By Electronic Filing July 1, 2016

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street S.W.
Washington, DC 20554

Re: Use of Spectrum Bands Above 24 GHz for Mobile Radio Services
GN Docket No. 14-177; IB Docket Nos. 15-256, 97-95;
WT Docket No. 10-112; RM-11664

Dear Ms. Dortch:

The purpose of this letter and the accompanying slides is to share some of my reflections on ways for the Commission to expand the opportunity for private sector-led innovation that would carry the American and global wireless industry to the next generation of communications – the fifth in a sequence of digital advances. In the years immediately preceding my tenure as FCC Chairman (1993-97) the first digital licenses were granted on an experimental basis. Lessons learned in industry and academe led to enthusiastic support for a rapid switch from analog to digital wireless communication. One fortunate feature of the Omnibus Budget Reconciliation Act of 1993 was the authorization for the Commission to auction spectrum licenses. For the last 22 years, the Commission has become the global leader in using auctions to create new market opportunities, structures, and investment. American firms have responded with capital and ideas to seize each generation of technological evolution.

The investment boom in information and communications technology (ICT) of the late 1990s was the single most important contributing factor to the salutary economic results of what Alan Blinder and Janet Yellen called the "Golden Decade." Everything that was supposed to go up went up: average income in each quintile, productivity, GDP, labor force participation. Everything that was supposed to go down went down: unemployment, monopoly rents, and the federal deficit. Between 1995 and 2003 American investors put almost $1 trillion dollars into a total rebuild of the communications platform in America. Hardly a single device used in the early 1990s would work on today's platform. Digital, fiber, packets, base stations, and handheld computers have largely replaced analog, copper, circuits, central offices, and mainframes.

It is not inconceivable that 5G can jumpstart a similar wave of investment, innovation, and economic success. Even secular stagnation, the *bête noire* of macroeconomists today, can become another worry allayed. Once again ICT can lead the way to an increasing standard of living for *all* Americans, and from this heartland of creative destruction waves of economic growth can spread around the world. The Commission has already taken bold and critical steps toward this possible future. The immediate and salutary next step is the Spectrum Frontier Proposal, about which Chairman Wheeler has correctly said, 5G "is essential to seizing the 21st

century opportunities in wireless broadband technologies," and opening new spectrum — including high-band spectrum — for flexible use wireless broadband is key to unlocking 5G's potential.[1]

Unlike 4G and its predecessors, 5G subsumes many different technological breakthroughs. These include advances in wave forms, antenna, signal processing, virtualization and other topics. Aggregating all the advances, 5G networks will vastly increase bit delivery, enabling a wide variety of new uses relying on enhanced mobile broadband, massive machine type communications, and ultra-reliable and low-latency communications. These capabilities will, among other things, make a true Internet of Things — encompassing everything from smart homes to real-time cargo tracking to enhanced environmental monitoring and myriad applications yet to be conceived — feasible.

Ensuring a continuous flow of sufficient, adequate, new spectrum is key to the expansion of the wireless market to 5G and beyond, and to building a strong and healthy 5G ecosystem. 5G will require spectrum in a variety of bands: low-band spectrum for wide-area applications such as sensor networks, mid-band spectrum for balancing coverage and capacity, and high-band spectrum for high-bandwidth applications (such as 4k/8k video and VR) requiring ultra-wide channels in localized areas.

The Spectrum Frontiers Proposal would take a significant step towards meeting these needs. Not only would the proposal make new high-band spectrum available for 5G, it also would reaffirm the Commission's commitment to adopting "effective sharing schemes to ensure that diverse users — including federal and non-federal, satellite and terrestrial, and fixed and mobile — can co-exist."[2] Such spectrum sharing is essential given increasing demands on a finite amount of useable spectrum. Although existing uses, especially for public service benefits, should be maintained, the means for furthering various uses should be developed through empirical analysis and not merely mathematical exercises. As the Commission emphasized in adopting rules to govern the new Citizens Broadband Radio Service, the Commission has consistently rejected "worst case approaches to measurements and interference protection

---

[1] "Fact Sheet: Spectrum Frontiers Proposal to Identify, Open Up Vast Amounts of New High-Band Spectrum for Next Generation (5G) Wireless Broadband," *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0623/DOC-339990A1.pdf (June 23, 2016) ("Spectrum Frontiers Proposal").

[2] Spectrum Frontiers Proposal at 1.

analysis" that "present an unrealistic view of the actual interference potential of any given device."[3]

The Commission also should take steps to expedite the process of making new spectrum available. One way to achieve this goal would be to grant experimental licenses for innovative networks to operate on a pilot basis on shared spectrum in limited areas where the risk to existing use cases is insignificant. In the event that such experiments generate empirical data suggesting no actual harm is likely to occur from the shared use, then the new network's operator can extend the network on the *prima facie* assumption that it can operate. The stakeholders involved in the sharing then would have a defined time period to demonstrate actual harm (if any) so that the new use case can be adjusted to maximize benefits as against costs in a quantifiable manner.

Another way to move forward in a sharing regime would be to grant sharing licenses that require the new user to compensate existing users under existing law in a fulsome manner, giving gives existing users — including governmental users — the opportunity to enhance the public benefits they wish to provide. Still a third approach would be to grant licenses to the sharing party that are conditioned on further testing and prompt mitigation of any in-band or adjacent-band issues that do arise, while allowing the Commission to more quickly evaluate new models based on real-world data. Such a dynamic approach is far better suited to the rapid pace of network innovation than the traditional, years-long process focused primarily on theoretical arguments and predictions.

In the attached slide presentation, I outline ways in which market structure, conduct and performance might be altered through innovative and competitive use of spectrum. Such uses will require sharing among private uses and also public-private sharing. Sharing spectrum is certainly the path to increasing the standard of living for all Americans. Sharing spectrum was not necessary in the salad days of digital wireless, but it is the only way forward for the future of wireless for three reasons: (1) the demand to send bits wireless is boundless, (2) physics teaches us that frequencies are limited in number, and (3) Moore's Law provides a nearly unconstrained roadmap to advances in the use of any given frequencies because of breakthroughs in all the fields that together constitute 5G.

---

[3] *See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Order on Recon. and 2nd R&O, FCC 16-55, GN Docket No. 12-354, at ¶ 105 (May 2, 2016)

The proposal that the Commission will vote and any further notice represent salutary progress toward this bright future.

Sincerely,

Reed Hundt

New Networks for 5G

Submission to FCC

Reed Hundt

July 2016

5G Changes Networks, Uses, Performance

New architecture for new networks

Beacons, Sensors, Monitors = leopard and zebra patterns for information gathering

Analytics require low latency high speed delivery networks

Satellite-terrestrial mixture for ubiquity; terrestrial coverage of declining importance

