Technical Advisory Council
Federal Communications Commission
Summary of Meeting
September 20, 2018

The Technical Advisory Council (TAC) for the FCC was convened for its twenty-eight meeting at 12:30 A.M. on September 20th, 2018 in the Commission Meeting Room at the FCC headquarters building in Washington, DC. A full video transcript of the meeting is available at the FCC website at http://www.fcc.gov/encyclopedia/technology-advisory-council together with a copy of all materials presented at this meeting. In addition, materials presented at this meeting are included in electronic form in an Appendix to this document.

In accordance with Public Law 92-463, the entire meeting was open to the public.

Council present:

Reza Arefi, Intel Corporation	Stephen Hayes, Ericsson North America
John Barnhill, Alianza	Frank Korinek, Motorla Solutions
Mark Bayliss, Visual Link Internet, Lc	Karri Kuoppamaki, T-Mobile
Nomi Bergman, Advance Newhouse Communications	Steve Lanning, Viasat, Inc
John Chapin, Roberson & Associates Consulting	Gregory Lapin, Independent Consultant
Marty Cooper, Dyna LLC	Kevin Leddy, Charter Communications
Brian Daly, AT&T	Hamidreza Memarzadeh, Samsung
Pierre De Vries, Silicon Flatirons Center for Law, Technology, and Entrepreneurship University of Colorado at Boulder	Lynn Merrill , Monte R. Lee & Company
Adam Drobot, OpenTechWorks	Jack Nasielski, Qualcomm, Inc.
Jeff Foerster, Intel Corporation	Dennis Roberson, Illinois Institute of Technology
Lisa Guess, Cradle Point	Jesse Russell, incNetworks
Russ Gyurek, Cisco Systems	Marvin Sirbu, Carnegie Mellon University
Dale Hatfield, Silicon Flatirons Center for Law, Technology, and Entrepreneurship University of Colorado at Boulder	Melanie Triano, CTIA

Attending Remotely:

Lynn Claudy, National Association of Broadcasters

FCC staff in addition to Mr. Johnston and Mr. Knapp included:

Robert Pavlok, FCC	Michael Ha, FCC

Meeting Overview

Dennis Roberson, TAC Chairman, began the meeting by commending the attendance of Russ Gyurek, Cisco at the present meeting, considering the devastation caused by the recent Hurricane Florence in North Carolina where Mr. Gyurek resides. Mr. Knapp next expressed confidence that the TAC would be able to meet the accelerated schedule for draft recommendations to the Chairman. Dennis Roberson also noted that the next meeting of the TAC would represent the 20th anniversary since its formation and indicated he would be making some plans in this regard and solicited volunteers to help. The work group chairs then proceeded with their presentations. A copy of the presentation is attached herein.

At the end of the presentations, the TAC Chairman thanked Melanie Tiano, for keeping the TAC meeting on time. Julie Knapp again thanked the TAC members for their efforts. Walter Johnston, the DFO, noted that he would be retiring at the end of the year and expressed his appreciated for having worked with the TAC members over the years. The meeting was then concluded.

Walter Johnston, Chief EMCD-OET
FCC

Tectological Advisory Council

September 20, 2018

Agenda

- Introduction - (Dennis Roberson/Julie Knapp)
- Computational Power and Stress on the Networks
- 5G and IoT
- Antenna Technology
- Communication Strategies for Drones
- Mobile Device Theft Prevention
- Wrap-up

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: September 20, 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
- Russ Gyurek, Cisco
- Stephen Hayes, Ericsson
- Mark Hess, Comcast
- Farooq Khan, Phazr
- Steve Lanning, ViaSat
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Tom McGarry, Neustar
- 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

- WG Presentations – more coming before the Dec TAC!

- Preliminary Report for Work in Progress

  - ❑ Growth
  - ❑ Trends
  - ❑ Impacts
  - ❑ Technologies
  - ❑ Consequences
  - ❑ Recommendations

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/)
- 08/20/2018: Allan V. Cook, Deloitte “AR and VR” (https://www2.deloitte.com/us/en.html) (http://www.exponentials.xyz/ar-and-vr)
- 06/18/2018 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)

❑ Growth: Demand on Network Resources and Evolution of Network Technologies

- **Big Picture**

  - Digitization and the Innovation around it is driving network demand!
  - This involves many technologies built on top of Communications, Computing, Storage, and Sensor Resources – which are increasingly tangled with each other in Network Service Offerings.

- Are the business models, policy incentives, and investments in technology keeping pace to meet demand?
- Are the new services and the deployment patterns serving the American population to satisfy their participation in the nations economy?
- Are there breakout applications and technologies that could further increase demand dramatically and have fundamental impacts on the Network?

❑ Growth: Demand on Network Resources and Evolution of Network Technologies

- **Big Picture**
  - The current US legal framework and governmental agency missions presume that the network infrastructure can be abstracted from the integration of communications, computation, storage and sensing that are required to deliver advanced digital services. It is worthwhile posing the question: Does the country need to fundamentally re-examine this approach to policy-making to recognize the trend in how digital products, services, and widely used processes are being deployed and used.
  - Arguably we have redefined modern packet-based communications as lying outside the scope of common carriage. The FCC should explore how to adapt to the emergence of next generation information infrastructures that are composed of communications, computing, storage and sensing.

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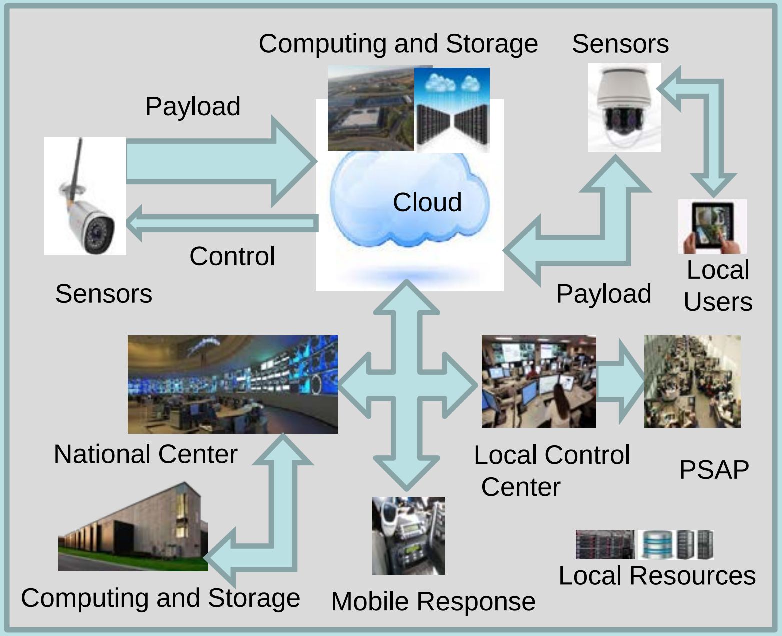
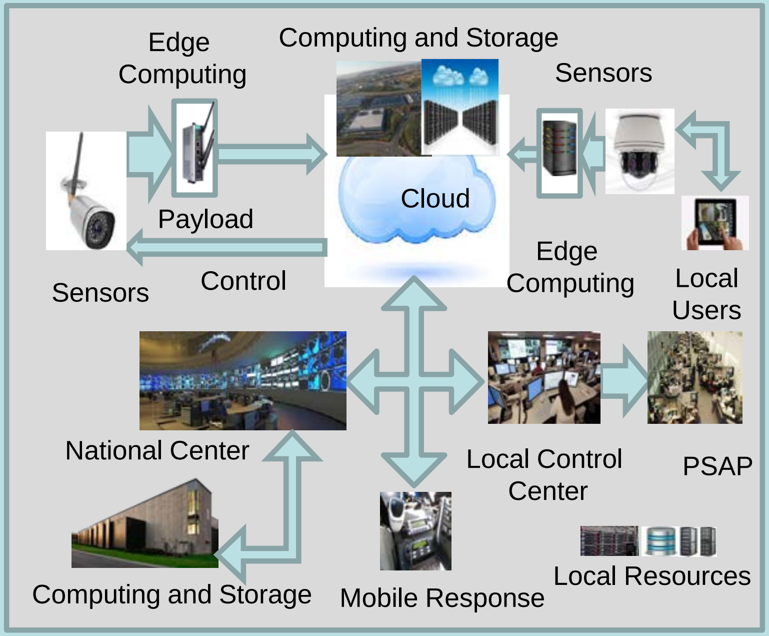
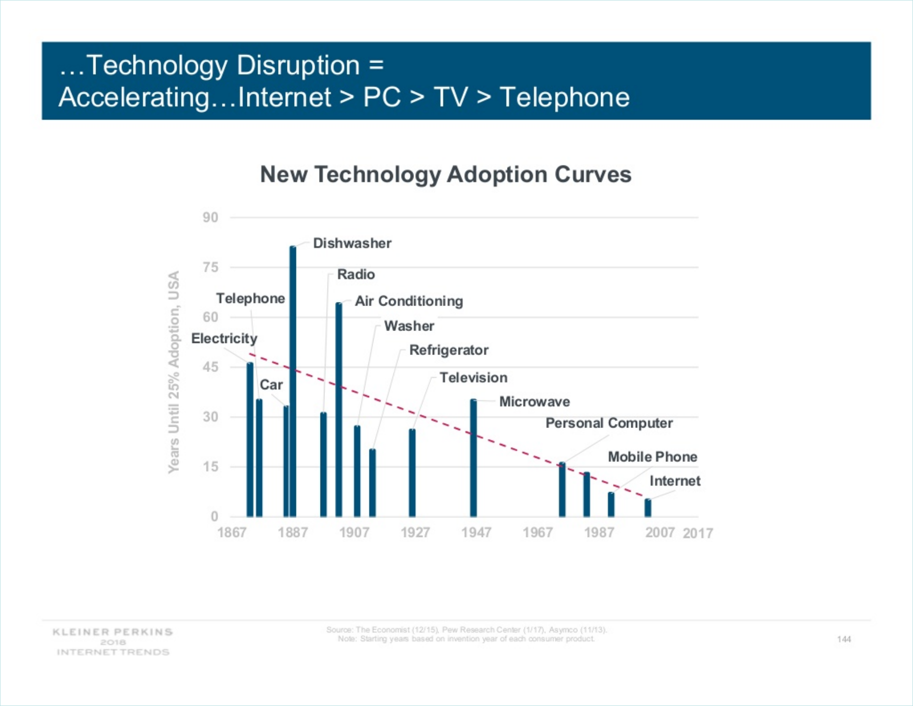
❑ Growth: Demand on Network Resources and Evolution of Network Technologies

- **Big Picture – An Example of "Network Resource" use for an application**





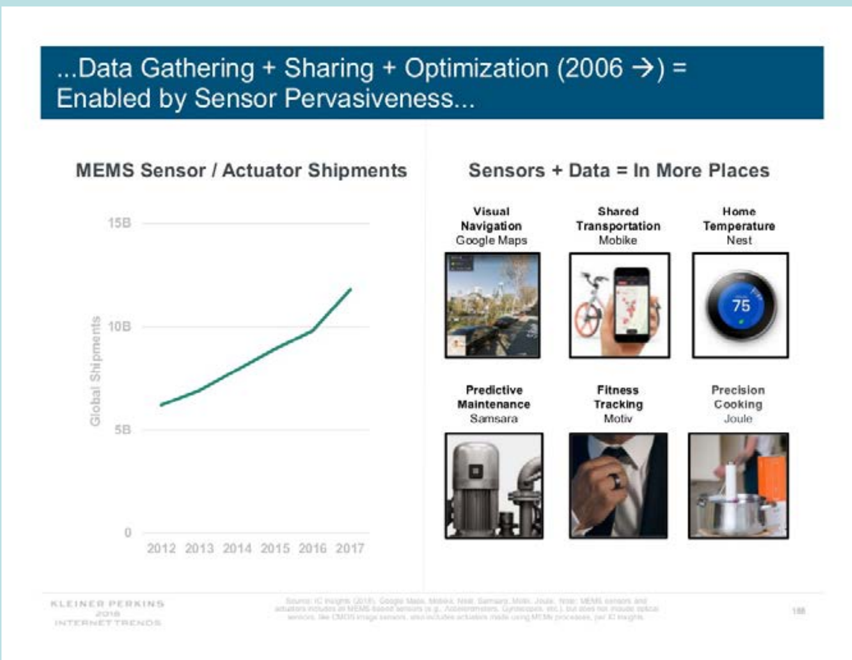
❑ Growth: Demand on Network Resources and Evolution of Network Technologies



Technologies in the Wings

- Cloud, Edge, and Fog Computing
- Video and Sensor Data Sources
- Augmented Reality
- Virtual Reality

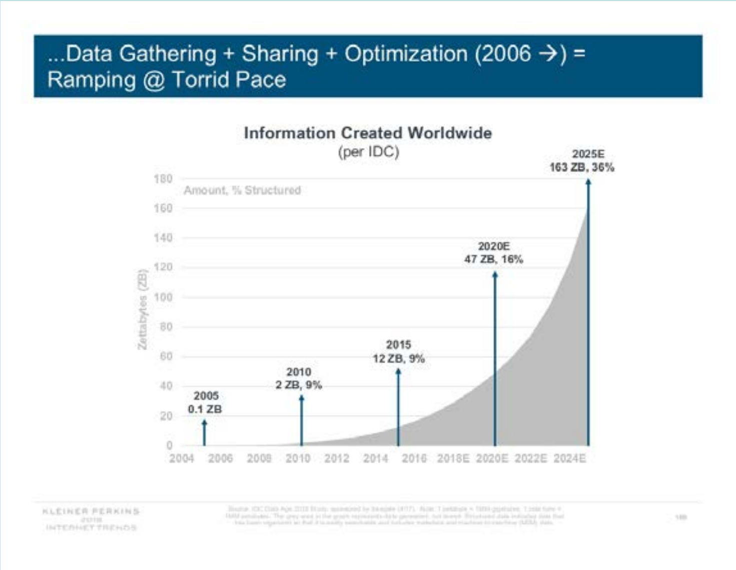
❑ Growth: Demand on Network Resources and Evolution of Network Technologies



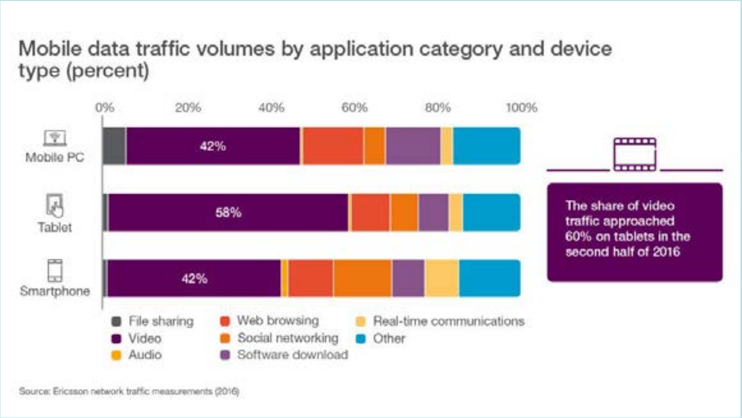
Technologies in the Wings

- Data Handling Technologies
  - Volume
  - Velocity
  - Variability
- Artificial Intelligence
- Machine Learning
- Block Chains

❑ Growth: Demand on Network Resources and Evolution of Network Technologies



Data Created World Wide

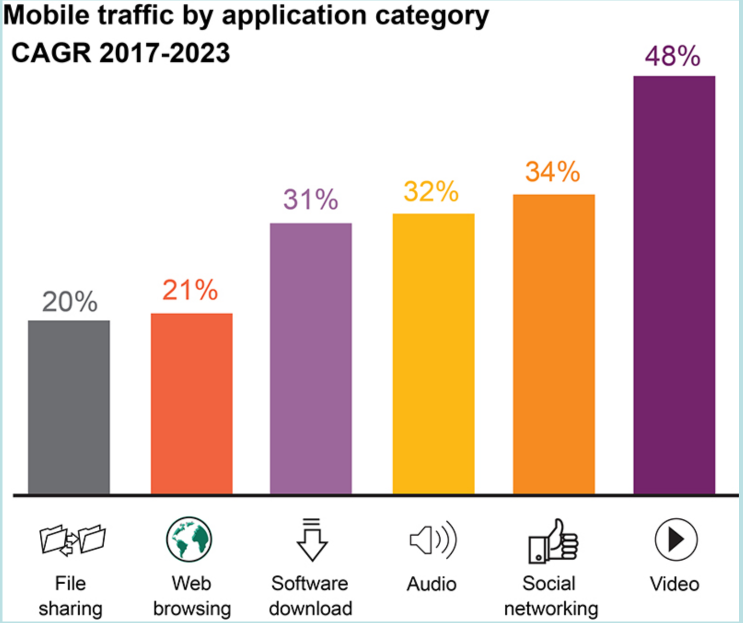


Usage Patterns by Platform For Mobile and Nomadic Devices

Source: Mary Meeker, Kleiner Perkins

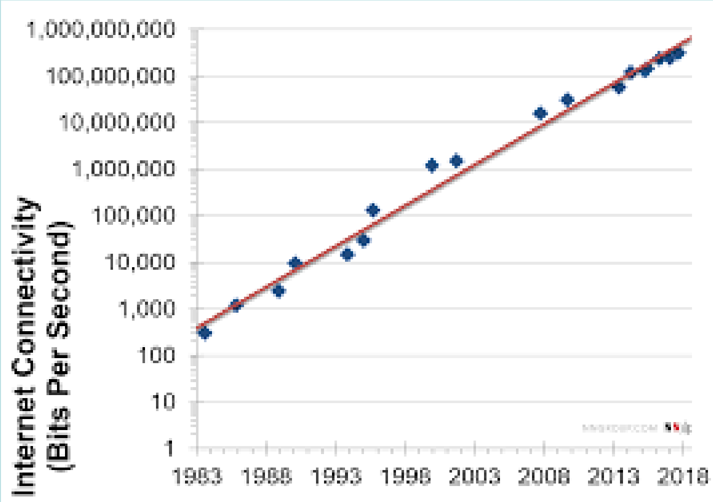
Source: Ericsson Mobility Report

❑ Growth: Demand on Network Resources and Evolution of Network Technologies

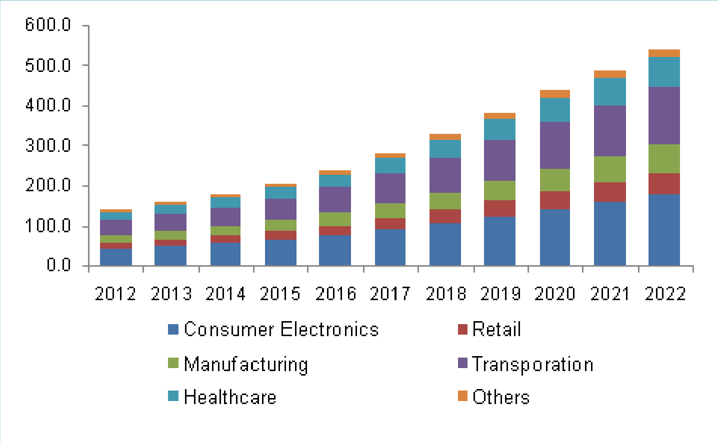


In the Consumer Mobile Space Rapid growth across all categories!

