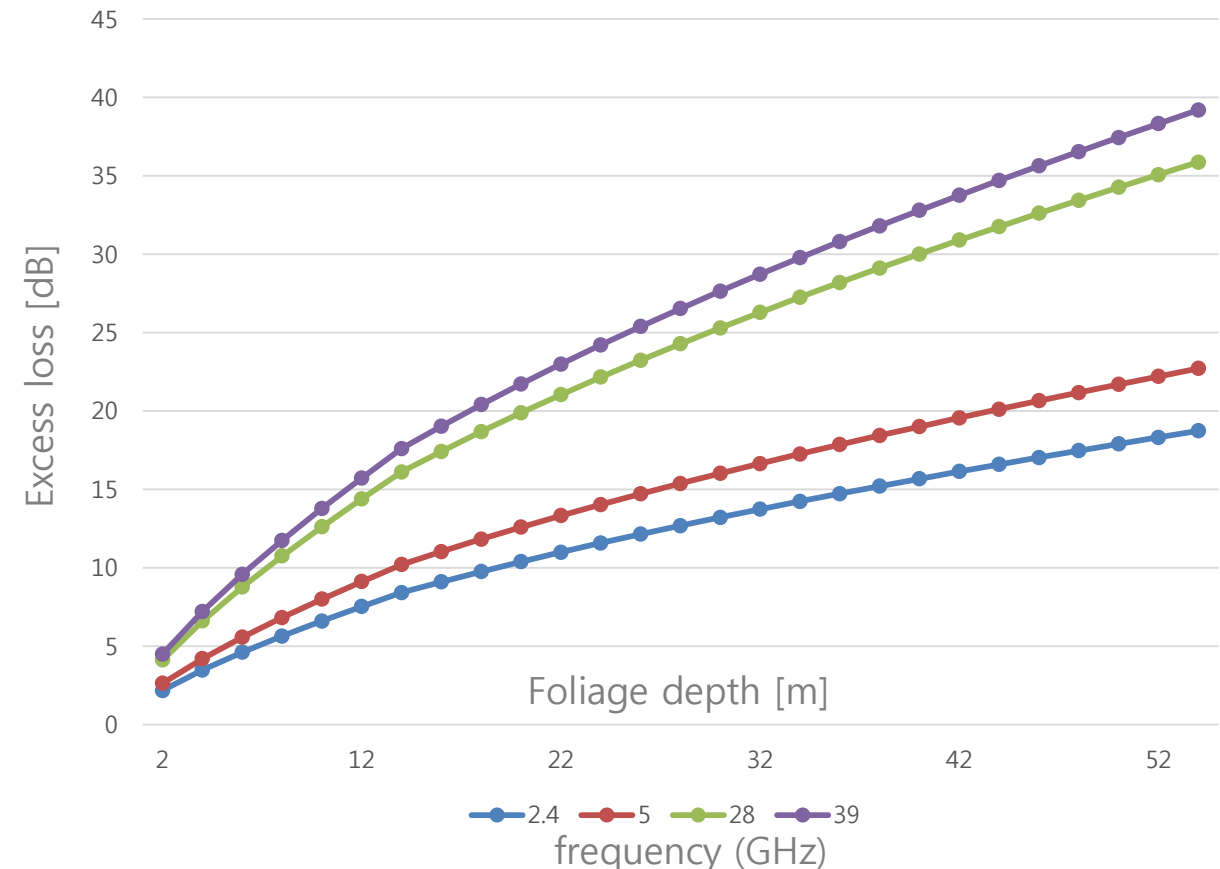
Typical FWA Environments (US)



Previous Studies for Foliage Loss

Model	Expression
Weissberger model [10]	$L_W \text{ (dB)} = \begin{cases} 1.33 \times f^{0.284} d^{0.588} & 14 \text{ m} < d \leq 400 \text{ m} \\ 0.45 \times f^{0.284} d & 0 \text{ m} \leq d < 14 \text{ m} \end{cases}$ <p>f is frequency in GHz, and d is the tree depth in meter</p>
ITU-R model [11]	$L_{ITU-R} \text{ (dB)} = 0.2 \times f^{0.3} d^{0.6}$ <p>f is frequency in MHz, and d is the tree depth in meter ($d < 400 \text{ m}$)</p>
COST235 model [12]	$L_{COST} \text{ (dB)} = \begin{cases} 26.6 \times f^{-0.2} d^{0.5} & \text{out-of-leaf} \\ 15.6 \times f^{-0.009} d^{0.26} & \text{in-leaf} \end{cases}$ <p>f is frequency in MHz, and d is the tree depth in meter</p>
ITU-R model [13]	$L_{FITU-R} \text{ (dB)} = \begin{cases} 0.37 \times f^{0.18} d^{0.59} & \text{out-of-leaf} \\ 0.39 \times f^{0.39} d^{0.25} & \text{in-leaf} \end{cases}$ <p>f is frequency in MHz, and d is the tree depth in meter</p>
MA model [14]	$L_{MA} \text{ (dB)} = A_m [1 - \exp(-R_0 d / A_m)]$ <p>A_m is the maximum attenuation, R_0 is the initial gradient of the attenuation rate curve, and d is the tree depth in meter</p>
NZG model [14]	$L_{NZG} \text{ (dB)} = R_\infty d + k \left(1 - \exp \left\{ \frac{-(R_0 - R_\infty)}{k} d \right\} \right)$ <p>d is the tree depth in meter, R_0 and R_∞ are the initial and final specific attenuation values in dB/m, and k is the final attenuation offset in dB</p>
DG model [15]	$L_{DG} \text{ (dB)} = \frac{R_\infty}{f^a w^b} d + \frac{k}{w^c} \left(1 - \exp \left\{ \frac{-(R_0 - R_\infty)}{k} w^c d \right\} \right)$ <p>The same definition for d, R_0, R_∞, and k with NZG model, f is frequency in GHz, w is the maximum effective coupling width between the transmitting and receiving antennas, and a, b, c, are estimated constant.</p>

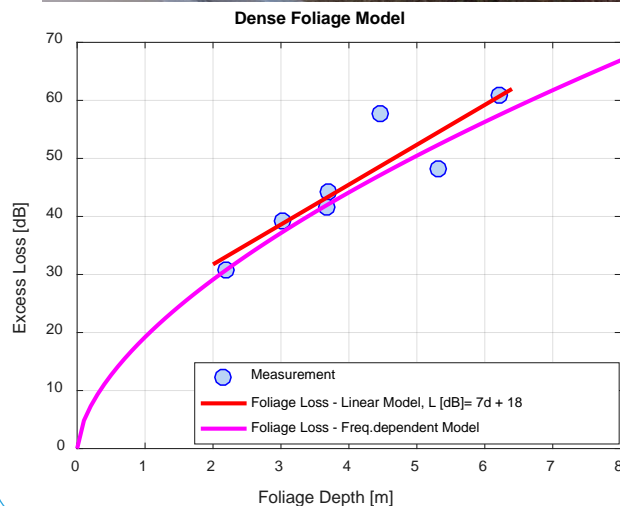
Foliage Loss : Average of [10], [11] and [13]



Foliage Loss ?

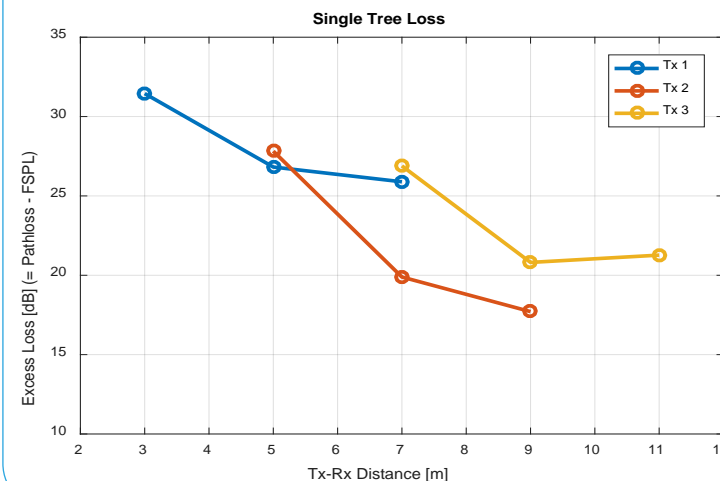
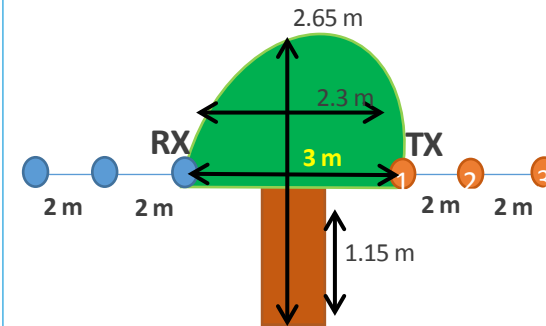
- Pure foliage penetration loss
- Excess loss considering reflection and diffraction path need between Tx and Rx

