



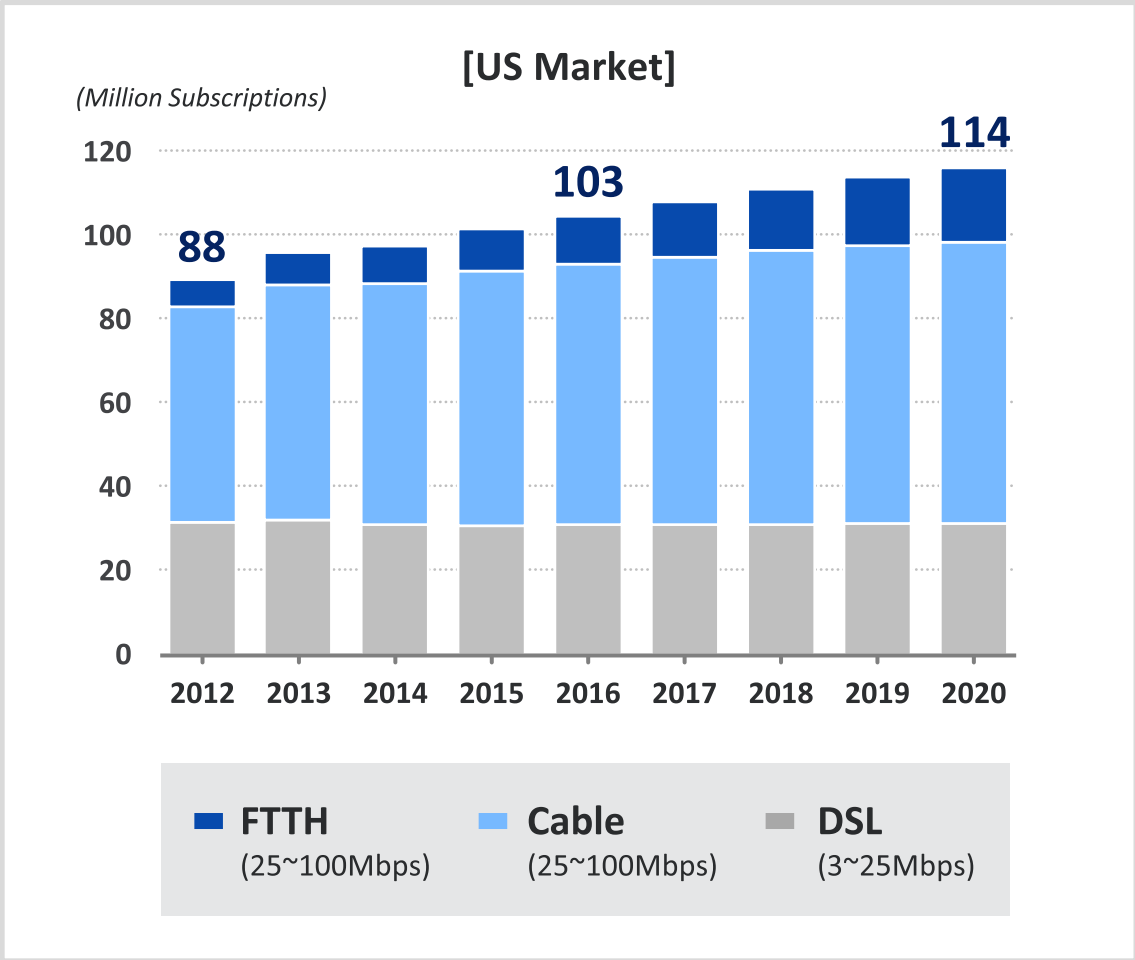
# **5G : From Vision to Reality**

**Dr. Wonil Roh**

**Vice President**

October 2016

## Business Opportunity for 5G FWA



(Source : Telegeography and OVUM)

