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5G : From Vision to Reality

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Vice President

October 2016

FWA (Fixed Wireless Access) as First 5G Application

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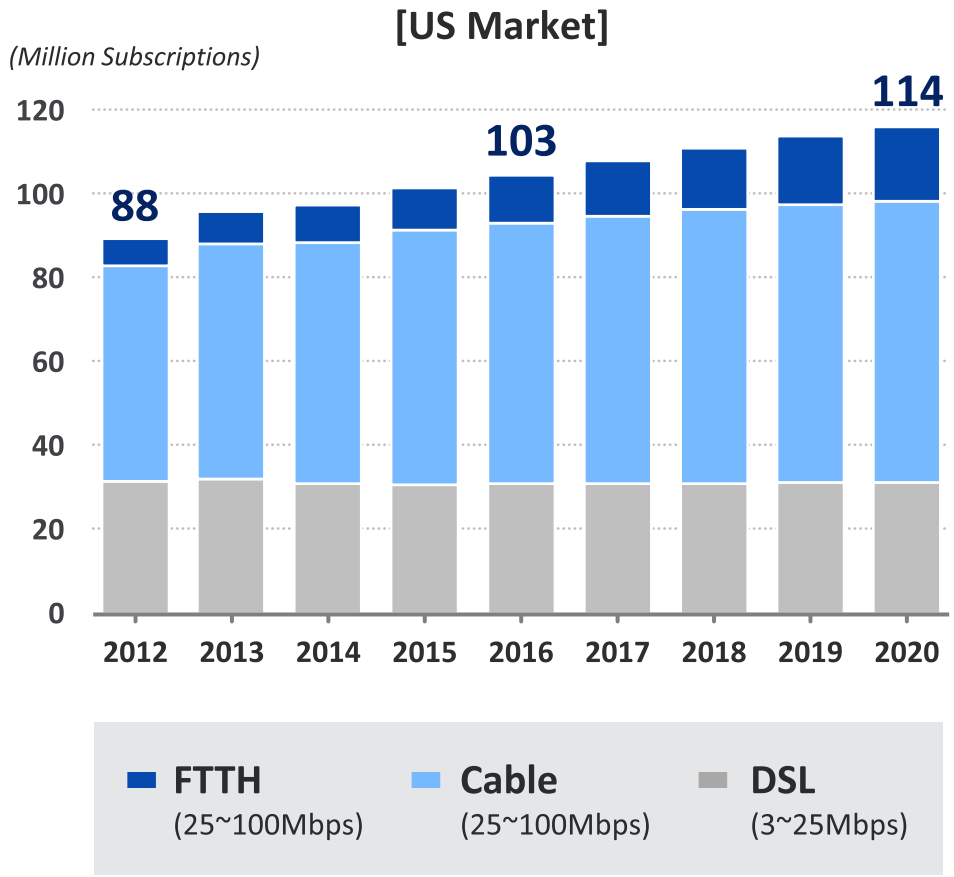
Business Opportunity for 5G FWA



(Source : Telegeography and OVUM)

- **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)

