5G Trial and Field Test

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5G Vision

Enabling New Services through Convergence

Massive Machine-type Communications

- U-health / Wearables
- Smart Home / Smart City

Ultra Reliable & Low Latency

- Smart Vehicle
- Industrial Automation

Enhanced Mobile Broadband

- Mobile Cloud Computing
- UHD Streaming

5G designed to enable entirely new domains of service.

Innovation

2013 - 2014

Base Station

Mobile Station

World's 1st mmWave High Speed Test

(October 2014)

· 7.5 Gbps at Stationary

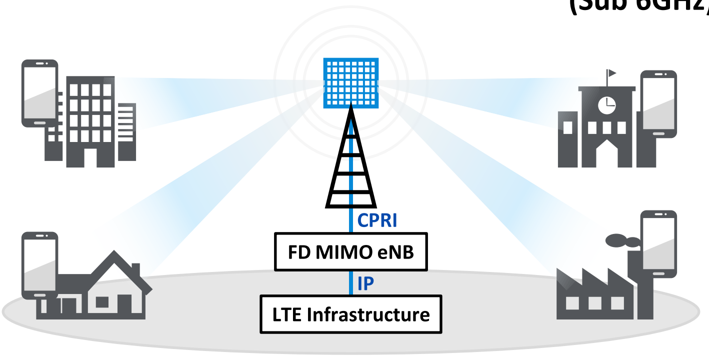
· 1.2Gbps at >100km/hr

2015

· Avg. 1.7Gbps at 25km/hr

FD-MIMO with Massive Antenna Tech.

(Sub 6GHz)



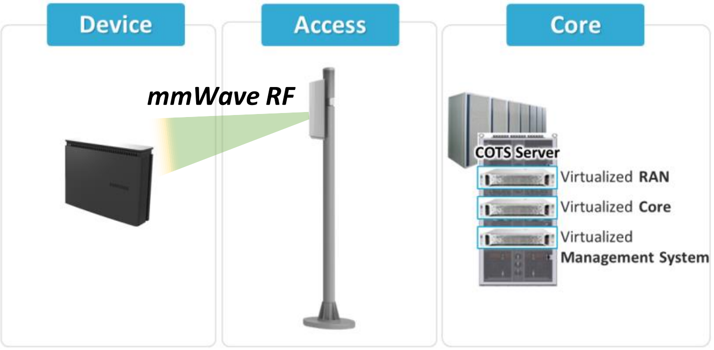
2016

3.7Gbps peak using live commercial backbone NW

'Samsung Delivers on Gigabit Wireless Promise of 5G'

5G End-to-End Products

(Commercial)



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Challenges and Opportunities

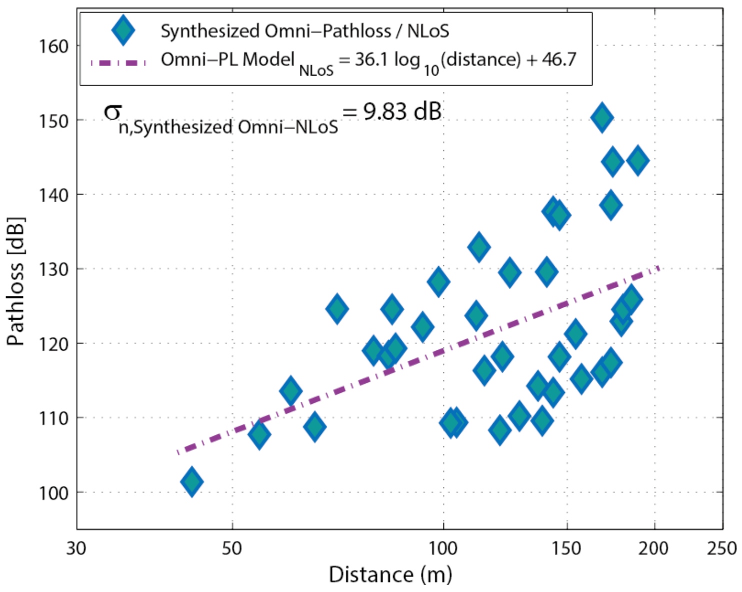
Challenges for mmWave

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

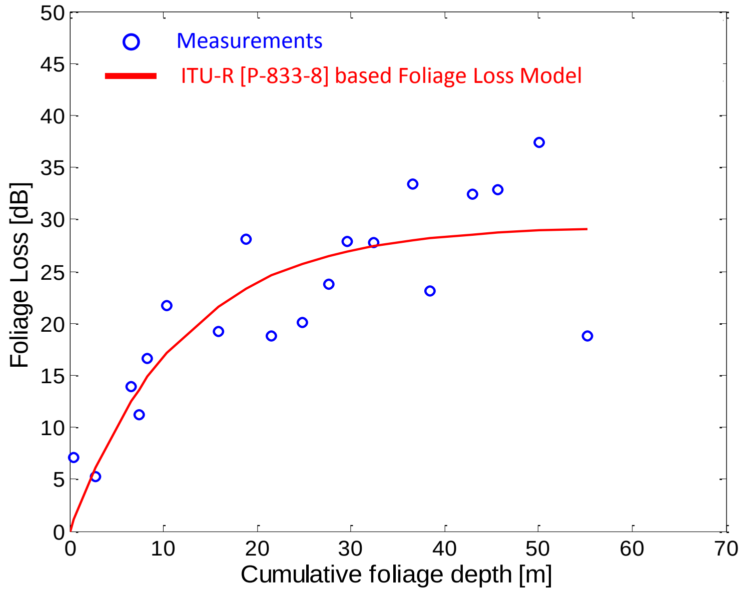
Realizing 5G mmWave

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

28 GHz Channel Sounder [TX]

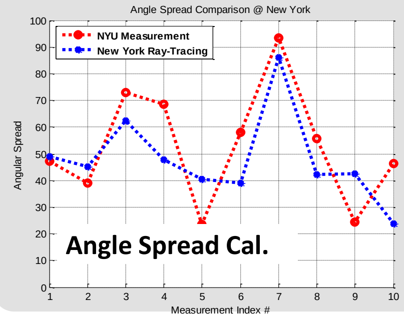
[RX]

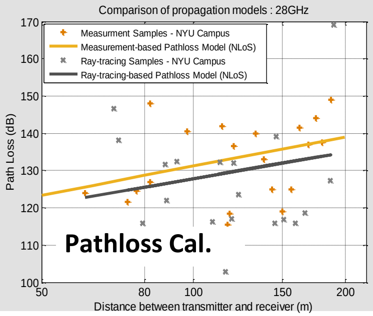
NYU campus

2018 Winter Olympic Resort

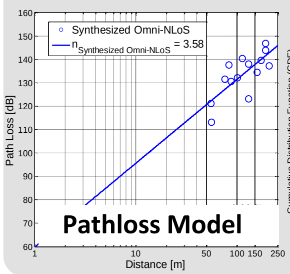
Channel Modeling

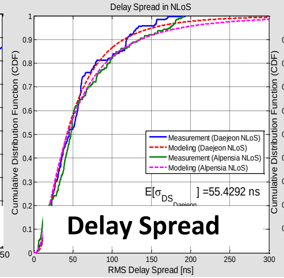
- Calibration

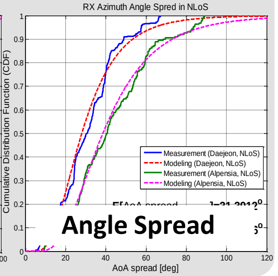




- Channel modeling







Samsung's Activity on Channel Modeling

- Universities & research centers
  - NYU, USC, KAIST
- Research projects
  - 5G PPP mmMAGIC, COST IC1004
- Standard
  - Rapporteur on 3GPP 5G Channel Model SI for > 6GHz