New architecture – new uses

ULTRA HD Ultra High Definition — Ultra high def

IoT

Tactile real-time control

Augmented reality

Connected health

Transport system

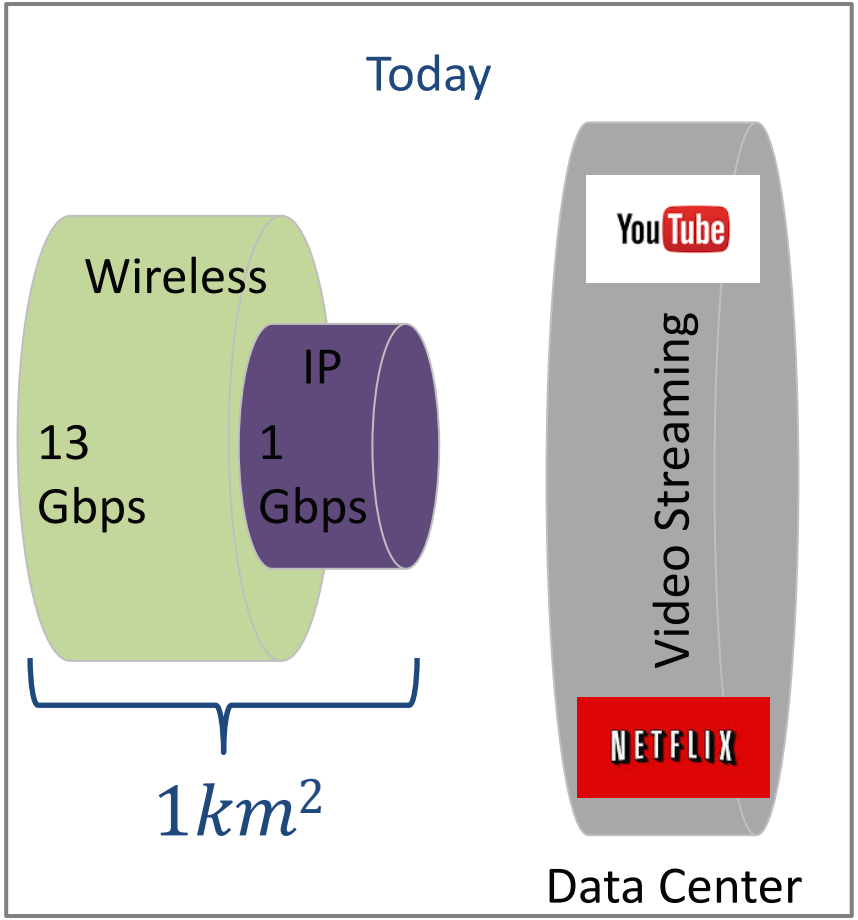
eMBB mMTC uMTC

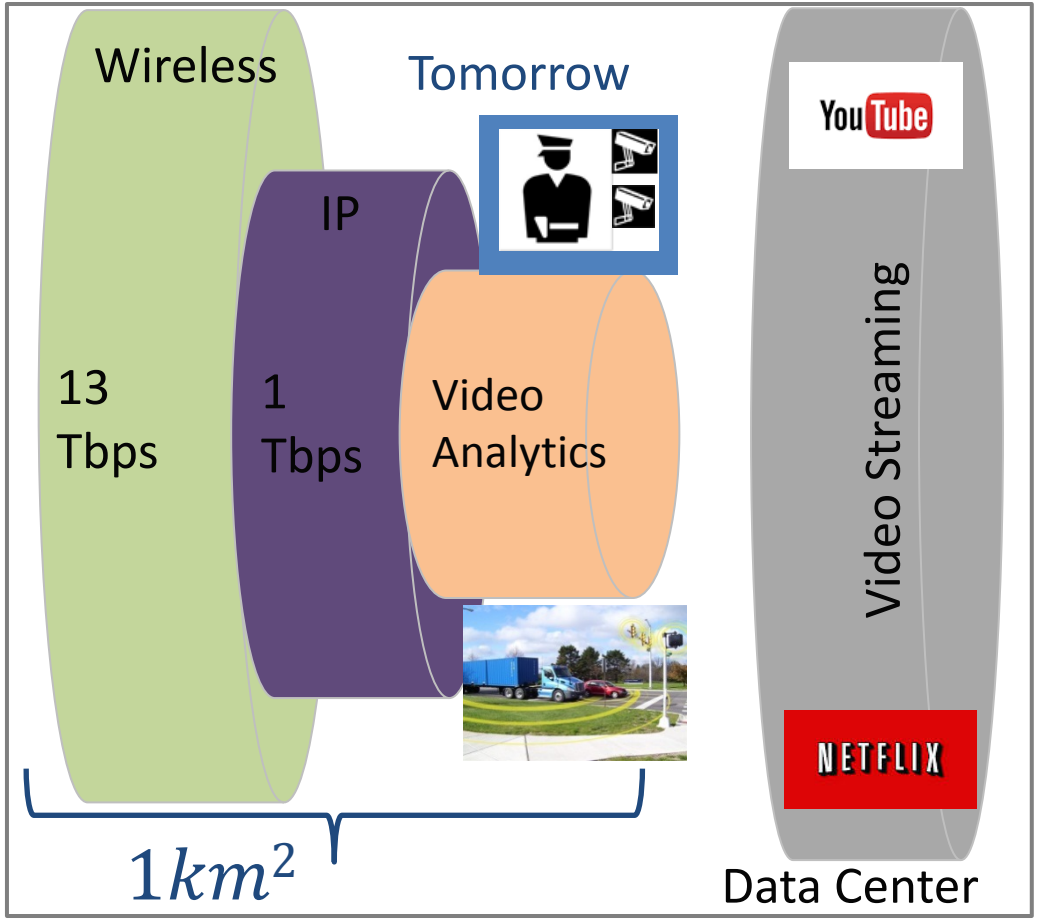
Technology determines history

- **User throughput**
  Up to **20Gbps**
- **Edge latency**
  Less than **1ms**
- **System Bandwidth**
  At least **100MHz**
- **Duplex**
  FDD and **TDD**
- **Spectrum**
  +100 GHz
- **Time Scale**
  2018 and ***Beyond***

eMBB – Enhanced Mobile Broadband, uMTC – Ultra-reliable and Low-latency Communications, mMTC – Massive Machine Type Communications

5G Networks Will Vastly Increase Bit Delivery





* Other names and brands may be claimed as the property of others.

