

Developments in Small Cells & Non Line of Sight (NLOS)

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National Spectrum Managers Association (NSMA) Annual Meeting

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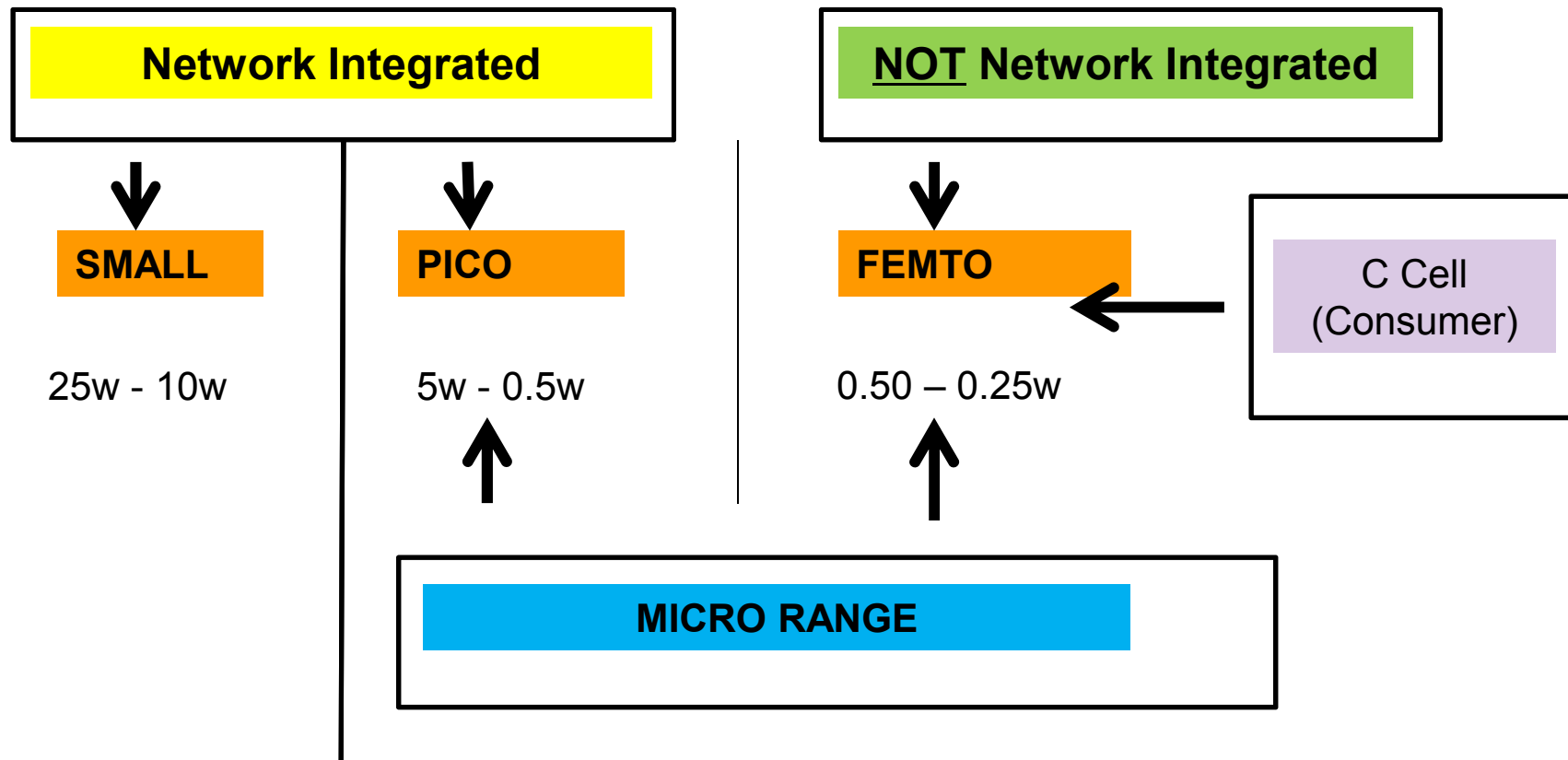


Overview

- ▶ What are small cells? Micro? Pico? Femto?
 - ▶ And what is the relation to capacity and Non-Line-of-Sight (NLOS) advancements?
- ▶ Market Forecasts
- ▶ Design, Deployment and Operations Challenges
- ▶ Spectrum
- ▶ Open Discussion

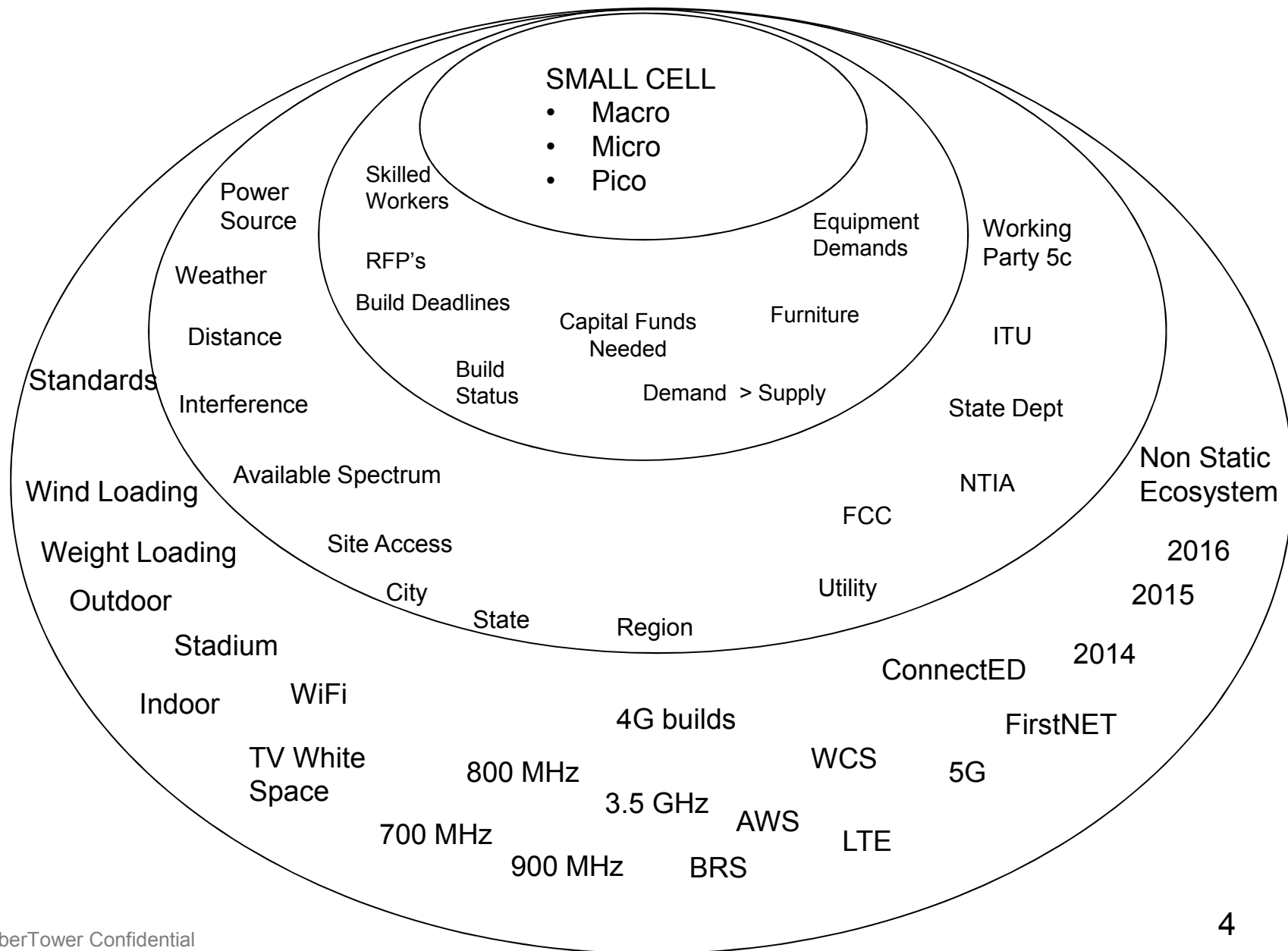


Small, Micro, Pico, Femto

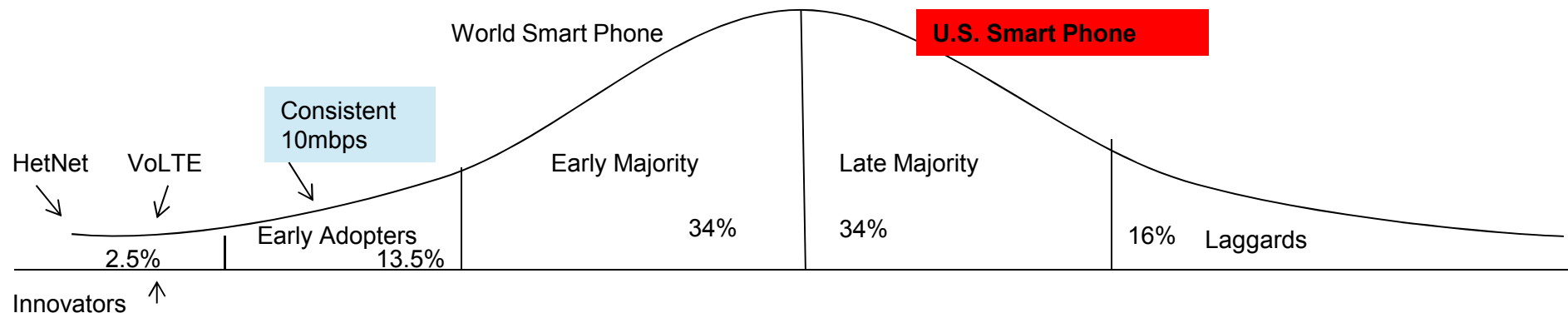


Small Cell: Complex Ecologies

What Data is Meaningful to You? Your Funders? Your Customers?



Mobile Broadband Status <-> Small Cell Markets

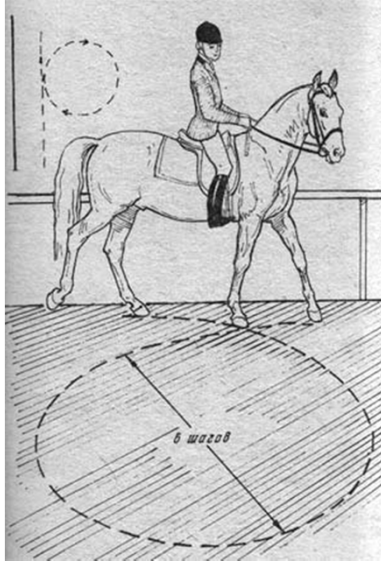


Small Cell Type	Residential	Small-Medium Business Enterprise	Service Provider
# Users per small Cell	1-8	1-32	1-16
Network	2G/ 3G/ 4G/ WiFi	2G/ 3G/ 4G/ WiFi	3G/ 4G/ WiFi
Status	Early Majority	Late Majority	Innovator
Typical Access Vendor	Juni, SK Telecom, ALV, Airvano, Cisco, IP-Access, NEC, Samsung, SpiderCloud	ALV, Airvano, Cisco, IP-Access, NEC, Samsung, SpiderCloud	ALV, Ericsson, Cisco, Huawei, NEC, Nokia, Samsung, SpiderCloud, ZTE
Rf Power Licensed	< 20mV	<0.2W	<10W
TYPE	Femto	Femto, Pico	Femto, Pico, Micro

Source:
Dell'Oro
Group



VoLTE



Volte : A very small circle that is used in the training of a horse. Of all the circles, it requires the most balance from the horse. Voltes are excellent training tools, encouraging engagement and power”

VoLTE : Voice over LTE

- Lower power consumption;
- Uses 50% less spectrum than 2G/3G voice
- Smaller Cells

Sources: Verizon; WirelessWeek “VoLTE: Coming Soon to a Phone Near You”, Oct. 15, 2013, <http://www.wirelessweek.com/articles/2013/10/volte-coming-soon-phone-near-you>



Small Cell Adoption Barriers

BACKHAUL:

Affordable/ Available

COMMERCIAL AVAILABILITY:

- Complete End-to-End Solution
- Performance Parity with Marco Cell

DEPLOYMENT CHALLENGE:

- Street Furniture
- Security
- Trust
- New territory/ skill sets needed to deploy
- Permitting/Site Access



Source: AT&T; Dell'Oro Group



What Are Small Cells?

- ▶ There are varying definitions. For purposes of today's presentation we will use the following:
- ▶ Macrocells are the original, wide area high power bases stations that cover areas typically reaching up to 20 miles radius (there are exceptions).
- ▶ Small cells are the generic umbrella term for a variety of smaller underlay cell technologies. Small cells do *not* replace Macrocells, and instead support and feed back to Macrocell networks.
 - Picocells are operated and managed by the network operator who also pays for site rental, and transmission back to the core network.
 - Femtocells are semi-autonomous systems. They are installed, powered and connected by the end user or business with less active remote management by the network operator who remains responsible for them.

	Macro	Small Cell
Radio	1-3 miles	0.1-0.5 miles
Per site capacity	-150 to 500 Mbps	-100 to 300 Mbps
Aggregation capacity	-500 to 2000 Mbps	-300 to 1000 Mbps