# 5G FWA

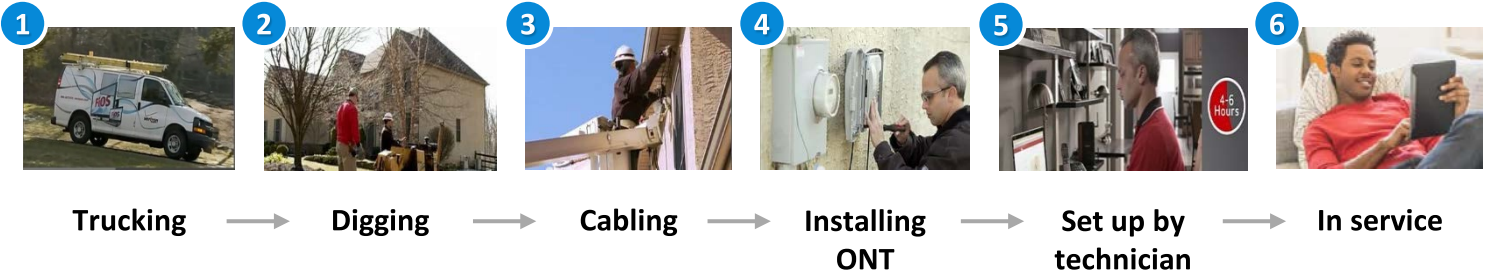
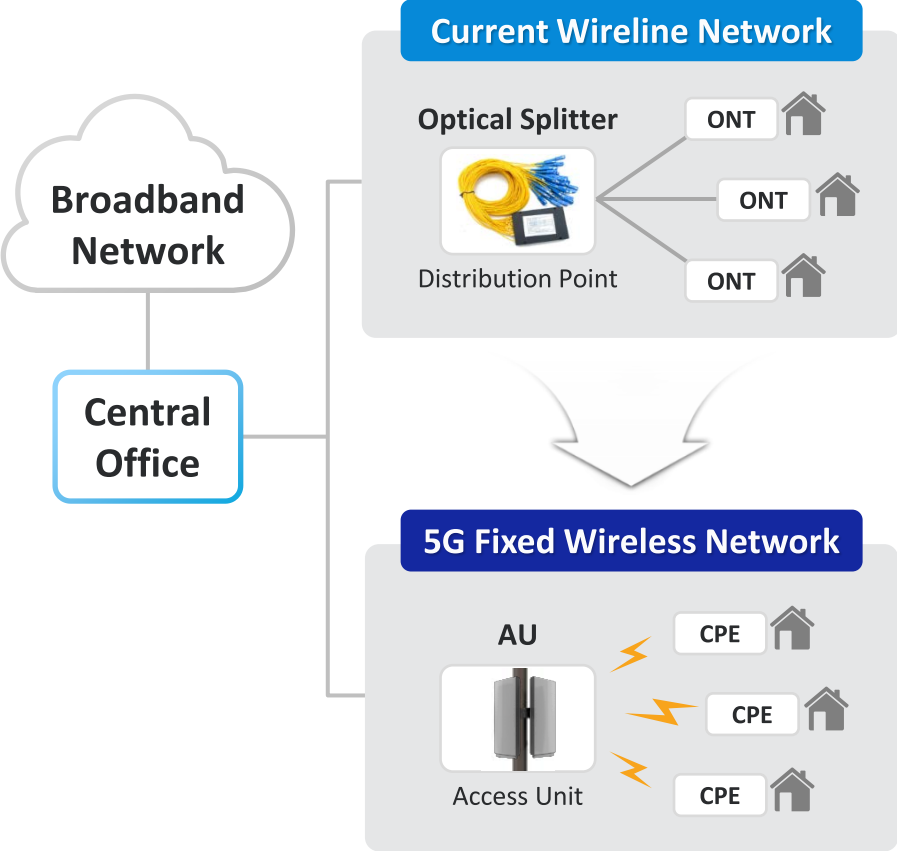
- 200Mbps Average, 5Gbps Peak User Data Rate
- 28GHz mmWave (800MHz bandwidth, TDD)

**30% ~ 40%**  
of Cable/DSL subscribers switched to 5G FWA

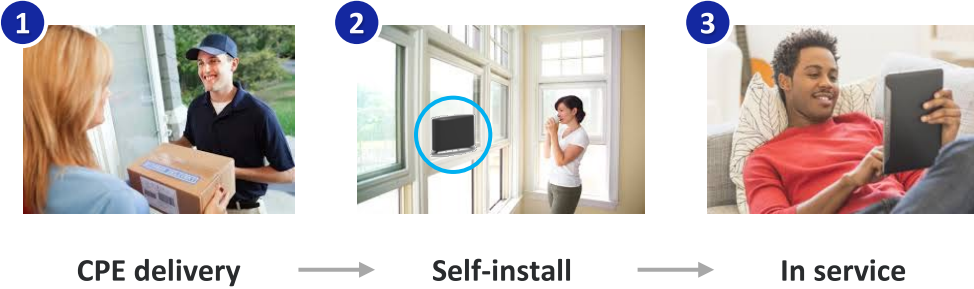
**\$35B ~ \$45B**  
Revenue estimated

(Samsung's assumption for 2017)

## Delivering 5G Broadband to Homes and Offices as an Alternative to Fiber



**Greatly Reduces CAPEX/OPEX, Deployment Times**  
(Weeks → Days)

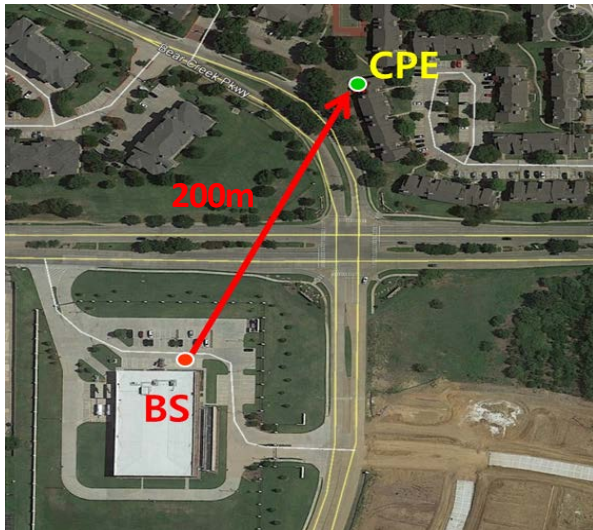


- Comparative Analysis between Measurement and Simulation for Sample Area
- Based on Realistic Material Parameters (Permittivity and Conductivity)