Networks are platform for multiple technologies

5G Key Technologies

Evolved Multi-Antenna Processing
Very Large or Massive MIMO Systems

New Modulation and Coding
Non-Orthogonal Multiple Access

New Access to Spectrum
Unlicensed, Licensed Shared Access, cmW, mmW

Low Energy Systems
Devices and Infrastructure

Coordinated Systems
C-RAN Topologies and Silicon Photonics

Network Virtualization
Software Defined Network

Multi-RAT Operation
Intelligence Traffic Routing

Device-Device Communications
MTC and V2V Applications

5G Key Radio Bands

m-Wave Sub-10GHz
~100-200MHz BW
SU/MU-MIMO

cm-Wave (cmW) 10-30GHz
100-500MHz+ BW
SU/MU-MIMO

mm-Wave (mmW) 30-90GHz
500MHz+ BW
Hybrid MU-MIMO-BF

Various markets may produce 5G network builders

Operators

Infrastructure

Automotive

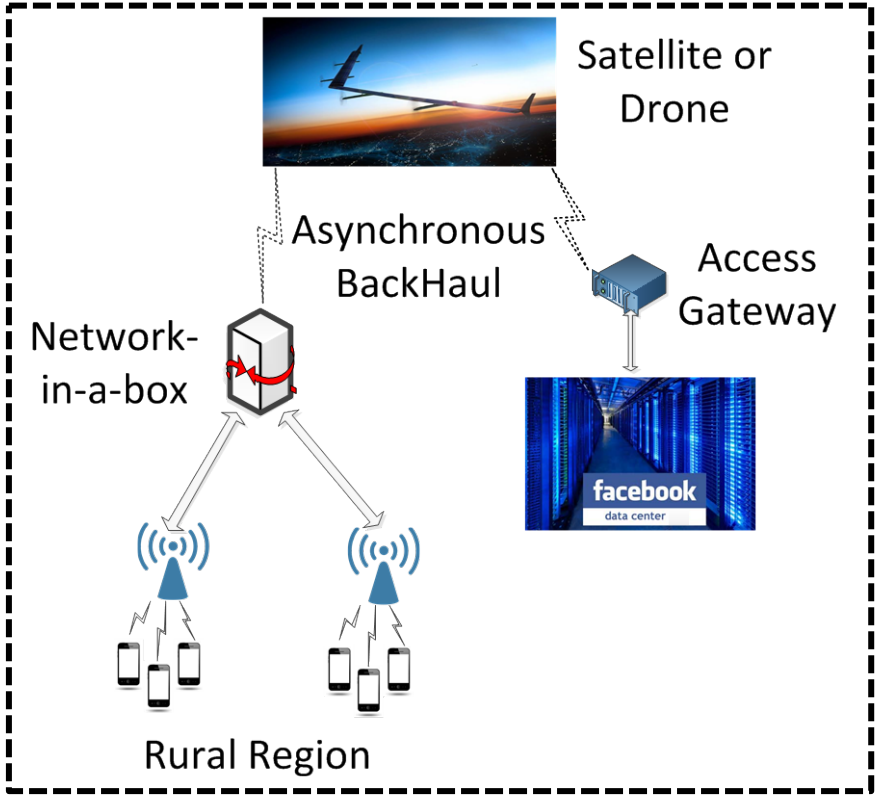
IoT

Handsets & PCs

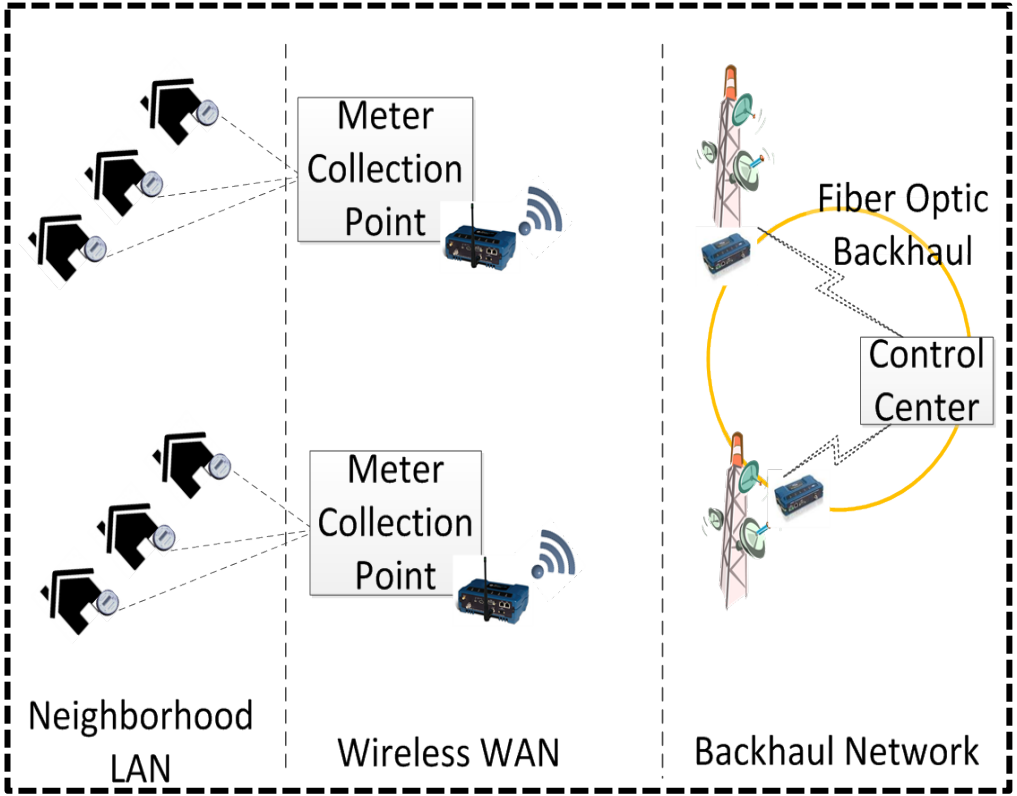
Disrupters

New Entrants Offer Open systems in Networks

Facebook
"Connecting the unconnected"



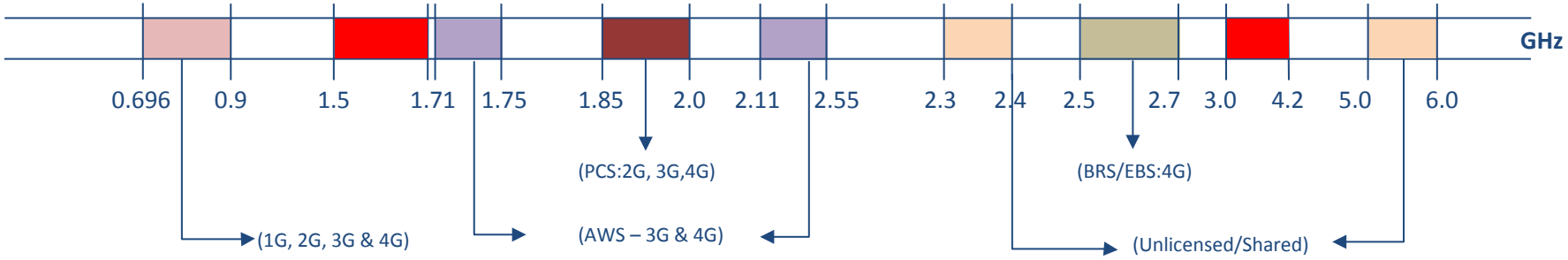
GE Vertical: Smart Grid
(Advanced Metering Infrastructure)



* Other names and brands may be claimed as the property of others.

5G Network Competition Requires Greenfield Spectrum

Spectrum Used for 2G, 3G and 4G Mobile Communications

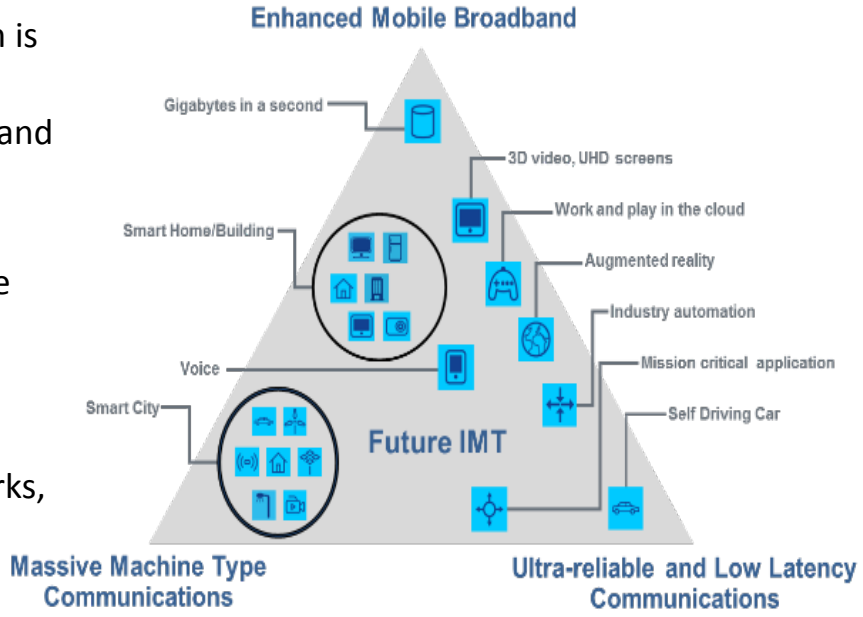


Red Marks 5G Spectrum

Spectrum Critical to 5G

- Continuous flow of sufficient, adequate, new spectrum is key to:
  - expansion of wireless market to 5G and beyond, and
  - building a strong and healthy eco-system
- Economies of scale achieved through availability of globally harmonized bands is essential to growth of the wireless market
- Consequently, a variety of spectrum bands/ranges are needed

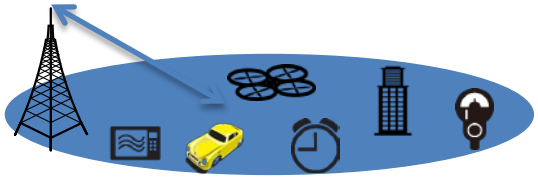
- < 1 GHz – for wide area applications, e.g. sensor networks, etc.
- < 6 GHz – for coverage/capacity trade-off, e.g. massive MIMO, outdoor-to-indoor
- Higher – for apps needing ultra-wide channels, e.g. 4k/8k video, VR, etc.