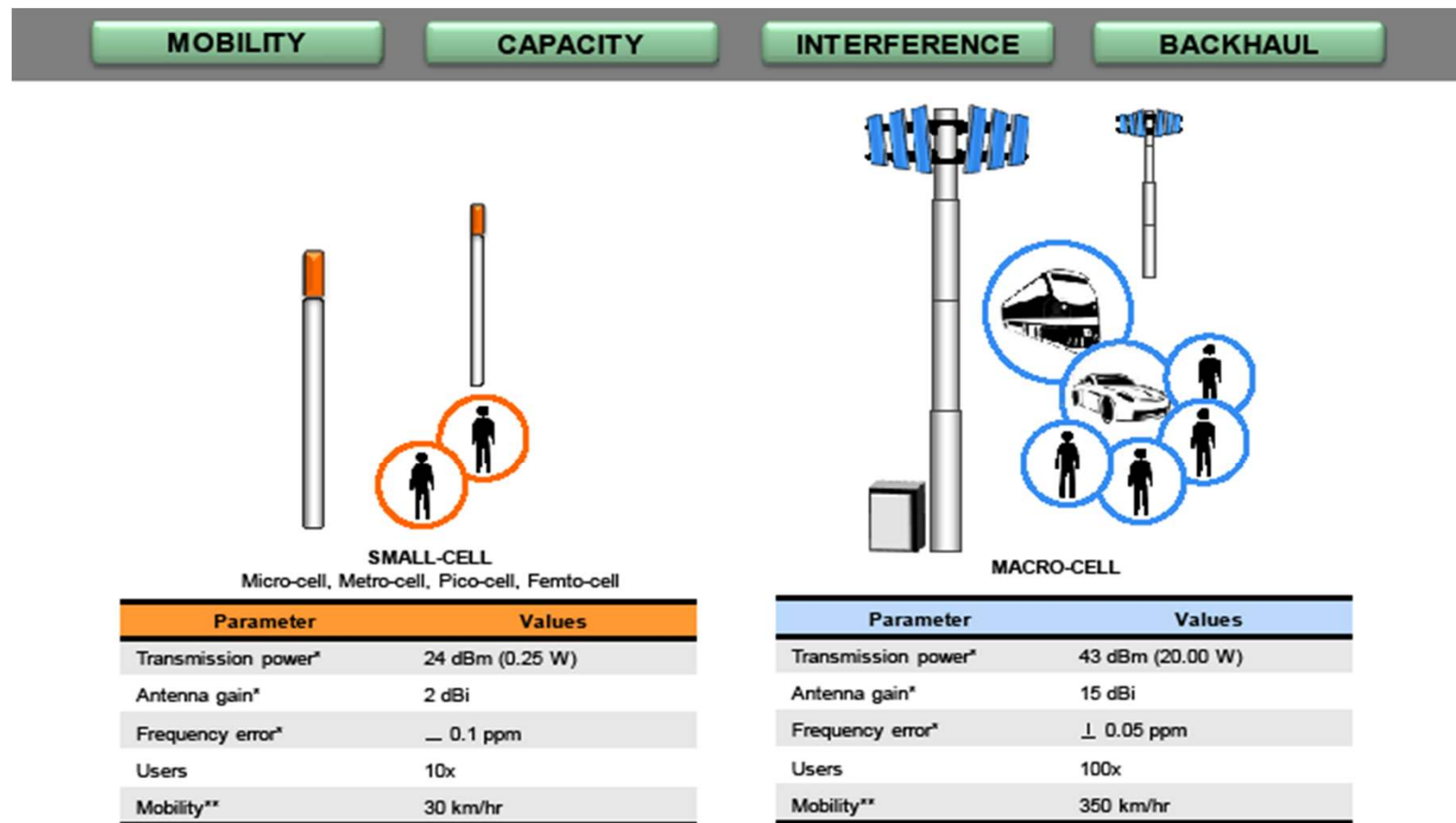


Small Cell Wireless Backhaul Solutions

	Unlicensed Millimeter Wave (60 GHz)	Lightly Licensed Millimeter Wave (70-80 GHz); 100 GHz+	Licensed Point-to-Point Microwave (6,11,18,23 GHz)	Licensed Wide-Area Microwave (24,28,31,38 GHz)	Sub-6 GHz Licensed/ Lightly Licensed (2.4 GHz; BRS; 3.65 GHz; etc)	Sub-6 GHz Unlicensed (TVWS; 900-928 MHz; 2400-2483.5 MHz; 5 GHz)
Capacity	+1Gbps (scalable)	10Gbps + Scalable	1Gbps +	1Gbps +	170 Mbps	1x1MIMO:150Mbit/s 2x2MIMO:300Mbit/s 3x3MIMO;450Mbit/s
Coverage	1km hop length	~ 3km hop length	2-4 Km	2-4 Km	- 1.5-2.5km urban - 10km rural	Up to 250 meters
Installation	Line of Sight	Line of Sight	- Line of sight - New NLOS product on market– viability being tested	- Line of sight - New NLOS product on market– viability being tested	- Non line of sight - New NLOS product on market– viability being tested	Non line of sight
Use Cases	Strong candidate to be primary wireless backhaul at the ‘street-level’	Suitable for ‘rooftop aggregation’ of small cells, back to macro	- Point to multipoint: Peppered Capacity - Point to Point: Remote not-spots	- Point to multipoint: Peppered Capacity - Point to Point: Remote not-spots	Significantly higher coverage enabling rapid rollout across a target area	- Remote isolated locations - backhaul of Wi-Fi access points
Challenges	- Requires line of sight - requires multiple hops - Complexity of install - Pole Sway	Required line of sight	Requires Line of sight	- Requires Line of sight - New NLOS products being tested for wide-scale viability	Limited by typical licensed spectrum allocation availability	- Uncoordinated causing interference - In unlicensed spectrum clear today does not guarantee clear tomorrow

Small Cells

Macro-Cells vs Small Cells



*3GPP TR 36.931. Radio Frequency (RF) requirements for LTE Pico Node B (Release 11)

** 3GPP TS 36.104. Base Station (BS) radio transmission and reception (Release 10)

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SOURCE: JDSU

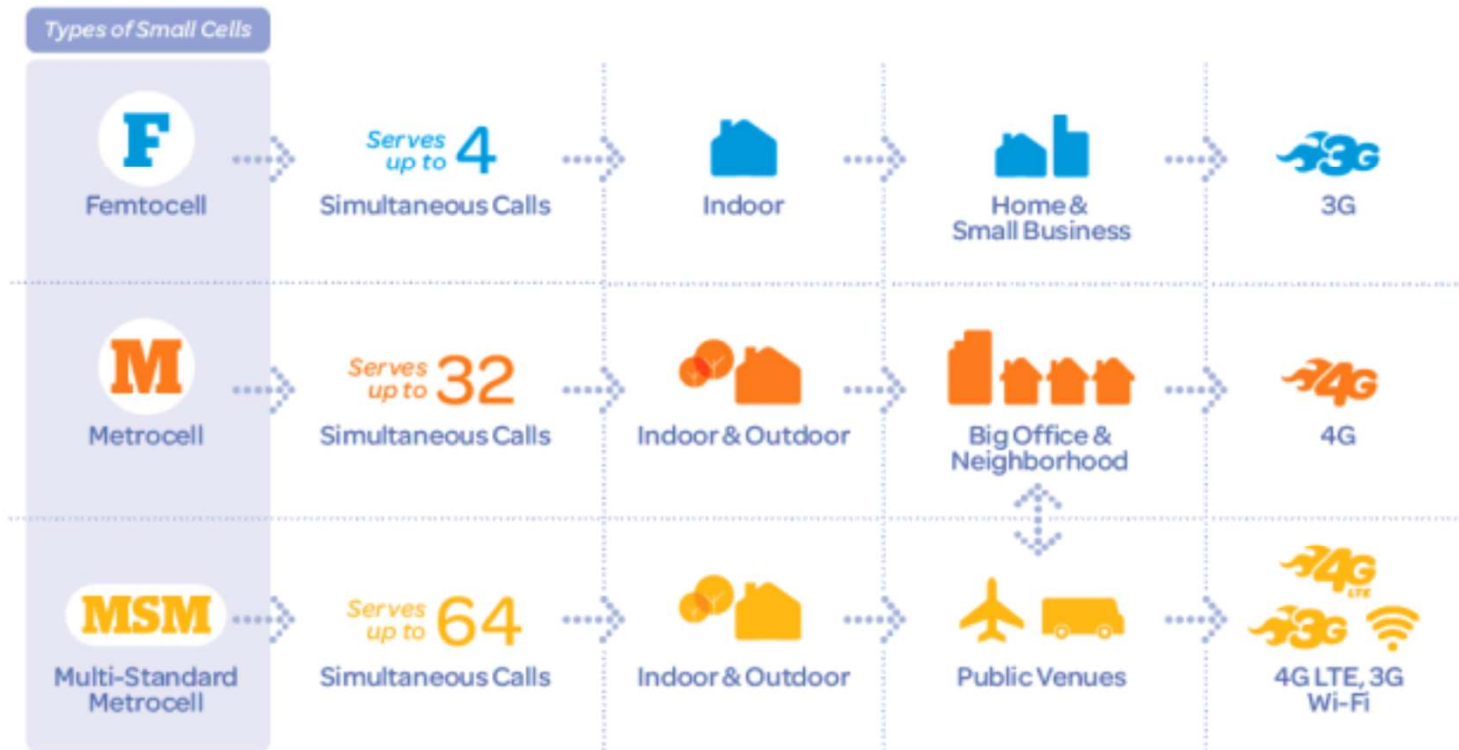


Small Cells

Types of Small Cells

AT&T Small Cell Line-Up

Small cells are a resourceful network solution that AT&T is deploying to provide you with flexible coverage.



By 2015, AT&T plans to deploy more than **40k** small cells in the network

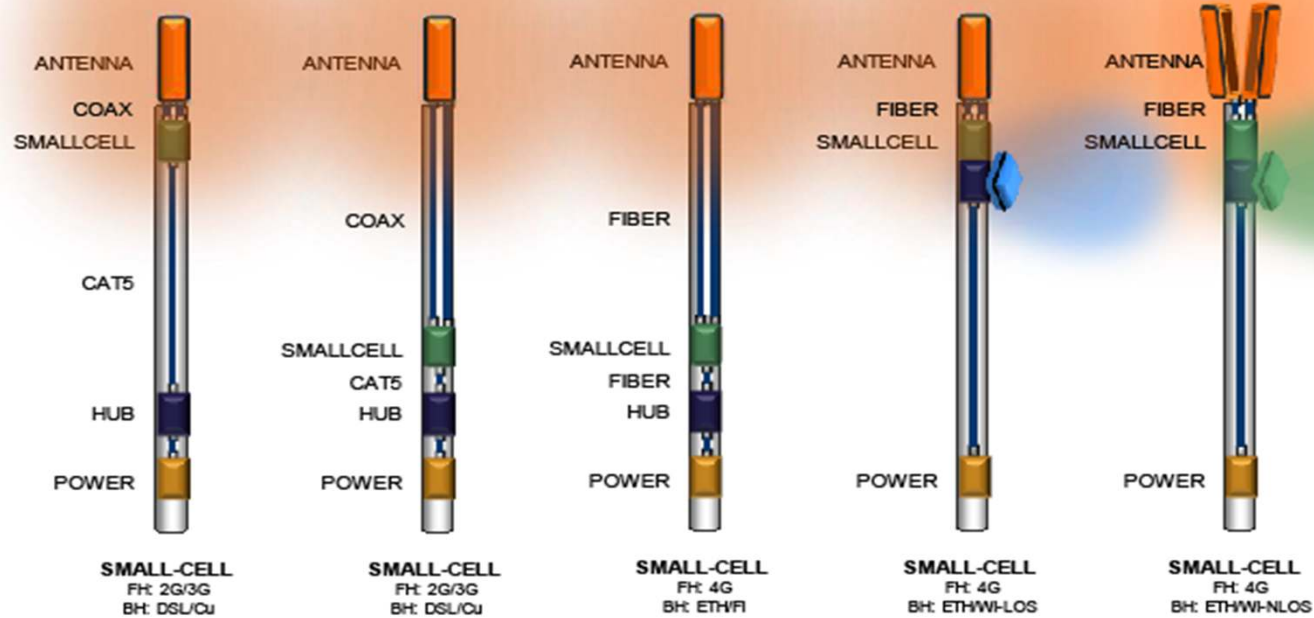
SOURCE: JDSU



Small-cells

Backhaul and Fronthaul Variations

- Small-cells architectures offer various solutions for back-haul and front-haul.



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SOURCE: JDSU



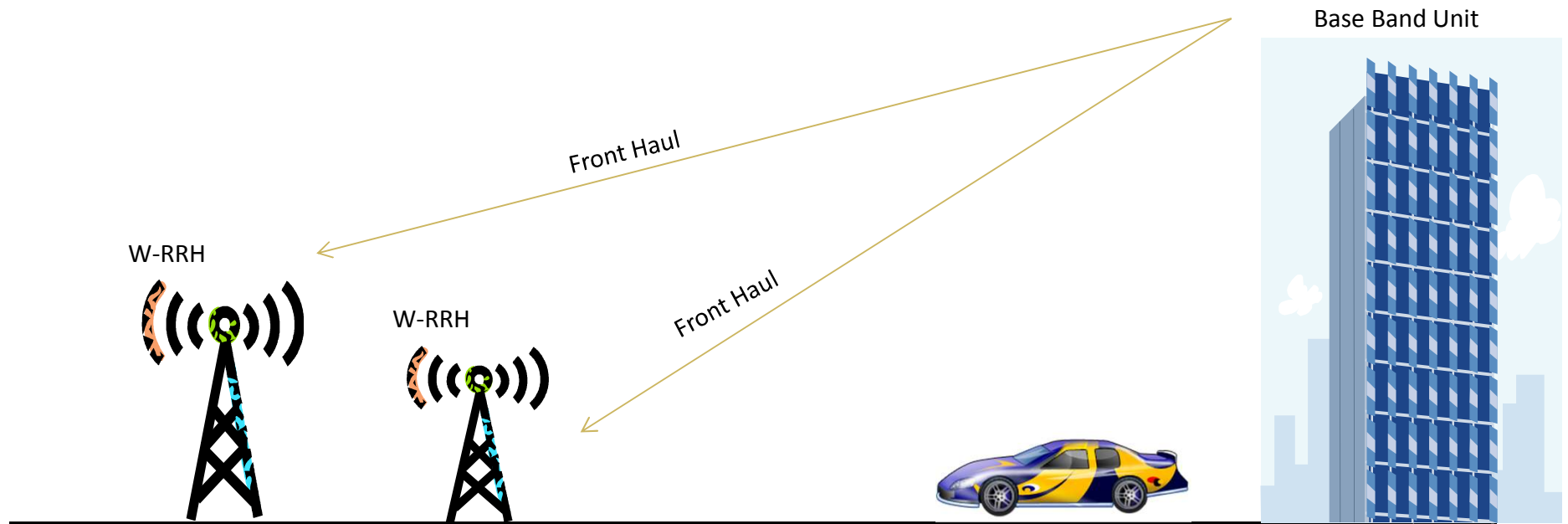
Small Cell Wireless Front Haul

Front Haul: Connection between the two main parts of a Mobile Base Station (1) Base Band Unit (2) Radio Unit

CPRI = Common Public Radio Interface

RRH = Remote Radio Head

WRRH = Wireless Remote Radio Head



FRONT HAUL

Type of Connection	Throughput Requirement	Maximum Round Trip Delay
Backhaul	Maximum: 150 Mbps Average: 21 Mbps	20 milliseconds
Fronthaul	Constant : 2.457 Gbps	0.300 milliseconds

Table 1 Comparison of requirements for a single-sector LTE 2x2 MIMO base station in a 20 MHz channel [Source: Marvedis



Cell metrics

▶ 1980s to the Present

- 3 Million mobile base stations operational worldwide
- ~25 years to construct

▶ Present to 2019

- 60 Million commercial mobile LTE base stations worldwide
 - 10-15% in the U.S.
 - Backhaul Wireline: +50%
 - Backhaul Wireless: 20-to-50%
 - Low band
 - Unlicensed
 - Licensed
 - High band
 - Unlicensed
 - Licensed
- Ratio of Small Cell to Macro: 5:1 (Suburban) to 20:1 (Dense Urban)



Other Uses

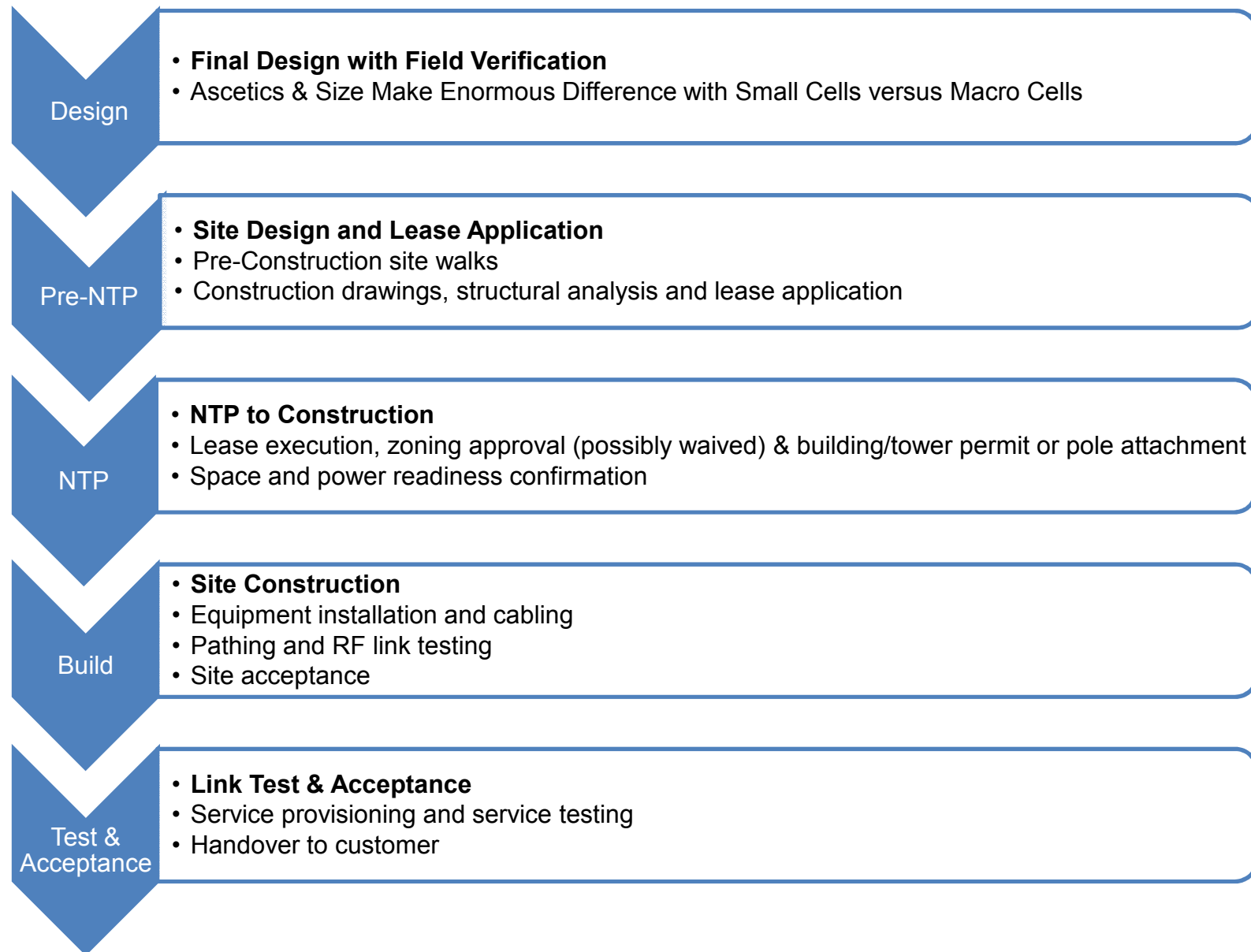
Other uses not included in the commercial network forecast tabulation:

- FirstNet: National First Responder Network
 - 45,000 Macro sites
- WiFi
- WISPs
- Fronthaul
- SmartGrid
- Intelligent Vehicle
- Electronic bill boards
- Stadium & Festival events
- Video > Fixed, Portable & Mobile
 - Surveillance; News
- Inside buildings

National and local level challenges to handle any A&E drawing, leasing, zoning, permitting or construction needs

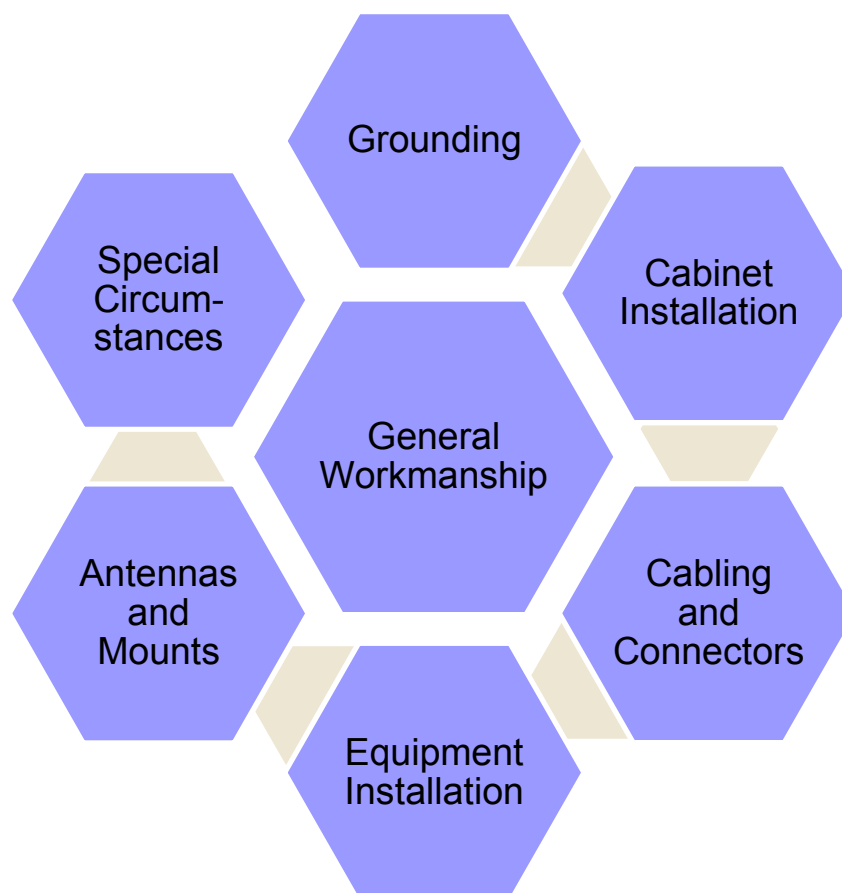


Network Deployment Process: Street Level Requires Different Thinking



Deployment: Construction Standards

- ▶ Detailed library of construction standards to cover all Metro authorities
- ▶ FCC Pole Attachment rules: utilities to 'make ready' within 45 days; ~\$12/yr
- ▶ Cross-functional teams must continually review and update based on field feedback
- ▶ Contractors are trained on the standards; Field Operations verifies compliance upon site acceptance



Project Macro and Small Cell Backhaul Network Architecture



Small Cell Accelerators

▶ **LTE Arriving: Funded projects**

- Verizon well underway
- AT&T, TMO, Sprint, Others in various (mostly early) stages
- National 1st Responder Network (45,000 sites; Funded Feb. 2012, Pub.Law 112-96).

▶ **FCC Pole Attachment Order**

- July 2011: Utilities must make poles ready within 45 days
 - Typically \$12 per year rent
 - Compared to +\$200 per month on typical towers and rooftops!

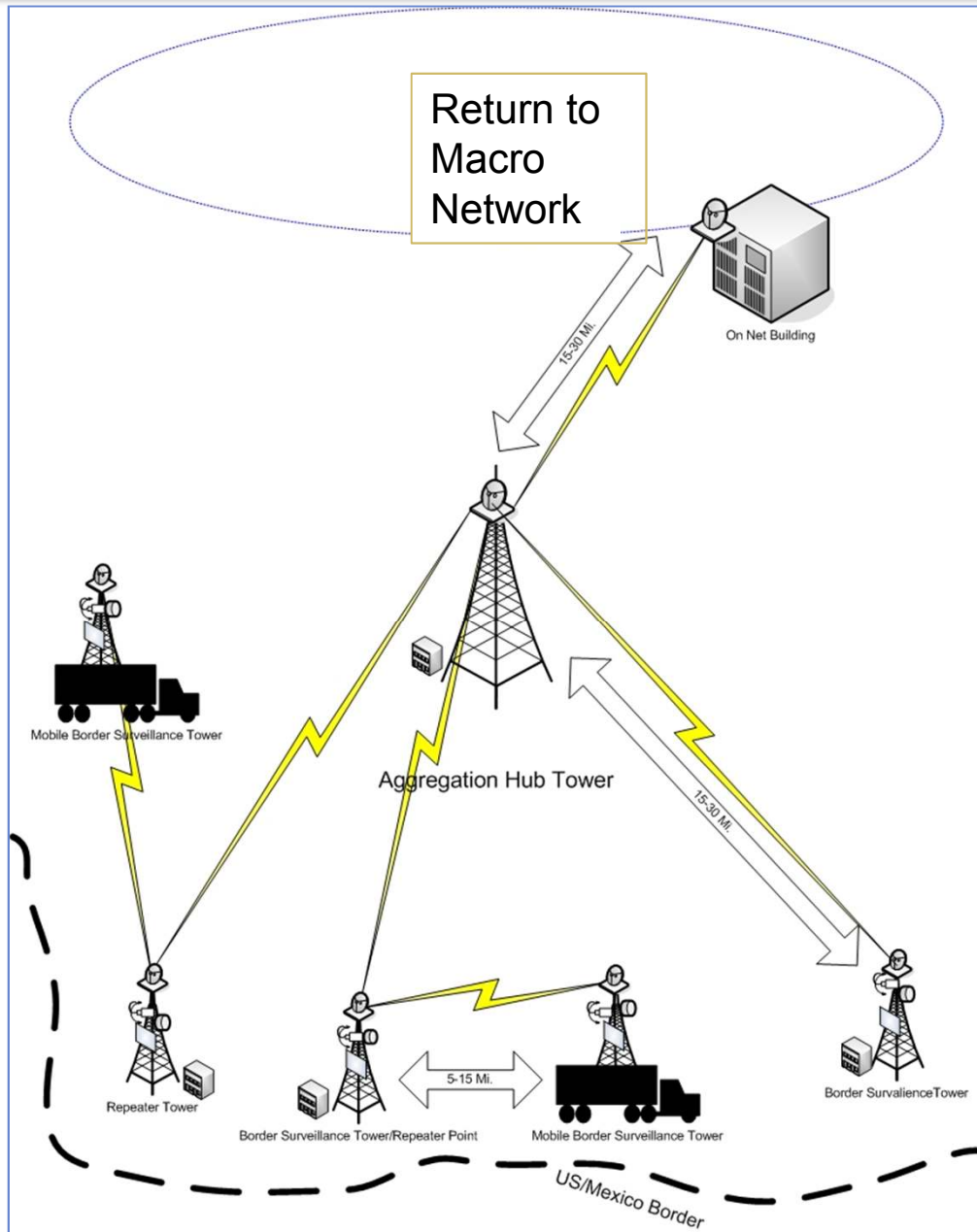
▶ **Small Cell backhaul gear developments**

- Low band
 - Unlicensed 928 MHz, 2.8 GHz, 5 GHz
 - Lite License: 3.65 GHz
 - 3.5 GHz SAS (testing)
 - Wide-area Licensed : BRS, WCS, 1.4, others
- High band
 - Unlicensed : 60 GHz ; Lite Licensed: 70-90 GHz
 - Point-to-point: 6, 11, 18, 23 GHz
 - Wide-area Licensed: 24 GHz (400 MHz); 28-31 GHz; 38.6-40.0 GHz





Small Cell Project Backhaul Network: Border Protection



► Primary Network Nodes:

- Fiber exchange points
 - On-net buildings/towers
 - Off-net buildings/towers
- Aggregation hub rooftops/owers
- Small-cell host poles/towers/buildings

► Microwave Backhaul Links

- Macro Aggregation links
- Small cell access links
 - Lightpoles/Power poles
 - Towers/Rooftops
 - Portable



Sample fixed wireless systems: small cell backhaul

- For use on licensed wide-area millimeter band licenses
 - EBand
 - DragonWave
 - Multiple point-to-point backhaul for pole-mounted LTE base stations
 - JRC
 - Point-to-multipoint (PMP) and Point-to-point (PTP)
 - BridgeWave
 - +1 Gbps
 - Ceragon
 - Ericsson
 - Alcatel-Lucent
 - Aviat
 - SAF T
 - Many others!



Highly Dense Deployments Reveal New Uses for Fixed Millimeter-Wave : NLOS, Portable, Mobile

- Once small cell deployments achieve critical mass
 - Hundreds or thousands of systems over a few square miles
 - Outdoors
 - Inside buildings
 - Portable
 - Mobile
 - Achieving line-of-sight from multiple angles
 - Easily installed low-cost, low-profile gear
 - Point-to-multipoint (PMP) and Point-to-point (PTP)
 - Thus allowing ‘ mobile-style’ performance on wide-area licenses
 - With superior bandwidth suddenly available
 - 400 MHz at 24GHz (5 x 80 MHz channels)
 - 1150 MHz in LMDS Block A
 - 1.4 GHz at 39 GHz (14 x 100 MHz channels)



NLOS, Portable, Mobile

- **ATT McCaw Era 6GHz Mobile**

Stanford: circa 2005 60GHz Mobile;

Ericsson: Figures from Non-Line-of-Sight Microwave Backhaul Small Cells Presentation from Feb 22 2013

Density-based Mobile



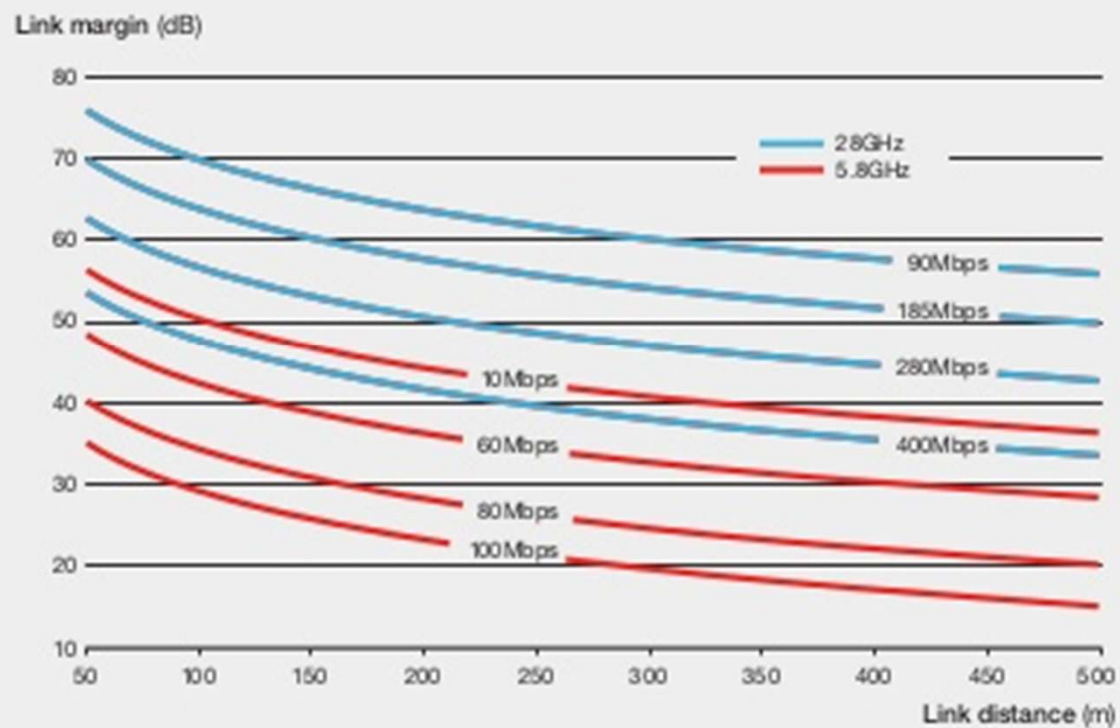
FIGURE 1 Microwave backhaul scenarios for small-cell deployment



Ericsson Review: 2013.3



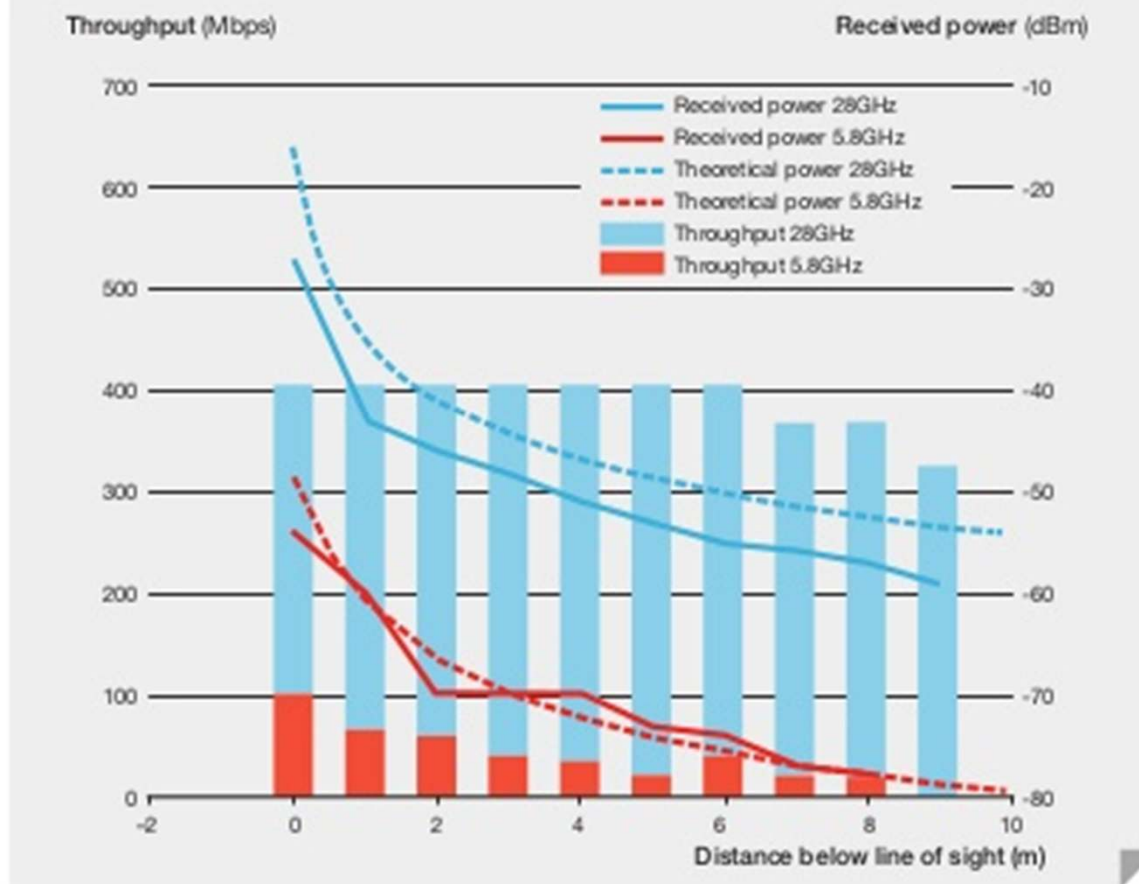
FIGURE 2 Link margin as a function of throughput and distance