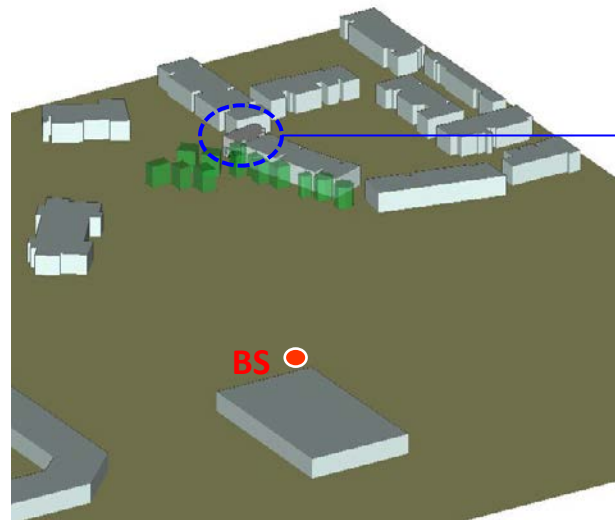
Building wall (concrete, brick, window, wood, iron, etc.)

Foliage (wood types, size, etc.)

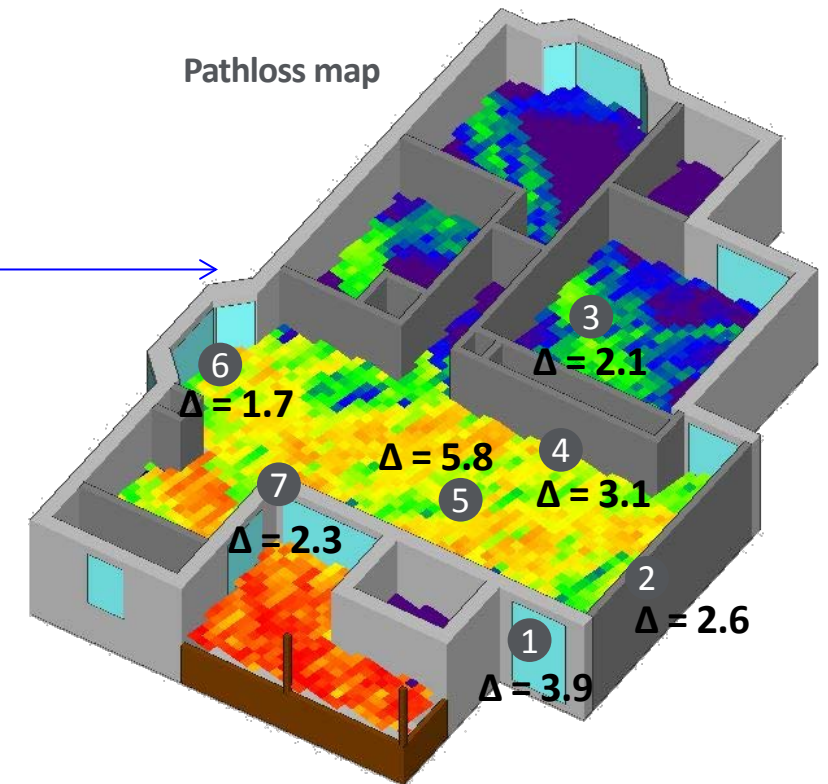
Terrain



Test Site

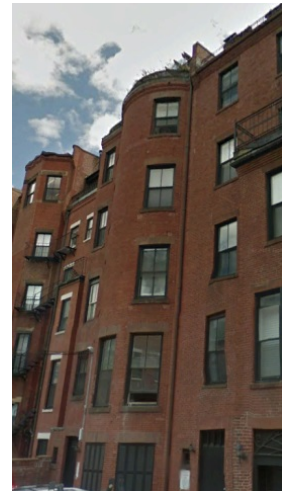
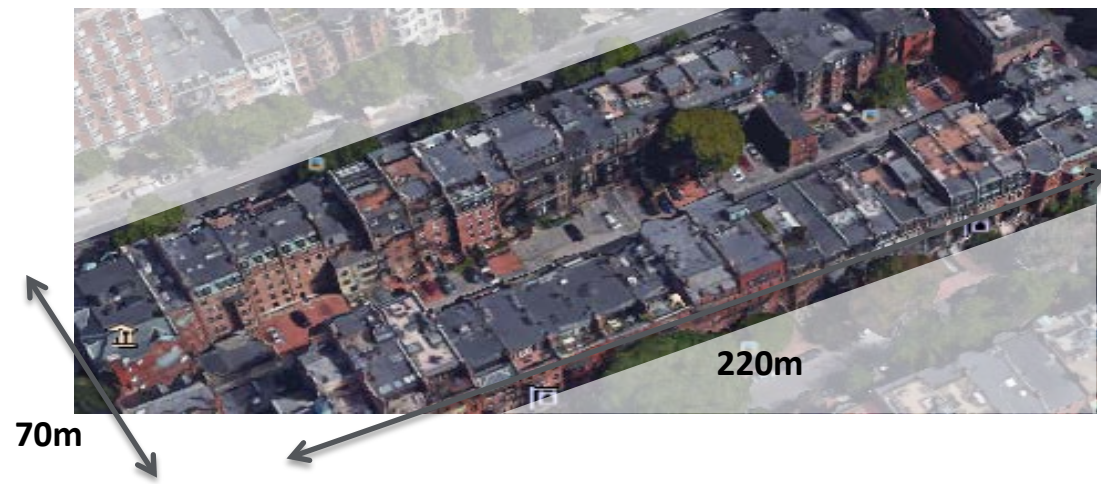


3D Map Modeling



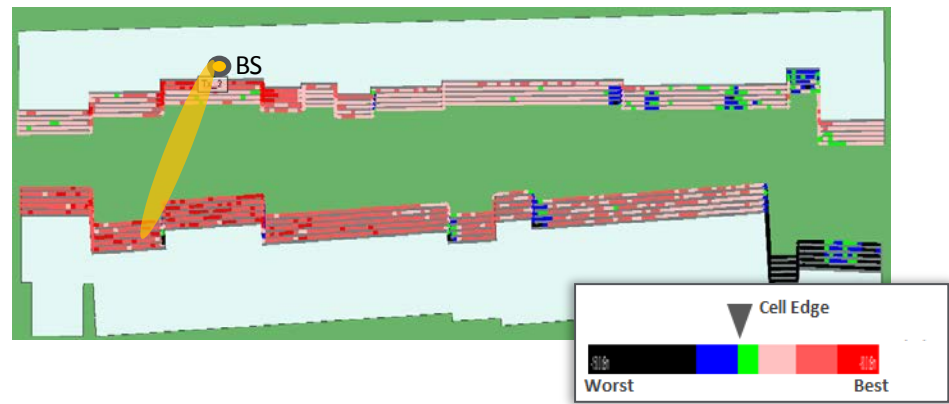
$$\Delta = |\text{Measured RSRP (dB)} - \text{Simulated RSRP (dB)}|$$

## Sample Area

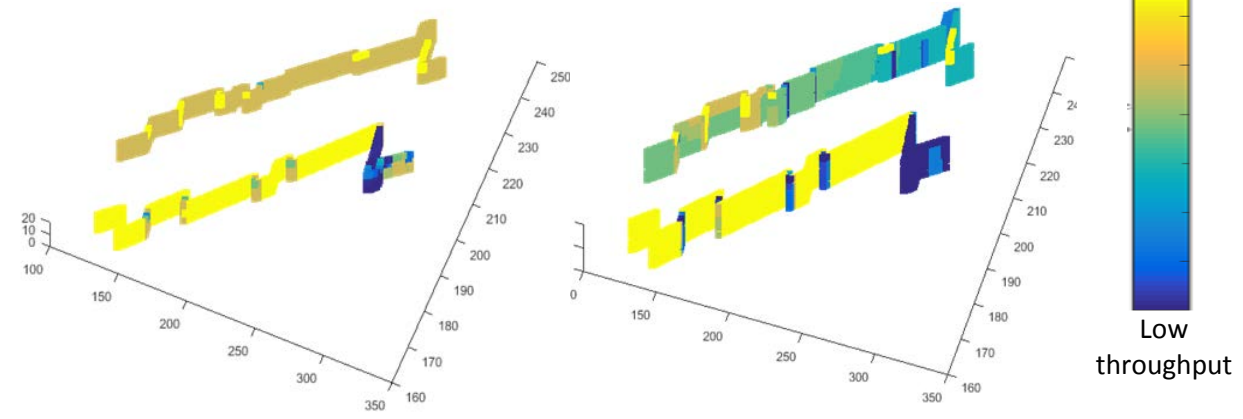


- High density of households
- Around 220 households per block in the area

## Simulation Results



Radio Map



DL & UL Link Throughput

## Evaluation Results Based on Ray-tracing and System Level Simulations

Available BW	DL : UL 80 : 20	AU Throughput	CPE Throughput			
		Average [Gbps]	Average [Mbps]	5% Edge [Mbps]	50% [Mbps]	95% [Mbps]
600 MHz	Downlink	<b>2.64</b>	<b>160.0</b>	31.8	144.1	412.5
	Uplink	<b>0.38</b>	<b>23.0</b>	5.2	18.5	63.4
200 MHz	Downlink	<b>0.88</b>	<b>53.33</b>	10.5	48.0	137.5
	Uplink	<b>0.13</b>	<b>7.68</b>	1.8	6.2	21.1