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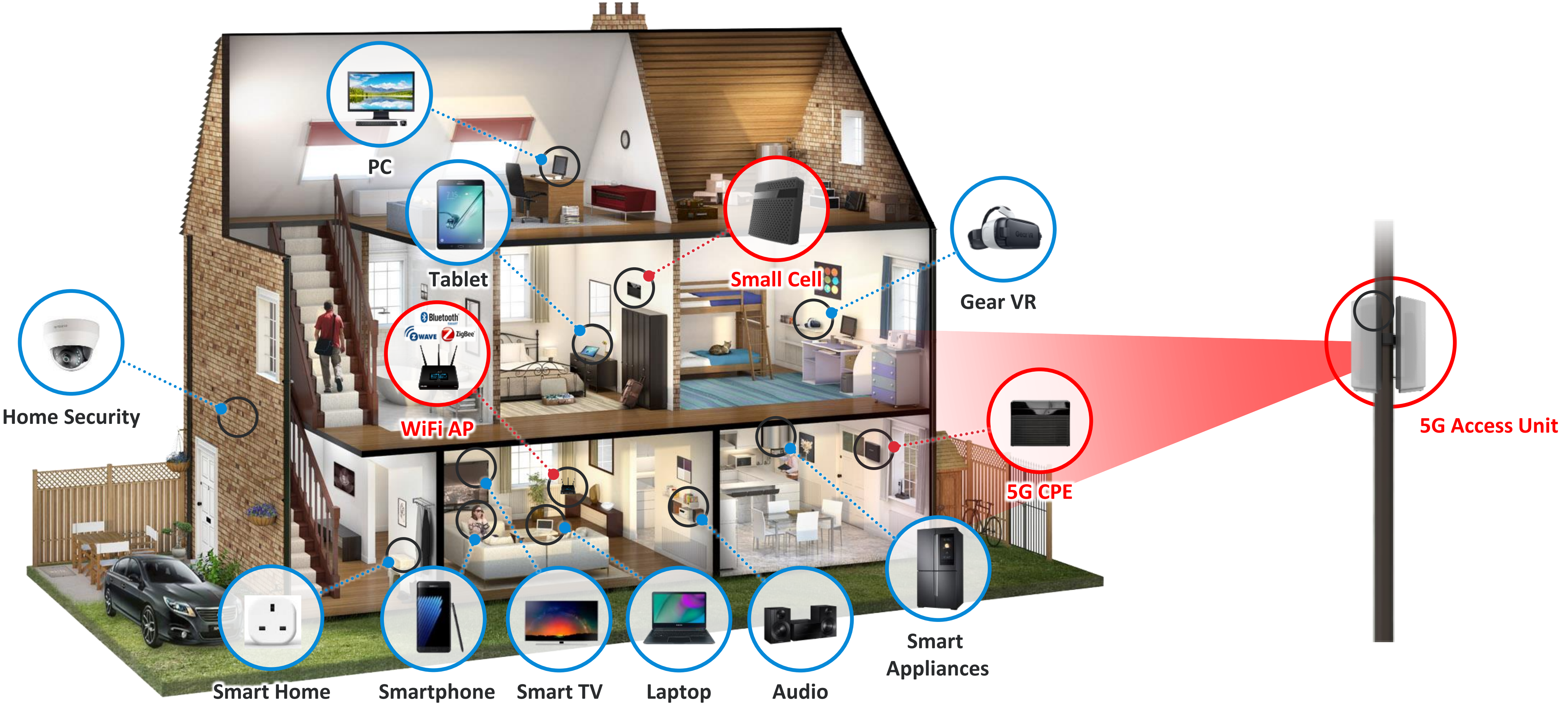
Fixed Wireless Access as First 5G Use Case

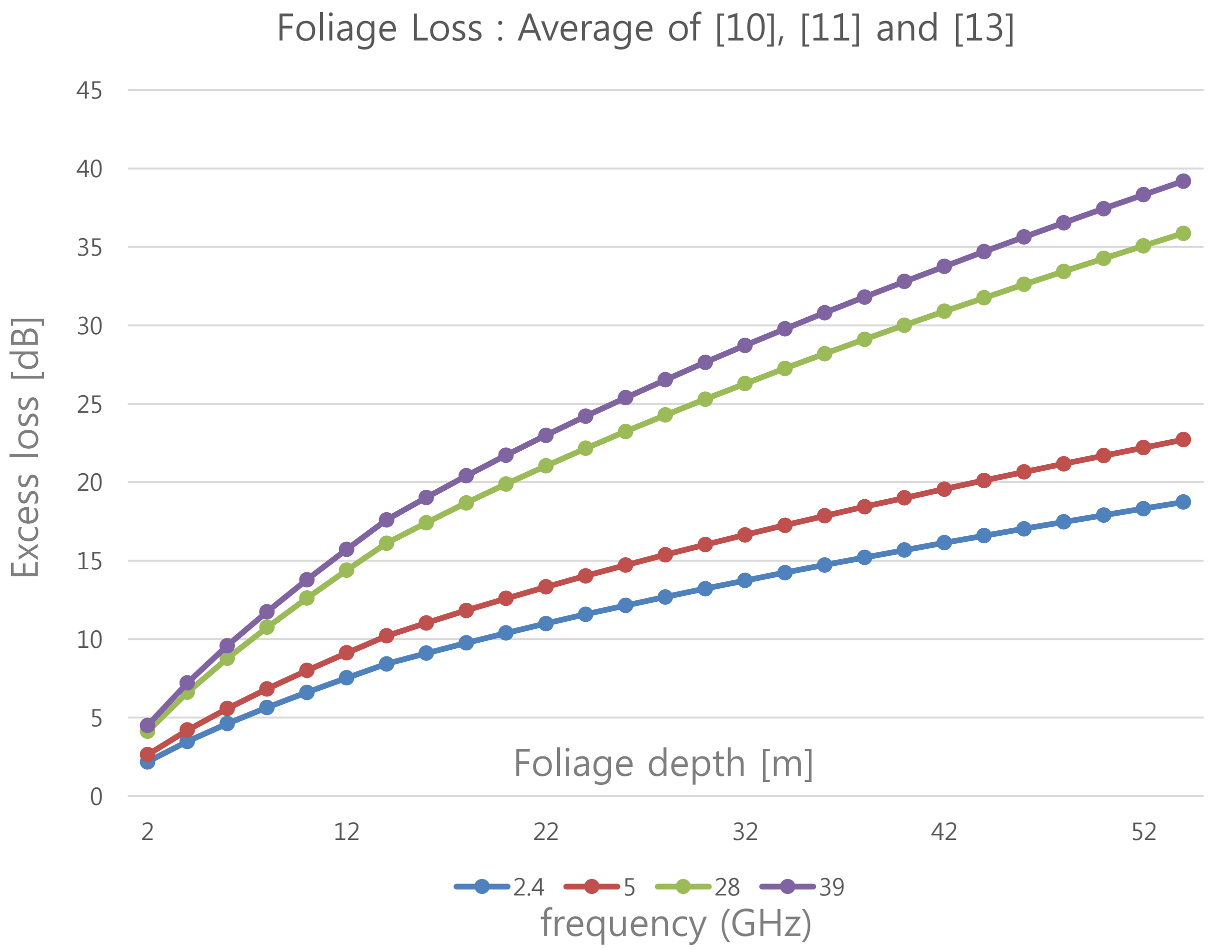
An Alternative to Fiber for Delivering 5G Broadband to Homes and Offices



Typical FWA Environments (US)

Previous Studies for Foliage Loss

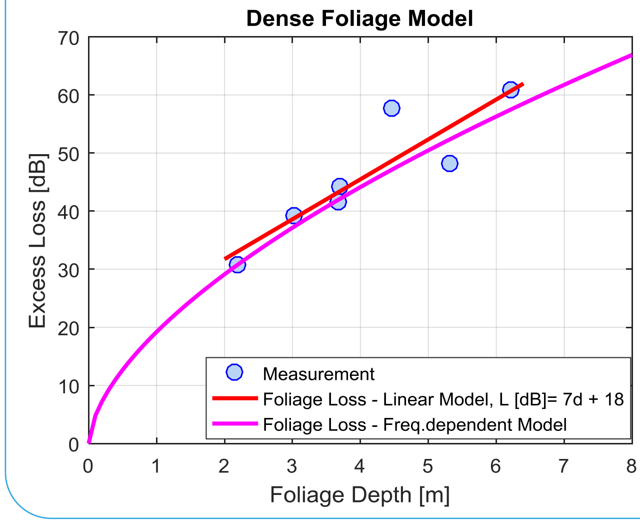
Model	Expression
Weissberger model [10]	$L_W\,(\text{dB}) = \begin{cases} 1.33 \times f^{0.284} d^{0.588} & 14\,\text{m} < d \le 400\,\text{m} \\ 0.45 \times f^{0.284} d & 0\,\text{m} \le d < 14\,\text{m} \end{cases}$ f is frequency in GHz, and d is the tree depth in meter
ITU-R model [11]	$L_{ITU\text{-}R}\,(\text{dB}) = 0.2 \times f^{0.3} d^{0.6}$ f is frequency in MHz, and d is the tree depth in meter ($d < 400\,\text{m}$)
COST235 model [12]	$L_{COST}\,(\text{dB}) = \begin{cases} 26.6 \times f^{-0.2} d^{0.5} & \text{out-of-leaf} \\ 15.6 \times f^{-0.009} d^{0.26} & \text{in-leaf} \end{cases}$ f is frequency in MHz, and d is the tree depth in meter
FITU-R model [13]	$L_{FITU\text{-}R}\,(\text{dB}) = \begin{cases} 0.37 \times f^{0.18} d^{0.59} & \text{out-of-leaf} \\ 0.39 \times f^{0.39} d^{0.25} & \text{in-leaf} \end{cases}$ f is frequency in MHz, and d is the tree depth in meter
MA model [14]	$L_{MA}\,(\text{dB}) = A_m\,[1 - \exp(-R_0 d / A_m)]$ 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
NZG model [14]	$L_{NZG}\,(\text{dB}) = R_\infty d + k\left(1 - \exp\left\{\frac{-(R_0 - R_\infty)}{k} d\right\}\right)$ 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
DG model [15]	$L_{DG}\,(\text{dB}) = \frac{R_\infty}{f^a w^b} d + \frac{k}{w^c}\left(1 - \exp\left\{\frac{-(R_0 - R_\infty)}{k} w^c d\right\}\right)$ 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.



Foliage Loss ?