❑ Growth: Demand on Network Resources and Evolution of Network Technologies



Communication Bandwidths

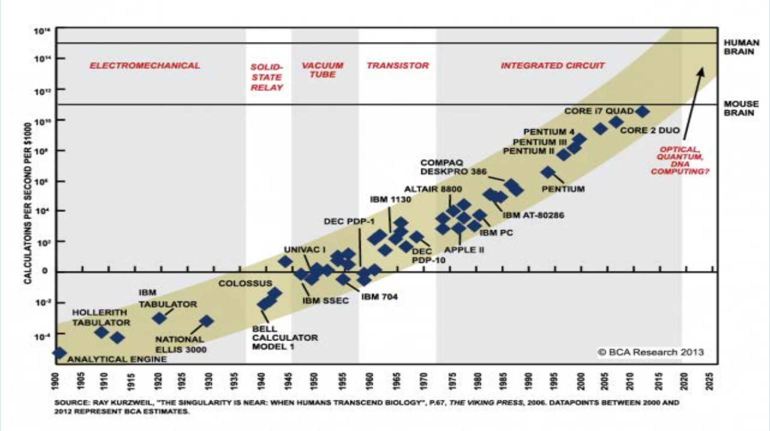


Rise of Connected Devices Growth in Revenue

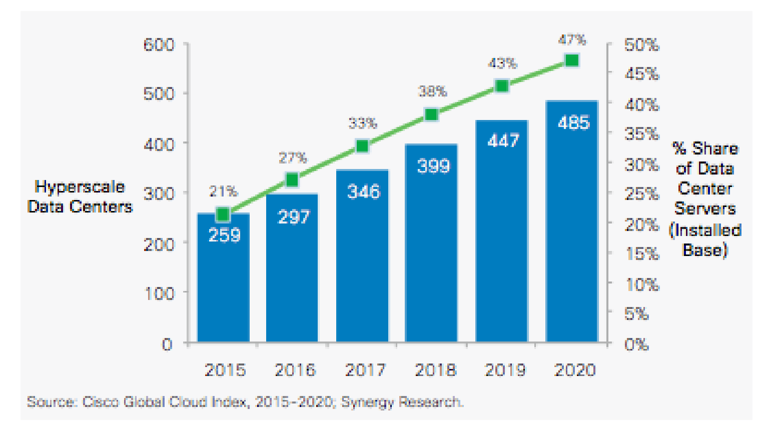
Source: Nielsen

Source: Grandview Research

❑ Growth: Demand on Network Resources and Evolution of Network Technologies



Processor Power Progression



Hyperscale Computing and Data Center Growth

Source: Ray Kurzweil

Source: Cisco

❑ Growth: Demand on Network Resources and Evolution of Network Technologies

The Advances in "Computing" Technologies Drive Traffic where:

- The Growth in both mobile and fixed access is dominated by Video like services:
- The issues that affect the requirements on the Network are complex and affected by many factors such as:
  - Format (Short, Long, Scheduled, Unscheduled, ………)
  - Symmetry of Traffic (Upstream, Downstream)
  - Ubiquity (Geographic accessibility, Area Coverage)
  - Economics (Affordability)
  - Criticality (From Emergency Response, to Entertainment)
  - Attributes (Security, Reliability, Latency, Jitter, ………..)

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❑ Trends

- Video – change in viewer habits

  - Operator conversion from downstream broadcast/multicast to unicast both upstream and downstream. [The ongoing transition to unicast will continue to require substantial investment until we reach an inflection point]
  - Growth in traffic increases both up and down driving more branching and buildouts close the access points.
  - Significant uptake by mobile and nomadic viewers/users
  - Video increasingly embedded in content
  - Video capabilities increasingly embedded in products and services

❑ Trends

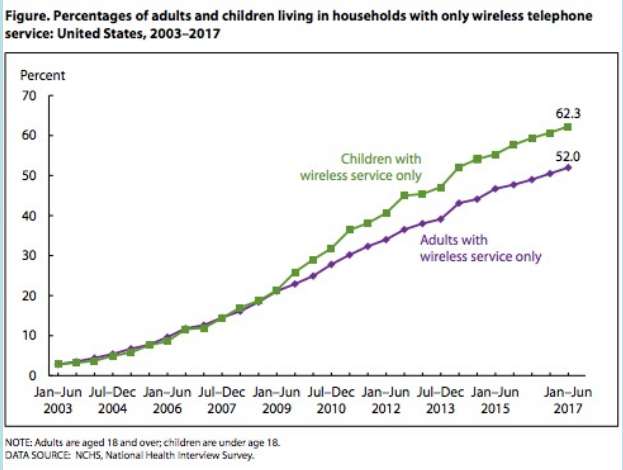
- Rise of cloud, fog, and edge services
  - "Computing" and the network become tangled in a fundamental way
  - Value from the computing infrastructure drives many of the architectural and investment decisions
  - The network itself is changing as a result – virtualization, NFV, "Software-ization"
  - Scalability drives hierarchy: A continuum of assets and facilities between the Cloud and the Edge.

❑ Trends

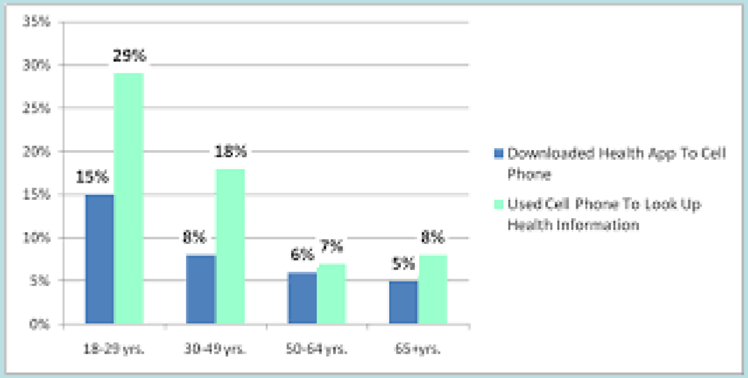
- Applications are increasingly woven into our society as part of everyday life that the population depends on in the consumer space, in industry, and in public sector services:

Consumer/Commercial	Public Services
• On demand services: Uber, Lyft, AirBnB, Etsy, etc. • Shopping and Retail • Entertainment • Financial Services	• Public safety and emergency response • Healthcare • Education • Elder Care

❑ Trends

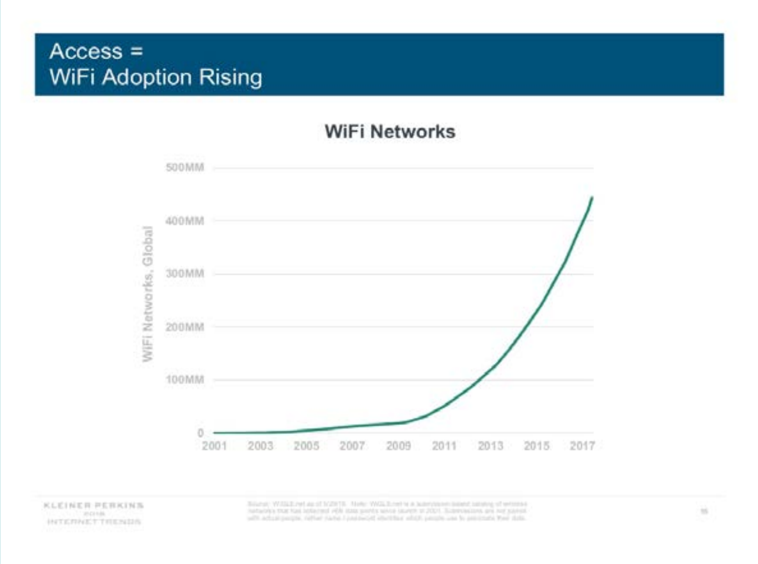


Connectivity Habits

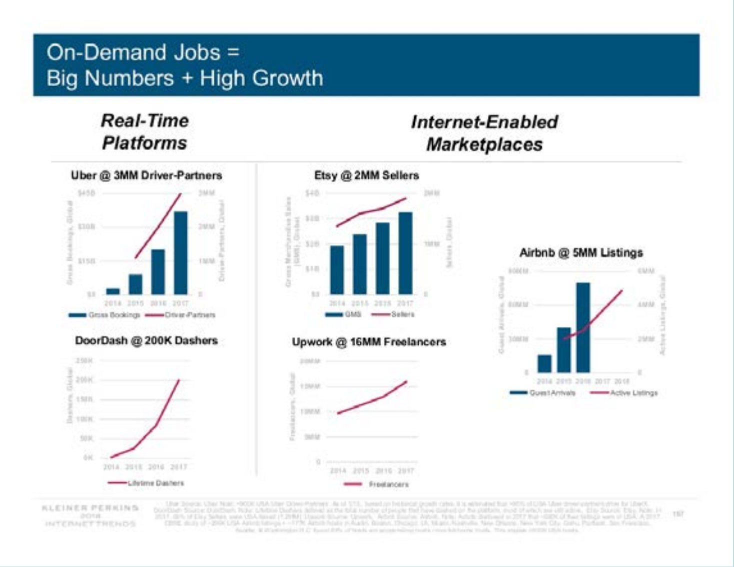


Example of Demographics For a Typical Application

❑ Trends

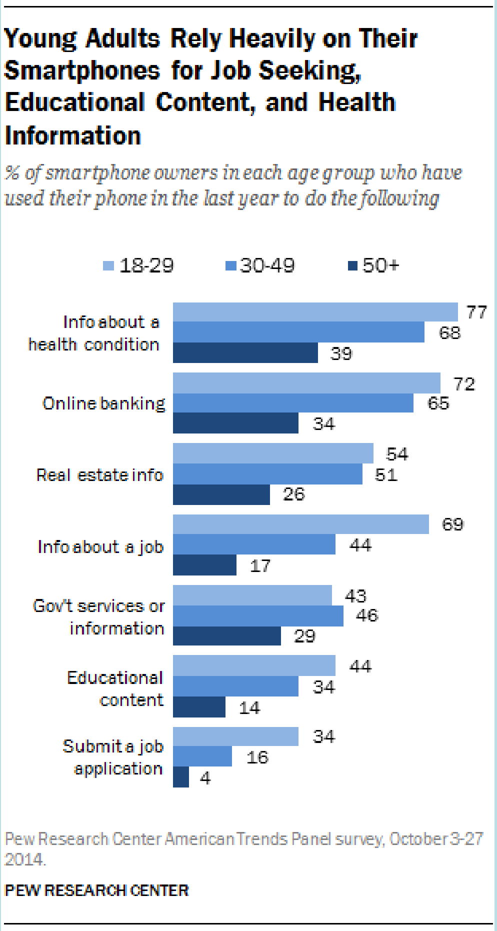


Penetration and universality of WiFi



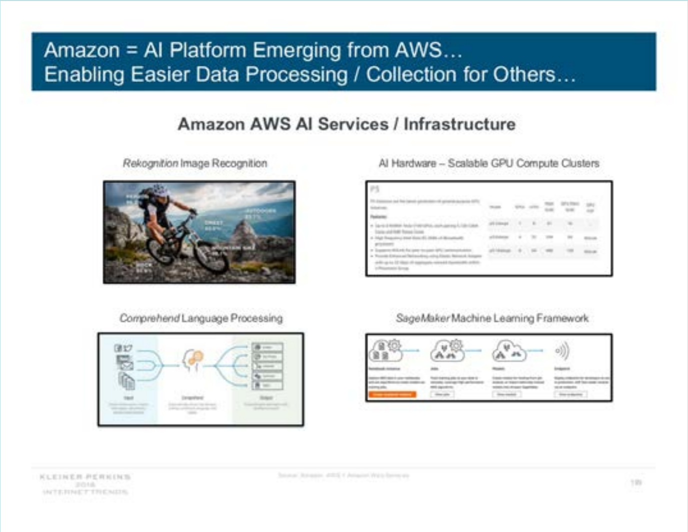
Digital applications now part of daily life.

❑ Trends

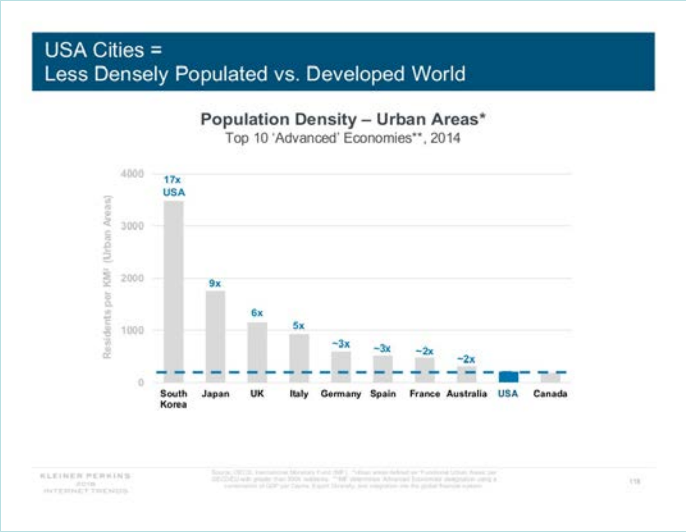


Digital Services as part of daily life in the US.

❑ Trends



Example: The basic Technologies described drive major applications



Example: Solutions that fit the US have to fit unique patterns

❑ Trends

- The Technologies we are examining are enablers for driving the "Digitization" of:
  - Products
  - Services
  - Processes
- The emerging patterns show that "Digitization" is increasingly woven into the daily life of the population
- This has deep impacts on advancements for Consumers, Industry, and the Public Sector
- The technologies contribute significantly to improvements in the efficiency and performance of Communication Networks and may be important to balance demand by reducing traffic through processing at the edge.

- One may argue that the Trends are the precursors to a "Digital Nation", where a digitally literate population, with access to key digital resources can harness advantages that Computing, Storage, Communications, and Sensing Technologies and Resources offer to address national issues of competitiveness, quality of life, and national defense.