### Simulation Assumptions

- 33 CPE subscribers serviced by an AU, 50% CPE activity, full buffer traffic model
- 28GHz, 2 x 2T2R per AU, Overhead = 40%, BW = 600/200MHz, X-pol 2x2 MIMO
- Outdoor2Indoor (window) Penetration loss = 10dB

*\* Note : This is a capacity limited case*

## 2013 - 2014

### World's 1st mmWave Testbed Systems

('13.5.12)

Base Station RFU

Mobile Station RFU



### World's 1st mmWave High Speed Test

('14.10.15)

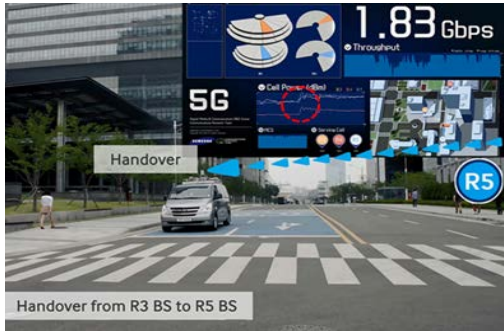


• 7.5Gbps at Stationary

• 1.2Gbps at >100km/hr

## 2015

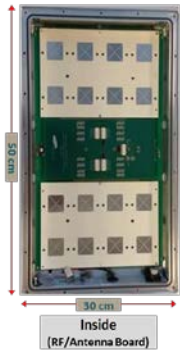
### World's 1st mmWave Multi-Cell Handover



• Avg. 1.7Gbps at 25km/hr • HO Latency: 21ms

### FD-MIMO with Massive Antenna Tech.

(Sub 6GHz)



• High-order(12 UEs) MU-MIMO with FD-MIMO PoC

## 2016

### 5G indoor & mobility tests

3.7Gbps peak using live commercial backbone NW

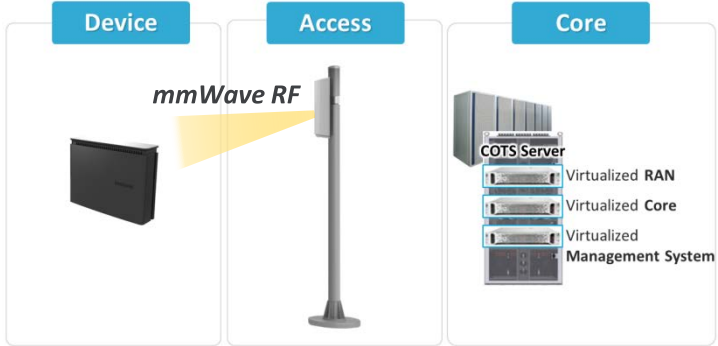


Here's what Verizon's 5G field test looks like (pictures)  
Read More >>>  
A big antenna for a big signal  
A bulky antenna is mounted atop the van, which was created in partnership with Samsung. It makes for a conspicuous ride around the parking lot.

'Samsung Delivers on Gigabit Wireless Promise of 5G'

### 5G End-to-End Products

(Commercial)



## Development of Antenna/RFIC for Mobile Device

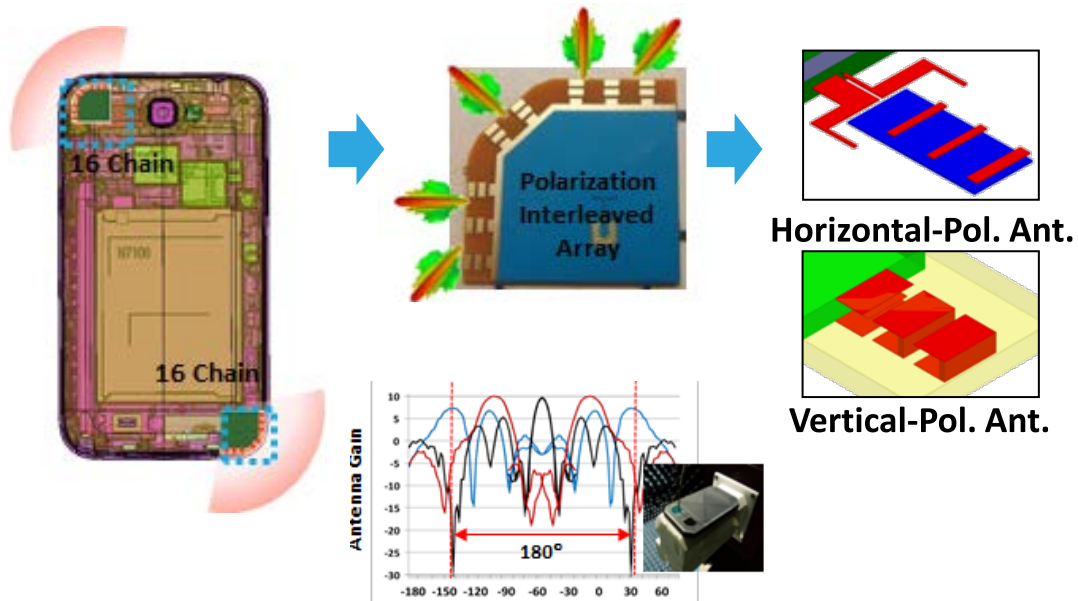
360° coverage polarization array antenna, CMOS RFIC and Modem