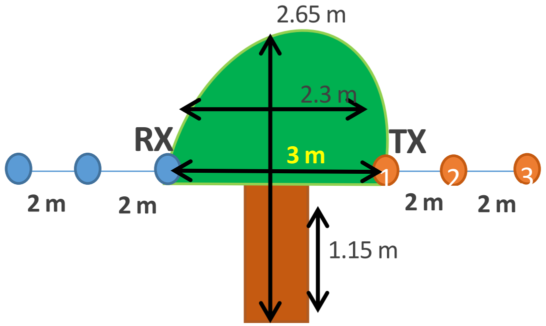
- Pure foliage penetration loss
- Excess loss considering reflection and diffraction path need between Tx and Rx

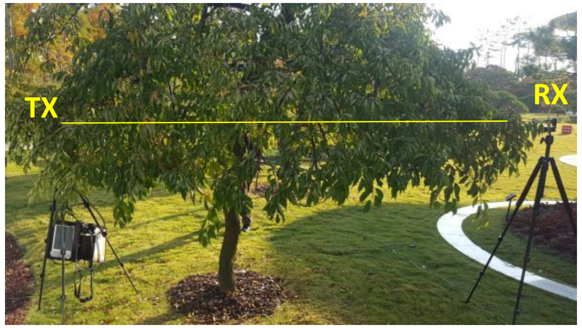
Measurement for Foliage-penetration Path

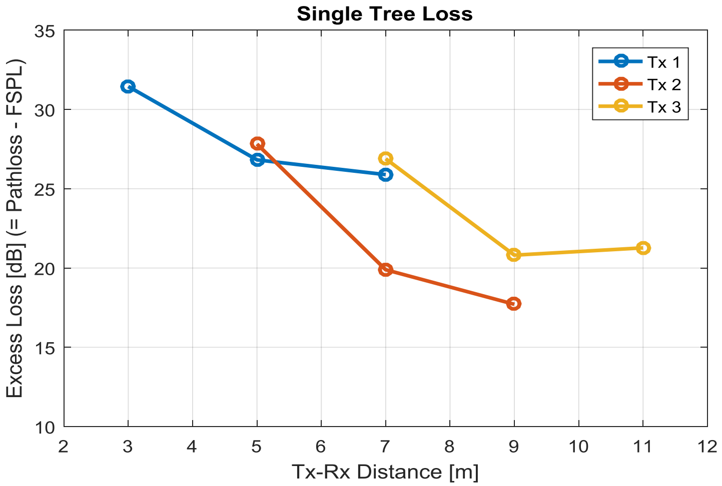


Pure foliage-penetrated path can be severely attenuated, as **7~10 [dB/m]**

Excess Loss Measurement on Single-tree





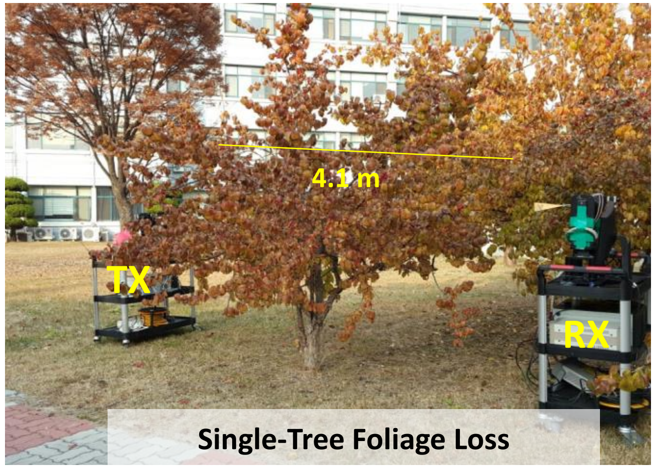


The long-distance between Tx/Rx and tree can help other propagation pathway

Penetration Loss (1/2)

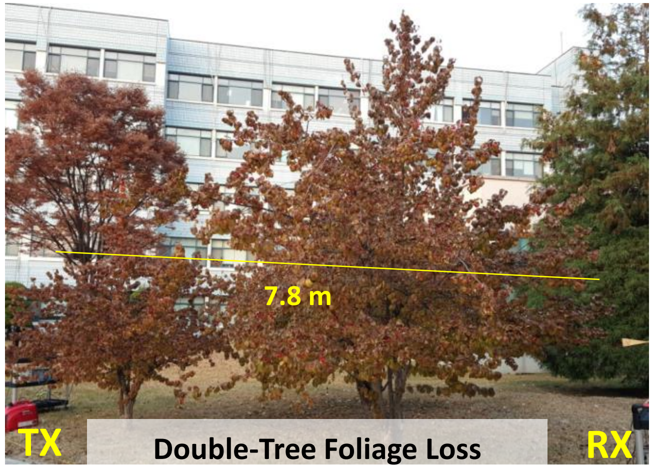
Power-Angular Spectrum Analysis on Foliage Loss

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



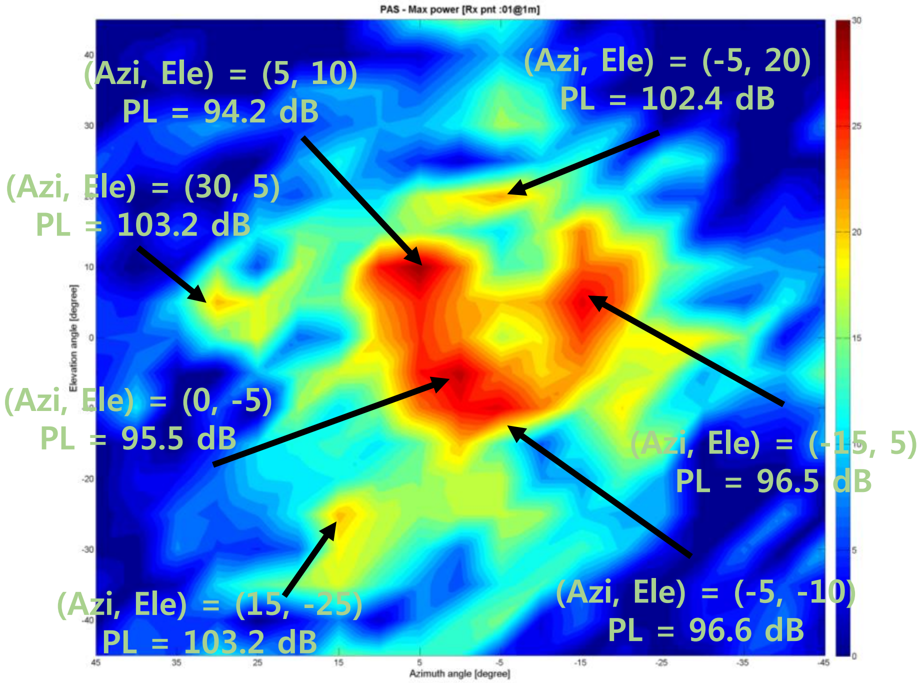
Single-Tree Foliage Loss

TX view



Double-Tree Foliage Loss

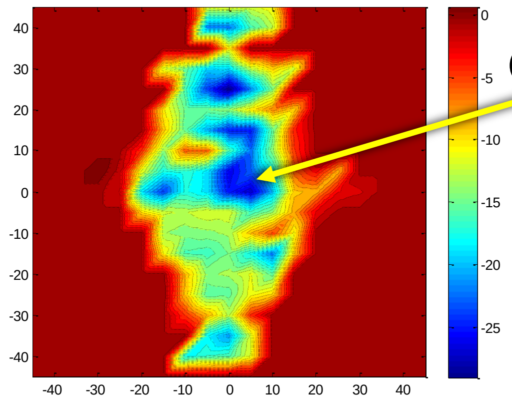
RX view @ 2nd tree



Power-Angular Spectrum (PAS) of Single-Tree Foliage Loss

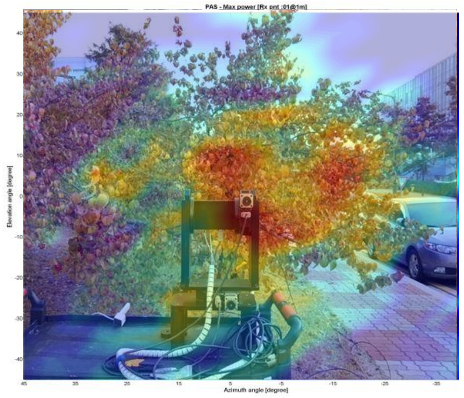
Penetration Loss (2/2)

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

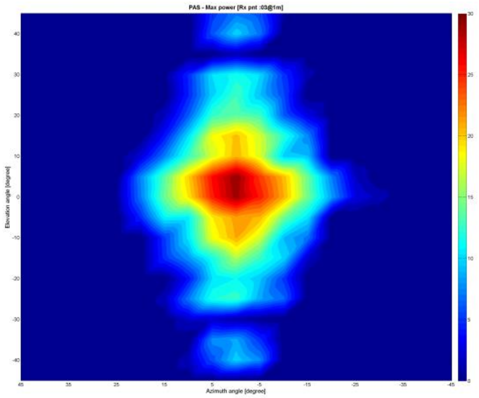


(Azi, Ele) = (0, 5)
-25.8 dB

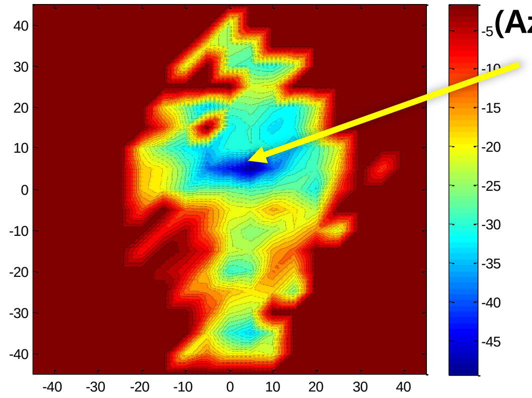
Excess Loss
10.5 dB @ (4.1m)



