Technological Advisory Council

Antenna Technology

Working Group

March 26, 2019

Antenna Technology Working Group

- **Chairs:**
  - Greg Lapin, ARRL
  - Marty Cooper, DynaLLC
- **FCC Liaisons:**
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  - Michael Ha, OET
  - Bahman Badipour, OET
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- **Participants / Contributors:**
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  - Lynn Claudy, NAB
  - Brian Daly, ATT
  - Pierre de Vries, Silicon Flatirons
  - Adam Drobot, Open Tech Works
  - Danilo Erricolo, Univ Illinois Chicago
  - Jeff Foerster, Intel
  - Bo Goransson, Ericsson

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- Stephen Hayes, Ericsson
- Farooq Khan, PHAZR Inc
- Kevin Leddy, Charter Comm
- Michael Marcus, Marcus Spectrum
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- Bob Miller, incNetworks
- Umesh Navsariwala, PCTel
- Sven Petersson, Ericsson
- Brennan Price, Echostar
- Sudhir Ramakrishna, PHAZR Inc
- Dennis Roberson, RAA
- Jesse Russell, incNetworks
- Harry Skinner, Intel
- Charlie Zhang, Samsung

Antenna Technology Developments

This working group was tasked to report on the state of development of antenna technologies and their implications for FCC policies, technical standards, regulatory and technical issues. The task was intended to cover as broad a scope of radio services as feasible as well as fixed and mobile applications.

- Multi-element array antennas can dynamically focus signals, enabling new forms of interference and interference avoidance, possibly necessitating new technical standards and rules.
- Metamaterials may offer possibilities to produce more efficient antenna elements for devices and arrays at lower cost.

Antenna Technology Developments [cont]

- Massive MIMO, Distributed MIMO, Spatial Division Multiple Access (SDMA) and other technologies promise increased spectrum efficiency.
- Today’s higher frequencies allow for smaller sizes and more complex antenna designs, acknowledging some trade-offs
- Necessity for large numbers of frequency bands presents challenges for cell site and phone designers.
- Disguised antennas may facilitate acceptance of dense deployments of small cell antennas; access to poles and street lights in municipalities present special challenges.

Antenna Technology Topics Investigated

- Array Antennas
  - Beam forming, electronic steering, and central processing
  - Reflect Arrays
- Metamaterials
  - Unique material properties promise to greatly reduce antenna sizes at all frequencies
  - Still in early days
- mm-Wave Antenna Technology
  - Small Cell Antennas
  - Satellite Antennas

Antenna Technology Topics Investigated (cont)

- Antenna Modeling Tools
- Antennas Incorporating Interference Rejection
- Filtering Antennas
- Quasi-Optic Antennas for mmWave and THz operation
- Other Innovative Antenna Materials
  - Gas Plasma
  - Spray-On MXene

Metamaterials

- Ryan Stevenson, Kymeta Corp
  - Metamaterial Satellite Antennas with commercial LCD material
- Richard Ziolkowski, Univ of Arizona
  - Metamaterial and Metamaterial-Inspired Antennas for Reduced Size, Directionality, Cloaking, Multi-band antennas, UWB antennas with embedded filtered notches.
- Eric Black, Pivotal Commware
  - Switchable Metamaterials

Smart Antennas

- Ted Rappaport, NYU
- Antonio Forenza, Artemis Networks
- Martin Cooper, DynaLLC
- Bo Göransson, Ericsson

Smart antennas can create a “personal cell” for each device, decreasing interference and increasing frequency reuse, thus improving spectrum utilization.

Smart antennas offer differing capabilities at millimeter wave frequencies and sub 6 GHz frequencies because of different radio multipath properties.

Electronically Steerable Antennas

- David Garood, Phasor
- Joe Carey, Trimble
- Jim Nevelle, Kathrein USA
- Kevin Linehan, Commscope

Steerable antennas can be used to create beams, to track satellites, or to decrease the number of “hot spots” by focusing the energy only where it is needed.

Testing

- Jonas Fridén, Ericsson
  - OTA Testing - Measurement of adjacent band and spurious emissions for integrated active array antennas
- Reza Biazaran, OET Lab
  - FCC Rules related to antennas
- Robert Paxman, Intel
  - ANSI C63.26 Proposed Total Radiated Power Rules

Cellular Base Station Appearance

- Michael Marcus, Marcus Spectrum Solutions
  - The appearance of base station antennas, particularly small cell installations on wooden utility poles, varies widely and can have a marked effect on public resistance to siting such base stations.
  - State legislation exempting such cell sites from all local design review may decrease carrier incentives for care in design to minimize neighborhood impact.
  - Reasonable esthetic appearance is a desirable design goal for rapid and continued roll-out of new sites.
  - Industry-based voluntary oversight of fielded base stations is preferable to any government action.

Cellular Base Station Appearance

- Michael Hughes and Bo Piekarski, Crown Castle Corp
  - One cell site company that has illustrated several examples of small cell designs with nice appearances
- However, a nice appearance must be balanced against maintainability.
  - Towers must be easily serviced to maintain life-safety communications.

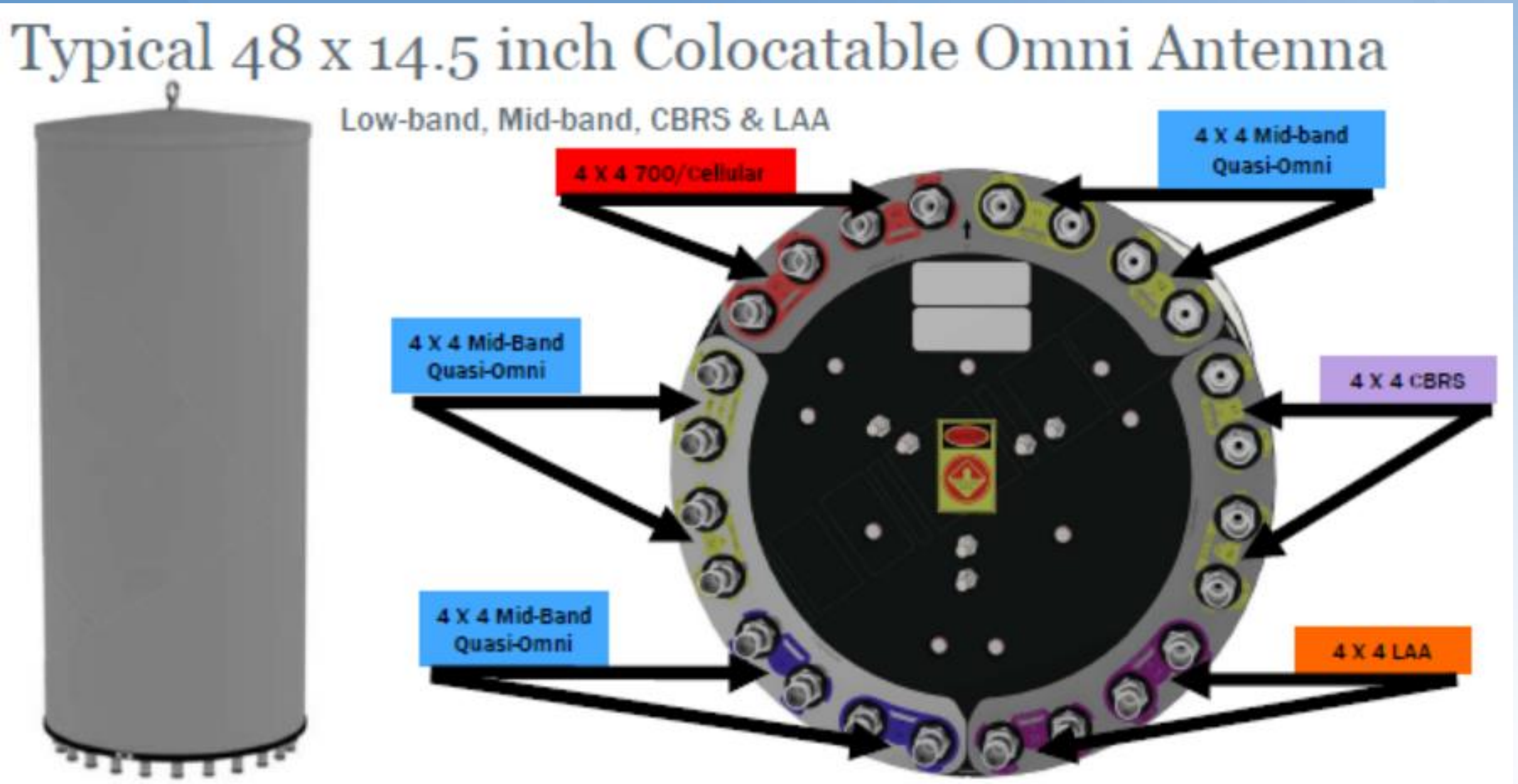
Small Cell Appearance - Bad

Small Cell Appearance - Good

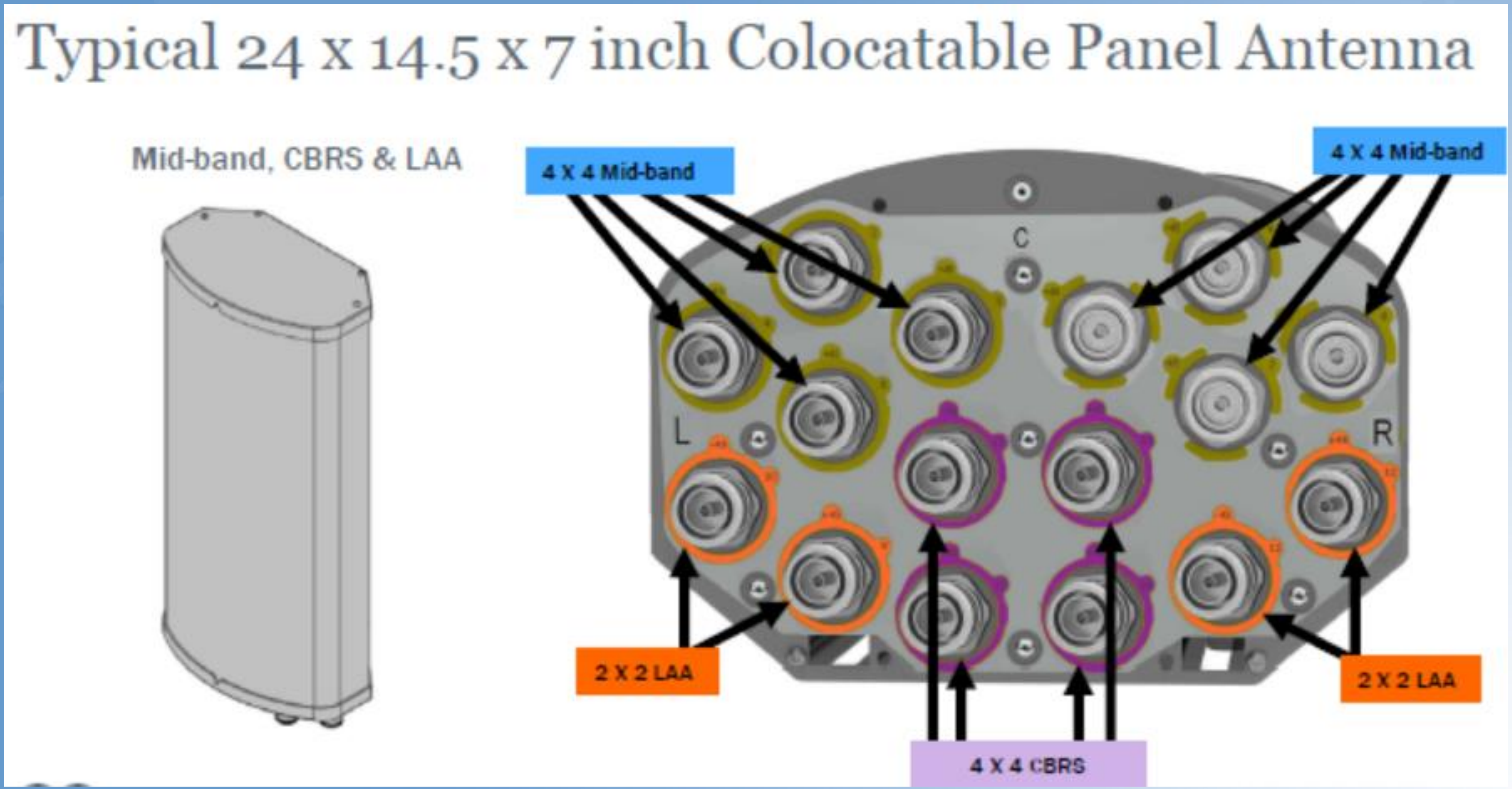




Compound Antennas Improve Cell Appearance



Compound Antennas Improve Cell Appearance



Other Antenna Topics

- Danilo Erricolo, UIC
  - Self interference cancelling antennas for full duplex communications
- Yahya Rahmat Samii, UCLA
  - Fractal Antennas
- Andy Paff, Universal Plasma
  - Plasma physics for commercial antenna deployment
- Adam Drobot
  - Survey of antenna modeling methods
- Yury Gogotsi, Drexel Univ
  - MXene Spray-On Antennas
- Josep Jornet, SUNY Buffalo
  - Quasi-Optical Antennas for mmWave and THz

FCC Technology Watchlist

- MIMO - Effective in improving spectral efficiency and coverage below 6 GHZ. Multi-element arrays are programmed to direct multiple beams simultaneously in increasingly tight patterns as the number of elements is increased. At millimeter wave frequencies MIMO is useful for improving coverage and speed. Expected impact immediate.

FCC Technology Watchlist

- Spatial Division Multiple Access - SDMA is a variant of MIMO that is effective in improving spectral efficiency and coverage in areas that exhibit multipath (Typically below 6 GHZ). SDMA uses multi-element arrays with local processing at the cell site. The working group was advised that equipment is available that multiplies spectrum capacities by 3 or 4 times. Expected impact immediate.

FCC Technology Watchlist

- Distributed Antenna MIMO – uses single antennas at multiple cell sites as an array, with processing at a central location to create a "personal cell" area. It can exhibit high spectral efficiency that is not dependent upon multi-path. Specialized applications such as stadium and large event coverage are being explored. Expected impact is for specialized applications.

FCC Technology Watchlist

- Antenna Analysis and Design – New antenna design tools can, with great precision and flexibility, predict performance of antenna designs. The process of antenna design is being formalized and accelerated in contrast with historical trial-and-error approaches. Expected impact evolving rapidly over the next few years.

FCC Technology Watchlist

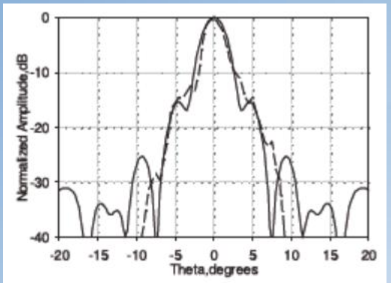
- Filtering Antennas – Antennas that replace the need for external filters or transmitter designs with embedded filters. Simplifies system design. Available in the next few years.

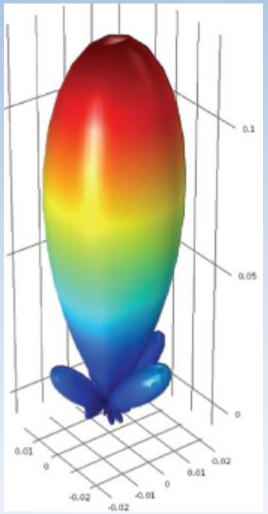
FCC Technology Watchlist

- Quasi-Optical Antennas – Antennas designed to operate above 500 GHz, up to 10 THz. Highly directional patterns are possible with high gain and suppressed sidelobes. Signal paths have been tested over distances are long as 2 km and sidelobes have been shown to not interfere with receivers in protected passive bands. Commercial use of these frequencies could be practical in the next 5-years.

FCC Technology Watchlist

- <u>Quasi-Optical Antennas (cont)</u>
  - Over 40 times the bandwidth is available from 0.275-10 THz than is being used in the rest of the spectrum
  - At very short wavelengths, lenses and nanomaterial arrays can be used to highly focus the signal beam, minimizing interference to other services. Typical antenna gains are 30 dB with sidelobes as low as -50 dB.





FCC Technology Watchlist

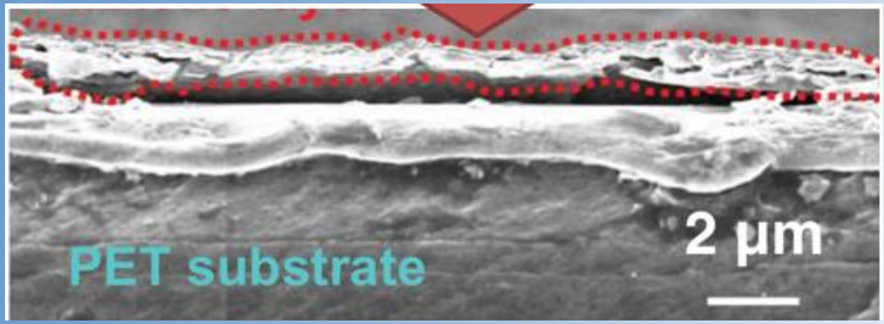
- Metamaterials – Metamaterials are manmade materials that exhibit properties not present in natural materials. Early research results show promise as a tool for reducing the size of antennas and antenna elements. The science of metamaterials for antennas is limited but evolving. There are antennas in use that already avail themselves of this technology. Although some implementations already exist, this technology is not fully mature.

FCC Technology Watchlist

- Self-Interference Cancellation for Full Duplex (SIC) – A method that uses a single antenna with a common frequency source for both transmit and receive eliminating the need for duplexers and some filtering. Simultaneous transmit and receive on the same frequency could yield a doubling in spectrum capacity. This technique is in early research stages and practical isolation of receivers and transmitter has yet to be achieved. Possible impact in the 10-year range.

FCC Technology Watchlist

- Spray-On Antennas – Material called "MXene" is sprayed on various substrates in very thin layers, as little as 1 μm thick. Can be made to be optically transparent and such antennas behave well even when flexed. In early stages of development and should be practical in the 10-year range.



Technology Explored but Not on the Watchlist

- Fractal antennas – Fractal antennas purport to use unique shapes to provide multi-frequency capabilities. Although there are various theories espoused for the value of fractal antennas, the Working Group was unable to uncover scientific or technologically reproducible evidence to support significant impact in the future. There continues to be some art and opportunity for creativity in the shape of antennas and antenna elements but fractal antennas have not yet exhibited design reproducibility except possibly in some proprietary products.

Technology Explored but Not on the Watchlist

- Plasma Antennas – Replacing metal with gas plasma in antenna designs is claimed to be lighter, more efficient, better focused, have reduced sidelobes. Impressive claims were presented to the Working Group but there was little concrete evidence of this. This is currently being developed commercially.

Actionable Recommendations

- The Working Group has considered the advancements in Antenna Technology that we have studied over the past year and has developed the following list of recommendations for the FCC to take action on in order to best realize the advantages of the technology.

Dynamic Antennas – Background for Recommendation

- Dynamic antennas provide versatility by being able to precisely direct radiated energy to, and receive signals from, specific users. This can avoid sending energy in unwanted directions or receiving energy from unwanted sources, facilitating co-channel sharing.
- The likelihood of co-channel interference is reduced due to highly directional beams, limited dwell times at any single location, low antenna heights, and significant down tilt.
- As antenna heights are reduced and radiated energy becomes highly focused, the potential for very high energy densities on the ground ("hot spots") increases. This could lead to interference to other services in the same location.

Dynamic Antennas – Background for Recommendation

- The commercial use of advanced antenna technology has matured since 2014 when the Commission issued an NOI about spectrum bands above 24 GHz (GN Docket 14-177).
- The use of narrow, dynamic antenna patterns at higher frequency bands such as mmWave may enable better sharing through enhanced interference management, including between different services such as Fixed Service, Mobile Service and Satellite Service, and between federal and non-federal systems.

Recommendation – Dynamic Antennas

- We recommend that the FCC:
  - issue an updated NOI that seeks input on modifying service rules and equipment certification.
  - determine if maximum power flux density limits below antennas are necessary to prevent interference to other services
  - commission an engineering study that examines the consequences and regulatory options for this technology

Recommendation – Dynamic Antennas (cont)

- Possible Questions for NOI
  - Should transmitter rules for dynamic antennas take into account the resulting signal strength patterns of dynamic antennas due to directionality, dwell time, etc.?
  - At what frequencies, for which services, and/or in which bands would dynamic antenna rules be most useful?
  - Should such rules apply at geographic boundaries as well as frequency boundaries?
  - How should resulting dynamic antenna rules be formulated and enforced?
  - How should technology neutrality be traded off against the characteristics of the service to be protected?
  - Should dynamic antenna rules apply to out-of-band emissions?

Recommendation – Smart Antenna Systems

- Smart antenna systems may additionally make use of signal patterns from multiple locations as well as other environmental factors that affect the pattern, such as multipath reflections, to calculate delivery of a signal to a specific user.
  - **We recommend that the FCC institute policies that incentivize the use of new spectrally efficient technologies where appropriate.**

Recommendation – Co-Channel Operation with Passive Systems

- Current FCC regulations prohibit all operation on some frequencies because of expected interference to passive systems (see e.g. Allocation Table Footnote US246). Current ITU-R recommendations give upper bounds for interference power at such receivers. This would provide a clear path to regulatory approval for novel system designs that can effectively protect passive systems. The multi-beam / narrow-beam technologies would permit co-channel operation.
  - **We recommend that the prohibition of co-channel operation on protected frequencies be replaced with a requirement that places a hard limit on all emissions that reach a protected passive terrestrial or satellite system.**

Recommendation – Industry Standards to Improve Small Cell Appearance

- The roll out of 5G is likely to be slowed appreciably by public resistance to installation of small cells in their communities and neighborhoods. Small cell installations can be designed to better blend in with the surroundings, potentially lessening resistance to their presence. We recommend that the FCC use its influence with the cellular industry to strongly recommend the development and maintenance of guidelines / industry standards to improve the appearance of small cell installations.
- **We recommend that the FCC:**
  - **issue a Public Notice to gather input from providers, citizens and communities.**
  - **facilitate a multi-stakeholder group to create such guidelines.**

THANK YOU

Communication Strategies for Unmanned Aircraft Systems (UAS)

Chair: John Chapin, Roberson & Associates

FCC Liaisons: Robert Pavlak, Office of Engineering and Technology
Brian Butler, Office of Engineering and Technology
Tim Maguire, Wireless Telecommunications Bureau
Anita Patankar-Stoll, Public Safety & Homeland Security Bureau

Date: March 12, 2019

Working Group Members

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- Brian Daly, AT&T
- Stephen Hayes, Ericsson

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- Pierre De Vries, Silicon Flatirons
- Steve Lanning, Viasat
- Michael Tseytlin, Facebook

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- Mark Bayliss, Visualink
- Rehan Ehsan, CTA
- Jeffrey Foerster, Intel
- Dave Gurney, Motorola Solutions
- Brian Markwalter, CTA
- Paul Misener, Amazon
- Young-Han Nam, Samsung
- Jack Nasielski, Qualcomm
- Mark Richer, ATSC
- Dennis Roberson, Roberson & Assoc.
- David Young, Verizon

Other Contributions

Briefings

- Mark Chen, DJI
- Eddy Hall, Qualcomm
- Marcus Johnson, NASA
- Jennifer Richter, Akin Gump
- Joel Roberson, Holland & Knight
- Steve Van Trees, FAA
- Feng Xue, Intel
- Chuck Malek, Roberson and Assoc.
- Frank Ganaden, Viasat
- Geoff Stern, Ligado

Subject Matter Experts

- Sean Cassidy, Amazon Prime Air
- Jackie McCarthy, CTIA
- Bruce Mueller, Motorola Solutions
- Jennifer Richter, Akin Gump
- Raj Sengupta, CTIA

Simulation Studies

- Intel
- Roberson and Associates

Terminology Used in this Briefing

- UAV – Unmanned Aerial Vehicle
- UAS – Unmanned Aircraft System
  - An unmanned aircraft and associated elements (including communication links and the components that control the unmanned aircraft) that are required for the pilot in command to operate safely and efficiently.
- C2 – Command and Control
- CNPC – Command and Non Payload Communications.
  - Includes C2, detect and avoid, air traffic management, etc.

Stakeholder Priority Topics

- Study the spectrum issues for UAS
  - Including C2, payload, identification, monitoring, collision avoidance
- Address the following specific questions:
  - What frequency bands are available today, and are they sufficient?
    - Consider payload needs as part of this
  - Which UAS activities can be carried out using existing systems or services (CMRS, Land-mobile, Satellite, Aviation, GNSS, etc.)?
  - What are the trade-offs for the various alternative frequency bands?
  - To what extent has loss of communications been a major contributor to loss of UAV?
  - What are the issues of harmful interference to systems on the ground?
  - What new requirements and roles for radar arise from UAS?

Stakeholder Priority Topics (continued)

- Specific questions (continued):
  - What is an appropriate FCC requirement for station ID in UAS transmissions?
  - What is an appropriate FCC requirement for radio certification?
  - What testing facilities are available to evaluate these concepts?
- Make recommendations including:
  - What taxonomy should the FCC use in its regulatory approach?
  - What should the FCC study or do to meet the various spectrum needs for UAS?
    - Considering the need to make efficient use of the spectrum

2018 UAS-WG Focus

- The working group had limited time to study the broad set of systems and bands relevant for UAS operation.
- The group focused its 2018 recommendations on terrestrial mobile bands and systems.
- Recommendations related to other systems (satellite, unlicensed) and bands are deferred to 2019 work items.

March 2019 addendum

- FAA 2018 reauthorization act Section 374(a)(3) directs FAA, NTIA, FCC, to submit by July 2, 2019:
  - Recommendations of other spectrum frequencies that may be appropriate for BVLOS operations
  - Other than World Radio Conference recommended 960-1164 MHz and 5030-5091 MHz bands
- This WG report provides information relevant to this topic.
  - Analysis and conclusion that 3GPP technologies satisfy communications requirements for low-altitude UAVs (Slides 29-32, 38-52)
  - Analysis of the availability of various bands, and regulatory conditions, for UAV use (attached spreadsheet, Slides 53-57)

UAS-WG 2018 Recommendation 1

1. The FCC should consider UAV access to terrestrial mobile bands, along with corresponding service rules and associated technical parameters, taking into account FAA regulations governing their use by UAVs.

In doing this the FCC should:

a) Consider issues of potential in-band and out-of-band interference to terrestrial or aeronautical incumbent services, enforcement challenges, and what harm claim thresholds to apply.

b) Collect data from studies done by industry, FAA sponsored projects, other government agencies, academia and foreign entities.

c) Reassess any service rules that prevent integration of UAV communications functions, for example command/control and payload functions, into shared data links.

High-Level Analysis: MHz of spectrum required per UAV using IMT-2020 technology

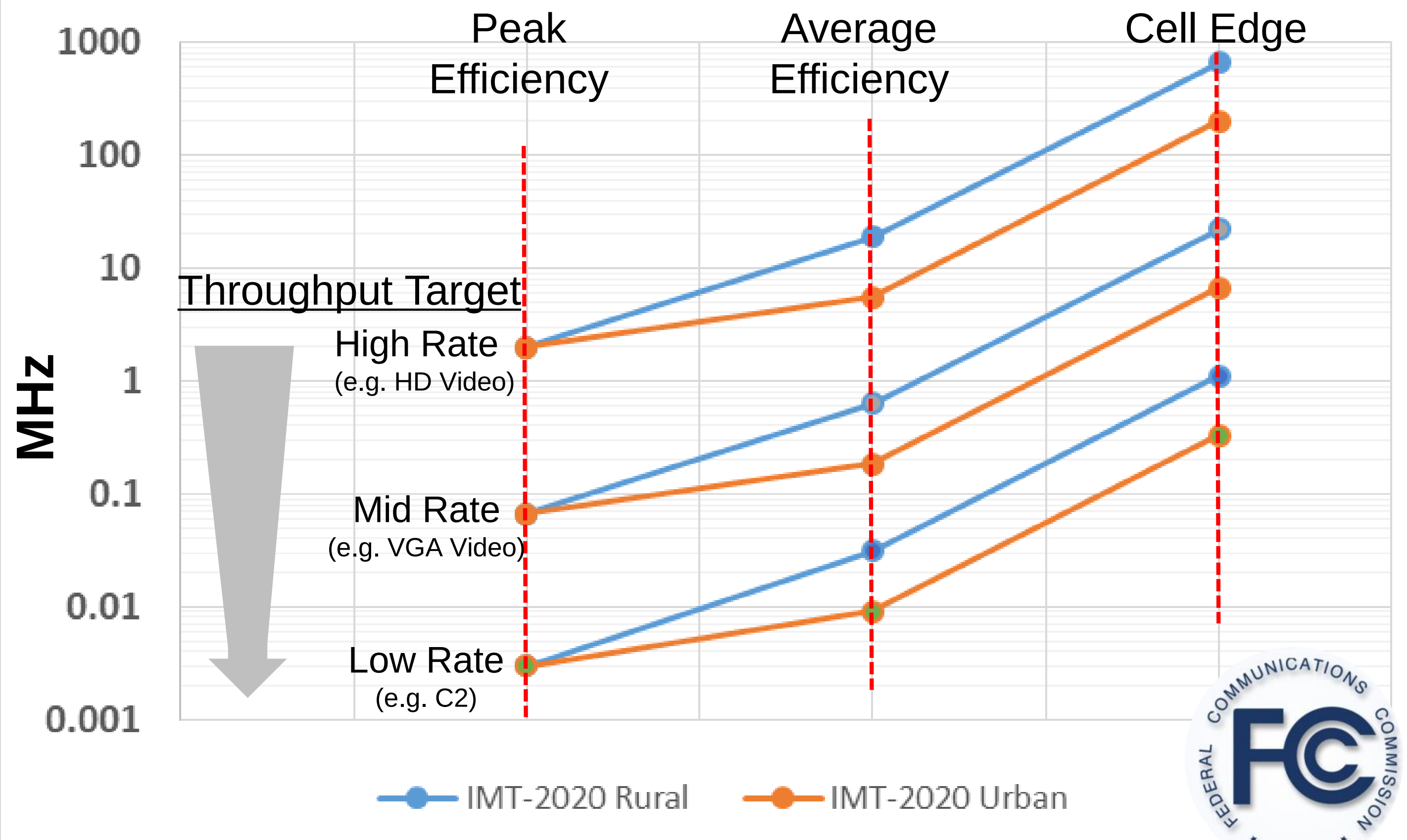
- based on minimum IMT-2020 performance requirements

Spectral Efficiency	
IMT-2020	**bits/s/Hz**
urban cell edge	0.15
rural cell edge	0.045
urban average	5.4
rural average	1.6
peak	15

Source: M.2410

Assumptions	
Throughput	**Mbit/s**
low rate	0.05
mid rate	1
high rate	30

Source: CTIA (consistent with M.2171)



High-Level Analysis: Terrestrial Mobile Bands, Spectrum Availability and Regulatory Conditions

- Analysis covered
  - Licensed, unlicensed, and pending bands
  - Regulatory conditions, particularly regarding aeronautical operation

Band	47 CFR Part	Total (MHz)	Lower (MHz)	Upper (MHz)	Lower (MHz)	Upper (MHz)	UL (MHz)	DL (MHz)	Unpaired (MHz)	Geography of Operation	Incumbent Services	Regulations	Aeronautical operation	Observations
Licensed Spectrum														
600	§27	70	663	698	617	652	35	35	-	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned	unspecified	Broadcasting, RAS, TVWS in adjacent bands
700 Upper	§27	22	776	787	746	757	11	11	-	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	Public Safety
700 Lower	§27	48	698	716	728	746	18	18	12	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	
Cellular / ESMR	§22	64	817	849	862	894	32	32	-	wide-area, nation-wide roaming	FS, MS (land mobile)	allocation, rules, assigned, operational	restricted	Allocated to LAND MOBILE, AERONAUTICAL MOBILE in 849-851
MSS/ATC	§25/87	15.6	1610	1617.8	1618.7	1626.5	7.8	7.8	-	?	MSS, RDSS, ARNS, RAS	allocation, rules, assigned(?)	unspecified	
MSS/ATC	§25/80/87	68	1626.5	1660.5	1525	1559	34	34	-	?	MSS	allocation, rules, assigned(?)	unspecified	
							n/a	n/a	5	nation-wide	FS, MS	allocation, rules, assigned	restricted	
											Federal Met-	allocation,		

- Observation: significant variance among bands
  - Amount of available spectrum
  - Duplexing
  - Regulatory conditions

Microsoft Excel Worksheet

See attached spreadsheet for analysis results. PDF printout is also provided in backup slides.