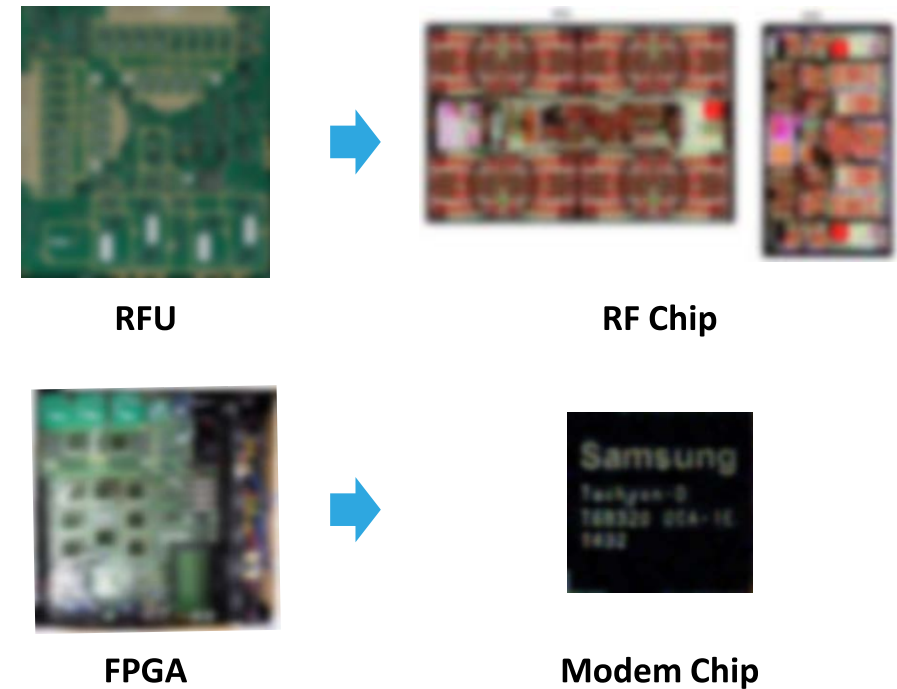
**Samsung develops antenna, power amp for 5G**

Samsung has developed an ultra-small antenna and a power amplifier that will make handsets and radio stations smaller for 5G.

### 28 GHz Array Antenna



### 28 GHz RF & Modem Chips





## Device

(Customer Premise Equipment)



User self-installation

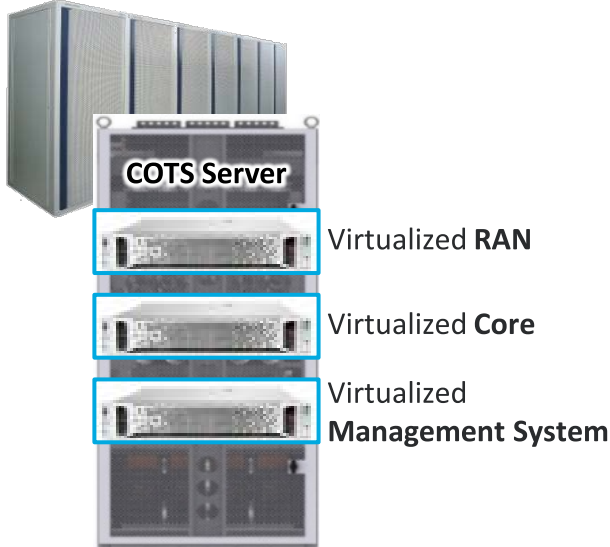
## Access

(5G Access Unit)



