The 5G Era

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Agenda

- What is 5G?
- What does 5G do?
- How big is 5G/ Impact of C-19?
- C-Band auctions
- 5G Cloud RAN
- Summary

What is 5G?

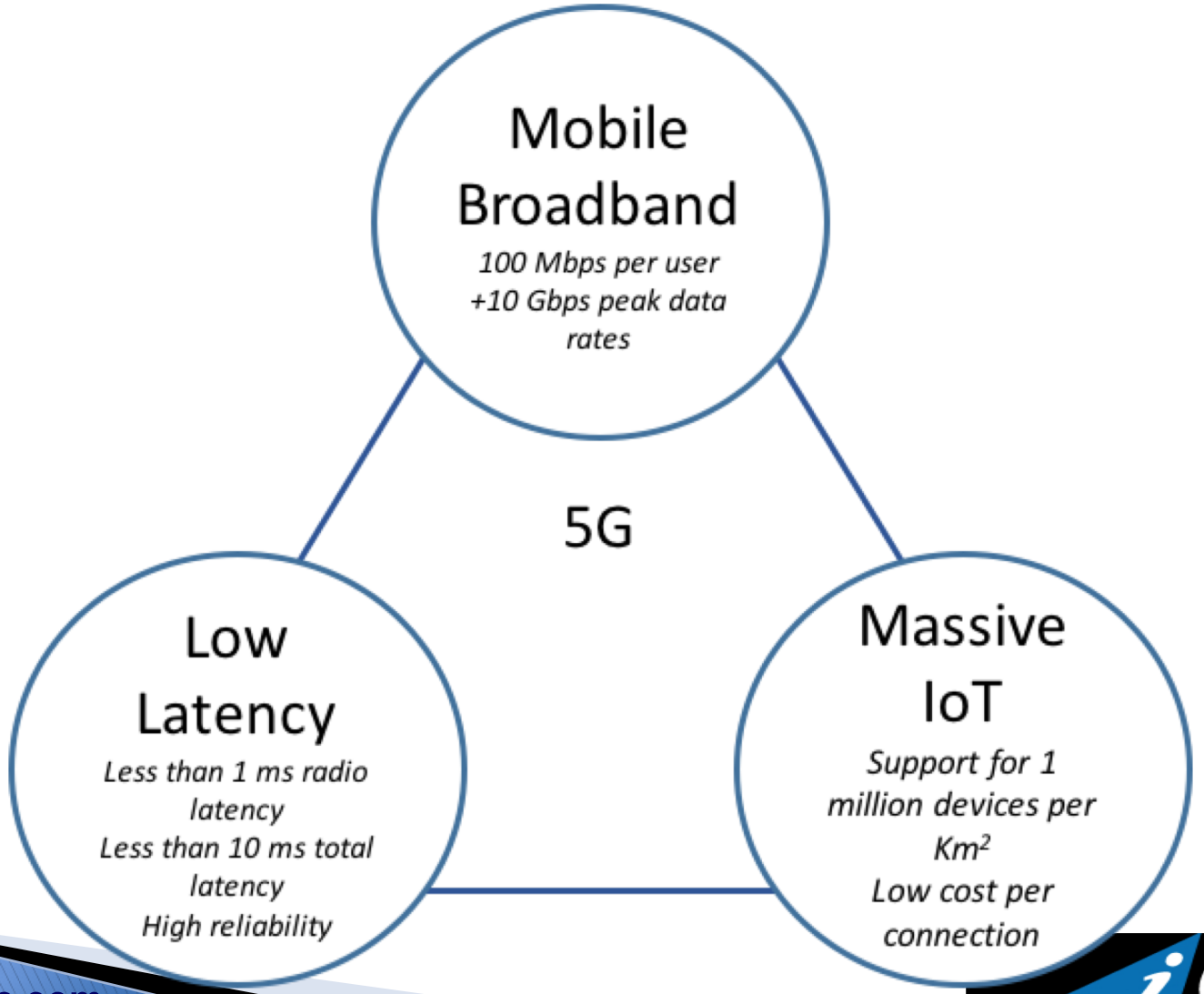
A little history from MNO perspective

- Goals of 3G
  - Offer mobile data to the masses ✓
  - Maintain control of network ecosystem ✓
  - Maintain control of device ecosystem ✗
- Goals of 4G
  - Broadband mobile data to the masses ✓
  - Lower cost mobile data ✓
  - Virtualize core network ✓
  - Open RAN to new vendors ✗
- Goals of 5G
  - Open up IoT opportunity
  - Massive reduce cost of operation
  - Enable new revenue streams