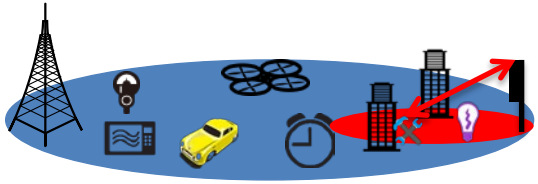


Source: Recommendation ITU-R M.2083, "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond"

IOT Requires 5G; 5G Requires New Radio Access Network on Greenfield Spectrum

5G Requires New Radio Access Network





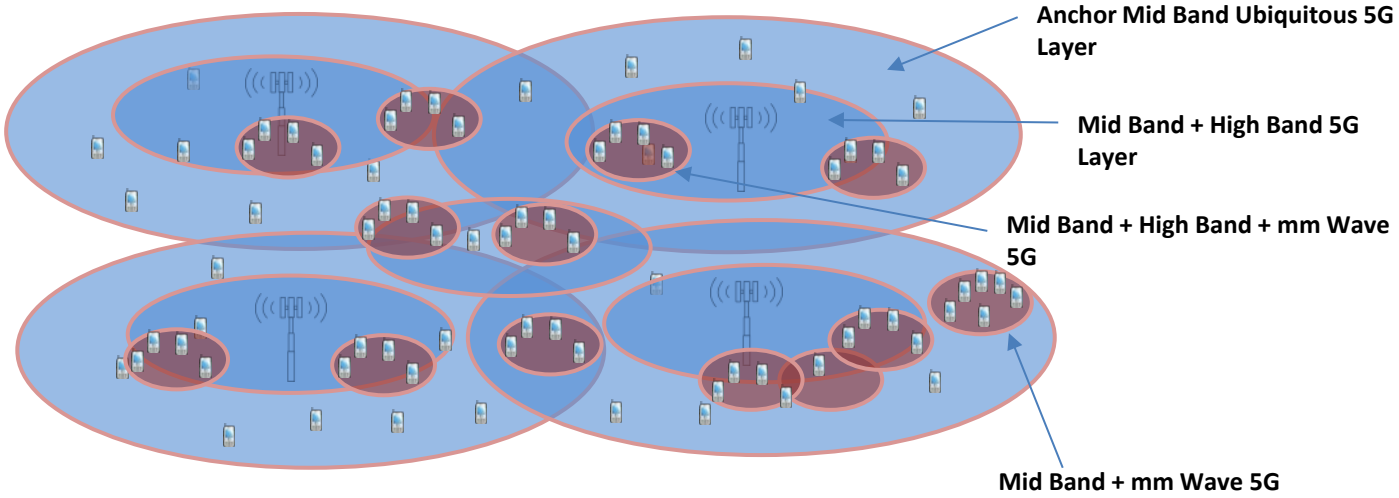
Localized hot spots suitable for higher frequency, unlicensed, sharing

- Information-gathering things need low, mid, and high frequencies
- Analytics need midband for distribution
- High data use cases need high frequency hot spots
- Unlicensed and 100 MHz licenses enhance competition

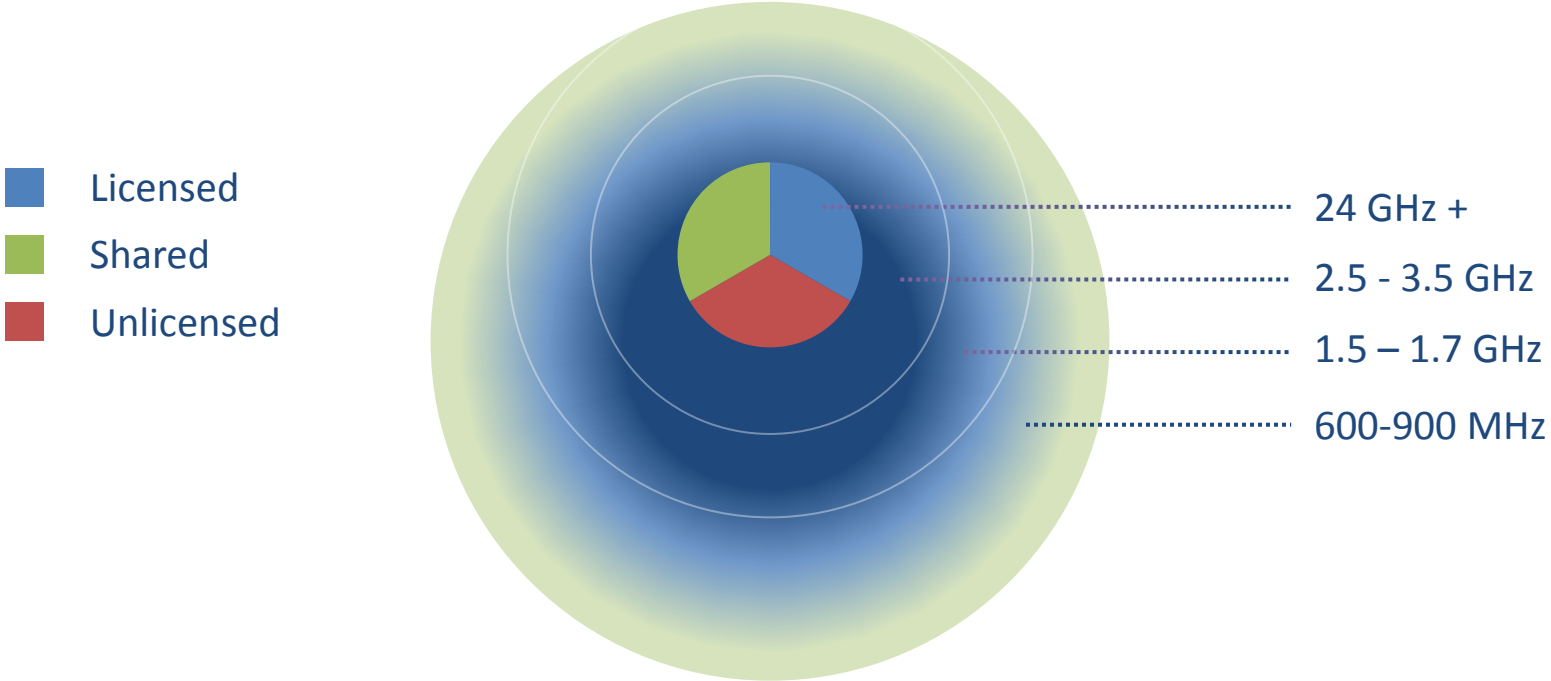
5G Requires Green Field Spectrum at Various Frequencies

Mid Band (Below 2 GHz), High Band (3.5- 6 GHz), and Very High MM Wave (24 GHz and Above)