Received PAS after single-tree penetration



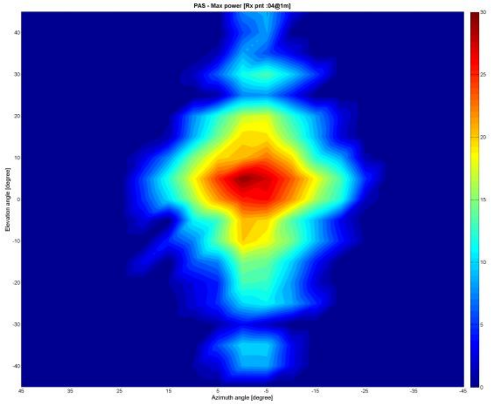
4.1m FSPL PAS



(Azi, Ele) = (5, 5)
-51.1 dB

Excess Loss
17.9 dB @ (7.8m)

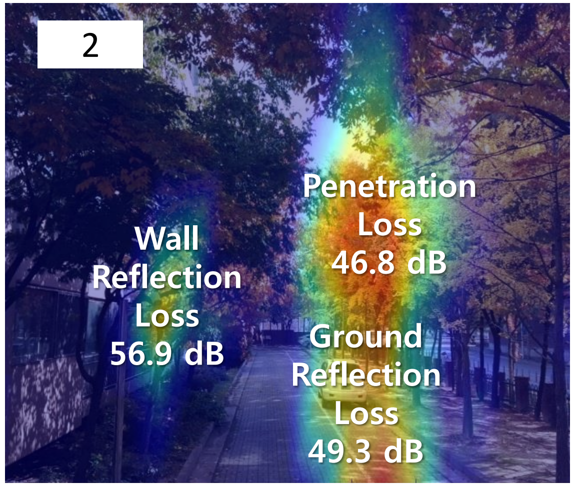
Received PAS after double-tree penetration

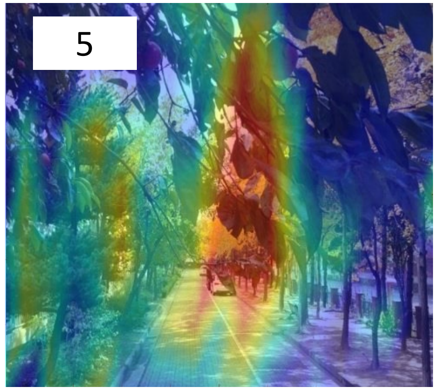


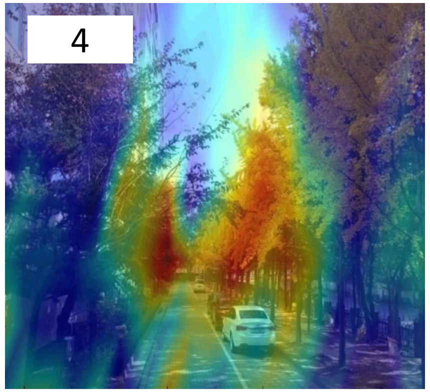
7.8m FSPL PAS

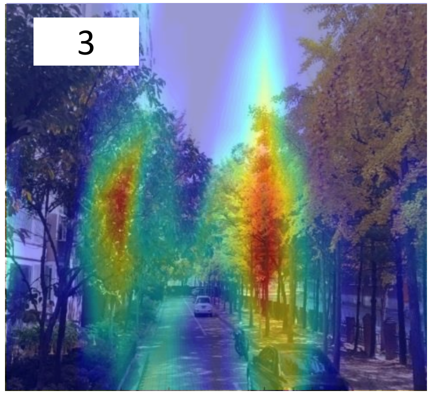
Excess Loss – Reflection Path

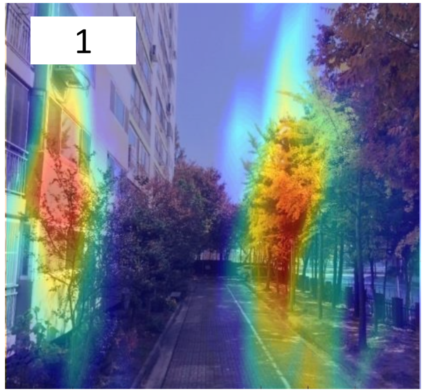
- Reflection path is one of major components of received signals





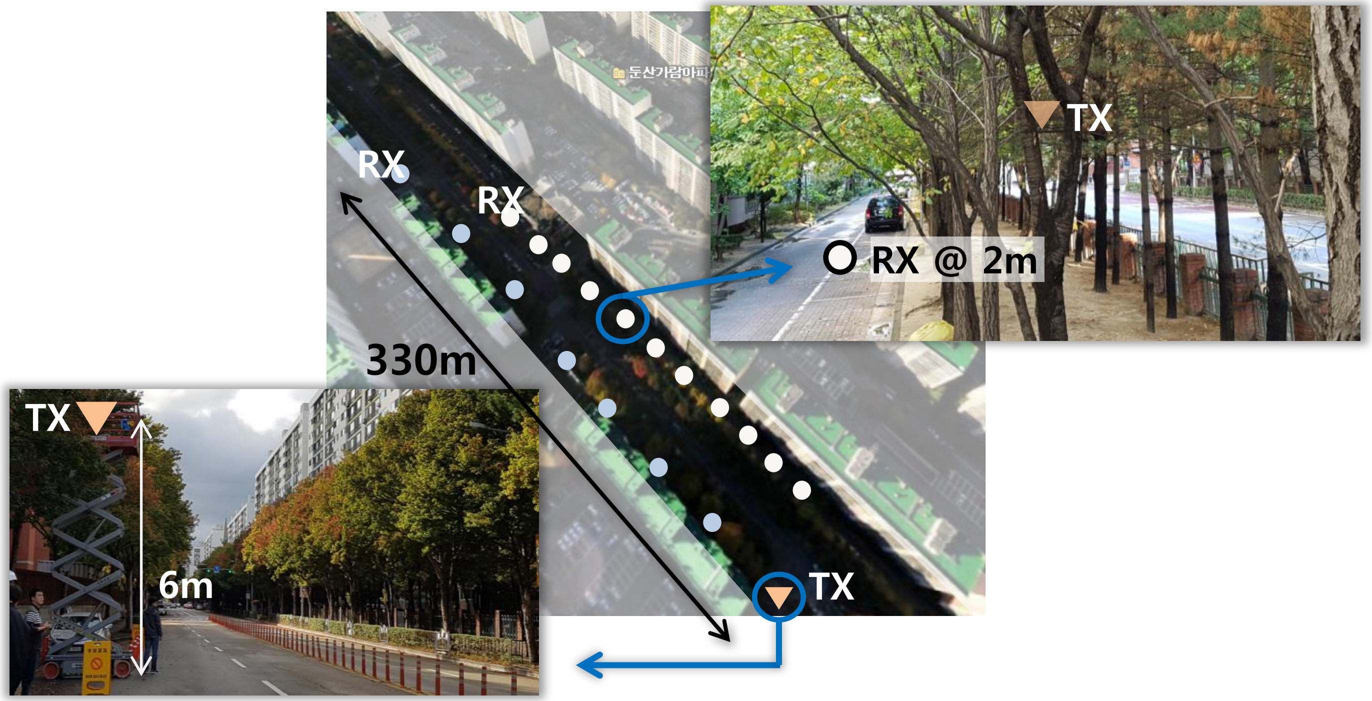


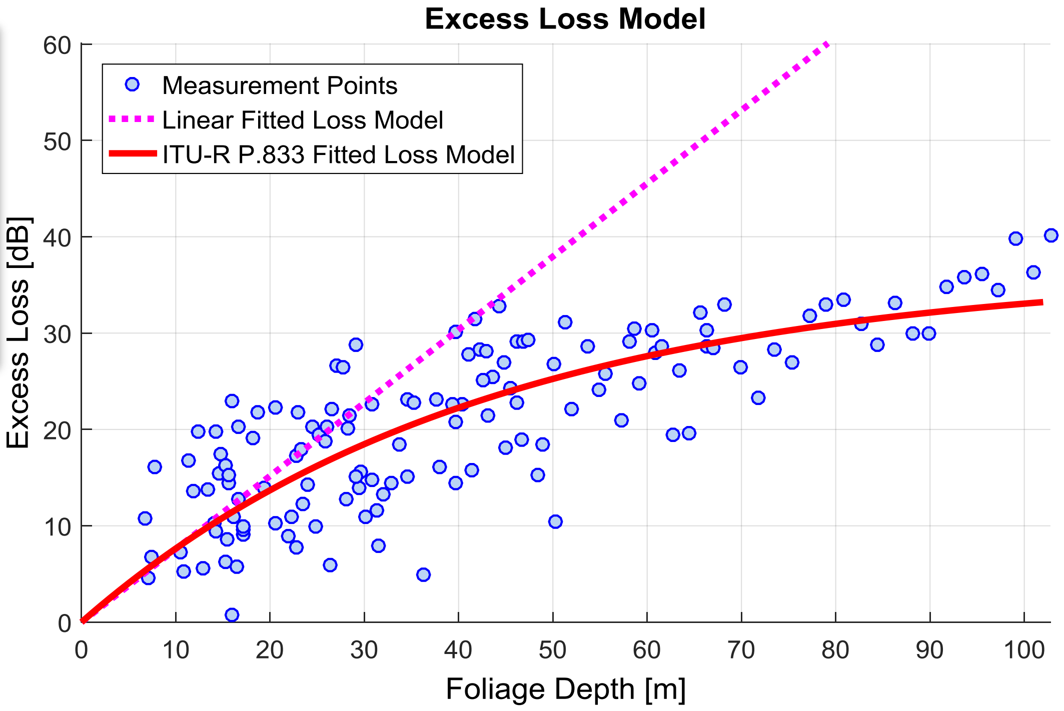




Excess Loss – Typical Roadside Trees (1/2)