FWA Benefits

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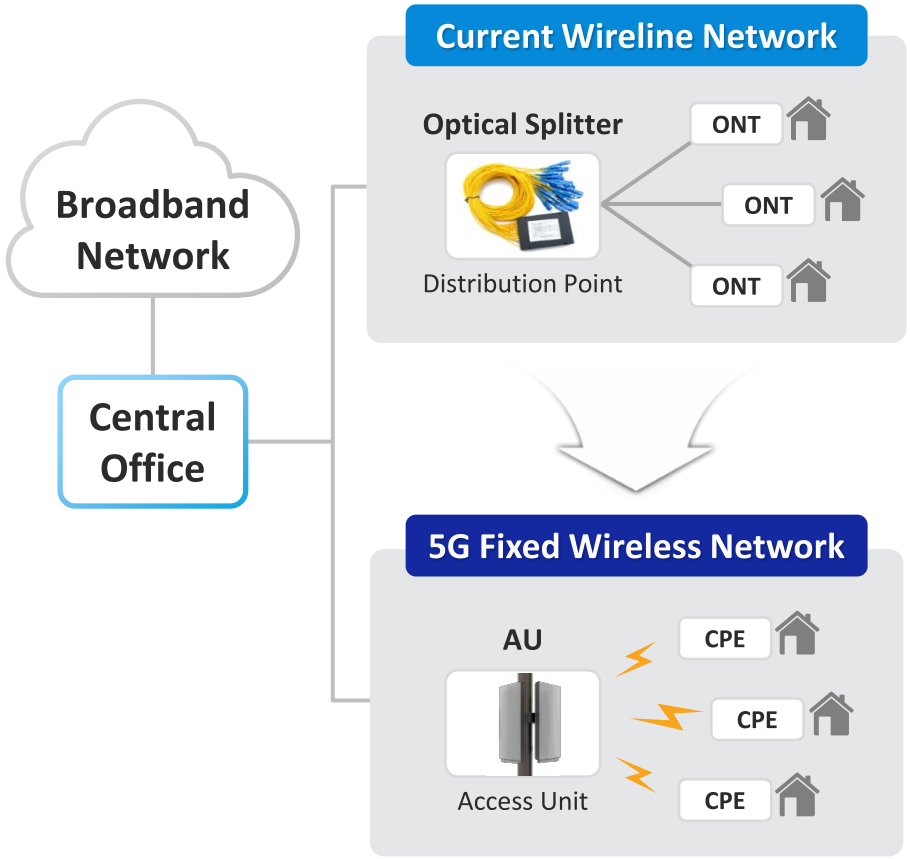
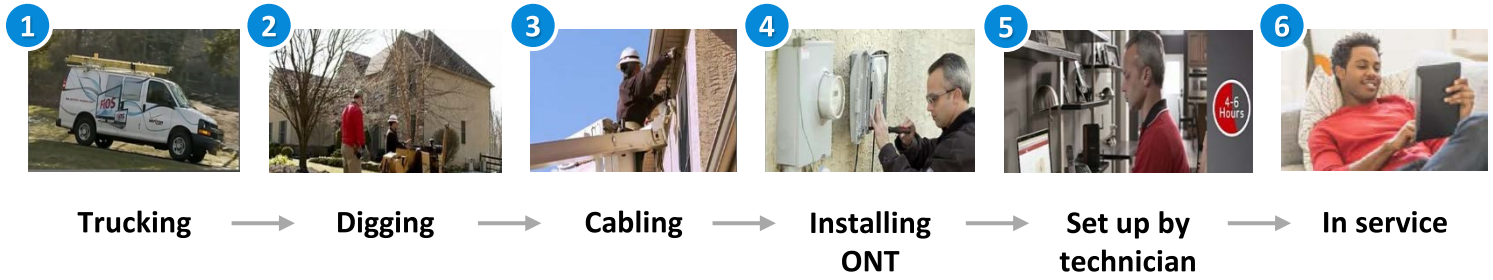
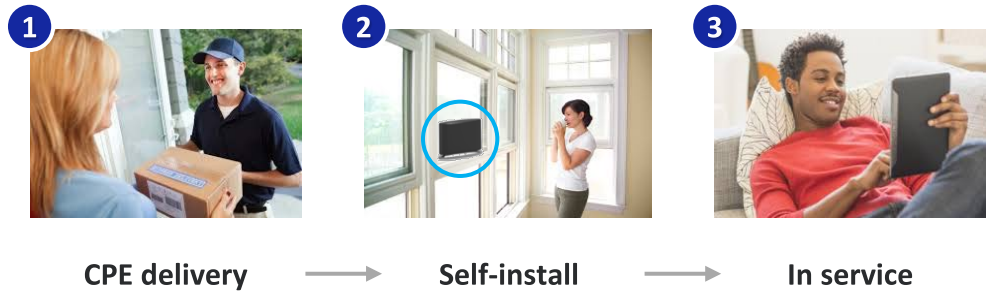
Delivering 5G Broadband to Homes and Offices as an Alternative to Fiber





Greatly Reduces CAPEX/OPEX, Deployment Times

(Weeks → Days)