Ericsson Review: 2013.3



FIGURE 3B Throughput and received power - diffraction



Ericsson Review: 2013.3



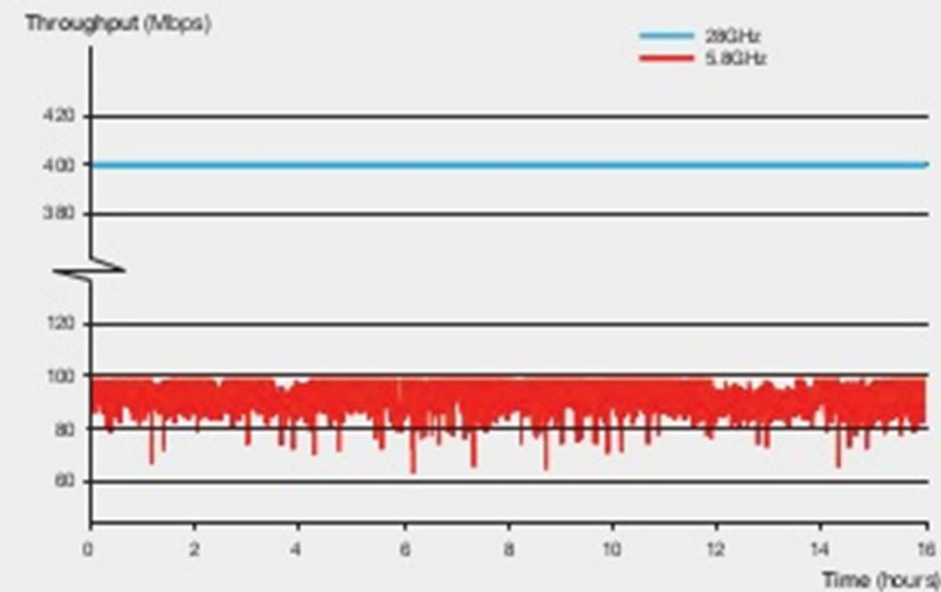
FIGURE 4A Test site for NLOS backhaul - reflection



Ericsson Review: 2013.3



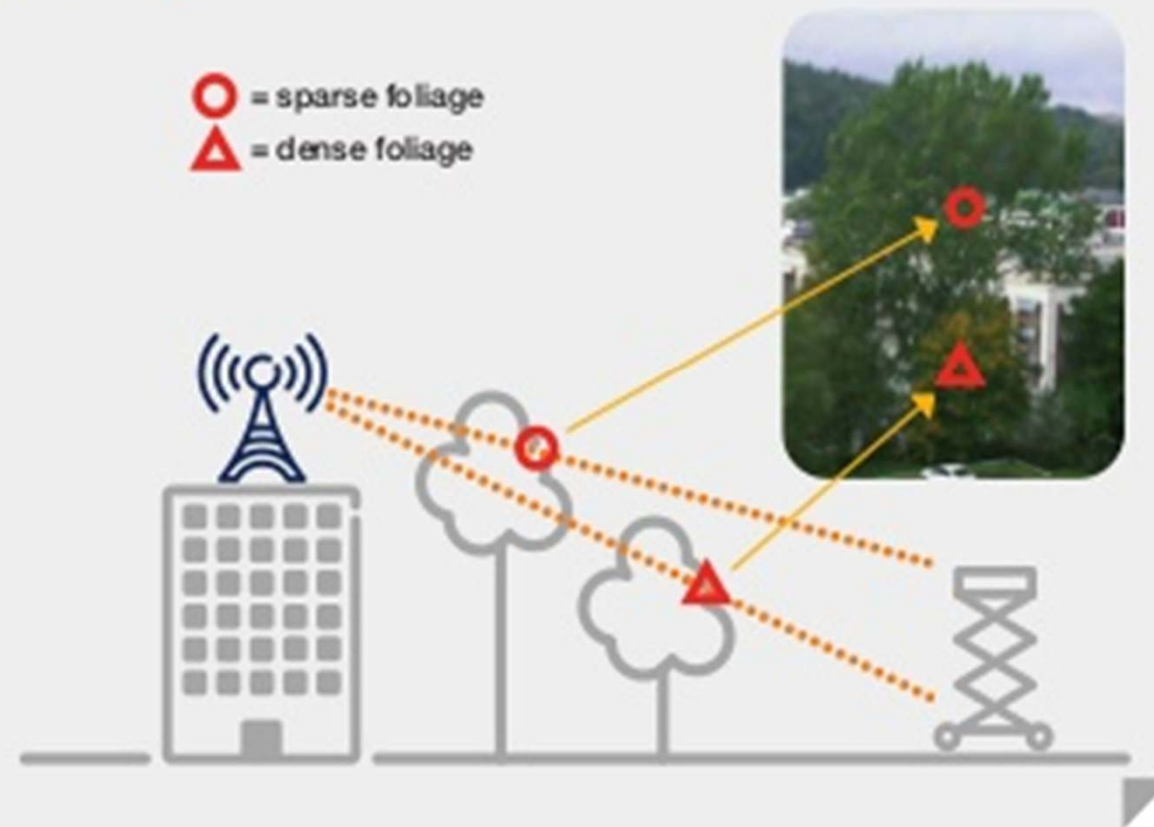
FIGURE 4B Throughput over time - single reflection



Ericsson Review: 2013.3



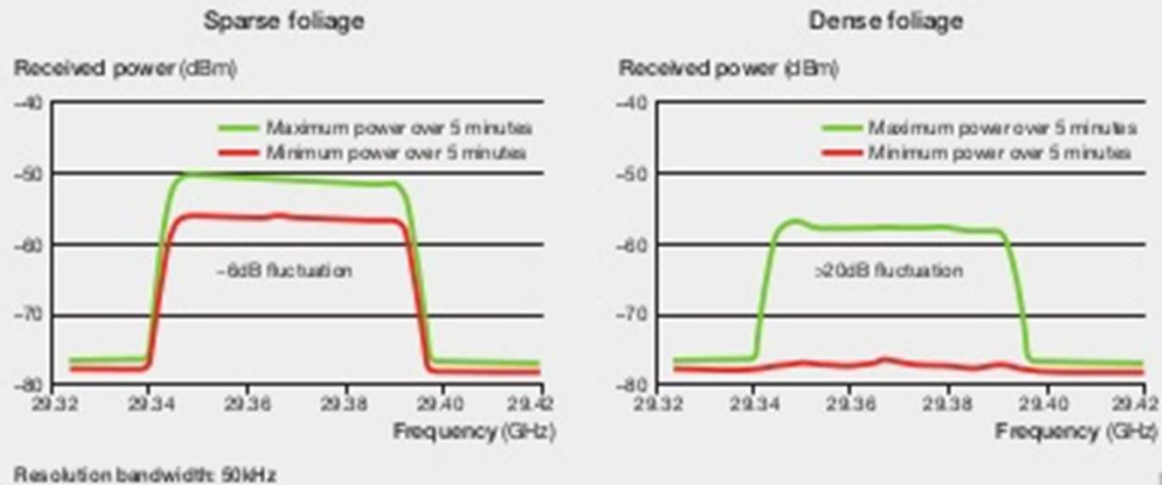
FIGURE 5A Test site for NLOS backhaul - penetration



Ericsson Review: 2013.3



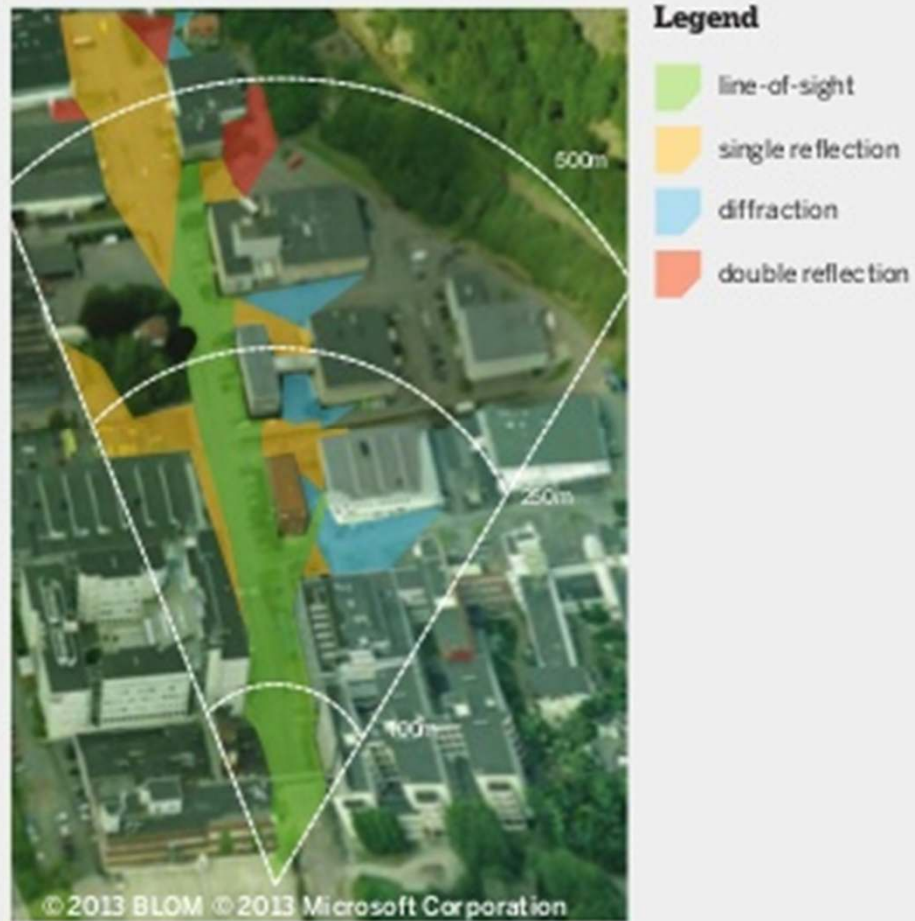
FIGURE 5B Channel amplitude response - penetration



Ericsson Review: 2013.3



FIGURE 6 NLOS backhaul trial area

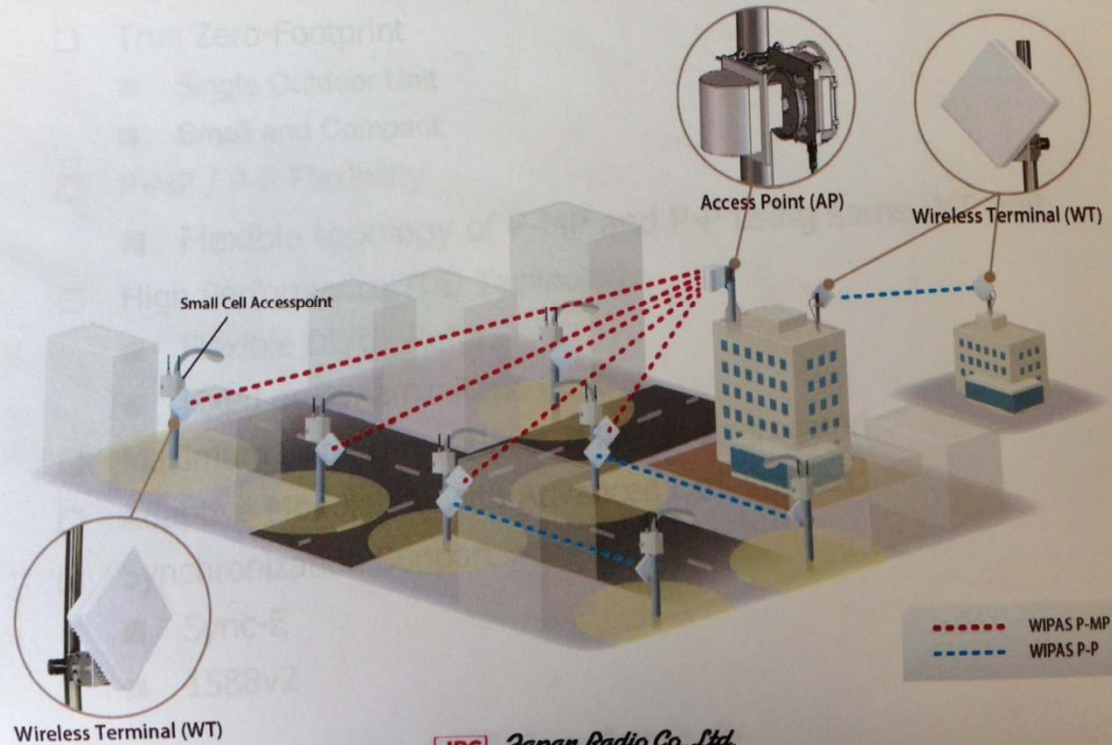


Ericsson Review: 2013.3



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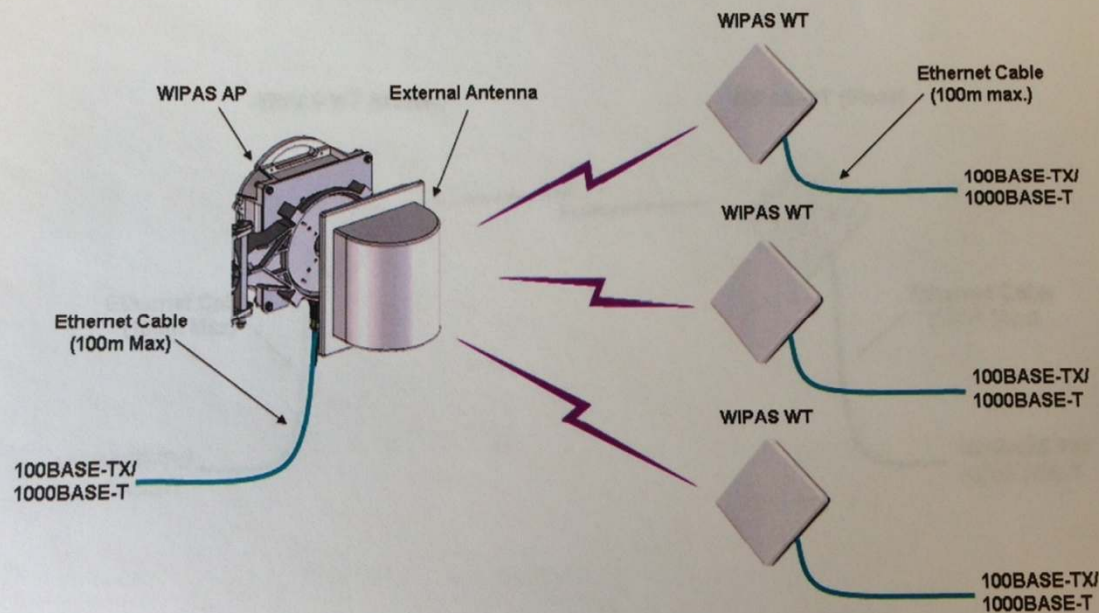
WIPAS Usages with Small Cell Backhaul



JRC Japan Radio Co., Ltd.