Compact & simple installation

## Core



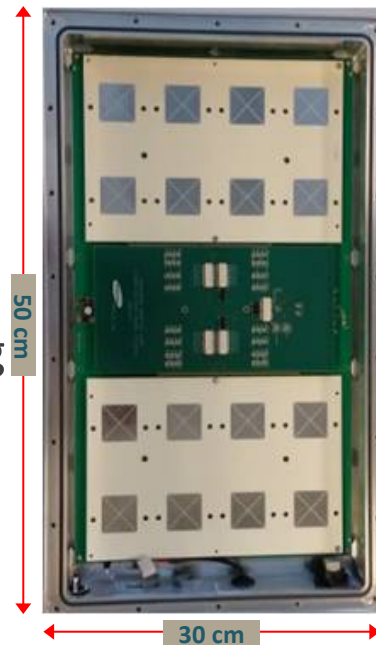
Virtualized RAN & Core Architecture

## ■ FD-MIMO with Massive Antenna Technologies

High-order(12 UEs) MU-MIMO demonstration by FD-MIMO system at 3.5GHz

### Key Features

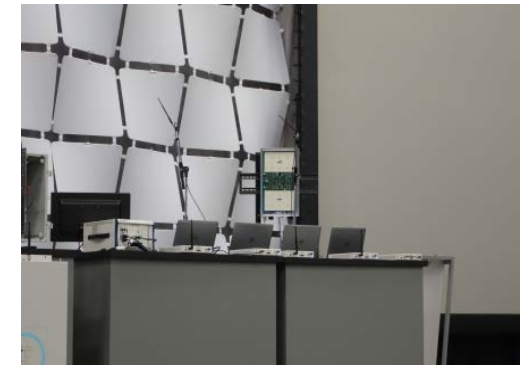
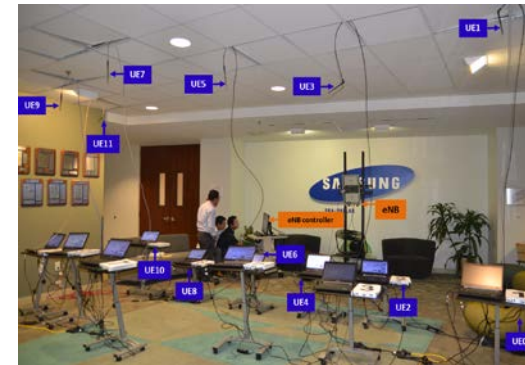
- LTE pre-release small-cell FD-MIMO
  - 20MHz BW TDD @3.5GHz, 32-TRX ports
  - Compact eNB with fully integrated array antenna, RF, and baseband
- Support of adaptive 3D-Beamforming and high-order MU-MIMO
  - Support of multi-user MIMO up to 8~12 UEs simultaneously



Inside  
(RF/Antenna Board)

### FD-MIMO MU-MIMO Test Results

- High-order multi-user MIMO with FD-MIMO PoC
  - 12-UE MU-MIMO indoor test: 422Mbps DL aggregated throughput
  - Realtime demo at NIWeek2015 (Aug. 2015, Austin TX)

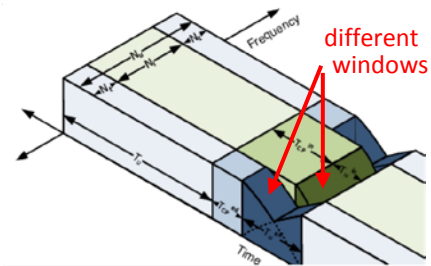


- New OFDM-based Waveform to Support Multiple Services in Same Frequency Band
- Enhanced Channel Coding Scheme for Multi-Gbps with Low Power Consumption

## New Waveform & Multiple Access

- OFDM shaping with filtering/windowing
  - Spectrum confinement enhancement
  - Support of Coexistence for eMBB, URLLC, mMTC services

eMBB : enhanced Mobile-Broadband  
 URLLC : Ultra-Reliable & Low Latency Comm.  
 mMTC : massive Machine-Type Comm.



**Multi-window OFDM**

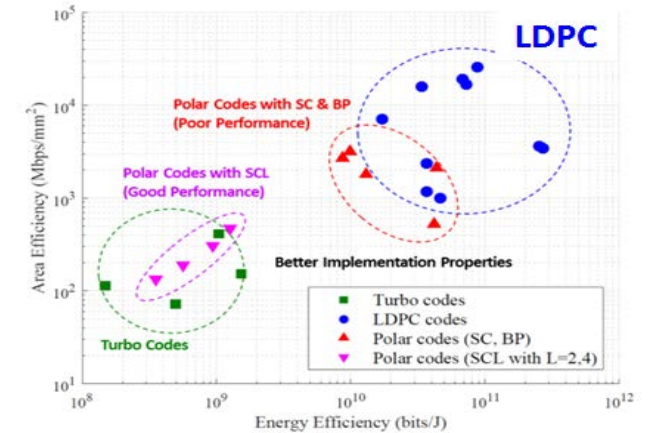
- Non-orthogonal MA (NOMA)
  - Spectral efficiency enhancement & low latency
  - Multiple UEs share the same time/freq. resources