Low cost operations

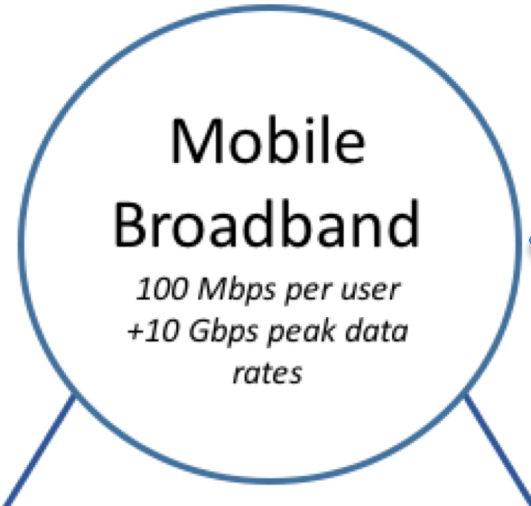
Low cost operations

Low cost operations



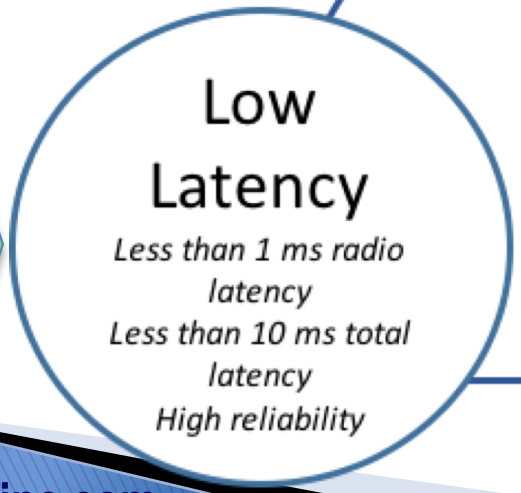
Not!

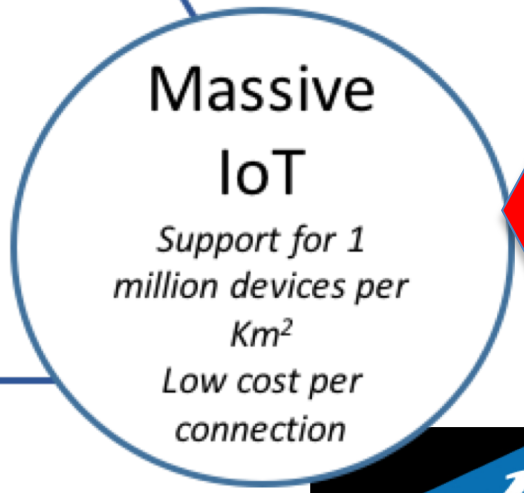
- A new spectrum band
- Limited to mmWave bands
- New air interface (it uses LTE-on-steroids)



5G Phase 1 (Rel. 15) NSA

5G





Along the way :)