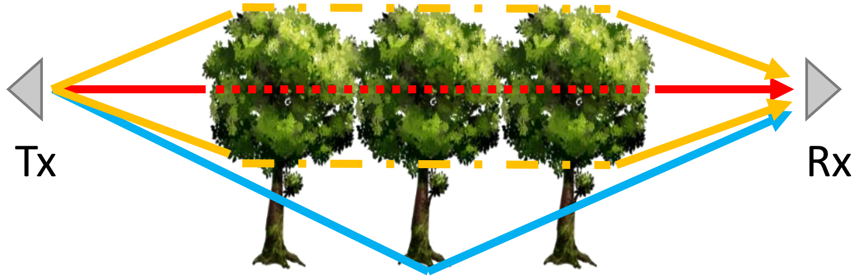
- Foliage loss is increasing along foliage depth, but “not linearly”





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

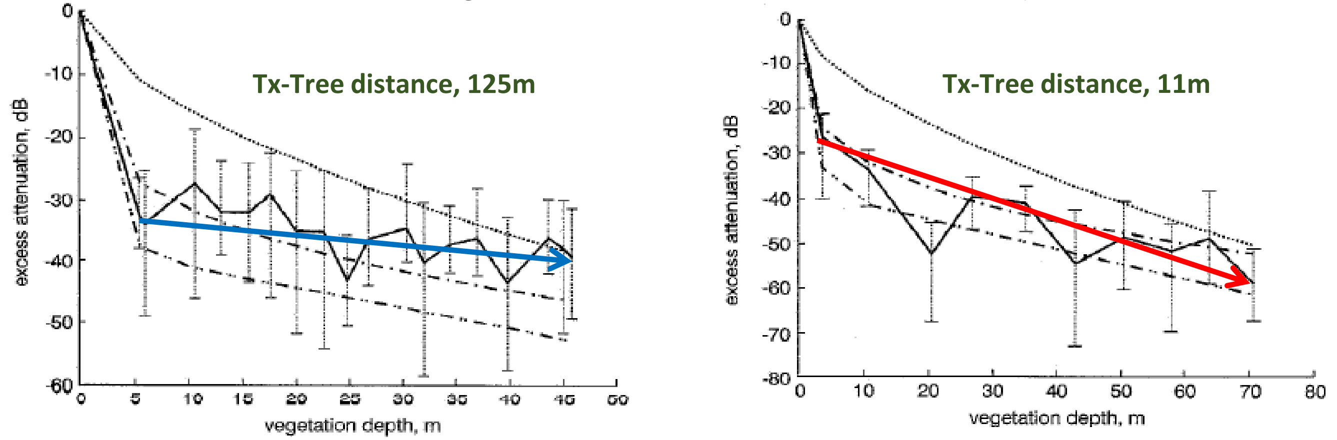


Excess Loss – Typical Roadside Trees (2/2)

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

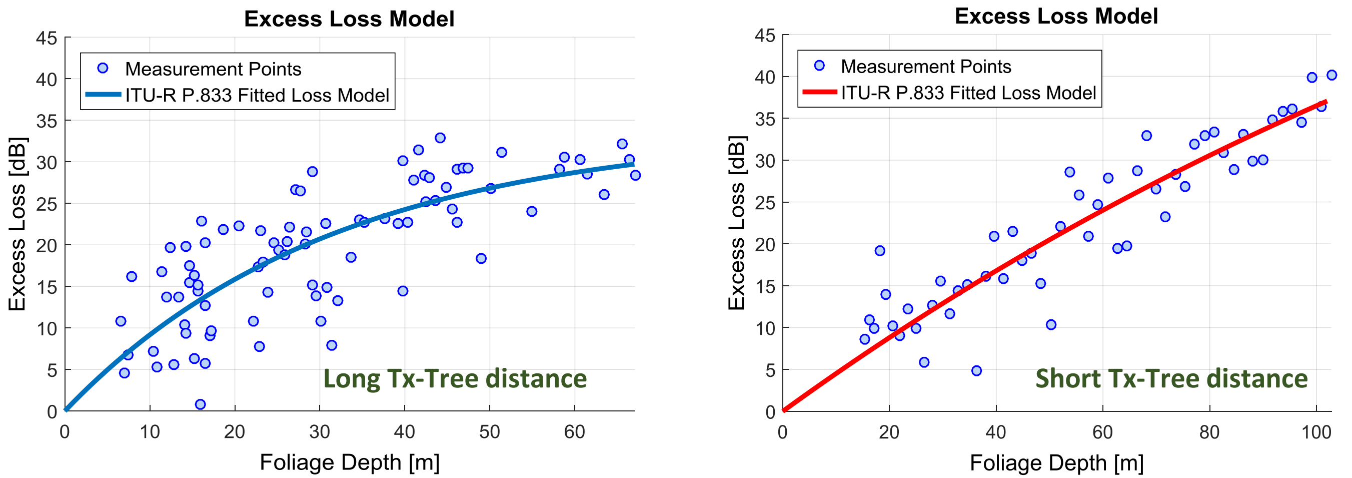
Foliage Loss Measurement at 20 GHz in [1]



Distance between Tree and Transmitter

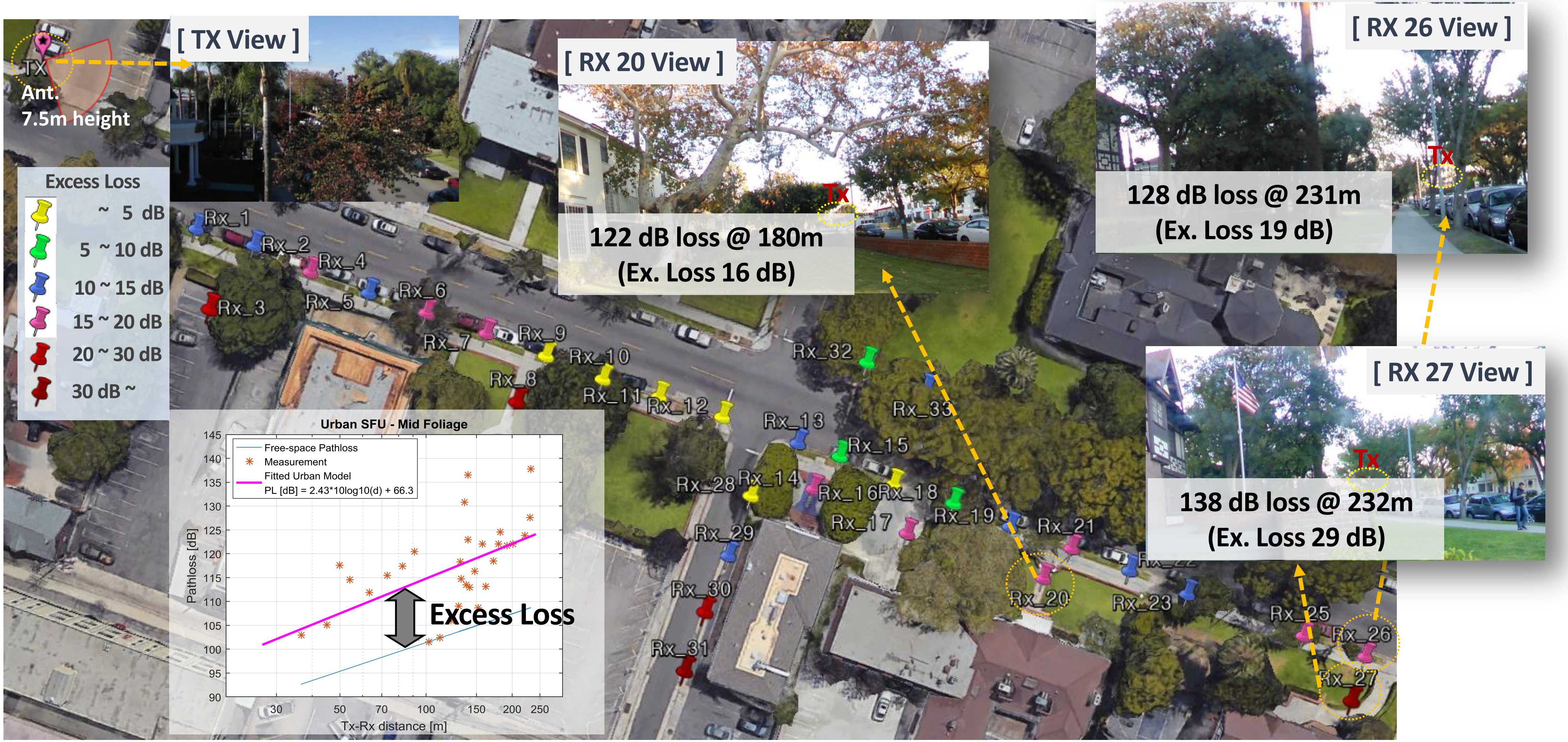
- Long distance is likely to have other propagation pathway
- Short distance may block reflected pathways
- Dual-gradient model