❑ Impacts - Examples

Use Types	Consumer	Commercial Industrial	Public Sector
High Bandwidth	Entertainment Gaming – VR/AR Communications - Video	Design Manufacturing Operations	Research Facilities Enterprise Systems
Low Bandwidth Large Numbers	Transactions Shopping Smart Home	Utility metering and billing	Information Services
Sensitive to Attributes (Latency, Security, Privacy, Reliability)	Personal Data Security Systems Personal Care	Control Functions Real Time Operations	Traffic Systems Emergency Services International Facilities
Essential for Participation	Job Hunting Education Social Life	Financial Services Markets	Healthcare Education

❑ Impacts

Technologies	Consumer	Commercial	Public Sector
Cloud and Edge Services	• Personal Information • Search	• Collaboration • Design • Operations • Processes	• Healthcare • Education • Law Enforcement
Artificial Intelligence	• Shopping • Smart Home • Investing	• Preventive Maintenance • Operations • Manufacturing	• Healthcare • Education • Services • Law Enforcement
Augmented and Virtual Reality	• Entertainment • Gaming • Work from home • Education • Training	• Design • Training • Repair and Maintenance • Pre-press • Content	• Military • Law Enforcement • Operations • Planning • Training

❑ Impacts - Examples

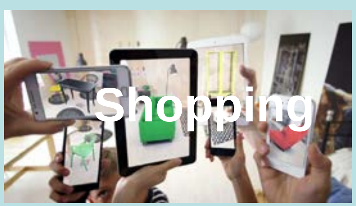
Use Types	Consumer	Commercial Industrial	Public Sector
Latency	Healthcare Smart Home Gaming	Connected Car Control Systems	Emergency Response Control Systems
Bandwidth	Entertainment Education Work from Home	Design Functions Maintenance Operations Cloud Services	Training Situational Awareness Education
Reliability and Availability	Smart Home Security Systems Emergencies	Manufacturing Critical Services Utilities	Law Enforcement Large Scale Public Services
Security and Privacy	Personal Data and Personal Communications	Critical Infrastructure Critical Control Functions Critical Data and IP	Data Control Functions

❑ Technologies

- Capabilities
  - What will the technology do for us and is it keeping up with demand?
  - Is it deployable in the right places?
    - Settings (Rural, Sparsely Populated, Suburban, Urban)
    - Does it support industries where they operate – Agriculture, Energy, Mining,

- Demand
  - What traverses the network
  - Will the network support it?
  - What drives resources needed:
    - In the Cloud
    - At Aggregation Points
    - At the Edge
    - On User Platforms

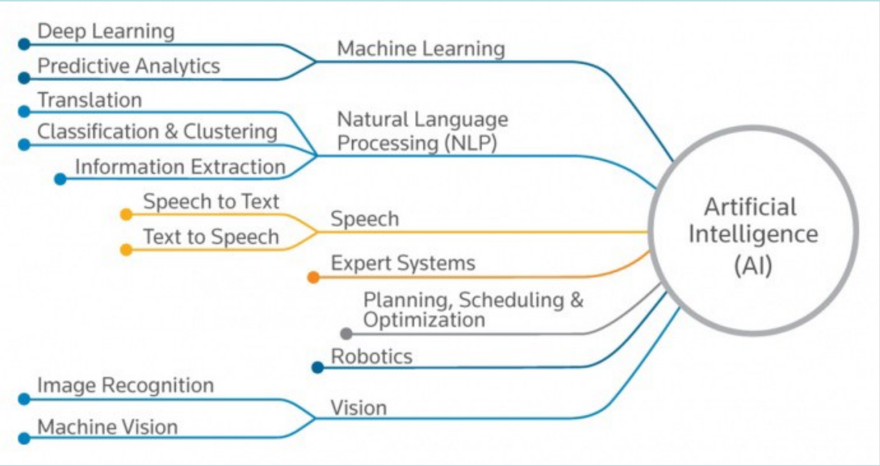
❑ Technologies



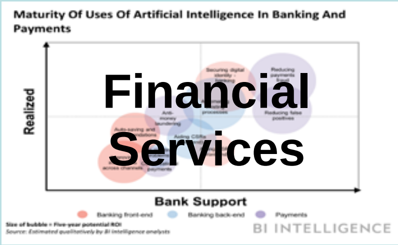
Augmented and Virtual Reality: 4K x 2 x 120 f/sec

Source: Augmera

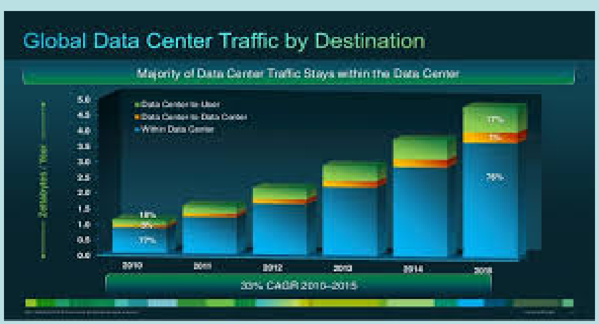
❑ Technologies

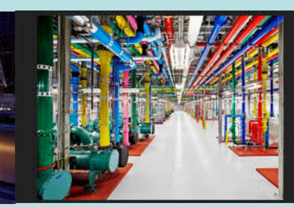


Artificial Intelligence



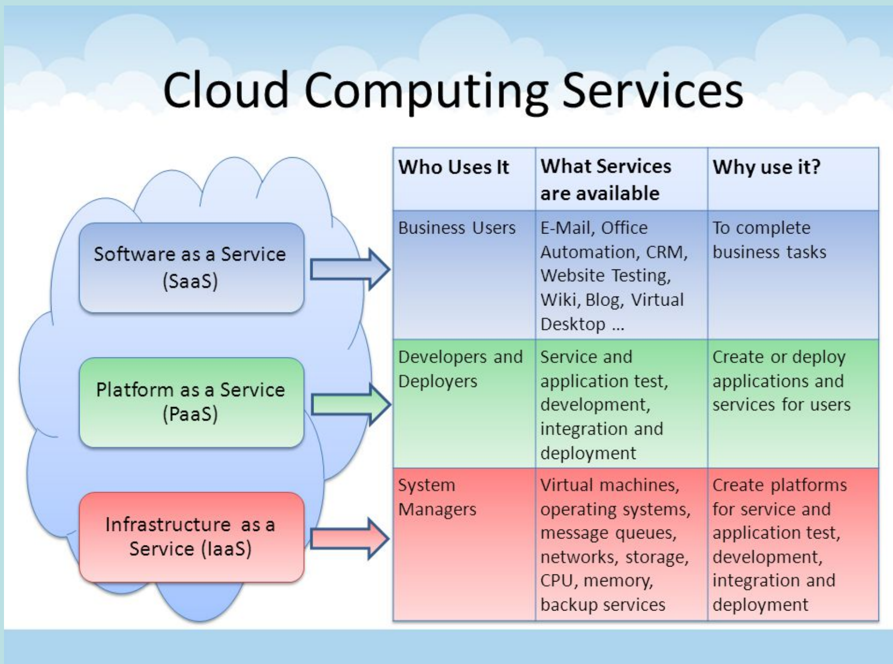
❑ Technologies



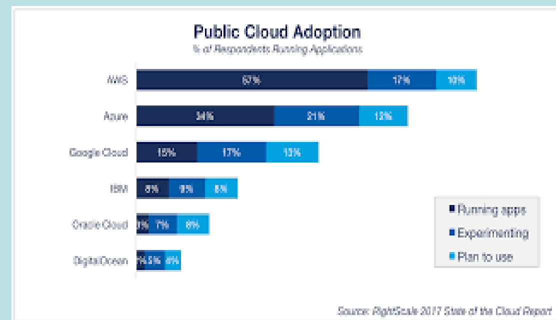


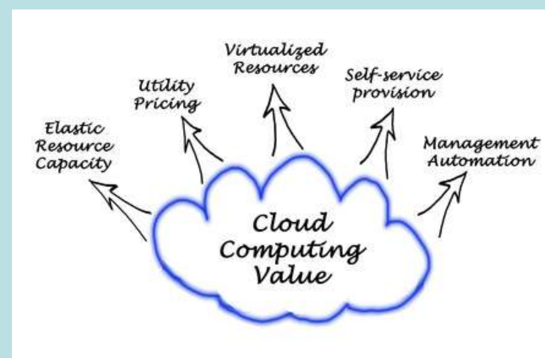
Cloud Computing – Hyperscale Facilities

❑ Technologies



Who Uses It	What Services are available	Why use it?
Business Users	E-Mail, Office Automation, CRM, Website Testing, Wiki, Blog, Virtual Desktop ...	To complete business tasks
Developers and Deployers	Service and application test, development, integration and deployment	Create or deploy applications and services for users
System Managers	Virtual machines, operating systems, message queues, networks, storage, CPU, memory, backup services	Create platforms for service and application test, development, integration and deployment





Cloud Computing

❑ Consequences

	Application Examples	Technologies
1. Possibilities for Explosion in Demand driven by new Applications Balanced by Technological Advances	Connected cars Manufacturing Oil and Gas Agriculture Healthcare and Education	Mobile Broadband ✓ Video ✓ Connected “X” Augmented Reality Virtual Reality Intracloud Connectivity
2. Impact on US Competitiveness, the Nation’s Quality of Life, and National Security	Basic Services Emergency Services Economic Advantage and Productivity	Artificial Intelligence Machine Learning Data Sciences Cloud and Edge Computing Sensor Systems
3. Increased Need for Area Coverage as well as Current Population Centric Patterns	Applications that are increasingly area focused, and critical to the general population whether rural or urban. [Health, Education, Agriculture, Emergency Services……]	Computing, Storage Connectivity Sensors

❑ Recommendations

Priority	What	How
1	Promote competitive and balanced infrastructure services that will preserve the economic leadership of the US.	Partner with other agencies to Develop a Strategic Policy Plan and Roadmap for a “Digital Nation” that incentivizes adoption and deployment accessible to all citizens.
2	FCC to determine how to carry out its mission with the “tangling” of communications with computing, storage, and sensor resources!	Dedicated Study Group with specific mandate to provide output by the end of 2019 . The objective is identify responsibilities and scope of what the FCC should and is authorized to take on in light of changing technologies, use patterns, and business models – and what should be left to other organizations.
3	Create and encourage practices and structures that minimize the divide between underserved areas of the country and urban centers such that all are desirable place to live and conduct business in.	Develop and prioritize policy options that address the challenge of providing economically viable services so that rural, sparsely, and underserved areas can be seen as desirable places to live. [That is – be a part of the “Digital Nation”]

Thank you!

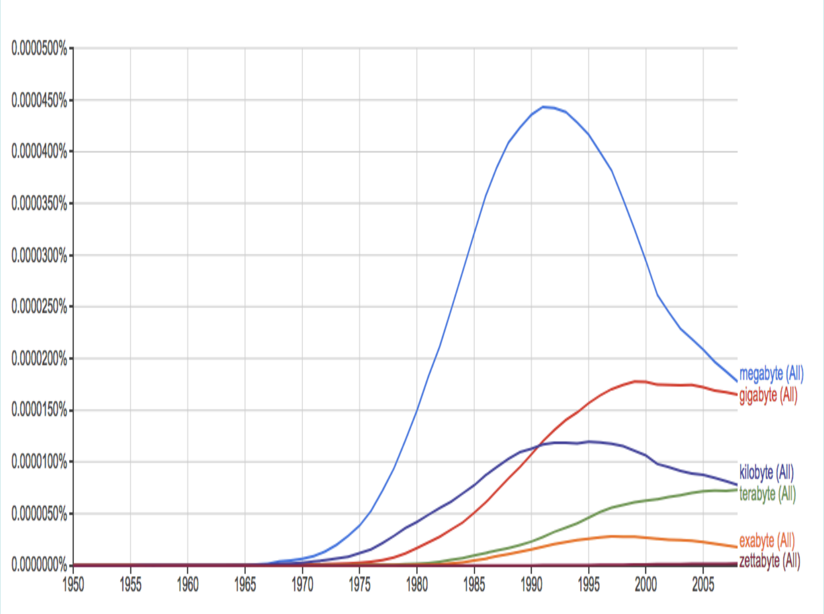
Backup Material

Terms of Reference and Observations on Bandwidth

Name	Size	~ Data Generated/Day Decimal	~ Bandwidth b/sec (bits)
Byte	2^{00}	1	1 x 10^{-07} Kb/sec
Kilobyte	2^{10}	1,000	1 x 10^{-04} Kb/sec
Megabyte	2^{20}	1,000,000	1 x 10^{-01} Kb/sec
Gigabyte	2^{30}	1,000,000,000	1 x 10^{+02} Kb/sec
Terabyte	2^{40}	1,000,000,000,000	1 x 10^{+02} Mb/sec
Petabyte	2^{50}	1,000,000,000,000,000	1 x 10^{+02} Gb/sec
Exabyte	2^{60}	1,000,000,000,000,000,000	1 x 10^{+02} Tb/sec
Zettabyte	2^{70}	1,000,000,000,000,000,000,000	1 x 10^{+02} Pb/sec
Yottabyte	2^{80}	1,000,000,000,000,000,000,000,000	1 x 10^{+02} Eb/sec
1 Byte = 8 Bits			
1 Day = 86,400 sec			

To be exact in Bytes:

1 Kilobyte = 1,024
1 Megabyte = 1,048,576
1 Gigabyte = 1,073,741,824
1 Terabyte = 1,099,511,627,776
1 Petabyte = 1,125,899,906,842,624
1 Exabyte = 1,152,921,504,606,846,976
1 Zettabyte = 1,180,591,620,717,411,303,424
1 Yottabyte = 1,208,925,819,614,629,174,706,176



Frequency of mention on the Internet – Google

Typical Daily Data Volumes and Data Rate by Industry

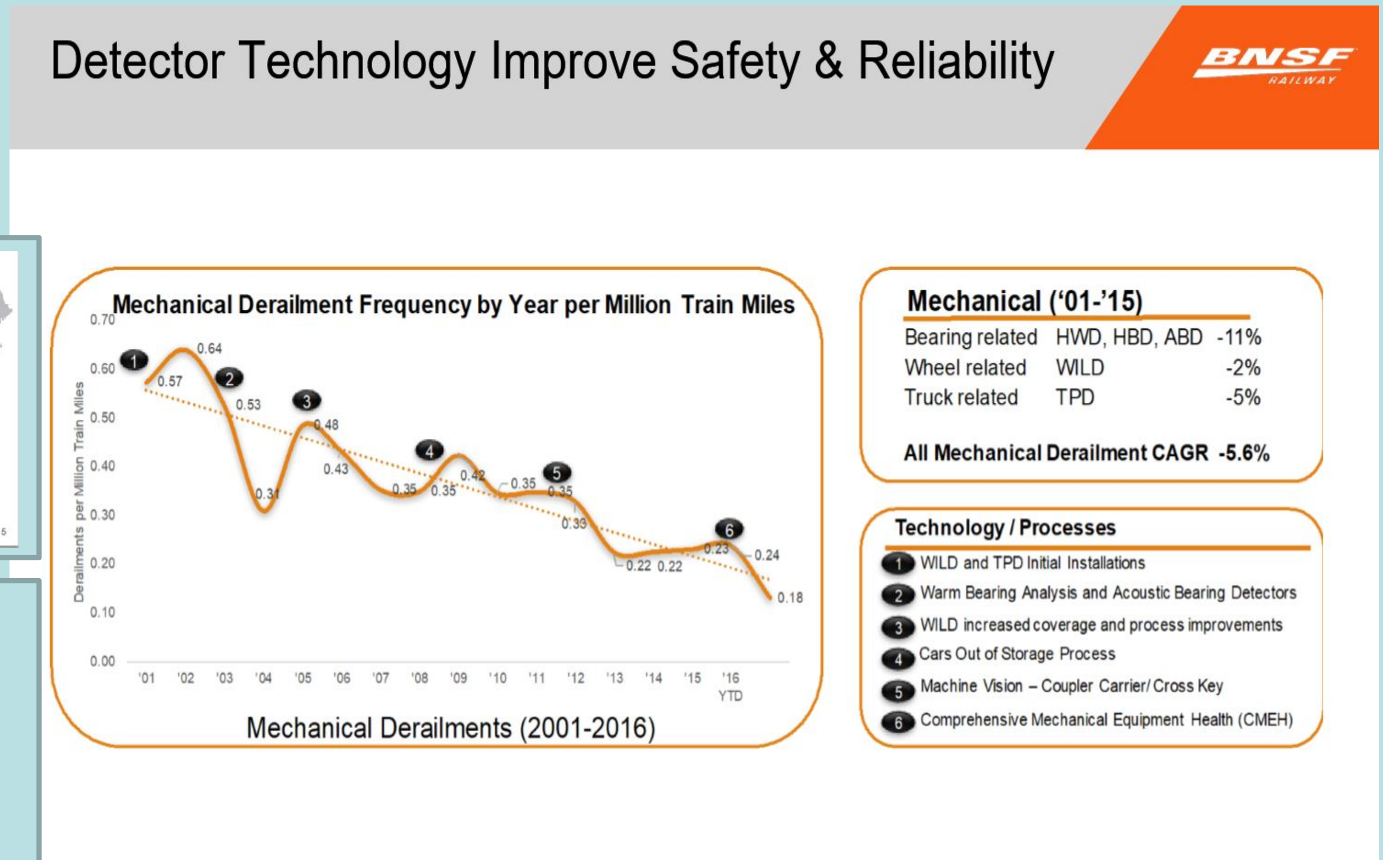
Industry	Data Volume Per Day	Data Rate if all Transmitted
US Smart Meters*	0.5 TB	46.3Mbps
Large Retail Shop*	0.8 TB	74.1Mbps
Large Refinery*	1.0 TB	92.6Mbps
Automated Manufacturing*	24.0 TB	22.2Gbps
Jet Engine*	480.0 TB	444.4Gbps
Mining Operations*	1.0 PB	925.9Gbps
Automotive**	2.0 PB	1,851.8 Gbps

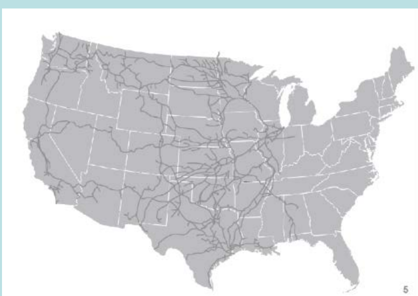
* Data taken from FogHorn Presentation 05/21/2018
** From AECC White Paper Assuming 100Million Vehicles 04/25/2018

❑ Network Area Coverage (Need for Ubiquity)

- From an early review of “Data Intensive” applications, current and projected Network capacity is likely to accommodate bandwidth needs. [Still analyzing Video]
- The range from 200 - 500 Mb/sec on general purpose networks will meet the majority of application requirements
- Based on trends in Industries that are adopters of “Computational Technologies” Area Coverage is a significant unmet need!
- For many such applications Network attributes such as Security, Reliability, Latency, and Jitter are also important.