Measurement for Foliage-penetration Path



Pure foliage-penetrated path can be severely attenuated, as **7~10 [dB/m]**

Excess Loss Measurement on Single-tree

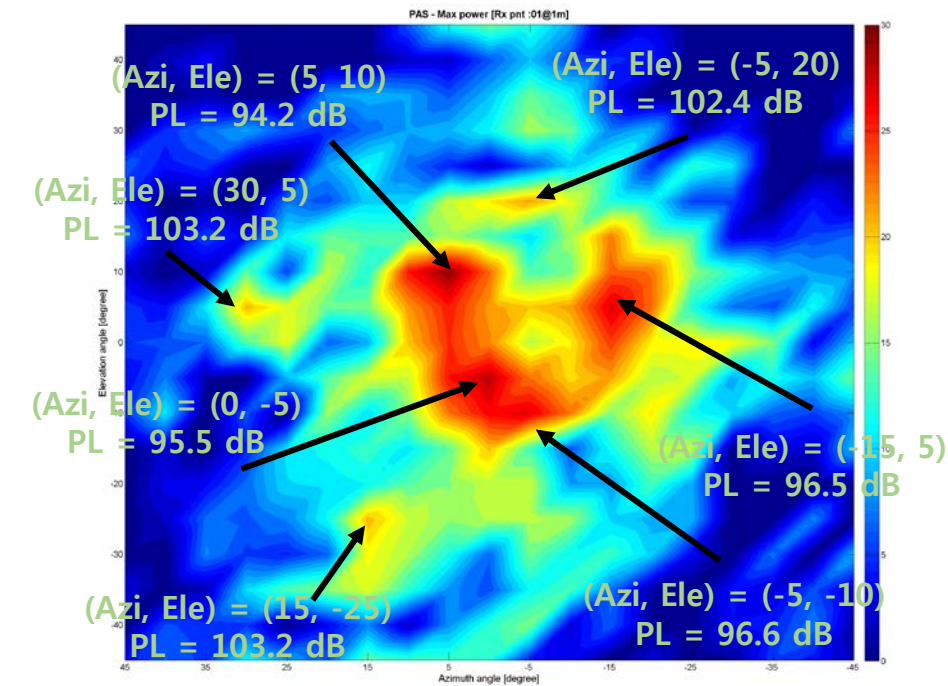
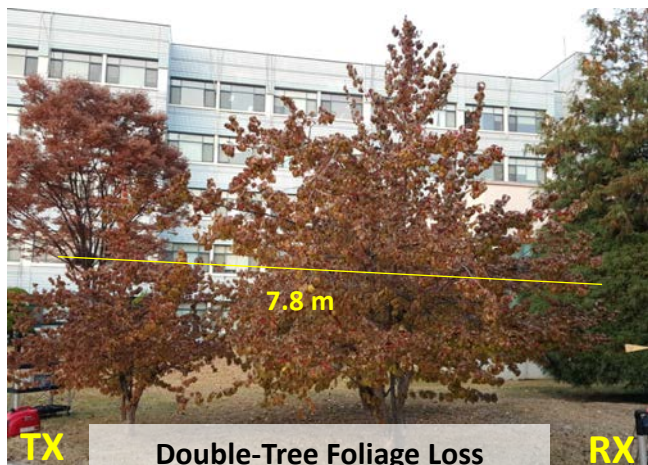
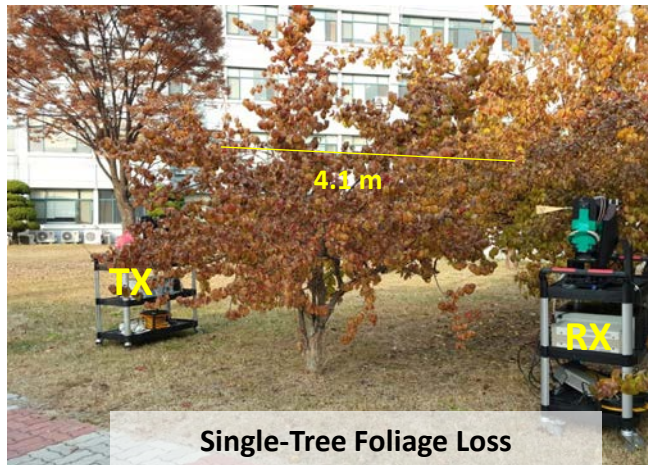


The long-distance between Tx/Rx and tree can help other propagation pathway

Penetration Loss (1/2)

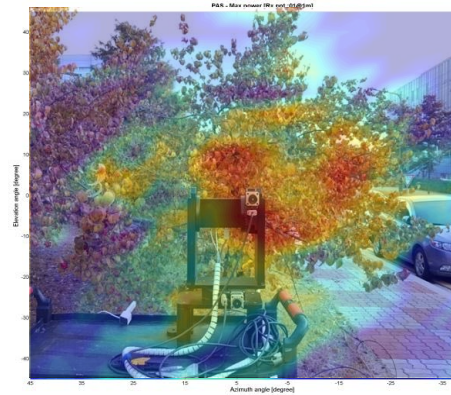
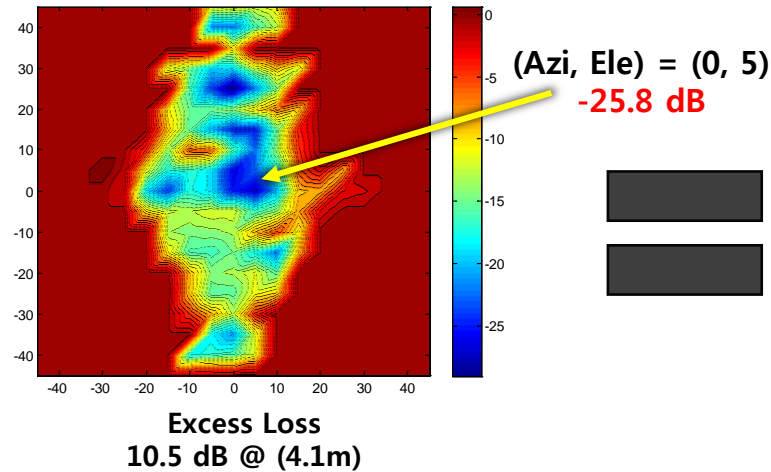
Power-Angular Spectrum Analysis on Foliage Loss

- Full-scanning on foliage-penetration path over azimuth / elevation angles
- Single-tree (depth 4.1m) and double-tree (depth 7.8) foliage penetration measurement

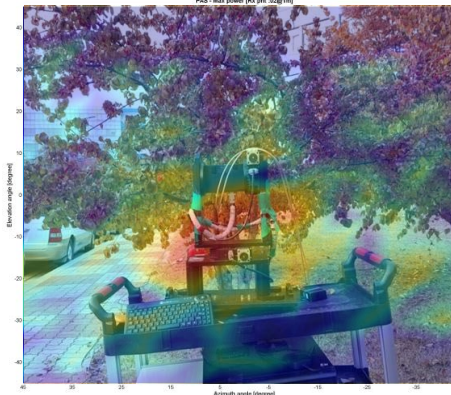
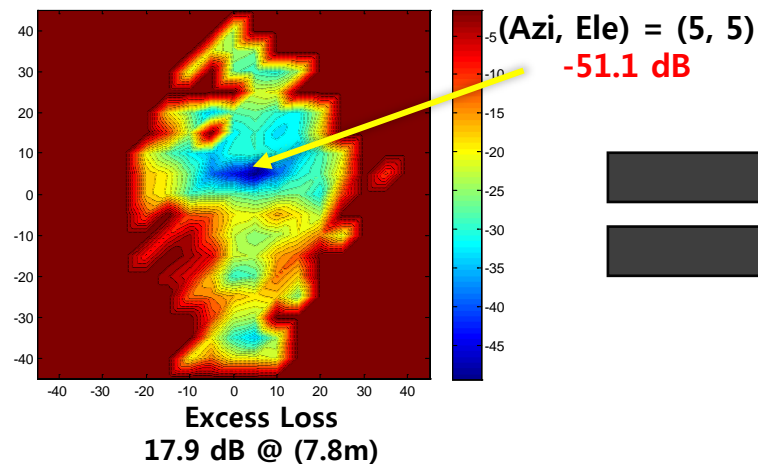
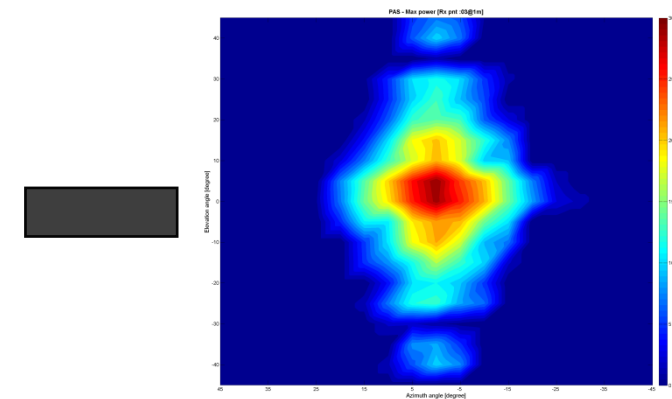


