

5G . . . What and when is it?

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CTO and Technical Sales Leader
US Major and Regional Accounts

July 2016

NOKIA - A financially strong leader, with massive capacity and deep expertise

Revenue*

\$30B

R&D spend*

\$5B

Net cash*

\$11B

Employees

106,000
(~20% in US)

R&D professionals

~40K

Services
professionals

~40K

World leading
intellectual property
(patent families)

~31K

Bell Labs

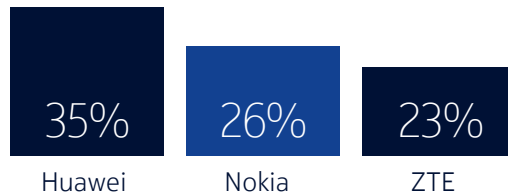
Nokia Technologies

A position of strength in key segments

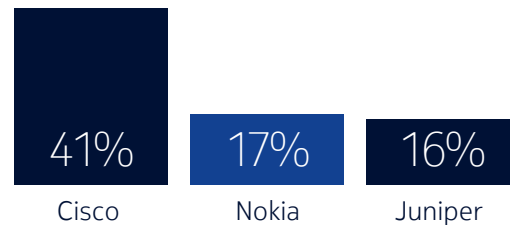
LTE, #1



Fixed broadband, #2



Service Provider IP switching and routing, #2



Cloud / Core

- #1 Subscriber management
- #1 Device management
- #1 Voice over LTE
- #1 Customer Experience Management