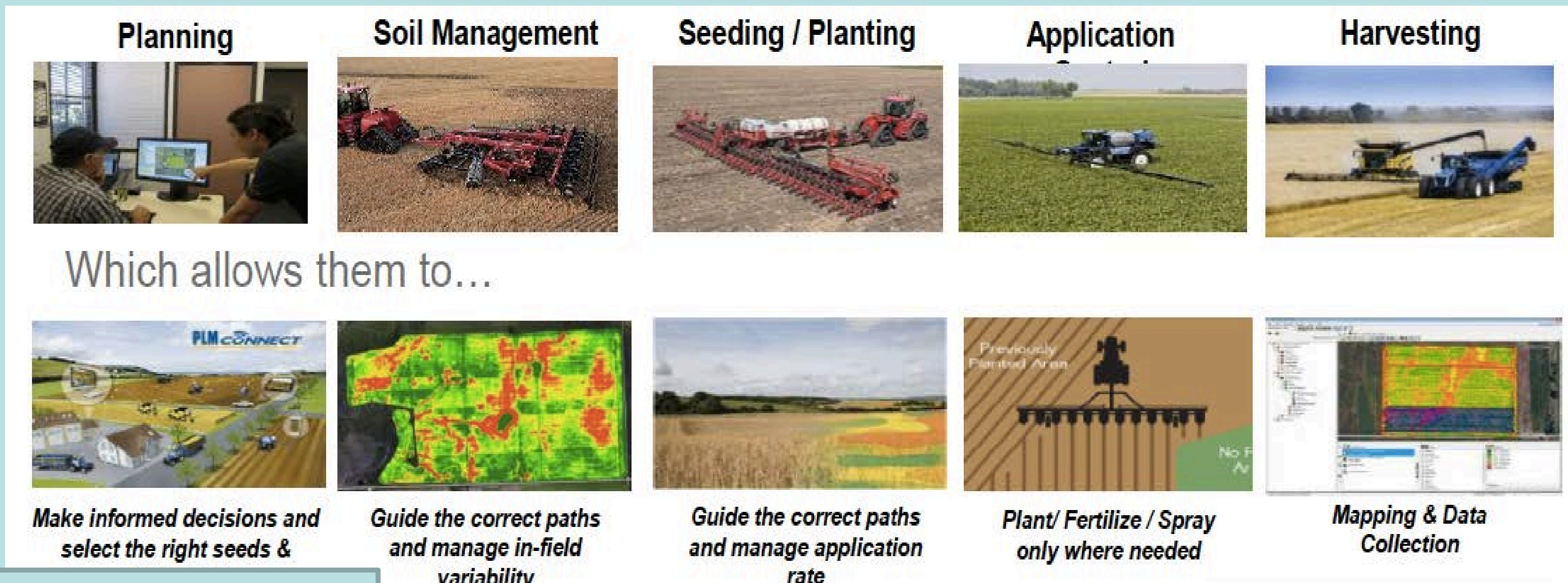
Rail Industry – Predictive Safety





Source:
Mike Garcia
Presentation
- BNSF

Precision Agriculture

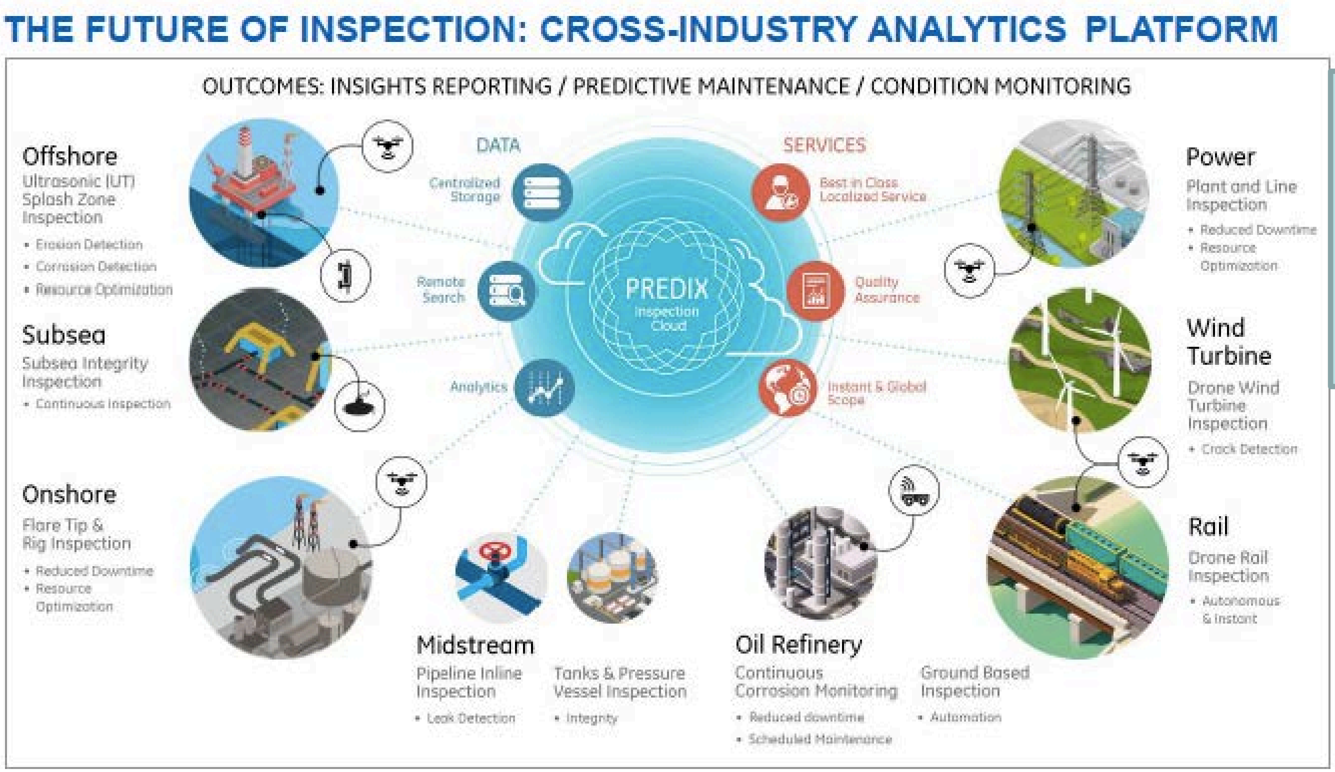


Source: Antonio Marzia - CNH Industries Presentation

Benefits

- Knowledgeable Farm Management Decisions
- Machine/Operator Efficiency
- Lower Input Costs for Crops
- Higher Product Yield

Industrial Applications



Source: Ashish Jain – GE Ventures Presentation

❑ Data Traffic Expansion on the Network

- The long term trend from all applications indicates a growth of data traffic of > 25% CAGR and wireless data > 50% CAGR
- The growth in revenues from that data traffic exhibits a much slower pace – that may be in the single digits
- For Networks to keep pace two major factors are:
  - Availability of capital for service providers and operators to continue Network expansion to meet demand (or for demand to fill Network capacity)
  - Continued improvements in Technology to meet capacity needs.

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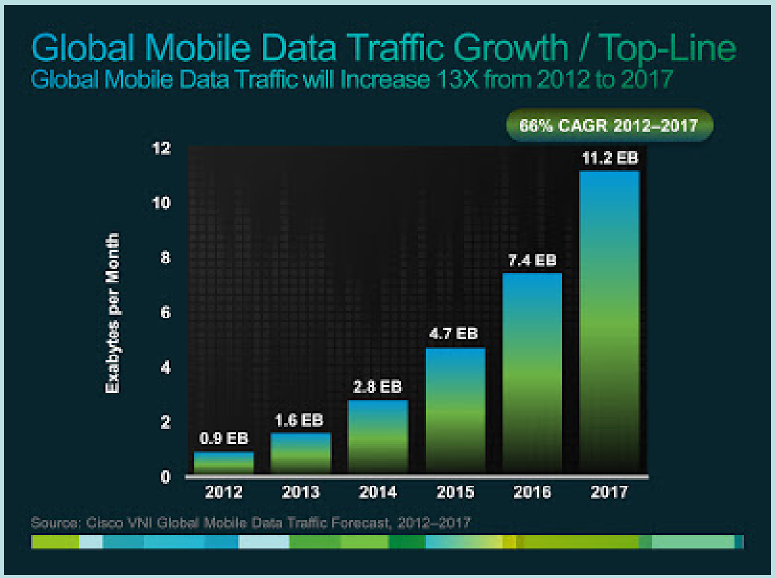
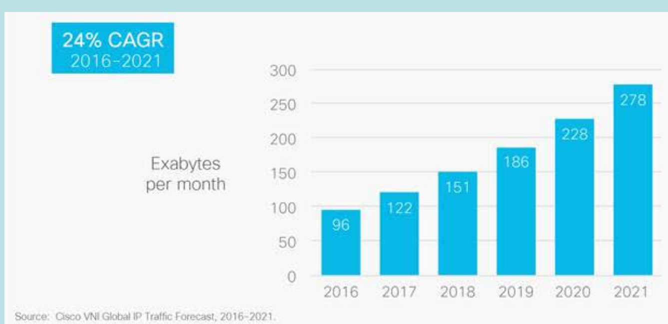
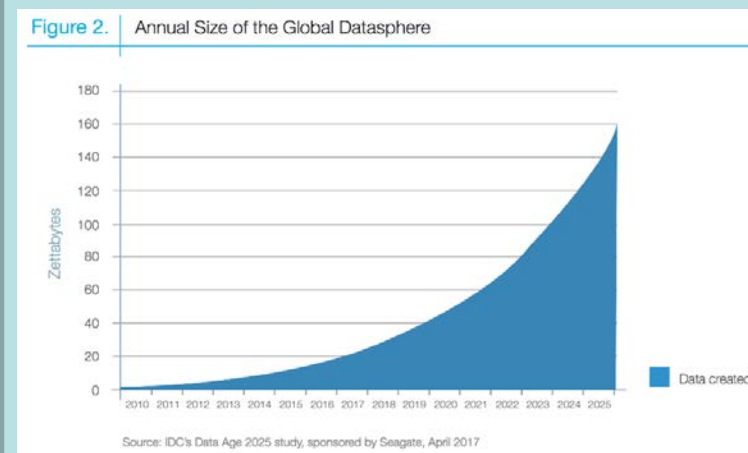
Growth in Data Traffic