Basis for Recommendation

- Given
  - potentially high UAV spectrum requirements
  - wide variation in available bandwidth
  - significant differences in regulatory conditions

  Identification of a single band or a small subset of terrestrial mobile bands for UAS use is not prudent.

- Conclusion: The FCC should consider UAS access to the **collection** of terrestrial mobile bands.

UAS-WG 2018 Recommendation 1

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In doing this the FCC should:

a) **Consider issues of potential in-band and out-of-band interference to terrestrial or aeronautical incumbent services, enforcement challenges, and what harm claim thresholds to apply.**
b) Collect data from studies done by industry, FAA sponsored projects, other government agencies, academia and foreign entities.
c) Reassess any service rules that prevent integration of UAV communications functions, for example command/control and payload functions, into shared data links.

UAVs Change the Status Quo

- The advent of affordable UAV technology significantly increases the expected number and density of flights

Units	2017	2018	2019	2020	2021	2022
Model (M)	1.1	1.6	2.0	2.2	2.3	2.4
Commercial (K)	111	159	229	312	407	452
Large						

Source: FAA

- In bands licensed for terrestrial use, elevating a large number of devices to UAV altitudes changes the assumptions that underlie previous regulatory decisions
- This creates the potential for increased interference

Technical Issues For Analysis

1. Potential interference – in-band
   - Even "low" UAS exceed the antenna height assumed in many band studies
     - Tall buildings are geographically rare; most deployments can ignore them
   - There are 400 foot buildings and 100 mph vehicles, but under FAA Part 107 there may be many UAS that do both at the same time

2. Potential interference – out-of-band
   - Noise-limited services may exist in the adjacent band
   - Studies of Out Of Band Emissions and Out Of Band Receiver Sensitivity may have assumed transmitters are in ground clutter

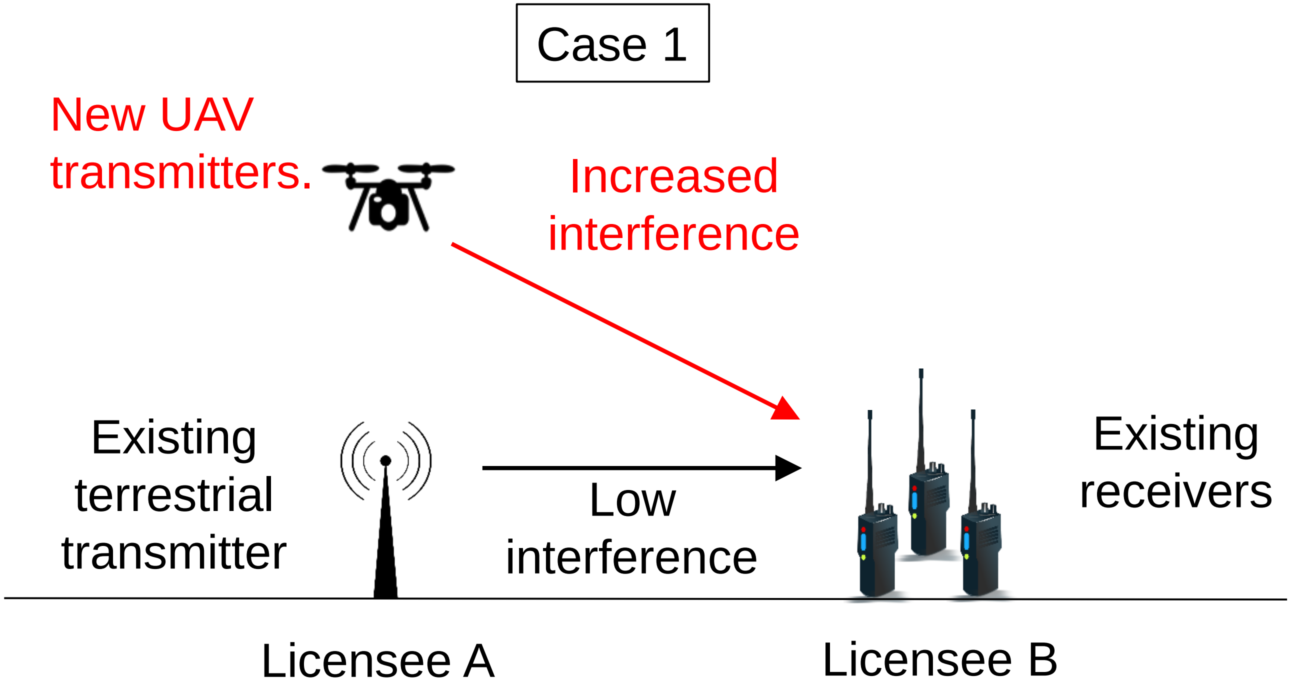
Technical Issues For Analysis

3. Enforcement challenges
   - Interference will often be intermittent and vary due to UAS motion

4. Additional technical questions
   - What conditions must be true about a band in order for transmission from UAVs to be authorized without a detailed study?
   - Will existing transmitters be compatible with airborne UAS operations? If not, what additional conditions, features or capabilities are needed?

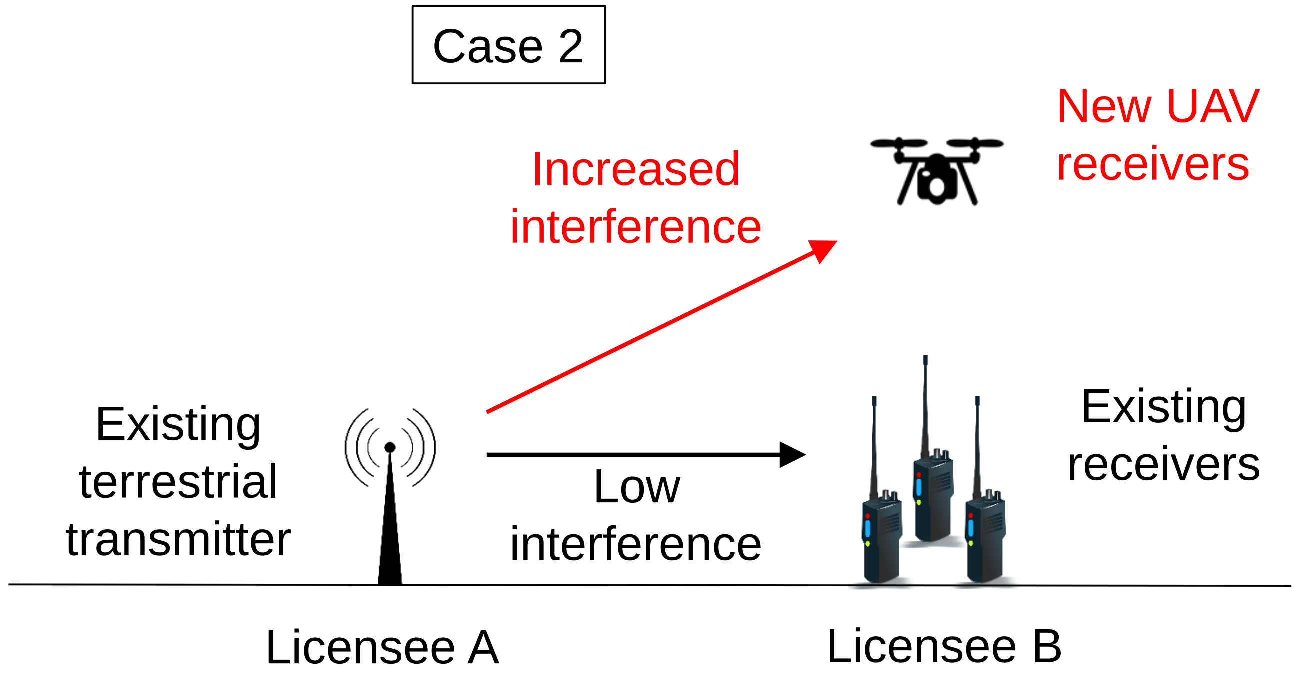
Harm Claim Thresholds Require Study (1)

- Licensee A and B have terrestrial licenses.
- Under what conditions may B seek FCC protection?



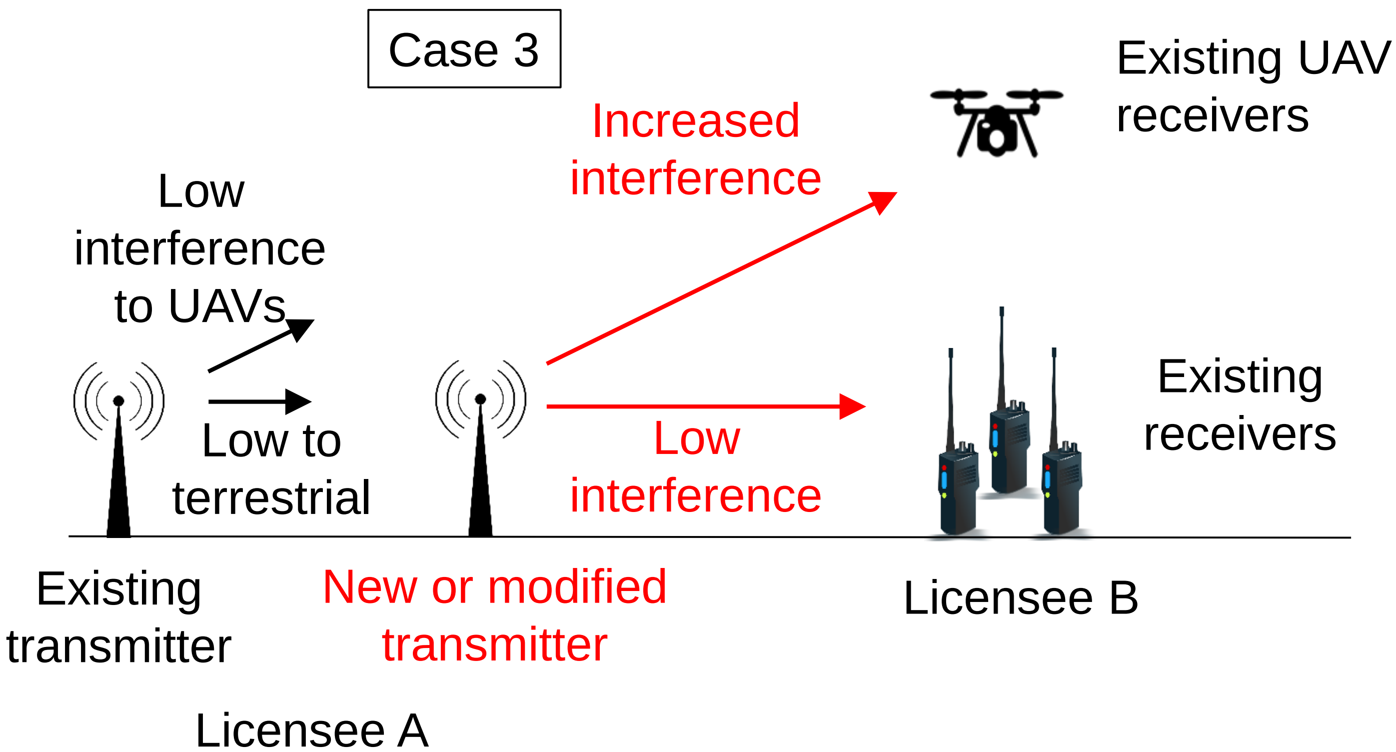
Harm Claim Thresholds Require Study (2)

- Under what conditions may B seek FCC protection?



Harm Claim Thresholds Require Study (3)

- Under what conditions may B seek FCC protection?



UAS-WG 2018 Recommendation 1

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b) Collect data from studies done by industry, FAA sponsored projects, other government agencies, academia and foreign entities.

c) Reassess any service rules that prevent integration of UAV communications functions, for example command/control and payload functions, into shared data links.

Relevant data is available from UAS market stakeholders

- Industry
  - Participants in FAA Integration Pilot Program
  - Private testing – component and system vendors, network operators
- Government agencies
  - NASA – UAS Traffic Management Pilot Program, other studies
- Academia
- Foreign entities
  - Governments testing 3GPP technologies – Dubai, Italy
  - Governments monitoring UAS market development – European Commission Administrative Cooperation Group under EU Radio Equipment Directive

Observations on data collection

- Available data is not well organized to support spectrum regulatory needs
- It is difficult to assess quality and applicability of the data
  - Little of the published literature has been peer-reviewed
- FCC and UAS industry may benefit from:
  - Formal collection of data – e.g. via an NOI
  - Organizing the data for easy access by FCC staff and other stakeholders
  - Annotating experiments and data sets with expert commentary
- This is a potential TAC or FCC work item for 2019
  - Some data available to the FCC may not be available to the TAC

UAS-WG 2018 Recommendation 1

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Radio Interface Sharing Among UAV Functions Is Desirable

- Various UAV radio functions could be interpreted as belonging to different Radio Services, thus requiring operation in separate bands
  - For example, globally-harmonized CNPC bands may be viewed as the only place for C2
- The technology exists for a single radio interface to support communications functions with different requirements
  - Example – share a radio channel between:
    - C2 – requires low latency and high reliability
    - payload video stream – requires low cost per bit
  - Multiple techniques exist:
    - On top of a common physical and MAC layer – "resource management"
    - With potentially different physical/MAC layer parameters – "slicing"
- Radio interface sharing is expected to improve spectrum efficiency while reducing system cost, weight and power
- FCC should not preclude radio interface sharing

UAS-WG 2018 Recommendation 2

2. With respect to 3GPP technologies specifically, the TAC has found that 3GPP technology satisfies the expected communications requirements for low altitude UAVs. Based on this, the FCC should:

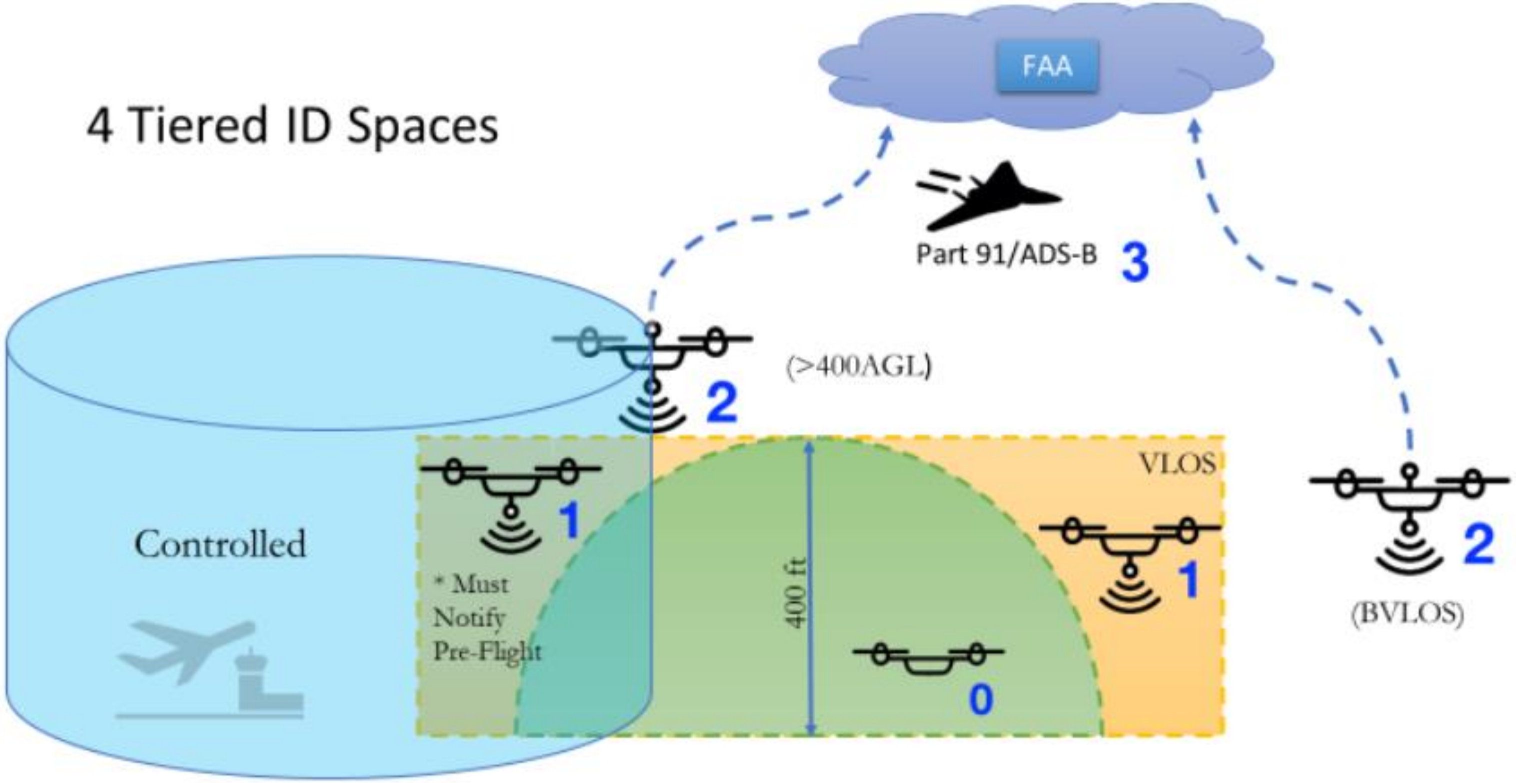
a) Consult with involved federal agencies including the FAA as necessary regarding the use of technology for UAVs in the terrestrial mobile bands.

b) Re-assess the technical basis for prohibiting use of certain terrestrial mobile frequency bands above ground level.

SYSTEMS EVALUATIONS PROCESS

- UAV communications requirements have not been finalized.
- The TAC-WG analyzed expectations from sources such as:
  - FAA Aviation Rulemaking Committee (ARC)
  - RTCA Drone Advisory Committee, Technical Group 2
- Communications functions considered:
  - Command and Control, with normal and backup systems treated separately; Payload; Separation Assurance; Network Tracking
- Communications system attributes considered:
  - Availability/Reliability; Capacity; Coverage; Security; Integration; Latency; Deployment issues; Cost
- More details are provided in the backup material

Tiers defined by FAA Aviation Rulemaking Committee*



*https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS%20ID%20ARC%20Final%20Report%20with%20Appendices.pdf

Evaluation Results

Communication type	Tiers in which required	Tiers where 3GPP satisfies*	WiFi	Other unlicensed	Satellite	ADS-B	DSRC
Normal C2	0,1,2,3	0,1,2**	NOT YET EVALUATED				
Backup C2	Depends on automation level	0,1,2**					
Payload	Depends on application	0,1,2**					
Separation Assurance	Likely depends on application	0,1,2**					
Broadcast ID	Not required for Tier 0	1,2**					
Networked Tracking	Not required for Tier 0	0,1,2**					

* As with all candidate systems, some development may be required to provide new capabilities, such as broadcast ID and UTM connectivity
**Terrestrial 3GPP technologies have not been evaluated at >300m height

UAS-WG 2018 Recommendation 2

2. With respect to 3GPP technologies specifically, the TAC has found that 3GPP technology satisfies the expected communications requirements for low altitude UAVs. **Based on this, the FCC should:**

a) **Consult with involved federal agencies including the FAA as necessary regarding the use of terrestrial mobile bands for UAV communications.**

b) Re-assess the technical basis for prohibiting use of certain terrestrial mobile bands above ground level.

Recommended consultation with other Federal agencies

- Rationale for the recommendation
  - While the FCC does not endorse technologies, other agencies such as the FAA may select communications technologies and require system capabilities as part of UAS regulations.
  - These selections may affect FCC goals.

- As part of this consultation, it is recommended that the FCC work with other federal agencies to:
  - minimize impediments to the utilization of suitable communications technologies
  - maximize benefit from already-allocated spectrum and already-deployed infrastructure
  - maximize global harmonization of regulations for UAS communications

UAS-WG 2018 Recommendation 2

2. With respect to 3GPP technologies specifically, the TAC has found that 3GPP technology satisfies the expected communications requirements for low altitude UAVs. Based on this, the FCC should:

a) Consult with involved federal agencies including the FAA as necessary regarding the use of terrestrial mobile bands for UAV communications.

b) Re-assess the technical basis for prohibiting use of certain terrestrial mobile bands above ground level.

Current Aeronautical Operation Restrictions for Selected Bands

Band	Lower (MHz)	Upper (MHz)	Lower (MHz)	Upper (MHz)	Incumbent Services	Regulations	Aeronautical operation
Licensed Spectrum							
Cellular / ESMR	817	849	862	894	FS, MS (land mobile)	allocation, rules, assigned, operational	restricted
AWS	1670	1675	n/a	n/a	FS, MS	allocation, rules, assigned	restricted
AWS	1695	1710	1995	2020	Federal Met-Sat in lower. FS, MSS in upper.	allocation, rules, assigned, operational	restricted
WCS	2305	2320	2345	2360	FS, MS, BSS, RLS	allocation, rules, assigned, operational	Partially restricted
MSS/ATC	2484	2495	n/a	n/a	RDSS, FS	allocation, rules, assigned(?)	restricted
BRS	2496	2690	n/a	n/a	FS	allocation, rules, assigned, operational	restricted
CBRS	3550	3700	n/a	n/a	FS, MS, FSS	allocation, rules	restricted
Frontiers	37000	40000	n/a	n/a	FS, FSS, MS	allocation, rules, partially assigned	Partially restricted (37-38 GHz)
Unlicensed Spectrum							
U-NII-3	5470	5850	n/a	n/a	RLS, MRNS, Met	allocation, rules, operational	unspecified (US), restricted (ITU)
WiGig	57000	71000	n/a	n/a	FS, FSS, MS, SRS, ISS, EESS, RLS, RNSS	allocation, rules, operational	unspecified (restricted in 64-66 GHz)
Under consideration							
UNII-5 to 8	5925	7125	n/a	n/a	FS, FSS, MS	TBD	restricted

SUMMARY

UAS-WG 2018 Recommendation 1

1. The FCC should consider UAV access to terrestrial mobile bands, along with corresponding service rules and associated technical parameters, taking into account FAA regulations governing their use by UAVs.

In doing this the FCC should:

a) Consider issues of potential in-band and out-of-band interference to terrestrial or aeronautical incumbent services, enforcement challenges, and what harm claim thresholds to apply.

b) Collect data from studies done by industry, FAA sponsored projects, other government agencies, academia and foreign entities.

c) Reassess any service rules that prevent integration of UAV communications functions, for example command/control and payload functions, into shared data links.

UAS-WG 2018 Recommendation 2

2. With respect to 3GPP technologies specifically, the TAC has found that 3GPP technology satisfies the expected communications requirements for low altitude UAVs. Based on this, the FCC should:

a) Consult with involved federal agencies including the FAA as necessary regarding the use of terrestrial mobile bands for UAV communications.

b) Re-assess the technical basis for prohibiting use of certain terrestrial mobile bands above ground level.

Potential TAC UAS-WG work topics for 2019

1. Study additional items from the 2018 stakeholder priority list (slides 5-6)
2. Recommend methodology for assessing potential interference (slide 15)
3. Assess enforcement challenges and additional technical issues (slide 16)
4. Conduct NOI for relevant data and analyze results (slide 22)
5. Evaluate systems and standards other than 3GPP technologies (slide 28)
6. Evaluate alternatives to current aeronautical restrictions (slide 32)

Communication Strategies for Unmanned Aircraft Systems (UAS)

Thank you to the FCC and to our home organizations for the opportunity to contribute to this important challenge.

Backup: Evaluation of 3GPP Technologies for UAS Communications

3GPP Technology - Normal C2

- How well does 3GPP Technologies meet the requirements for the normally used C&C function?
- 3GPP TS 36.777 has evaluated the capabilities of LTE to support C&C functions in a variety of scenarios using both simulations and field tests
  - Data Rate: 60-100 kbps
  - Latency < 50uS
  - UAV Heights: 50m, 100m, 200m, 300m
  - Speeds: 3km/h, 30km/h, 160km/h
  - UAV population varying from 0% to 50% of total UEs (devices)
  - Rural Macro (700Mhz), Urban Macro (2Ghz), Urban Micro (2Ghz) environments
  - Network heavily loaded and lightly loaded
  - Many other parameters and assumptions as documented in 36.777
- The study concluded that LTE could satisfy the UAV C&C requirements, but were more expensive in terms of resource utilization than terrestrial UEs
- The study assumed that the UAVs moved horizontally in an unplanned manner. If preknowledge of flight plans exist, then it may be possible to more efficiently manage wireless and network resource allocation.
- 3GPP Tehcnology provides multiple strategies to maintain connectivity including using alternative frequencies, fallback mechanisms, and coordinated multipoint.
- Various mitigation strategies to reduce the resource requirements for supporting UAVs were proposed and many already exist or were added to the standard
- 5G has not been evaluated, but is expected to be at least as capable

3GPP Technology – Characteristics Evaluation for Normal C&C

Characteristics	Evaluation	Description
Availability/Reliability	✓✓	Highly dependent on service provider deployment. Can be overloaded in times of disaster
Capacity	✓✓✓	Different tiers of capacity (guaranteed and non guaranteed can be provided)
Coverage	✓✓	Coverage normally good, but may be challenging in extreme rural areas
Security	✓✓✓	Extremely good in all aspects
Integration	✓✓✓	Chipsets and antennas can be used to provide other UAV communications function
Latency	✓✓✓	Different tiers of latency can be provided. 50ms should not be a problem.
Deployment issues	✓✓✓	Network already established. Additional improvements could be rolled out.
Cost	✓✓✓	Since using commercial chipsets, should be low

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3GPP Technology - Backup C2

- How well does 3GPP Technology meet the requirements for the backup C&C function?
- The physical characteristics are the same as for Normal C2, but additional issues need to be considered with regards to using network cellular as a backup C2
  - If reusing the same chipset but accessing different cellular networks, then this is introducing a single point of failure.
  - Since operators often co-site, any disaster knocking out one operators network, may also disable other networks.
  - Given that coverage patterns are often commercially determined, multiple operators may have similar coverage holes.
  - Different operators may have different frequencies so the backup C&C may be able to overcome jamming or interference that affects the normal C&C.
  - Mechanisms exist that allow for critical functions to get priority, but it is unclear if backup C&C would merit priority.
  - The FirstNet network could be used as a backup C&C for critical UAS communications and this is already included in the requirements for mission critical communications

3GPP Technology – Characteristics Evaluation for Backup C&C

Characteristics	Evaluation	Description
Availability/Reliability	✓✓	Depending on siting issues, cellular networks may not be fully independent (e.g., a hurricane may disable both the normal and safety network)
Capacity	✓✓✓	Different tiers of capacity (guaranteed and non guaranteed can be provided)
Coverage	✓	Coverage likely to be inadequate in the same operating locations as normal C&C.
Security	✓✓✓	Extremely good in all aspects
Integration	✓✓	Integration provides a single point of failure since both normal C&C and backup C&C use same HW on the UAV
Latency	✓✓✓	Different tiers of latency can be provided. 50ms should not be a problem.
Deployment issues	✓✓✓	Network already established. Additional improvements could be rolled out.
Cost	✓✓✓	Since using commercial chipsets, should be low

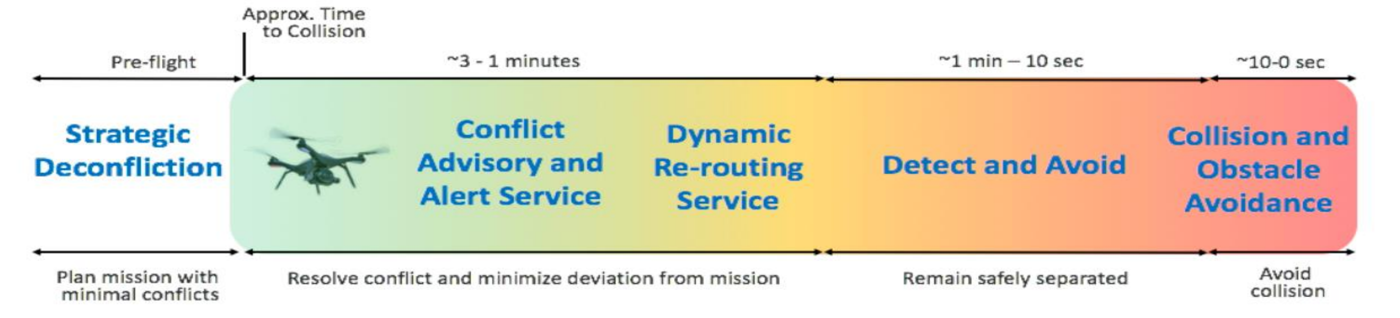
3GPP Technology - Payload

- How well does 3GPP Technology meet the requirements for payload?
- 3GPP TS 36.777 has evaluated the capabilities of LTE to support payload functions in a variety of scenarios using both simulations and field tests
  - Data Rate: 50Mbps (from the UAV). This is sufficient for 4K video.
  - Latency < 50uS
  - UAV Heights: 50m, 100m, 200m, 300m
  - Speeds: 3km/h, 30km/h, 160km/h
  - UAV population varying from 0% to 50% of total UEs (devices)
  - Rural Macro (700Mhz), Urban Macro (2Ghz), Urban Micro (2Ghz) environments
  - Network heavily loaded and lightly loaded
  - Many other parameters and assumptions as documented in 36.777
- The study concluded that LTE could satisfy the UAV payload requirements, but were more expensive in terms of resource utilization than terrestrial UEs
- Various mitigation strategies to reduce the resource requirements for supporting UAVs were proposed and many already exist or were added to the standard
- 5G has not been evaluated, but is expected to be at least as capable

3GPP Technology – Characteristics Evaluation for Payload

Characteristics	Evaluation	Description
Availability/Reliability	✓✓	Highly dependent on service provider deployment. Can be overloaded in times of disaster
Capacity	✓✓✓	Different tiers of capacity (guaranteed and non guaranteed can be provided)
Coverage	✓✓	Coverage normally good, but may be challenging in extreme rural areas
Security	✓✓✓	Extremely good in all aspects
Integration	✓✓✓	Chipsets and antennas can be used to provide other UAV communications function
Latency	✓✓✓	Different tiers of latency can be provided. 50ms should not be a problem.
Deployment issues	✓✓✓	Network already established. Additional improvements could be rolled out.
Cost	✓✓✓	Since using commercial chipsets, should be low

3GPP Technology – Separation Assurance



- How well does 3GPP Technology meet the requirements to prevent collisions?
  - This includes preventative strategies with longer time lines that require network communications
  - This includes last minute collision avoidance with short timeframes that may bypass network communications
- 3GPP technology provides a tool kit to address different tiers of separation assurance:
  - V2I and regular network communications for operations with longer timeframes
  - V2V for close quarters avoidance with other UAVs using 3GPP technology
  - Does not provide for obstacle avoidance of non-cooperative objects (buildings, birds, non V2V transmitting objects)
- No studies were found quantifying the applicability of V2X to UAS. V2X (or similar capabilities) currently supports collision avoidance messaging with:
  - Closing speed of 500km/h
  - Message payloads up to 1200 bytes
  - Max V2V latency of 100ms
- It is unclear what frequency band V2X would be deployed in for UAS. However options include:
  - Licensed cellular frequencies (UL frequencies). Unlicensed frequencies, 5.9GHz
- Both LTE and 5G versions of sidelink exist, although the V2X functionality has only been fully developed for LTE

3GPP Technology – Characteristics Evaluation for Separation Assurance

Characteristics	Evaluation	Description
Availability/Reliability	✓✓✓	Works both in and out of network coverage. In network coverage, then the network assists in minimizing interference
Capacity	✓✓✓	Capacity should be adequate
Coverage	✓✓✓	Does not depend on network coverage
Security	✓✓✓	Extremely good in all aspects
Integration	✓✓✓	Integrated into network chipsets
Latency	✓✓✓	Should be adequate for UAVs moving < 250km/h
Deployment issues	✓✓	V2X fully standardized, but not yet deployed in phones. Any V2X tweaks for UAS support not yet standardized.
Cost	✓✓✓	Since using commercial chipsets, should be low

3GPP Technology – Broadcast ID

- How well does 3GPP Technology meet the requirements Broadcast ID?
- The mechanism which 3GPP technologies would use for D&A is the sidelink capability developed for V2X (Vehicle to Anything).
- The specific broadcast requirements have not yet been established. No studies were found quantifying the applicability of V2X to UAS. However the 3GPP technology can support broadcast with the following capabilities:
  - Broadcast rate of up to 10Hz
  - Message payloads up to 300 bytes
- It is unclear what frequency band V2X would be deployed in for UAS. However options include:
  - Licensed cellular frequencies (UL frequencies), unlicensed frequencies, 5.9GHz
- Both LTE and 5G versions of sidelink exist, although the V2X functionality has only been fully developed for LTE
- A key advantage is that if sidelink enabled phones become common, no special hardware will be required to read the broadcast ID from a drone.
  - Sidelink capability is being incorporated into chipsets but the level of support in user devices is not clear

3GPP Technologies – Characteristics Evaluation for Broadcast ID

Characteristics	Evaluation	Description
Availability/Reliability	✓✓✓	Works both in and out of network coverage. In network coverage, then the network assists in minimizing interference
Capacity	✓✓✓	Capacity should be adequate
Coverage	✓✓✓	Does not depend on network coverage
Security	✓✓✓	Extremely good in all aspects.
Integration	✓✓✓	Integrated into network chipsets
Latency	✓✓✓	NA
Deployment issues	✓✓	V2X fully standardized, but not yet deployed in phones. Any V2X tweaks for UAS support not yet standardized.
Cost	✓✓✓	Any phone (using appropriate app and credentials) should be able to read ID

3GPP Technologies – Networked Tracking

- How well does 3GPP Technology meet the requirements for Networked Tracking?
- The requirements for Network Tracking communications is similar to what is required for UAS-UTM communications (in fact, they may be the same).
- The latency (<50ms) and throughput (60-100kpbs) should satisfy the tracking requirements.
- The cellular network can provide independent verification of the location information provided by the UAS.
- 3GPP Technologies support a variety of positioning methods that can supplement onboard GPS and may work in areas (such as indoors) where GPS does not work.