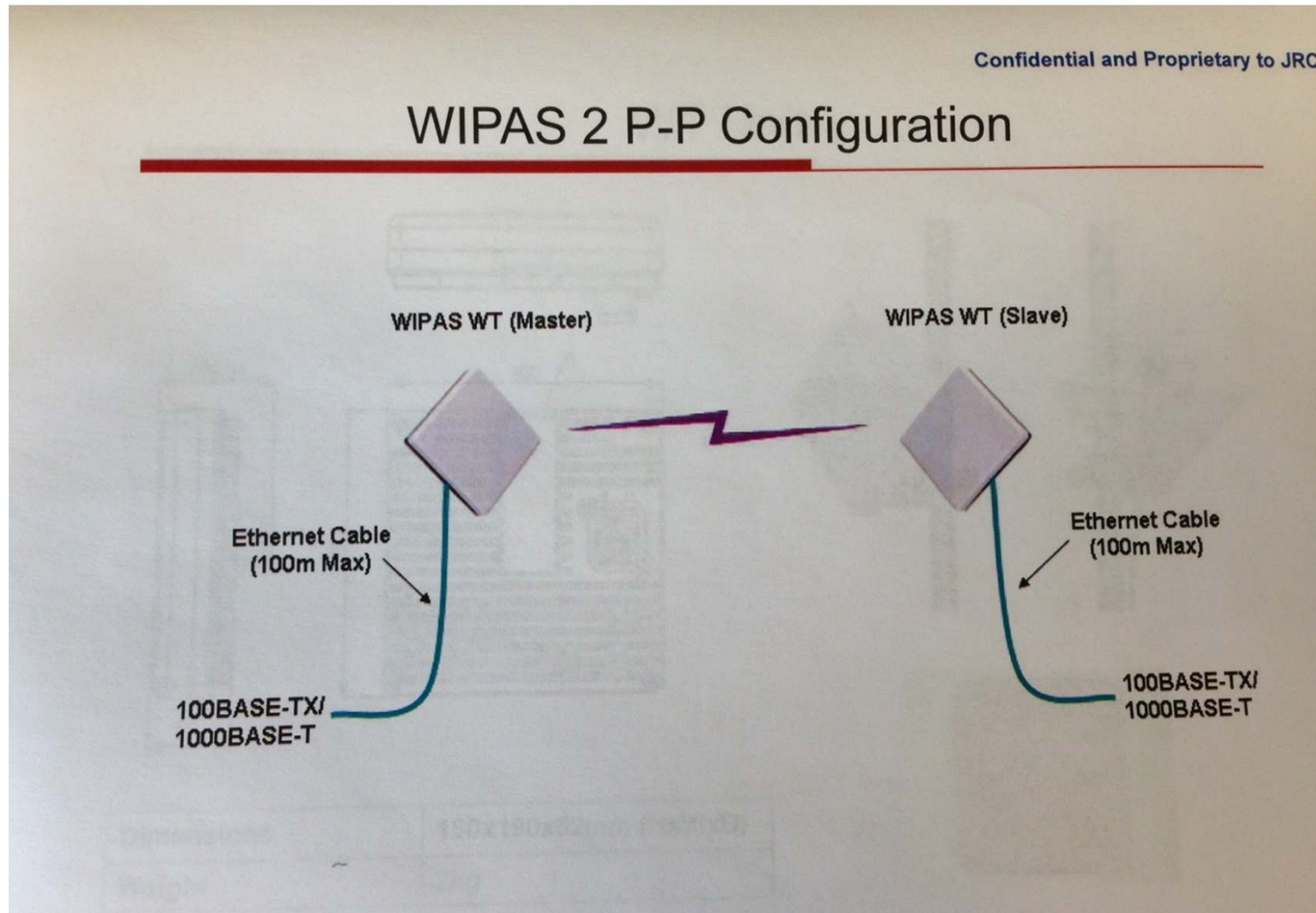
WIPAS 2 P-MP Configuration



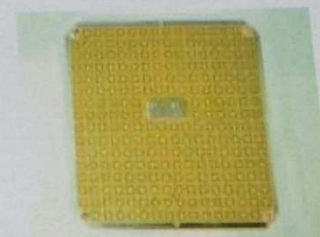
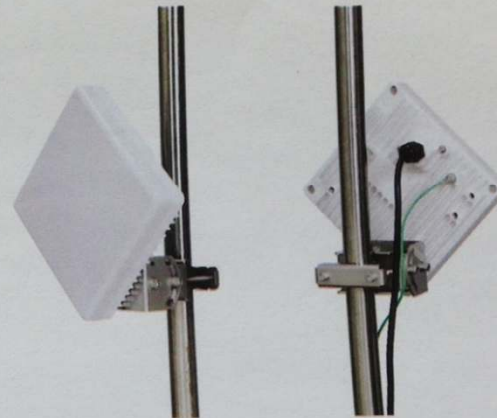
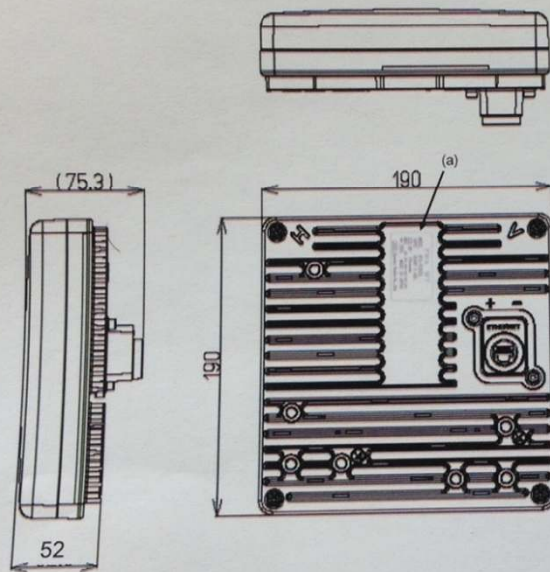
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WIPAS 2 P-P Configuration



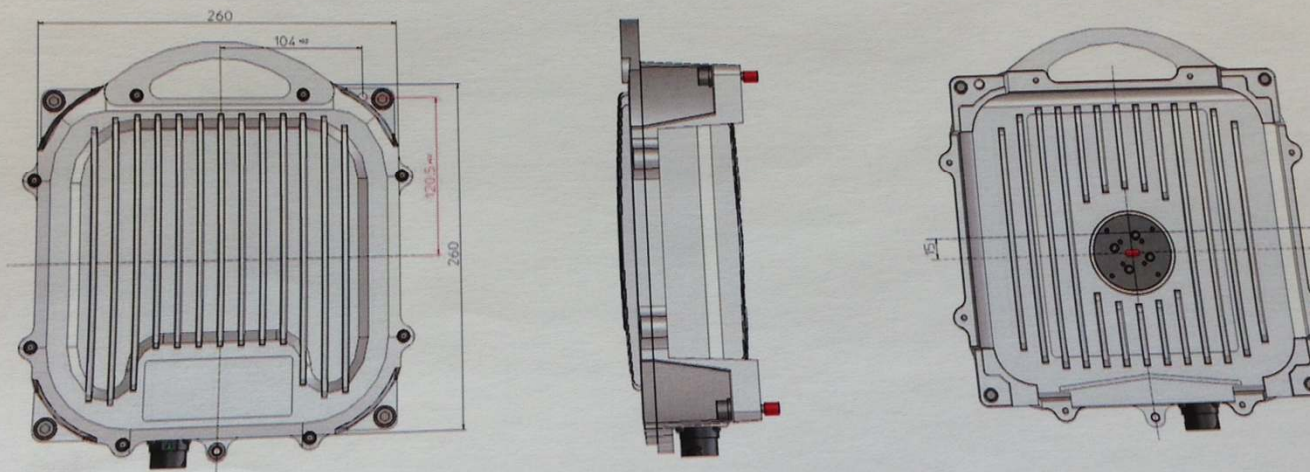
WT Unit



Built-in Antenna

Dimensions	190x190x52mm (HxWxD)
Weight	2kg
Power Consumption	20W

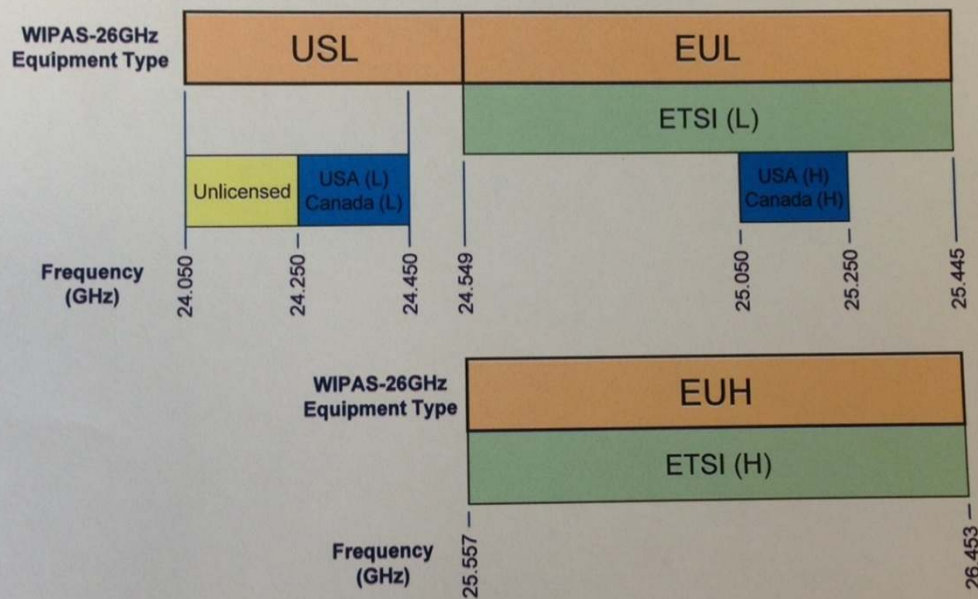
AP Unit



Dimensions	260x260x91.7mm (HxWxD) Excluding Protrusions
Weight	6.0kg
Power Consumption	35W



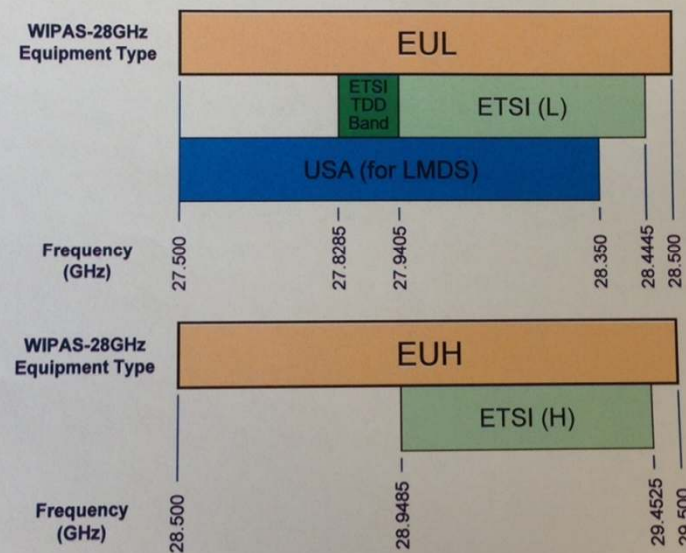
Frequency Coverage: 24-26.5GHz Band



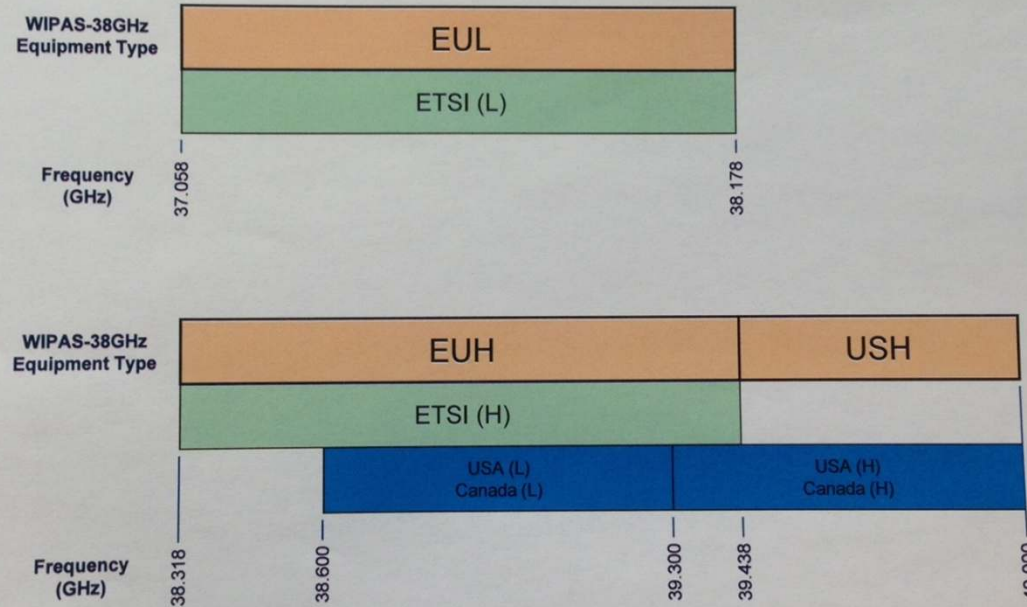
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Frequency Coverage: 27.5-29.5GHz Band



Frequency Coverage: 37-40GHz Band



WIPAS 2 Specifications

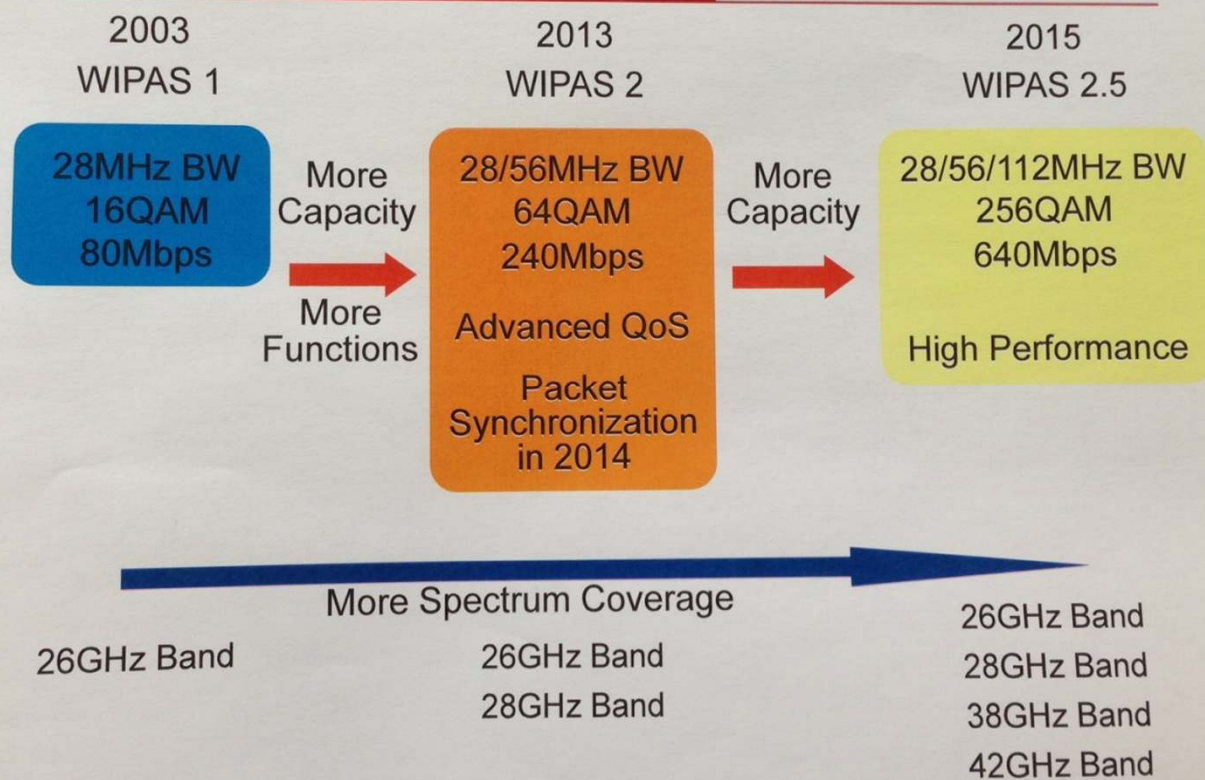
Item		Description			
Duplex		TDD (Flexible DL / UL Ratio)			
Modulation		QPSK, 16QAM, 64QAM (Adaptive Modulation or Fixed)			
Channel Spacing		20MHz	28MHz	40MHz	56MHz
Radio Transmission Rate (Aggregated DL and UL)	QPSK	28.5Mbps	40Mbps	57Mbps	80Mbps
	16QAM	57Mbps	80Mbps	114Mbps	160Mbps
	64QAM	85.5Mbps	120Mbps	171Mbps	240Mbps
Data Throughput (aggregated DL and UL)	QPSK	20Mbps	30Mbps	42Mbps	60Mbps
	16QAM	40Mbps	60Mbps	82Mbps	120Mbps
	64QAM	62Mbps	90Mbps	124Mbps	180Mbps
Transmit Output Power	QPSK	AP +20dBm / WT+14dBm			
	16QAM	AP +17.4dBm / WT +11.4dBm			
	64QAM	AP +16.3dBm / WT +10.3dBm			
Antenna Gain	AP	17.0dBi (90deg x 6deg)			
	WT	31dBi(Built-in) , 35.3dBi(External:30cm) , 40.7dBi(External:60cm)			
Receiver Sensitivity at Antenna Port BER < 1E-6	QPSK	-82.0 dBm	-80.5 dBm	-79.0dBm	-77.5 dBm
	16QAM	-75.0 dBm	-73.5 dBm	-72.0dBm	-70.5 dBm
	64QAM	-67.0 dBm	-65.5 dBm	-64.0dBm	- 62.5 dBm
Encryption		Camellia*1 128bit			
Interface	AP	1 x 100/1000BASE-T			
	WT	1 x 100/1000BASE-T			
Cable Length		100m (for data and power)			
Operating Temperature Range		-33°C to +50°C			

*1: "Camellia" is a registered trademark of Nippon Telegraph and Telephone Corporation (NTT) and Mitsubishi Electric Corporation.