mmWave RF Simulation & Test Results

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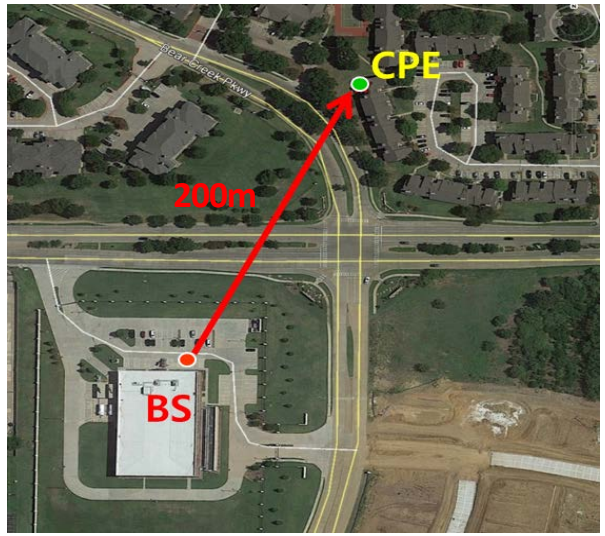
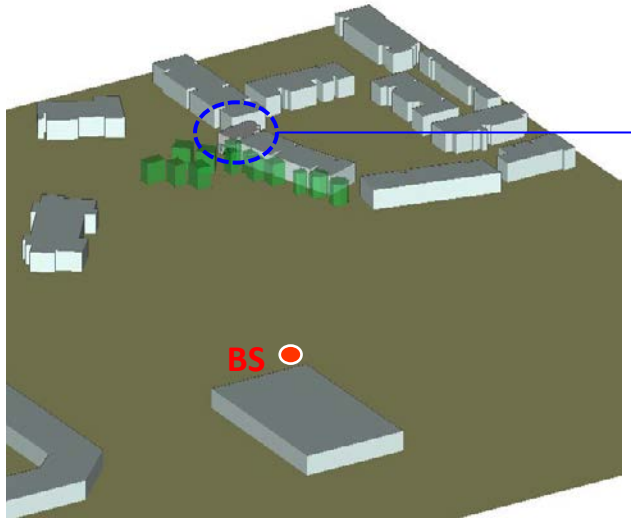
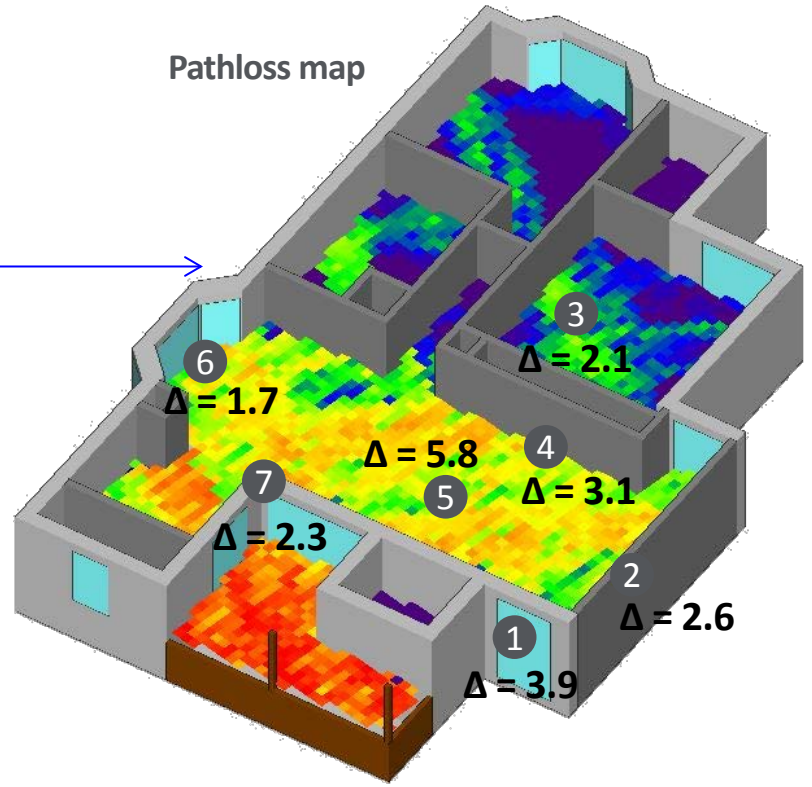
- **Comparative Analysis between Measurement and Simulation for Sample Area**
- **Based on Realistic Material Parameters (Permittivity and Conductivity)**
  - Building wall (concrete, brick, window, wood, iron, etc.)
  - Foliage (wood types, size, etc.)
  - Terrain



Test Site



3D Map Modeling



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

RF Planning Example : MDU (Multi Dwelling Unit)