3GPP Technologies – Characteristics Evaluation for Network Tracking

Characteristics	Evaluation	Description
Availability/Reliability	✓✓	Highly dependent on service provider deployment. Can be overloaded in times of disaster
Capacity	✓✓✓	Different tiers of capacity (guaranteed and non guaranteed can be provided)
Coverage	✓✓	Coverage normally good, but may be challenging in extreme rural areas
Security	✓✓✓	Extremely good in all aspects
Integration	✓✓✓	Chipsets and antennas can be used to provide other UAV communications function. Network integrates well with UTM.
Latency	✓✓✓	Different tiers of latency can be provided. 50ms should not be a problem.
Deployment issues	✓✓✓	Network already established. Additional improvements could be rolled out.
Cost	✓✓✓	Since using commercial chipsets, should be low

Conclusion of 3GPP Technologies Evaluation

- 3GPP Technologies meet all expected communications requirements for supporting low flying UAVs
  - Supports UAV Tiers 0,1,2. The max supported height for tier 2 has not been determined.
  - As with all technologies, additional development is required to support UTM or broadcast ID, but similar capabilities already exist within 3GPP technologies
- Advantages of 3GPP Technologies
  - Leverages already deployed network infrastructure
  - Employs mass produced communications hardware
  - Different communications classes are provided to meet different communications requirements for different communication aspects and mission types
  - Extensive security and privacy support
- This is an evaluation of whether the 3GPP Technology meets UAV requirements, but NOT an endorsement of a particular technology

3GPP Evaluation – sources for requirements

- FAA Aviation Rulemaking Committee
  - https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS%20ID%20ARC%20Final%20Report%20with%20Appendices.pdf
- RTCA Drone Advisory Committee
  - https://www.rtca.org/sites/default/files/dac_tg2_final_reccomendations_11-17_update.pdf

Backup: Analysis of Terrestrial Mobile Bands, Spectrum Availability and Regulatory Conditions

Band	47 CFR Part	Total (MHz)	Lower (MHz)	Upper (MHz)	Lower (MHz)	Upper (MHz)	UL (MHz)	DL (MHz)	Unpaired (MHz)	Geography of Operation	Incumbent Services	Regulations	Aeronautical operation	Observations
Licensed Spectrum														
600	§27	70	663	698	617	652	35	35	-	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned	unspecified	Broadcasting, RAS, TVWS in adjacent bands
700 Upper	§27	22	776	787	746	757	11	11	-	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	Public Safety
700 Lower	§27	48	698	716	728	746	18	18	12	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	
Cellular / ESMR	§22	64	817	849	862	894	32	32	-	wide-area, nation-wide roaming	FS, MS (land mobile)	allocation, rules, assigned, operational	restricted	Allocated to LAND MOBILE, AERONAUTICAL MOBILE in 849-851 MHz
MSS/ATC	§25/87	15.6	1610	1617.8	1618.7	1626.5	7.8	7.8	-	?	MSS, RDSS, ARNS, RAS	allocation, rules, assigned(?)	unspecified	
MSS/ATC	§25/80/87	68	1626.5	1660.5	1525	1559	34	34	-	?	MSS	allocation, rules, assigned(?)	unspecified	
AWS	§27	5	1670	1675	n/a	n/a	n/a	n/a	5	nation-wide	FS, MS	allocation, rules, assigned	restricted	
AWS	§27	40	1695	1710	1995	2020	15	25	-	wide-area, nation-wide roaming	Federal Met-Sat in lower. FS, MSS in upper.	allocation, rules, assigned, operational	restricted	

AWS	§22/27/101	160	1710	1780	2110	2200	70	90	-	wide-area, nation-wide roaming	FS, MS, SRS, MSS in 2180-2200 MHz	allocation, rules, assigned, operational	unspecified	
PCS	§15/24/27/101	130	1850	1915	1930	1995	65	65	-	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	
AWS	§27	5	1915	1920	n/a	n/a	n/a	n/a	5	wide-area, nation-wide roaming	FS, MS	allocation, rules, assigned, operational	unspecified	
WCS	§27	30	2305	2320	2345	2360	10	10	10	wide-area, nation-wide roaming	FS, MS, BSS, RLS	allocation, rules, assigned, operational	Partially restricted	SDARS
MSS/ATC	§25	11.5	2483.5	2495	n/a	n/a	n/a	n/a	11.5	?	RDSS, FS	allocation, rules, assigned(?)	restricted	
BRS	§27	194	2496	2690	n/a	n/a	n/a	n/a	194	wide-area, nation-wide roaming	FS	allocation, rules, assigned, operational	restricted	MSS, RDSS allocations only below 2500 MHz
CBRS	§25/96	150	3550	3700	n/a	n/a	n/a	n/a	150	local-area, wide-area, nation-wide roaming	FS, MS, FSS	allocation, rules	restricted	3-tier CBRS, Mix of PAL and GAA FSS only above 3600
Frontiers	§15/30	200	24250	24450	n/a	n/a	n/a	n/a	200	wide-area, nation-wide roaming	FS	allocation, rules	unspecified	
Frontiers	§15/25/30	500	24750	25250	n/a	n/a	n/a	n/a	500	wide-area, nation-wide roaming	FS, FSS	allocation, rules	unspecified	
Frontiers	TBD	2250	25250	27500	n/a	n/a	n/a	n/a	2250	TBD		TBD	TBD	3rd FNPRM

Frontiers	§15/25/30/101	850	27500	28350	n/a	n/a	n/a	n/a	850	wide-area, nation-wide roaming	FS, FSS, MS	allocation, rules, partially assigned	unspecified	former LMDS, auctions Nov. 2018
Frontiers	§25/30	3000	37000	40000	n/a	n/a	n/a	n/a	3000	wide-area, nation-wide roaming	FS, FSS, MS	allocation, rules, partially assigned	Partially restricted (37-38 GHz)	
Frontiers	§25/30	1000	47200	48200	n/a	n/a	n/a	n/a	1000	wide-area, nation-wide roaming	FS, FSS, MS	allocation, rules	unspecified	
Frontiers	TBD	500	42000	42500	n/a	n/a	n/a	n/a	500	TBD	FS, MS	TBD	TBD	3rd FNPRM
Sub-Total		9313.1												
Unlicensed Spectrum														
900 MHz	§18/97	26	902	928	n/a	n/a	n/a	n/a	26	n/a		allocation, rules, operational	unspecified	ISM
2.4 GHz	§15/18/97	83.5	2400	2483.5	n/a	n/a	n/a	n/a	83.5	n/a	FS, MS	allocation, rules, operational	unspecified	ISM, used by hobby UAVs
U-NII-1, 2	§15/18/97	200	5150	5350	n/a	n/a	n/a	n/a	200	n/a	FSS, ARNS	allocation, rules, operational	unspecified	
U-NII-3	§15/18/80/90/97	180	5470	5850	n/a	n/a	n/a	n/a	180	n/a	RLS, MRNS, Met	allocation, rules, operational	unspecified (US), restricted (ITU)	
U-NII-4	§90/25/97	75	5850	5925	n/a	n/a	n/a	n/a	75	n/a	FSS, MS	allocation, rules, operational	unspecified	incl. DSRC
WiGig	§15	14000	57000	71000	n/a	n/a	n/a	n/a	14000	n/a	FS, FSS, MS, SRS, ISS, EESS, RLS, RNSS	allocation, rules, operational	unspecified (restricted in 64-66 GHz)	WiGig
Sub-Total		14564.5												

Under consideration														
4 GHz		500	3700	4200	n/a	n/a	n/a	n/a	500	TBD	FS, FSS	TBD	unspecified	NPRM issued
UNII-5	§15/25/101	500	5925	6425	n/a	n/a	n/a	n/a	500	Local Area indoor/outdoor	FS, FSS	TBD	restricted	NPRM draft issued
UNII-6	§15/25/101 /74F/78	100	6425	6525	n/a	n/a	n/a	n/a	100	Local Area indoor	FSS, MS	TBD	restricted	NPRM draft issued
UNII-7	§15/25/101	350	6525	6875	n/a	n/a	n/a	n/a	350	Local Area indoor/outdoor	FS, FSS	TBD	restricted	NPRM draft issued
UNII-8	§15/25/101 /74F/78	250	6875	7125	n/a	n/a	n/a	n/a	250	Local Area indoor	FS, FSS, MS	TBD	restricted	NPRM draft issued
CNPC (dedicated)														
UAS	§87	61	5030	5091	n/a	n/a	n/a	n/a	61	n/a	AM(R)S, AMS(R)S, ARNS	allocation, rules?	Allowed	CNPC

FCC TAC CPSN-WG
Computational Power Stress on the Network

Chairs: Lisa Guess, Cradlepoint
Adam Drobot, OpenTechWorks, Inc.

FCC Liaisons: Walter Johnston, James Miller, Aalok Mehta

Date: December 5th, 2018

2018 Working Group Team Members

- Shahid Ahmed, Independent
- Nomi Bergman, Advance Newhouse
- Brian Daly, ATT
- John Dobbins, Windstream
- Adam Drobot, OpenTechWorks
- Dale Hatfield, Silicon Flatirons
- Lisa Guess, Cradlepoint
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- Steve Lanning, ViaSat
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Marvin Sirbu, SGE
- Kevin Sparks, Nokia Bell Labs
- David Tennenhouse, VMware

Computational Power Stress on the Network Mission

- Big Data Analytics, Artificial intelligence, Augmented Reality, and Virtual Reality have emerged recently as critical tools in many fields.
- This can involve the exchange of massive amounts of data across communications networks, often in real time, in ways perhaps not anticipated only a few short years ago.
- The task of this work group is to study how Big Data Analytics, Artificial Intelligence, Augmented Reality, Virtual Reality, and applications such as Block Chain, Bitcoin mining, Gaming, etc. may be affecting network performance

Computational Power Stress on the Network - Mission

Some parties estimate an increase in data traffic of several hundred percent in just the next few years leading to the natural questions:

- What strategies are network operators, both wireline and wireless, employing to monitor the growth of big data?
- How are the networks planning to accommodate this growth?
- How are operators meeting the needs of big data relative to factors such as available bandwidth, latency, reliability, security, resiliency, etc.?
- To what extent are big data analytics and distributed computational resources able to improve the performance of networks?

The working group is encouraged to explore these and other technical matters that may be relevant to informing the Commission about the impact of big data on IT and communications network infrastructure.

Agenda

- Introduction
- Evolution of the Network
  - ✓ Convergence of Network Access Technologies
  - ✓ Integration of Computing, Storage, and Sensing Assets
  - ✓ Emergence of the "Converged Integrated Information Network"
- Summary
- Observations
- Recommendations

- An Extensive Addendum
  - Aspects of Network Evolution and Underlying Technologies
  - List of Speakers and Presentations

Introduction

- Advances in computing hardware and software, storage of digital information, and widely used end devices and programmable electronics goods, are significantly impacting:

  - ✓ The pace of change in the architecture and operation of ”The Network”
  - ✓ Business models for operators, suppliers, and end-users. This includes the emergence and enablement of new value chains.
  - ✓ The network use patterns of consumers, commercial enterprises, and the public sector

Introduction

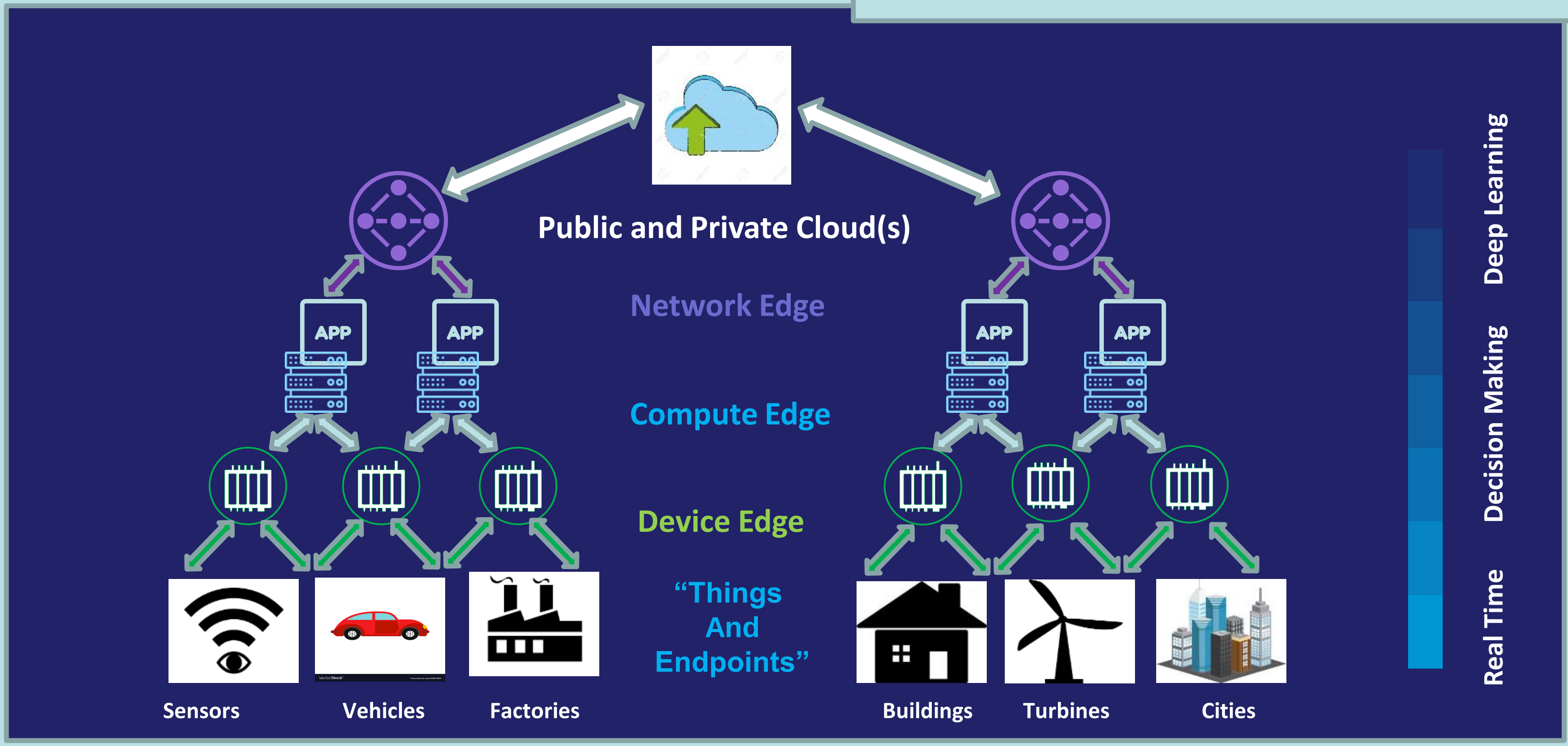
- The changes are important to national economic competitiveness, to quality of life for the population, to regional viability, and to the delivery of public sector services. “Digitization” technologies such as:

  ✓ Artificial Intelligence and Machine Learning
  ✓ Virtual and Augmented Reality
  ✓ Cloud, Fog, and Edge Computing
  ✓ The Data Sciences
  ……..

  Have the potential: To greatly improve efficiency in manufacturing, maintenance, avoidance of hazards, and operations in commercial enterprises; deliver desirable new experiences for consumers; and provide more effective public services in education, healthcare, and law enforcement.

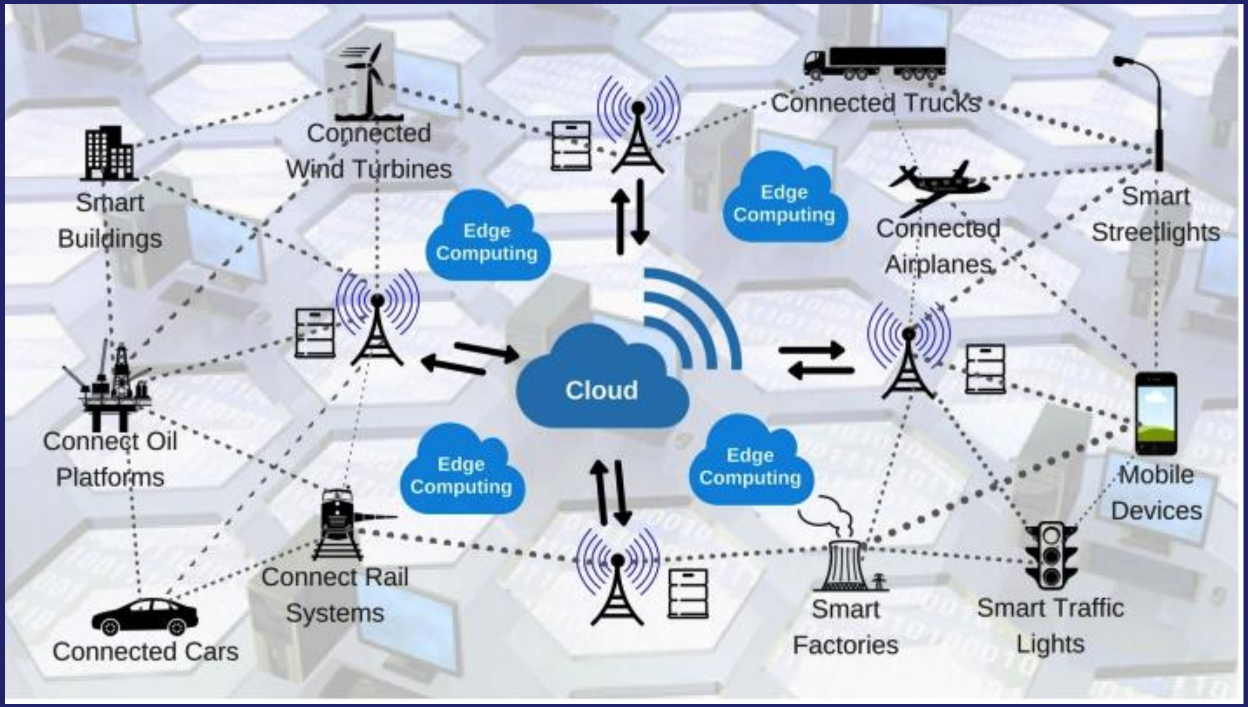
Evolution of the Network - 1

The Impact of Computing
On Network Architectures



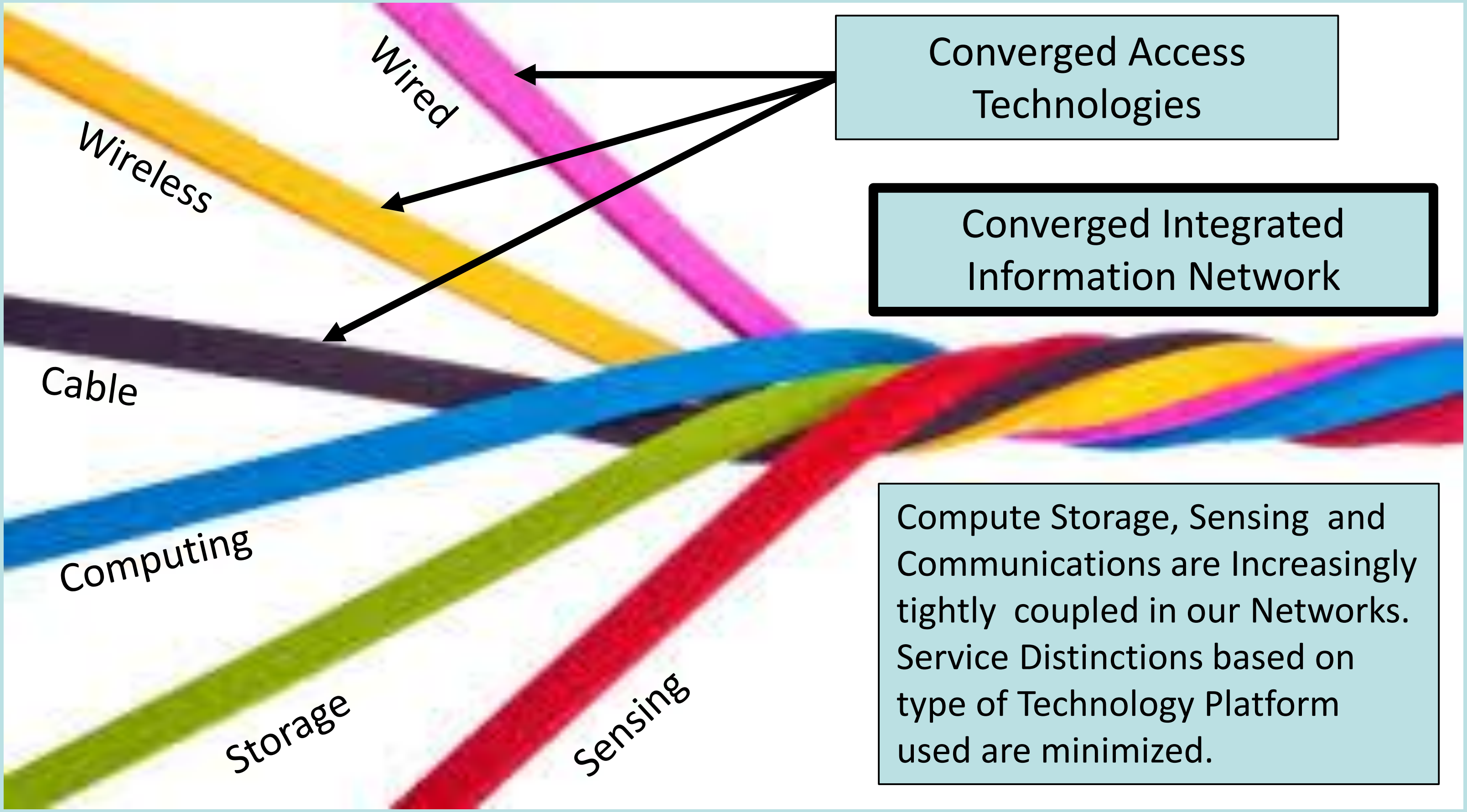
Evolution of the Network - 2

The Consequence of Mobility
On Network Architectures



- Multi-purpose General Network
- Converged Access
- New requirements
  - Jitter/Latency
  - Security/Privacy
  - Availability
  - Reliability
  - Ubiquity
- Influence of non-Communication Technologies

Evolution of the Network – 3 Two Levels of Convergence



Compute Storage, Sensing and Communications are Increasingly tightly coupled in our Networks. Service Distinctions based on type of Technology Platform used are minimized.

Evolution of the Network – Accelerating Pace of Change

A prior TAC WG Recommendation

Anticipating the Future - Recommendations

Getting ahead of the curve

Institutionalizing a process at the FCC for anticipating and keeping up with major shifts in technology, usage patterns, and business models:

- FCC should engage in an **annual facilitated study exercise** to gain essential insights on the impact of emerging technologies and innovations for disruptive change in the communications sector. FCC staff, representative of all key Bureaus and Offices, would interact in a **highly focused workshop environment** with experts representing industry, academia and other stakeholders on key forward challenges and opportunities facing the FCC.*
- The results of this exercise should be the foundation for the **development of plans and strategies** to address anticipated change, in support of a robust US digital innovation economy and the furtherance of societal goals.*

Summary

- During this term the FCC TAC CPSN WG will have heard from twelve external presenters and held over a dozen sessions discussing the trends of how various aspects of communications and computing technologies will affect ”The Network”
- The WG examined how computing technologies:
  - Affect Aggregate **Demand**, **Usage Patterns**, and the need for specific Network Resources
  - Influence **Network Architectures**, Operation, and Business Models
  - Can be exploited to better manage the Network itself
  - Where communications and computing may have the greatest impact on economic competitiveness
  - Where there are likely to be bottlenecks and significant issues to resolve
- The WG has recognized the emergence and importance of “Converged & Integrated Information Networks” (C&IIN) and their impact on consumers, industry, and public services. The WG has considered what actions the FCC might or should take in response.
- Our observations and recommendations follow

Observations

1. The compounded annual growth rate in traffic on "The Network" will continue to grow at double digit rates for the near term and foreseeable future. In all likelihood the progress in networking technologies and the ongoing investments in network capacity will keep pace with the growth in demand.

2. Emerging technologies such as AR/VR, higher resolution video, the greater use of Sensor Data from IoT Applications, and adoption of AI driven processes could potentially accelerate the rate of traffic growth and demand on network resources. The WG believes that advances in computing and networking technologies will likely result in techniques that mitigate the effects of such growth .

Observations

3. In addition to Communications, the design, deployment, and operation of Networks increasingly involves tight integration with Computing, Storage, and Sensing assets – "Converged & Integrated Information Networks". This trend greatly affects Network Architectures and requires new technical, business, and policy considerations. Within Communications the trend implies the convergence of traditional access technologies in applications and solutions, in a continuum from the endpoint to the edge and the cloud.

4. Computing and associated technologies are an essential source of value on general purpose Networks and profoundly impact Economic Activity, Quality of Life, and Critical Services affecting Consumers, Industry, and the Public sector. Examples among others include:

- Healthcare	- Law Enforcement	- Manufacturing	- Transportation
- Education	- Financial Services	- Entertainment	- Govt. Services

Observations

5. The trend towards integrated services is likely to exacerbate the "Digital Divide", including:

- The longstanding problem of delivering "quality of life, business and public services" to unserved rural and sparsely populated area, where it is important to continue the existing efforts at the FCC . (The Geographic Divide)
- The difficulty of providing affordable "quality of life services", in all areas. (The Economic Divide)
- The barriers to adoption of emerging services, important for economic competitiveness, that favor ubiquity, emphasizing area vs population coverage. Examples would be connected cars, industries such as Agriculture and management of Natural Resources, and Education. (A Technology Divide - a consequence of the Geographic and Economic Divides)

6. There is no single government organization that considers the whole picture of the "Converged & Integrated Information Network" – there is currently a vacuum. The decomposition which considers communications in the network on a stand alone basis and not part of a greater information infrastructure may no longer work well.

Opp for FCC to be out-front in cheerleading mode- they should take position of leadership. Cant do this by themselves

Recommendations

1. Leadership Opportunity of Planning for a "Digital Nation"

What: Establish and promote a holistic view of "Converged & Integrated Information Networks" and the Infrastructure and Services that that will preserve the economic leadership of the US.

Why: The world has changed! Services are at an inflection point so that focusing on communications without worrying about what else hangs off the network does not adequately reflect value. The network increasingly has to satisfy other demands, including aspects that are not traditionally part of the FCC mission. In making policy and regulations, there is an advantage in accounting for a much more complete view of where economic and societal value is created. This is the big why.

How: Partner with other agencies to Develop a Strategic Policy Plan and Roadmap for a "Digital Nation" that incentivizes adoption and deployment of "Converged & Integrated Information Network" services accessible to all consumers, industries, and public institutions. In doing so maintain a light touch that promotes innovation and actively encourages an open, competitive marketplace, private investment, with bottoms up participation and experimentation. A key part of such a plan is the thorough examination of the policy and regulatory structure to meet the challenges created by the rapid pace of technological change and the benefits from adopting practices that can better anticipate future change.

Current fcc organization is related to access- FCC needs to examine how to have more holistic approach

Recommendations

2. **Seizing the Mission and Organizing for Success**

What: FCC to assess how it can best influence the mission it has and how best to execute it. The underlying consideration being the "tangling" of its traditional focus on communications with other aspects of networks such as computing, storage, and sensor resources in the "Converged & Integrated Information Network!"

WHY: Given the challenges of converged technologies emerging in the market place and the composition and structure within the FCC it is difficult to include consideration of other essential assets. Examining the FCC structure to better enable it to create policy and rules so that holistic tradeoffs are performed across the converged technology environment as needed. Policies and rules can subsequently reflect a more complete view of the landscape.

How: Dedicated Study Group with specific mandate to provide output by the end of 2019. The objective is to identify responsibilities and scope of what the FCC should and is authorized to take on in light of rapidly changing technologies, use patterns, and business models. Explicitly identify what should be left to other organizations.

Recommendations

3. Overcoming the "Divides"

What: Rethink the current practices and policy structures to better track and minimize the divides we have identified (Geographic/Supply, Economic/Affordability, and the resulting Technological Divide/Competitiveness). Working with Industry, identify and prioritize alternate approaches to improve quality of life, industrial productivity, and public services in unserved, rural, sparsely populated and underserved areas as a step in attacking the problem.

Why: Purely market driven mechanisms, may work well in most dense population areas – where there can be effective scale to provide services on a competitive basis. For locations that are hard to serve, or where affordability is a problem – a purely competitive model may discourage the ability to provide such services on an economic basis. It may be worthwhile to consider mechanisms for demand aggregation and a combination of incentives and-competition to promote the most cost-effective solutions to attack this long standing problem.

How: Develop and prioritize policy options that address the challenge of providing economically viable services so that unserved, rural, sparsely populated, and underserved areas can be seen as desirable places to live [That is – be a part of the "Digital Nation"]. Consider as part of this, services based on emerging technologies that place a premium on ubiquity.