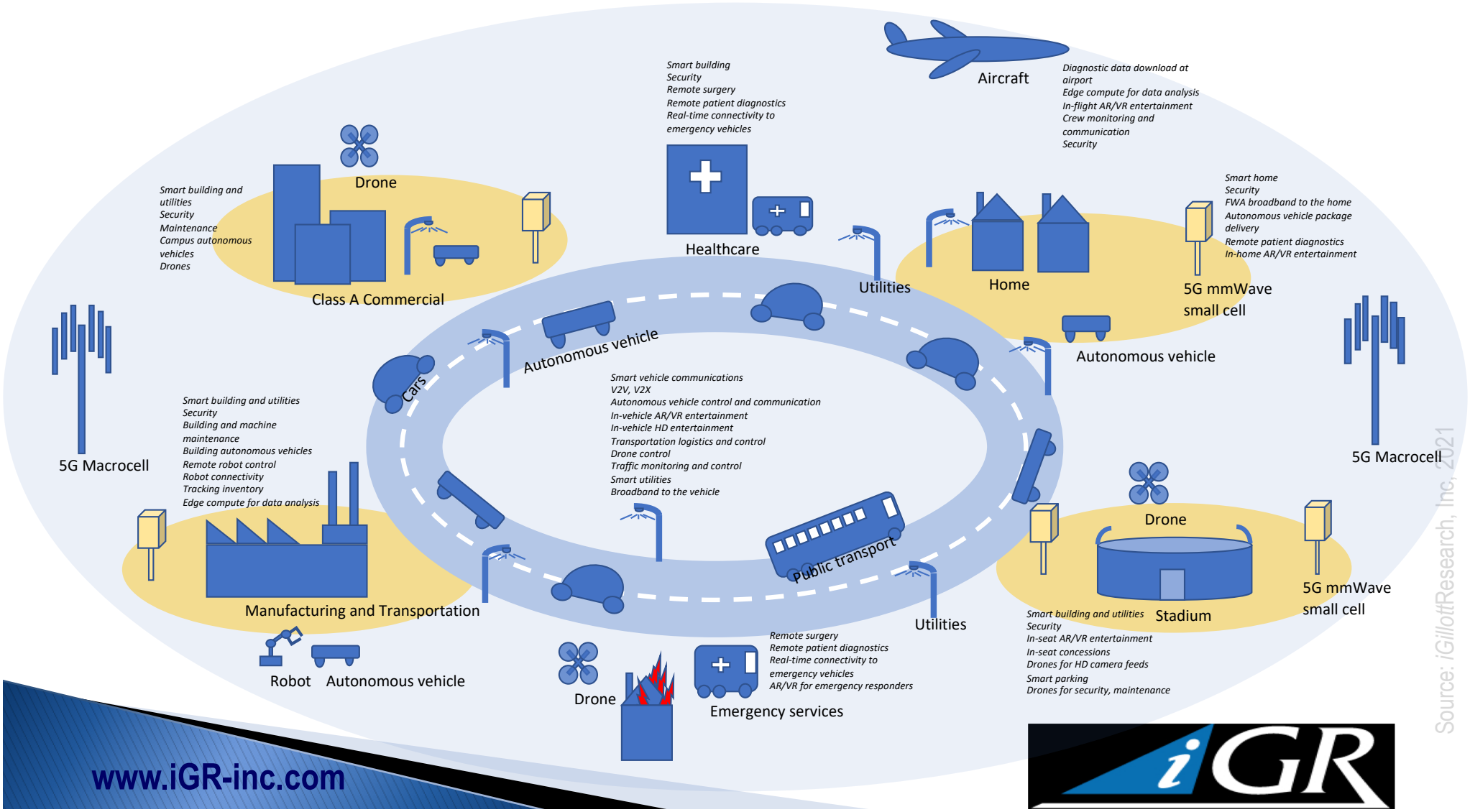
5G Phase 2 (Rel. 16/17) SA Enhanced EPC

Source: 021

What does 5G do?

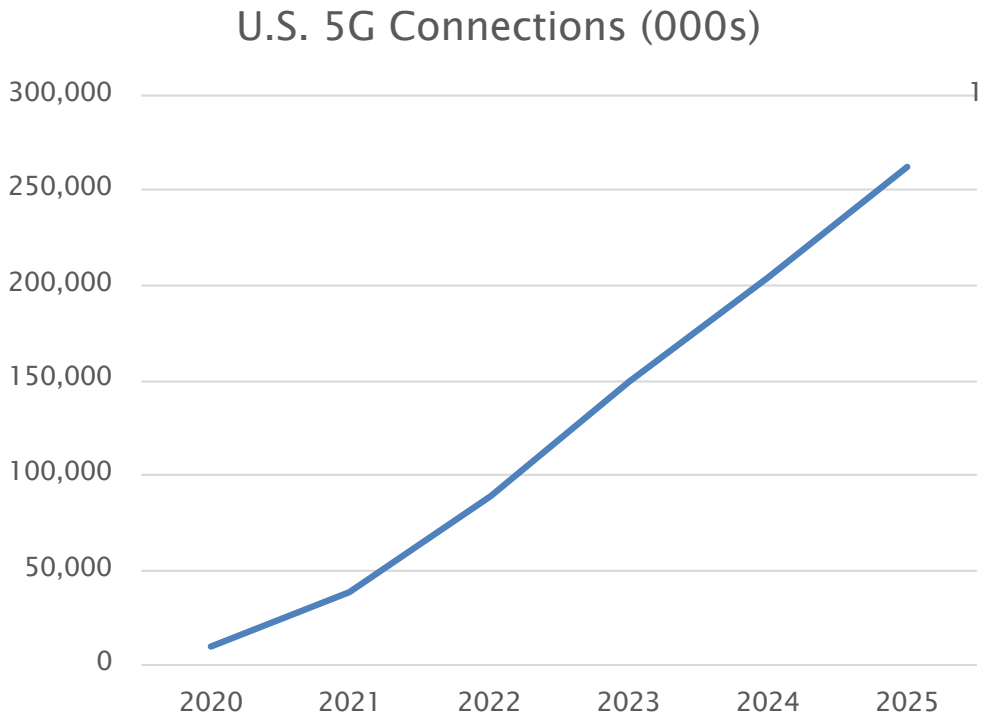
5G Revenue Sources

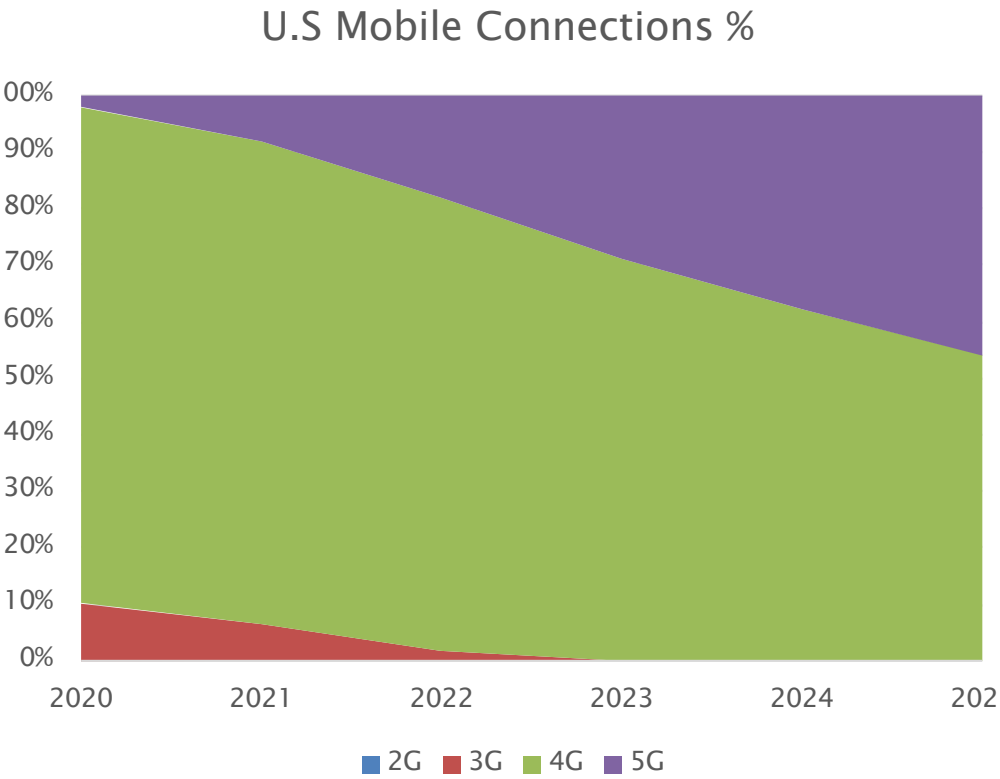
- Mobile Broadband
- Home Broadband
- Entertainment
- Advertising
- IoT
- Network Slicing



How big is 5G? What impact has C-19 had?