Penetration Loss (2/2)

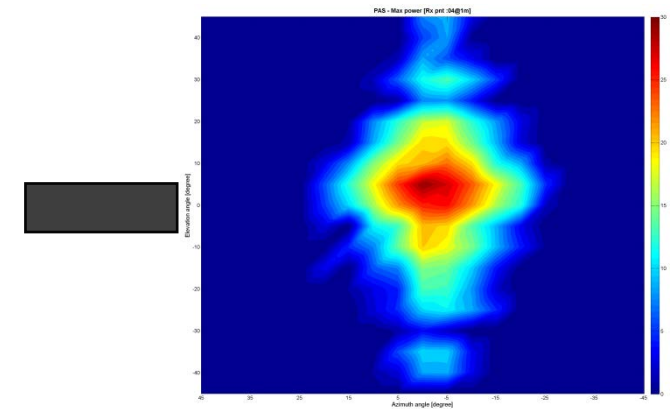
6.3 and 6.5 dB/m penetration loss was observed respectively for single tree and double tree



Received PAS after **single-tree** penetration

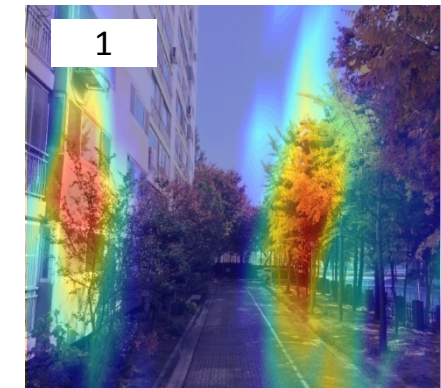
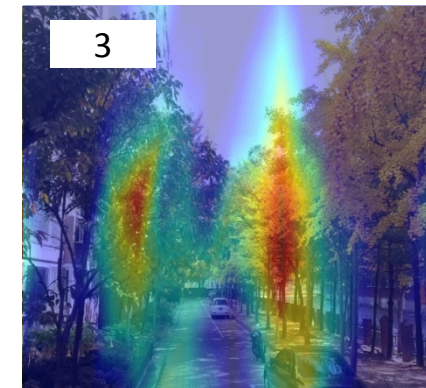
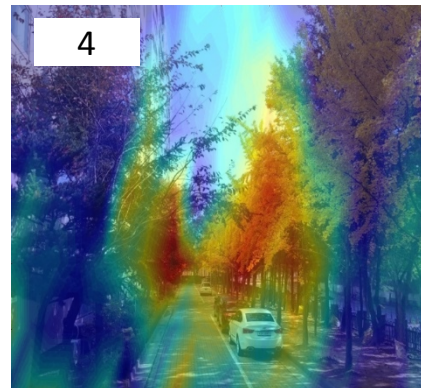
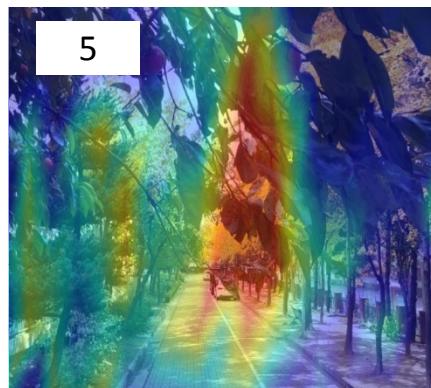
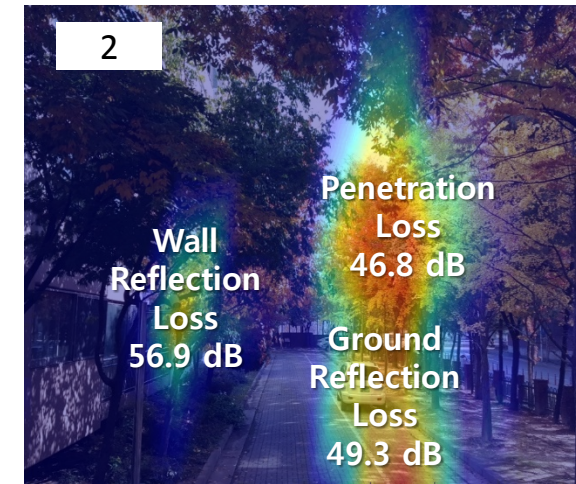


Received PAS after **double-tree** penetration



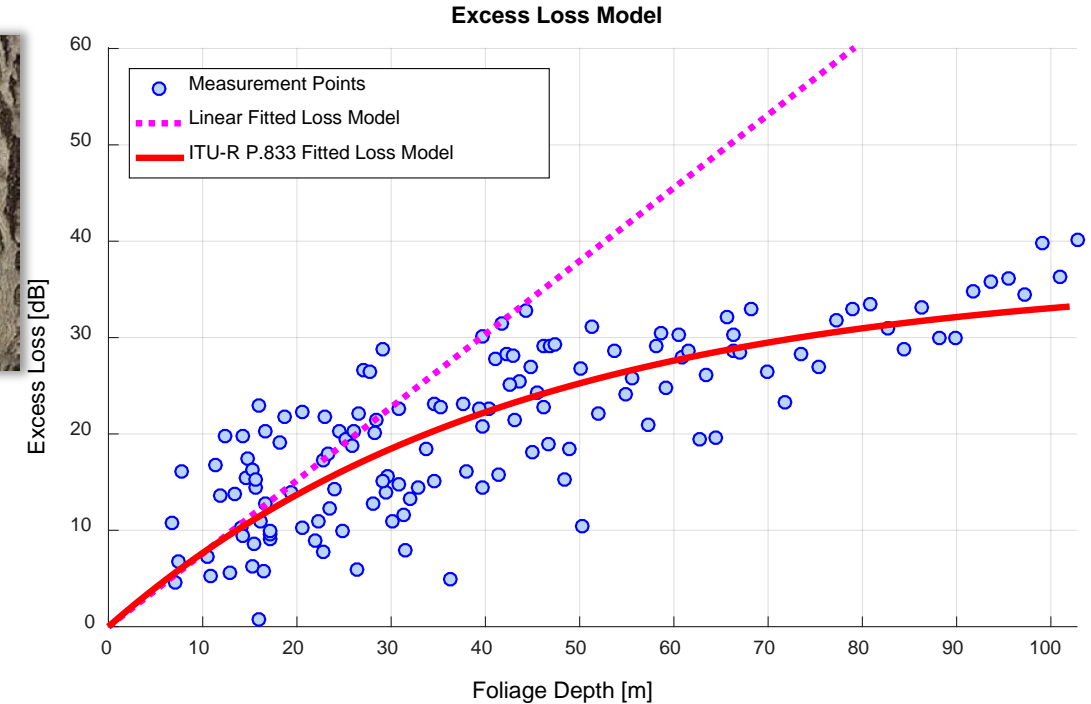
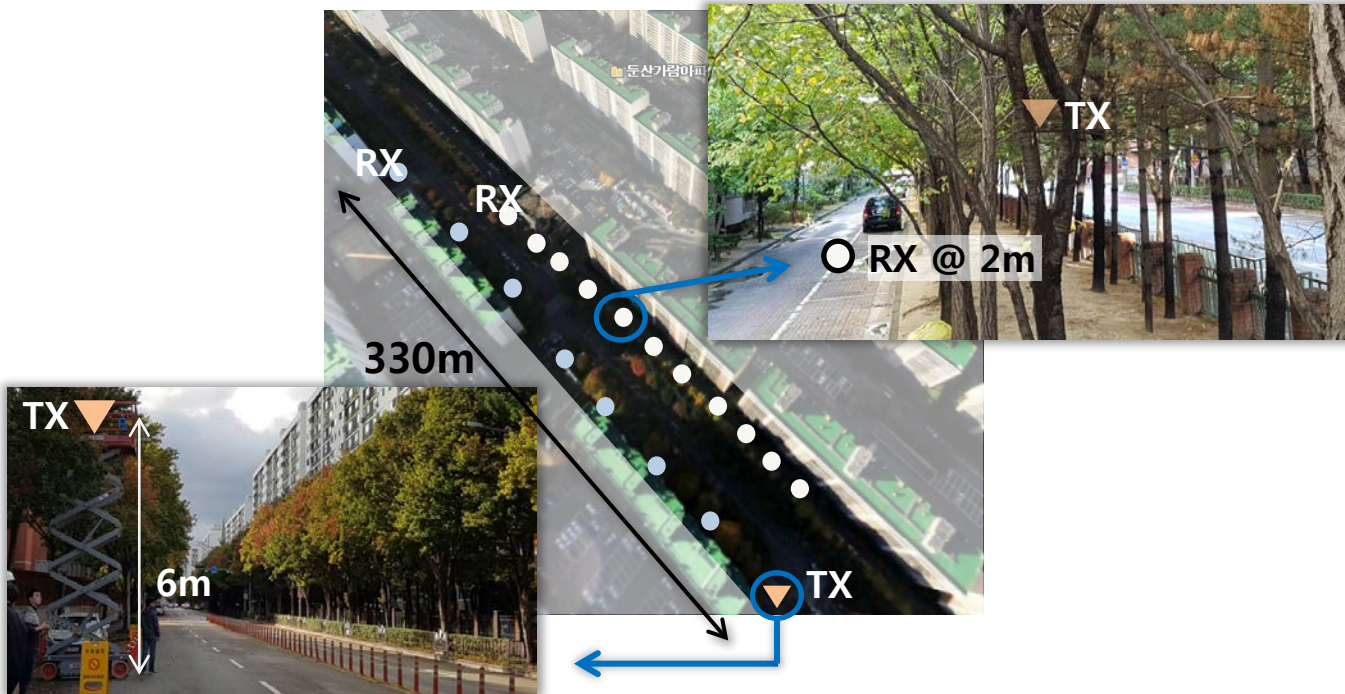
Excess Loss – Reflection Path