All specifications subject to change without notice.



WIPAS Roadmap



JRC Japan Radio Co., Ltd.



Small-Cell Wide-Area Licensed Spectrum: 24GHz, 28GHz, 31GHz, 38GHz

Quality of Service:

- **Commercial Contract Standards:**
 - **Exclusively Licensed**
 - **Wide-area planning**
 - **99.995% Signal Availability**
 - **4-to-8 hour Mean Time to Repair**
- **High Density**
 - **+50 Links Per Square Mile**
- **Low-profile customer node**
 - **Sample: Less than 12"**
 - **NOTE: Some are substantially smaller**



FCC Enforces Renewal Standard

Four links per million people by June 1, 2012 resulted in:

- **2/3rds licenses returned**
- **Approximately 60 Extension Requests denied and licenses terminated**
- **Perfectly good state-of-the-art systems torn down**
- **National small-cell backhaul network rejected**
- **Some systems built using ancient technology**
- **FiberTower sought and received Federal Court injunction against FCC re-authorizing its terminated 24GHz and 39GHz licenses**
 - **Briefing schedule estimated Mid-2014**



FCC Wide-Area Millimeter Renewal Policy: DMC XP4 Radio & 99.5% Signal Availability



15 year old radio with a life cycle that ended in 2007.

- **Effective FCC Policy:**
 - **Dismantle many high-quality networks**
 - **Renew licenses built out cheaply with obsolete technology**
 - **Discourage commercial grade Research & Development.**



Small-Cells Mobility and Spectrum Benefits



Small-cells enhance **coverage** of macro-cells and **capacity** for indoor and outdoor environments:

- Increases throughput and mobility performance
- Optimizes power and spectrum efficiencies

SOURCE: JDSU



Poll Question

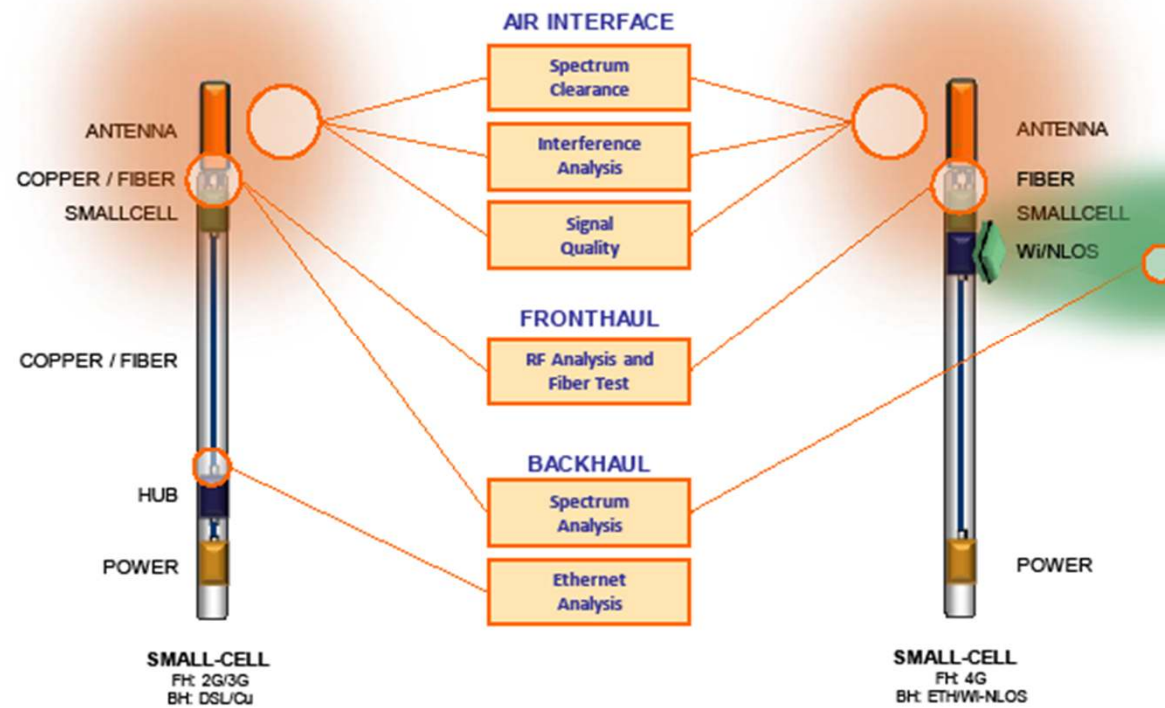
- **What type of backhaul technology will be most commonly used in small-cells:**
- 1.DSL over copper
- 2.Ethernet over copper
- 3.Ethernet over fiber
- 4.Ethernet over non-line-of-sight μ W (< 6GHz)
- 5.Ethernet over line-of-sight μ W (6GHz to 30GHz)
- 6.Ethernet over mmW (30GHz to 300GHz)

SOURCE: JDSU



Small-Cells Test Points

- Different types of small-cells will co-exist demanding different test methodologies.



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SOURCE: JDSU

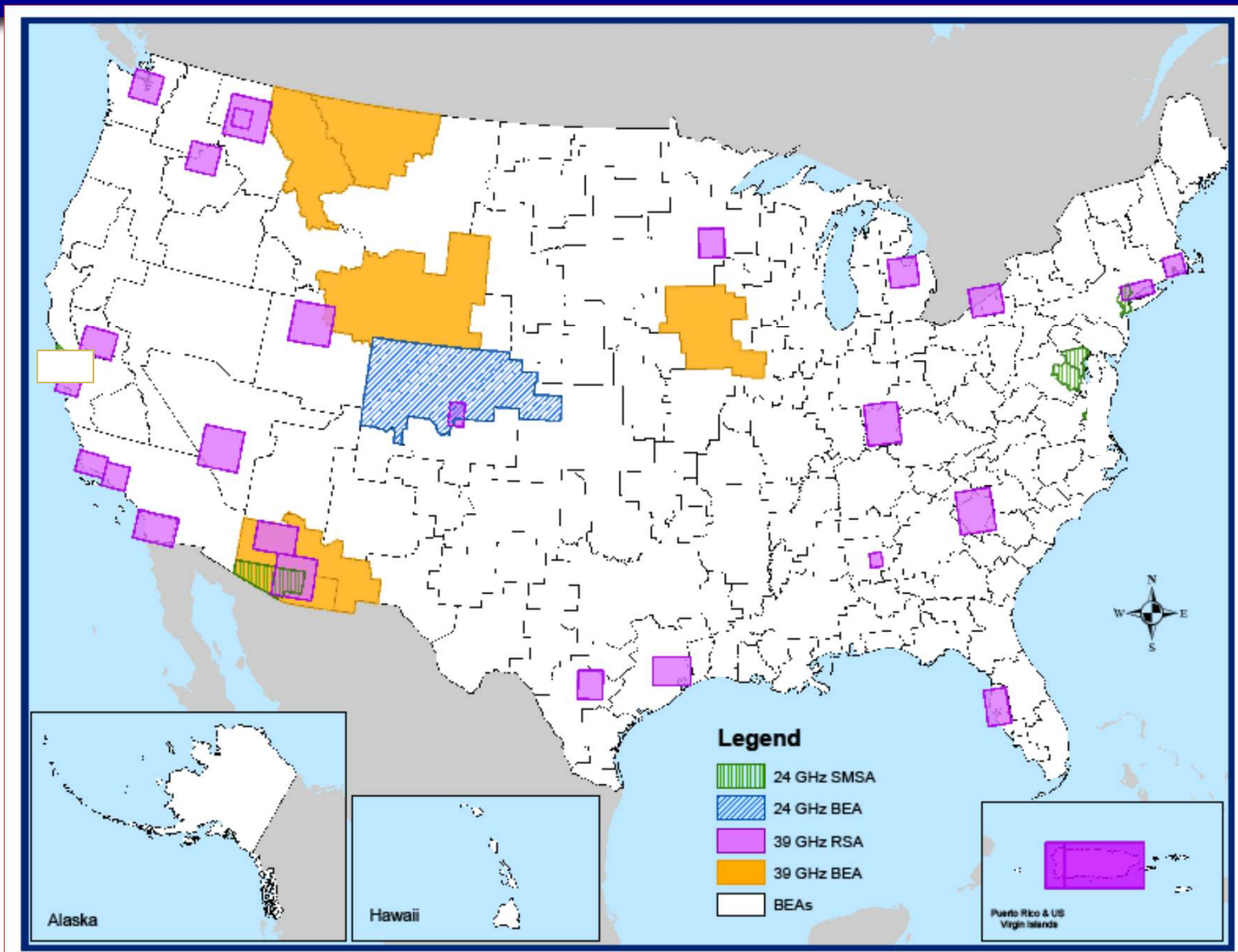


FiberTower – Restructured as Private Company

- ▶ Restructured Effective Spring 2014
- ▶ Privately Held
- ▶ 46 Active Wide-area market licenses
 - ▶ Actively leasing and operating
 - ▶ Approx. 100M Spectrum POPs
- ▶ Also contesting licenses that the FCC states it took back.
 - ▶ U.S. Court of Appeals (DC Circuit)



Active National Spectrum: 24GHz & 39GHz



Today: Ideal spectrum for rapid deployment of high capacity small cell site backhaul – Tomorrow: Glide Path for 5G



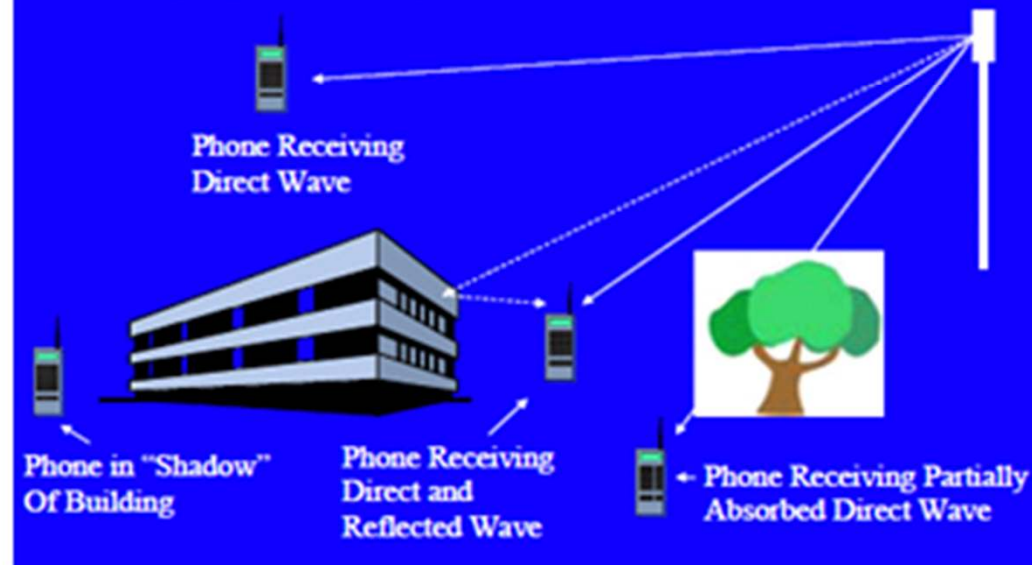
Traditional Line of Sight Considerations.

Location, Location, Location!

TV Band Spectrum (< 1 GHz) is uniquely valuable:

- Larger Coverage Areas
- Lower Infrastructure Costs
- Better In-Building Penetration

• Propagation Impairments



Source: New America Foundation: SHLB Conference, 5/9/2014



TV White Spaces: Small Cell Examples



Base station: 3' tall, 5" cylinder.

Nodes: Flat panel 10" x 8" x 1"

Advantages: NLOS

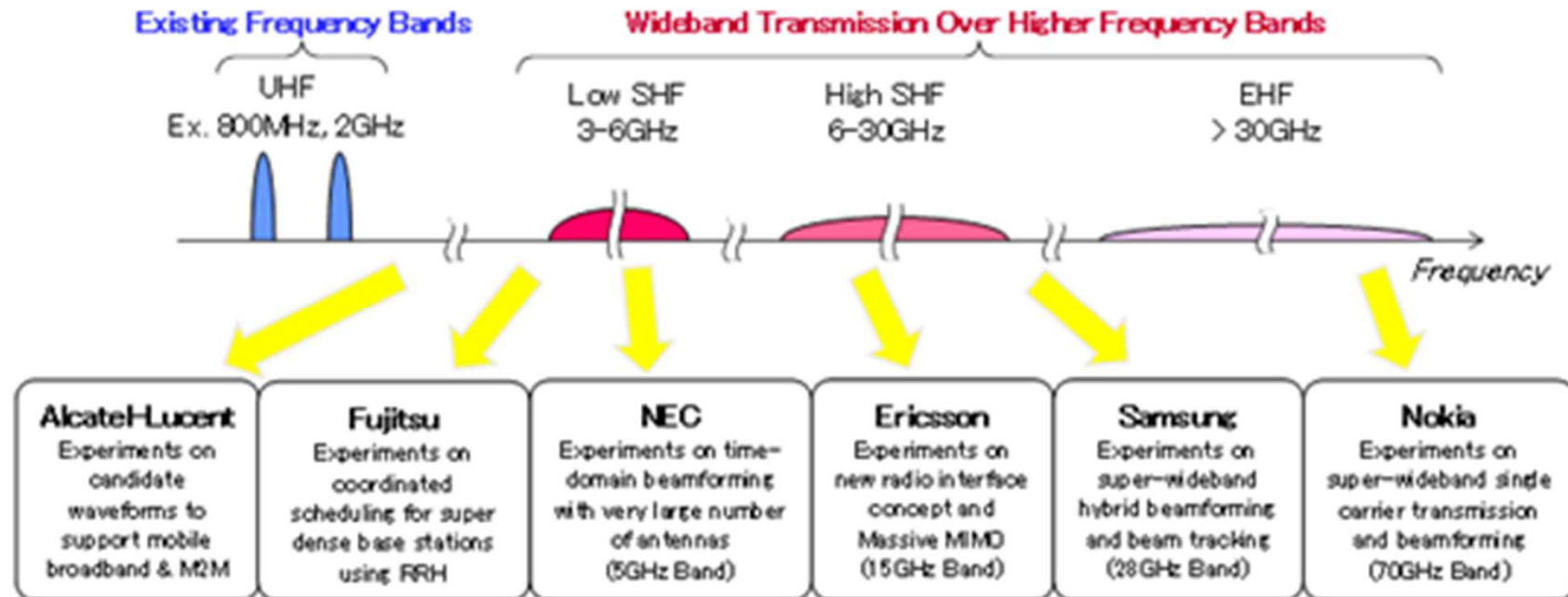
Performance: 3Mbps down; 1 Mbps up

Source: Pascagoula School District: TV White Space Project Presentation, SHLB, May 9, 2014, Washington, DC"



Non Line of Sight (NLOS): Network Tests Announced

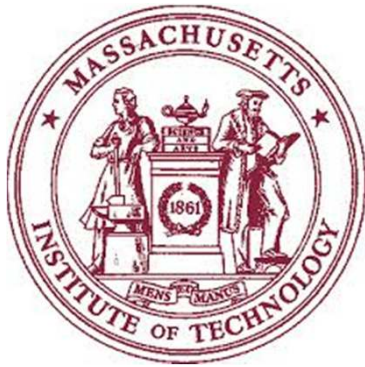
May 8, 2014



Source: NTT DOMOCO, 5/8/2014, "DOMOCO to Conduct 5G Experimental Trials with World-leading Mobile Technology Vendors"