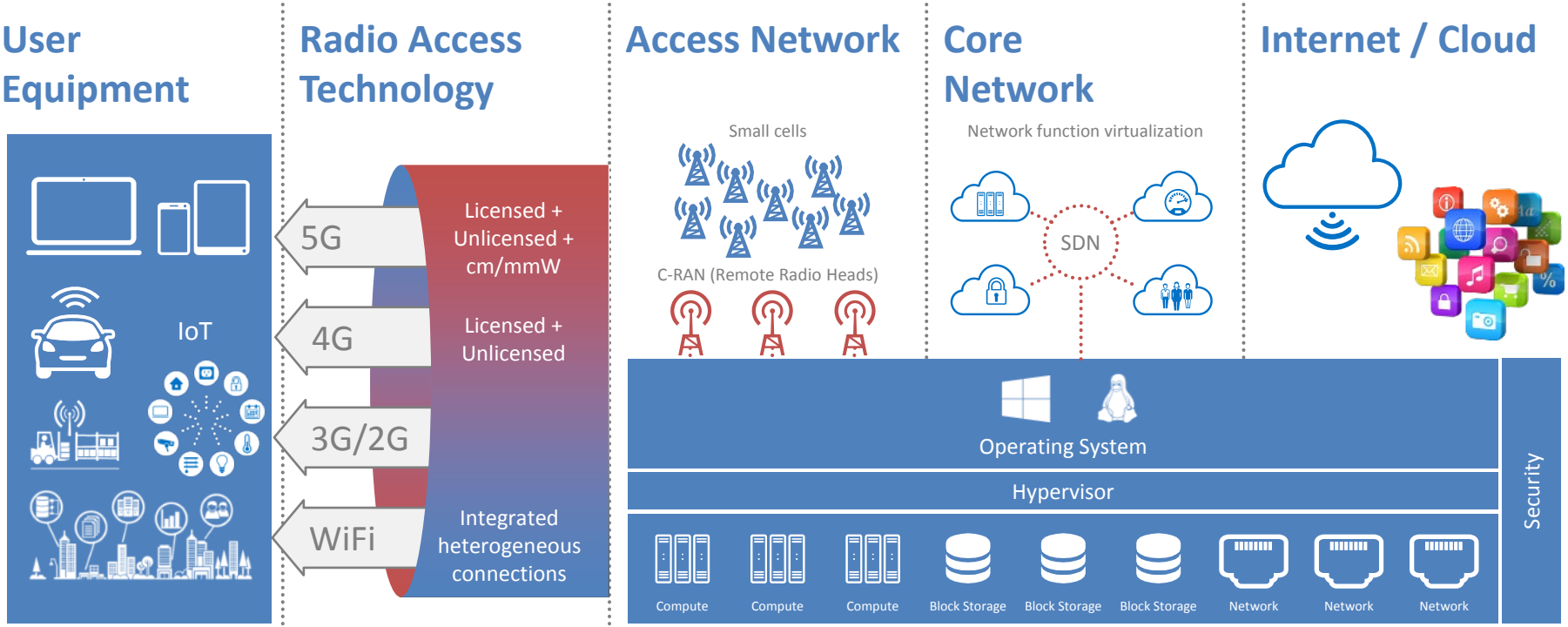
- 5G on mid band spectrum (Below 2 GHz) anchors use cases to provide seamless experience



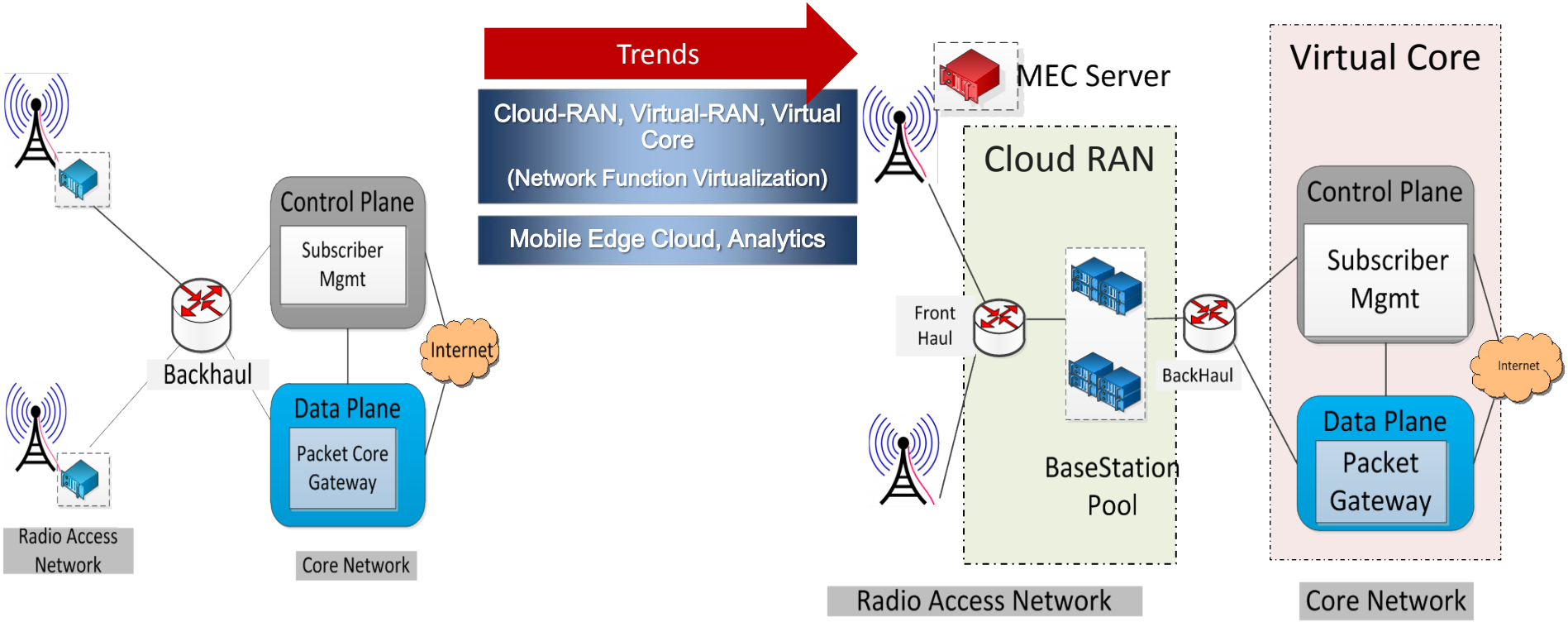
Illustrative Top Down Look at Network Deployment x Spectrum