Foliage Loss Measurement at 28 GHz in Daejeon, Korea



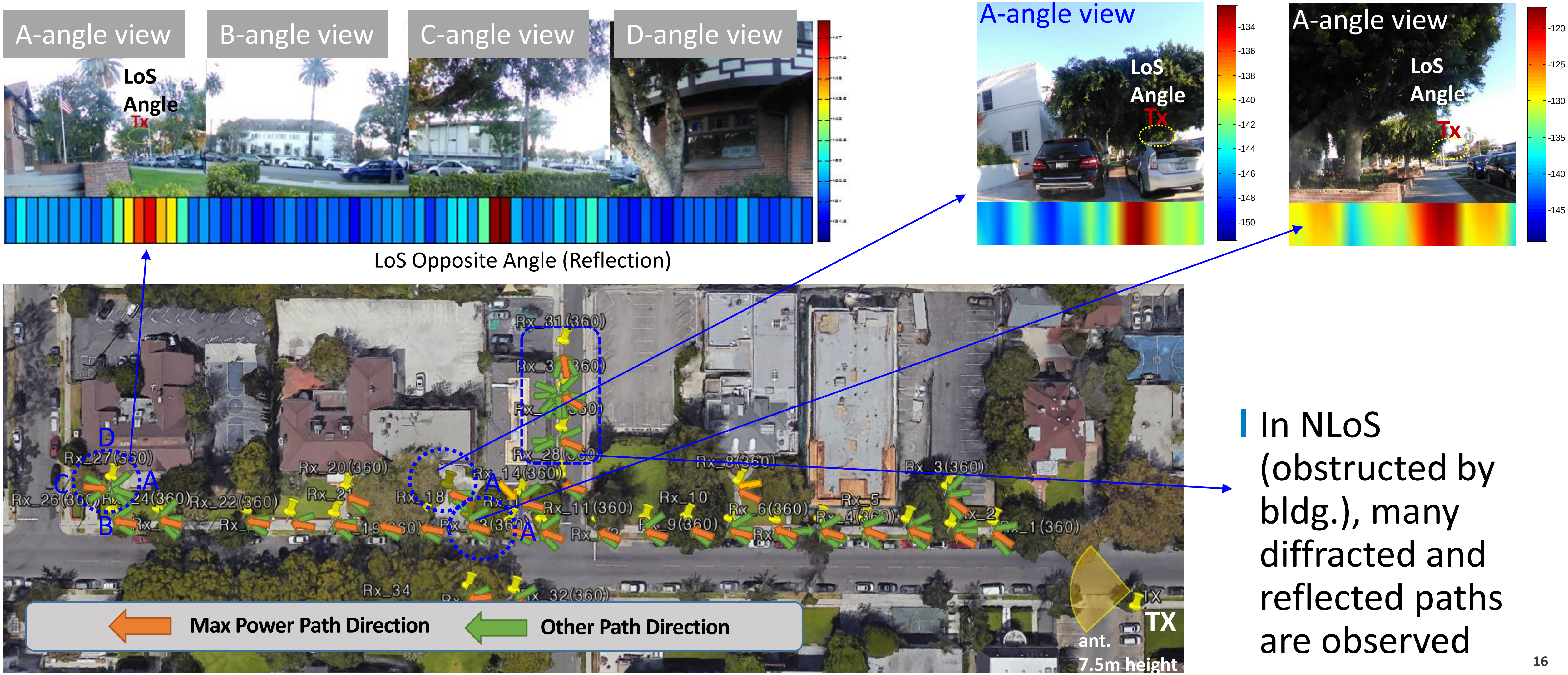
Sub-urban Measurements (1/4)

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



Sub-urban Measurements (2/4)

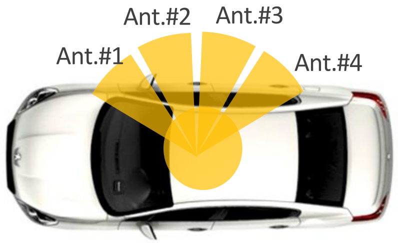
- In vegetated LoS, LoS direction path usually gives strong power

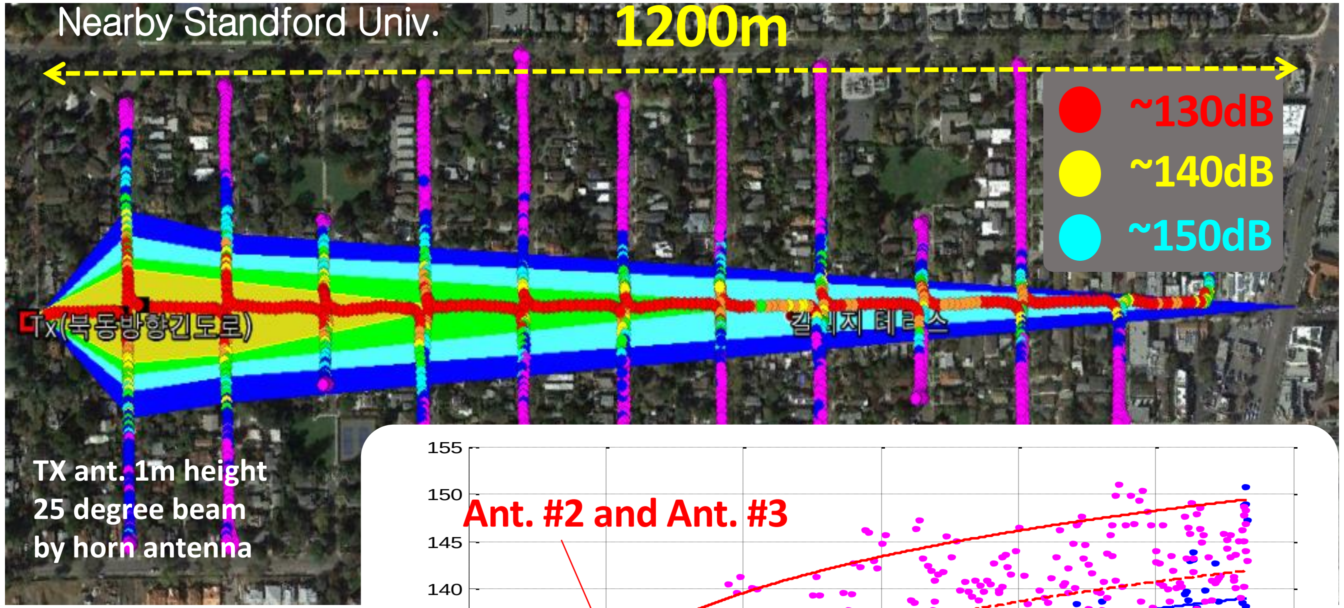


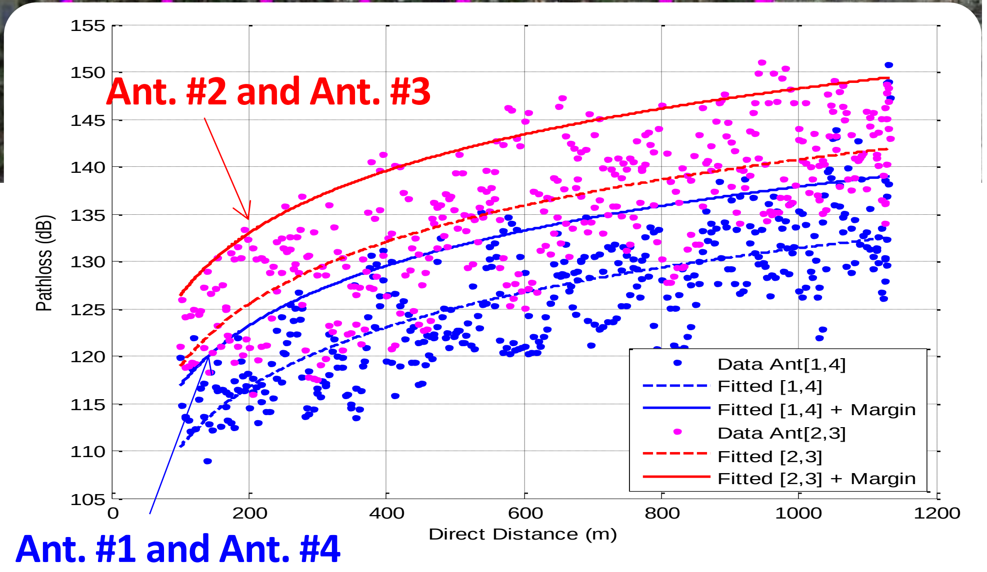
- In NLoS (obstructed by bldg.), many diffracted and reflected paths are observed

Sub-urban Measurements (3/4)