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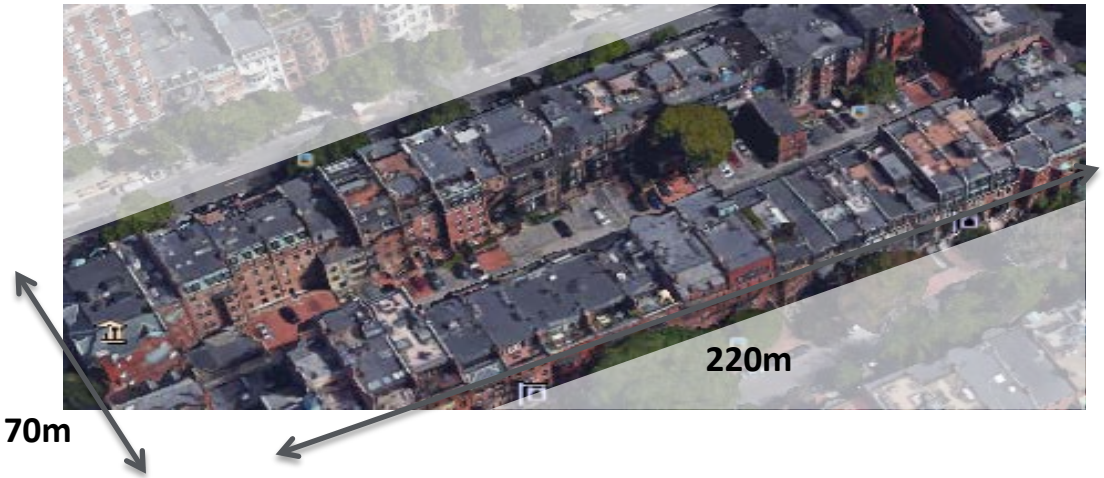
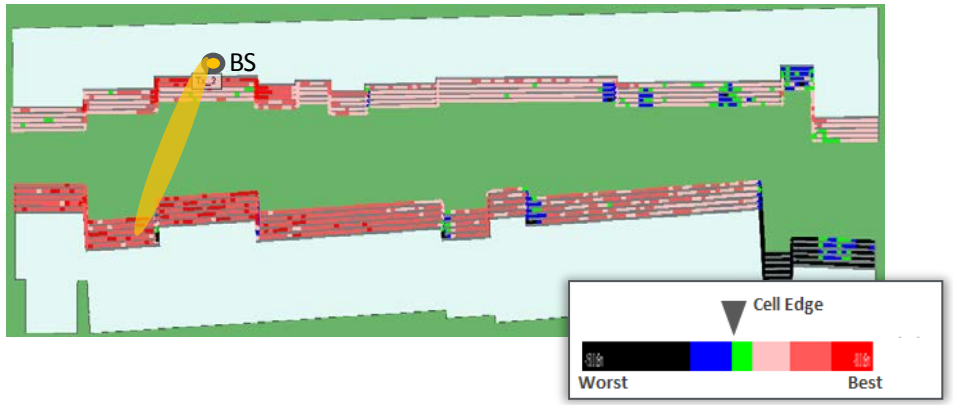
Sample Area

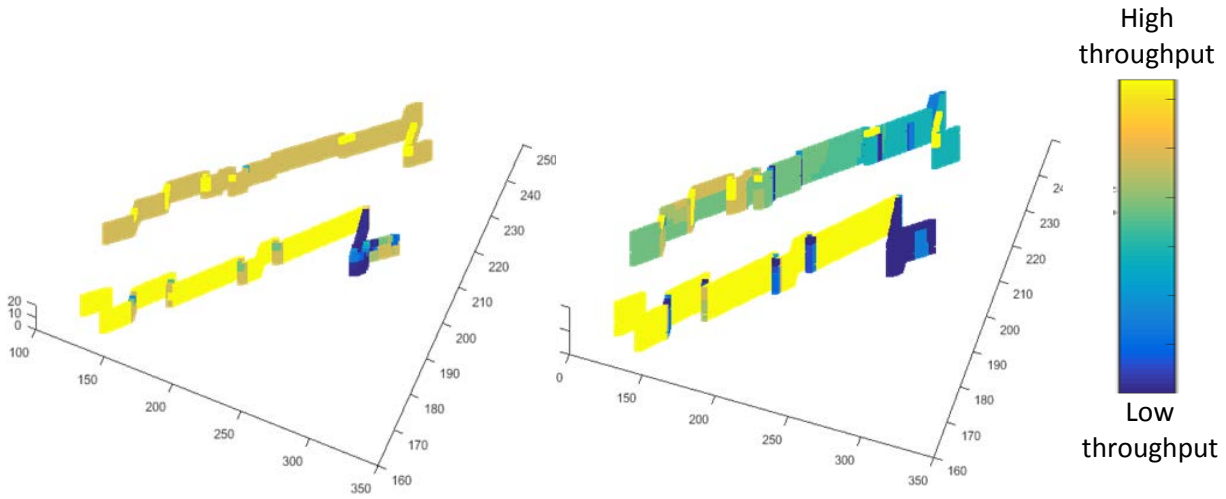


- High density of households
- Around 220 households per block in the area

Simulation Results



Radio Map



DL & UL Link Throughput

FWA Performance Evaluation

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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	**2.64**	**160.0**	31.8	144.1	412.5
	Uplink	**0.38**	**23.0**	5.2	18.5	63.4
200 MHz	Downlink	**0.88**	**53.33**	10.5	48.0	137.5
	Uplink	**0.13**	**7.68**	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*