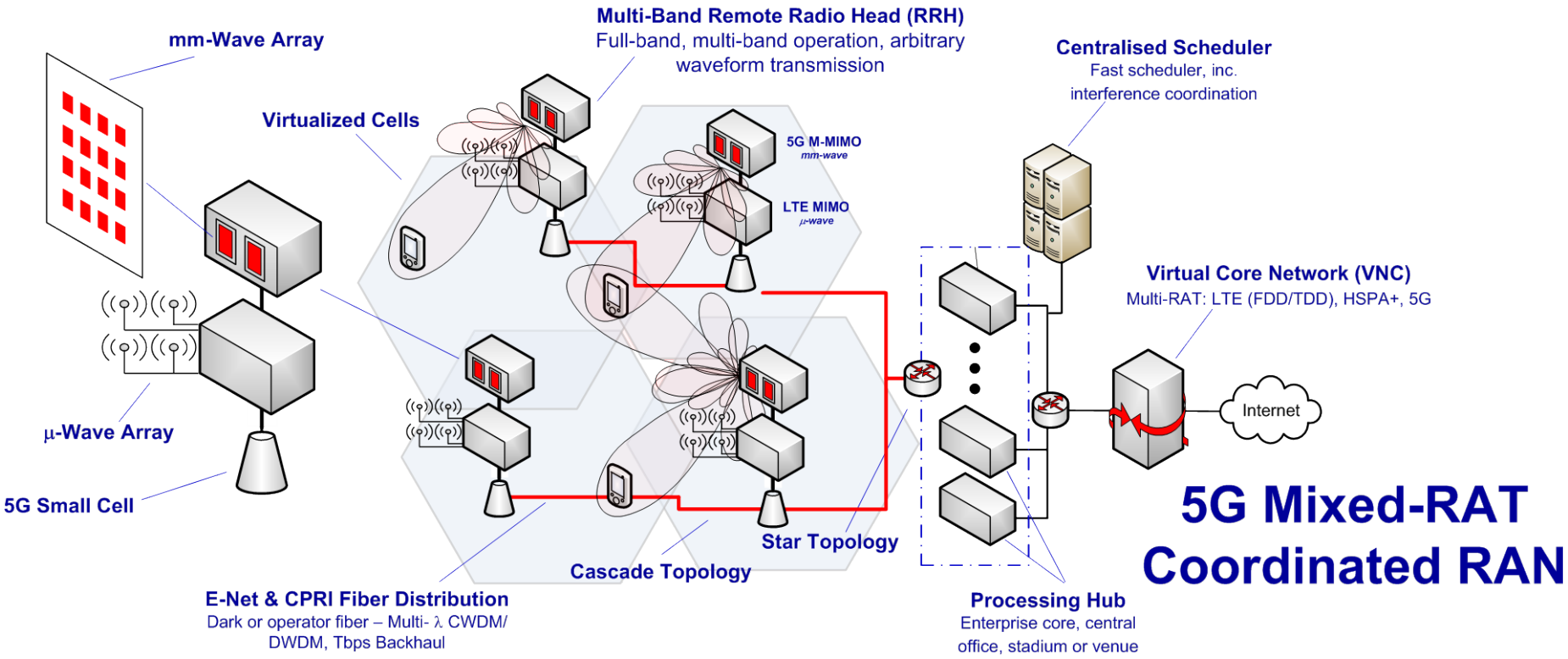
5GNetworks Must Link to Cloud



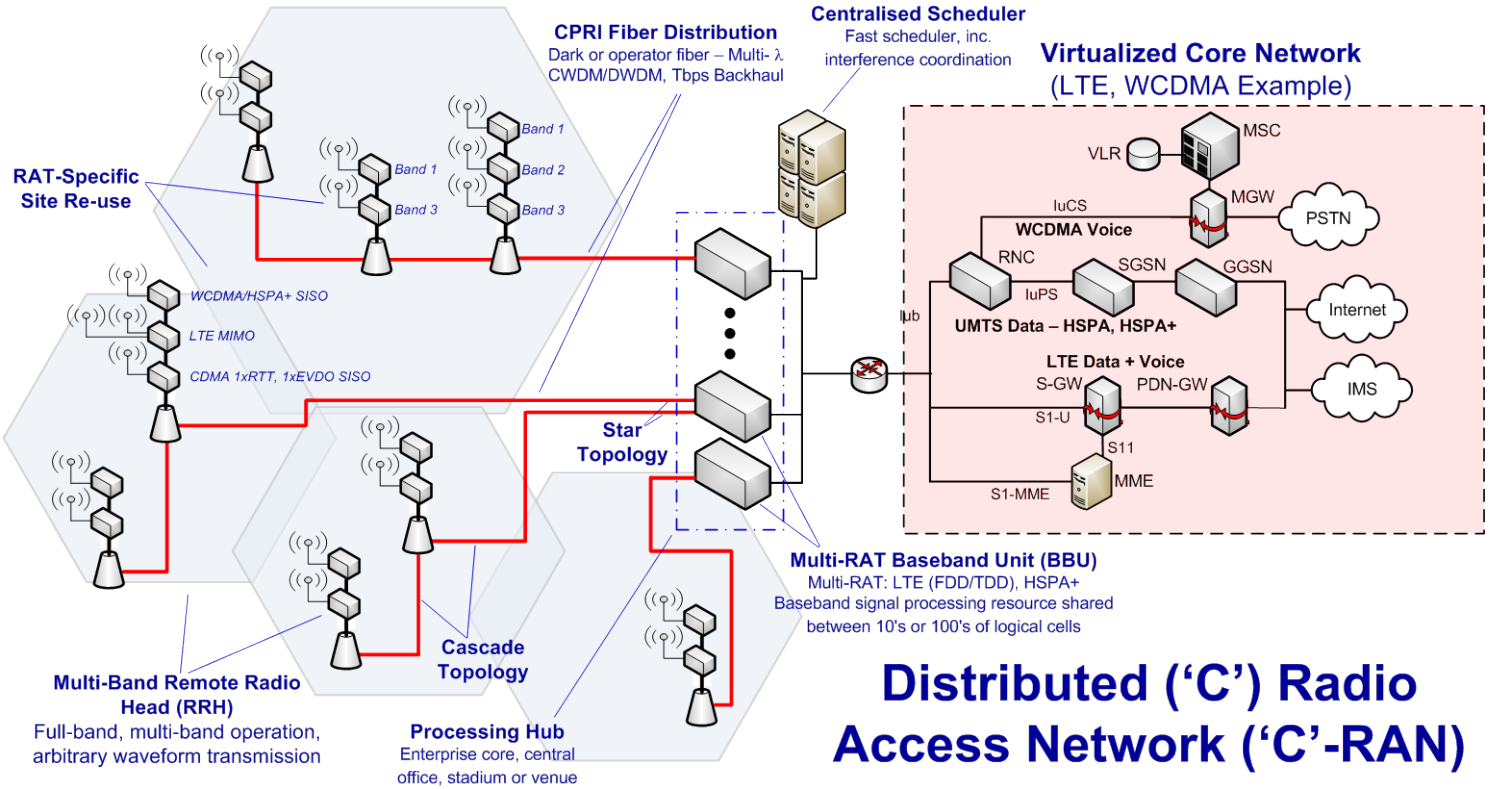
Traditional Cellular Network architecture is evolving