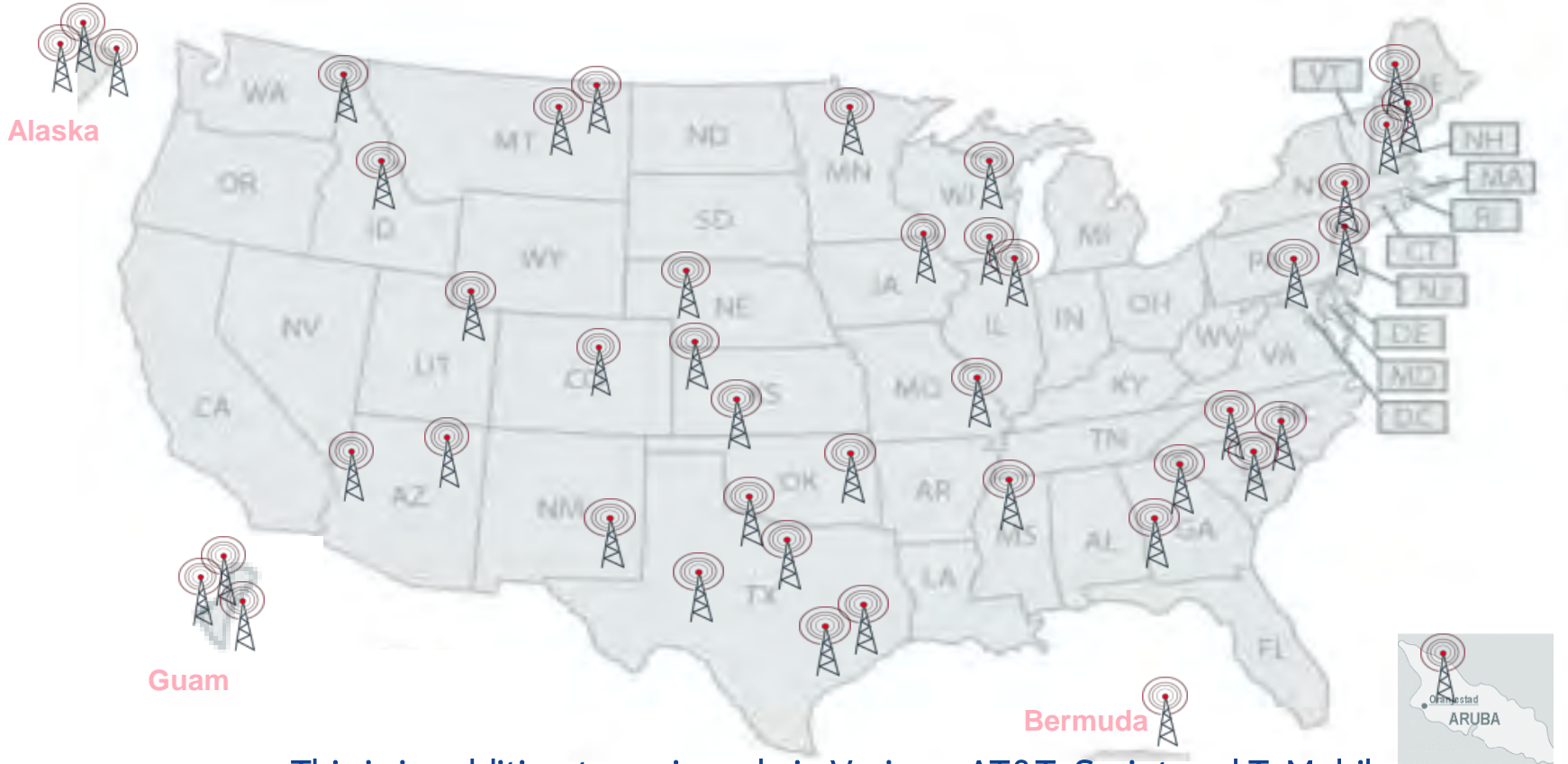
Software Defined Networks



Services

- #1 Network integration
- #2 Customer care
- #2 Professional services

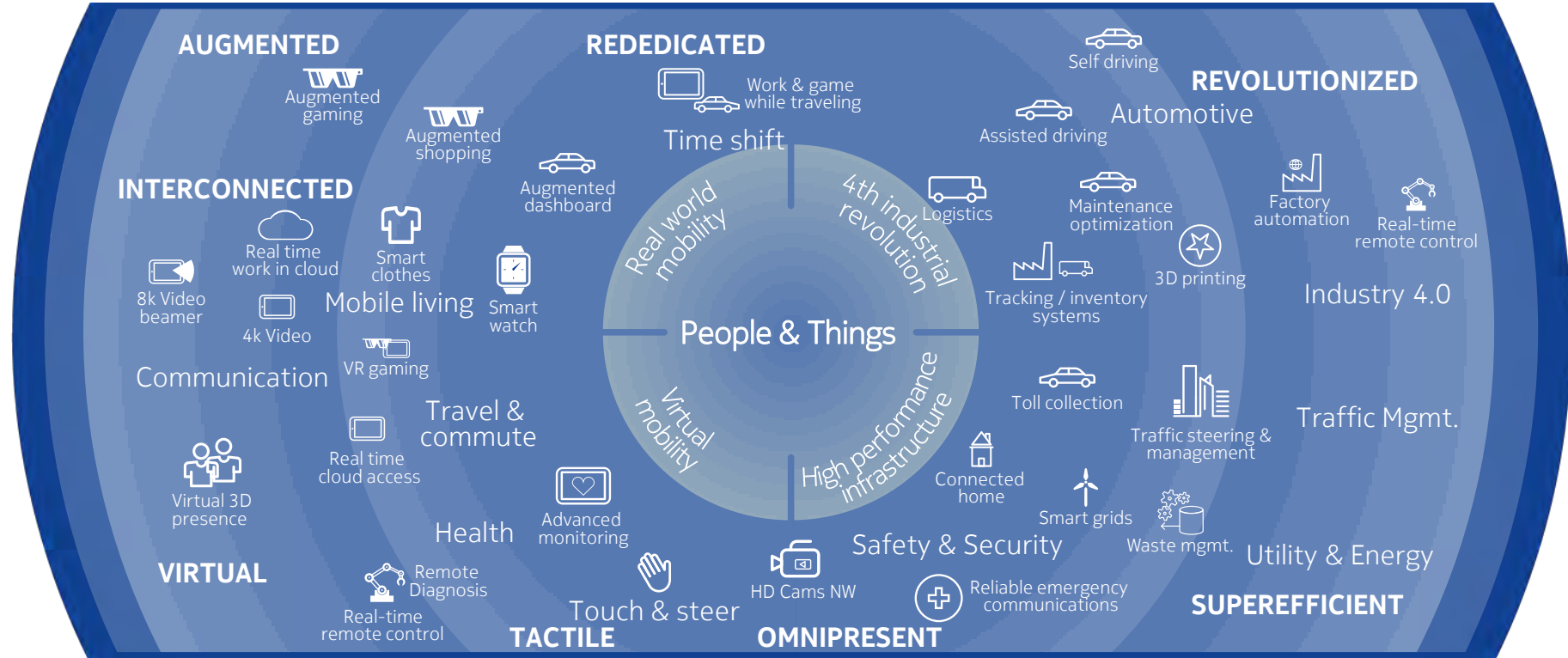
Nokia – Over 40 Rural/Regional Wireless Deployments



This is in addition to major role in Verizon, AT&T, Sprint and T-Mobile

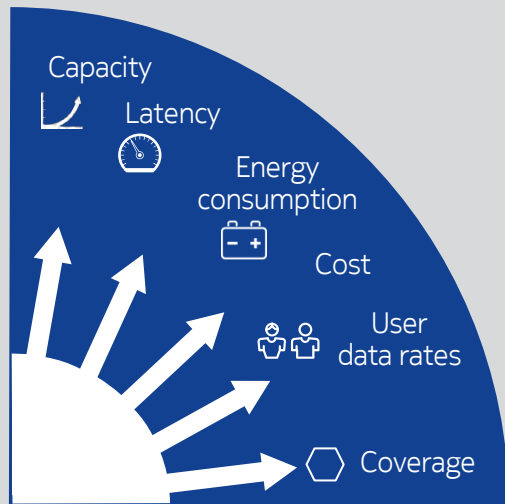
New applications and innovations drive evolution to 5G