U.S. Growth of 5G





Source: 5GHotResearch, Inc, 2021

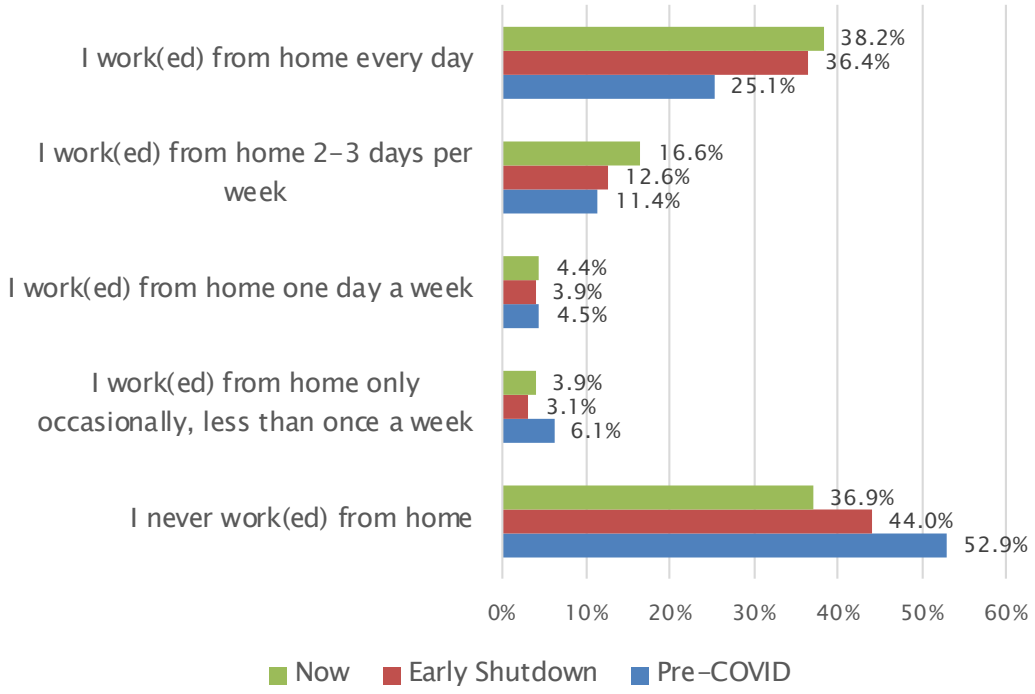
www.iGR-inc.com

COVID-19 has changed where we use spectrum

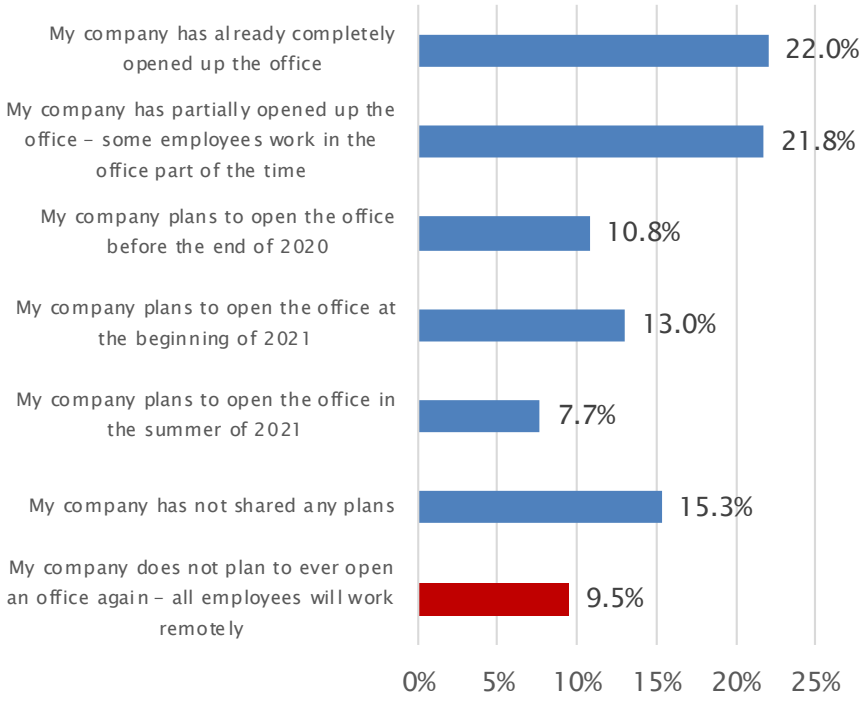
- Less need for capacity in downtown/business areas
- Increased need in suburbs as more people work from home
- 2021 will not see an immediate return to 'normal'
  - Likely a gradual return to offices in some capacity over the next few years
  - But some capacity has permanently moved to suburbs/smaller markets
- mmWave 'less' desirable now – cannot provide cost effective coverage over larger areas needed