5G Networks Comprise Multiple Wave Forms, Cells

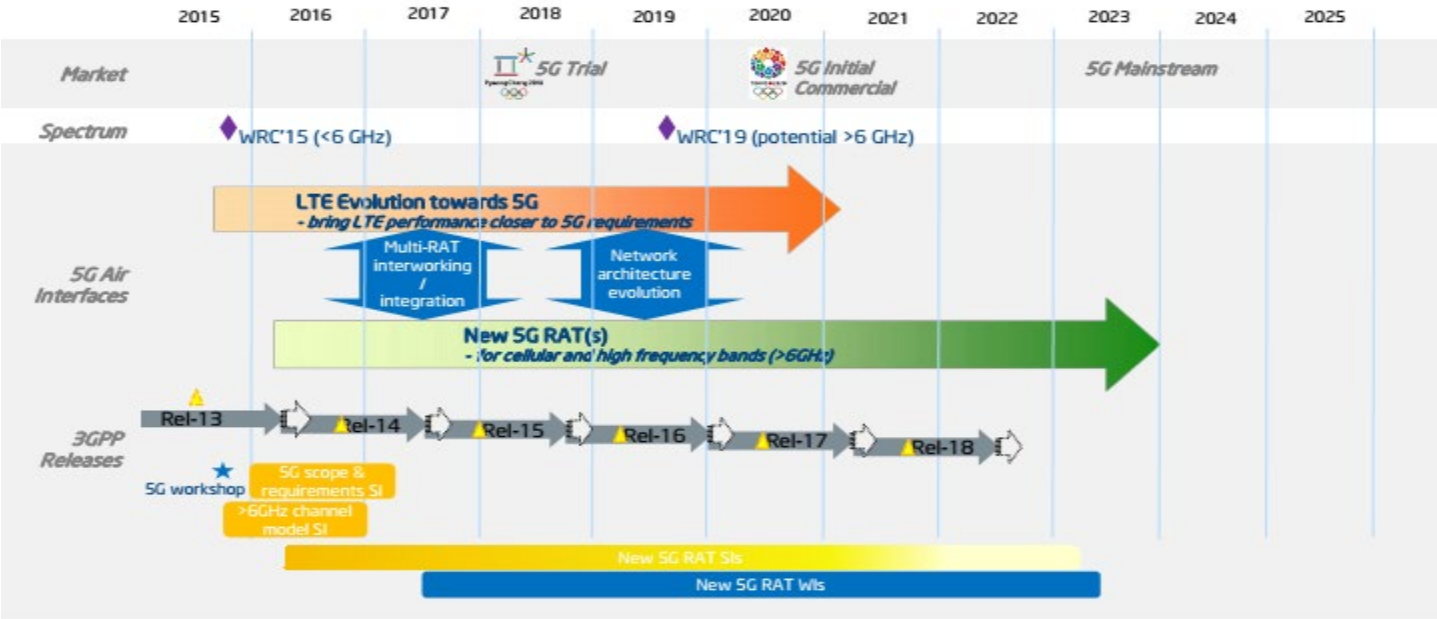


5G Can Lead to Virtualized Networks

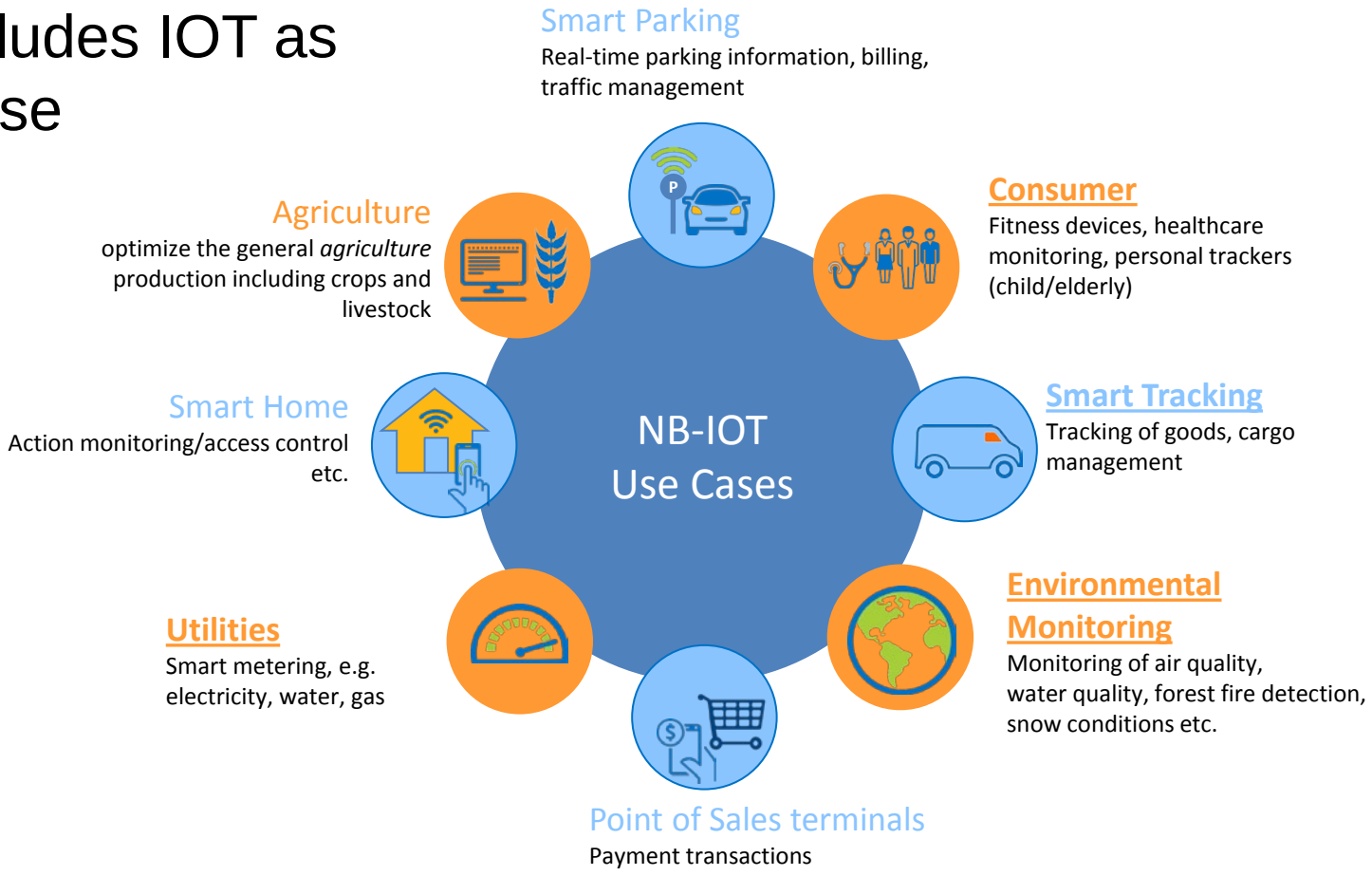


Distributed ('C') Radio Access Network ('C'-RAN)

5G Will Subsume, Use 4G, IOT



5G includes IOT as use case



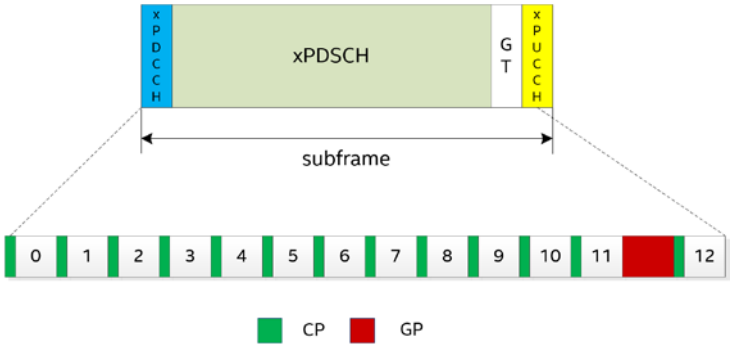
5G Could Lead to Wireline/Wireless Convergence

Parameter	Value
Carrier Bandwidth	100MHz
Waveform	OFDM
Sampling Rate	153.6MHz
Subcarrier Spacing	75kHz
Symbol Duration	13.3us
OFDM Symbols per TTI	14
CP Length	0.94/1.04us
TTI Length	0.2ms
Radio Frame Duration	10ms

Primary Numerology

Parameter	Value
Peak Rate (DL) – UE	1.3-5.0Gbps
BS-UE Delay RTT	2ms

Primary Performance



Frame Structure

Locus of Network Building May Change

Wireline Value Chain

Search

Google

WWW

Web Channels

amazon.com

COMCAST

NETFLIX

ISP

COMCAST

Wireless Value Chain

Communicating

facebook

Publishing

Disney

Retail

amazon.com

Apps

Google Search

SAMSUNG

Q

Wireless Carriers

at&t

verizon

Spectrum

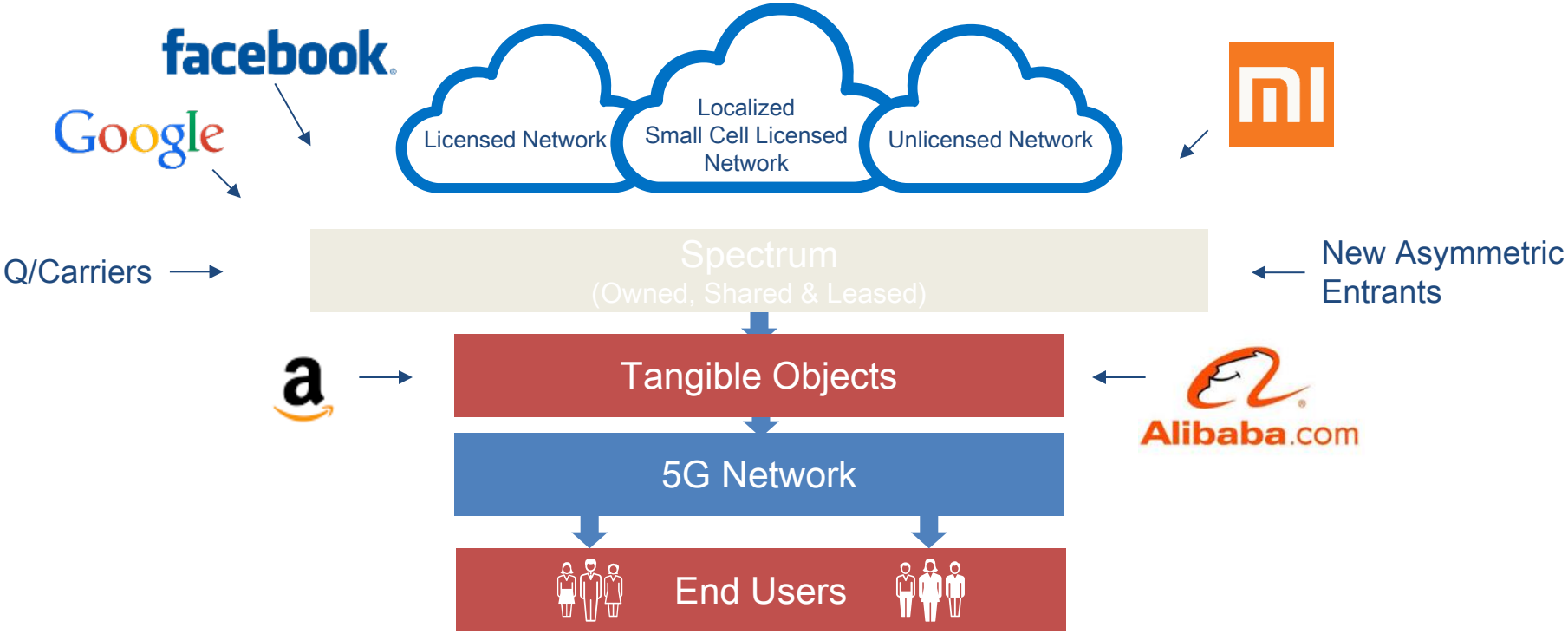
Network

End Users

What's Up With Facebook?