Network scalability from low to high end applications



5G key building blocks

5G



Multi Gbps to narrowband

- High bands, low bands (?)
- 3-6Ghz, mm/cm wave
- Dynamic and wide bands
- Massive MIMO & beamform



5G hot spots -4G integrated

- Initially in high dense areas
- Seamless LTE A interworking
- Multi (RAT) connectivity



Cloud architecture

- Radio in cloud
- Mobile edge computing
- Core in cloud
- Network slicing

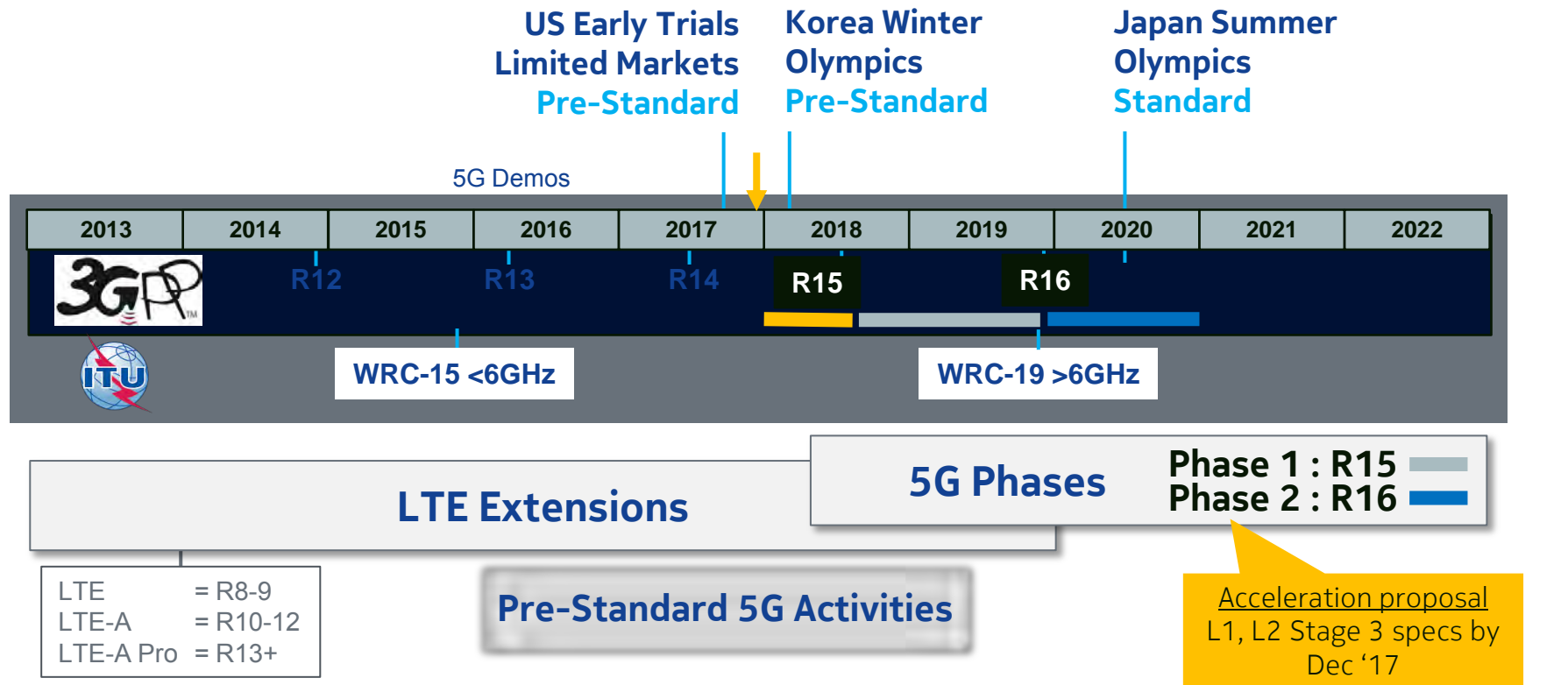


Apps, devices & operations

- Low end to high end apps
- Extreme device scalability
- Easy to deploy & operate



5G Timeline



WRC = World Radiocommunication Conference

Recent Announcements

CableLabs seeks STA to test 5G gear from multiple vendors (June 30, 2016)

“test the performance characteristics of 5G network equipment . . . 27.5-28.35 GHz and 71.0-75.0 GHz bands”

Sprint strikes goooooooooaaaaaalllllll with 5G demo in Santa Clara (June 6, 2016)

“4K video . . . 73 GHz . . . Beamforming and low latency applications . . . VR headsets . . . Thanks to prototype provider Nokia”

AT&T: 5G mostly about fixed wireless for next two to three years (June 2, 2016)

“5G millimeter wave trial . . . start with 15 GHz in the summer . . . then go to 28 GHz at the end of the year”