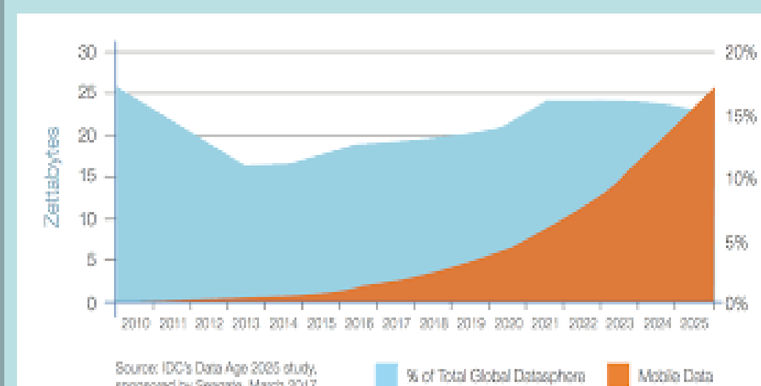


Source: Cisco

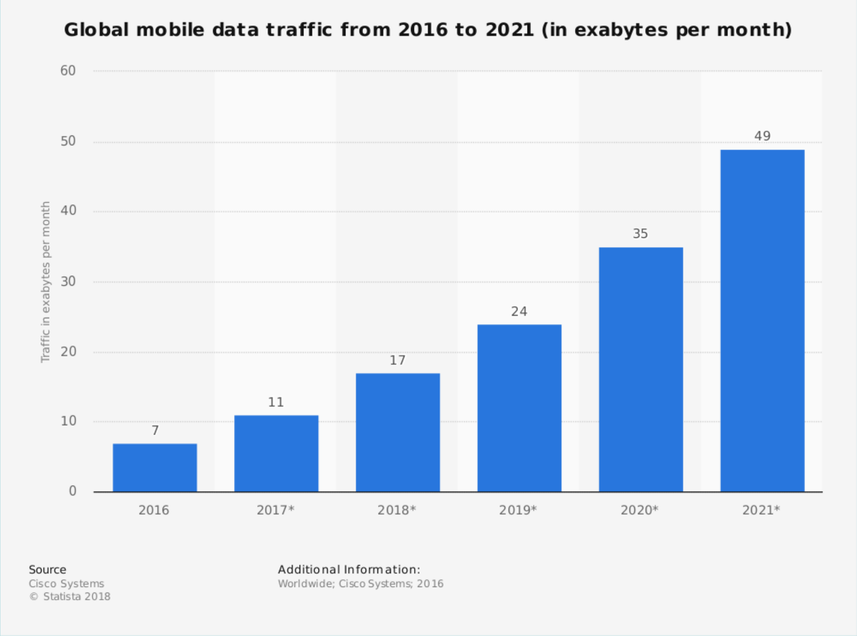


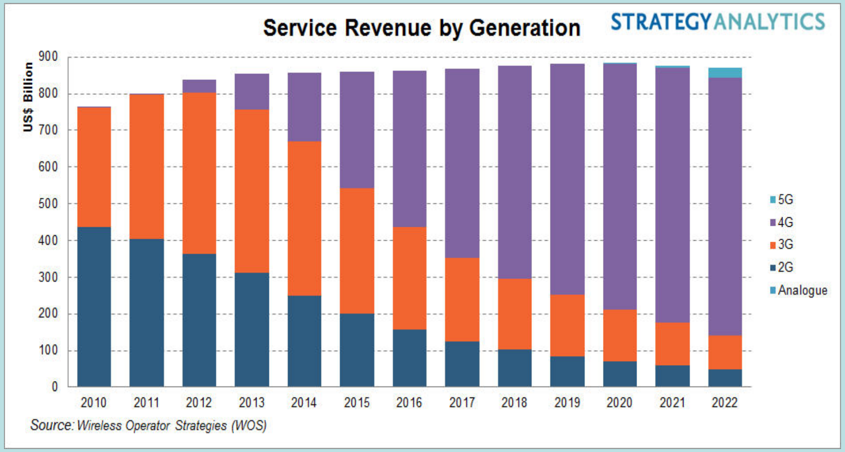
Source: Data Age 2025 Study - IDC

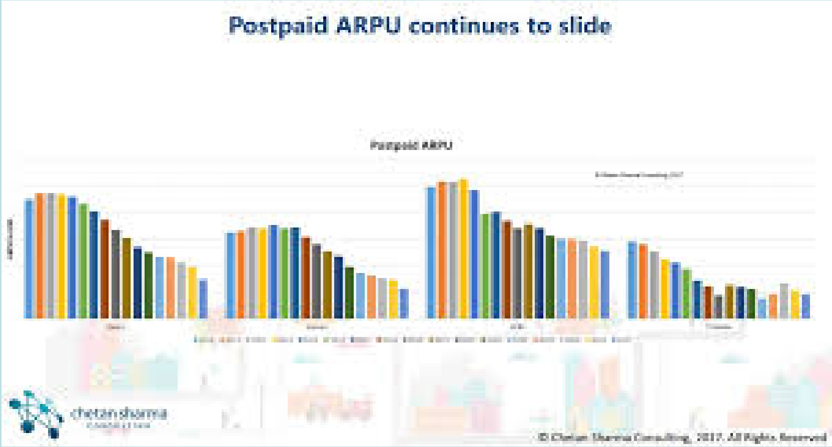




Contrast Traffic vs Revenue



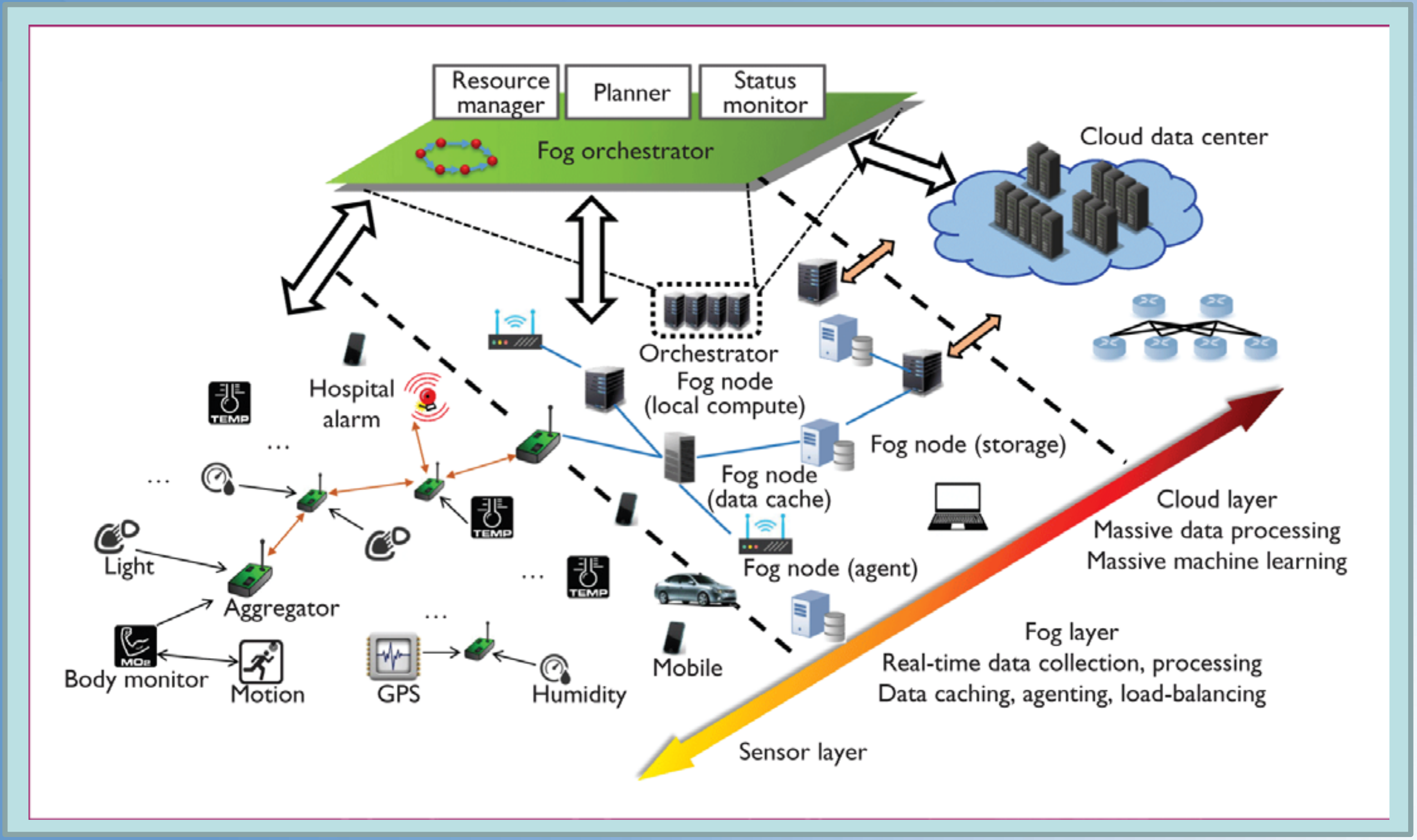




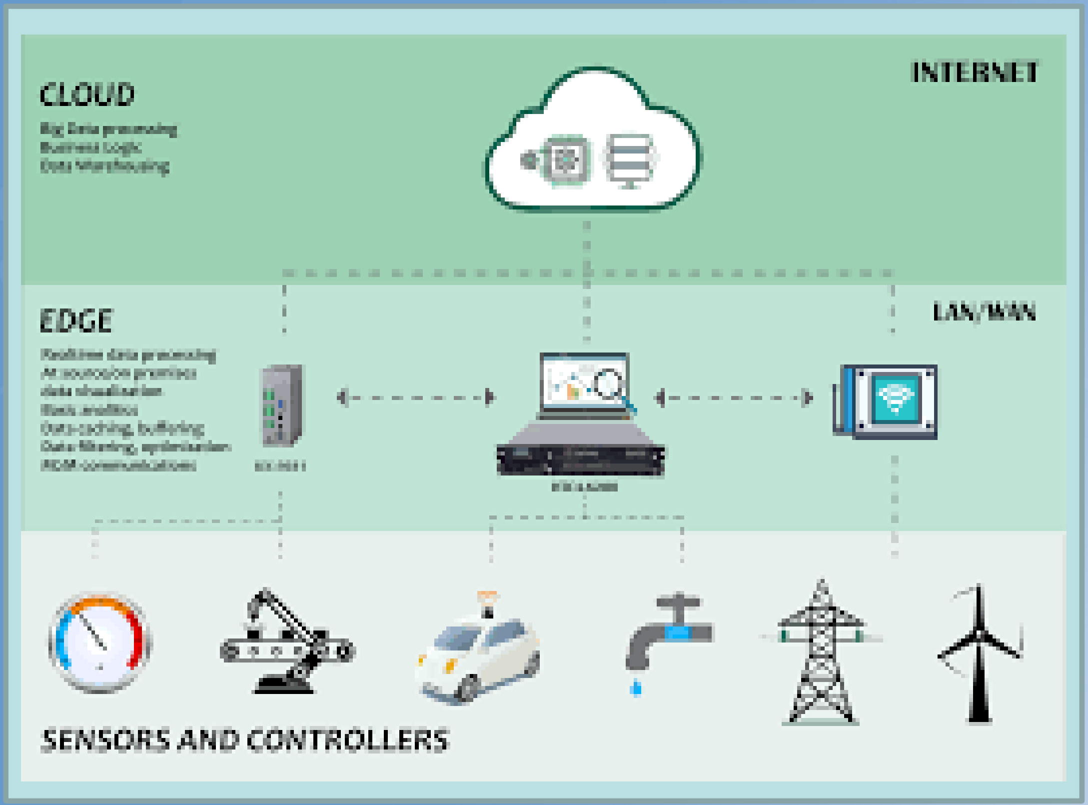
❑ Tight Coupling of Network Communications Services and Computing at the Edge

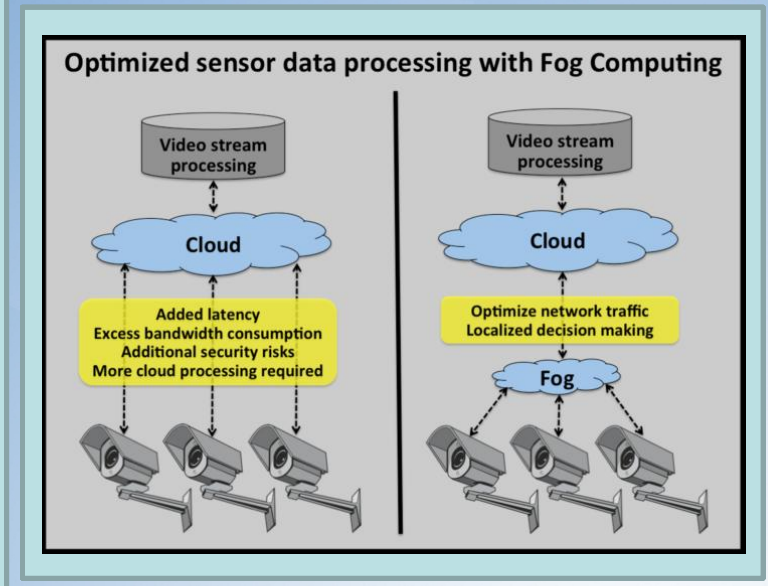
- General purpose public networks are being used for critical and time sensitive applications and services. The resources required include infrastructure that may consist of computing, storage, sensors, and other services.
- To emphasize a point already made Network attributes such as Security, Privacy, Reliability, Assurance, High Levels of Availability, Latency, Jitter, and progression to higher Bandwidths are increasingly expected.
- Networks are looked on as a combination of traditional Telecommunications (now IP based) and non-traditional components. To be scalable the Network is supported by a hierarchy of assets that range from large shared multi-user Cloud Data Centers to Edge/Fog Platforms. The later are tightly integrated in the Network to provide attributes such as low Latency and Jitter.

Examples of Edge and Cloud Computing Uses



Examples of Edge and Cloud Computing Uses





Examples of Edge and Cloud Computing Uses

Focus for WG for next meeting

- Impact of Specific Computing and Sensor Technologies (in progress)
    - Video (Proliferation of use and High Definition Formats)
    - High Volume Sensors(e.g. Hyperspectral)
    - Augmented Reality
    - Virtual Reality
    - Artificial Intelligence
    - …….
- Use of Artificial Intelligence for Network Management, Optimization, and Security

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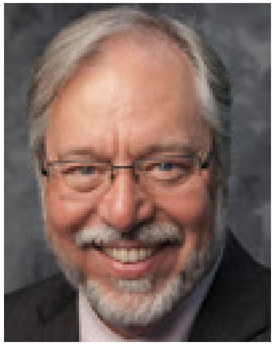
Speaker Biographies and Backgrounds

Speaker bio:



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

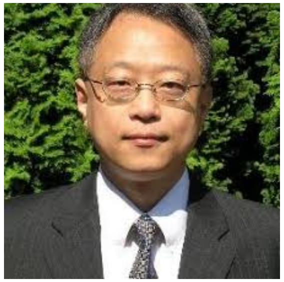
Dr. Cline is currently responsible the cryptocurrency strategy and initiatives for Lancium. Dr. Cline serves as a member of the IEEE Blockchain Initiative Steering Committee and is President/CEO of RWI Mining, LLC, a Blockchain mining firm.

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)

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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:

NOKIA Bell Labs

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.

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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.

5G/IoT Working Group

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

FCC Liaisons: Walter Johnston, Padma Krishnaswamy, Jonathan Campbell

Date: Sept 20, 2018

2018 Working Group Team Members

- Shahid Ahmed, Independent
- Maqbool Aliani, Ligado Networks
- Kumar Balachandran, Ericsson
- John Barnhill, Alianza
- Mark Bayliss, Visualink
- Marty Cooper, Array Comm
- Pierre de Vries, Silicon Flatiorns
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dick Green, Liberty Global
- Dale Hatfield, Silicon Flatirons
- Stephen Hayes, Ericsson
- Tim Kagele, Comcast
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Dave Gurney, Motorola Solutions
- Amy Putnam, Neustar
- Lynn Merrill, NTCA
- Jack Nasielski, Qualcomm
- Mark Richer, ATSC
- Kevin Sparks, Nokia Bell Labs
- David Young, Verizon

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 relative to 5G and IoT to facilitate such developments?*

FRAMING THE 5G LANDSCAPE

Summer Session 2018 Work

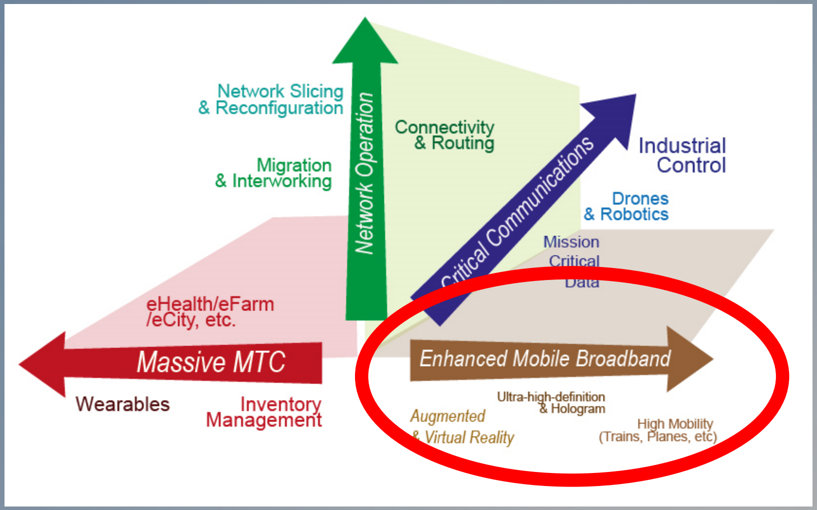
- Invited speakers from:
  - ITU-R Working Party 5D
  - 5G Americas
  - AR/VR experts (collab with Adam WG)
  - 5G ACIA
  - 5GAA
  - CTIA
  - Smart roaming research- Univ Waterloo- Catherine Rosenberg, PhD
- Investigate 5G relative to Digital Divide
- Investigate barriers and roadblocks to deployment
- Explore spectrum [tech] policy

Areas of Discussion

- Framing Discussions
  - Standards
  - Deployment
  - Potential Barriers to Deployment
  - LTE
  - IoT
  - Slicing
  - Edge Computing
- Policy & Spectrum Management Topics
- Education
- Digital Divide

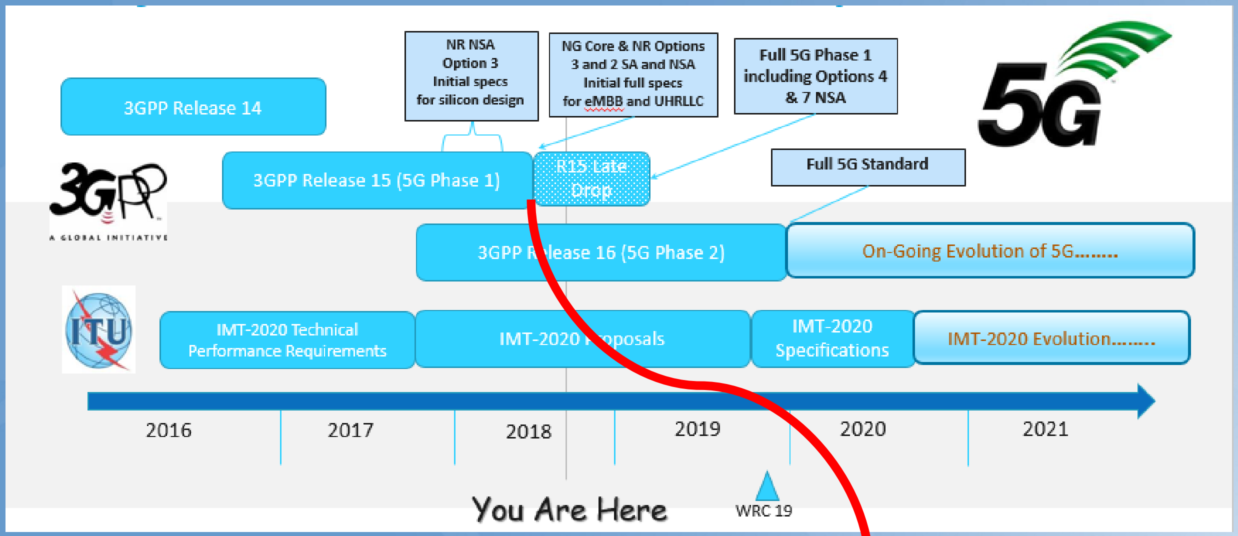
Framing Discussion - Standards

- 5G 3GPP specifications aim to define the full system (Radio, Core Network, MEC)
- 3GPP Release 15
  - Focus on enhanced mobile broadband use case
  - All 3GPP specifications Release 15 onward will be "5G"
    - Includes not only NR and 5G-NGC, but also LTE and EPC evolution
  - Release 15 includes support for both non-standalone (NSA) as well as standalone SA) deployment scenarios
  - Release 15 has 3 standards "drops"
    - December 2017 priority on NSA option 3
    - June 2018 priority on SA option 2
    - December 2018 priority on NSA options 4 & 7
- 3GPP Release 16 has started
  - IMT-2020 Submission
  - Massive IoT, URLLC use cases
  - Network Slicing



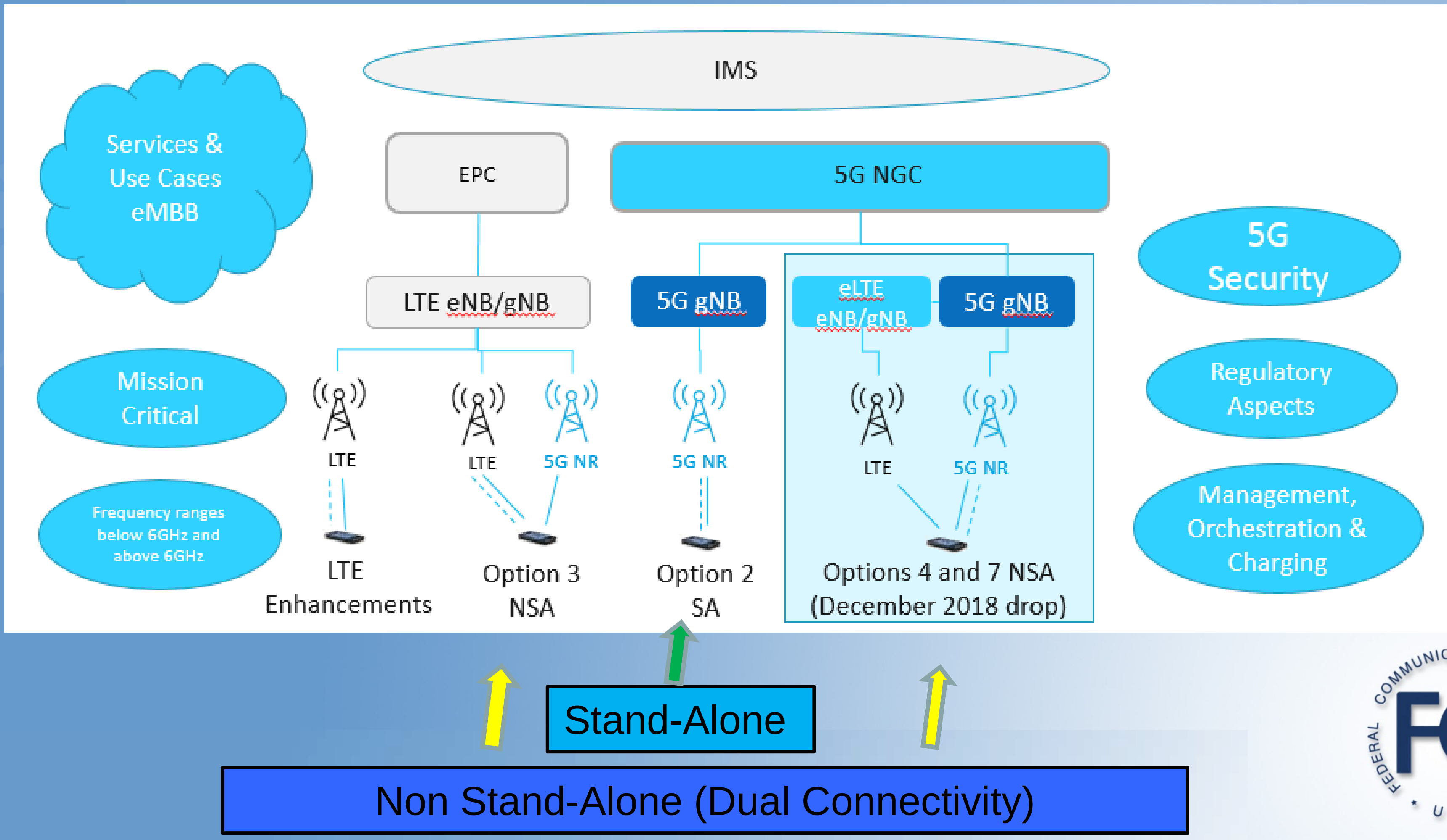
Source: 3GPP

5G Projected Industry Standards Timelines

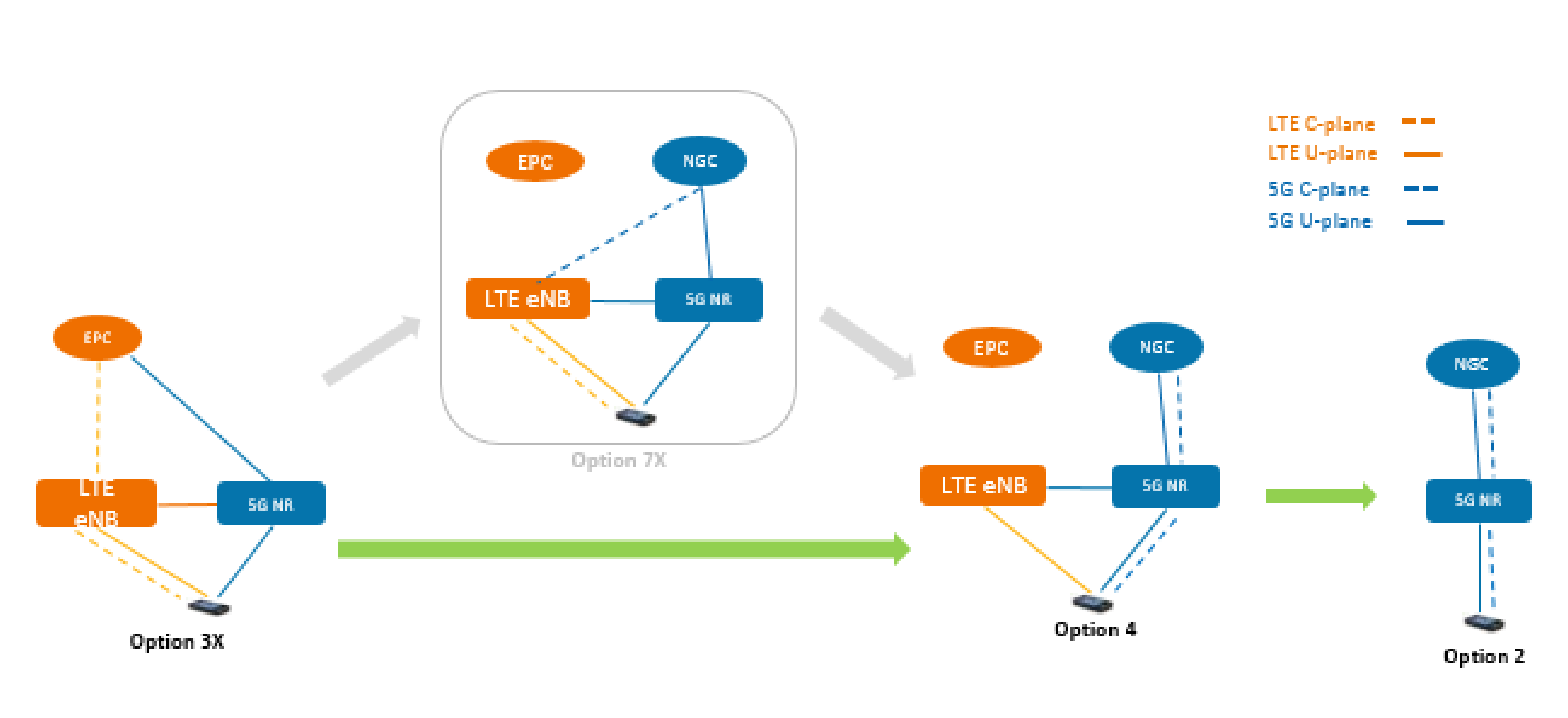


← Release 16 Phase →

3GPP Release 15 System



Possible 5G Evolution Paths- *How we get there*



Framing 5G - Deployment

- PoC's and Trials are well underway
  - U.S. and worldwide
- U.S. Deployment Announcements
  - 5G commercially available starting in 2018, more in 2019
  - Initially NSA, SA for FWA