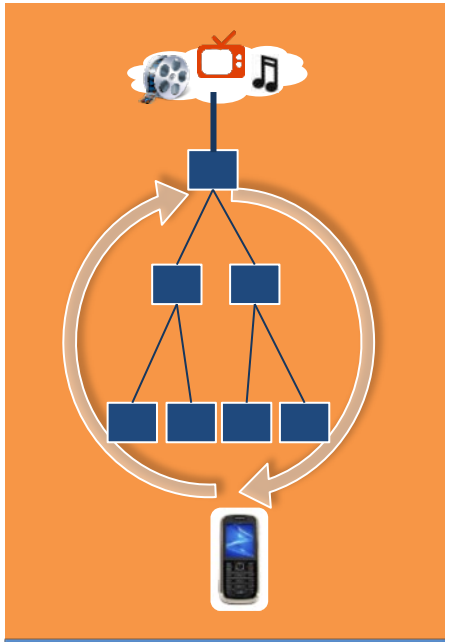
Wireline vs wireless? Is this relevant for ROW?

FCC Should Permit Spectrum Ownership To Fragment

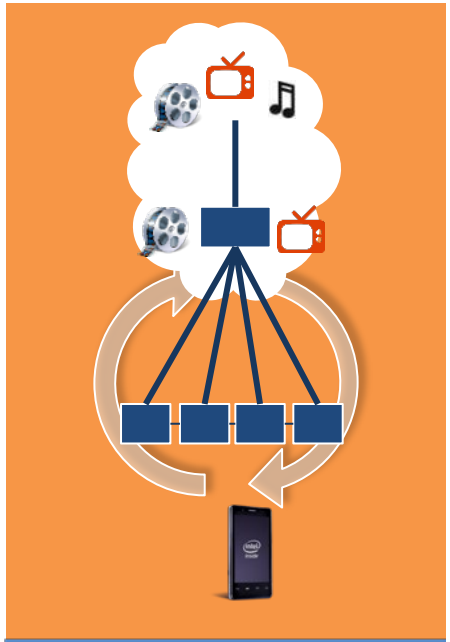


*other names and brands may be claimed as the property of others

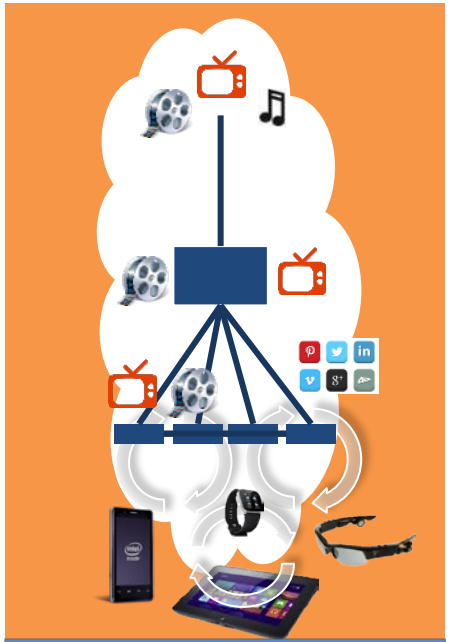
FCC Should Permit Storage, Computing, Community To Compete In Communications Networks



Remote Cloud / Basic Terminal



CDN / Cooperative Radio



Edge Cloud / Underlay Net Clusters

Logos shown represent categories of common Internet content and are used for conceptual illustration only.

Summary

- Static, “Purpose Built”, Vertical Network does not enable use cases of next 10 years & beyond

- FCC Licensing Should Enable Deployment Of
  1. Prototype Heterogeneous (Sat-Terrestrial) Networks
  2. Prototype of front haul (Radio IO) over Ethernet, Fiber, Wireless Point to Point
  3. Enhancements in SDN/NFV with SoftRAN
  4. Model Densification Networks
  5. Advanced IOT Networks
  6. Many Sizes To Fit All Competitive Circumstances

FCC Should Let Competitors Seek Bottleneck

FCC: 5G Competition Goals

- 5G to Enhance Competition in Access Networks, Data Gathering and Content Delivery
- Firms Can Seek Bottleneck Position, Net Neutrality Assures Open Access to Content
- Enable Markets To Choose
  - Optimal band size (let competitors build up from 100 MHz, not down from 800 MHz)
  - Most efficient geographical deployments (densified network will vary place to place)
  - Optimal heterogeneous networks (satellite allocations need to share with terrestrial in and out of band; 3g, 4g, 5g must be accommodated)

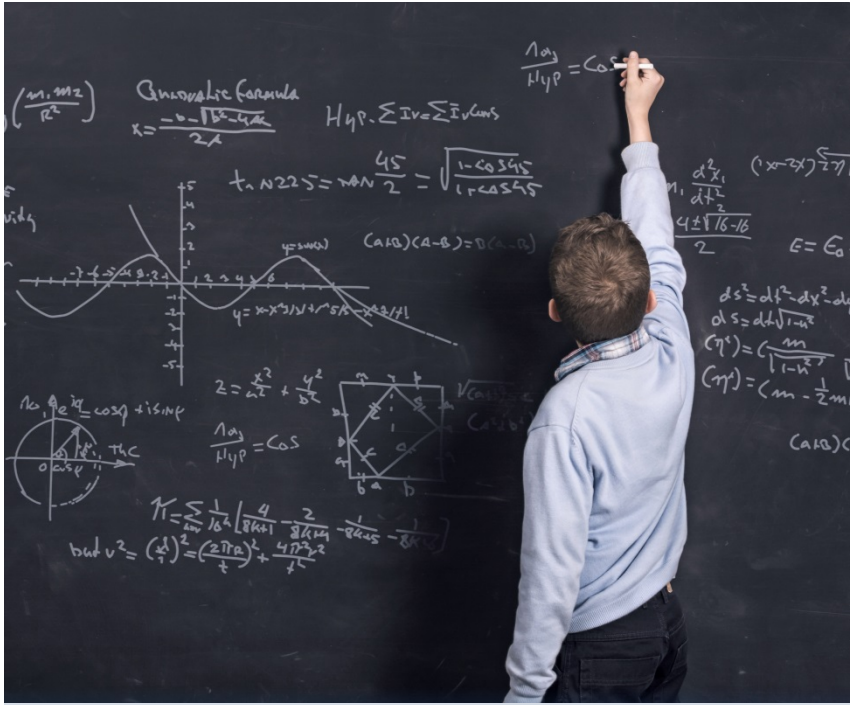
FCC 5G Competition Tactics

- Expedite Inter-Agency Decision-Making
  - Set end dates for spectrum sharing decisions
  - Prima facie showing compels resolution

- 5G Requires Competition in Backhaul
- IOT Needs Open Access to Public Property

- Enable Experimentation
  - Rapid model deployment
  - Grant licenses subject to further testing
  - Flexible build-out requirements
  - Empirical testing supersedes finger exercises

Networks Could Commoditize Intelligence, Leave Consciousness



Doing math

Lying on the beach

Intelligent Networks Will Design World Differently (Humans May Not Understand)

Thank You

Reed Hundt, rehundt@gmail.com, 202 494 4111