Reflection path is one of major components of received signals



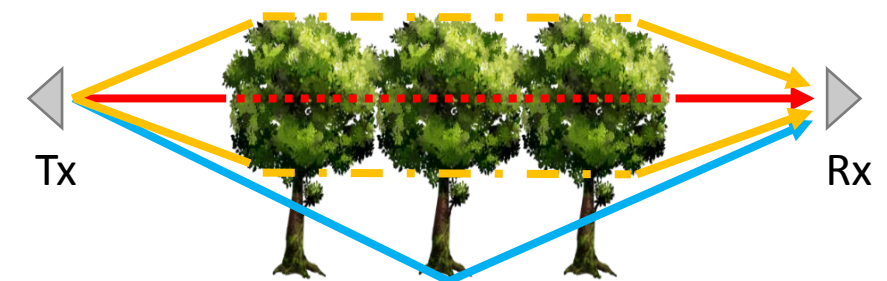
Excess Loss – Typical Roadside Trees (1/2)

Foliage loss is increasing along foliage depth, but “not linearly”



Main propagation mechanisms on foliage are

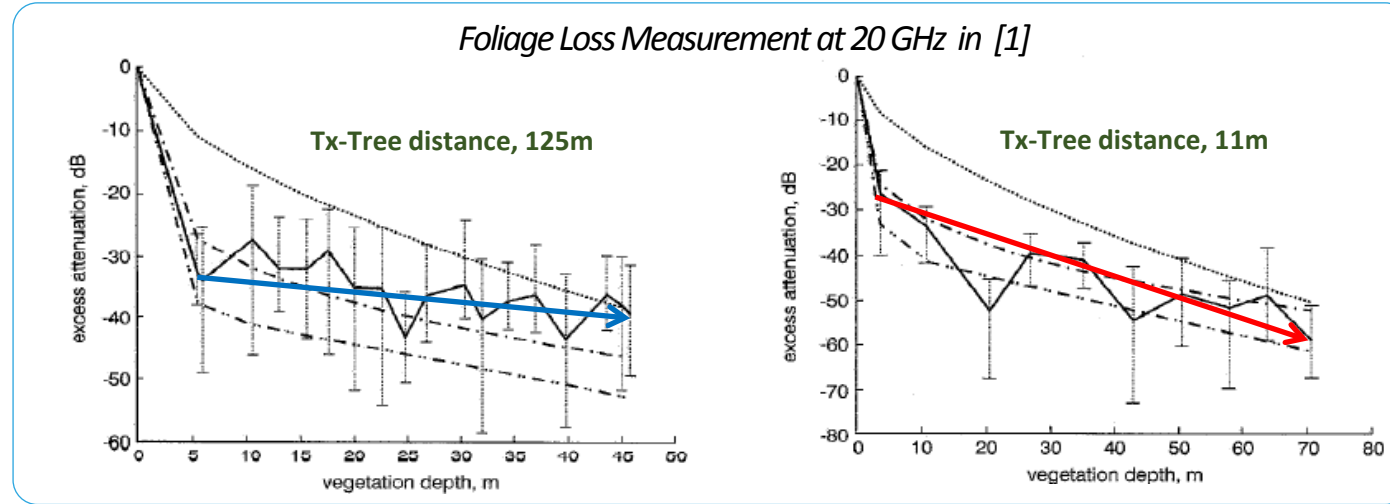
- 1) surface-wave propagation over tree-top/bottom
- 2) forward-scattering within vegetation
- 3) ground-reflected path on tree-trunk



Excess Loss – Typical Roadside Trees (2/2)

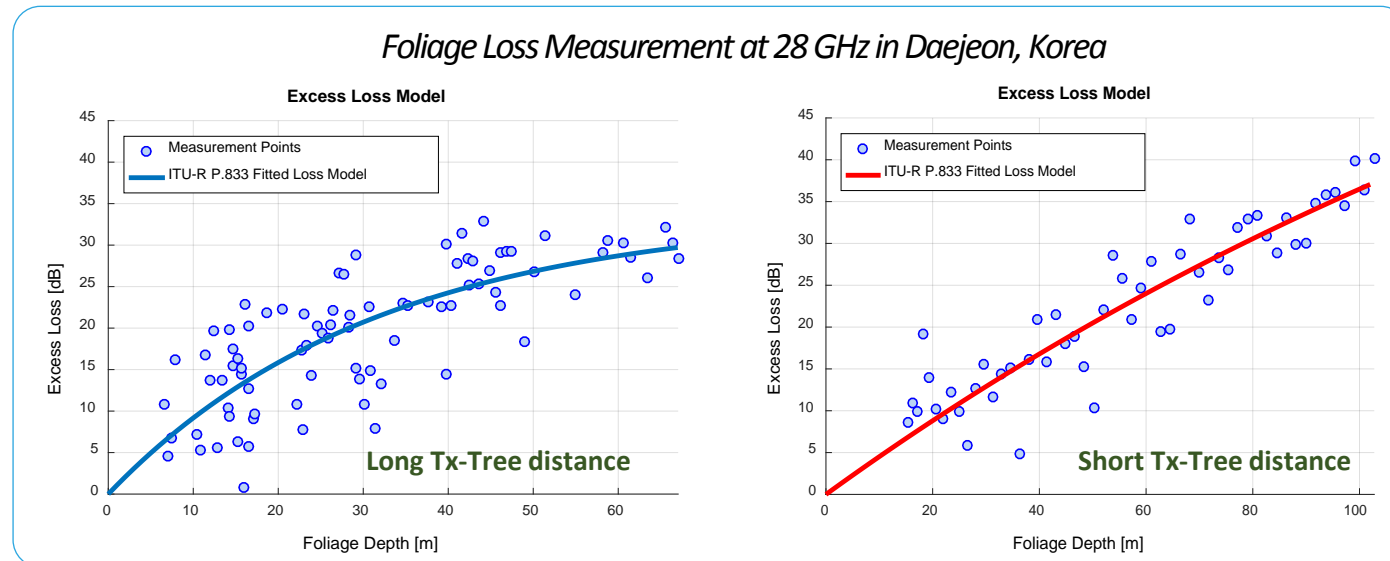
Foliage loss is not extremely increased

- Foliage loss measurement at 20 GHz [1]
- Tendency matches with previous results
- 30~35 dB excess loss up to 50m depth