Strategy for CPSN-WG for 2019

- Greater focus on Artificial Intelligence

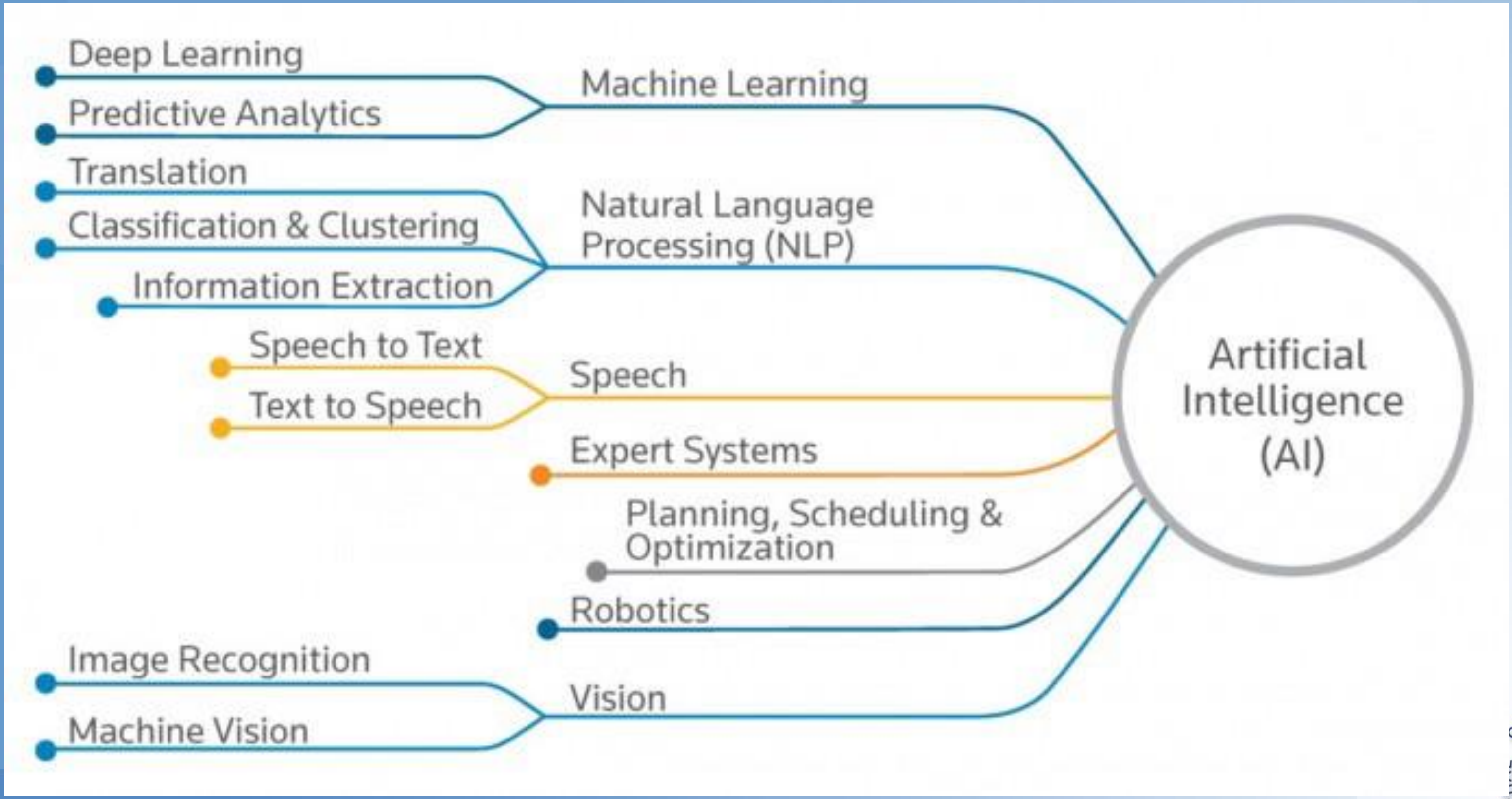
- AI for the network itself
  - Automated management for traffic characteristics (growth/spare capacity)
  - Automated fault detection and repair
  - Automated security response
- AI for high impact Industries
  - Industry examples: Financial Services, Healthcare, Agriculture, Education, Legal
  - In servicing these industries, what is the impact on the Network?
    - Nature of the architecture
    - Load on the network
- AI for internal use for the FCC
  - Easier access for the public regarding regulatory topics
  - Automation to optimize regulation of the network
  - Automated enforcement of regulations

Execution Plan for CPSN-WG for 2019

- Greater focus on Artificial Intelligence

- Learn from the experts
  - Artificial Intelligence (AI)
    - Technology experts to describe an relevant overall view of AI
  - Industry
    - Recruit speakers from industries with large scale AI strategies
  - Network Automation and Architecture
    - Include a deeper dive into Cloud DC, remote workers and the network impact
  - Regulatory view
    - Understand how the FCC can optimize workflow and execution
- Desired Outcomes
  - Education
    - Understanding the impact of AI on fundamental network structure and the FCC mission
  - Actionable Recommendations (examples below)
    - How to use AI within the process of the FCC to make regulations more accessible
    - Identify where, because of AI, the regulatory structure that exists today isn't relevant

AI and the various components



- The world is about to change, yet again, in very fundamental ways
- The possibilities unleashed by information and communication technologies play a key role driving innovation, with broad societal and economic impacts
- The FCC has has the opportunity and a responsibility to plan for and help guide this change to the benefit of the Nation and its Peoples

Addendum

Addendum Content

1. Intertwining of Communications and Computing
2. Evolution of Wireless Systems
3. Evolution of the Wireline
4. Evolution of Media (Cable, Broadcast, ….)
5. Evolution of Computing
6. Evolution of Data Storage
7. Evolution of Services
8. FCC Structures – Offices and Bureaus

9. List of Speakers and Presentations

1. Intertwining of Computing and Communications

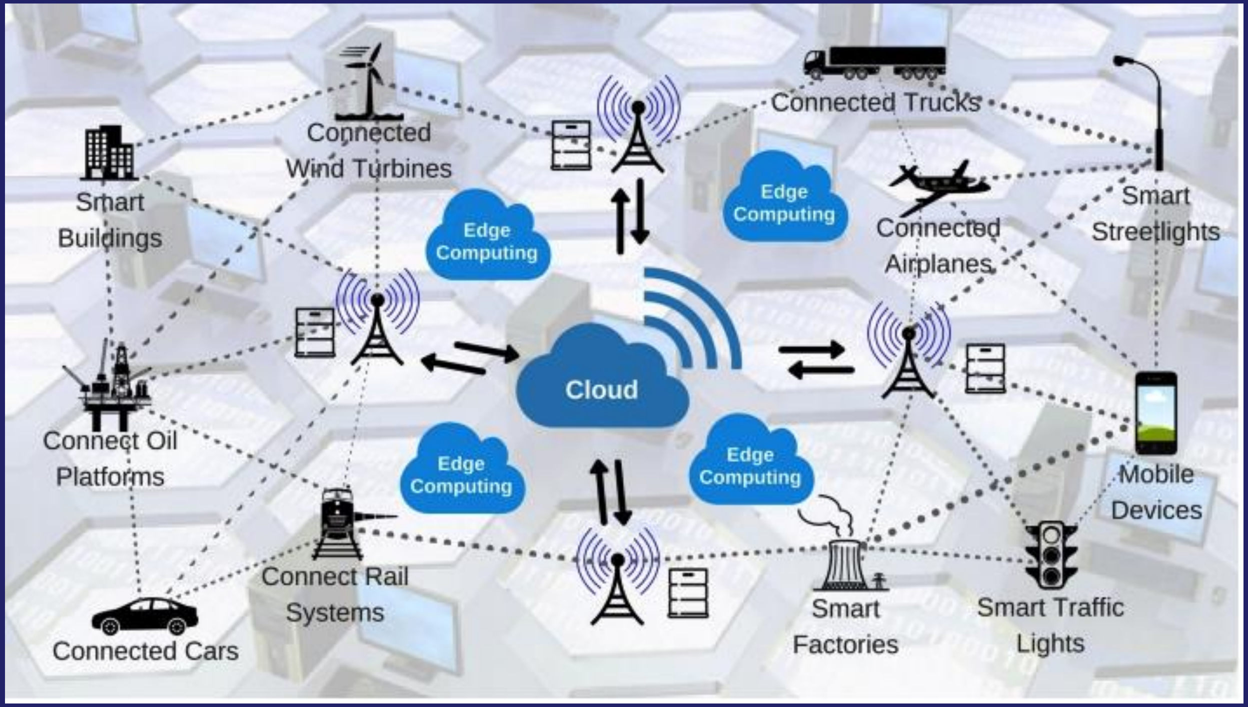
Mainframe	Client-Server	Mobile-Cloud	Edge Intelligence
			
Centralized 1960-1970	**Distributed** 1980-2000	**Centralized** 2005-2020	**Massively Distributed** 2020 +

1. Intertwining of Computing and Communications

Vertical	Facilities	Energy	Manufacturing & Industrial	Transportation	Retail	Smart Cities
Locations	Office Airports Education	Generation Distribution Rigs	Processing plant Oil rigs Mines	Air Rail Marine	Distribution Hotels Gas stations	Roads Towns Highways
Devices	HVAC Lighting Fire alarms Security Access	Turbines Generators Fuel cells Windmills	Motors Pipelines Assembly Tanks	Tools Signages Sensors	Terminals Tags Vending	Traffics lights Road sensors Alarms

1. Intertwining of Computing and Communications

The Consequence of Mobility
On Network Architectures



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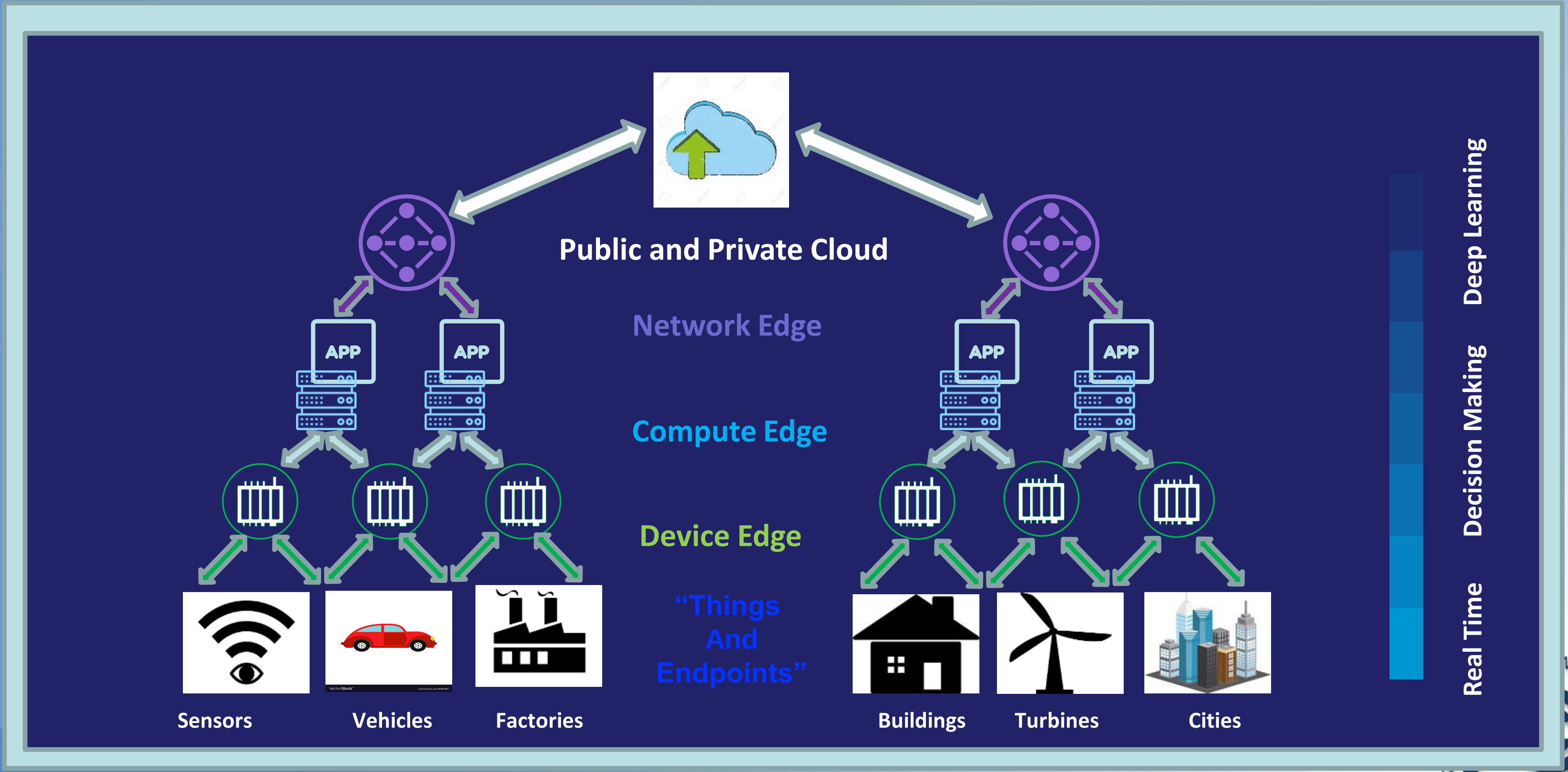

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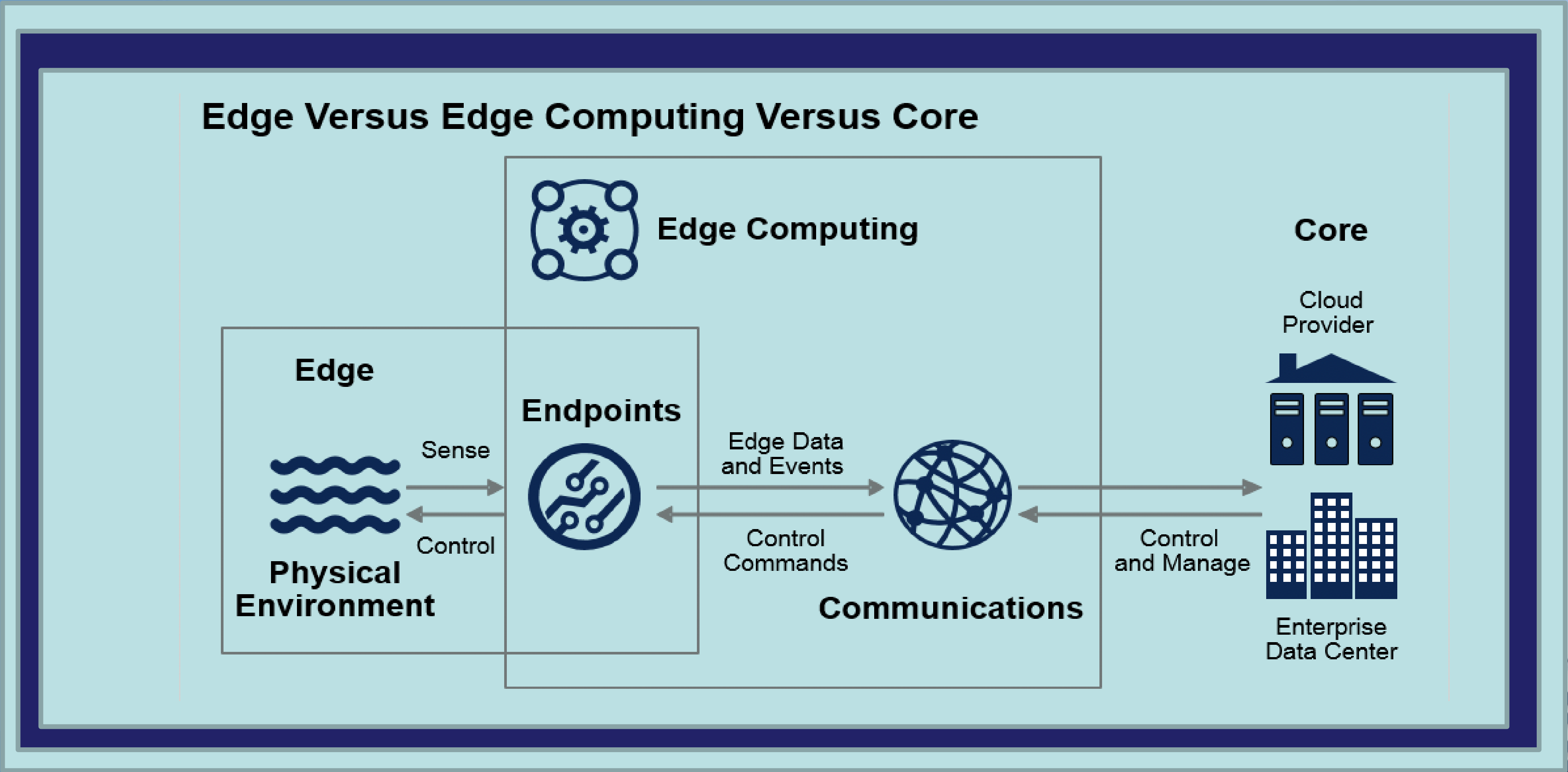
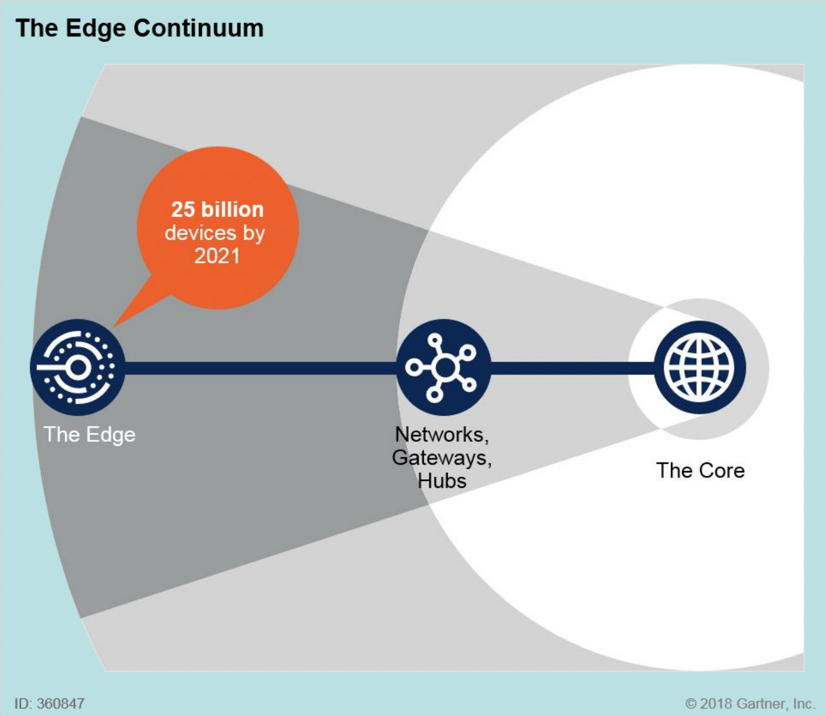


Source: Gartner

1. Intertwining of Computing and Communications



Each portion of the continuum adds value:

- Aggregation and Analysis of Data – Pattern Discovery and Classification from Deep Learning in the Core.
- Models and Analytic Tools to support Decision Making at Hub points.
- Real time processing, operations and controls at the Edge.

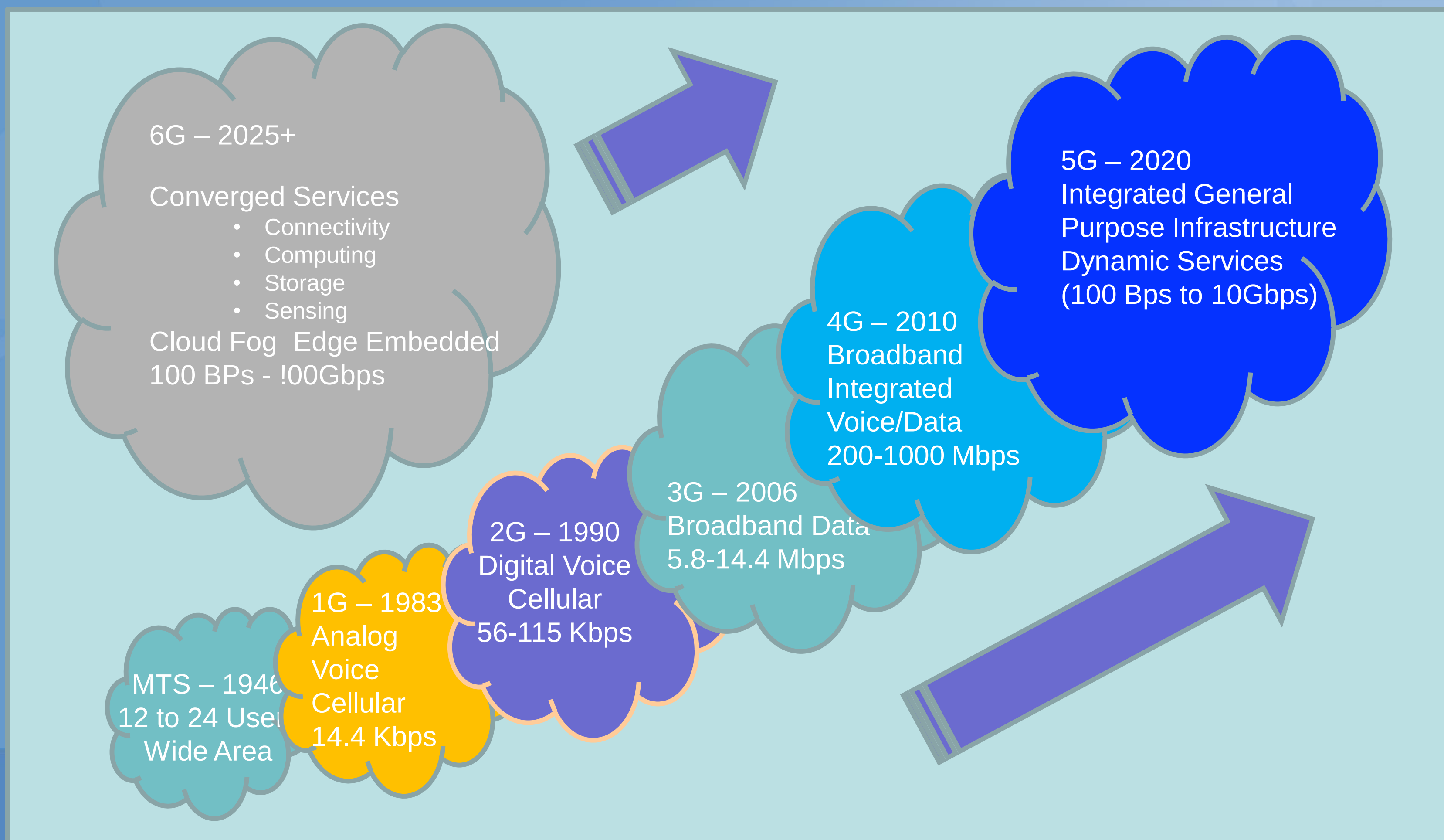
Source: Gartner

1. Intertwining of Computing and Communications

Takeaway

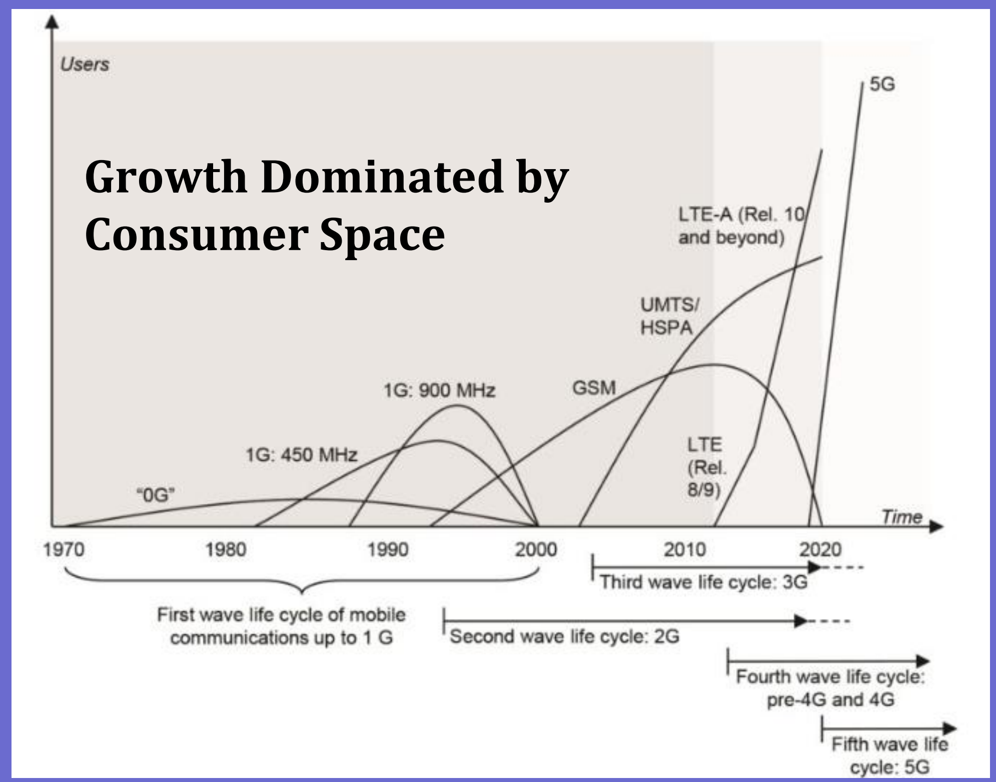
- The design, implementation, and operation of competitive applications and solutions for delivering services over ”The Network” can be characterized as a complex system problem with a large technology and business model tradeoff space. In this setting the engineering decompositions used in the past may not work well.
- A significant, and increasing portion of value comes from “Digitization”, relying on underlying technologies where computing, storage, and sensing dominate and significantly affect the requirements for Communications Network Architectures.
- Computing has a long trend of moving from centralized monolithic systems to embedded, granular elements located in a continuum from the core to the edge of the network. This trend will continue and will profoundly affect assets location, the kind of assets used, and the investments that they will draw – favoring holistic approaches!

2. The Evolution of Wireless Systems



2. The Evolution of Wireless Systems

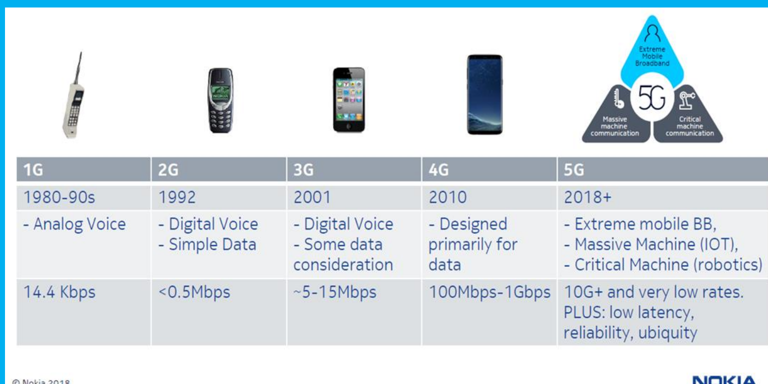
Population Served



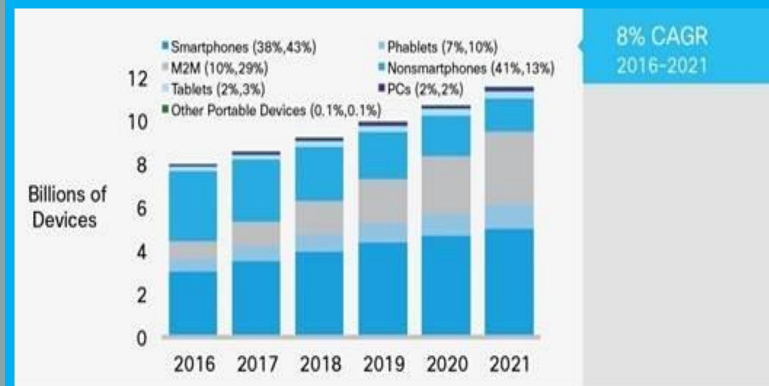
Time

Source: Interference Technology

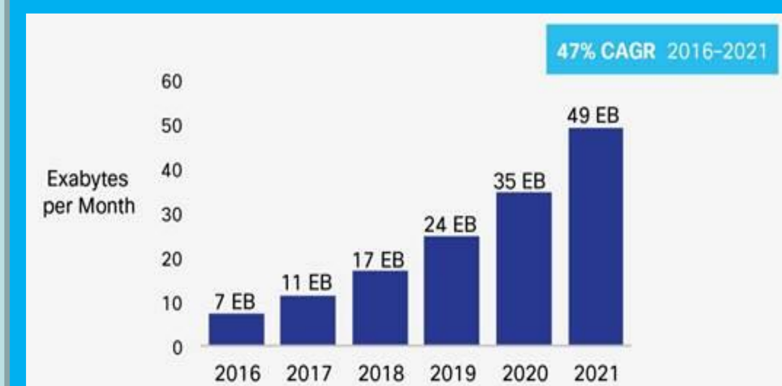
2. The Evolution of Wireless Systems



1G	2G	3G	4G	5G
1980-90s	1992	2001	2010	2018+
- Analog Voice	- Digital Voice - Simple Data	- Digital Voice - Some data consideration	- Designed primarily for data	- Extreme mobile BB, - Massive Machine (IOT), - Critical Machine (robotics)
14.4 Kbps	<0.5Mbps	~5-15Mbps	100Mbps-1Gbps	10G+ and very low rates. PLUS: low latency, reliability, ubiquity

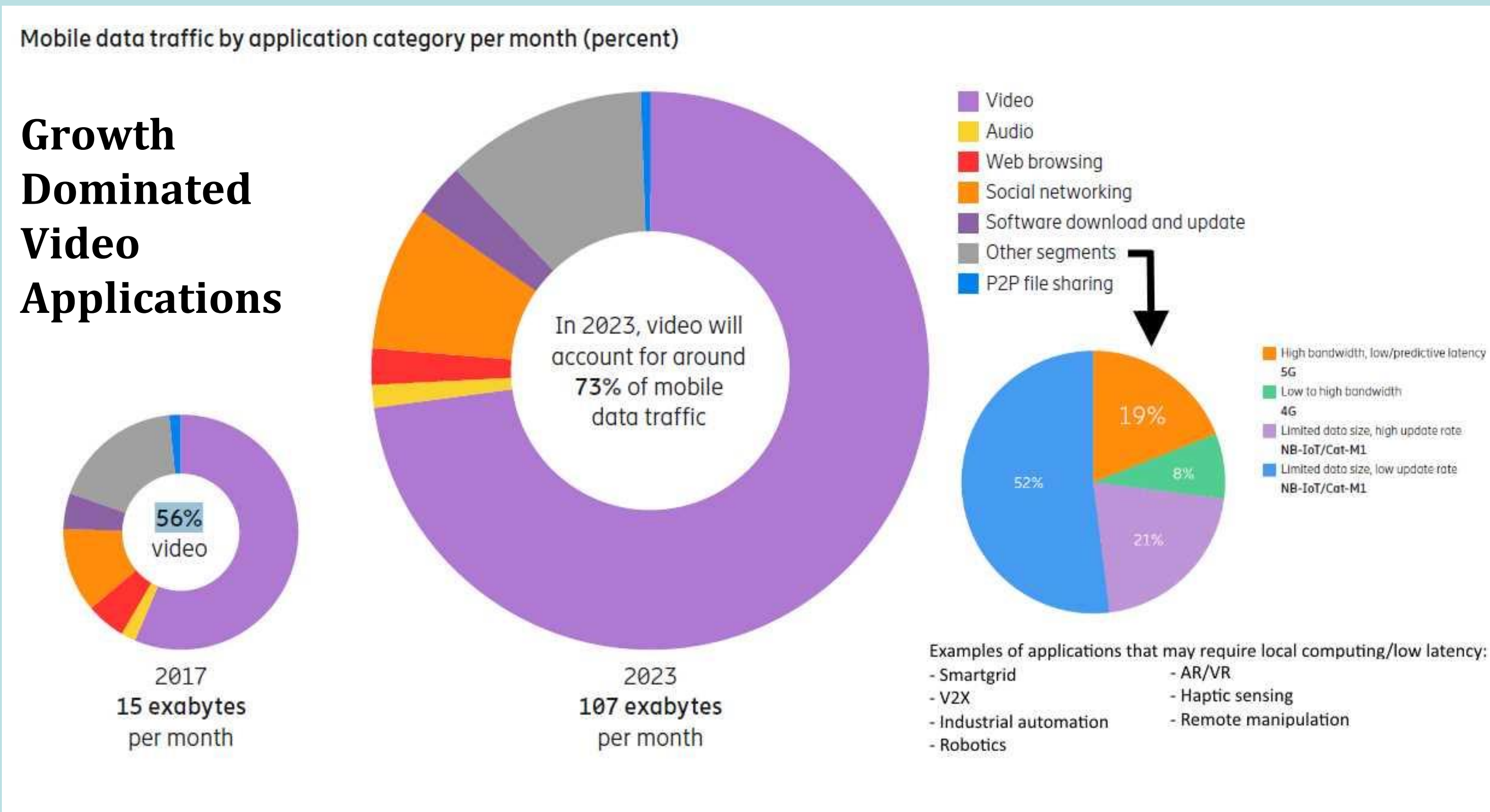


Growth Transitioning To Connected Devices and Integrated Resources



Source: Cisco VNI Mobile 2017

2. The Evolution of Wireless Systems

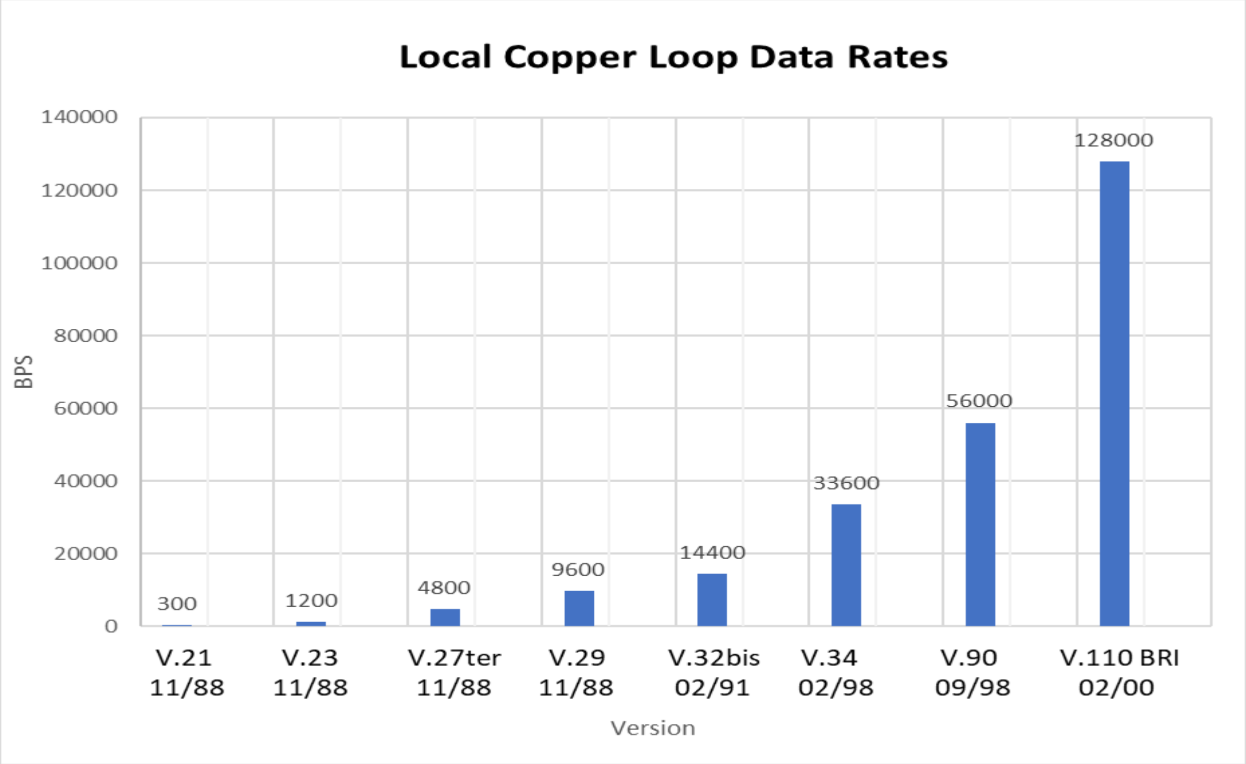


2. The Evolution of Wireless Systems

- Compound Annual Growth of Wireless Capabilities projected to be in Double Digits – now and in the foreseeable future!
  - Volume of Traffic
  - Number of Connected Devices
  - Improvement in Technologies leading to:
    - Better spectral efficiency
    - Higher bandwidths
    - Greater Automation in Network (10’s of Billions of Devices)
- Acceleration of Devices and Applications that Require a High Level of Network Performance
  - Latency and Jitter
  - Reliability and Availability
  - Security and Assurance
- Emergence of New Classes of Devices/Applications requiring Edge Based Computing and Storage as part of Network Services