Work from Home

Work from Home Pre-COVID, Early Shutdown and Now



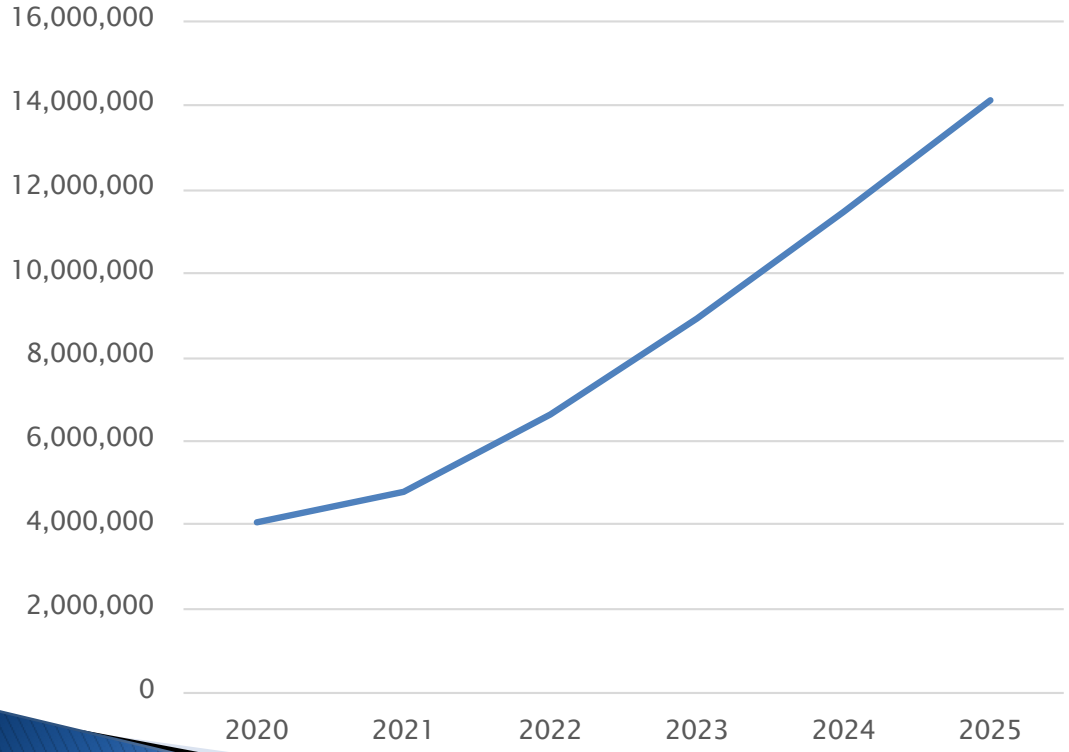
Company Plans to Open the Office



Source: iGR Research, Inc, 2021

U.S. Mobile Bandwidth

TB per month



U.S. mobile bandwidth grows 347 percent from 2020 to 2025

But C-19 has impacted growth significantly – just 15 percent from 2020 – 2021

Pre-C-19 growth was ~30 percent

Source: iGillottResearch, Inc, 2021

COVID-19 has impacted network deployment

- Discussions with infrastructure OEMs, fiber providers, small cell providers, construction companies
- MNO investment moving from urban cores to suburbs
  - Following demand for bandwidth
- Bandwidth demand increasing overall
  - *"Battle for bandwidth is in your household"*
- Likely to remain this way for the next few years
- Impacts choice of macrocells, small cells, spectrum, etc