ZDNet

AT&T to launch 5G across 19 cities

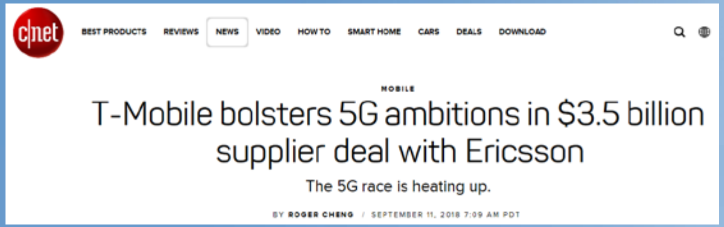
AT&T is working with Ericsson, Nokia, and Samsung to launch 5G in Las Vegas, Los Angeles, Nashville, Orlando, San Diego, San Francisco, San Jose, San Antonio, New Orleans, Houston, Jacksonville, Louisville, Dallas, Atlanta, Waco, Charlotte, Raleigh, and Oklahoma City.

By Corinne Reichert | September 10, 2018 -- 19:18 GMT (12:18 PDT) | Topic: Mobility

TALKING TECH

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

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

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

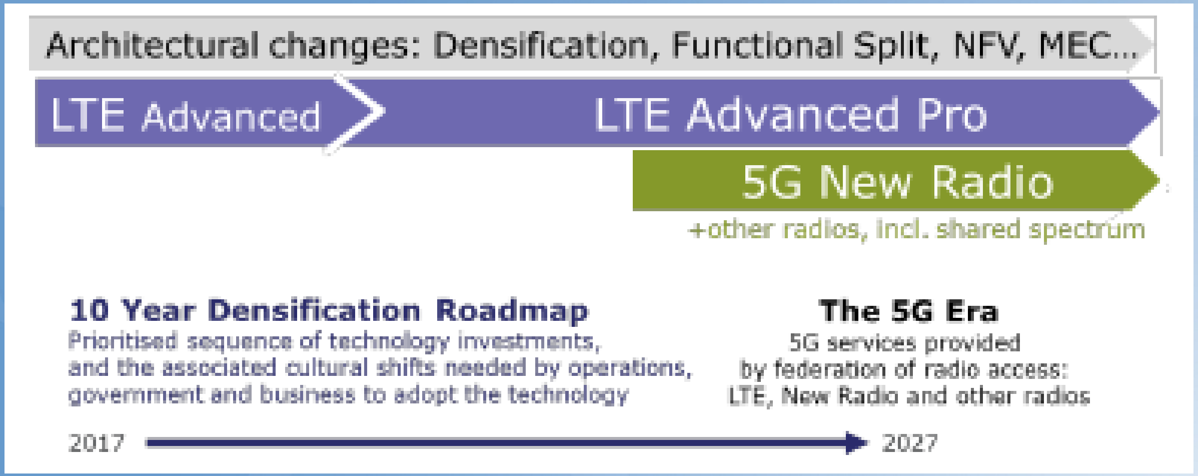
Across the U.S., 5G Runs Into Local Resistance

City officials also complain they don't have enough staff to handle the applications. But state and federal authorities are in the carriers' corner.

By Drew FitzGerald

Sept. 11, 2018 2:57 p.m. ET

Framing 5G – LTE Is Not Going Away



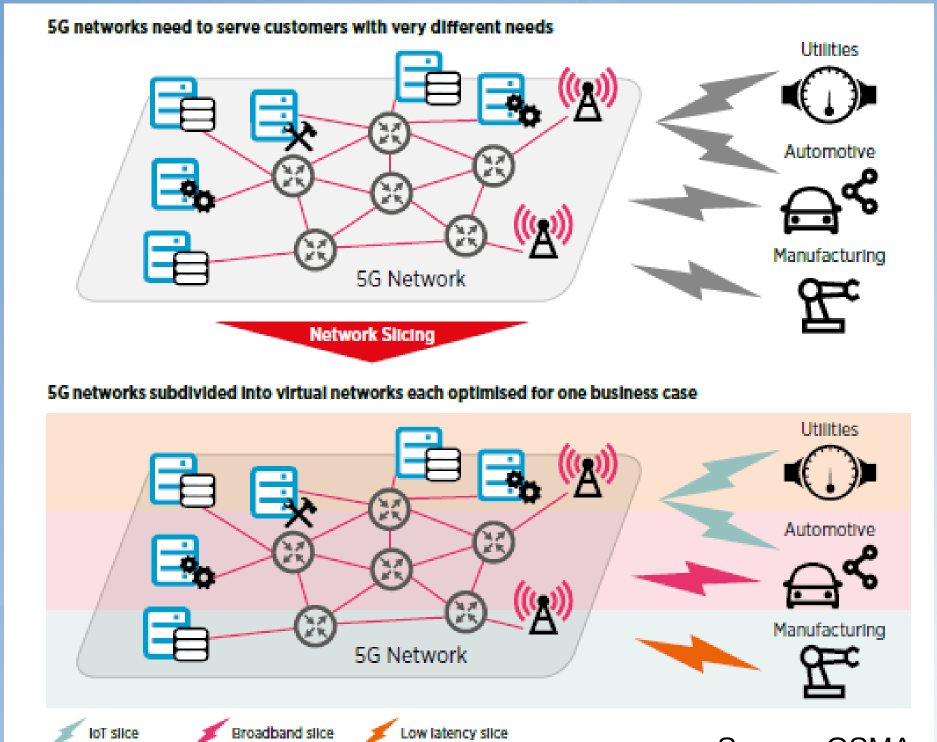
- Many 5G use cases can be achieved already with LTE at a scale sufficient to start establishing new business processes for early adopters ahead of full-scale adoption by mainstream markets with 5G systems

Source: SCF

5G Network Slicing

From resource provisioning to new services

- Network slicing — introduced in LTE but never fully realized in 4G
- Enables the network elements and functions to be easily configured and reused in each network slice to meet a specific requirement
- 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, engineering mechanism and network provisioning
- A network slice comprises dedicated and/or shared resources, e.g. in terms of processing power, storage, and bandwidth and has isolation from the other network slices
- Could span across multiple parts of the network (e.g. terminal, access network, core network and transport network) and could also be deployed across multiple operators
- IoT support: offers options on QoS, latency, etc



Source: GSMA

How many slices? A factor of business and operational needs

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 and lower latency than would be possible in a centralized cloud environment
- Low latency and ultra-high reliability are critical for applications such as:
  - Automatic driving, traffic control and V2X.
  - VR applications.
  - Mission-critical use cases such as public safety communications.
  - Remote health care (g., remote surgery).
  - Extreme real-time applications such as tactile internet.
  - Real-time HD video sharing
  - Industrial and manufacturing applications that require real-time remote control and operations (e.g., robotic controls).

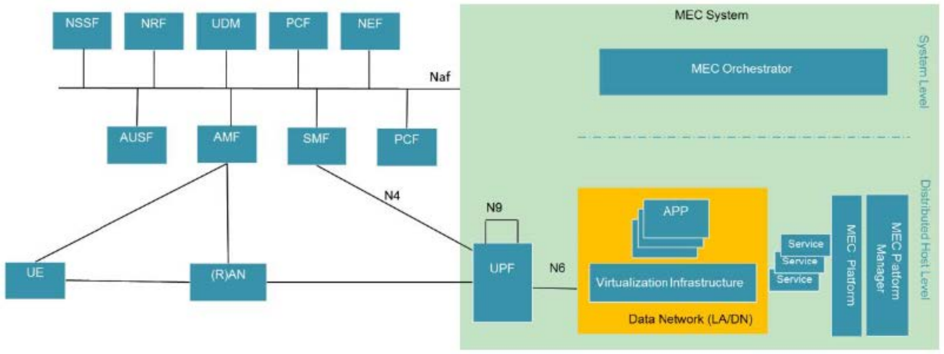


Figure: Integrated ETSI MEC deployment in 5G network

Source: ETSI

5G and the Digital Divide- pg1

- 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 broadband service
    - Will take time to learn all we need to know about & really take full advantage of mmWave → will not stop the deployments, will simply adjust and learn over time as per previous generations
  - Rural communities will benefit after transport infrastructure is established with mid-band and mmW
    - Some deployments are likely to be capital-intensive
  - Combination of low and high frequency bands are crucial for coverage and capacity
    - 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

5G and the Digital Divide- pg2

- Rural Communities 5G Buildout
  - Size 4k to 20K pop
    - Requires some existing fiber infrastructure in place
  - Less dense rural areas: Communities 1k to 4K pop
    - Complete existing fiber infrastructure with backhaul required to support wireless infrastructure
    - Many cases a fixed wireless access (FWA) architecture can cost-effectively reach homes and businesses where fiber cannot
  - Rural areas outside of towns
    - Requires use of lower bands for coverage to facilitate IoT services for Agriculture
- Investment opportunities
  - Healthcare, agriculture, education, connected highways

NEXT STEPS- DECEMBER FINISH

5G/IoT WG Final Deliverables [proposed]

- Whitepaper on Network Slicing
- Whitepaper on Mobile Edge Compute (MEC)
- Recommendation related to 5G impact on Digital Divide
- Recommendation on multi-stakeholder group- cross sector conflict resolutions
  - Balance NR placement with community desires
- Potential recommendation on Public Notice related to experimental use of spectrum

THANK YOU!

Technological Advisory Council

Antenna Technologies

Working Group

September 20, 2018

Antenna Technology Working Group

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  - Marty Cooper, DynaLLC
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- Sudhir Ramakrishna, PHAZR Inc
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- Harry Skinner, Intel
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Antenna Technology Developments

This work group is tasked to report on the state of development of antenna technologies and their implications for FCC policies, technical standards, regulatory and technical issues. The tasking is 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, creating new forms of interference avoidance and possibly necessitating new technical standards and rules.
- Metamaterials may offer possibilities to produce more efficient antenna elements for devices and arrays at lower cost but this technology is not yet mature.

Antenna Technology Developments [cont]

- Massive MIMO, Multi-User MIMO, Spatial Division Multiple Access and other technologies promise increased spectrum efficiency.
- Today's higher frequencies allow for smaller sizes and more complex antenna designs, acknowledging some trade-offs
  - Such designs have been explored in other settings; manufacturing at scale can make them more affordable
- 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.

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Antenna Technology Topics Being Investigated

- Array Antennas
  - Electronically Steered Antennas
  - Reflect Arrays
- Metamaterials
  - Unique material properties may be useful in the future
  - Still in early days
- mm-wave Antenna Technology
  - Small Cell Antennas
  - Satellite Antennas

Antenna Technology Topics Being Investigated

- Antenna and Propagation Modeling Tools
- Near Field Interactions
- Antennas in Interference Rejection
- Filtering Antennas

Possible Deliverables

- Recommendations for FCC action to accommodate new antenna technologies
- White Papers
  - Spectral Efficiency
  - Interference Rejection
  - Regulatory Implications, e.g. Spectrum Sharing
  - Direction Finding Antennas for Enforcement

Things We're Learning - 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

Things We're Learning – Smart Antennas

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

Smart antennas 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 multi-path phenomena.

Things We're Learning – 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.

Things We're Learning – 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

Things We're Learning – 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 neatness 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.

Things We're Learning – Cellular Base Station Appearance

- Michael Hughes, Crown Castle Corp
  - One cell site company that has illustrated several examples of designs with nice appearances
  - Only metal poles were shown; wooden poles often present problems.
- However, a nice appearance must be balanced against maintainability.
  - Towers must be easily serviced to maintain life-safety communications.

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Cellular Base Station Appearance - Bad

Cellular Base Station Appearance - Good

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

Tentative Conclusions

- Combinations of smart antenna and other technologies show promise for shaping coverage areas and reducing interference protection areas.
- This could mean major improvements in spectral efficiency.
- Smart Antennas offer different attributes at mm wave vs. lower bands.
- FCC action should allow creative use of the spectrum, while still providing interference protection.
- FCC rules must be reexamined from time-to-time in light of new antenna technologies.

Tentative Conclusions

- Advances in antenna technology allow us to put in smaller, more aesthetic antenna installations.
- The FCC cannot legislate aesthetic appearance of base station installations.
  - However, certain minimum installation standards should be encouraged.

Topics for Actionable Recommendations

- Smart Antennas
  - Develop rule approaches to accommodate highly directional antennas, eg. Field strength limits
- Innovative Antennas
  - Certify antennas for use as detachable on Part 15 devices
  - Consider operation in passive bands (>100 GHz) if very small sidelobes
- Small Cell Roll-Out
  - Urge industry to set aesthetic standards for pole placement
  - Define necessary aspects of small cell installations that local jurisdictions may not modify in their siting deliberations

Topics for Actionable Recommendations (cont)

- Testing
  - Simplify Testing Protocols
  - Clarify power measurement method in Part 15 UNII 1 antennas
  - Explore new measurement approaches to align FCC allowed measurement procedures (TRP) with industry standard measurement procedures near fixed transmitters.
  - Allow static testing of dynamic antennas

THANK YOU

Communication Strategies for Unmanned Aircraft Systems (UAS)

Chair: John Chapin, Roberson & Associates

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Date: September 20, 2018

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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

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 requirement for station ID in UAS transmissions?
  - What is an appropriate 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

Sub Groups

- Use of Existing Systems and Standards for UAS
- Spectrum Availability Analysis
- Regulatory Technical Analysis

USE OF EXISTING SYSTEMS AND STANDARDS FOR UAS

UAS Systems Evaluation Framework

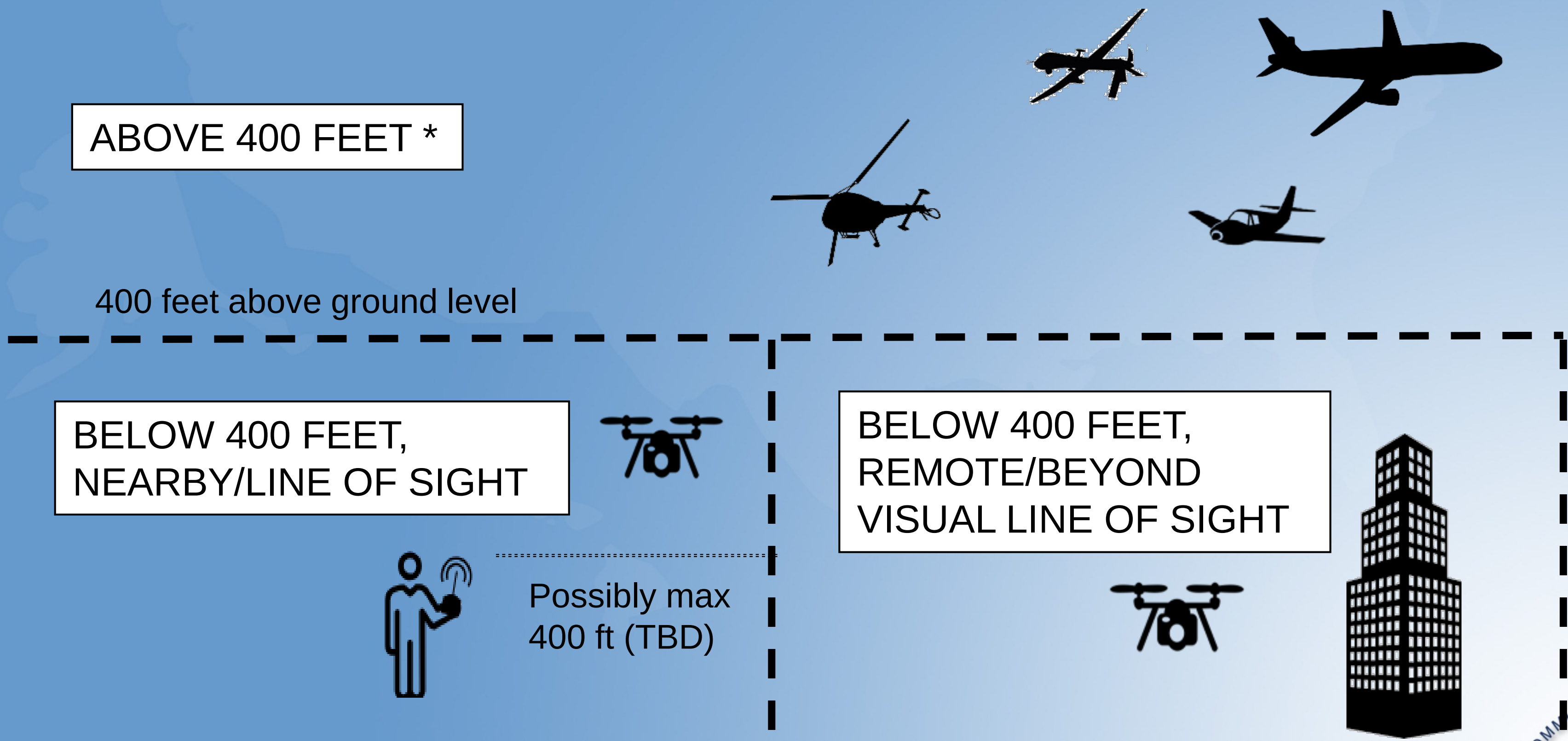
- Evaluate communications systems for potential use by UAS with respect to different communications functions
- Consider different levels of autonomy, user communities, whether UAV flies in line of sight of pilot (LOS), etc.