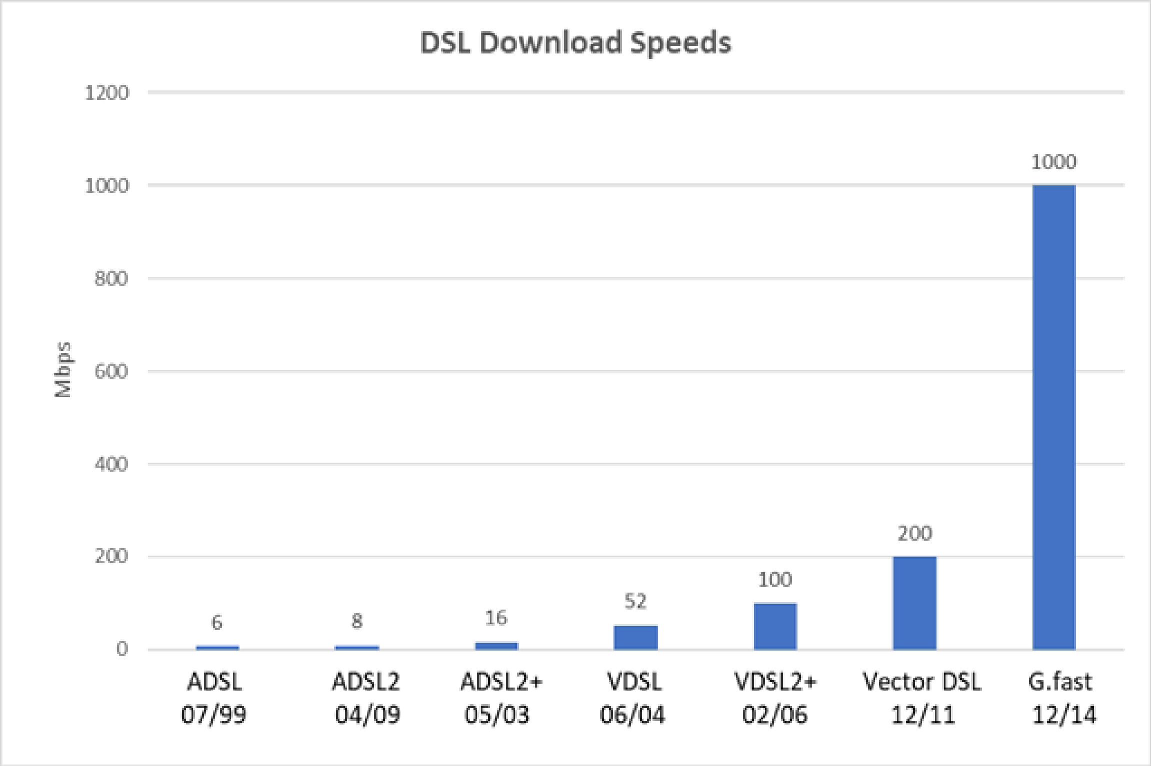
3. The Evolution of Wireline

Historical Look at Analog and Digital Modem Speeds



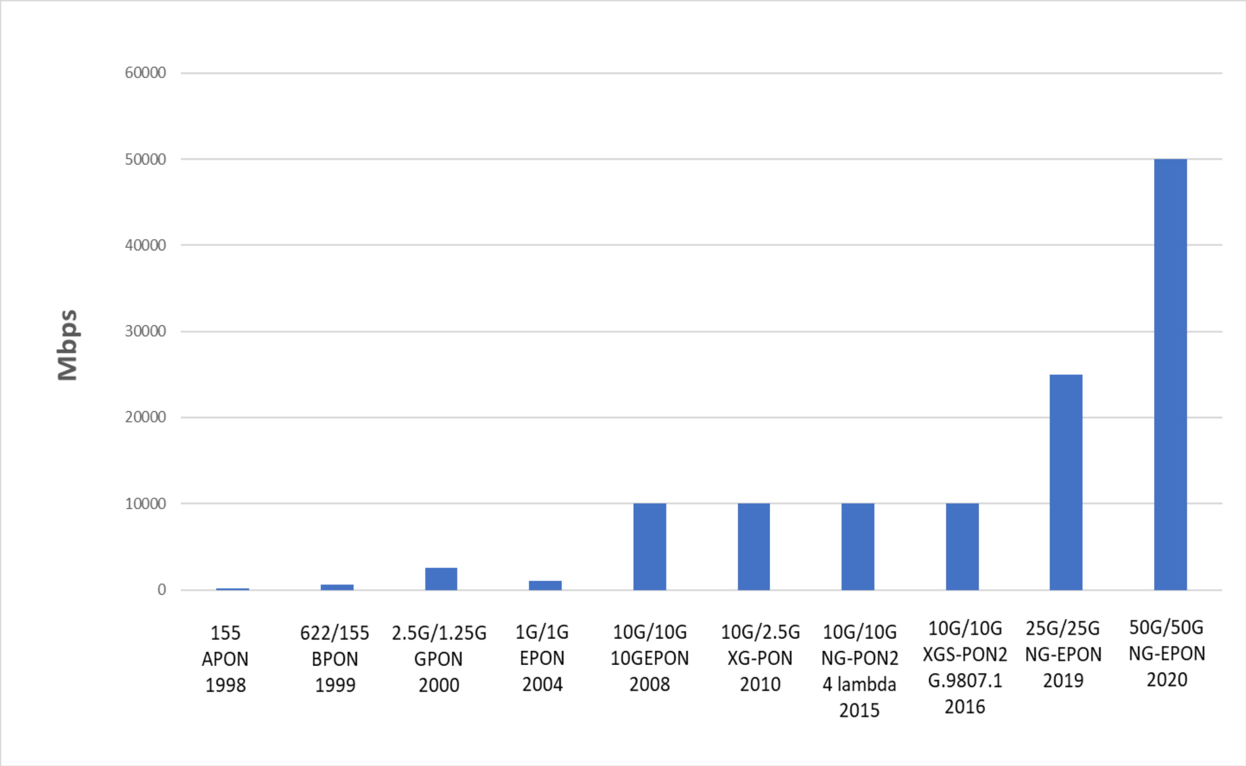
3. The Evolution of Wireline

Historical Look at DSL Download Speeds Over Copper Loops

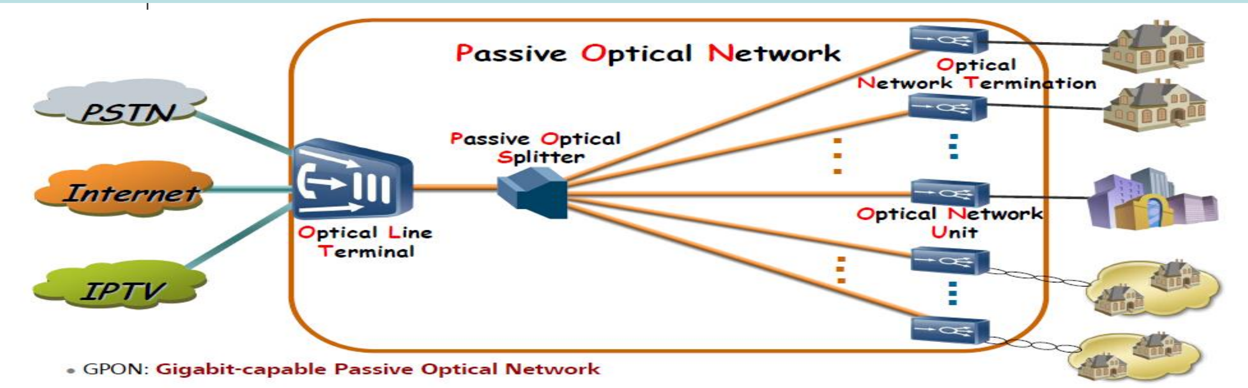


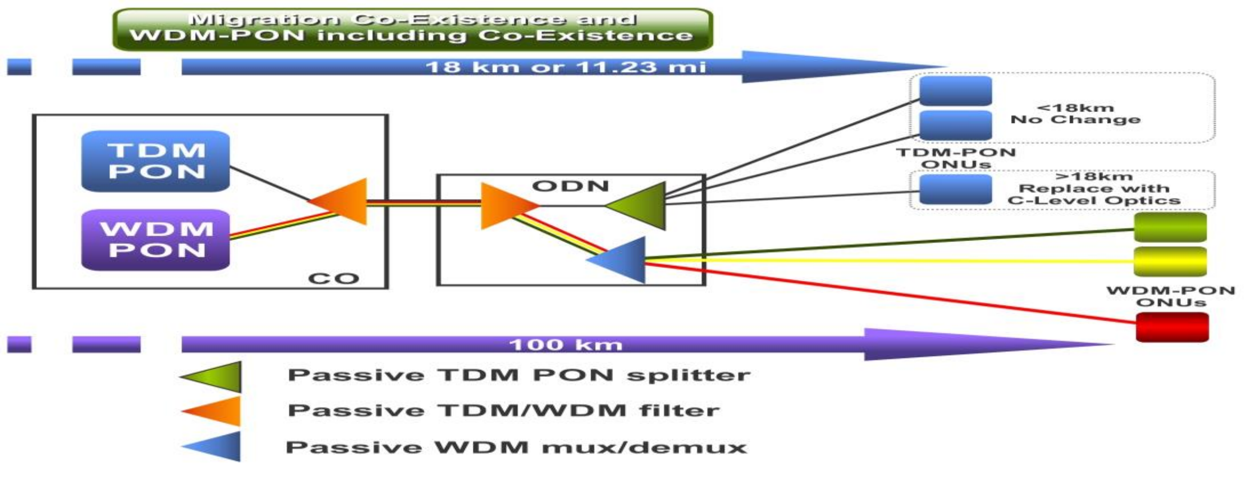
3. The Evolution of Wireline

Historical and Future Data Speeds Over Local Fiber Facilities



3. The Evolution of Wireline





Migration Path for Fiber PON Technologies

3. The Evolution of Wireline (Key Take-A-Ways)

- **Copper**
  - Has played a vital role in providing voice/data service and through electronic developments, has extended the useful life of copper plant installations.
  - This includes broadband, but as data speeds increase, reach of service shortens.
  - Current applications include line powering of electronics serving MDU facilities with G.Fast technology.
- **Fiber**
  - Economically provides long-haul high speed transmission rates efficiently, as well as local services with high data throughputs.
  - Used as a transport median extending broadband service to rural areas where copper or other facilities serve the last mile.

3. The Evolution of Wireline (Key Take-A-Ways) Cont.

- **Fiber – Continued**
  - Serves as a component of the hybrid architecture for both front-haul and backhaul for wireless cell sites.
  - Can be used by multiple types of architectures to support services (G-PON, E-PON, Active Ethernet and high speed Ethernet service, SONET, Analog Video, DOCSIS, etc.)
  - Laser and wave management electronics continue to improve, extending the fiber's useful life to meet future throughput demands on the network.
  - Fiber has a small form factor and as a non-conductive median allows for placement through micro-trenching techniques or placement in power space both significantly reducing installation costs.

4. Cable Technology Evolution…

1950s – 1960s

- 12 Channels
- All signals compatible with exiting TVs
- First true amplifiers support Ch 2 - 13

1980s

- Moving from 35 to 77 Channels
- Franchise wars = increased content
- Advancement in amplifiers
- Cable-ready TVs
- Conditional access
- HFC introduced in Rochester

Mid-2000s to current

- BB (1Gig/10Gig)
- HSD / DOCSIS (3.1 OFDM, Full Duplex, Low Latency)
- VOD
- Phone
- Interactive services
- Separable security

54 MHz | 216 MHz | 300 MHz Analog broadcast | 500 MHz Digital broadcast | 750 MHz – 1GHz

- Hardware to software focus shift
- Product convergence
- Clouds
- Artificial Intelligence
- Cloud UI
- Open source CPE: RDK (STB and CM/eMTA)
- Powerful in-home WiFi

1970s

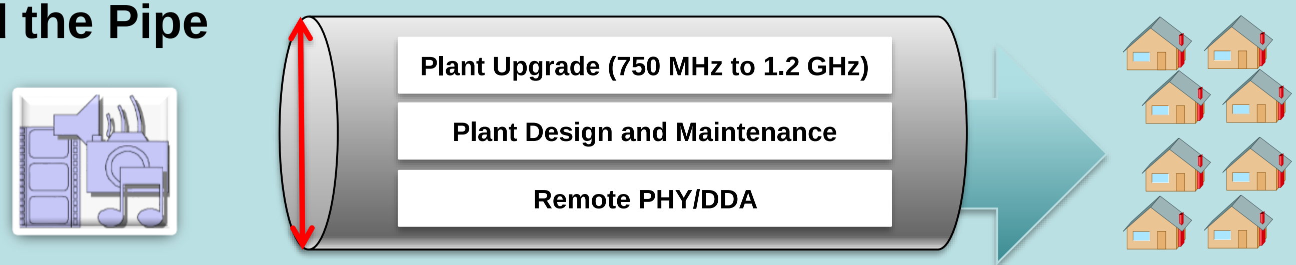
- 21 Channels
- Introduction of cable box (Ch 14-22)
- Launch of premium and super stations

1990s – Early 2000s

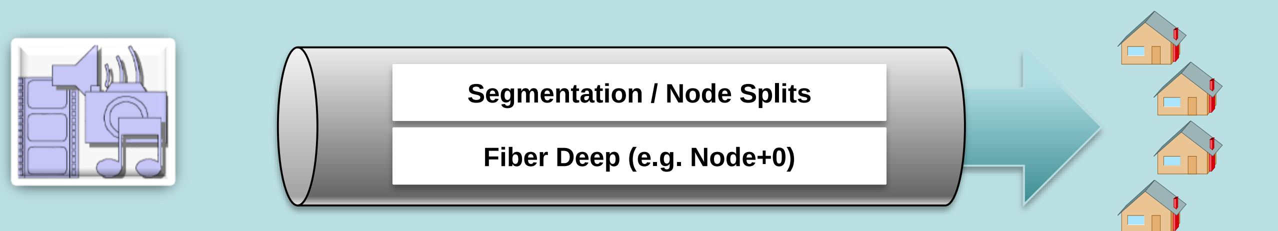
- Moving from analog to digital
- HFC more widely deployed

4. Cable Technology Evolution - Capacity is added in 3 ways…

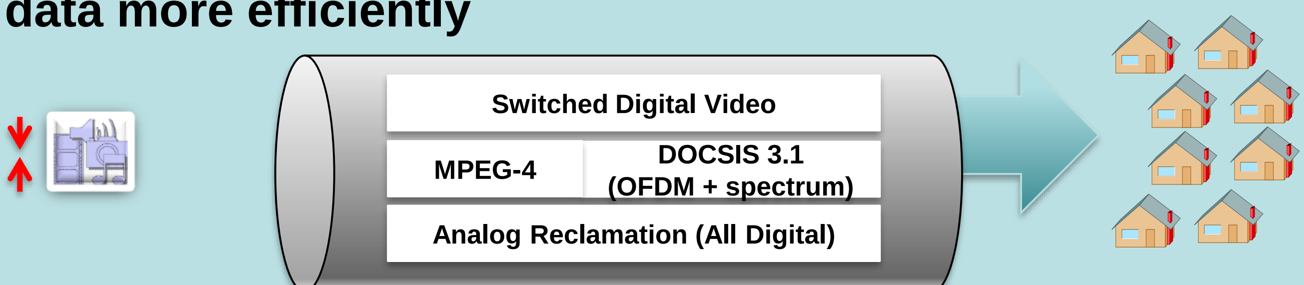
1) Expand the Pipe



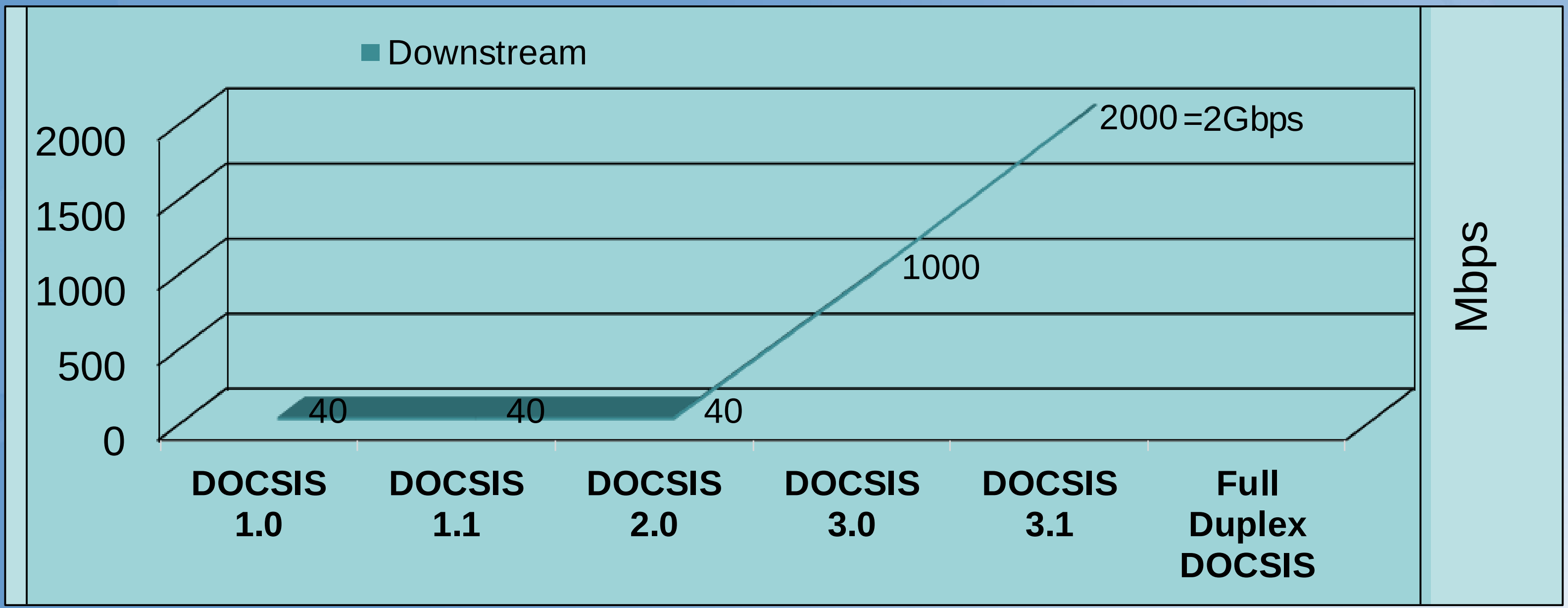
2) Reduce # of homes sharing the Pipe



3) Deliver data more efficiently



4. Cable Technology Evolution - DOCSIS Technology Advances



1996

- ✓ *High Speed Internet*

Early 2000s

- ✓ *Voice, Gaming & Streaming*
- ✓ *Capacity for symmetric services*

2012

- ✓ *Channel Bonding*
- ✓ *IPV6*

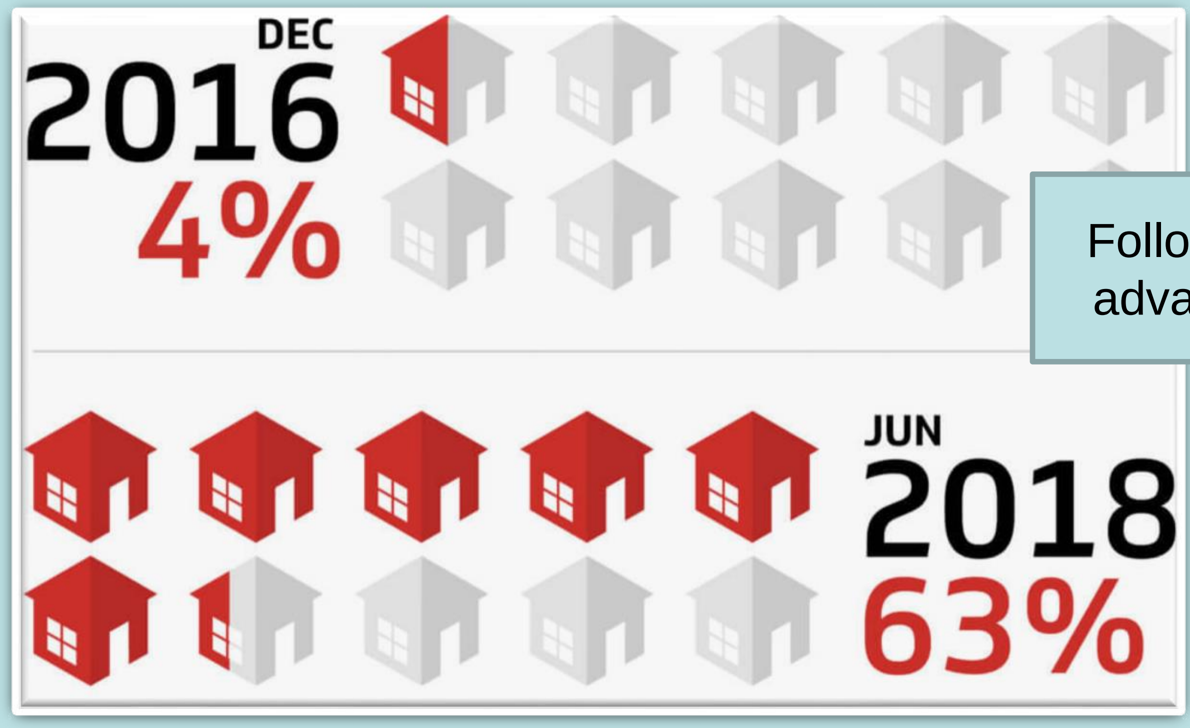
2017

- ✓ *OFDM*
- ✓ *Wideband Channel*

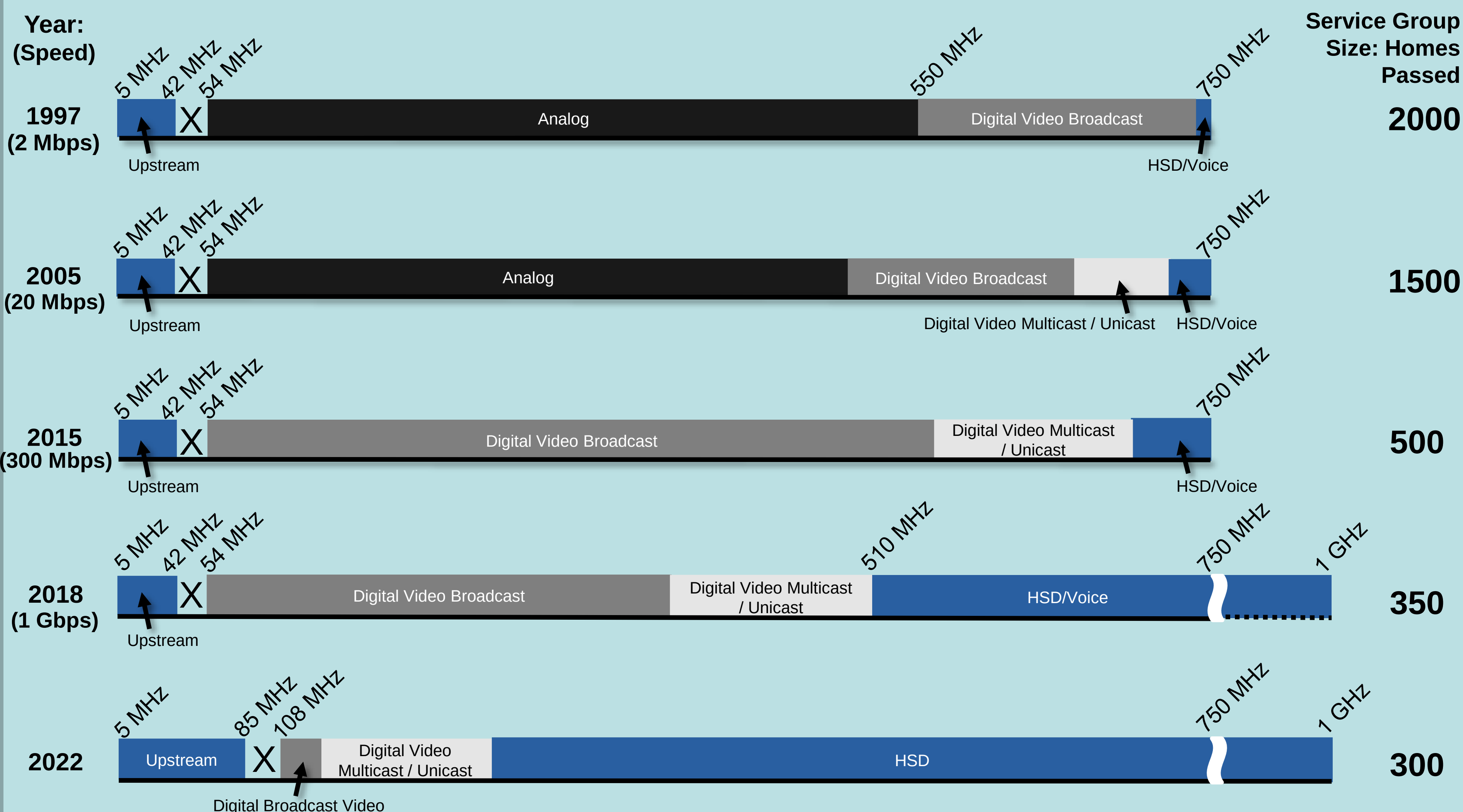
TBD

- ✓ *Full Duplex*
- ✓ *Low Latency*

4. Cable Technology Evolution - Gigabit Households Served by Cable

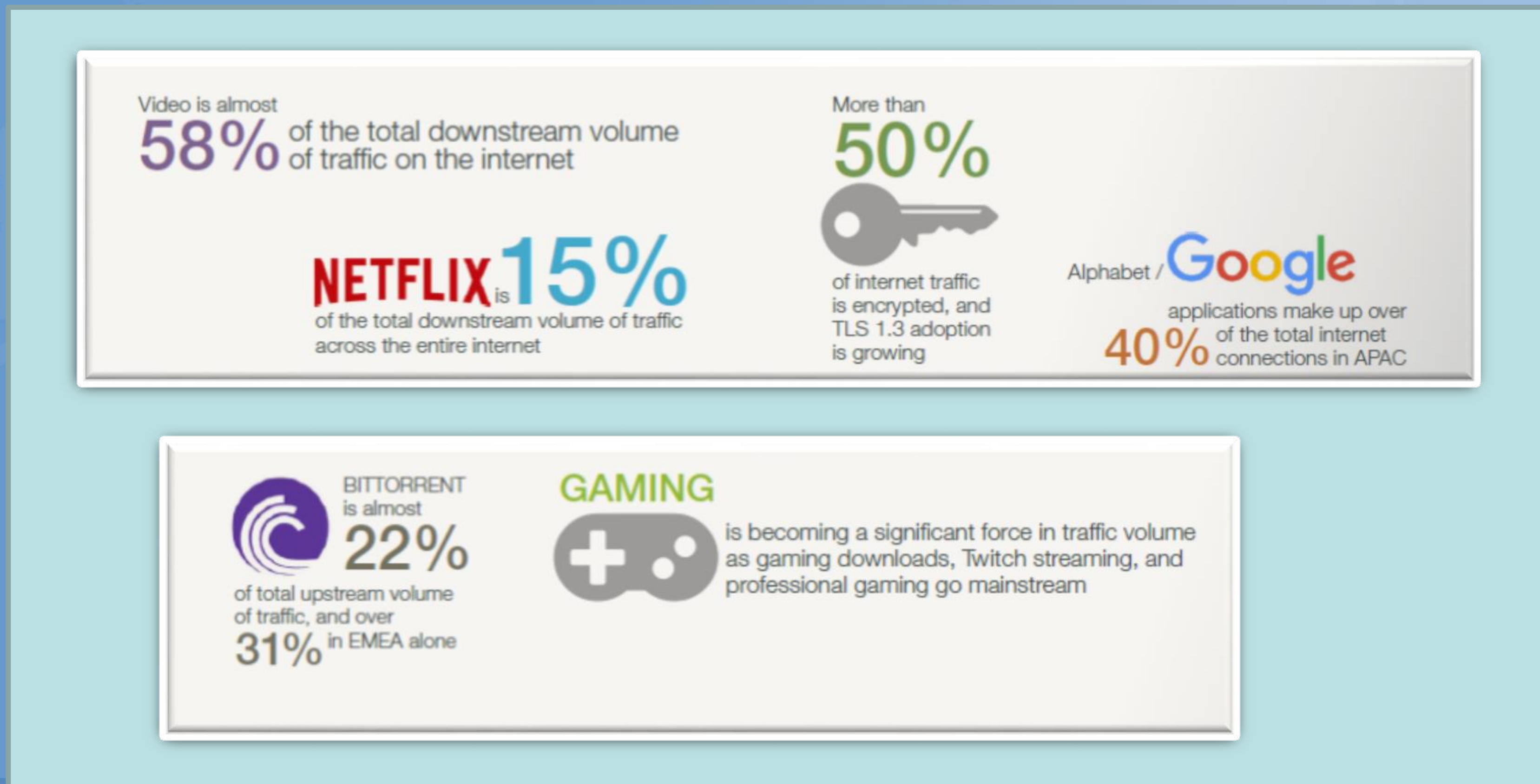


Following the trends and advances in Technology



1997- 2022: Bandwidth Created to Meet Demand

4. Cable Technology Evolution - Traffic on our networks



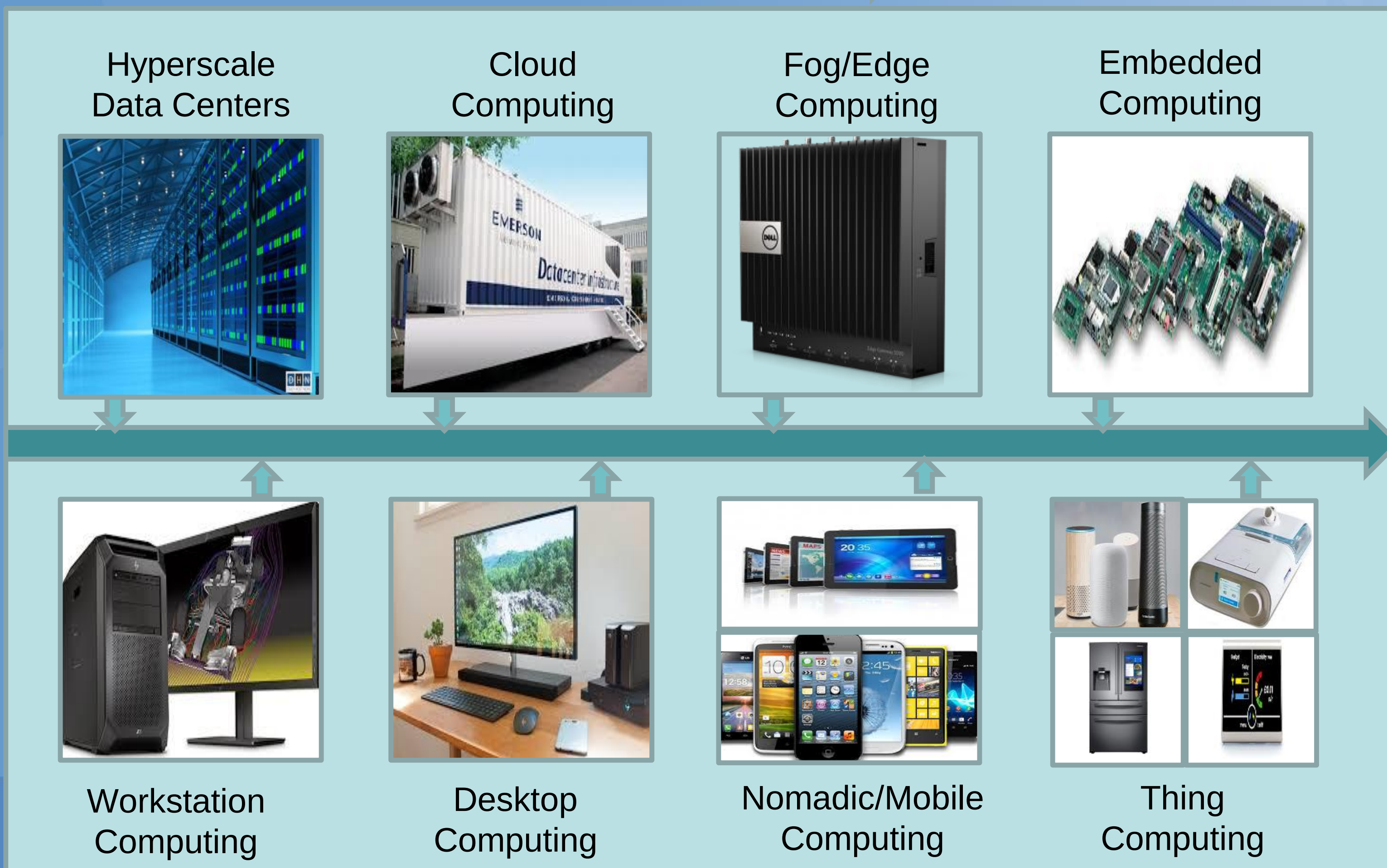
Source: Sandvine, The Global Internet Phenomena Report, October 2018