AT&T's 5G trials could deliver speeds around 5 Gbps this year (May 25, 2016)

“5G trial with friendly customers by end of year . . . Trials in Austin”

Nokia wants to demonstrate 5G prototype gear at CSpire in July (May 9, 2016)

“helping the industry to adopt rules the rules on 5G deployment . . . Bands above 24 GHz”

Verizon's Shammo: 5G pilot in 2017 is all about fixed wireless (April 21, 2016)

“helping the industry to adopt rules the rules on 5G deployment . . . Bands above 24 GHz”

Nokia Recent Achievements

Nokia 2 Gbps mmWave (70 GHz) high-rise trial w/DoCoMo

September, 2015

SK Telecom and Nokia Networks achieve 19.1Gbps over the air in joint 5G trial

October, 2015

Verizon and Nokia conduct live 5G pre-commercial trial in Dallas-Fort Worth, hits 10-Gig speeds

February, 2016

Sprint and Nokia demo 5G at Copa Soccer Game
June, 2016



Indoor testing



Material penetration testing



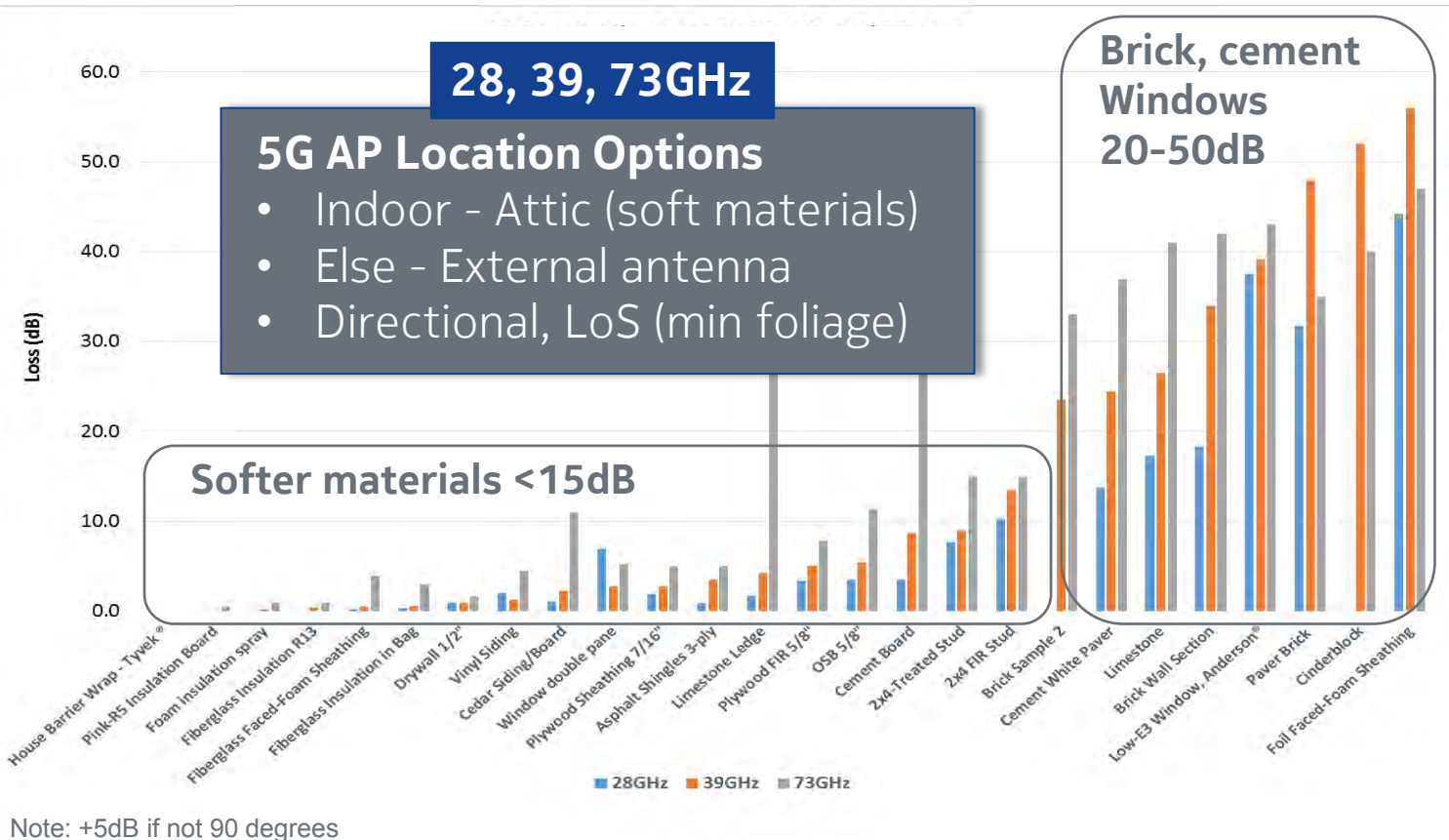
Nokia EVP Ricky Corker stands next to the Nokia base station that was used in Sprint's 5G demo