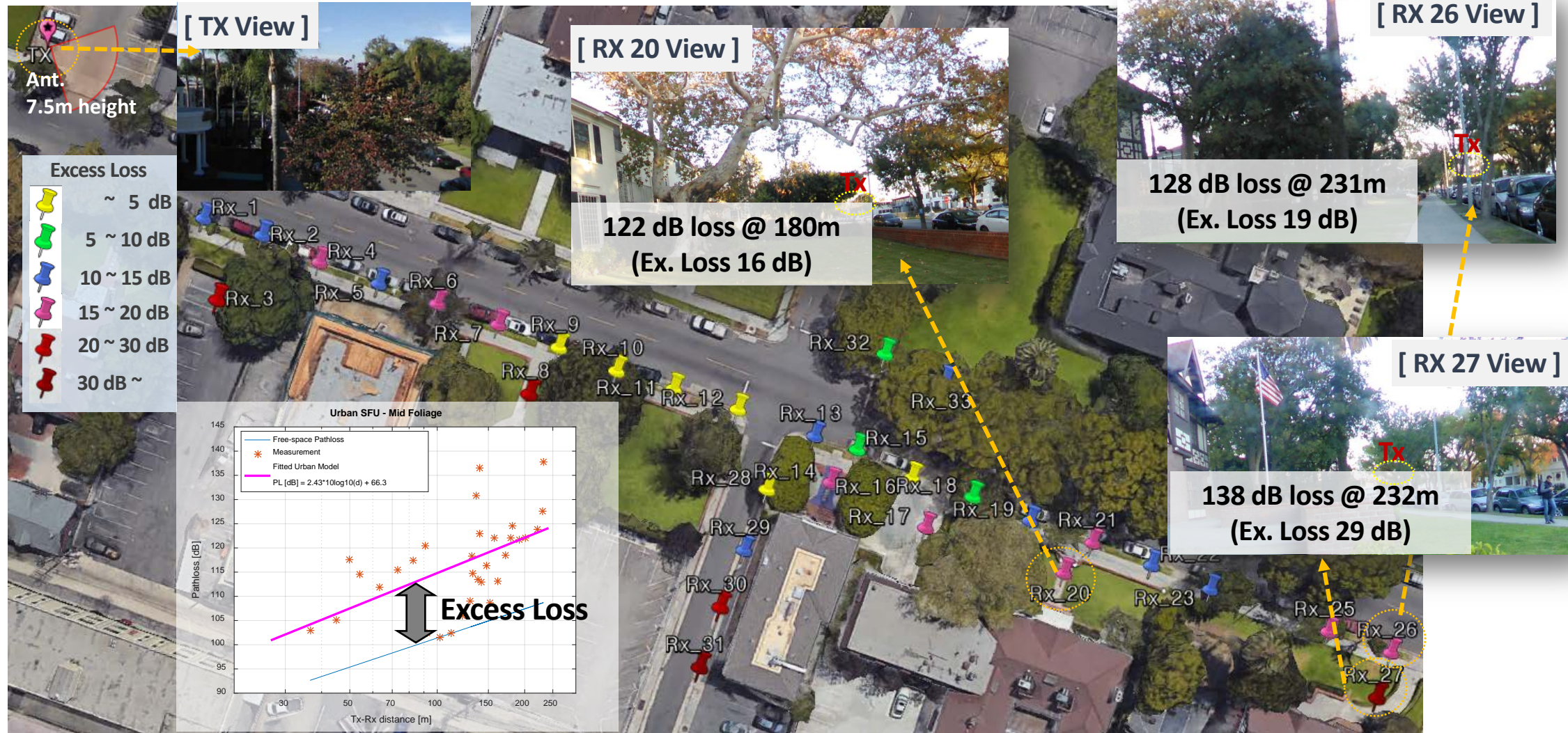
Distance between Tree and Transmitter

- Long distance is likely to have other propagation pathway
- Short distance may block reflected pathways
- Dual-gradient model



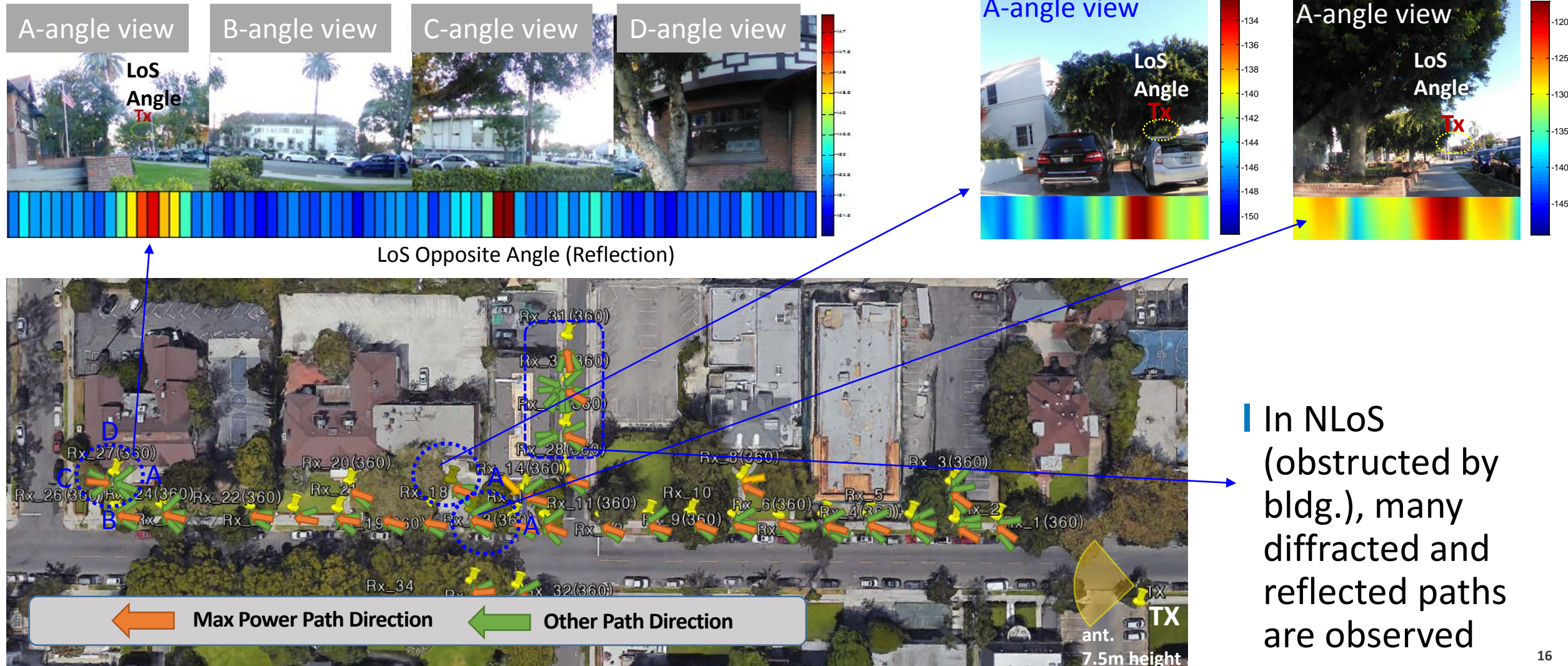
Sub-urban Measurements (1/4)