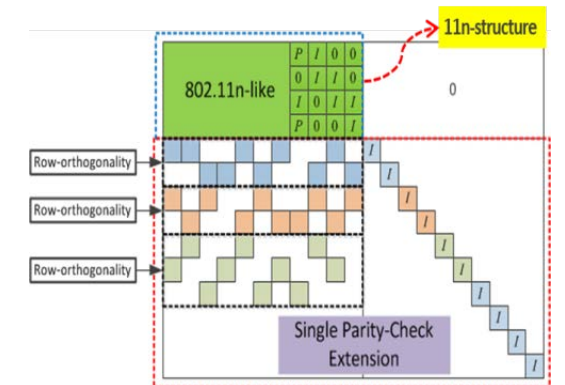
**IGMA (Interleave-Grid Multiple Access)**

## Advanced Channel Coding

- LDPC for Multi-Gbps
  - Much better areal/energy efficiency for implementation

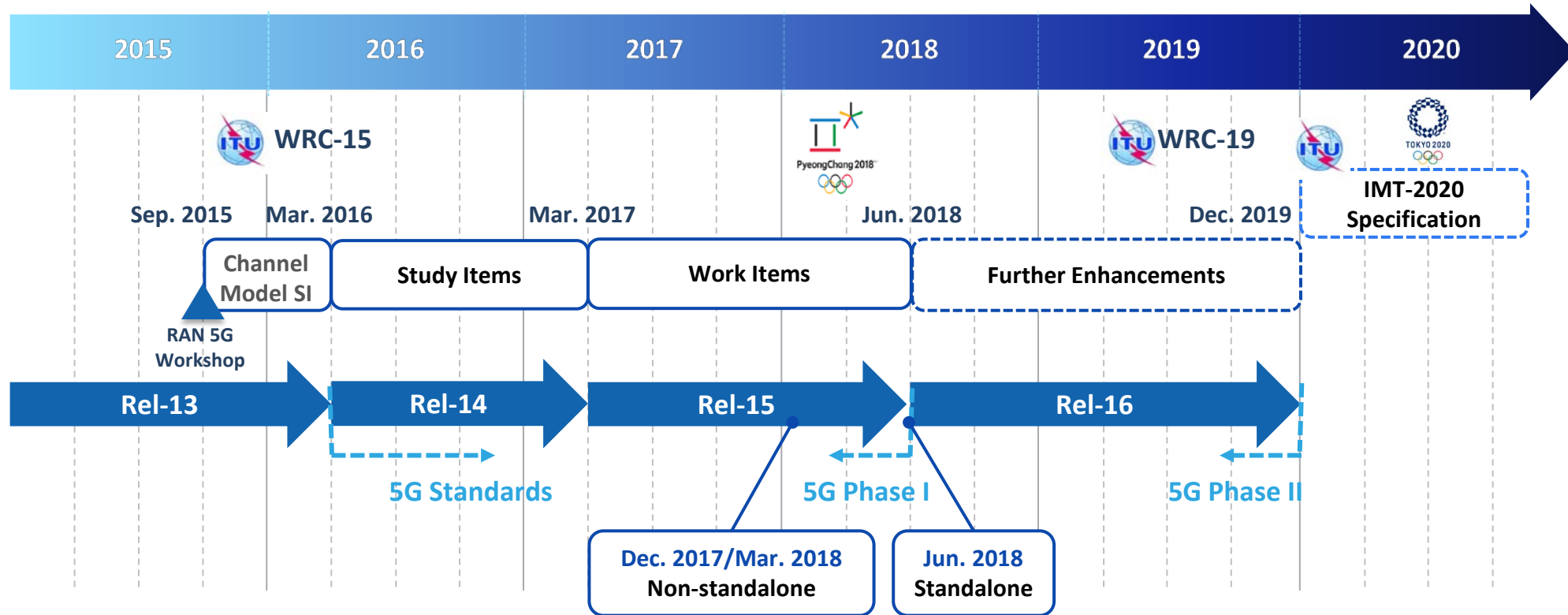


- LDPC-based IR-HARQ
  - Comparable performance to LTE Turbo IR-HARQ



## 3GPP Rel-15 Scope and Schedule

Scope : Above 6GHz & below 6GHz, both 5G standalone & non-standalone



## 5G Networks will Depend on Convergence and Aggregation of Network Components

Collaboration, Synergy and Interworking Competencies will Define the Success of 5G

### Transforming Innovation ...

The collage illustrates various 5G technologies and their applications. It features a 3D visualization of a network grid, a satellite map showing 5G coverage areas, a Samsung 5G van, a diagram of a Polarization Interleaved Array, a diagram of a Single Parity-Check Extension, a diagram of a different window structure, and a graph showing SNR Gain.

### ... to Practical Application

The 3D cityscape diagram illustrates the practical application of 5G. It shows various services and network components: 1. Fixed Broadband, 2. Mobile Broadband, 3. Mission Critical Service, and 4. Massive IoT.