Communications Function	Short	Notes
Normal Command & Control	Normal C2	
Backup Command & Control	Safety C2	May be called "primary" in FAA terminology
Communications to Unmanned Traffic Management system	UAS-UTM	May not require a data link separate from C2 or Tracking
Payload	Payload	
Detect and Avoid	DAA	Cooperative, involves ground-air or air-air comms
Sense and Avoid	SAA	Standalone, onboard, e.g. radar or optical
Broadcast Identification	ID	Ability to "read license plate" of a drone in the air
Networked Tracking	Tracking	Share flight path data via a server on the ground

SYSTEMS EVALUATIONS PROCESS

- Evaluate which systems/standards are suited to different categories of UAS
  - This is NOT an endorsement for a particular system
  - Must focus in order to conduct further analysis
- Characteristics of each will be further evaluated in the expected scenarios
  - Availability/Reliability
  - Capacity
  - Coverage
  - Security
  - Integration (systems that fulfil multiple roles are preferable)
  - Latency
  - Deployment issues
  - Cost

Categorization to support Systems Evaluation



* Systems supporting these aircraft may also need to support low-altitude usage during takeoff and landing.

Below 400 feet, Nearby-LOS

- Includes hobbyist operations under "Section 336" rules and commercial operations under "Part 107" rules
  - Additional restrictions if weight > 55 lbs, or flight over people
- Automation not required
- Typical use cases:
  - Hobbyist
  - Media
  - Inspection
  - Surveillance
  - Disaster relief
- Since FAA and market still undecided, both broadcast identity and networked tracking must be investigated.

Communication Function	Required?	Notes
Normal C2	✓	
Safety C2		
UAS-UTM		
Payload		
DAA		
SAA		
Broadcast ID	✓ and/or	Both required if exceeding FAA Part 107 restrictions
Networked Tracking	✓	Tracking can come from operation station

Below 400 feet, Nearby-LOS – Candidate Systems To Evaluate

	Network Cellular	3GPP Sidelink	WiFi	Satellite	Custom unlicensed	ADS-B	DSRC
Normal C2	✓		✓	✓	✓		
Safety C2	✓			✓			
UAS-UTM	✓			✓			
Payload	✓		✓	✓	✓		
DAA		✓				✓	✓
SAA							
Broadcast ID		✓	✓			✓	✓
Networked Tracking	✓			✓			

[orange box] = required

BELOW 400 FEET, REMOTE/BVLOS

- Commercial and Government
- Still assumes 400' ceiling
- Use cases
  - News Gathering
  - Package Delivery
  - Traffic monitoring
  - Agriculture
  - Disaster relief
- Assume that the UAVs have sufficient autonomy to survive brief outages
- Unknown if Detect & Avoid will be required

Communication Function	Required?	Notes
Normal C2	✓	
Safety C2	?	May depend on level of UAV autonomy
UAS-UTM	✓	
Payload		Many use cases will require high resolution video feed
DAA	✓	
SAA	✓	
Broadcast ID	✓	
Networked Tracking	✓	

BELOW 400 FEET, REMOTE/BVLOS – Candidate Systems To Evaluate

	Network Cellular	3GPP Sidelink	WiFi	Satellite	ISM	ADS-B	DSRC	Radar
Normal C2	✓			✓				
Safety C2	✓			✓				
UAS-UTM	✓			✓		✓		
Payload	✓		✓	✓				
DAA		✓				✓	✓	
SAA								✓
Broadcast ID		✓				✓	✓	
Networked Tracking	✓			✓		✓		

= required

ABOVE 400 Feet

- Commercial and Government
- Use cases
  - Similar to Zone 1 Remote
- May also need to be able to interoperate and integrate with aeronautical communication systems
  - Air Traffic Control (possibly relay through Unmanned Traffic Management UTM system)
  - ADS-B
  - Mode C transponders
  - Etc.

Communication Function	Required?	Notes
Normal C2	✓	
Safety C2	?	Requirement depends on use case and vehicle attributes
UAS-UTM	✓	
Payload		Many use cases will require high resolution video feed
DAA	✓	
SAA	✓	
Broadcast ID	✓	
Networked Tracking	✓	

ABOVE 400 Feet – Candidate Systems To Evaluate *

	Network Cellular	3GPP Sidelink	WiFi	Satellite	ISM	ADS-B	DSRC	Radar
Normal C2	✓**			✓				
Safety C2	✓**			✓				
UAS-UTM	✓**			✓				
Payload	✓**		✓	✓				
DAA		✓				✓	✓	
SAA								✓
Broadcast ID		✓				✓	✓	
Networked Tracking	✓**			✓		✓		

*In many cases support of aeronautical systems will also be required.

**At lower altitudes

SPECTRUM AVAILABILITY ANALYSIS

General Spectrum Considerations for UAS

- Identification of service allocations for UAVs is an important first step in analyzing spectrum needs of UAVs
- Examples:
  - PRIMARY vs Secondary
  - International and FCC footnotes
  - Aeronautical prohibition
  - Adequate service rules

- Additionally, FCC prohibits aeronautical use of a mobile assignment unless specific service rules have been defined

Example from Table of Allocations

Table of Frequency Allocations		21.2-27 GHz (SHF)		
International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
21.2-21.4 EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE SPACE RESEARCH (passive)			21.2-21.4 EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE SPACE RESEARCH (passive) US532	
21.4-22 FIXED MOBILE BROADCASTING-SATELLITE 5.208B 5.530A 5.530B 5.530C 5.530D	21.4-22 FIXED MOBILE 5.530A 5.530C	21.4-22 FIXED MOBILE BROADCASTING-SATELLITE 5.208B 5.530A 5.530B 5.530C 5.530D 5.531	21.4-22 FIXED MOBILE	
22-22.21 FIXED MOBILE except aeronautical mobile 5.149			22-22.21 FIXED MOBILE except aeronautical mobile US342	
22.21-22.5 EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) 5.149 5.532			22.21-22.5 EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) US342 US532	

Impact of UAV Categorization on Spectrum Requirements

- It is reasonable to expect that UAVs of different categories will have different spectrum needs
- The categories are related to the UAV mission and include elements such as:
  - transmitter power – related to size of UAV and battery life
  - operational altitude (related to mission and environment)
  - receiver performance (related to complexity and cost)
  - operational environment (e.g. urban vs rural)

Summary of High-Level Requirements (Work In Progress)

One table for each category of UAS

Communication Function	Reliability Requirement	Latency Requirement	Bandwidth Requirement
Normal C2	High	Low	Low
Safety C2	Very High	Low	Low
UAS-UTM	Medium		Low
Payload			Low to High
DAA			
SAA			
Broadcast ID	Medium		Low
Networked Tracking			

Estimation of spectrum needs

- Requires technical information and reasonable assumptions
  - Key Technical Performance Requirements (TPRs) – e.g. peak data rate, areal capacity
  - Expected device density
  - Spectral Efficiency
  - Reliability and Coexistence Requirements
- Requires usage scenarios
  - Coverage area, deployment environments, target applications

- A few examples are presented in the following slides

Example 1 – 3GPP System Assumptions in Rel-15 UAS Studies

Items	Value
Data type	1. C&C: This includes telemetry, waypoint update for autonomous UAV operation, real time piloting, identity, flight authorization, navigation database update, etc. 2. Application Data: This includes video (streaming), images, other sensors data, etc.
Latency (NOTE)	1. C&C: 50ms (one way from eNB to UAV) 2. Application data: similar to LTE UE (terrestrial user)
DL/UL data rate	1. C&C: 60-100 kbps for UL/DL 2. Application data: up to 50 Mbps for UL
C&C Reliability	Up to 10^{-3} Packet Error Loss Rate

Data rate and latency assumptions from CTIA

<table>
<tr><th>Capability</th><th>Data Rate (kbps)</th><th>Latency (ms)</th></tr>
<tr><td>Telemetry only</td><td>12 per craft</td><td>1000</td></tr>
<tr><td>Update flight path</td><td>0.01</td><td>1000</td></tr>
<tr><td>UTM Services</td><td>50</td><td>1000</td></tr>
<tr><td>Low Bandwidth Data</td><td>1,000</td><td>N/A</td></tr>
<tr><td rowspan="3">Video streaming for business need</td><td>4,000</td><td rowspan="3">1000</td></tr>
<tr><td>9,000</td></tr>
<tr><td>30,000</td></tr>
<tr><td rowspan="3">Video streaming to aid pilot in DAA for C2</td><td>4,000</td><td rowspan="3">140</td></tr>
<tr><td>9,000</td></tr>
<tr><td>30,000</td></tr>
<tr><td>Real time C2</td><td>60 w/o video</td><td>140</td></tr>
<tr><td>C2 to backup microwave nav infrastructure</td><td>60 w/o video</td><td>10</td></tr>
<tr><td>C2 replacement for microwave nav infrastructure</td><td>60 w/o video</td><td>10</td></tr>
</table>

Preliminary observations on UAS Spectrum Needs

- A variety of spectrum resources are required.
  - C2: Latency may be the critical requirement.
  - Payload: May require up to hundreds of MHz of communications bandwidth.
  - SAA: May require up to hundreds of MHz of radar bandwidth.
- As a result, access to a variety of bands offering different bandwidth options, from a few MHz to hundreds of MHz, is needed.
  - It is noted that mobile broadband spectrum bands collectively provide for this requirement.

Analysis of Current UAS Spectrum Availability

- In the next work period, the UAS-WG will conduct this analysis
- For each spectrum band:
  - Licensed: 700 lower, 700 upper, Frontiers, ...
  - Unlicensed: 900 MHz, 2.4 GHz, U-NII-1,2,3,4, ...
  - Under Consideration: 3.7-4.2 GHz, 5.925-7.125 GHz, ...
- The UAS-WG will assess information of the following types:
  - Scope of licenses (if applicable)
  - Co-Channel services
  - Regulatory Status
  - Whether service rules are defined for aeronautical use
  - Other observations relevant for UAS communications usage

Preliminary Observations on UAS Spectrum Regulatory Challenges (1/2)

- **Role of autonomy** – Autonomous operation may reduce the need for dedicated C2 spectrum in some cases.
  - FCC rules should take into account advancements towards more autonomous operation of UAVs and the impact it could have on spectrum needs.

- **Legacy conditions and definitions** – Legacy restrictions, e.g. prohibition of transmission under certain assignments or rule parts on board aircraft, may not be appropriate for some categories of UAVs.
  - These legacy restrictions should be reevaluated.

Preliminary observations on UAS Spectrum Regulatory Challenges (2/2)

- **Integration of Communication Functions** – Multiple UAS communications functions may be integrated into shared data links resulting in use of common spectrum bands for multiple functions.
  - FCC should consider potential for integrated radio interfaces when assessing spectral requirements
  - Service rules that prevent integration of communication functions should be reassessed.

REGULATORY TECHNICAL ANALYSIS

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						

- 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

Example regulatory challenges

- May the operator claim harm if a device on a UAV receives interference from a geographically neighboring licensee, whose transmissions do not interfere with terrestrial receivers?

- May an operator claim the right to operate UAV transmitters under its current license, even if the OOBE to an adjacent-band terrestrial receiver exceeds the levels experienced prior to UAV deployment?

Evaluation Approach

- Consider possible paths the FCC might take to address these challenges
- Identify issues critical for those decisions
- Conduct technical studies to provide input on those issues

Possible regulatory path 1
Classify “low and slow” UAS as ground stations (mobile or fixed)

- Parameters can be selected to match expected high-volume UAS market
- “Low”
  - Civil small UAS - FAA Part 107 current limits – 400 feet above ground level
  - Recreational UAS – FAA strongly advises flight below 400 feet AGL
- ”Slow”
  - Civil small UAS – FAA Part 107 current limits – 100 mph

Rationale for regulatory path 1

- Low-slow UAS fit in current terrestrial usage envelope
  - There are buildings over 400 feet tall
  - There are vehicles over 100 mph speed
- Provides immediate access to a broad class of spectrum, equipment, systems
  - Supports anticipated rapid growth of civil small UAS applications
- Frees FCC to focus its UAS-oriented regulatory work on the needs of faster/higher UAS

Possible regulatory path 2
Extend terrestrial licenses to cover stations on aircraft

- FCC could declare that, when existing rules are silent regarding aerial operations, a terrestrial license extends in a defined way to operation of stations on aircraft, e.g.
  - Stations on aircraft 0-400 feet AGL, < 100 mph ground speed
    - Transmission authorized
    - Receivers may claim harm under the same conditions as devices on the ground
  - Stations on aircraft 400-1200 feet AGL, or < 400 ft AGL and > 100 mph
    - Transmission authorized after coordination with potentially impacted licensees
    - Receivers may only claim harm from transmissions that violate FCC regulations
  - Stations on aircraft > 1200 feet AGL
    - Transmission external to an aircraft requires a waiver

Rationale for regulatory path 2

- Respects ITU definition of aeronautical mobile stations
- Provides a framework for clarifying how terrestrial license rights change with altitude
  - Currently, different stakeholders may make different interpretations
    - For example, CMRS licensees interpret that their current licenses impose no restrictions on altitude of operation
  - High-volume UAV flights may make these latent disagreements problematic
- Enables FCC to evaluate/adapt at the granularity desired
  - All the bands of a specific service
  - A single band
  - Per licensee
  - Per license

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Technical Issues For Analysis

1. Potential interference to terrestrial users – 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 many be many UAS that do both at the same time

2. Potential interference to terrestrial users – out-of-band
   - Noise-limited services may exist in the adjacent band
   - OOBE studies may have assumed transmitters are in ground clutter

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

Technical Issues For Analysis

4. Potential interference to Aeronautical users
   - Some terrestrial allocations share bands with aeronautical allocations
   - Will high-volume UAV operations change the impact on aeronautical users sufficiently to require new mitigations?
5. Additional questions
   - What conditions must be true about a band in order for transmission from UAVs to be authorized without a detailed study?
   - What conditions must be true in order for current certified radio devices to be used on UAVs without additional compliance testing?

Communication Strategies for Unmanned Aircraft Systems (UAS)

QUESTIONS?

Mobile Device Theft Prevention WG
Report to the FCC TAC

September 20, 2018

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- Mark Harman, Recipero
- Bill Alberth, Roberson and Associates
- Maxwell Szabo, City and County of San Francisco
- Mark Younge, T-Mobile
- Steve Sharkey, T-Mobile
- Samir Vaidya, Verizon Wireless
- Samuel Messinger, U.S. Secret Service

Thank You!

Focus Areas for 2018

- Study future mobile device theft threats and instances or pervasiveness of stolen device trafficking across international borders and make further recommendations.
- Continue to work with law enforcement to assess the costs and benefits of the information portal (stolenphonechecker.org) to relevant stakeholders and identify recommendations for the continued industry collaboration with law enforcement for prevention efforts and analysis of the effectiveness of the prevention efforts.
- Develop mobile device theft baseline statistics based on data from directed consumer surveys and law enforcement to help track near and long-term trends and identify theft scenarios.

STUDY FUTURE MOBILE DEVICE THREATS AND TRAFFICKING ACROSS INTERNATIONAL BORDERS AND MAKE FURTHER RECOMMENDATIONS

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

- Dialogue:
  - Collaboration global blacklist database
  - Country specific concerns, items to address
    - Duplicate IMEIs
    - Whitelisting
  - Best practices and coordination across borders

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Continue to work with law enforcement to assess the benefits of the information portal to relevant stakeholders and identify recommendations for enhancements

- Continuing to work to identify enhancements to the Stolen Phone Checker
- Identifying new scenarios where the Stolen Phone Checker may be useful
- Continuing to promote the Stolen Phone Checker throughout the law enforcement community
  - Local law enforcement agencies
  - Engaging with IACP to brainstorm ways to advertise broadly

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 Annual Survey

- Law Enforcement Statistics
  - Working to obtain statistics

- Reviewing Theft Scenarios
  - Review flow charts of the lifecycle of stolen devices first presented in 2014
  - Identifying new trends for device thefts

Next Steps. . .

- Continue to collect information to fill in gaps
  - Discussions with law enforcement
  - Continue international engagement

- Continue to promote the Stolen Phone Checker
  - Domestically and internationally

2018 Harris Poll Results

Consumer Cybersecurity Topline Results – Year Five

2018 CTIA Harris Poll Results

Methodology

These findings are the results of an **online survey of 1,007 adults (18+), who own and use a personal smartphone (942 users)**, tablet (599 users), or both (534 users).