Pathloss at 232m distance is 138 dB and Max. excess loss is around 30 dB



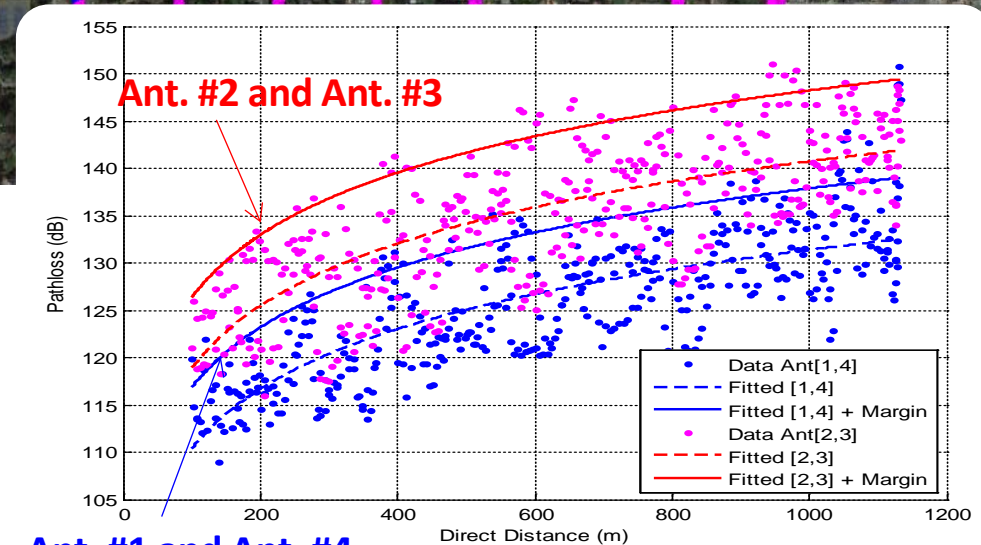
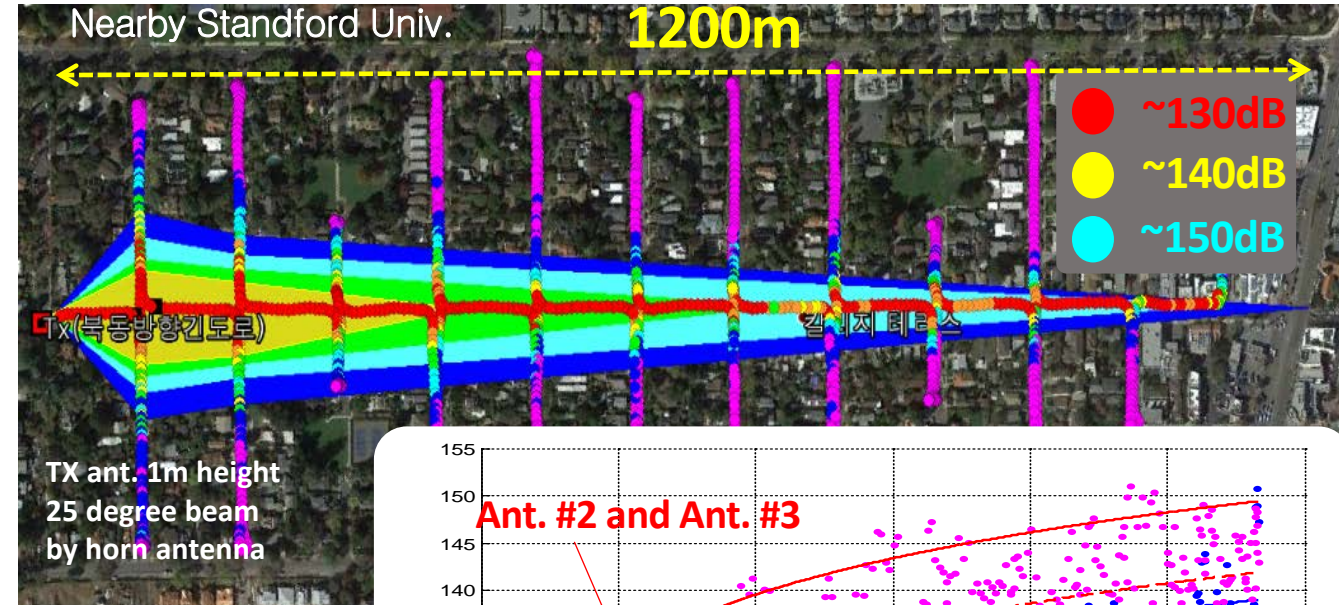
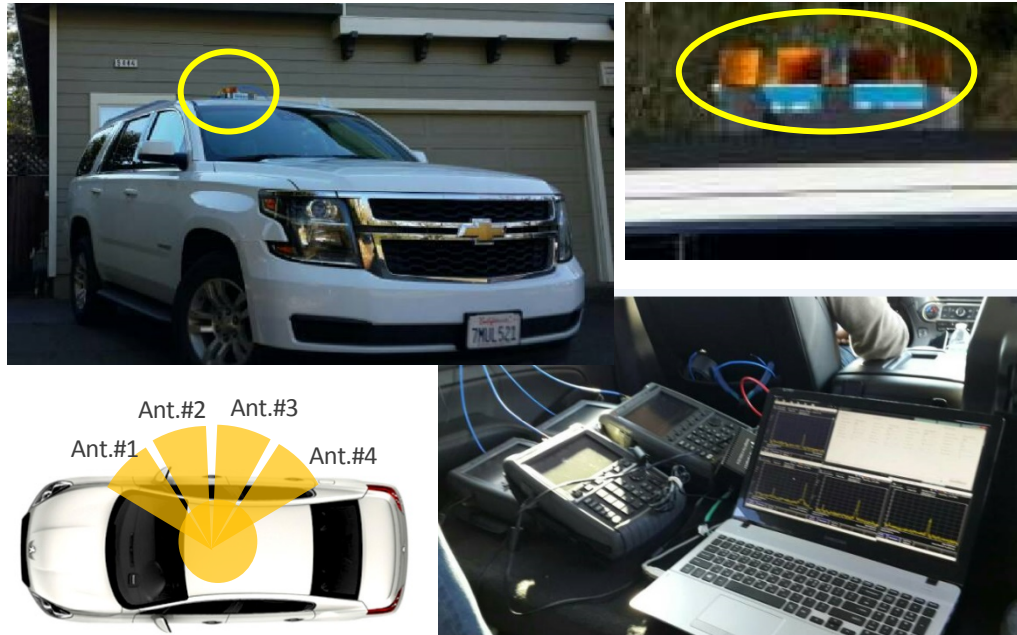
Sub-urban Measurements (2/4)

In vegetated LoS, LoS direction path usually gives strong power



Sub-urban Measurements (3/4)

Measurements indicates several hundreds meter can be supported even in NLoS

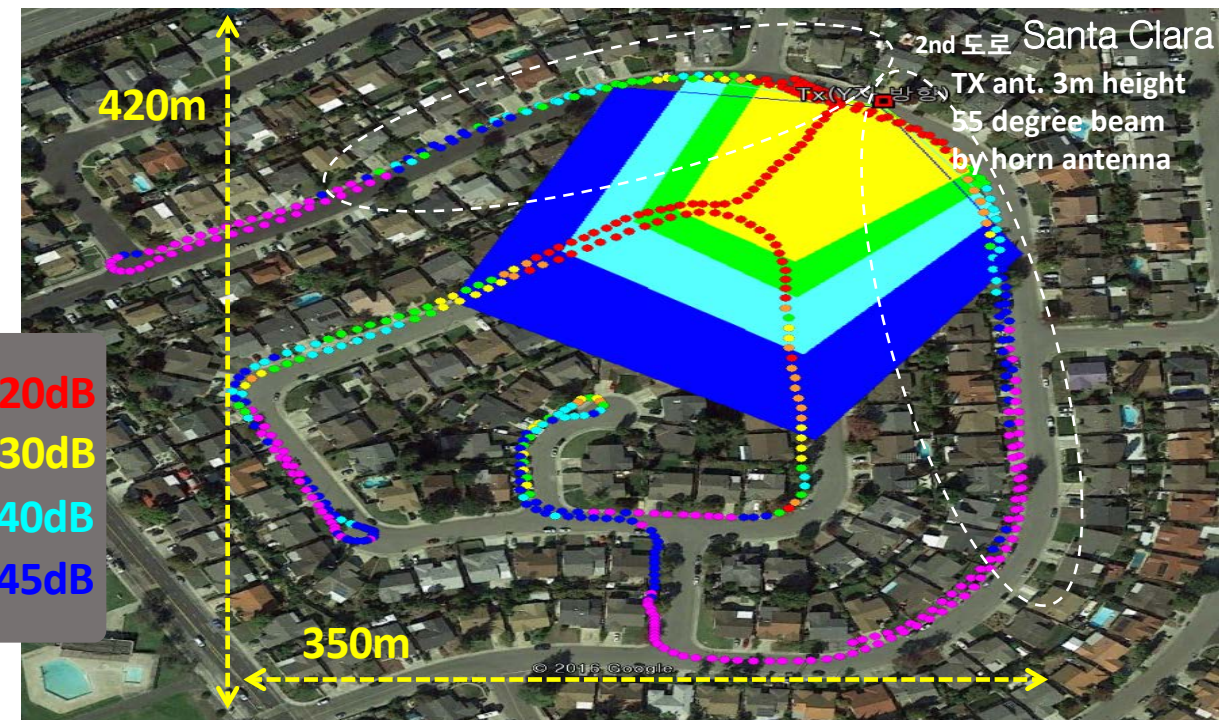
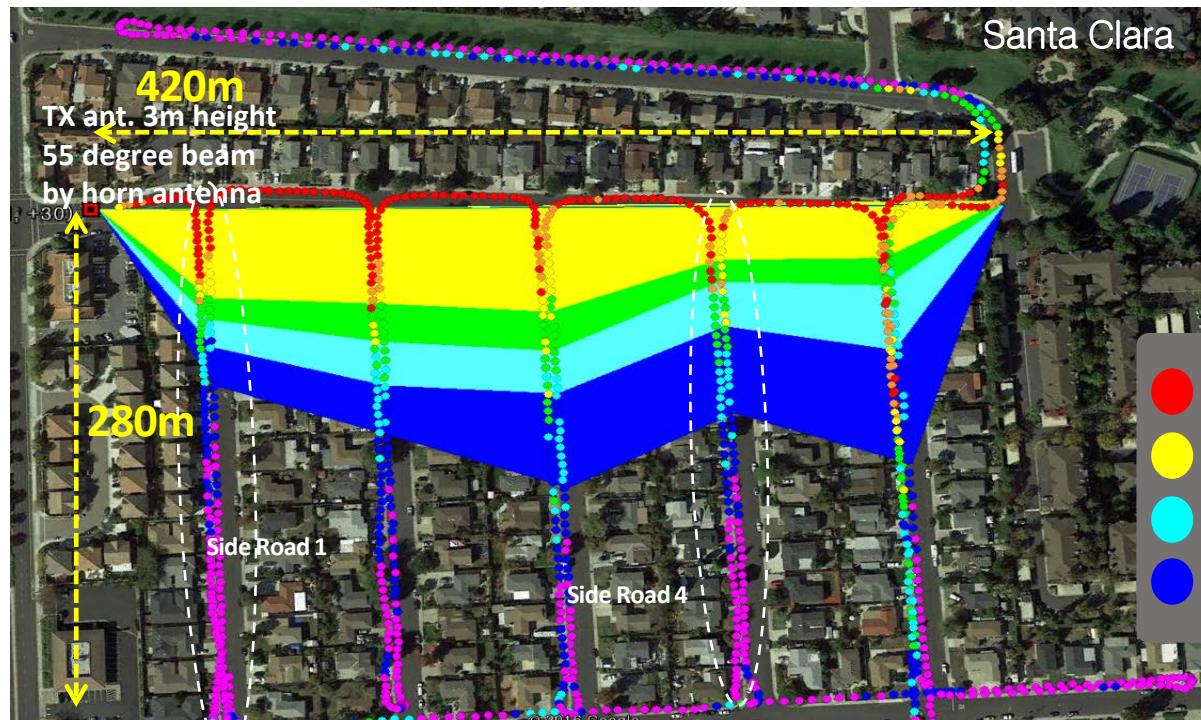