NLOS & Superfast 5G: Unlocking Microwave, Millimeter Wave and Above



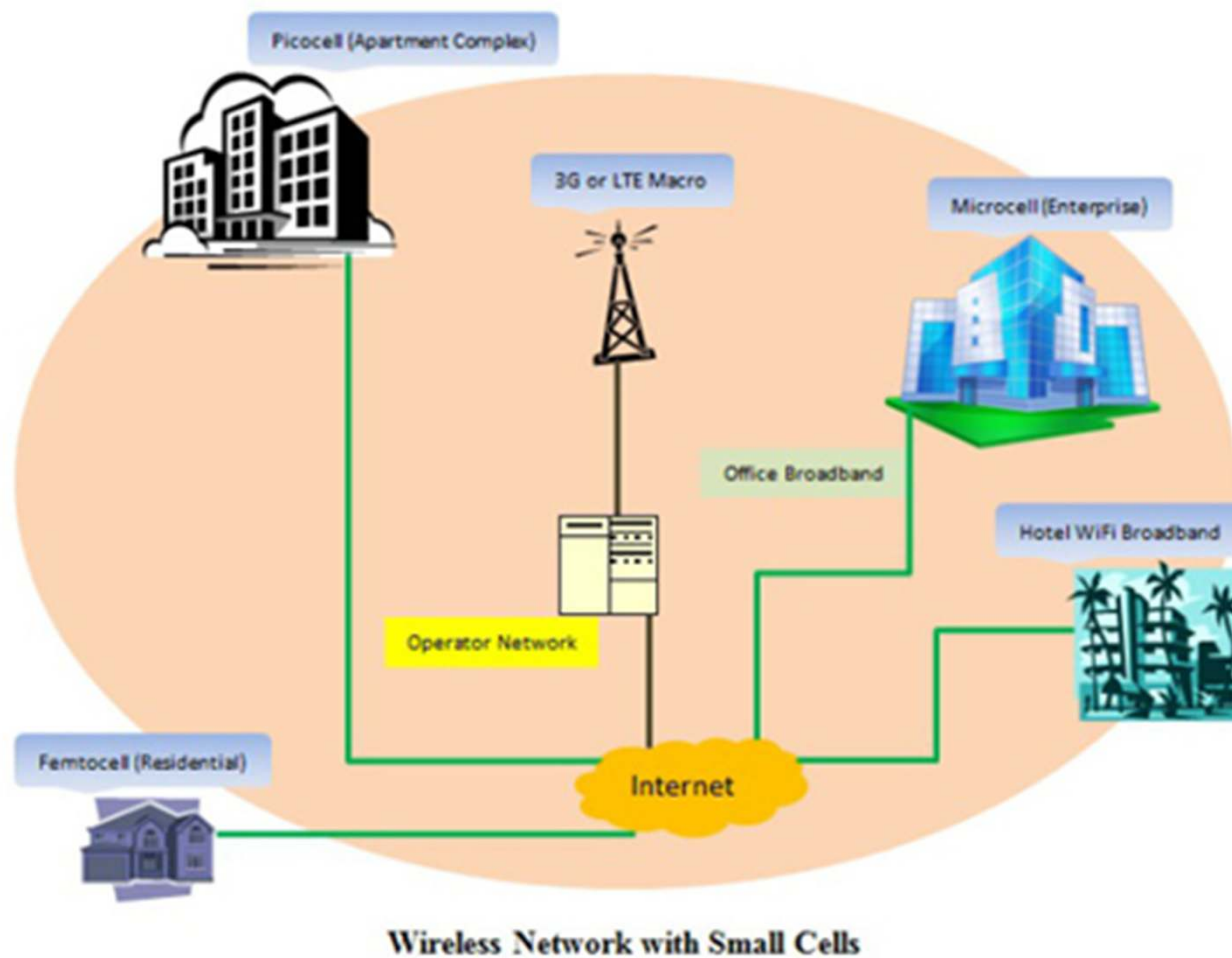
MIT is looking closely, with due caution, at 5G NLOS claims

“Roh said that in tests—with a transmitter mounted on an outside wall at the third-floor level of an 11-story concrete building and the receiver moving around, with part of the building blocking the signal—the new technology delivered error-free data at 256 megabits per second, reaching a rate of 512 megabits per second with negligible errors. This compares to the theoretical maximum of about 75 megabits per second that current 4G LTE technology can provide.”

Source: “Samsung Says New Superfast “5G” Works with Handsets in Motion” MIT Technology Review 6/3/13
<http://www.technologyreview.com/news/515631/samsung-says-new-superfast-5g-works-with-handsets-in-motion/>



Macro, Pico, Micro, Femto, WiFi



Source: WirelessTelecom.Wordpress.com , 5/4/2014



3.5 GHz Small Cell

- 3550-3650 MHz
- Novel: Real-time spectrum coordination system suggested
- Technical Papers submitted Jan. 2014.
- Licensing/use not expected this year.

Sources: FCC; Fletcher Heald & Hildred CommLaw Blog, 11/20/2013



5G Service Vision

Enabling the Immersive Service Experiences

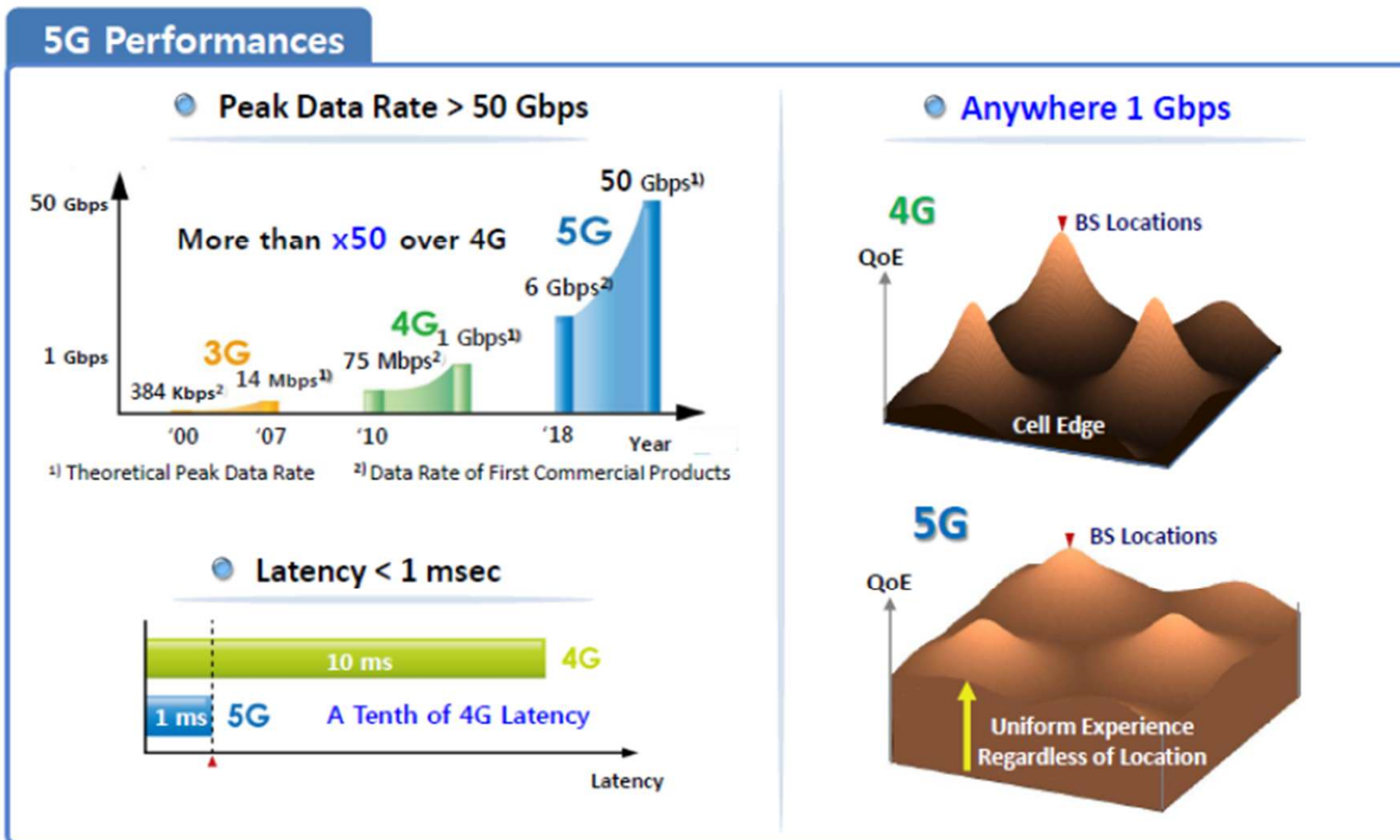


Source: 2013 Samsung DMC R&D Communications Research



5G Key Performance Targets

- Providing Gigabit Experience to Users Anywhere



Source: 2013 Samsung DMC R&D Communications Research



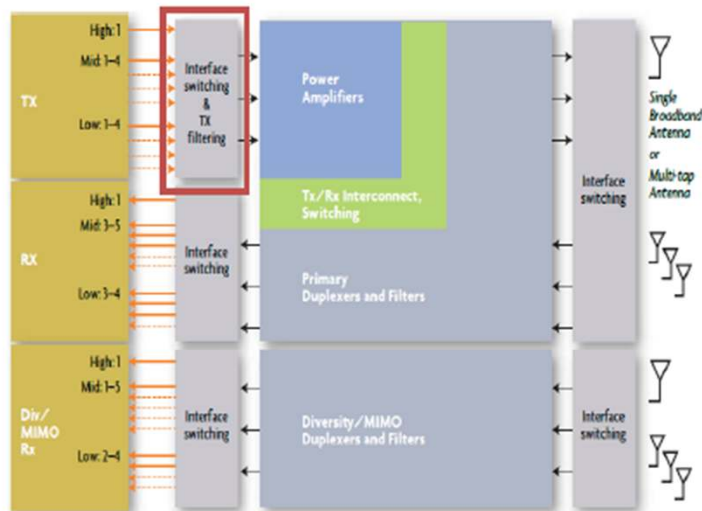
Spectrum Remains a Key Challenge

Fundamental limits in using spectrum below 7 GHz for 5G

- Limit in expanding bandwidth: Carrier aggregation degrades system performance
- Significant increase in modem cost due to increased RF front-end complexity

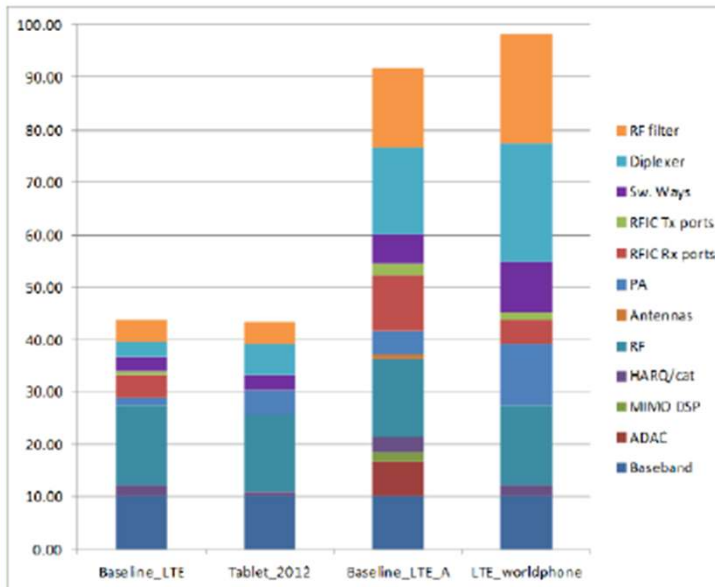
Performance degradation in carrier aggregation

- ▷ Switch loss (1dB per switch)
- ▷ Power amplifier & antenna inefficiency



※ SIGNALS Ahead, "Improve Your [RF] Front-end in Seven Easy Steps!", May 23, 2012 Vol.8 No.6

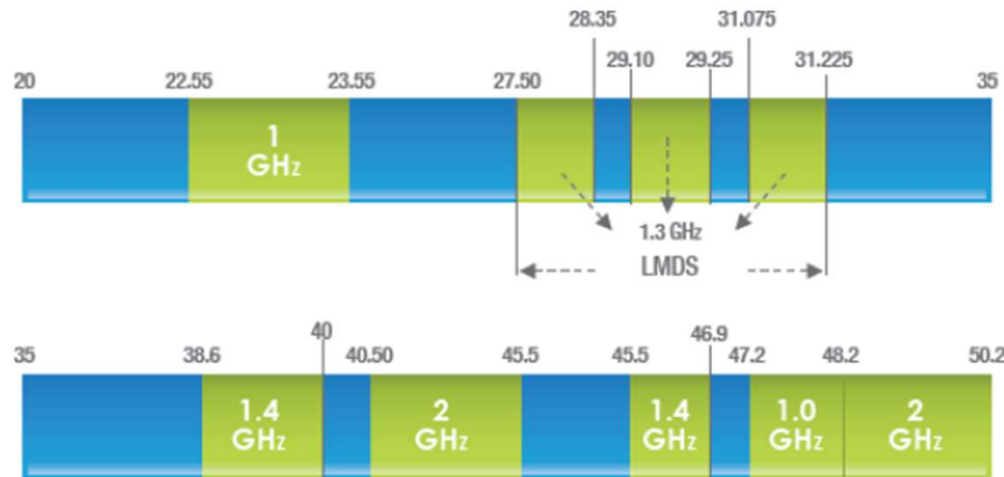
Impact of the number of bands on the cost of LTE modems



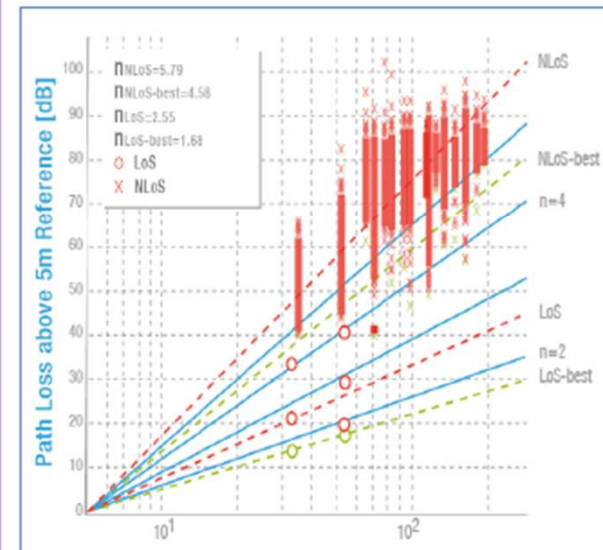
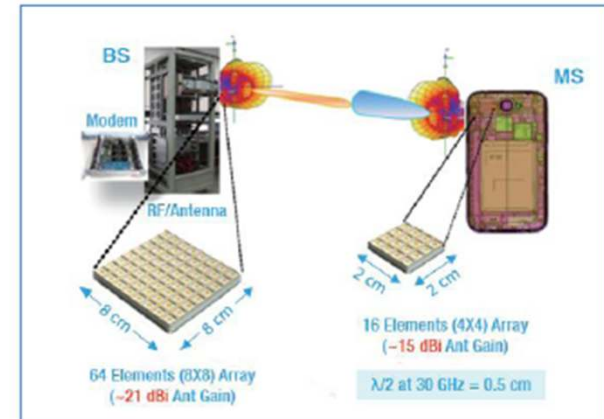
※ RF Front End Technology Challenges
ICT KTN-Cambridge Wireless joint Position Paper,
December 2012



Unlocking mm-Wave Spectrum for 5G



- ▶ The mm-Wave bands provided up to 25 times more spectrum than available for 4G
- ▶ Very large blocks of contiguous spectrum to support future applications
- ▶ Small wave-length makes possible use of large antenna arrays for adaptive beam forming
- ▶ Propagation exponent is very similar to spectrum below 7 GHz, as long as beam forming is maintained between BS and terminal