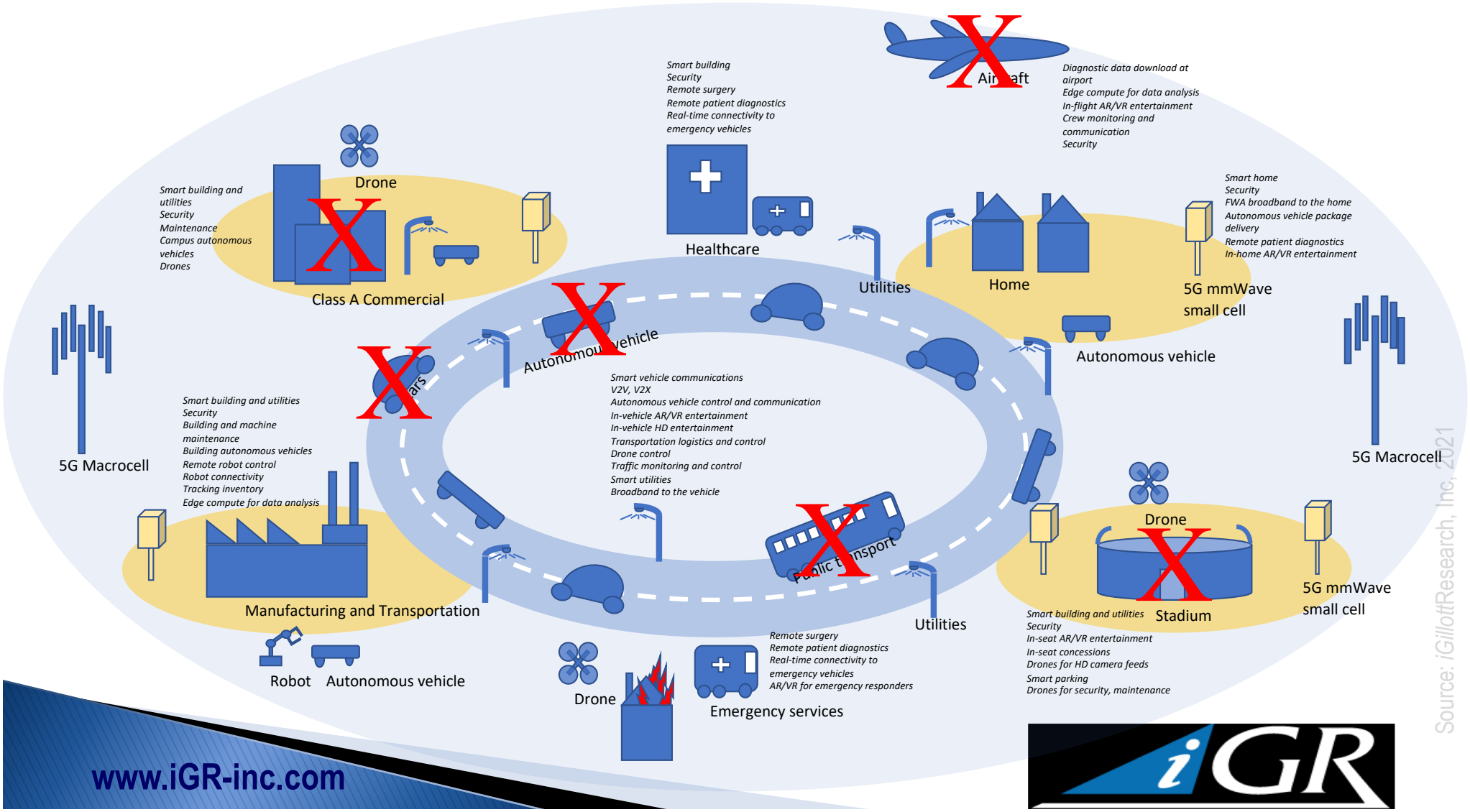
Macrocell demand

- Not declining
- Consistent demand for new macro cell sites
- M&A multiples increasing
  - American Tower buys InSite Wireless: 30x earnings
  - Vertical Bridge acquires Eco-Site
- Macrocell demand will not decrease
  - Anchor for all new technologies, including 5G
  - T-Mobile has deployed 5G first on macrocells
- Movement of bandwidth to suburbs increases demand for macrocells and towers

Small Cells

- Sub-6 GHz small cells to fill gaps between macrocells, especially for 5G
  - Demand appears to be strong
  - ExteNet deployed record number of small cells in 2020 and see no slow-down for 2021
- mmWave demand is uneven
  - MNOs appear to be looking for low cost deployment options
    - Minimize cell deployments; fill gaps with repeaters as much as possible
    - Coverage, not capacity at present
- Edge data center deployment just starting
  - Next few years will see more integration between mobile networks and cloud via edge data centers

Source: iGillottResearch, Inc, 2021



C-Band

The Basics

- 5,684 licenses across 14 unpaired 20 MHz blocks in 3.7 – 3.98 GHz band for a total of 280 MHz
  - Plus 20 MHz guard band
- FCC auction strted December 8th – ended January 15th
- PEA auction areas
- Spectrum needs to be cleared by satellite providers
  - Satellite providers will be paid to repack operations to 4.0 – 4.2 GHz band
  - Lower 300 MHz to be auctioned
- Traditional auction and ownership
  - You pay: you own
  - Not like CBRS shared model
- Bidding topped $80.9 Billion
  - Largest ever auction
  - Higher than all expectations
  - $0.942 per MHZ Pop
    - AWS-3 ~$1.00 per MHZ Pop, 700 MHz auction was $1.28 per MHZ Pop

When will the C-Band be available?

- Two phases to clear C-Band
- Phase 1: spectrum in 46 of the top 50 markets will be cleared first with a target date of December 5, 2021
  - 100 MHz
- Phase 2 markets are due to be available by December 2023
  - 180 MHz
  - Less valuable as not available for three years?
- Last major auction on the current schedule
  - Additional mid-band spectrum expected in late 2021 but nothing confirmed yet
  - Last opportunity for operators to get significant mid-band spectrum

Source: iGillottResearch, Inc, 2021

Who bid?