4. Cable Technology Evolution

Key Takeaways

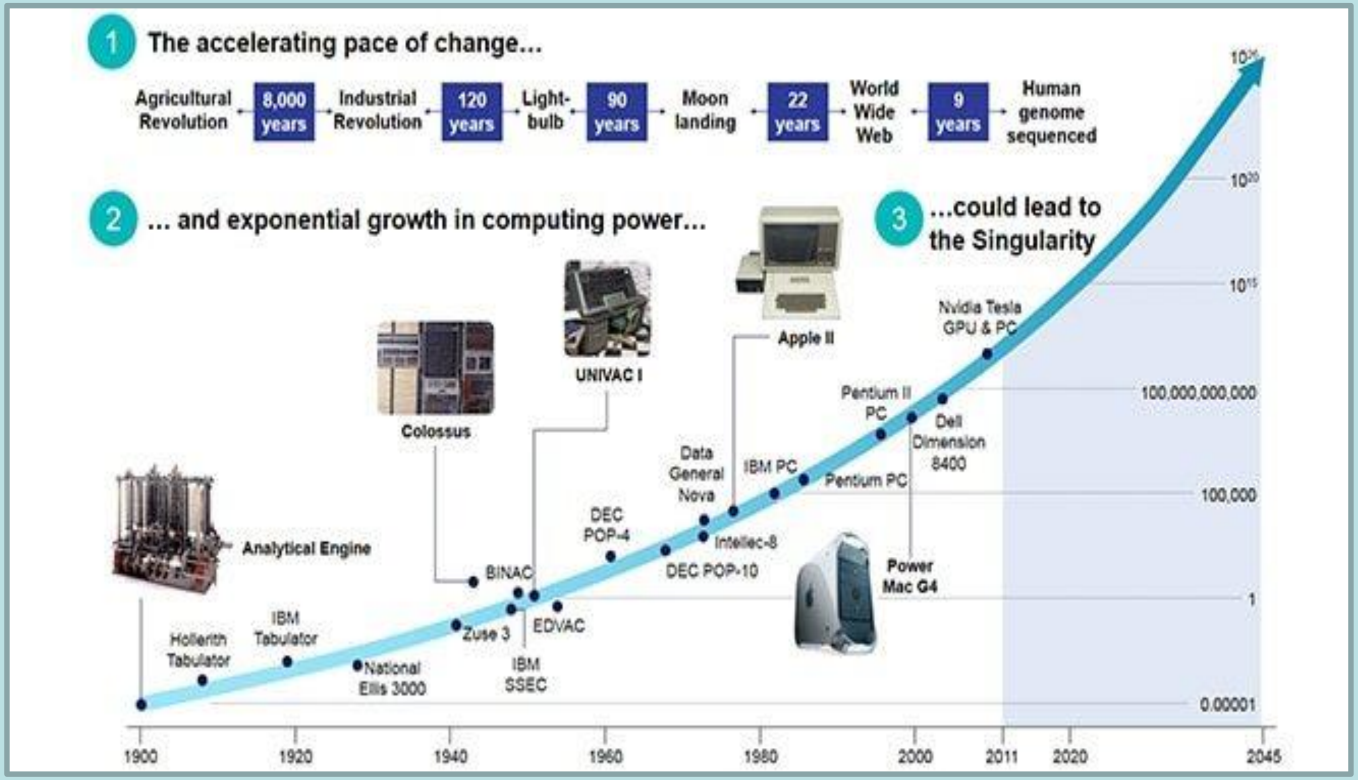
- Cable Broadband capacity has increased substantially enabling consumption to rise ½ GB per month per customer in the late 1990s, to 200 GB today.
- DOCSIS technology has evolved to enable greater network efficiency and higher speeds to meet rapidly rising consumer demand and the need for new products and services.
- Cable's Hybrid Fiber Coax dynamic and flexible network architecture allows for continued capacity expansion to meet future growth and the needs of new, high computational power applications. Both Downstream and Upstream capacity are being augmented as needed to support growth across all product lines.
- The Cable industry today has evolved from hardware, to software-based services. Computational power used for video is being pulled into the cloud and network capacity allows for continued scale – Remote DVR, VOD, Cloud-based User Interfaces, etc.

5. The Evolution of Computing → Hyper Connected



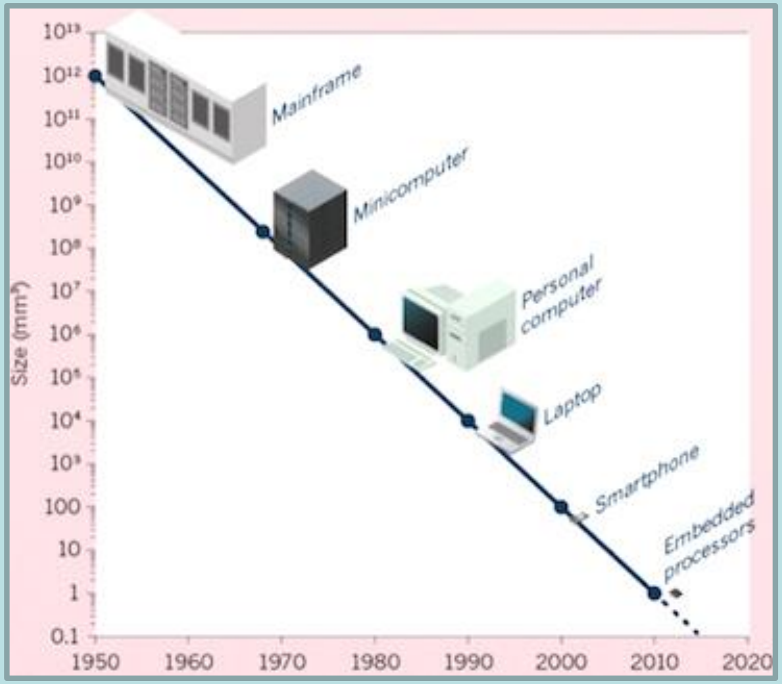
5. The Evolution of Computing → Exponential Growth

Processing Power

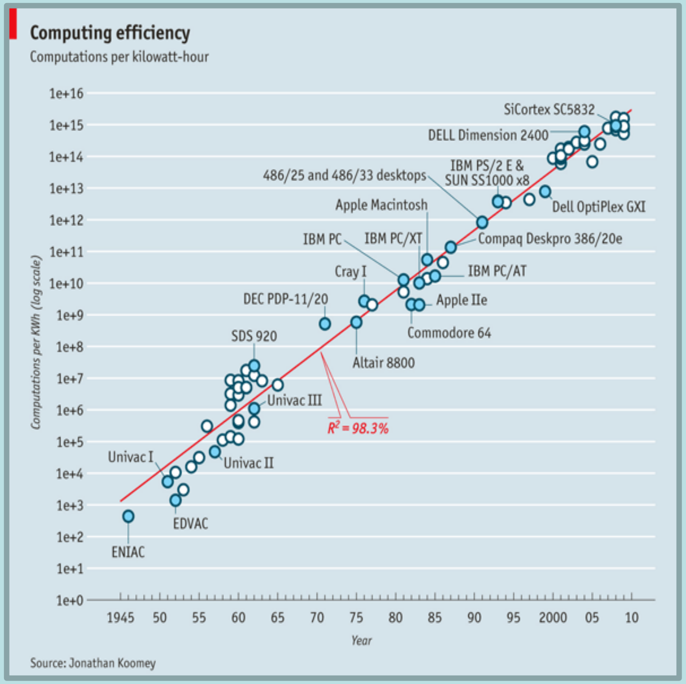


5. The Evolution of Computing → Exponential Growth

Shrinking Form Factor

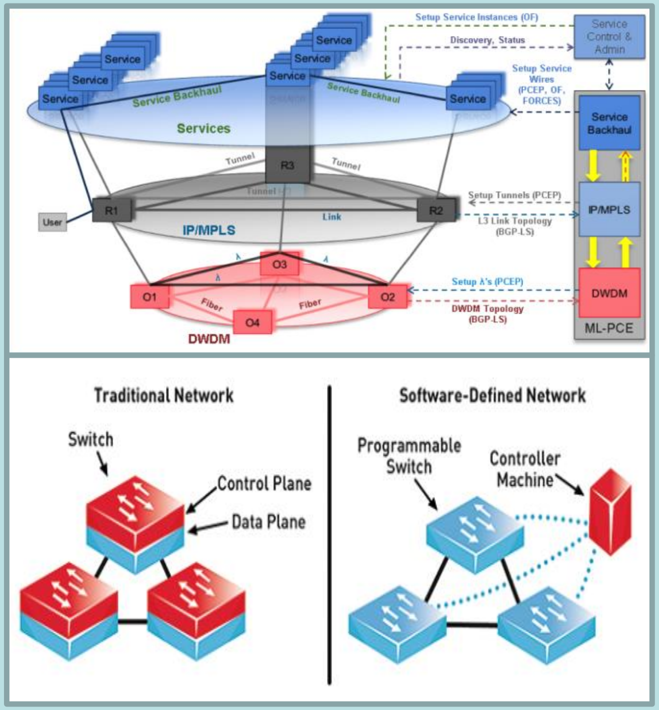


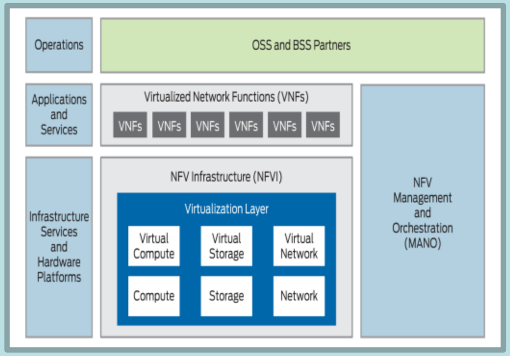
Power Efficiency
Operations per kWh



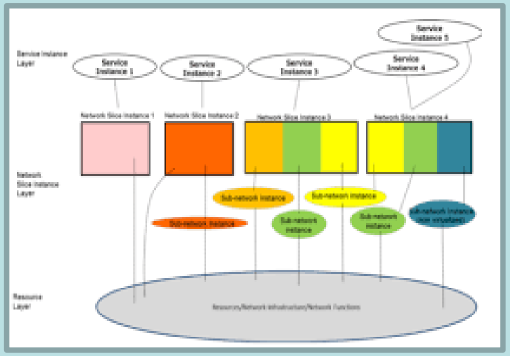
5. The Evolution of Computing → It is the Network!

Software Defined Networking





Network Function Virtualization



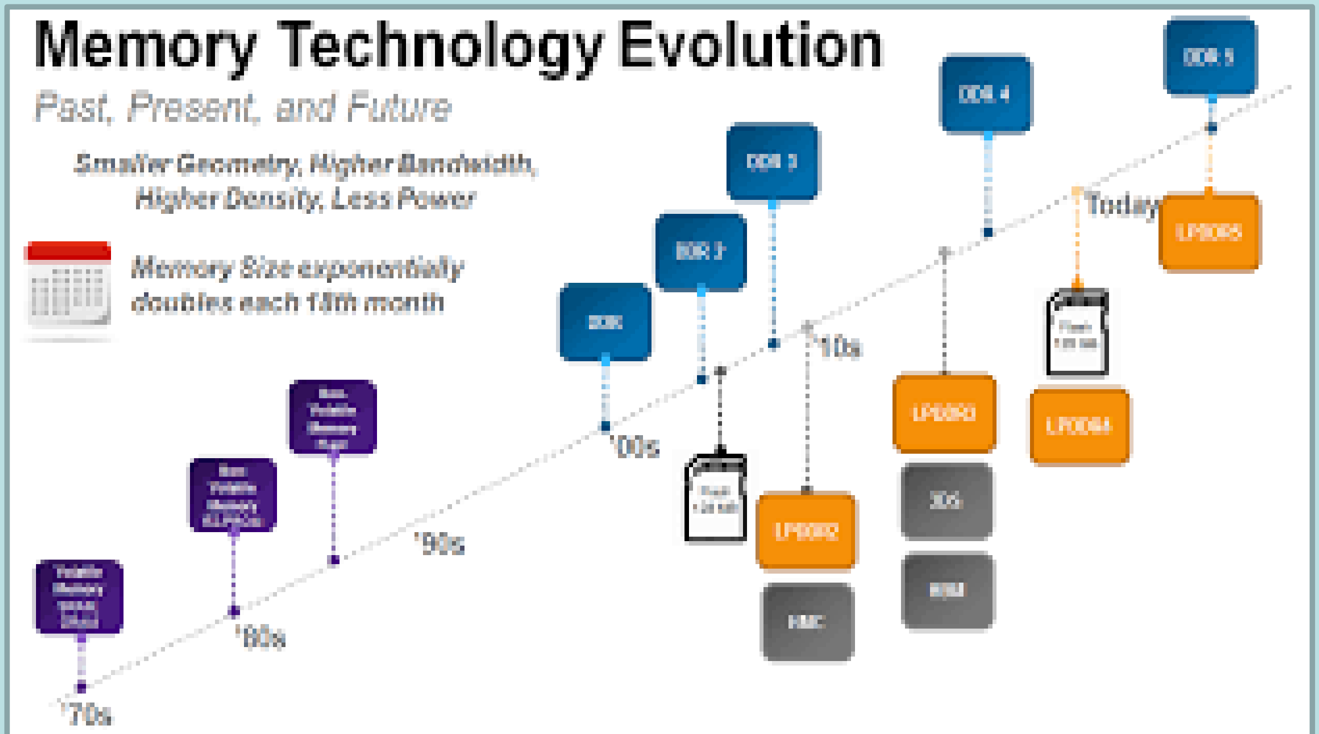
Network Slicing

5. The Evolution of Computing

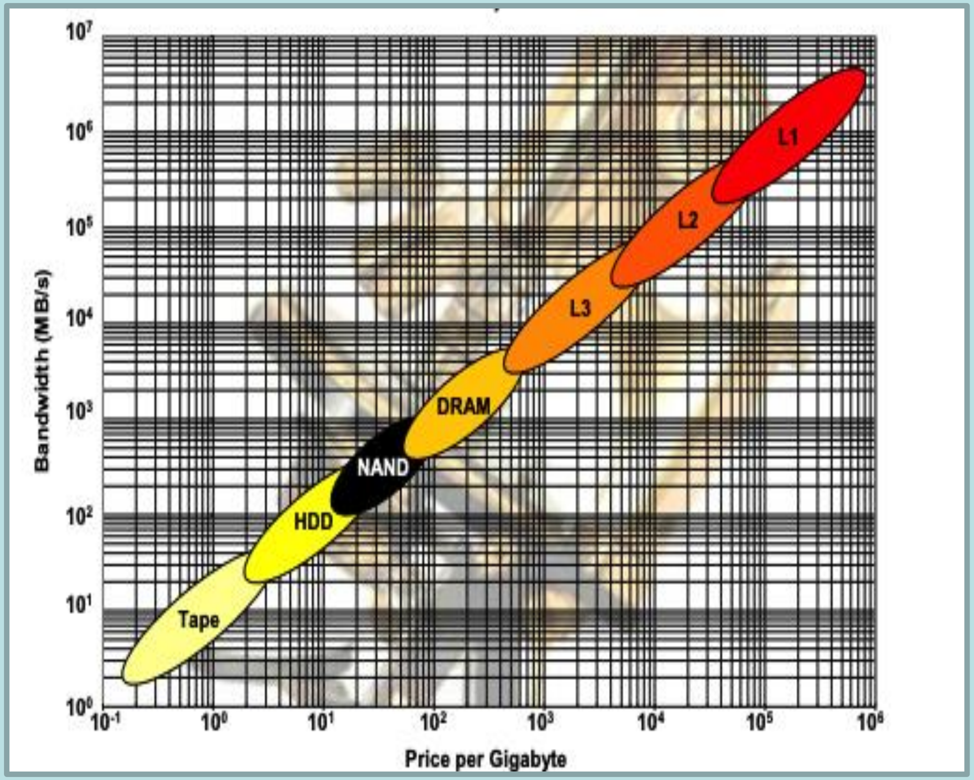
Key Takeaways

- Computing hardware and software technologies will continue improving at exponential rates and reshape what is possible in fundamental ways. The important factors are:
  - ✓ Processing capability – Operations/sec
  - ✓ Power Efficiency – Operations/Watt
  - ✓ Form Factor – Operations/Unit Volume
  - ✓ A computing hierarchy that runs from Hyper-scale data centers to embedded computing in small devices – such as AR/VR glasses.
  - ✓ The ability of software technologies to efficiently solve hard problems though use of techniques such as AI, Machine Learning, Data Science, ……..
- Compute power increases in the cloud, at the edge, and in devices will drive demand for communication resources at compound annual rates as high as 20-40%.

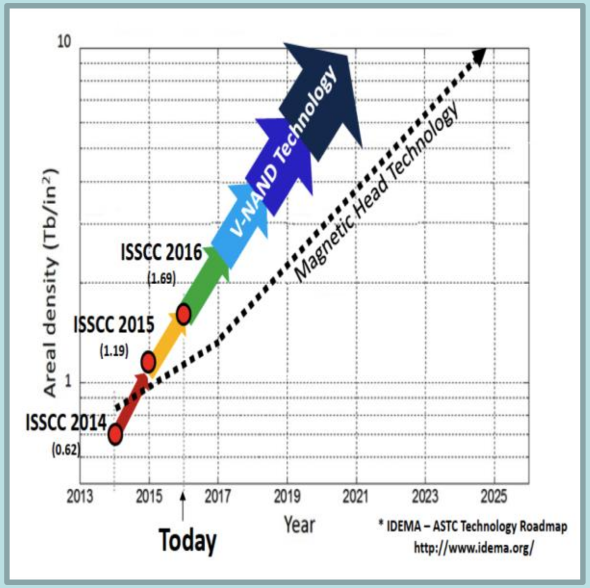
6. The Evolution of Storage

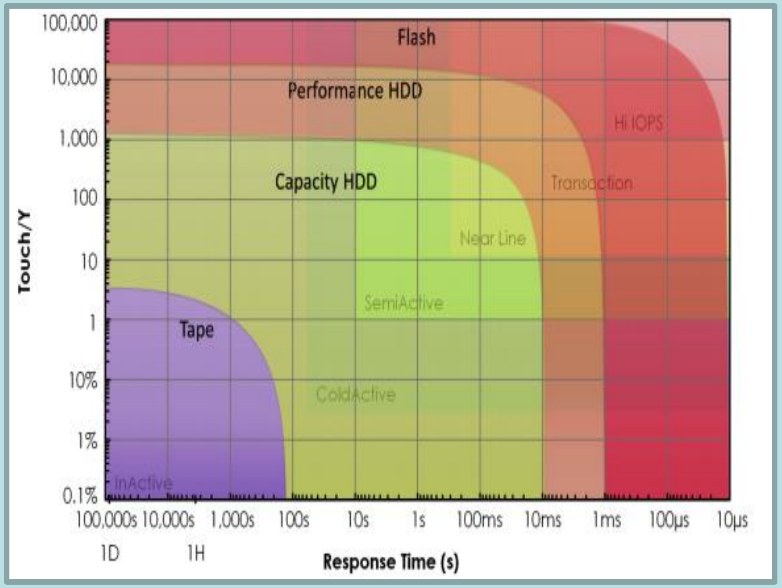


6. The Evolution of Storage



6. The Evolution of Storage





6. The Evolution of Storage

Key Takeaways

- Like computing, storage capabilities are also likely to continue growing at exponential rates for the foreseeable future. The outcomes and consequences include:
  - ✓ Storage in central large scale facilities used for aggregation of data – both for individual consumers and for enterprises
    - ✓ For consumers retrieval of data and media over the network combined with capable end devices contributes significantly to traffic on the network. Examples are: Sharing of photographs and video, access to personal records, streaming of media products.
    - ✓ For the enterprise it is the ability to cost effectively collect and curate massive amounts of data from disparate sources and to exploit analysis techniques such as AI, Machine Learning, …. to improve efficiency, decision making, and drive automation deeper into operational processes. An important aspect of competitiveness.

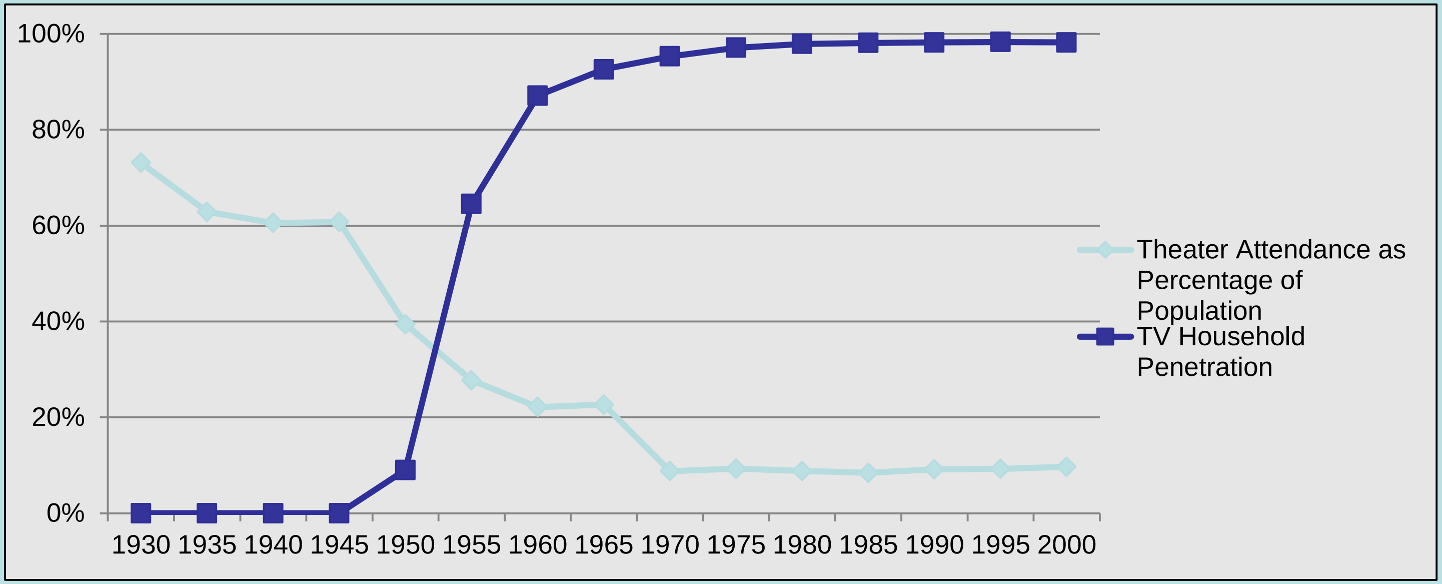
7. The Evolution of Services

Macro Trends in Consumer Services and Technology

- Consumers choose convenience (over quality)
- Quality catches up, pace of change is faster
- Can’t get enough screens – Video Dominates

7. The Evolution of Services

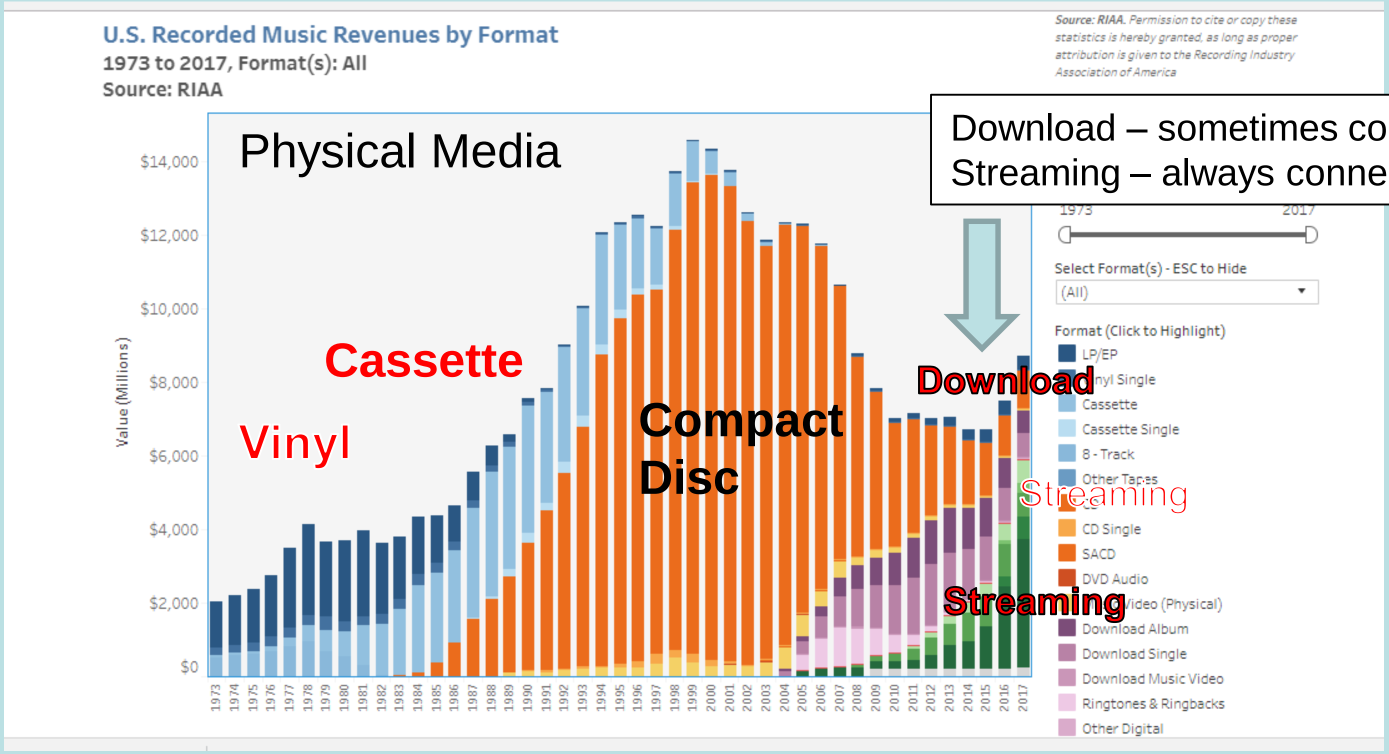
Choosing Convenience – Fleeing Theaters



Comparing U.S. Weekly Theater Attendance and TV Adoption

7. The Evolution of Services

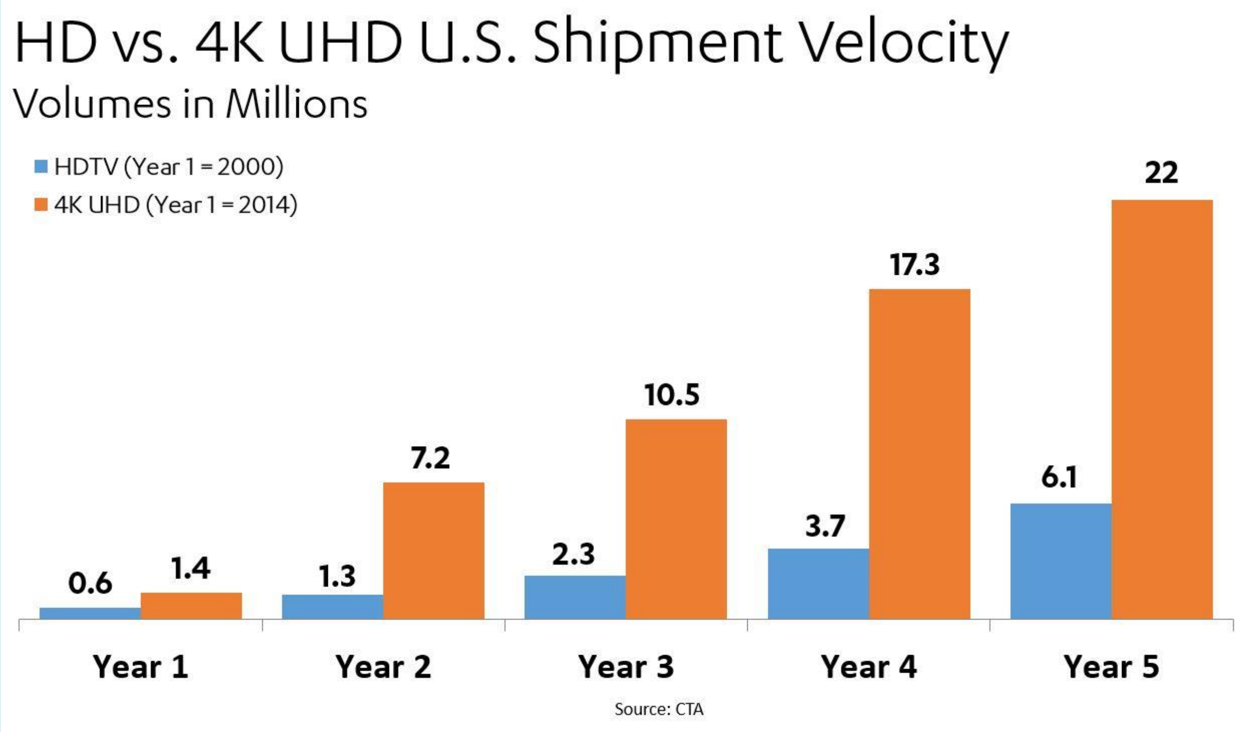
Audio Formats



Download – sometimes connected
Streaming – always connected

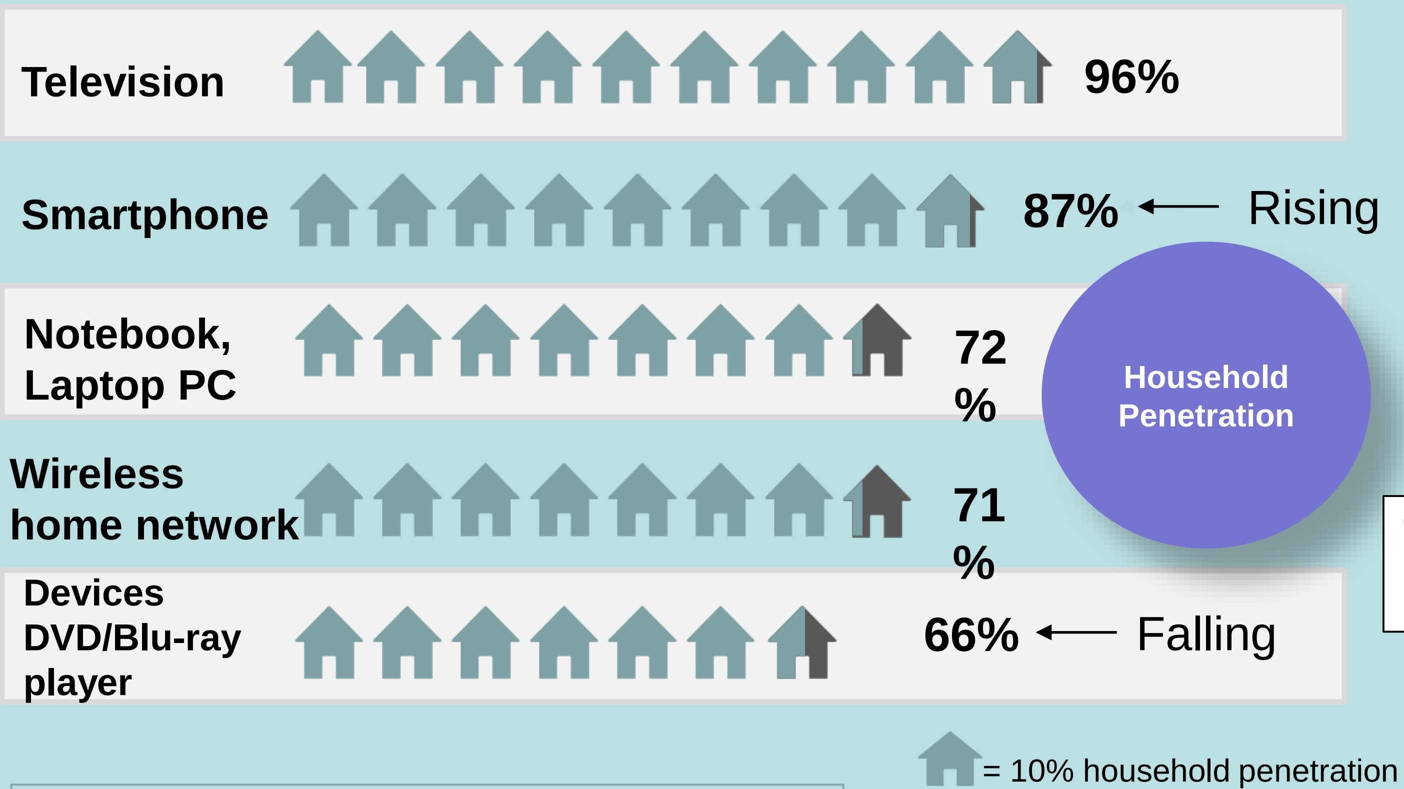
7. The Evolution of Services

Quality Gets Better, Pace of adoption Is Picking Up



7. The Evolution of Services

Four of top six most commonly owned tech products feature screens



Tablets 64 % HH penetration

Base: U.S. adults (n=2,016)

Source: CTA 20th Annual Ownership & Market Potential Study

7. The Evolution of Services

Consumer Technology Ownership 2018

30%	• Purchase intent - the smartphone, for a second consecutive year, is the most desired consumer technology product for purchase in the next 12 months among U.S. households.
39%	• Digital media streaming devices saw the largest percentage increase in U.S. household installed base from 77 million in 2017 to 107 million in 2018.
15 pp.	• 4K UHD TV and HDR saw the largest growth in U.S. household ownership between 2017 and 2018.