- Measurements indicates several hundreds meter can be supported even in NLoS



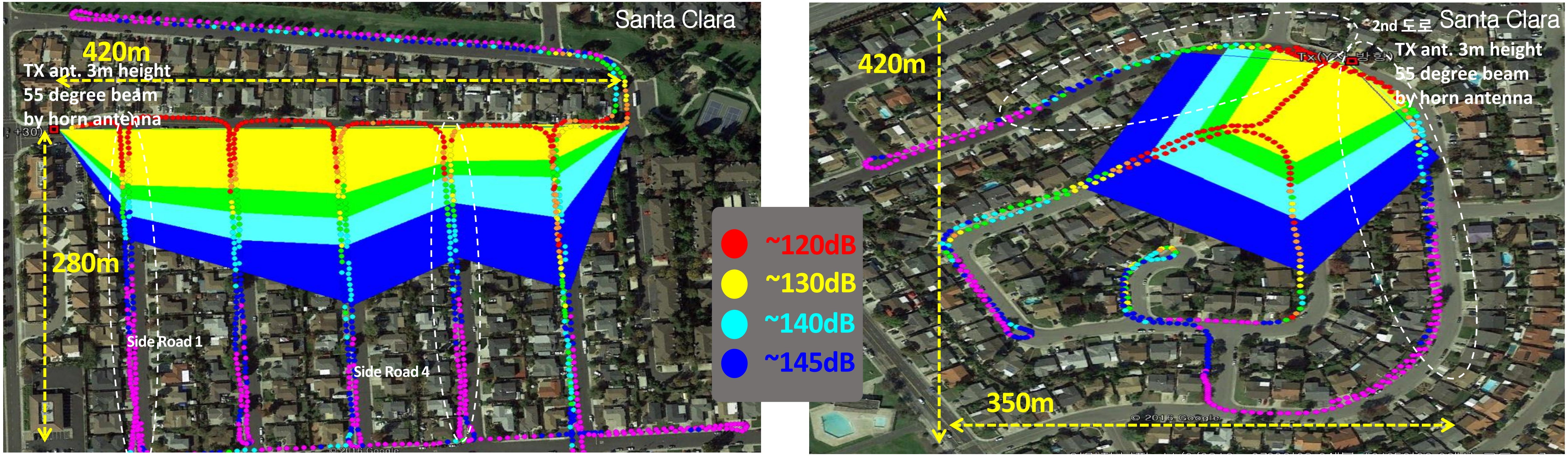




Pathloss measurements in main drive path

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

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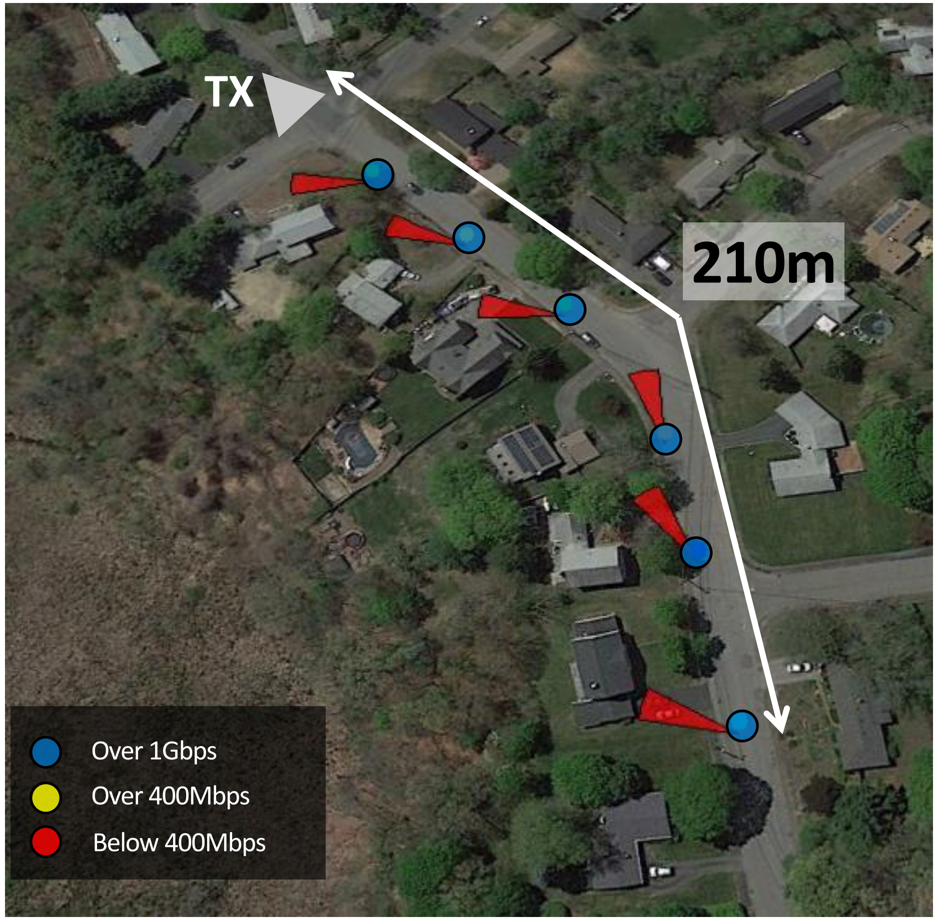
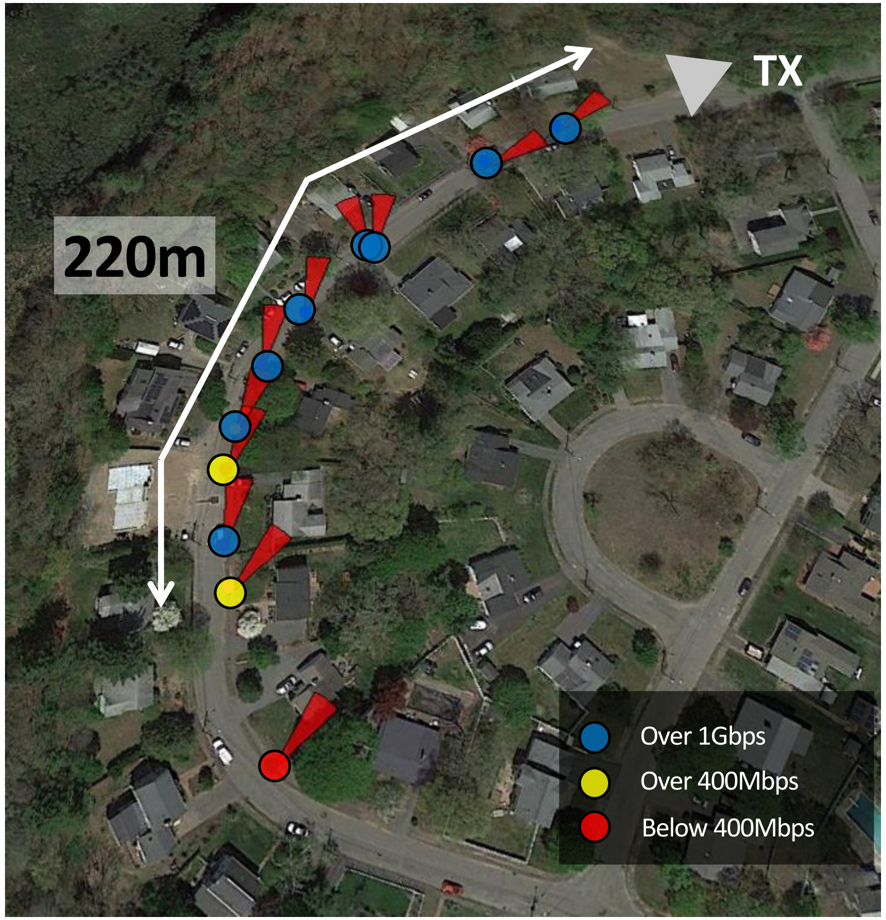
Rural Measurements (2/2)

- **SFU with Curved Road**



- **SFU with Highly Curved Road**



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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

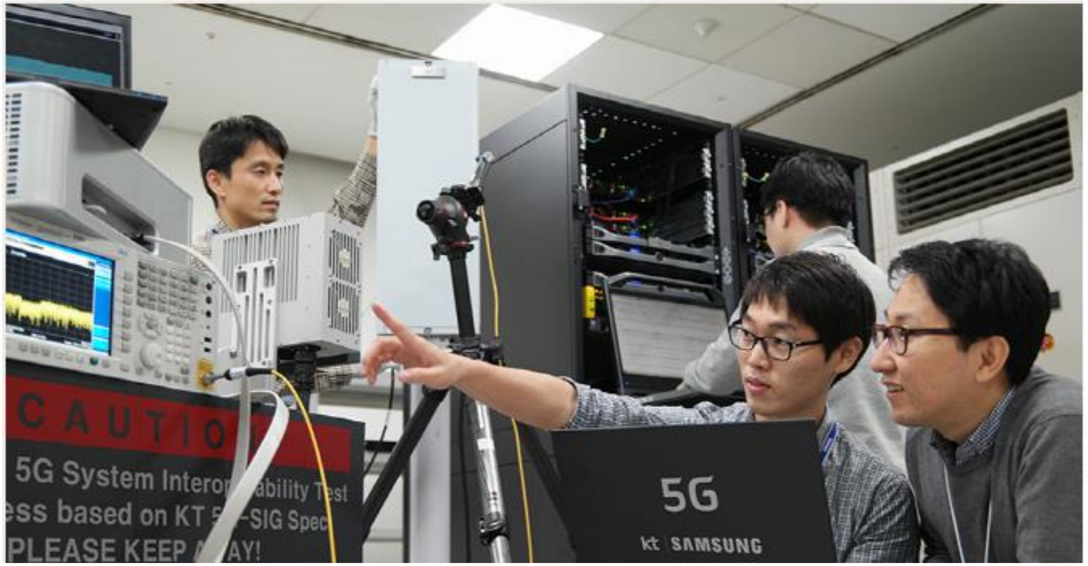
독자의견 | 좋아요 0

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]