- Answered by who needs mid-band spectrum
- Approximate spectrum holdings
  - Sub 6 GHz (including CBRS PAL)
    - DISH ~75 MHz
    - Verizon ~140 MHz
    - AT&T ~135 MHz (No CBRS PAL)
    - T-Mobile ~310 MHz (No CBRS PAL)
  - mmWave
    - DISH ~700 MHz
    - AT&T ~1050 MHz
    - T-Mobile ~1200 MHz
    - Verizon ~1650 MHz
- T-Mobile has largest Sub 6 GHz spectrum holdings, thanks to Sprint
- AT&T needs mid-band
- Verizon especially needs mid-band
  - Currently holdings boosted by CBRS PALs
  - Has largest mmWave holdings
- Cable companies, especially Comcast
- Investors

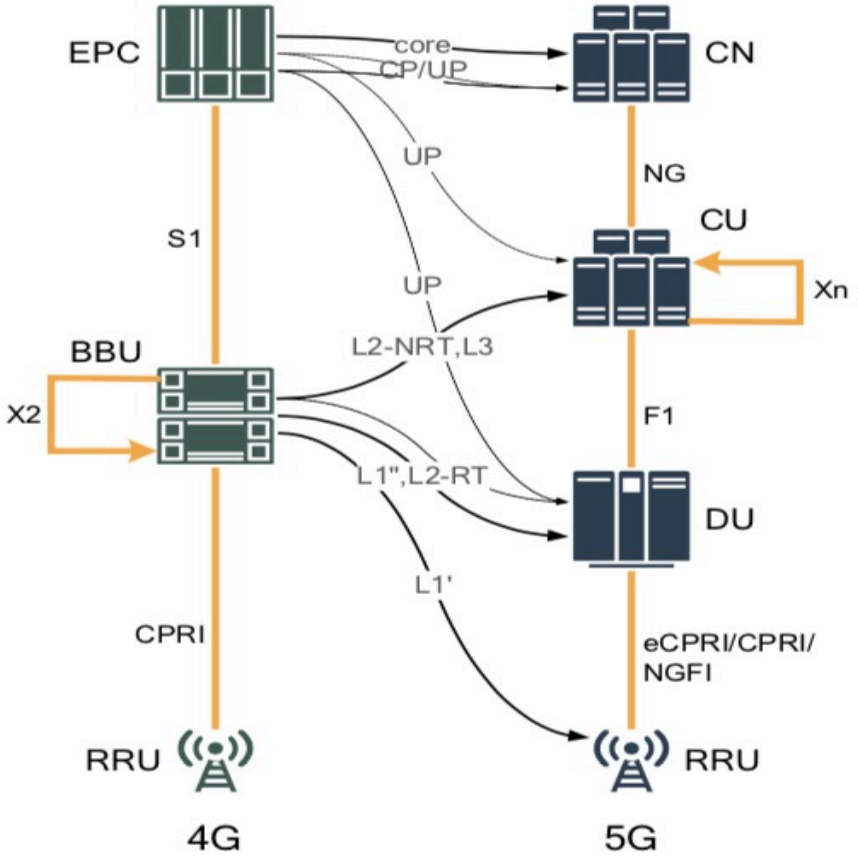
Source: iGillottResearch, Inc, 2021

Implementing C-Band

- C-Band is very close to CBRS equipment
  - No problem with availability of equipment for Dec 2021 commercial launch
  - Nokia demonstrated 5G at 1 Gbps in June 2020 in C-Band drive testing on Airscale equipment
- Depending on who wins what between Phase 1 and Phase 2, network will be deployed in 2021 or 2023
  - Phase 2 winners have advantage of longer runway to plan and raise money

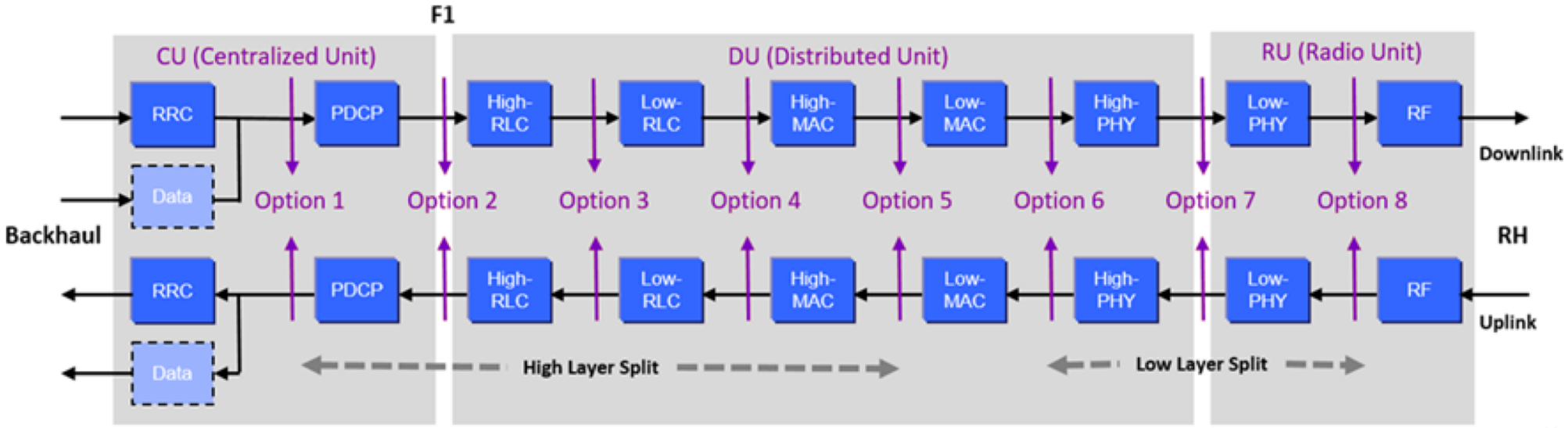
5G Cloud RAN Architecture

4G RAN and the CU-DU Split in the 5G RAN



CN – Core Network or 5G Core
CU – Centralized Unit
DU – Distributed Unit
RRU – Remote Radio Unit
EPC – Evolved Packet Core (4G)
BBU – Baseband Unit (4G)
CPRI – Common Public Radio Interface