Innovation toward 5G Realization

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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

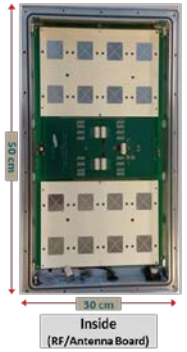
2015

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

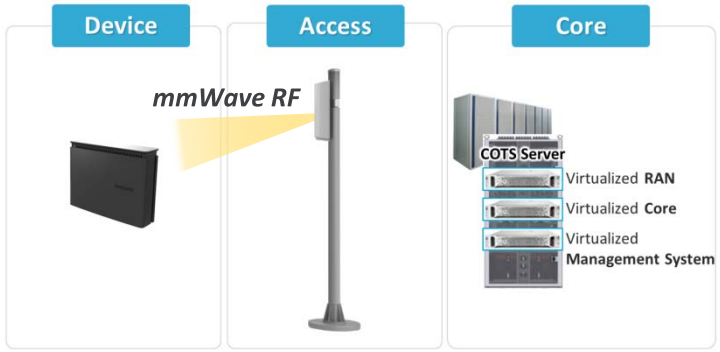
5G indoor & mobility tests

3.7Gbps peak using live commercial backbone NW

'Samsung Delivers on Gigabit Wireless Promise of 5G'

5G End-to-End Products

(Commercial)



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Development of Antenna/RFIC for Mobile Device

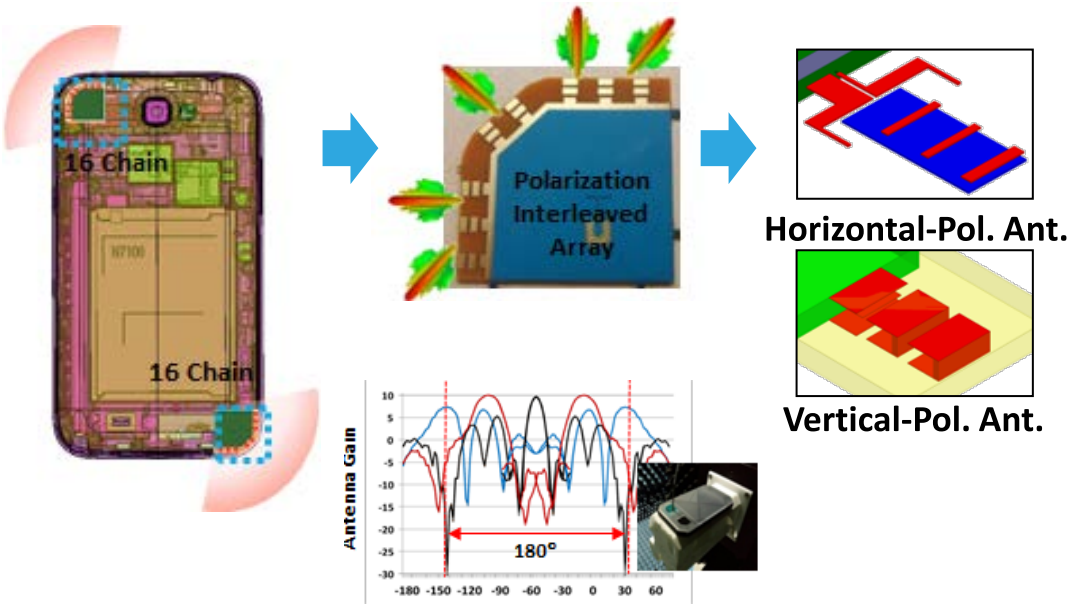
360° coverage polarization array antenna, CMOS RFIC and Modem