<http://www.fiercewireless.com/tech/story/nokia-5g-demo-copa-soccer-game-just-beginning/2016-06-05>



Low latency robotic arm

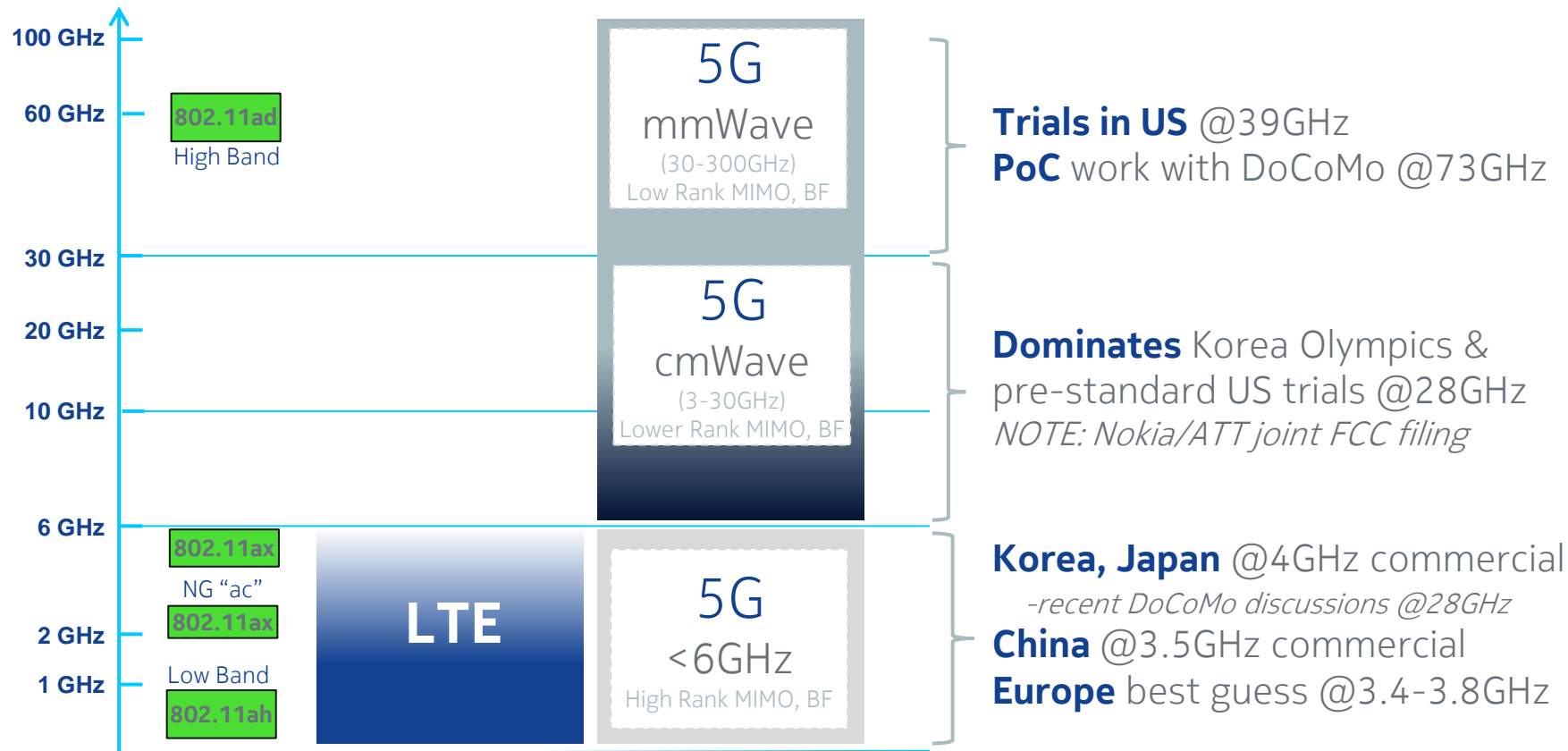
cmWave & mmWave : Penetration Loss



Note: +5dB if not 90 degrees

Note: 3GPP SIG channel model for 6-100GHz urban done

Spectrum



US Spectrum – Candidates for Wireless

From FCC TAC

<6GHz

US Band	MHz	Use
600	120	TV
3550	150	DoD
3700	500	Satellite
4200	40	Altimeters
5.x	195	Fed/ITS
28	1300	LMDS
37/42	2100	Radio astronomy
39	1400	LMDS
57	7000	Unlicensed
64	7000	Inter-Satellite (ISS)
70/80	10000	P2P
100+	12000	

>6GHz

Current discussions
in US (not closed)

<6GHz

- 600
- AWS3

>6GHz

3.5/3.7
28, 39

Large blocks: 28GHz-100GHz
(You'll only get 10Gbps from these!)