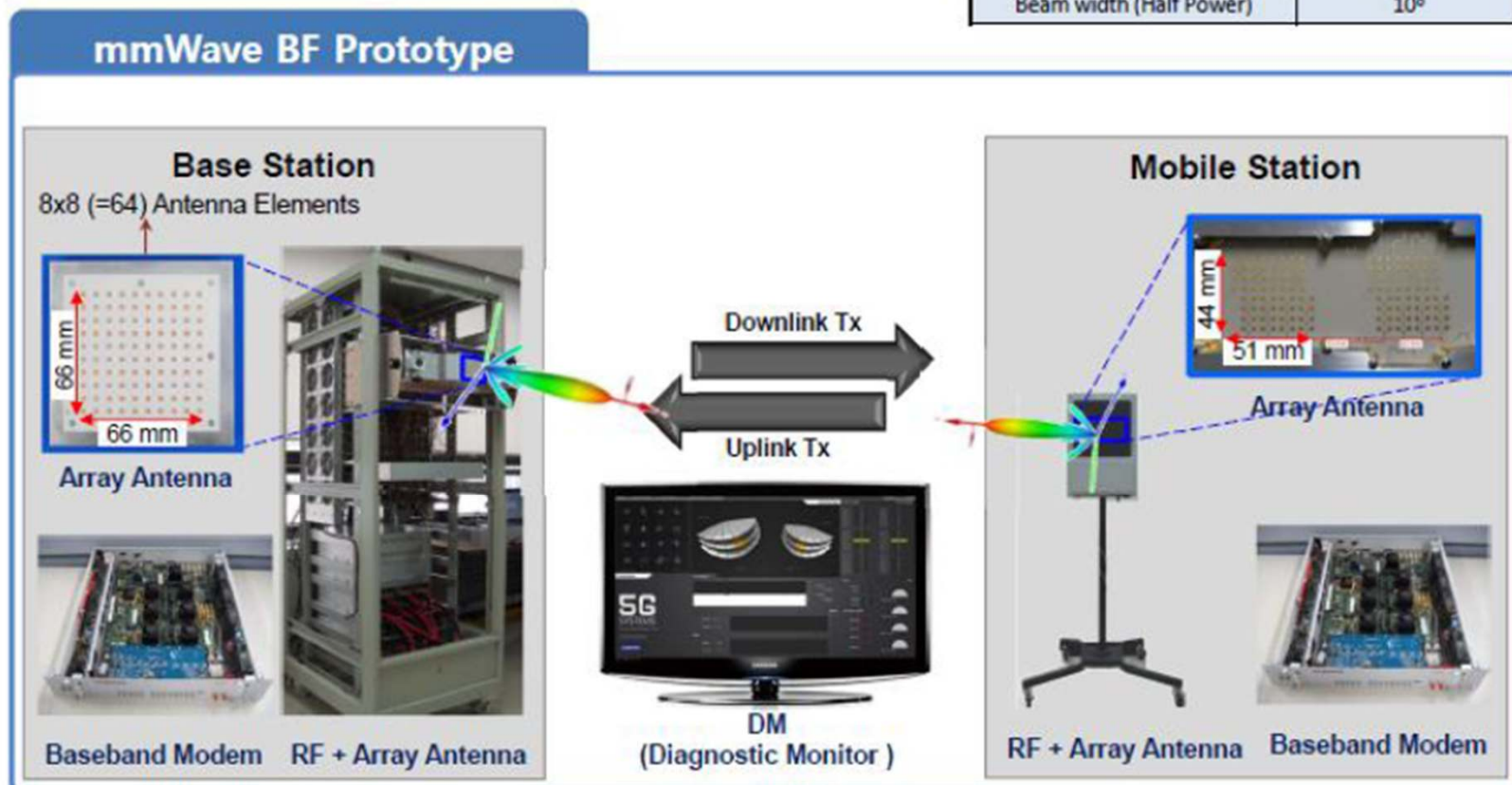
Source: 2013 Samsung DMC R&D Communications Research



mmWave Mobile Communication Prototype

- **World's First mmWave Mobile Technology**
 - Adaptive array transceiver technology operating in the millimeter-wave frequency bands for outdoor cellular

Carrier Frequency	27.925 GHz
Bandwidth	500 MHz
Max. Tx Power	37 dBm
Beam width (Half Power)	10°



Source: 2013 Samsung DMC R&D Communications Research



- **Performance Tests of mmWave OFDM Prototype**

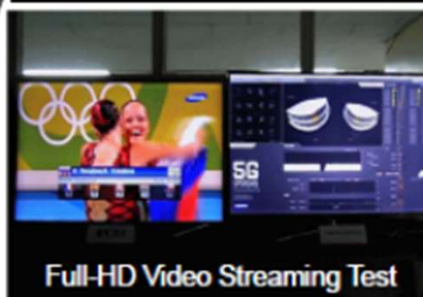
- OFDM system parameters designed for mmWave bands
- Indoor & outdoor measurements performed for data rates and transmission ranges

System Parameters & Test Results

PARAMETER	VALUE
Carrier Frequency	27.925 GHz
Bandwidth	500 MHz
Duplexing	TDD
Array Antenna Size	8x8 (64 elements) 8x4 (32 elements)
Beam-width (Half Power)	10°
Channel Coding	LDPC
Modulation	QPSK / 16QAM



PARAMETER	VALUE	REMARKS
Supported Data Rates	1,056Mbps 528Mbps 264Mbps	
Max Tx Range	Up to 2Km @ LoS	>10 dB Tx power headroom



Source: 2013 Samsung DMC R&D Communications Research



Test Result Range

- **Outdoor Line-of-Sight (LoS) Range Test**

- Error free communications possible at 1.7 km LoS with > 10dB Tx power headroom
- Pencil BF both at transmitter and receiver supporting long range communications

LoS Range

- ☐ **Support wide-range LoS coverage**

- ✓ 16-QAM (528Mbps) : BLER 10^{-6}
- ✓ QPSK (264Mbps) : Error Free



BLER : Block Error Rate
Modulation

QPSK : Quadrature Phase Shift Keying

QAM : Quadrature Amplitude

8



Test Results - Mobility

- Outdoor Non-Line-of-Sight (NLoS) Mobility Tests

- Adaptive Joint Beamforming & Tracking Supports 8 km/h Mobility even in NLOS

Mobility Support in

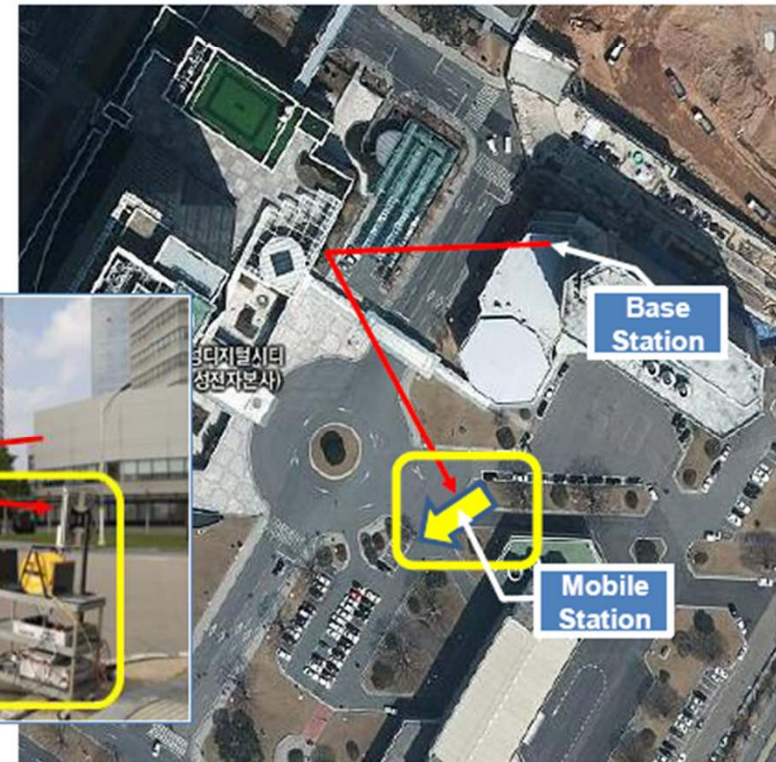
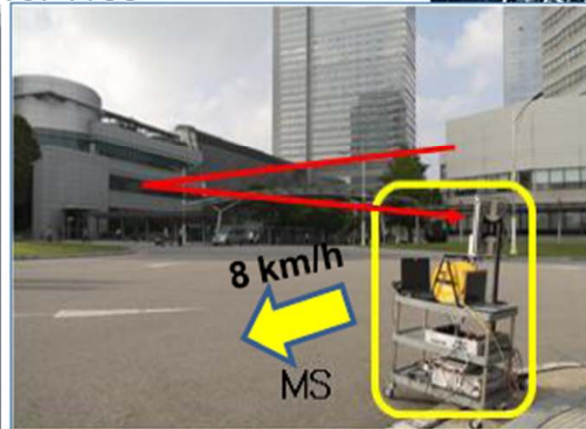
□ Mobility support up to 8 km/h at outdoor

NLoS environments

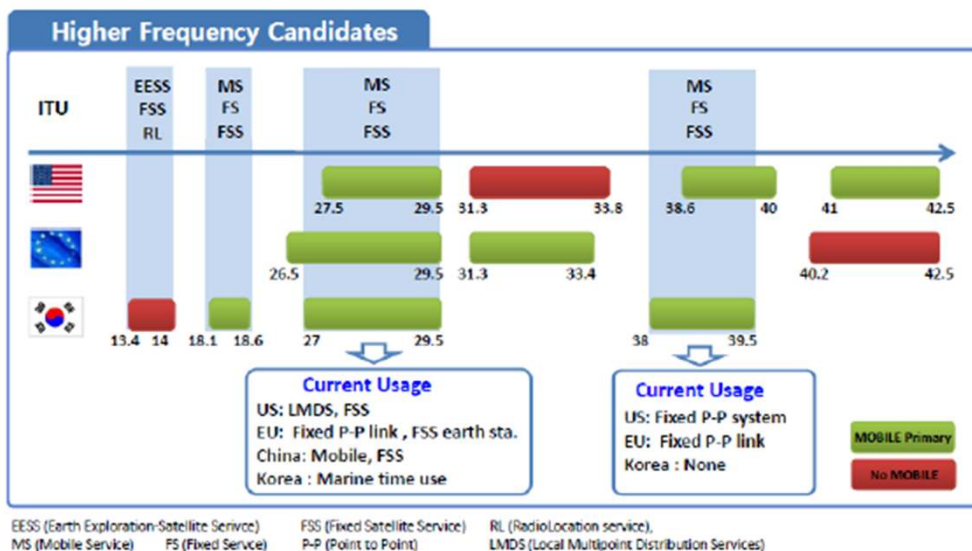
- ✓ 16-QAM (528Mbps) : BLER 0~0.5%
- ✓ QPSK (264Mbps) : Error Free



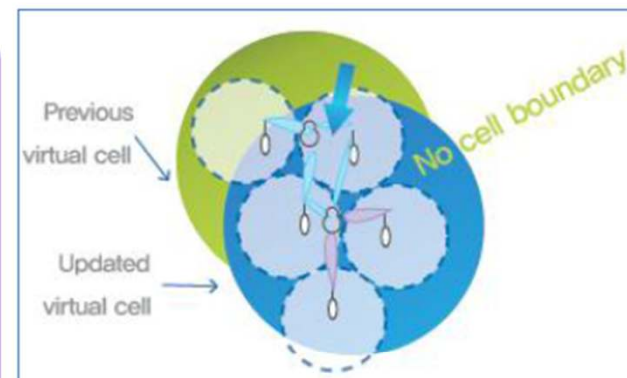
[DM Screen during Mobility Test]



Mm-Wave 5G Opportunities & Research Challenges



- ▷ The lower mm-Wave bands are already allocated to other services (mobile backhaul, Satellite)
- ▷ Feasibility of sharing need to be researched
- ▷ Sharing mechanism will be required, e.g. cognitive radio techniques, databases , interference cancellation
- ▷ Opportunity to develop shared use of mm-Waves for both backhaul and access, hence enabling fast spectrum release



Advanced cooperation between base stations to realize virtual cell concept ("edge-less" user experience)



Multi-tier and multi-frequency network architectures including mm-wave overlay



NLOS – Millimeter Wave Band Test

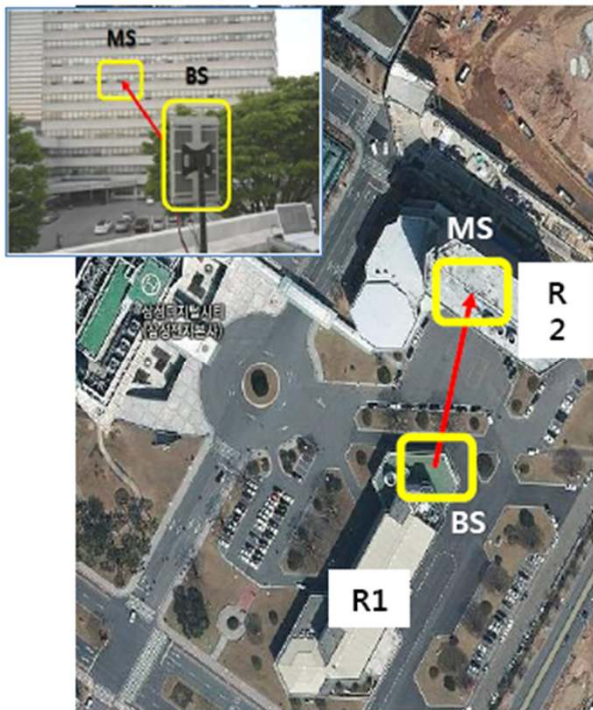
• Outdoor-to-Indoor Penetration Tests

- Most Signals Successfully Received at Indoor MS from Outdoor BS
- Outdoor-to-indoor penetration made through tinted glasses and doors

Outdoor to Indoor #1

□ Signal measured inside office on 7th FL of R2

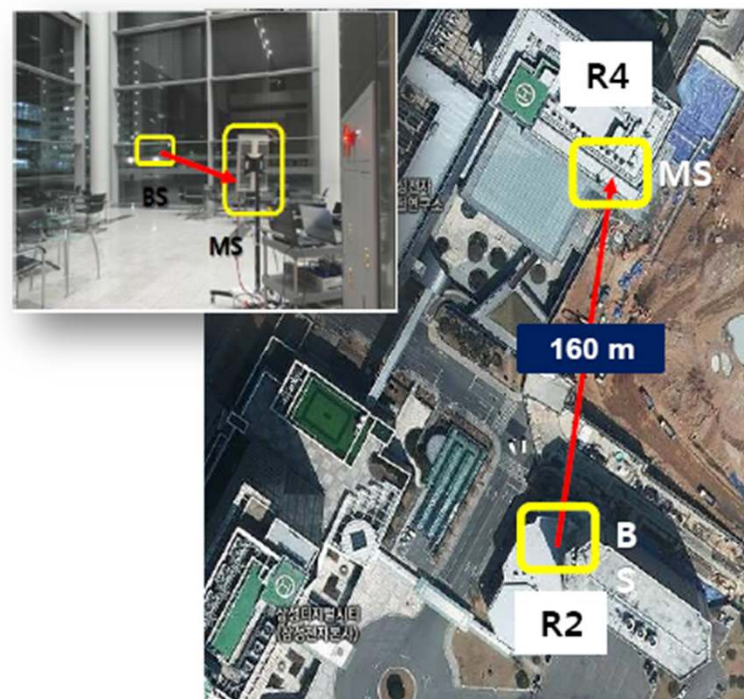
- QPSK : BLER 0.0005~0.6% (Target : < BLER 10%)



Outdoor to Indoor #2

□ Signal measured inside the lobby at R4

- QPSK : BLER 0.0005~0.3% (Target : < BLER 10%)



Source: 2013 Samsung DMC R&D Communications Research



Conclusion

- Forecasters are showing that 4G Small Cell Deployments will 'arrive' in volume in 2015
 - Drivers:
 - 4G
 - FirstNet
 - ConnectED (Schools & Libraries deployments)
 - M2M
- VoLTE will drive more small cells, because it saves: (1) mobile spectrum & (2) energy
- Non-Line-of-Sight:
 - Small cells (along with micro, pico, femto) in turn will drive NLOS solutions, resulting in 5G NLOS use for bands above 6GHz.
 - Opens exponentially the amount of spectrum available for mobile applications

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THANK YOU!

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