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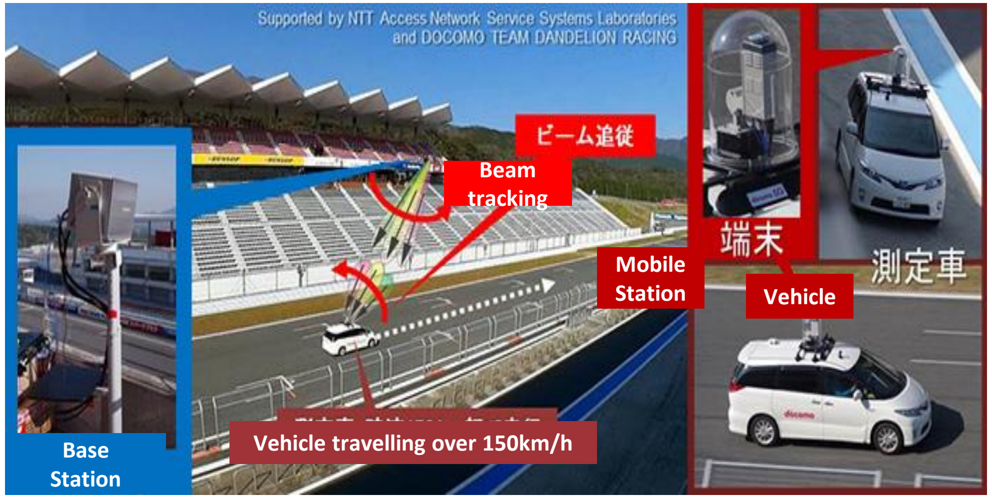
Field Tests in Japan

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

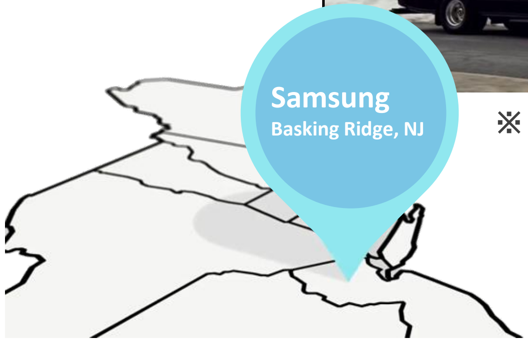
BY SHUSUKE MURAI

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)



※ 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/

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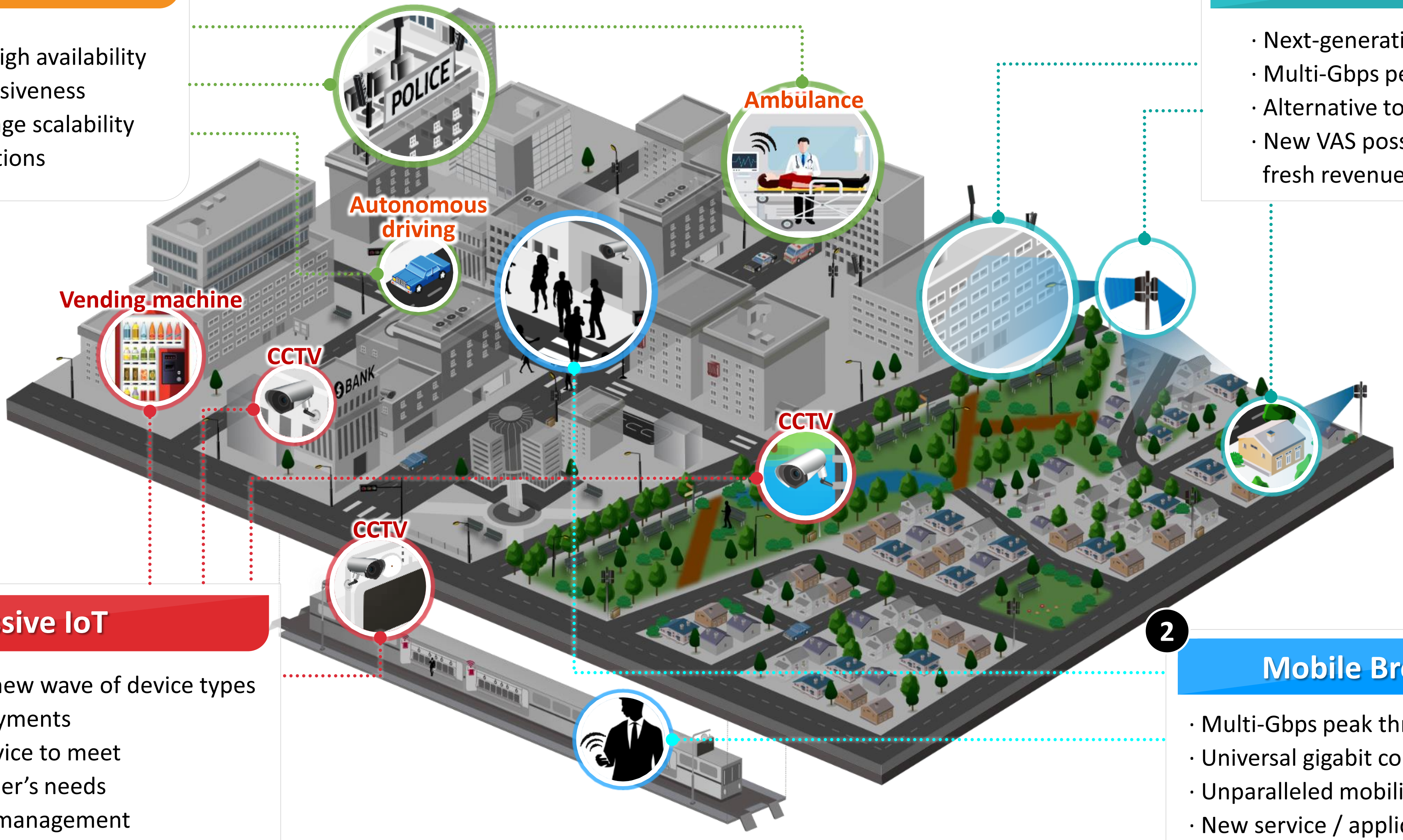
5G Service Scenarios

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

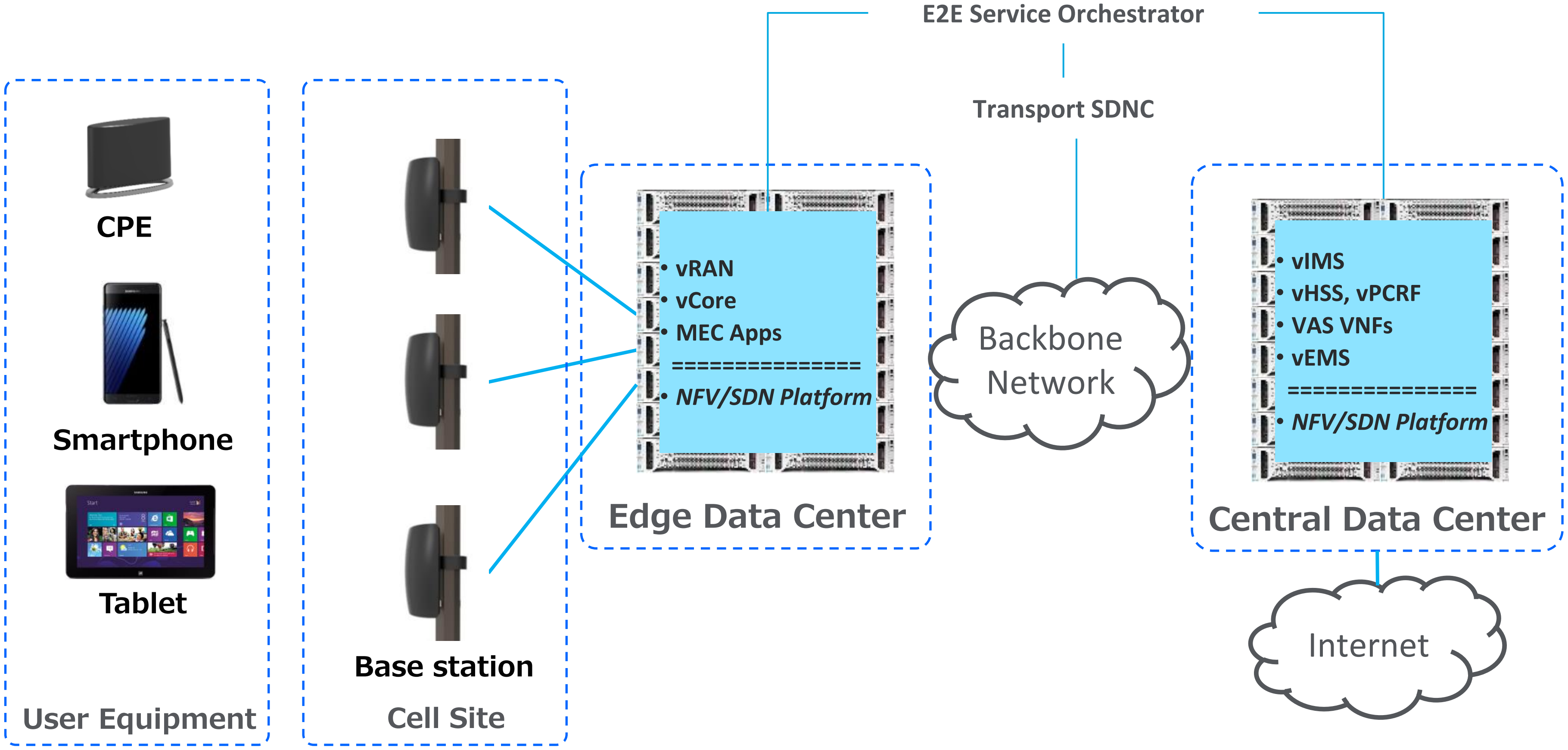
- Connectivity for a new wave of device types
- High density deployments
- Networks-as-a-Service to meet each service provider's needs
- Robust QoE / QoS management
- New revenue opportunities

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