Ant. #1 and Ant. #4

Pathloss measurements in main drive path

Sub-urban Measurements (4/4)

Measurements indicates several hundreds meter can be supported even in NLoS



Rural Measurements (1/2)

○ SFU with **Straight** Road



○ SFU with **Slightly Curved** Road

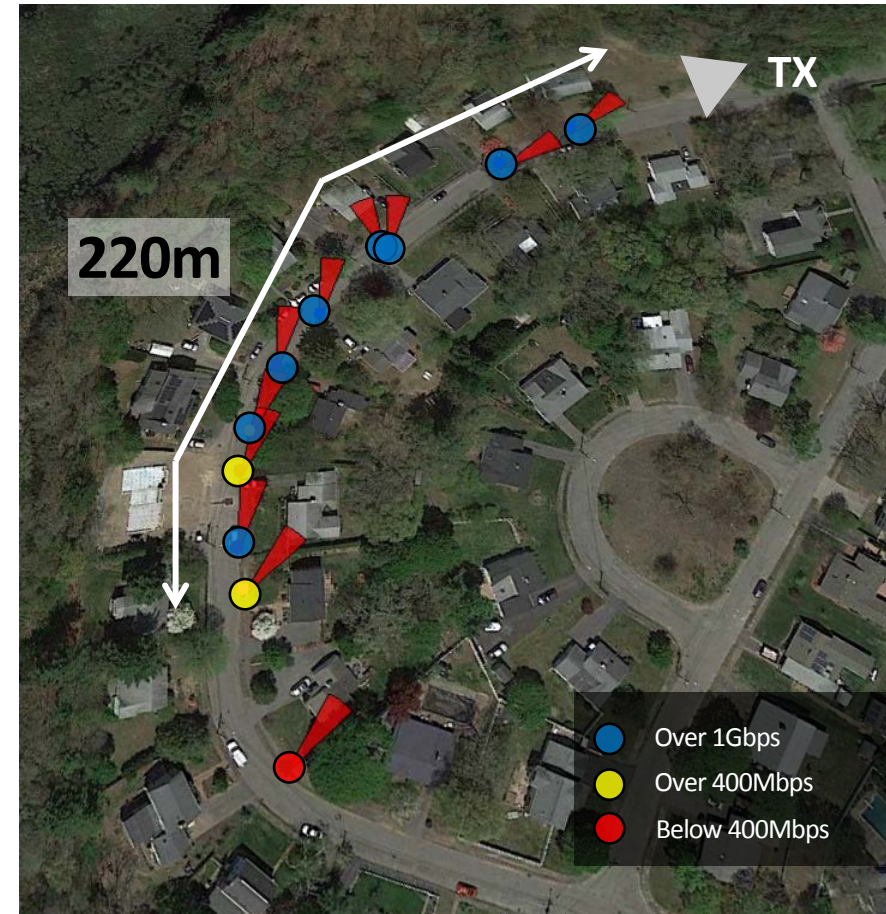


Rural Measurements (2/2)

○ SFU with Curved Road



○ SFU with Highly Curved Road



Field Tests in Korea

Handover Test with SKT (Sept., 2016)

아시아경제

SKT-삼성전자, 세계 첫 5G 핸드오버 시험 성공

본문듣기 | 설정

기사입력 2016-09-20 08:51

기사원문

0 >

공감해요



20일 SK텔레콤 분당사옥 주변에서 SK텔레콤 연구원과 삼성전자 연구원들이 밀리미터파 5G 시스템과 연동한 풀HD

급 영상통화 및 UHD 스트리밍 서비스를 동시에 이동환경에서 시연하고 있다.(사진=SK텔레콤)

Pyeongchang Spec. 1st Call with KT (Oct., 2016)

KT-삼성전자, 5G 평창규격으로 데이터통신 성공

입력시간 | 2016.10.26 09:06 | 김현아 기자 chaos@edaily.co.kr

기자의 다른 기사보기

독자의견

f 좋아요 0

f t y

✉ ⬇ ⬆ + -

KT-삼성전자, 세계최초 KT 5G-SIG 규격' 기반 End-to-End '퍼스트 콜' 성공
 KT, 글로벌 제조사들과 지난 해 11월부터 6월까지 'KT 5G-SIG 규격' 개발
 'KT 5G-SIG 규격' ITU 5G 요구사항 만족, 주요 단체의 핵심 기술요소 반영

[이데일리 김현아 기자]

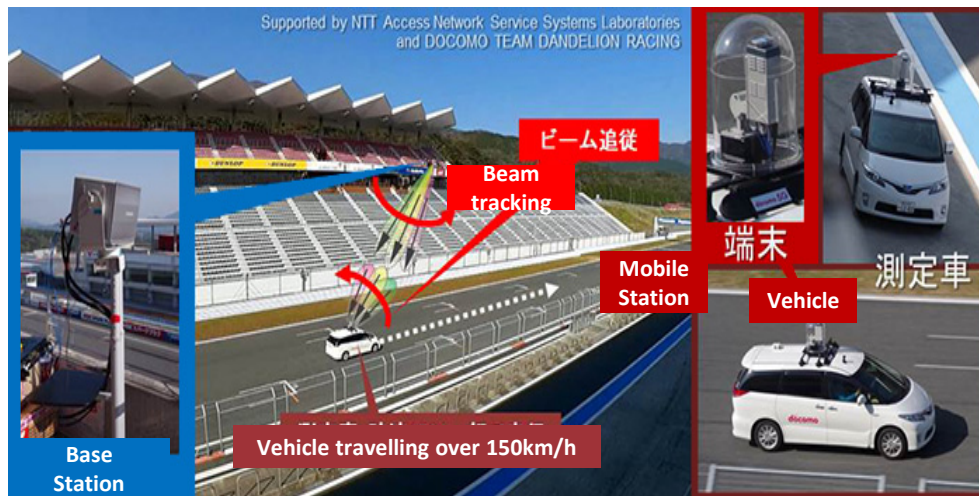


Field Tests in Japan

Trial with Docomo (Nov., 2016, Fuji Speedway)

5G Development Moving Quickly; NTT Docomo, Samsung Achieve 2.5 Gbps at 150 km/h

11/16/16 at 3:54 PM by Andrew Burger



<http://www.telecompetitor.com/5g-development-moving-quickly-ntt-docomo-samsung-achieve-2-5-gbps-at-150-kmh/>

Trial with KDDI (Feb., 2017, Tokyo)

BUSINESS / TECH | ADVANCES IN PROGRESS

With blazing speeds and better connectivity, next-generation 5G network may lay 'foundation' for the future

BY SHUSUKE MURAI

STAFF WRITER



<http://www.japantimes.co.jp/news/2017/03/12/business/tech/blazing-speeds-better-connectivity-next-generation-5g-network-may-lay-foundation-future/#.WNicelXyhhE>

Field Tests in US

Trial with Verizon (Feb., 2016, New Jersey)



Samsung
Basking Ridge, NJ



✂ Verizon, "Verizon Trials Driving 5G Ecosystem" (<https://youtu.be/XFjmrzw-9EM>)