CTA *20th Annual Consumer Technology Ownership and Market Potential Study*, May 2018

Smart Speakers showed 8 percentage point Year-over-Year growth.

FEDERAL COMMUNICATIONS COMMISSION USA

7. The Evolution of Services

Streaming Services

- **$19.7 billion** in 2018 and will **grow 23%** in 2019
- Paid **Music** Streaming:
  - **32%** growth over 2017
- Paid **Video** Streaming:
  - **42**% growth over 2017

Consumer Expenditures on Streaming Services ($ Millions)

	2014	2015	2016	2017	2018e	2019p
Subscription Music Streaming Services	$1,576	$2,104	$3,525	$4,780	$6,301	$7,650
Subscription Video Streaming Services	$4,006	$5,251	$6,747	$9,438	$13,374	$16,604
Grand Total	**$5,582**	**$7,355**	**$10,272**	**$14,218**	**$19,676**	**$24,254**

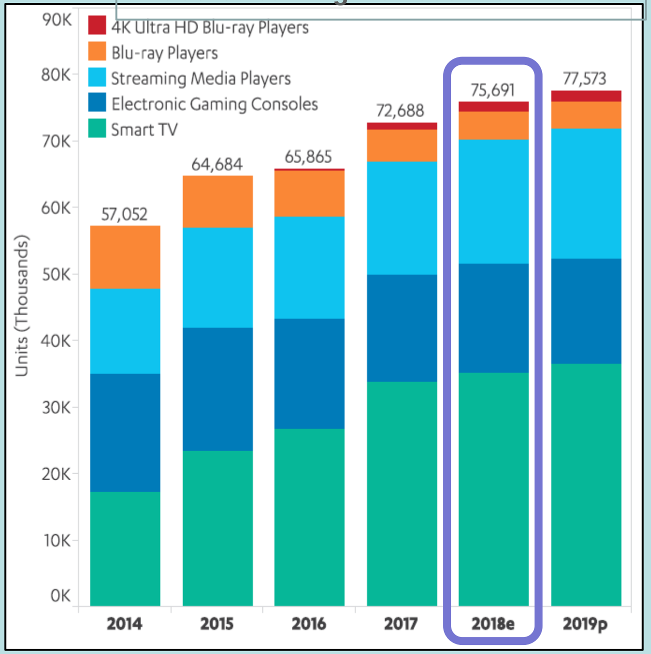
Source: CTA Sales & Forecast July 2018

7. The Evolution of Services

Devices & Streaming

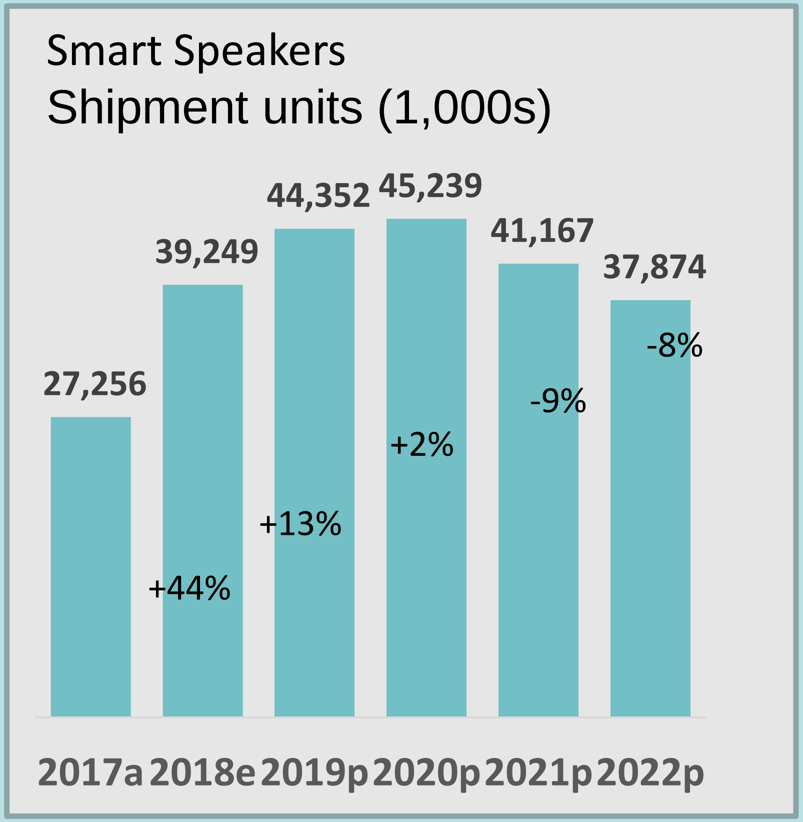
- **75.7 million** Blu-ray DVD players, smart TVs, gaming consoles and streaming media players will ship this year
  - **2.5% growth** projected for 2019
- **Smart TVs** and **streaming media players** make up the bulk of streaming devices
- **4K Blu-Ray** shipments nearly doubled in 2017 (≈1.2M 2018)
- **Streaming media players** will grow to over 18 million units in 2018 (up 10% from 2017)

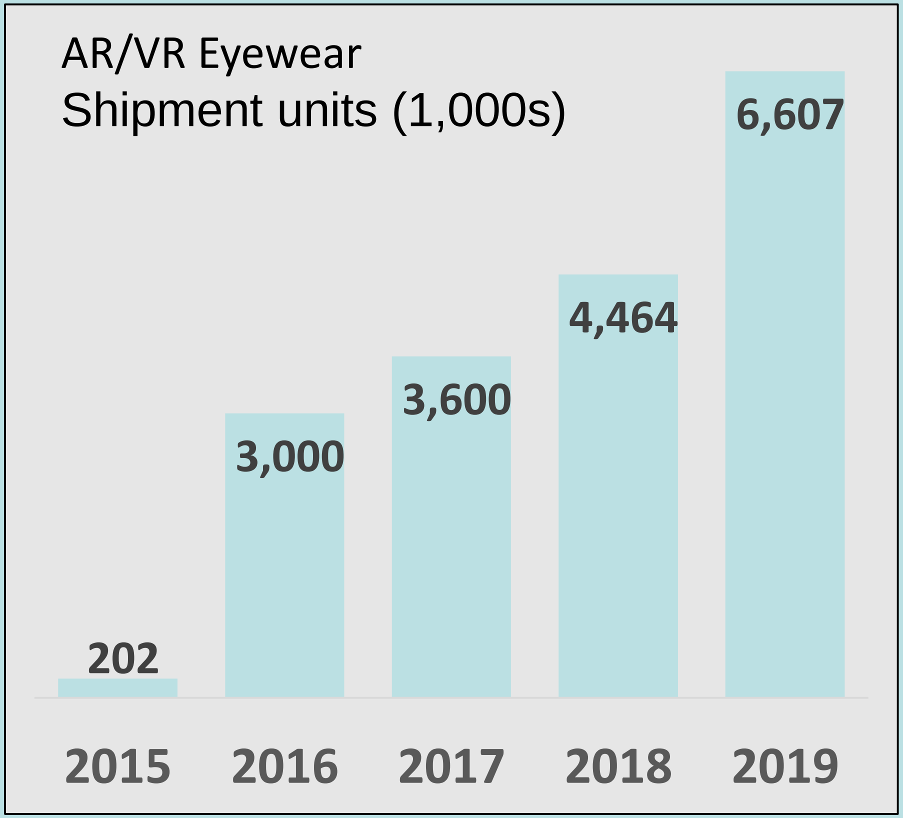
Video Streaming Devices – Unit Sales



Source: CTA Sales & Forecast July 2018

7. The Evolution of Services - Two Emerging Markets





Source: CTA Sales & Forecast July 2018

7. The Evolution of Services

Key Takeaways

- Storage

9. The FCC Structure – Offices and Bureaus

	Offices		Bureaus
1.	Administrative Law Judges	1.	Wireline Competition
2.	Communication Business Opportunities	2.	Wireless Telecommunications
3.	Engineering and Technology	3.	Public Safety and Homeland Security
4.	General Counsel	4.	Media
5.	Inspector General	5.	International
6.	Legislative Affairs	6.	Enforcement
7.	Managing Director	7.	Consumer and Government Affairs
8.	Media Relations		
9.	Secretary		
10.	Strategic Planning and Policy		
11.	Workplace Diversity		

- List of Speakers and Presentations

Presentations

- ❖04/30/2018: Dr. Raymond Cline, Jr., Lancium, LLC – "Nexus of Energy and Block Chain Technology" (https://www.lancium.com/)
- ❖05/07/2018: Dr. Tao Zhang , Open Fog Consortium – "Fog Computing"
- ❖ (https://www.openfogconsortium.org/)
- ❖05/21/2018: David King, Foghorn Systems "Intelligence at the Edge for Industrial IoT" (https://www.foghorn.io/)
- ❖06/18/2018 Mark Lewellen and Chris Masucci, John Deere, "Mobile Broadband Data Needs over Cropland",
- ❖07/09/18 Mark Winter, CareSpan, "Digital Healthcare" (https://www.carespanhealth.com/)
- ❖07/16/2018 Prof. Mahadev Satyanarayana, Dept. of Computer Science, CMU, "Edge Analytics" (https://www.cs.cmu.edu/)

Presentations - Continued

- 08/06/2018: Craig Mathias, Farpoint Group, – "Computation and Networking: New Strategies to address demand" (http://www.farpointgroup.com/)
- 08/13/2018: Dr. Chris White, Nokia Bell Labs, "Artificial Intelligence" (https://www.bell-labs.com/)
- 08/18/2018 Mauricio Aracena, Ericsson, "5G – The Road to AR/VR", (https://www.ericsson.com/en)
  (https://www.ericsson.com/en/trends-and- insights/consumerlab/consumer-insights/reports/merged-reality)
- 08/20/2018: Allan V. Cook, Deloitte "AR and VR" (https://www2.deloitte.com/us/en.html)
  (http://www.exponentials.xyz/ar-and-vr)

Presentations - Continued

- ❖011/26/2018: Chris Donnelly, Switch – Las Vegas, – “Hyper-scale Data Centers” (https://www.switch.com/)
- ❖12/03/2018: Dr. Ganesh Sundaram, Alef Mobitech, “The Edge Internet – Here and Now!” (http://www.alefmobitech.com/)

Speaker Biographies and Backgrounds

Speaker bio:

Raymond E. Cline, Jr., *PhD, Chief Mining Officer, Lancium LLC*

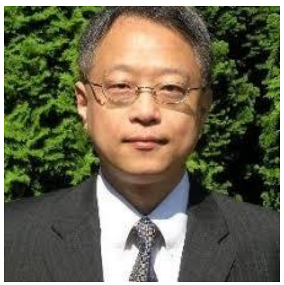
Dr. Cline is currently responsible the cryptocurrency strategy and initiatives for Lancium. Dr. Cline serves as a member of the IEEE Blockchain Initiative Steering Committee and is President/CEO of RWI Mining, LLC, a Blockchain mining firm.

He has participated in the development of a broad range of technologies, including high performance computing and communications technology, distance computing, collaborative computing, parallel processing, distributed computing, distributed object computing, distributed multimedia, networking protocols, and Asynchronous Transfer Mode (ATM) networking. He has applied these technologies to the development of systems to address needs in the petroleum, national security, manufacturing, and medical industries, with a specialization in recent years toward digital energy solutions (the application of dynamic, network centric operational models in the energy space).

Dr. Cline serves on the board of HARC, a research hub providing independent analysis on energy, air, and water issues to people seeking scientific answers; is a Fellow of the Borders, Trade, and Immigration Institute, a DHS Center of Excellence; and is a technical advisor to Advanced Green Computing Machines. Dr. Cline had previously led the Department of Energy funded Smart Grid Education and Training Coalition; was a member of the Executive Committee of TMAC, the Texas affiliate of the Manufacturing Extension Partnership (MEP) program of National Institute of Standards and Technology (NIST); served on the board of the Global Energy Safety Institute; and served as the Chairperson of the Cluster Development Committee of the Greater Houston Partnership Energy Collaborative.

Dr. Cline earned a PhD in Chemical Physics from the University of Illinois and a BS in Chemistry from Kent State University.

Speaker bio:



Dr. Tao Zhang, an IEEE Fellow, joined Cisco in 2012 as the Chief Scientist for Smart Connected Vehicles. Since then, he has also been leading the creation of strategies, technology and eco-systems for the internet of things and fog computing. Prior to Cisco, he was Chief Scientist and Director of Vehicular Networking, and Director of Mobile Networks at Telcordia Technologies (formerly Bell Communications Research or Bellcore). For over 25 years, Dr. Zhang has been in various technical and executive positions directing research and product development, which led to ground-breaking results in vehicular, mobile and broadband networking, including new technology, standards and products.

Dr. Zhang co-founded, and is a Board Director for, the Open Fog Consortium. He is the CIO and a Board Governor of the IEEE Communications Society. He co-founded and was a founding Board Director for the Connected Vehicle Trade Association. Dr. Zhang holds 50 US patents and has co-authored two books, *Vehicle Safety Communications: Protocols, Security and Privacy* (2012) and *IP-Based Next Generation Wireless Networks* (2004), both published by John Wiley & Sons. He co-founded the IEEE Communications Society Technical Sub-Committee on Vehicular Networks and Telematics Applications and served as its Chair from 2013 to 2015. He is a founding steering committee member of the IEEE Symposium on Edge Computing and the IEEE International Conference on Collaboration and Internet Computing. He was a co-founder and founding general chair and steering committee vice chair of the International Conference on Collaborative Communications (CollaborateCom). Tao has been serving on the editorial boards or as a guest editor for numerous leading technical journals. He has served on the industry advisory boards for multiple research organizations, has been an adjunct professor at multiple universities, and a frequent invited speaker at international conferences and industry events.

Speaker bio:

David King, CEO at FogHorn Systems, Inc

Company Overview:

FogHorn is a leading developer of “edge intelligence” software for industrial and commercial IoT applications. FogHorn’s software platform brings the power of machine learning and advanced analytics to the on-premise edge environment enabling a new class of applications for advanced monitoring and diagnostics, asset performance optimization, operational intelligence and predictive maintenance use cases. FogHorn’s solutions are ideally suited for OEMs, systems integrators and end customers in vertical markets such as manufacturing, power and water, oil and gas, mining, transportation, healthcare, retail, as well as Smart Grid, Smart City and Smart Car applications.

Speaker bio:

CareSpan®

Healthcare Without Borders™

Mark Winter, MBA

Mr. Winter is CEO of CareSpan. He has over thirty years of management experience in high technology, information services and health informatics for both private and public companies. He previously served as the executive Prize Lead for the XPRIZE Foundation and managed both the Nokia Sensing XCHALLENGE and Qualcomm Tricorder XPRIZE which are focused on catalyzing innovation in health sensing and diagnostic systems for consumers. He previously founded and served as Executive Vice President of Gluco Fitness Center, Inc. which offers wireless blood glucose and physiological monitoring of people with diabetes as part of an integrated exercise, diet and education program. As CEO of Simulis LLC he led the development of advanced clinical skills simulation-based training and assessment services that help large healthcare systems verify that their personnel follow evidence-based care practices and can safely operate medical devices. Mark has extensive knowledge of biosensors, interpretive medical devices, electronic medical record systems and consumer health portals and has spoken at numerous conferences on innovations in mobile health. Mark holds a MBA from Pepperdine University and has a BFA in Communications from Art Center College of Design (with Honors)

Mark Lewellen
Manager Spectrum Advocacy
John Deere & Company

Mr. Lewellen' s position as Manager of Spectrum Advocacy serves the needs of the company as it relates to regulatory, technical and government affairs, issues concerning the electromagnetic spectrum. Of particular interest is rural broadband as agriculture is driven more than ever by technology. Rural broadband is now a key enabler as our large self-propelled machines all come with data modems installed as a standard device. Mark is on the Smart Rural Community Advisory Committee (SRCAC) of NTCA–The Rural Broadband Association. He is also an active participant in the Rural Broadband Working Group whose members include, American Farm Bureau Federation (AFBF)—Co-chair, Association of Equipment Manufactures (AEM)—Co-chair, American Soybean Association (ASA), National Corn Growers Association (NCGA), AGCO, Trimble and Deere.

Chris Masucci
Senior Engineer (ISG)
John Deere & Company

Engineering Development Lead - Responsible for a team of Systems Engineers focused on developing wireless communications infrastructure. This includes a large variety of wireless and wired communications projects, and is aimed at providing all of the wireless solutions necessary for John Deere's data needs to and from all equipment in the field, on the farm or on the job site.

I am in the loop and provide engineering direction in all required aspects of product development, deployment and maintenance.

Mahadev Satyanarayanan (Satya)

Carnegie Mellon University School of Computer Science

Satya's multi-decade research career has focused on the challenges of performance, scalability, availability and trust in information systems that reach from the cloud to the mobile edge of the Internet. In the course of this work, he has pioneered many advances in distributed systems, mobile computing, pervasive computing, and the Internet of Things (IoT). Most recently, his seminal 2009 publication "The Case for VM-based Cloudlets in Mobile Computing" has inspired many technical efforts worldwide at the intersection of mobile computing, cloud computing, and IoT and has led to the emergence of Edge Computing (also known as "Fog Computing").

Research: As an experimental computer scientist, Satyanarayanan designs, implements, and evaluates systems. His research interests span mobile computing, pervasive computing and distributed systems (especially distributed file systems). Performance, availability, security, usability and manageability are some of the key attributes that he pays attention to in his work. One outcome of Satyanarayanan's studies is the Coda File System, which supports disconnected and bandwidth-adaptive operation. Key ideas from Coda have been incorporated by Microsoft into the IntelliMirrorcomponent of Windows. Another outcome is Odyssey, a set of open-source operating system extensions for enabling mobile applications to adapt to variation in critical resources such as bandwidth and energy. Coda and Odyssey are building blocks in Project Aura, a research initiative at Carnegie Mellon to build a distraction-free ubiquitous computing environment. Earlier, Satyanarayanan was a principal architect and implementor of the Andrew File System (AFS), which was commercialized by IBM.

Speaker bio:

Craig J. Mathias
Farpoint Group

Craig J. Mathias is a Principal with Farpoint Group, a wireless and mobile advisory firm based in Ashland, MA. Founded in 1991, the company works with manufacturers, network operators, enterprises and other organizations, and the financial community in technology assessment and analysis, strategy development, product specification and design, product marketing, education and training, and the integration of emerging technologies into new and existing business operations, all across a broad range of markets and applications. Craig is an internationally-recognized expert on wireless communications and mobile computing technologies and has published numerous technical and overview articles on a wide variety of topics. He is a well-known and often-quoted industry analyst and frequent speaker at industry conferences and events, including Webcasts, Webinars, videos, and podcasts. He currently serves as a columnist for various sites at TechTarget and ITProToday.com, and writes monthly feature articles for *Networkworld.com*. Craig holds an Sc.B. degree in Computer Science from Brown University. He is a member of the IEEE, the Executive Committee of the IEEE Communications Society (Boston Section), and the Society of Sigma Xi.

Speaker bio:

Christopher White
Nokia – Bell Labs

CHRISTOPHER A. WHITE leads the Network, Algorithms, Analytics, Control and Security (NAACS) lab in Bell Labs. He joined Bell Labs in 1997 after graduating with a Ph.D. in theoretical quantum chemistry from the University of California in Berkeley, California. His research interests include the development of computational models and methods for the simulation and control of interesting physical and digital systems. This has included work in areas ranging from linear scaling quantum chemistry simulations, to the design of new optical devices, to the global control of transparent optical mesh networks and to understanding and facilitating the propagation of ideas in organizations. In addition to the management of an international team of world-class researchers, Dr. White's current work focuses on the creation of assisted thinking tools that leverage structural similarity in data with the goal of augmenting human intelligence.

Speaker bio:

Allan V. Cook
Deloitte

Allan is the Global and US Technology, Media & Telecommunications Sector leader for Deloitte's Operations Transformation practice, and has more than 30 years of industry experience. Allan works with a wide variety of organizations building their innovation strategies, corporate visions, and business plans. His client work has focused on strategy, scenario planning, business transformation, innovation, and Digital Reality™ (augmented reality/mixed reality/virtual reality/360/immersive). As one of the global leaders of Deloitte's Digital Reality offering, Allan works with clients to develop and implement their strategies, pilots, and solution implementations in extended reality. He is also an active member of the Television Academy for Arts and Sciences in their Interactive Media branch.

Speaker bio:

Mauricio Aracena
Ericsson

Mauricio Aracena is Media Standardization Manager at Ericsson and he has more than sixteen years' experience in working with multimedia technologies for the mobile phone industry. He has actively contributed in defining the next generation multimedia standards for 3GPP, ATSC and DVB, recently in the area of High Dynamic Range. Currently, he is the Secretary and Board Member of the Virtual Reality Industry Forum (VRIF); he also co-chairs the Distribution Task Force within the same organization. Mauricio holds a M.Sc. in Electrical Engineering from The Royal Institute of Technology in Stockholm and an MBA from Blekinge Institute of Technology, Sweden.

Speaker bio:

Chris Donnelly
Switch

Chris Donnelly is the CXO (Chief Connectivity Officer) at Switch. Since joining Switch in 2008, Chris has focused his efforts on the development of the digital services and telecom wholesale buying consortium known as Switch CONNECT®. This unique and powerful
entity aggregates the collective buying power of over 800 clients to create the single largest purchasing cooperative in the marketplace. The combined market capitalization of Switch CONNECT's users has over $6.7+ trillion of purchasing power.

Chris works closely with the company's global carrier partners to ensure the Switch data centers are among the most cost-effective and network-enabled facilities in the world. The company's unique fiber optic gateway is one of the most robust network access points (NAP) in North America.

Prior to joining Switch, Chris has over 25 years of experience in the telecom industry and held various executive positions in the combined companies of Verizon (MFS, UUNET, WorldCom, MCI) as well as Qwest Communications. Chris also served as the President of Splice Communications, Inc. from 2003 until 2007. Chris serves on the American Red Cross Board of Directors, Southern Nevada Chapter.

Speaker bio:

Ganesh Sundaram
Alef Mobitech

Dr. Sundaram is the founder, and CEO of Alef Mobitech – an Edge Internet company. He is a leader in wireless technology with over 20 years of rich experience in technology creation and has worked extensively with operators globally. Prior to founding the company, he was a Distinguished Member of Technical Staff and lead multiple secure wireless solutions initiatives at Bell Labs, New Jersey. He has developed several foundational technologies, leading to new standards, products and deployments, and has authored over 50 patents relating to mobile data networking, architecture, security, cryptography, resource management and mobility management. He was a Bell Labs Fellow in 2012, inducted in to the Alcatel-Lucent Technical Academy in 2009, and is a recipient of two Bell Labs president's awards. He has a Phd in Mathematics from Purdue University and Master of Science degrees in Applied Mathematics and Mechanical Engineering from Oklahoma State University.

5G/IoT Working Group

Chairs: Russ Gyurek, Cisco
Brian Daly, AT&T

Date: ~~Dec 5, 2018~~ ~~Jan 14, 2019~~ March 26, 2019 [TAC 2018]

2018 Working Group Team Members

- Kumar Balachandran, Ericsson
- John Barnhill, Alianza
- Mark Bayliss, Visualink
- Marty Cooper, Dyna
- Pierre de Vries, Silicon Flatirons
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dick Green, Liberty Global
- Dale Hatfield, Univ of Colorado
- Tim Kagele, Comcast
- Steve Lanning, Viasat
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Jack Nasielski, Qualcomm
- Jesse Russell, incNetworks
- Kevin Sparks, Nokia Bell Labs
- Marvin Sirbu, Spec. Gov. Emp.
- David Young, Verizon

FCC Liaisons: Walter Johnston, Padma Krishnaswamy, Jonathan Campbell

Simplified Working Group Mission

- *The purpose of this working group is to study and report on the state of development of 5G era IoT applications across various market sectors and the network impact/evolution.*

- *Goal: Are there things that the Commission or other government agencies can or should do or shouldn't do relative to 5G and IoT to facilitate such developments?*

FRAMING THE 5G LANDSCAPE

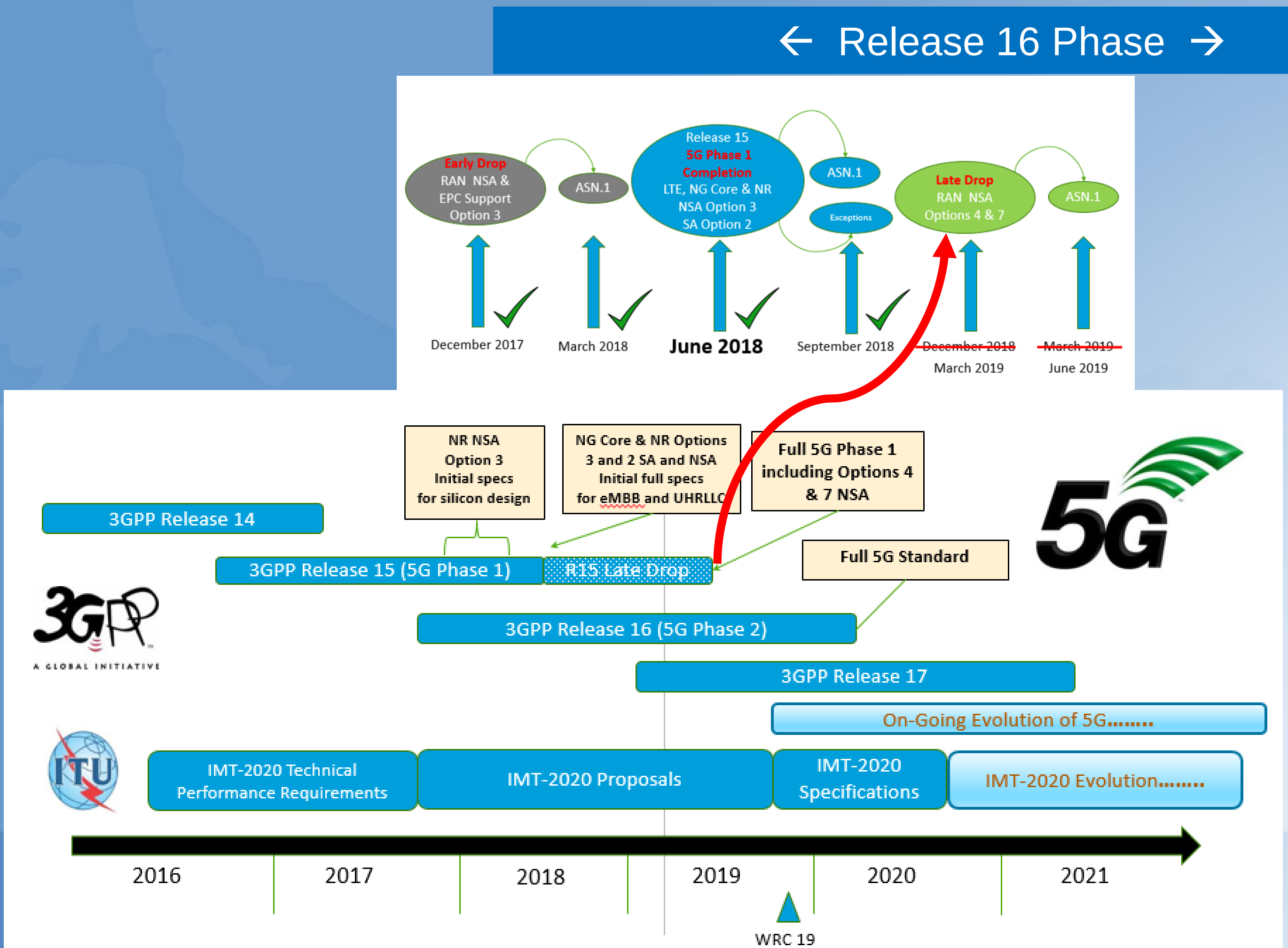
Areas of Discussion Q4

- 5G Opportunities & Challenges
  - Potential Barriers to Deployment
  - Massive IoT: EC, Slicing intersection
  - Slicing services and what it means for providers and customers
  - Edge Computing – Network compute convergence
- Policy & Spectrum Management Topics
- NR/Antenna Aesthetics
- Underserved and Rural
  - Digital Divide
  - Education

FRAMING DISCUSSION

Standards Status, Slicing, Edge Compute , NR Aesthetics & Underserved

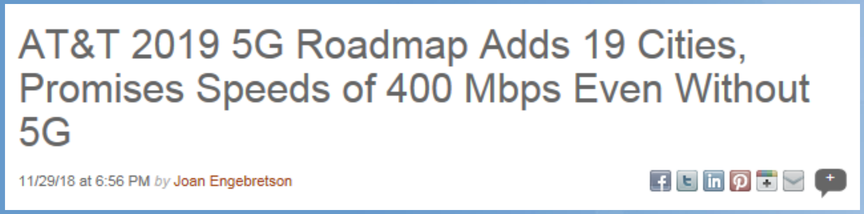
5G Projected Industry Standards Timelines



NSA: Non-Stand Alone
SA: Stand Alone
NR: New Radio

Framing 5G - Deployment

- Trials, PoC's and real deployments are underway
  - U.S. and worldwide deployments
- U.S. Deployment Announcements
  - 5G commercially available starting in 2018, more in 2019
  - Initially non-stand alone (NSA), stand alone (SA) for fixed wireless access (FWA)
  - 5G Largely an enterprise play – at least to start (AT&T)



AT&T 2019 5G Roadmap Adds 19 Cities, Promises Speeds of 400 Mbps Even Without 5G

11/29/18 at 6:56 PM by Joan Engebretson

TALKING TECH

BUZZ VIDEO PODCASTS NEWSLETTER

Sprint says it will bring first 5G smartphone to U.S. next year

Eli Blumenthal, USA TODAY Published 12:36 p.m. ET Aug. 14, 2018 | Updated 3:43 p.m. ET Aug. 14, 2018

cnet

BEST PRODUCTS REVIEWS NEWS VIDEO HOW TO SMART HOME CARS DEALS DOWNLOAD

MOBILE

T-Mobile bolsters 5G ambitions in $3.5 billion supplier deal with Ericsson

The 5G race is heating up.