ZDNet

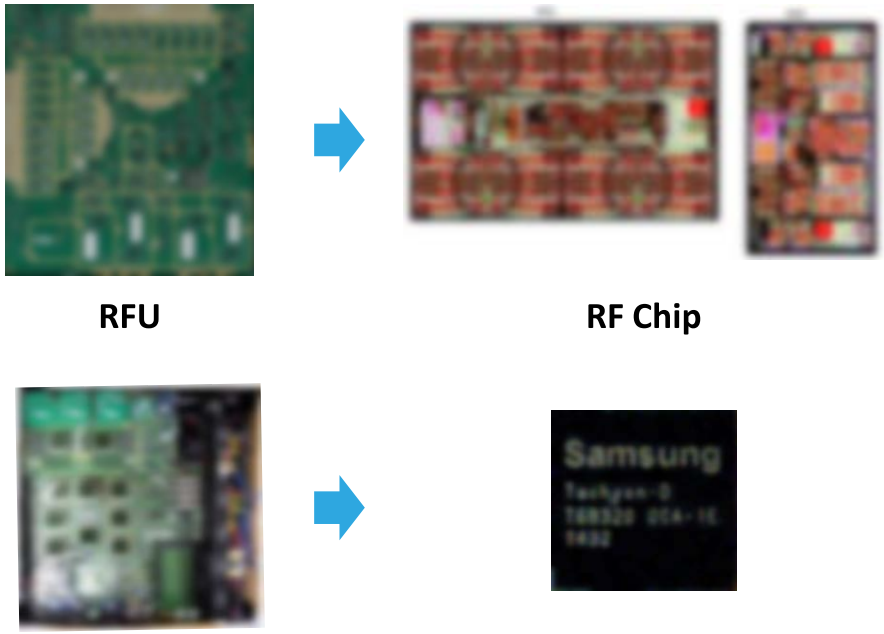
Samsung develops antenna, power amp for 5G

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



First-Wave 5G FWA E2E Product Portfolio

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Device

(Customer Premise Equipment)

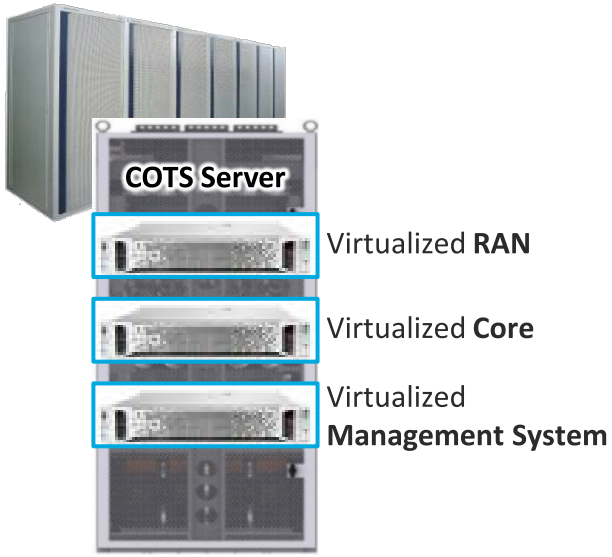
User self-installation

Access

(5G Access Unit)

Compact & simple installation

Core



Virtualized RAN & Core Architecture

5G Technologies Below 6GHz (1/2)

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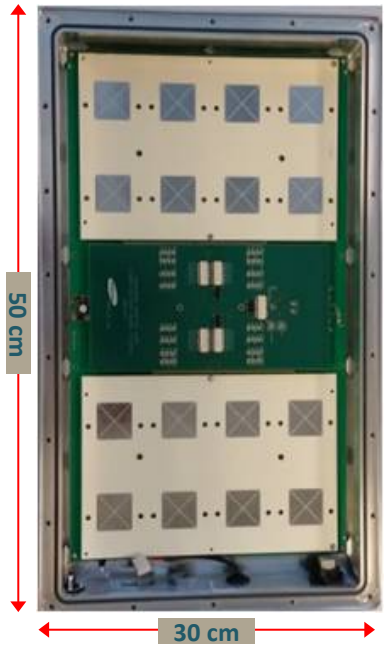
FD-MIMO with Massive Antenna Technologies

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

Key Features

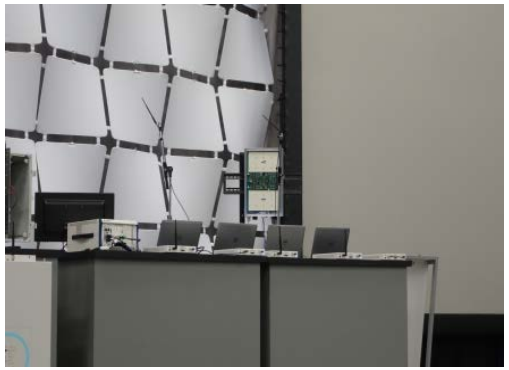
- LTE pre-release small-cell FD-MIMO
  - 20MHz BW TDD @3.5GHz, 32-TRX ports
  - Compact eNB with fully integrated array antenna, RF, and baseband
- Support of adaptive 3D-Beamforming and high-order MU-MIMO
  - Support of multi-user MIMO up to 8~12 UEs simultaneously