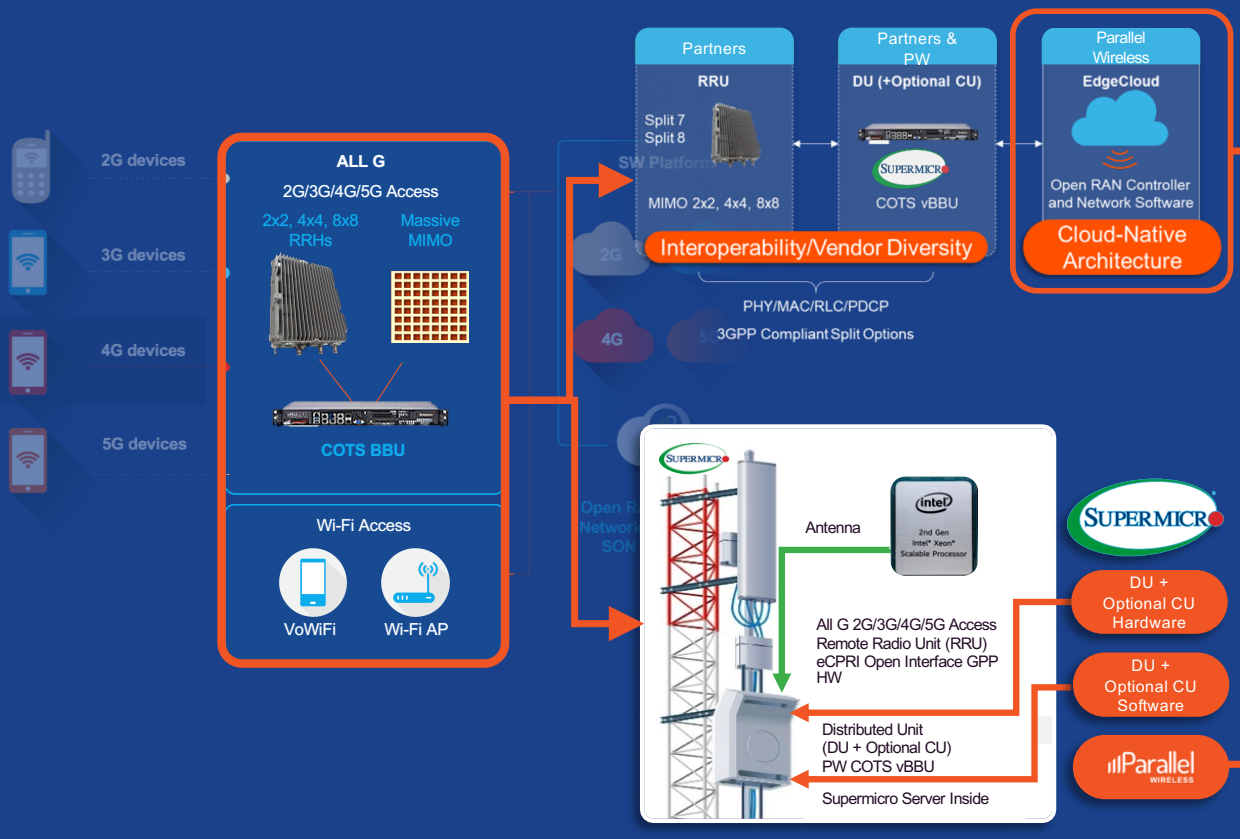
Functional Split Options



Source: Earlswood Marketing/3GPP

PARALLEL WIRELESS AND SUPERMICRO

EDGE-CENTRIC ARCHITECTURE



- Accelerate Innovation
- Remove Vendor Lock-In
- Enable New Revenue Opportunities
- Futureproof to Any G
- Maximize Investments and Lower TCO

- Support of 3GPP compliant splits depending on a use case; future proof to any split
- Flexible architecture
- vBBU hardware that enables OpenRAN radios
- Resource orchestration with OpenRAN controller
- Network slicing and subscriber QoS management across ALL G
- Easy to deploy and maintain w/ simple remote software upgrades

What does Cloud RAN mean for valuations?

- Several impacts from Cloud RAN on how value networks
  - Use of COTS hardware, not network –specific hardware
  - RAN is defined in software
  - Core may be deployed in commercial cloud
  - CN may be deployed in local data center
  - Result is lower deployment cost
- Open RAN
  - Defines standard open interfaces between components
  - Can use different vendors within RAN
    - Today RAN is vertically integrated by one vendor
  - Open RAN advocates have shown 40 percent lower deployment cost

What this all means

- 5G is here and growing quickly
  - Subscriber growth expected to grow 682 percent in the U.S. by 2025
  - Multiple smartphones and devices
  - Consumer and business users
- Networks deployed and more coming
  - Will eventually fill all spectrum bands
- New C-Band auctions provide more spectrum for MNOs
  - But not until late 2021 and late 2023
- C-19 slowed growth of connections and bandwidth
  - Has also changed where people use bandwidth
  - Unlikely to change quickly in 2021 – will take some time to recover
- Cloud Ran and Open RAN will fundamentally change how networks are built…and the cost structure