BY ROGER CHENG / SEPTEMBER 11, 2018 7:09 AM PDT

THE VERGE TECH SCIENCE CULTURE MORE

HOME \ MOBILE \ TECH

Verizon will launch 5G home internet service starting October 1st

Starting Houston, Indianapolis, Los Angeles, and Sacramento

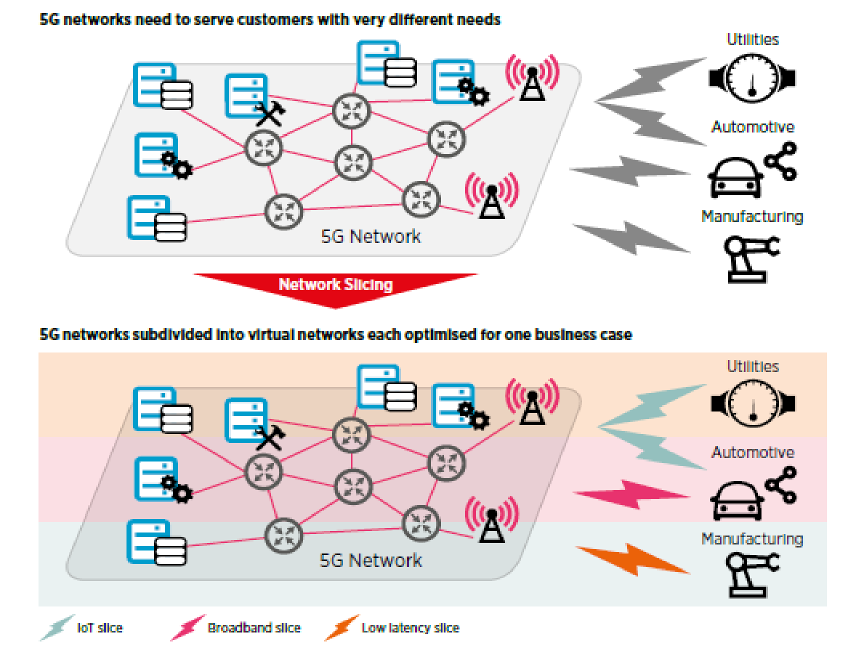
By Nick Statt | @nickstatt | Sep 11, 2018, 5:00pm EDT

Framing 5G – Potential Barriers to Deployment

- Small cell **densification**/mmWave deployment- up to 2-year cycle
  - For every cell, an MNO needs to gain site & equipment approvals; negotiate fees with the city or other landlord; deploy, provision & maintain the base station; ensure it has appropriate backhaul & power; and conform to the city's aesthetic and environmental regulations.
- **Transport** (backhaul, fronthaul, x-haul)
- **Location:** Real estate owners/property managers understand what they can do to ensure their buildings are 'small cell ready'

5G Network Slicing
From resource provisioning to new services

- Network slicing — early forms begun in LTE but never fully realized in 4G
- Enables network elements & functions to be easily configured/ reused in each network slice to meet specific needs
- Network slicing is conceived to be an end-to-end feature that includes the core network and the RAN
- Each slice can have its own network architecture and network provisioning (independent control)
- A network slice comprises dedicated and/or shared resources, e.g. processing power, storage, & bandwidth and has isolation from the other network slices
- Could span across multiple network parts (e.g. terminal, access, core, transport) and across multiple operators
- IoT support: options on QoS, latency, etc



Source: GSMA

Framing 5G – Edge Computing

- Basic premise is to place generic compute and storage close to the network edge
  - Extends the cloud—typically a centralized, single resource—to the local environment
- Proximity to the user enables higher bandwidth/ lower latency than possible in a centralized cloud environment

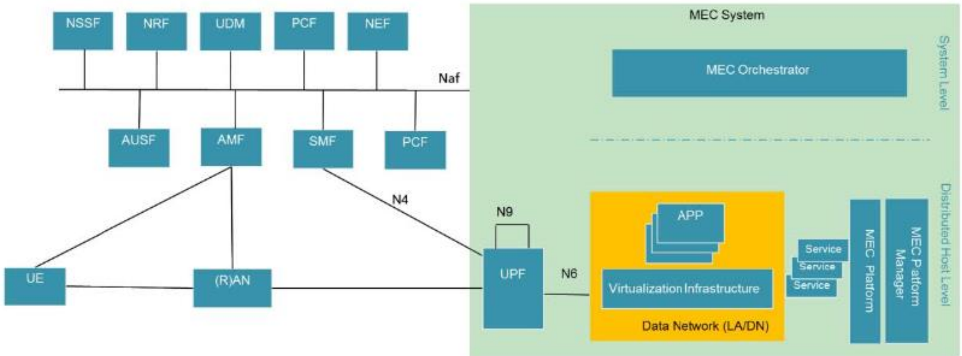


Figure: Integrated ETSI MEC deployment in 5G network   Source: ETSI

- Low latency and ultra-high reliability are critical for applications such as:
  - Automatic driving, traffic control, V2X
  - AR/VR
  - Mission-critical use cases such as public safety communications.
  - Remote health care (telemetry, analytics)
  - Extreme real-time apps (tactile internet)
  - Real-time HD video sharing
  - Industrial & manufacturing applications that require real-time remote control and operations (e.g. robotic controls).
  - Enterprise

NR/Antenna Aesthetics

- Intent is to reduce barriers to NR acceptance
- Issue is aesthetics of design
  - Densification for 5G mmWave will require greater number of antennas compared to traditional spectrum
  - Need guidelines for technologists for antenna design and placement
  - Need to meet varied zoning requirements of municipalities and enterprises
  - Address both brownfield and greenfield deployments

Source: Ericsson

5G and the Digital Divide: Both Opportunities and Challenges

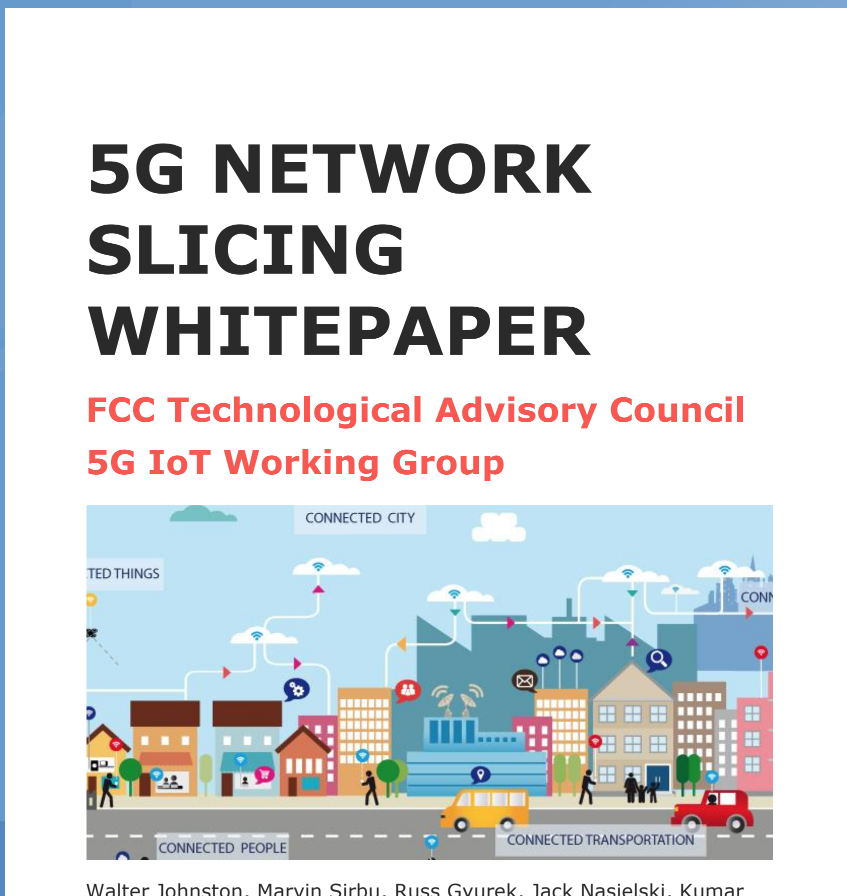
- Rural vs. Urban
  - Without 5G wireless BB in rural areas run risk of falling behind Urban areas
    - While LTE continues to evolve speed/latency, expect deployed LTE speeds less than urban areas (~100 Mbps versus up to Gigabit speeds in urban areas)
  - mmWave bands will have early benefit in urban and suburban areas
    - mmWave Deployments will be very localized
    - Inter-site distances will reduce across the board when provisioning BB service
- 5G NR technology is not restricted to mmWave - will eventually be deployed in the low cellular bands which may bring benefit to rural areas
- Rural communities benefit as transport infrastructure is built w/ mid-band & mmWave
  - Some deployments are likely to be capital-intensive, challenging economics
  - Wider bandwidths than 4G anticipated at mid-band and mmWave
  - Lower bands (Sub 6 GHz, for coverage) and mmWave developed in parallel, carriers are not choosing one over the other
  - Difference is in timing and how carriers manage spectrum in the sub 6 GHz bands

RECOMMENDATIONS
& SUPPORTING DOCUMENTS

5G/IoT WG Final Deliverables

- Whitepaper on **Network Slicing**
- Whitepaper on **Edge Compute** (EC)
- **Recommendation:** Slicing - Regulatory Clarity
- **Advisement:** related to 5G impact on Digital Divide
- **Recommendation*** on multi-stakeholder group – cross-sector conflict resolutions
  - Balance Antenna/NR placement with community desires
  - *Joint recommendation with Antenna TAC WG
- **Recommendation** on Public Notice related to 5G opportunities to support underserved areas tied to education

Tech-sharing: Whitepapers

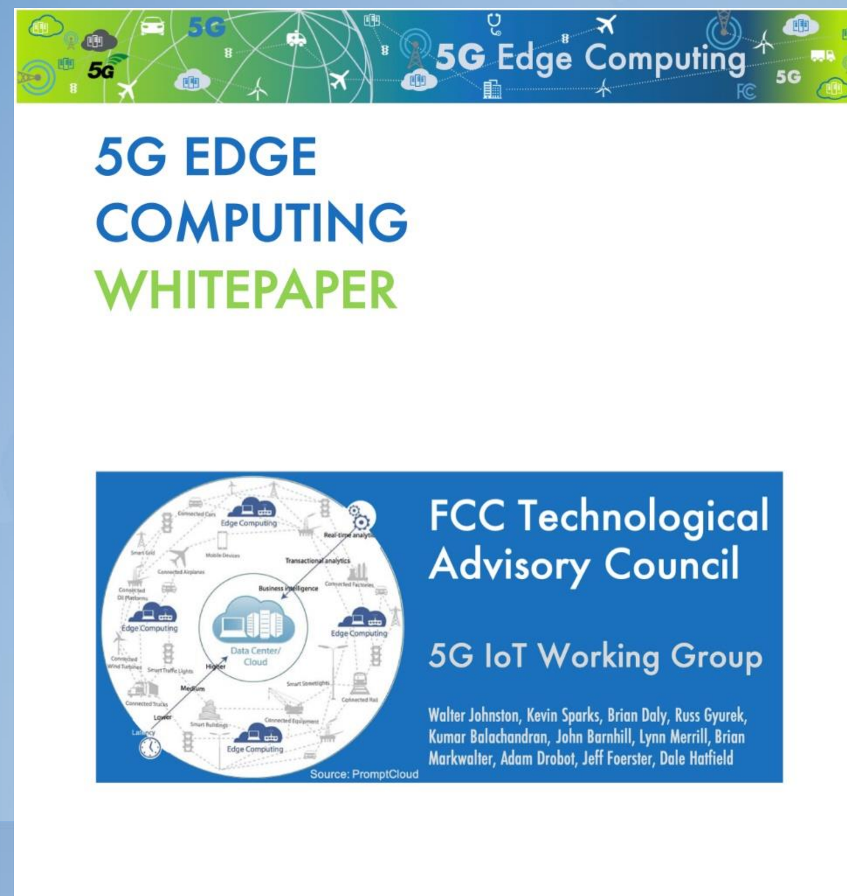


5G NETWORK SLICING WHITEPAPER

FCC Technological Advisory Council

5G IoT Working Group

Walter Johnston, Marvin Sirbu, Russ Gyurek, Jack Nasielski, Kumar



5G EDGE COMPUTING WHITEPAPER

FCC Technological Advisory Council

5G IoT Working Group

Walter Johnston, Kevin Sparks, Brian Daly, Russ Gyurek, Kumar Balachandran, John Barnhill, Lynn Merrill, Brian Markwalter, Adam Drobot, Jeff Foerster, Dale Hatfield

Slicing

- **Recommendation (a)**: Assuring these capabilities can be implemented consistent with regulatory policy with timely policy development.
  - FCC to provide "regulatory certainty" related to the offering and use of 5G network slicing
  - what are do's and don'ts (protect investments).
  - Will slicing deployments collide with any existing or potential rules?
  - How does slicing fall into "communications services" definition?
- **Recommendation (b)** FCC explore how to leverage "slicing" to provide emergency/critical services; public safety and support
  - Opportunity to bring emergency services into the core infrastructure
  - **Advisement**: FCC stay alert to potential market disparities as 5G slicing technology is deployed and evolves

5G Antenna Aesthetics

- 5G roll out is likely to be slowed by public resistance to install of small cells in their communities/neighborhoods.
- Small cell installations can be designed to better blend in with surroundings, potentially reducing resistance to their presence
- **We recommend** that the FCC use its influence with the cellular industry to strongly recommend the development & maintenance of guidelines/ industry standards to improve the appearance of small cell installations.

Source:wsj

Recommendation

- Issue Public Notice to gather industry, providers, citizens, and community input
- FCC facilitate a multi-stakeholder group to create such guidelines

***Goal**: aesthetics and fit of antenna design and placement*

Underserved Communities and 5G Impacts

- *How can 5G impact digital divide?*
  - *Education, Healthcare, Agriculture and Smart Transportation are all potential use cases.*
  - *In general the economics tied to customer density do not support rural and underserved communities.*
  - *Low frequencies targeted for rural deployments don't have the channel BW that will allow the expected 5G data rates. Support massive IoT/delay tolerant apps*
  - *There is no easy answer to incenting 5G for underserved areas.*
- **Recommendation**: the FCC initiate an inquiry into economic models to support service ubiquity
  - Consider 5G in terms of vertical deployments and the need for ubiquity:
    - Agriculture, Healthcare, Education, Transportation, etc.
- **Advisement:** TAC directs attention to the issue of a potential widening digital divide between underserved areas and served areas as 5G is deployed.

5G/IoT Working Group

Proposed CY 2019 Focus

Simplified Working Group Mission- *proposed 2019*

- *The purpose of this working group is to study and report on the state of 5G related technologies, applications and capabilities and the impact to the communications network and related markets/verticals. 5G creates many new service types and models including; slicing, MEC, eMBB, URLLC (automation/AG), and massive IoT, all of which should be studied related to current rules and requirements. The working group should advise the FCC on ways to encourage ubiquitous 5G build-out and adoption as well as any potential impediments.*

Will seek additional team members from cloud companies and ISP's

Proposed WG Focus and Priorities 2019

- Track and advise FCC in relation to status and impact of WW and U.S. 5G deployments
  - Advise and update FCC on standards progression: Release 16, Release 17, IMT-2020
  - How FCC can encourage deployments and remove potential barriers
- Collaborate with FCC TAC CPSN WG on impact of 5G related technologies on network
- Examine WW spectrum allocation strategies and models. Examples:
  - Non-Public 4G/5G spectrum: eg. 37Ghz, CBRS, 900Mhz, top end of 6Ghz
  - Examine potential of [57]64-71Ghz band
  - Explore “Lightly licensed” framework- affordability; spectrum rights associated to property/geographies
  - Interference mitigation technologies: what is technically feasible
  - CBRS opportunity

Proposed WG Focus and Priorities 2019

- Examine slicing related to service exchanges and interconnects
  - Explore FCC role in driving slicing-roaming agreements, “slicing templates”, service federations
- Rural/Under-served: How can FCC encourage 5G opportunities in these sectors
  - Interconnect, peering and transport (x-haul) issues for rural, shared facilities models
  - The economic impact of 5G and related business models: Agriculture, education, healthcare, transportation, etc
- 5G Security and trust
  - Malicious IoT attacks, up the stack attacks including DDoS
  - Physical layer- illegal transmitter, jamming, spoofing
  - Standard bodies work and related solutions

Proposed Additional 2019 Topics: "*Get Smart About It*"

- MAEC/MEC: how in-network compute will affect the network, services
  - Transition intelligence being distributed- what is impact on end-to-end
- Standards
  - Beyond Release 15, track Release 16 and 17 progress
- Industry use of "open"- to what extent is 5G open?
  - Openness in the network infrastructure (Ex. Open RAN)
- Explore impact on verticals
  - Standards focus on verticals
  - Plus how MEC, Slicing, URLLC, TSN, related to vertical success
- New players in the eco-system:
  - SDN, Edge, vRAN, SD-WAN, O-RAN
- Identity management
- SIM evolution
- Privacy

Proposed Speakers 2019

- ATIS
- CBRS Alliance
- GSMA- slicing federation
- 5G ACIA- TSN/URLLC, industrial
- 5GAA, SAE- Automotive/transportation
- Digital Globe
- Rural communications company (TBD)
- Rural: Grain processors, other
- IEEE: WiFi- impact and effect of 5G
- NR tune-ability speaker
- Verticals:
  - Industrial
  - Enterprise: ex. Walmart
  - Smart cities

THANK YOU!

Acronym List

- AR/VR: Augmented Reality/Virtual Reality
- CBRS: Citizens Broadband Radio Service
- DDoS: Distributed Denial of Service
- eMBB: enhanced Mobile BroadBand
- FWA: Fixed Wireless Access
- IoT: Internet of Things
- LTE: Long Term Evolution
- MAEC/MEC: Multi-access Edge Compute/Mobile Edge Compute
- NB-IoT: Narrow-band IoT
- NR: New Radio
- NSA: Non-Stand Alone
- O-RAN: O-RAN Alliance
- QoS: Quality of Service
- RAN: Radio Access Network
- SA: Stand Alone
- SDN: Software Defined Network
- SD-WAN: Software-Defined networking in a Wide Area Network
- SIM: Subscriber Identity Module
- TSN: Time-Sensitive Networking
- URLLC: ultra reliable low latency communications
- V2X: Vehicle to Everything
- vRAN: virtual RAN

Mobile Device Theft Prevention WG

Report to the FCC TAC

December 5, 2018

WG Participants

- Co-Chairs:
  - Melanie Tiano, CTIA
- FCC Liaisons:
  - Walter Johnston
  - Charles Mathias
  - Elizabeth Mumaw
  - Michele Wu-Bailey
- FCC TAC Chair:
  - Dennis Roberson

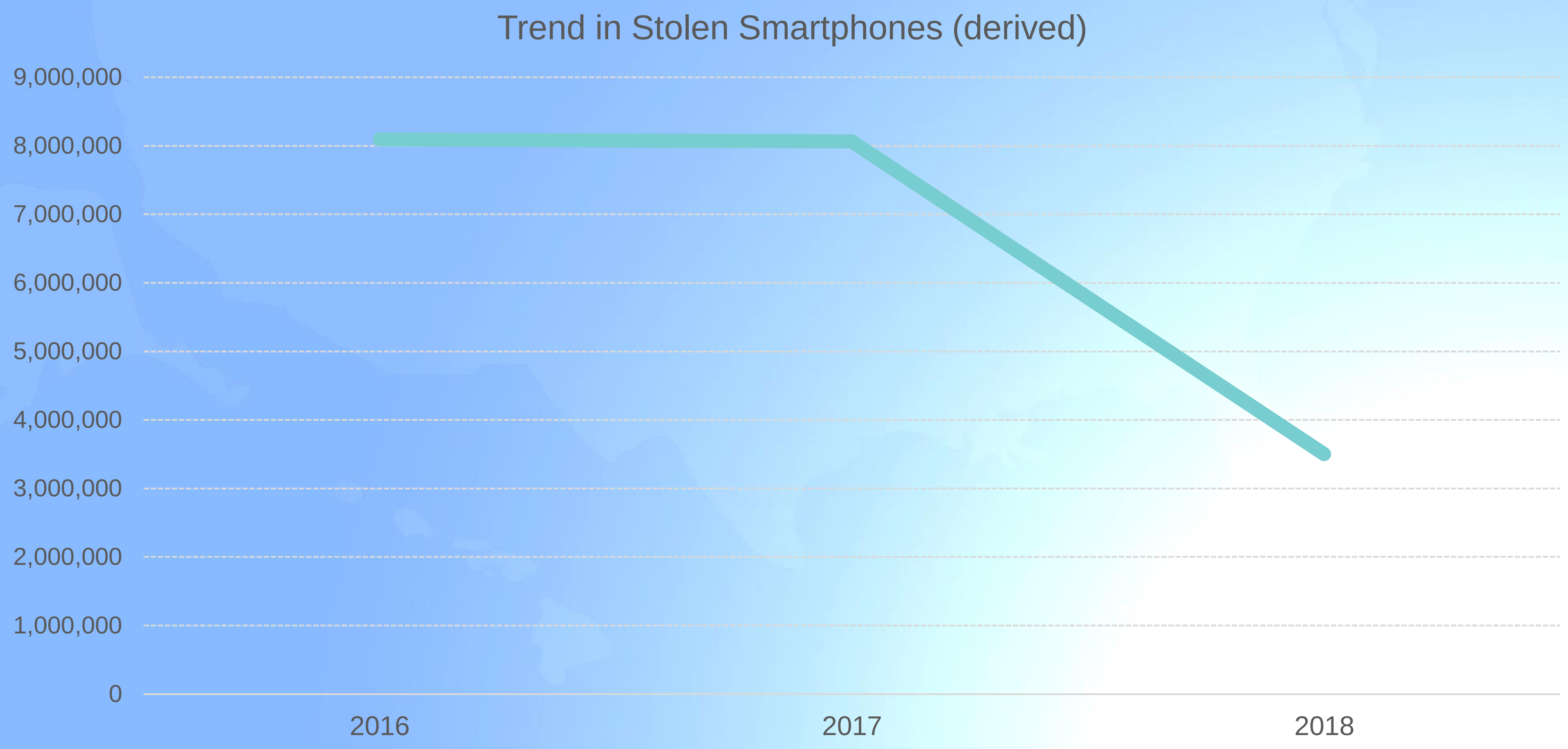
- Jason Novak, Apple
- Maria Kirby, Apple
- Brian Daly, AT&T
- John Marinho, CTIA
- Joseph Heaps, DOJ National Institute of Justice
- Max Santiago, ecoATM
- Kevin Harris, ecoATM
- James Moran, GSMA
- Thomas Fitzgerald, NYPD
- Joseph Hansen, Motorola Mobility
- Joes Voss, Motorola Mobility
- Jack McArtney, Recipero
- David Dillard, Recipero
- Les Gray, Recipero
- Mark Harmon, Recipero
- Bill Alberth, Roberson and Associates
- Robert Kubik, Samsung
- Maxwell Szabo, City and County of San Francisco
- Steve Sharkey, T-Mobile USA
- Gary Jones, T-Mobile USA
- Mark Younge, T-Mobile USA
- Samuel Messinger, United States Secret Service

Thank You!

Efforts of MDTP WG

- Industry Voluntary Commitment to Include Anti-Theft Tools on Devices
- Stolen Phone Checker

Impact of Efforts



2018 Focus

- Focus on supporting FCC efforts in working with foreign regulatory agencies to combat the theft and use of illegal mobile devices, including working to identify where devices go once they are stolen.
- Reassess the effectiveness of the information portal and make recommendations, as appropriate, for its future improvement.
- Study whether mobile device theft has declined in the United States since these efforts have been implemented.

- With this tasking, the MDTP WG focused on three primary areas:
  - Continue to work with law enforcement to assess the benefits of the information portal to relevant stakeholders (*i.e.* stolenphonechecker.org) and identify enhancements.
  - Develop baseline statistics on device theft based on data from directed consumer surveys and law enforcement to help track long-term progress and identify theft scenarios.
  - Study future mobile device threats and trafficking across international borders and make further recommendations.

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Continue to work with law enforcement to assess the benefits of the information portal to relevant stakeholders (*i.e.* stolenphonechecker.org) and identify enhancements.

- Evolution
  - Contraband
  - Streamline Onboarding Process

- Efforts to Increase the Awareness

Recommendations

- Since its launch in May 2017, the Stolen Phone Checker has been increasingly adopted by consumers, commercial resellers, and law enforcement—more than one million queries have been made. While this is a successful and promising start, the MDTP WG recommends that:
  - CTIA and GSMA monitor the Stolen Phone Checker to identify possible enhancements and make any necessary changes to increase effectiveness and encourage broader adoption, including efforts to streamline law enforcement access to and enrollment in the Stolen Phone Checker service.
  - The FCC continues to promote the Stolen Phone Checker to consumers, retailers and traders of devices, and throughout the law enforcement community, possibly through engagement with local law enforcement agencies and with law enforcement associations, such as the IACP.

Develop baseline statistics on device theft based on data from directed consumer surveys and law enforcement to help track long-term progress and identify theft scenarios.

- CTIA Survey Data
  - The survey confirmed that consumers continue to adopt strong cybersecurity practices to protect their mobile devices and personal information. The survey found that:
    - Almost three quarters of wireless consumers reported using PINs/passwords on their smartphones, up significantly from the first survey in 2012 where only 50 percent of users reported using these features; and
    - Fifty-seven percent are aware of having built-in remote lock and erase software installed on their smartphones.
    - Nearly three quarters of consumers run software updates every or almost every time on their personal smartphones;
    - Almost half of users responding have an anti-virus program installed on their smartphones, up 18 percent from 2015, and up 52 percent from 2012; and
    - Ninety percent say they are familiar with the term cybersecurity, defining it as protection, safety and prevention of unauthorized access.

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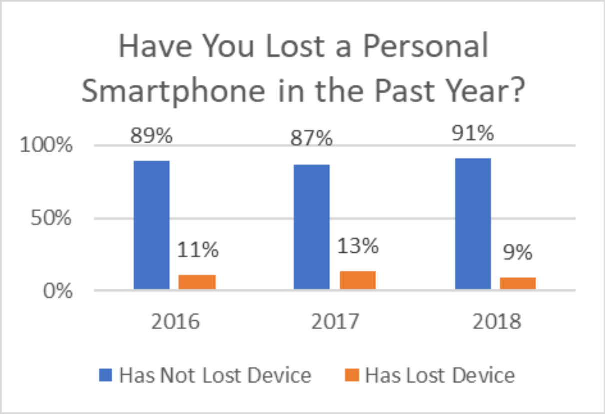
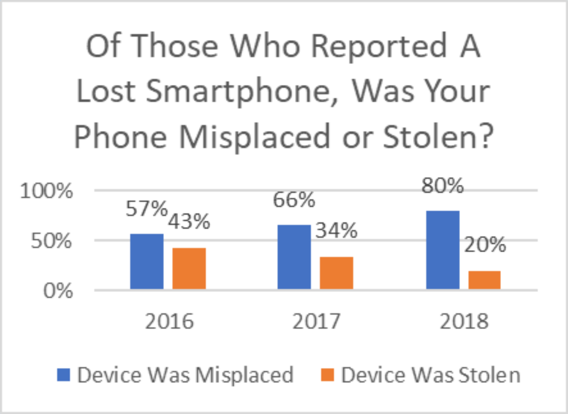
Statistics Continued

The survey also found that only nine percent of respondents reported losing a smartphone. This is down from 13 percent last year. Of those consumers who reported having lost a device, only 20 percent reported that the device was stolen, with the rest reporting it was simply misplaced. The percentage of devices being reported as stolen, as opposed to misplaced, has decreased year over year.





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Statistics Continued

- Available Public Information
  - Since 2013, reports of mobile device thefts have shown indications of steady decline. In Washington, D.C., Metro Transit Police data show a decline of 51 percent in the theft of cell phones from 2013 to 2015.
  - The New York City Police Department's (NYPD) Crime Complaint database includes details about crimes related to electronic devices. According to this data, thefts of personal electronic devices in New York have fallen by a third since 2013. Another survey, from 2015, found that smartphone thefts dropped as phone manufactures and carriers enabled deactivation mechanisms or "kill switches" which make lost or stolen phones unusable.

Recommendations

- Stakeholders, including FCC and industry, focus attention on building an enduring relationship with groups that have broad membership (e.g. IACP, Major Cities Chiefs Police Association (MCCA), National Sheriffs' Association (NSA)) to help simplify the efforts of gathering mobile device theft statistics. CTIA's Stolen Phones Working Group could be a possible point of contact outside of the TAC MDTP WG.

- FCC consider additional methods to gather statistics related to mobile device theft. For example, the FCC could work with IACP, MCCA, or NSA to conduct a survey of members.

- Finally, industry groups are encouraged to conduct surveys to identify consumer trends, awareness, and adoption of available security and anti-theft tools. Future surveys could expand upon the source of consumer knowledge and awareness (i.e. are consumers implementing these practices based on carrier recommendations, law enforcement public awareness campaigns, or news and consumer-oriented tips and best practices?). Determining where most consumers are obtaining information about mobile device security practices may help sharpen the focus of existing messaging, identify potential gaps in information, and enhance the most effective means of reaching end-users.

Study future mobile device threats and trafficking across international borders and make further recommendations.

- Engaged with South American counterparts thru FCC Staff, CITEL/OAS
  - Colombia
  - Brazil
  - Peru
  - Costa Rica

Country Interviews

Country	Blacklist	Whitelist	Challenges
Colombia	Yes	Yes	IMEI Tampering
Peru	Yes	Yes	Flashing IMEIs
Brazil	Yes	Yes - Pilot Program	IMEI Tampering
Costa Rica	Yes	No	IMEI Security – Focusing on a solution that will allow blocking from the network while also allowing roaming. Slow response times. Currently takes 24 hours to refresh the lists, would like to have that down to 15 minutes.

Recommendations

- Request and review evidence from international counterparts to assess differences internationally—including the prevalence of substandard and counterfeit devices in local markets—that make IMEI duplication a problem abroad and not a problem domestically.

- Continue to engage with South American counterparts on mobile device theft issues relating to collaboration on the global blacklist database; country specific concerns, such as duplicate IMEIs and issues related to whitelisting; international trafficking of stolen devices; and sharing best practices and improving cross-border coordination.

- Continue to promote and expand awareness and use of the GSMA Black List, IMEI security weakness reporting and correction enablers, and device-based anti-theft features internationally.

Recommendations Continued

- Continue to study the movement of stolen devices from the U.S. to other jurisdictions and use that information to encourage other countries to adopt measures to combat the import and use of devices stolen abroad.

- Work with relevant standards organizations (e.g. ATIS) and industry associations such as GSMA, which operates an IMEI security monitoring and reporting service to assess mobile device IMEI security levels and the availability of hacking tools, to better understand security of IMEI and why IMEI reprogramming is reported as a major source of fraud in foreign countries.

Thank You

Questions