Verizon Press Release (Feb., 2017)

Verizon to test 5G in 11 US cities in 2017, Samsung to help

NEWS by Andrew Grush February 22, 2017



<http://www.androidauthority.com/verizon-5g-samsung-751503/>

5G Service Scenarios

3

Mission Critical Service

- full reliability & high availability
- Real-time responsiveness
- On-the-fly coverage scalability for disaster situations

1

Fixed Broadband

- Next-generation broadband
- Multi-Gbps peak throughputs
- Alternative to costly fibre
- New VAS possibilities for fresh revenue generation

4

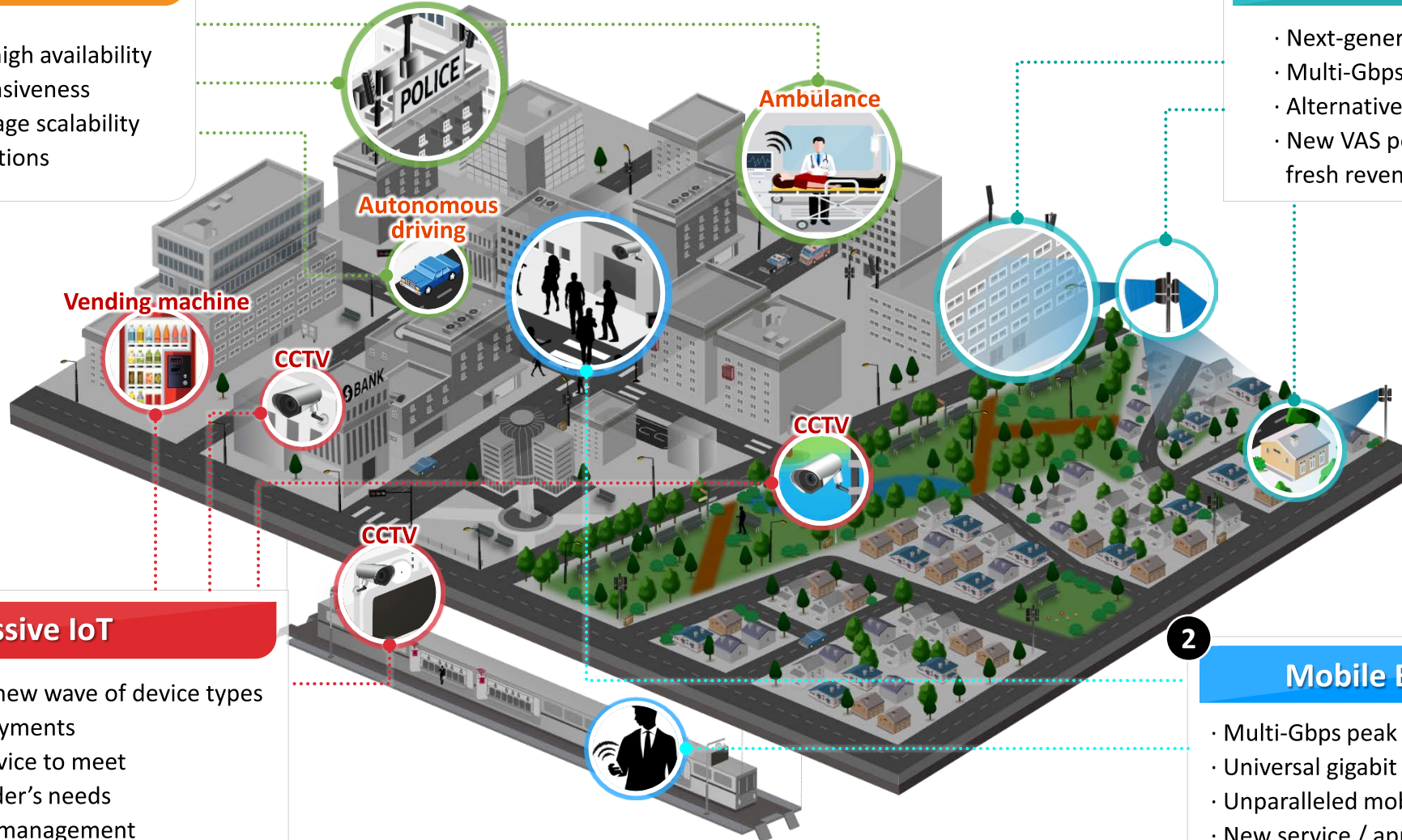
Massive IoT

- Connectivity for a new wave of device types
- High density deployments
- Networks-as-a-Service to meet each service provider's needs
- Robust QoE / QoS management
- New revenue opportunities

2

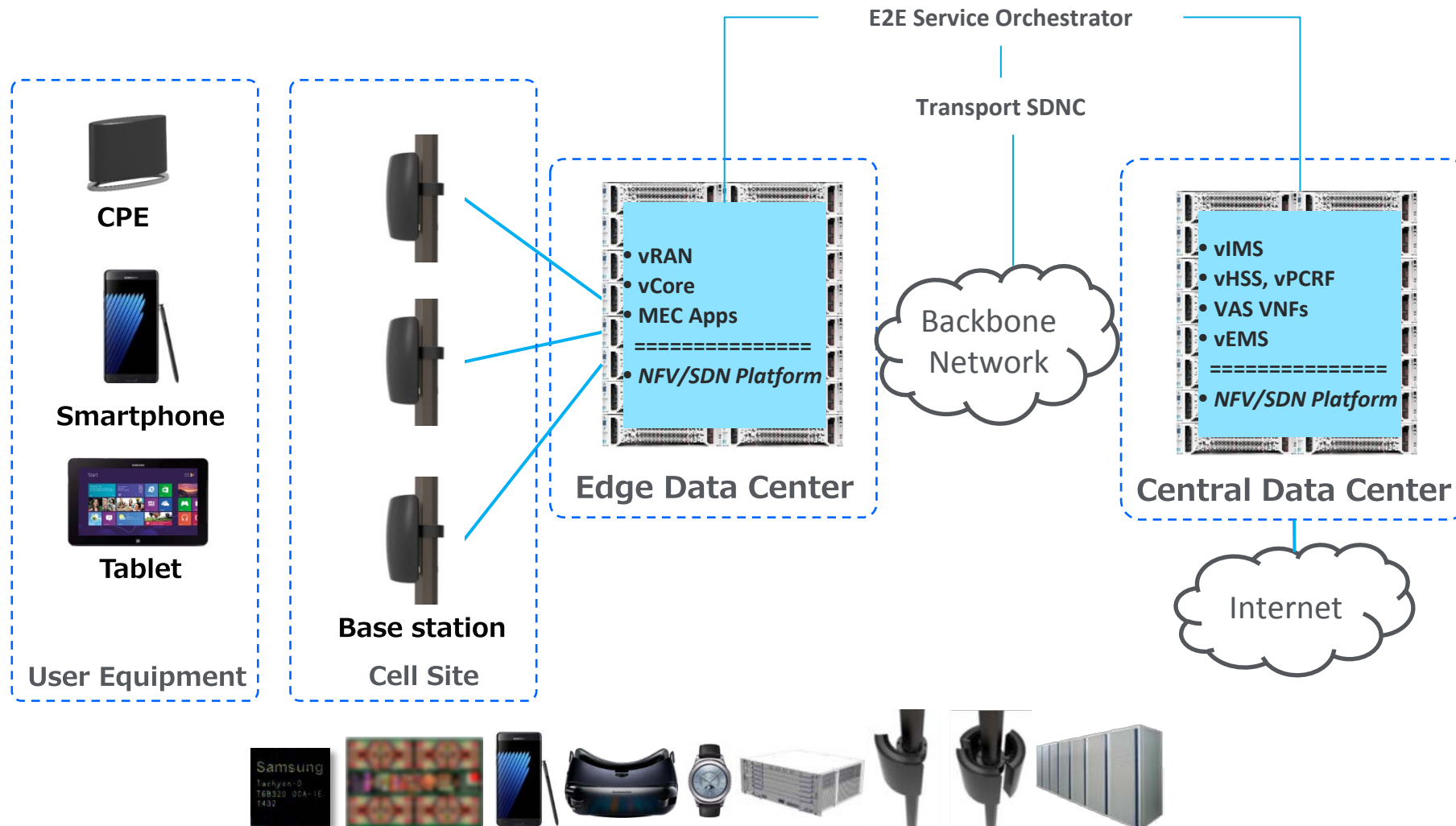
Mobile Broadband

- Multi-Gbps peak throughputs
- Universal gigabit connectivity
- Unparalleled mobility support
- New service / application enablement
- Advanced big data analytics



5G End-to-End Systems

| Samsung is Developing an E2E Portfolio of 5G Products : UE, Access, and Core



Thank You