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)



5G Technologies Below 6GHz (2/2)

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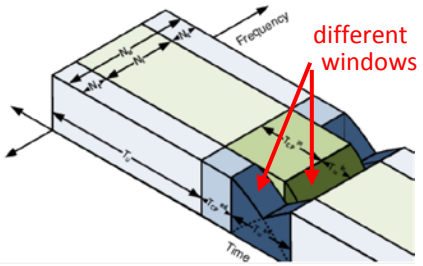
- **New OFDM-based Waveform to Support Multiple Services in Same Frequency Band**
- **Enhanced Channel Coding Scheme for Multi-Gbps with Low Power Consumption**

New Waveform & Multiple Access

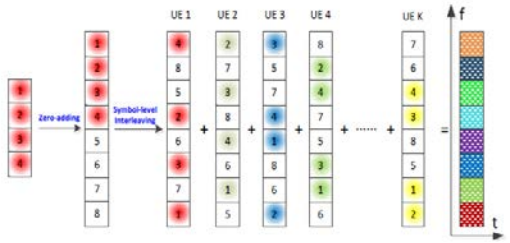
- OFDM shaping with filtering/windowing
  - Spectrum confinement enhancemen
  - Support of Coexistence for eMBB, URLLC, mMTC services

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



Multi-window OFDM

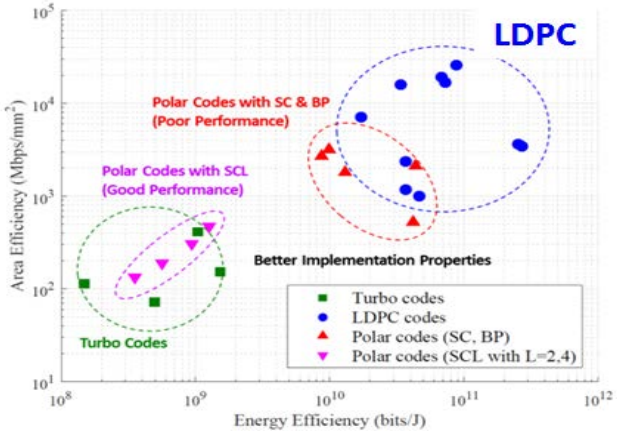
- Non-orthogonal MA (NOMA)
  - Spectral efficiency enhancement & low latency
  - Multiple UEs share the same time/freq. resources



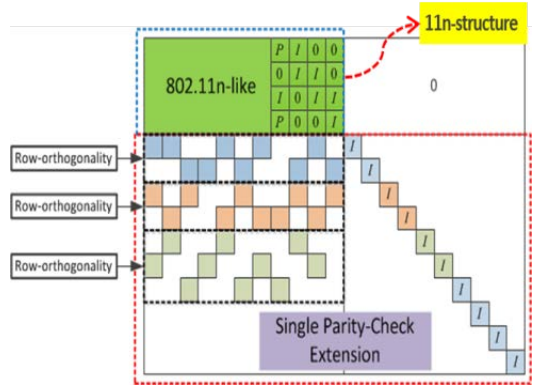
IGMA (Interleave-Grid Multiple Access)