First Use Case : Extreme Broadband

The last 200m



Business Proposal

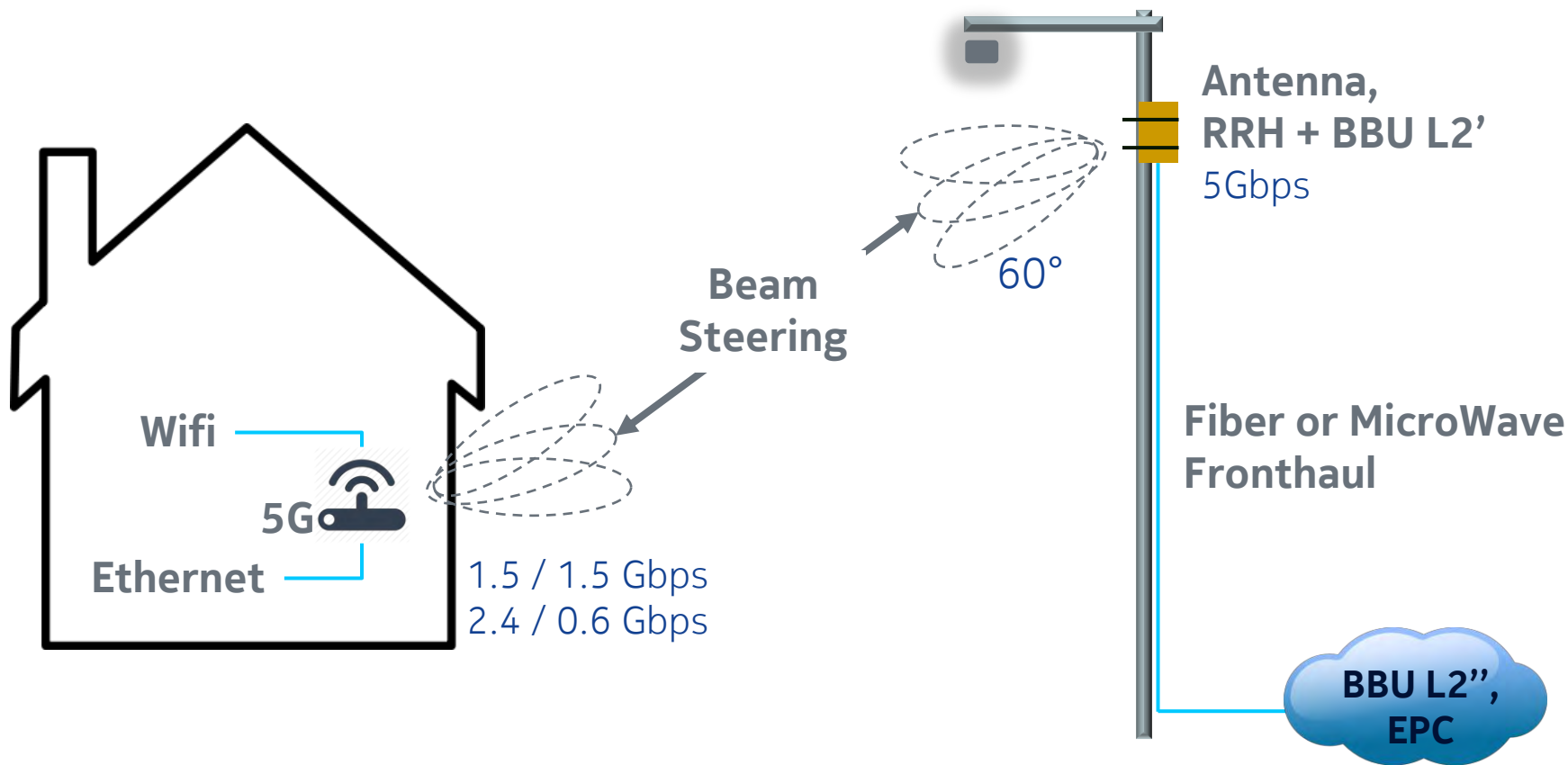
- Alternative to FTTH

Technical Solution

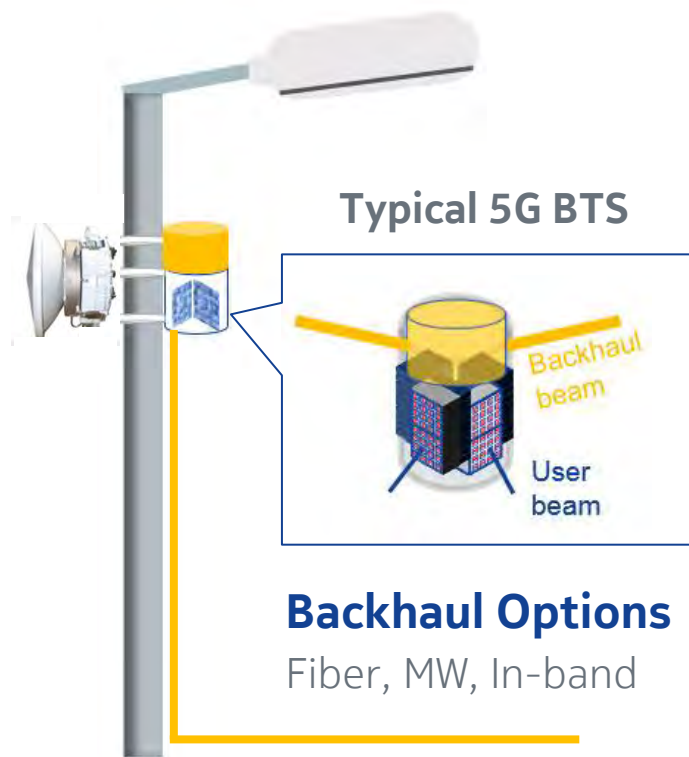
- 1.5Gbps cell edge
- 28GHz, 800MHz, 2x2
- Fixed, indoor CPE
- Fiber or wireless backhaul
- OTSA spec
- LTE core network

**Commercial
2017**

Physical Layout



Small Cells



*Cell Size (Radius)

DL 4x4	Typical
28GHz	~200M
60 GHz	119 m
75 GHz	109 m
95 GHz	103 m

Significant Variations

- Blockage, e.g., foliage
- Building materials
- Line of Sight

5G is small cells on steroids!

Requires cautious network planning

- e.g. old windows 7dB loss, low-E 38dB
- e.g. rain fading increases antenna gain 2x