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



5G Standardization Timelines

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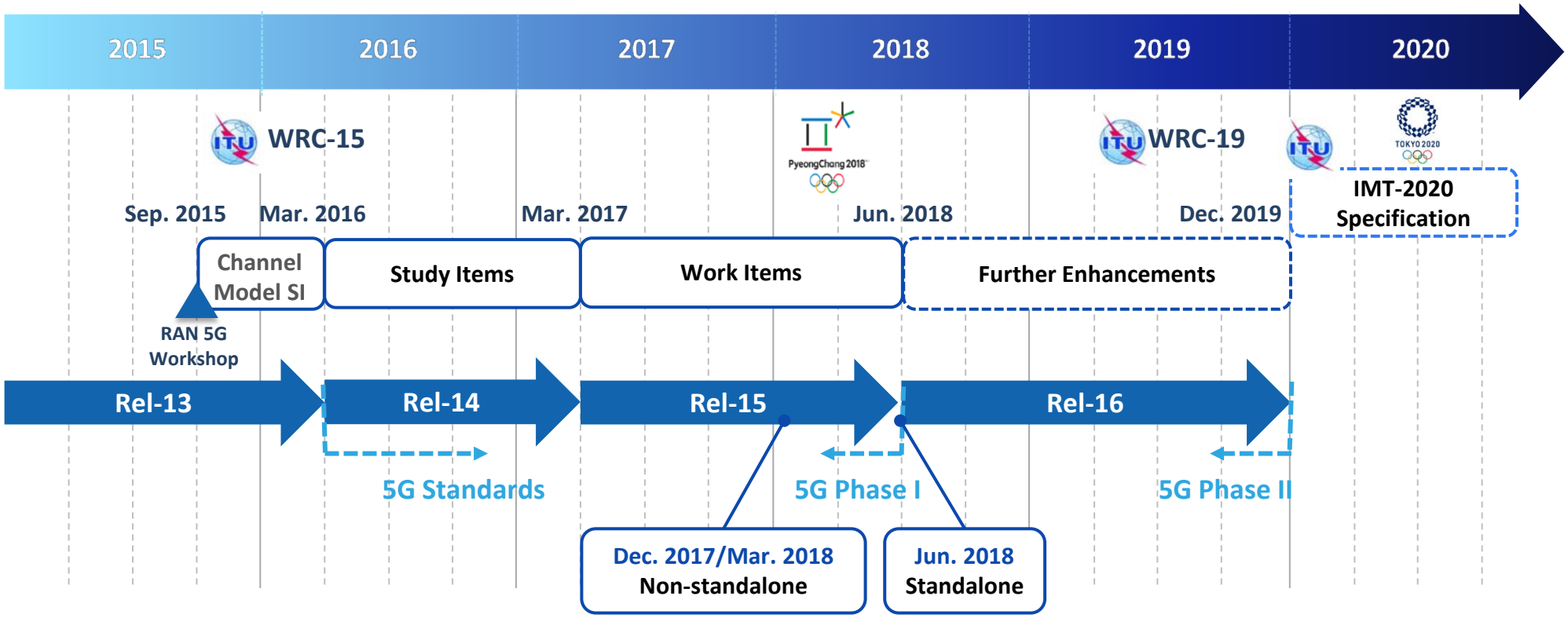
3GPP Rel-15 Scope and Schedule

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



The Way Forward to Successful 5G

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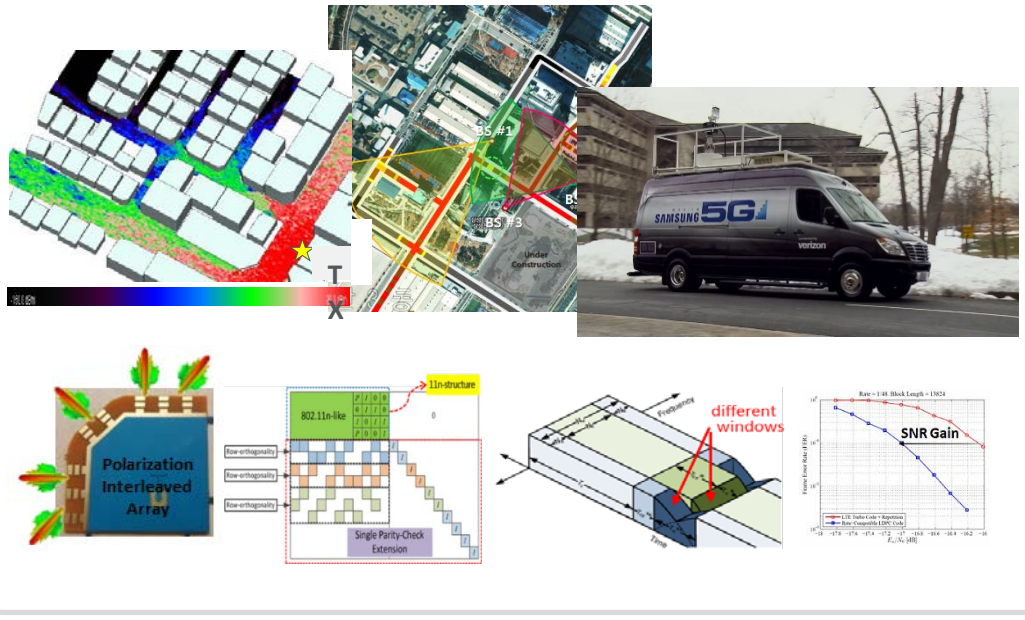
5G Networks will Depend on Convergence and Aggregation of Network Components

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

Transforming Innovation …



… to Practical Application