Second Use Case: Mobility

Real-Time Video



Business Proposal

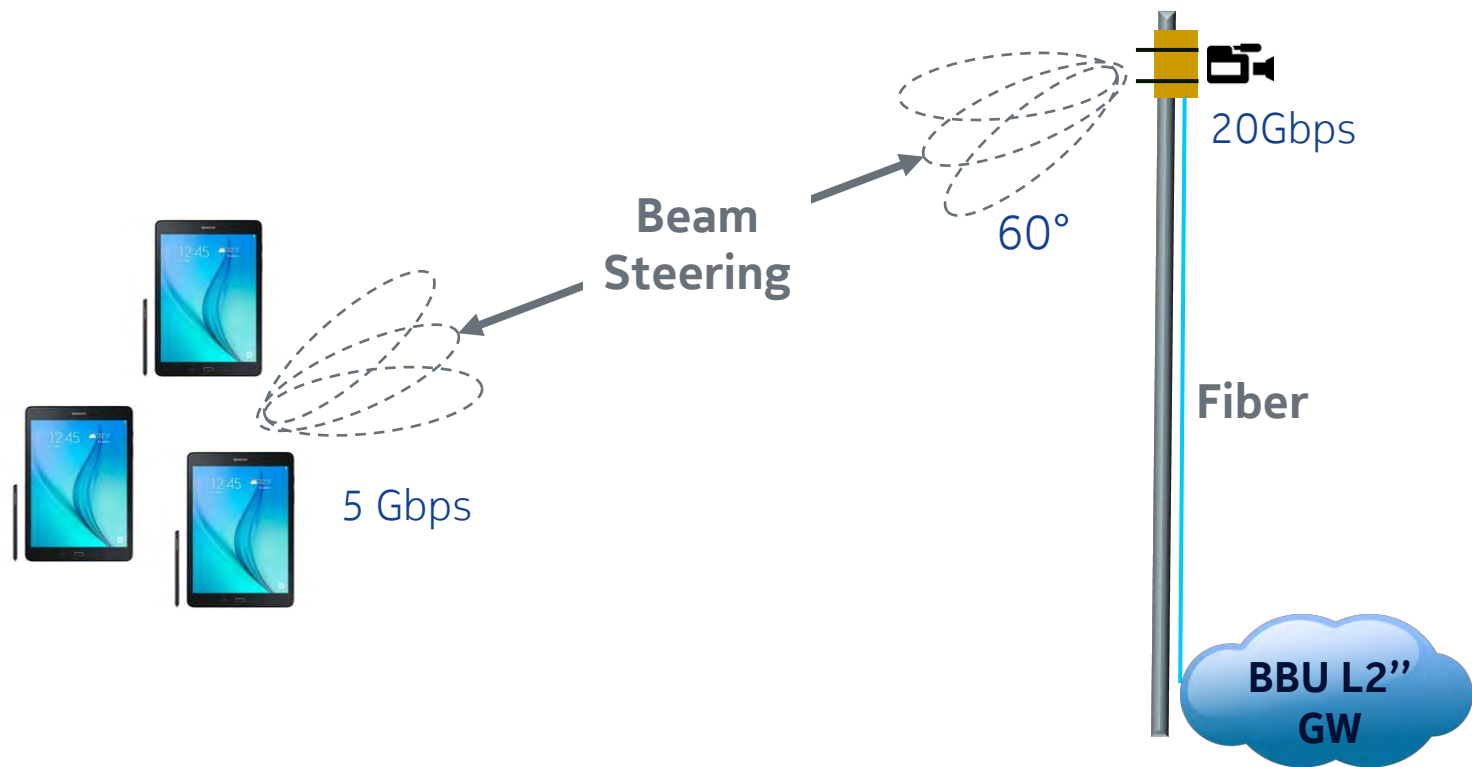
- New real-time services

Technical Solution

- 5Gbps cell edge
- 28GHz, 800MHz, 2x2 / 4x4
- Mobile CPE
- Fiber backhaul
- OTSA spec
- LTE core network

**Commercial
2018**

Physical Layout



Distributed Core

Central sites
(few)



Distributed Sites
(100s)



Drivers

- Meeting latency targets
- Offloading to PDN faster

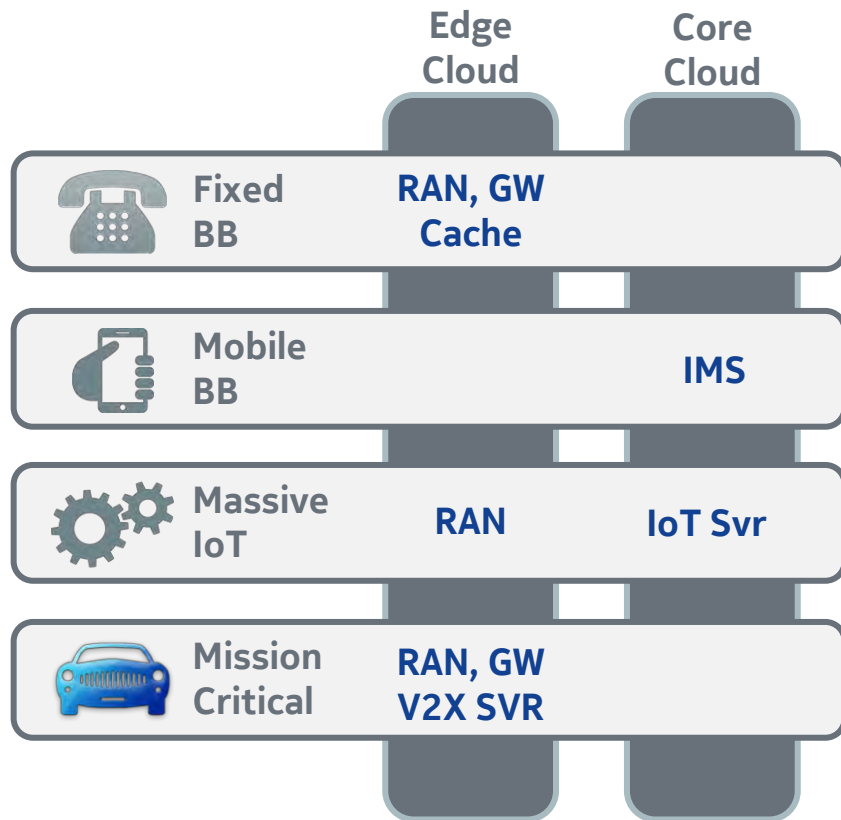
Some Characteristics

- Distributed virtual RAN
- Optional co-located GW
- Slicing for IoT (multiple GW)

Real Example

5 types of distributed sites

Network Slicing



5G Network Slicing

- Per service treatment
- Enables alignment of network cost with sales value
- Improvement over 4G

Implementation

- Devices provide indicator directing it to service MME

Building bridge between 4G and 5G

Key 5G building blocks implemented already in LTE A networks

LTE-Advanced Pro

MIMO 4x4
CA 3CC
NB IoT, LTE M
Public safety



MU-MIMO
5-7 x CC
Cell edge
>Gbps

Spectrum optimization

Refarm
New bands



New bands
LSA

Advanced Radio Site

6-Sector
RAS



Multi & Wide band
AAS
3D Beamforming
SW defined radio

Baseband evolution

Hoteling
C-RAN
Single RAN
Data encryption



Distributed
Centralized
Virtualization
Cloud

Flexible Small Cells

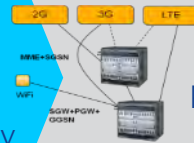
Micro
Pico
Carrier Wi-Fi



HetNet
Multi CA
LAA
LWA

Multi-access connectivity

2G/3G/4G
WiFi
5G
4D scalability



Broadcast
IoT, Slicing
Public Safety
5G & MEC

Cloud core

NFV
SDN
Security



Resource pooling
Orchestration
Service chaining

Mobile transport

Site capacity
VPNs
Security



Adv IP/MPLS
Front haul
SDN

Operations & Big data

FCAPS
SON
CEM



Personal
IoT
Predictive
Colossal data

NOKIA