The online survey was conducted by The Harris Poll in May 2018.

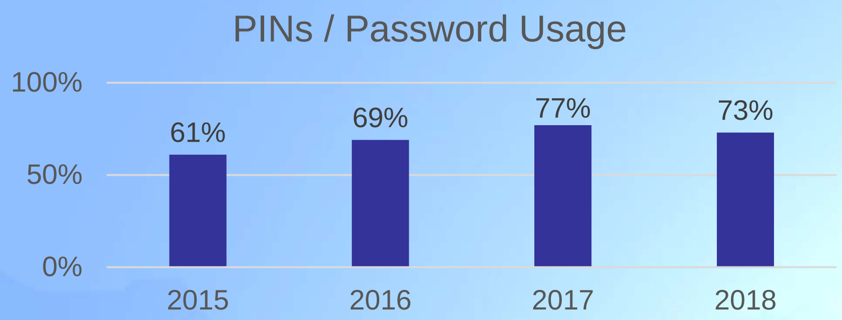
This is the fifth such poll conducted by The Harris Poll on behalf of CTIA.

The survey population was representative of the demographics of the U.S. population.

2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

Use of PINs / passwords was constant year over year (73% - 77% not being statistically significantly different). It is up significantly from 61% in 2015, and from 50% when first measured in 2012.



The top 3 reasons for deciding to use PINs / passwords:

- 44% because it was included in their smartphone's hardware/software.
- 38% to block specific people from being able to access their smartphone.
- 26% because the feature was easy to install on my own.

No need for security, too much of a hassle, and too many passwords to keep track of cited as key reasons to **not** enable pins / passwords.

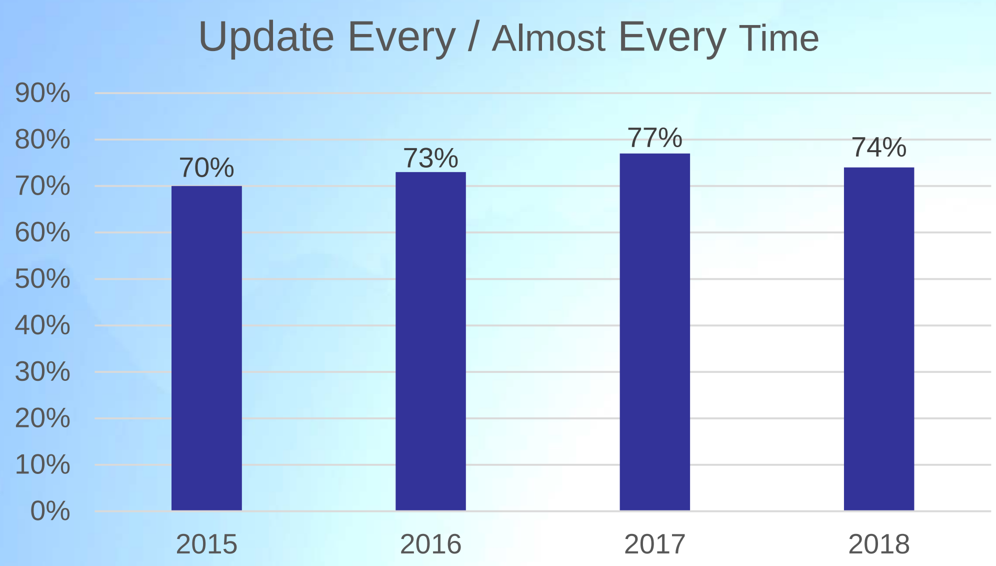
2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

Running device software updates was constant year over year, with 74% of reporting running updates every / almost every time. (74% - 77% (not statistically significantly different)).

2018 breakdown:

- 47% every time;
- 27% almost every time;
- 12% sometimes;
- 7% rarely;
- 5% never; and
- 2% don't know.



2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

Consistent with past years, 47% have software that scans for malware or anti-virus programs installed on their smartphone.

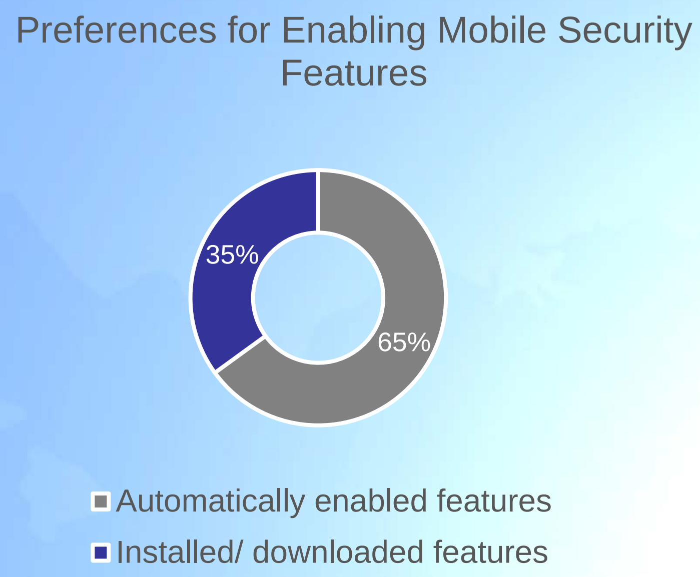
- 17% report that the program came pre-installed.
- 30% subsequently installed a program.

- Additionally,
  - 29% do not have this software.
  - 11% were not aware their smartphone could have this software.
  - 13% don't know.

2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

65% agree that they prefer the security features be automatically enabled with an option to opt out, compared to 35% preferring that the features are not automatically enabled, but installed / downloaded themselves.



2018 CTIA Harris Poll Results

Mobile Device Cybersecurity

In the past twelve months, of all smartphone owners:

- 24% have experienced a phishing cyberattack (25% in 2017);
- 12% have experienced a malware attack (15% in 2017);
- 6% have experienced ransomware (6% in 2017).

Top 3 recovery methods for smartphone owners:

- 51% rebooting or resetting their device;
- 49% being protected by malware detection software;
- 7% avoided it/did not click the link/did not open the message.

54% of smartphone owners think their mobile devices are somewhat vulnerable.

22% think they are very vulnerable to surveillance, location tracking, and other forms of cyber attacks.

2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

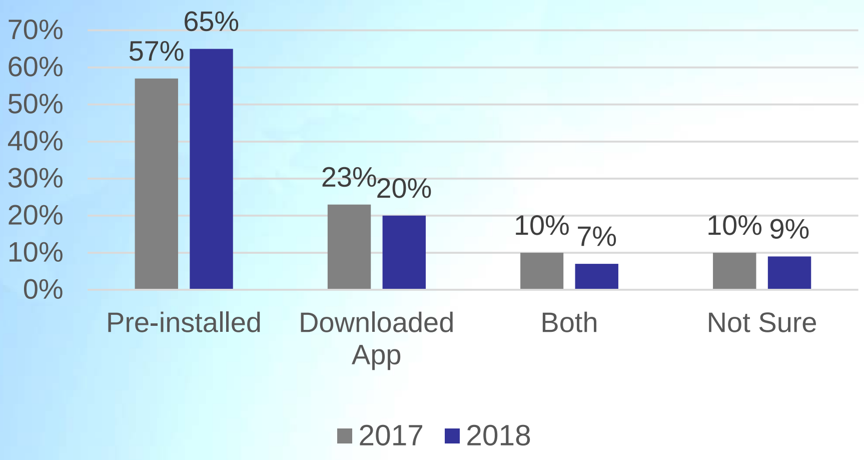
57% of smartphone owners were aware they have “find your phone” capabilities, which enable them to remotely locate, lock, or wipe their phone.

- **Number is consistent year over year** (57% - 59% (not statistically significantly different)).

Installation (for those with capability)

- 65% pre-installed (up from 2017).
- 20% downloaded app.
- 7% said both.
- 9% are not sure.

Find My Phone Installation Method



2018 CTIA Harris Poll Results

Taking Action to Protect Devices and Information

Within smartphone owners who report having the pre-installed "find your phone" capability, 73% have enabled it.

40% enabled the pre-installed capability more than two years ago, while 39% did so within the last 12 months and 21% did so in the past 12-24 months.

Top 3 reasons for <u>not enabling</u> "find my phone":

- 43% don't see a need for the capability.
- 32% have not had time to set it up.
- 15% are worried of accidentally locking or erasing.

Top 3 prompts that would <u>encourage</u> enabling the feature:

- 34% say their phone being lost or stolen.
- 29% say more information about how to enable it.
- 26% say more information about how the capability works.

2018 CTIA Harris Poll Results

Smartphone Loss and Recovery

In the past year, 9% of respondents report losing a personal smartphone.

- **Down from 13%** in 2017 **and 11%** in 2016.

Of those respondents who reported lost smartphones:

- **20% were stolen.**
- **80% were misplaced.**

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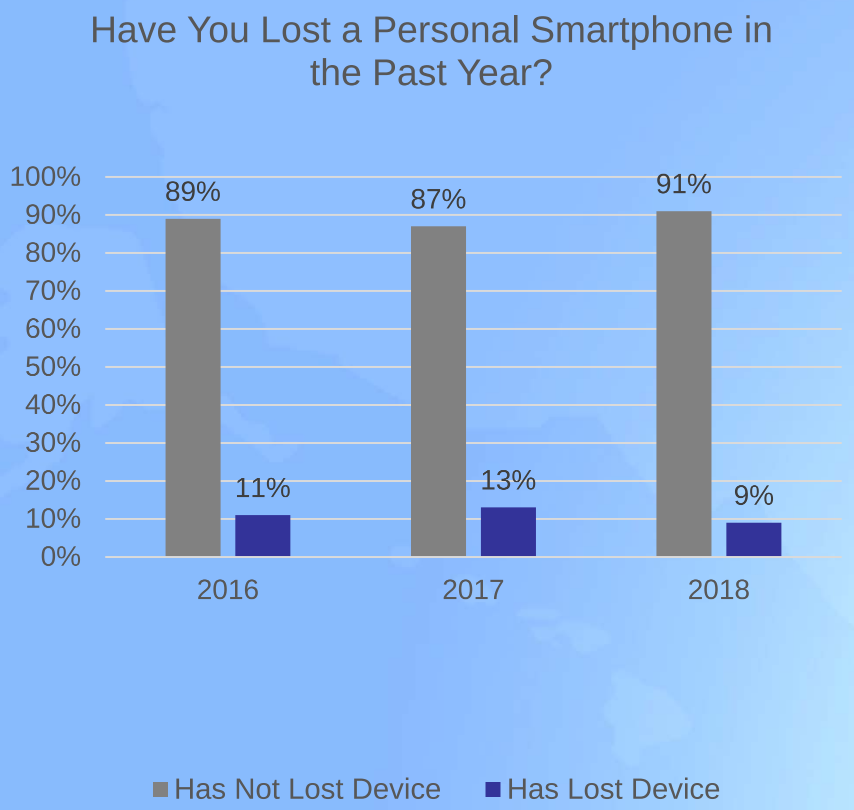
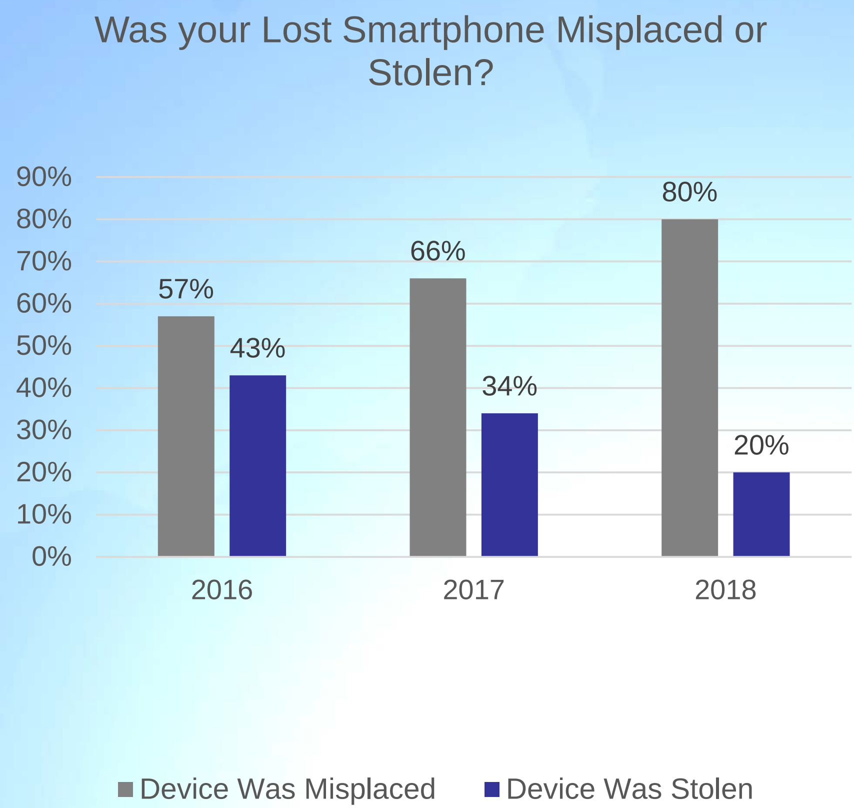
2018 CTIA Harris Poll Results

Smartphone Loss and Recovery



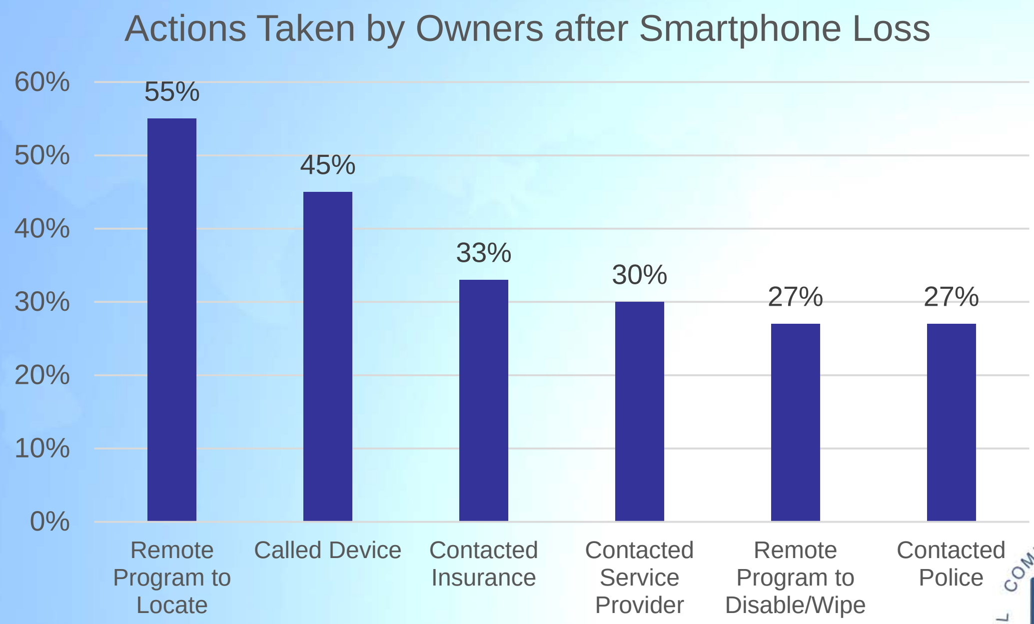


2018 CTIA Harris Poll Results

Smartphone Loss and Recovery

Once smartphone owners lost their device:

- 55% used a remote program to locate the device;
- 45% called the device to listen for a ring or vibration;
- 33% contacted their insurance carrier;
- 30% contacted their cellphone service provider to suspend service;
- 27% used a remote program to disable or wipe the device;
- 27% contacted local police;
- 3% said other; and
- 2% did none of these.



2018 CTIA Harris Poll Results

Smartphone Loss and Recovery (Note Small Sample Size)

Of those responding smartphone owners who misplaced their device in the past year, the vast majority (90%) recovered it. (up from 2017)

- 69% found their phone at home or another location.
- 22% had it returned by a friend or family member.

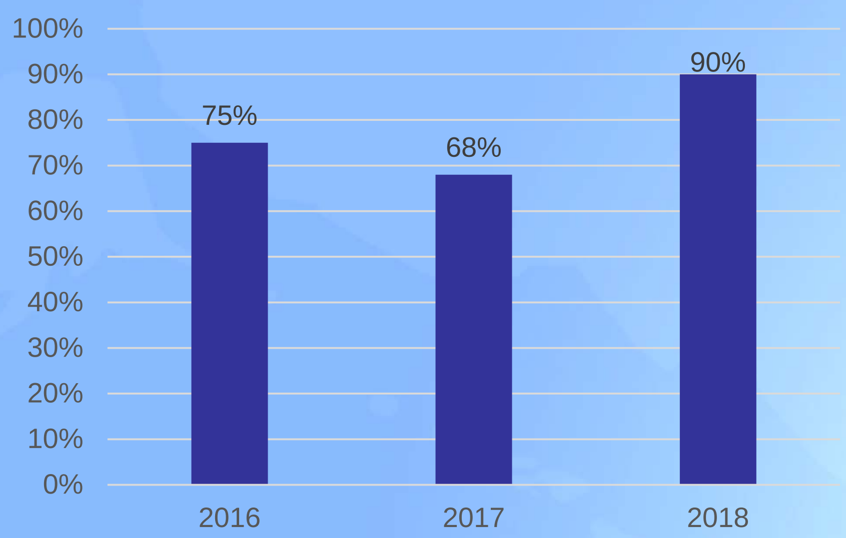
Of the ~2% of smartphone owners who had their device stolen in the past year, 59% (~1%) reported recovering it.

- 52% recovered their phone with the help of police or law enforcement;
- 24% (3 users) paid a ransom to recover it; and
- 22% “recovered” it through insurance coverage (versus 26% last year).

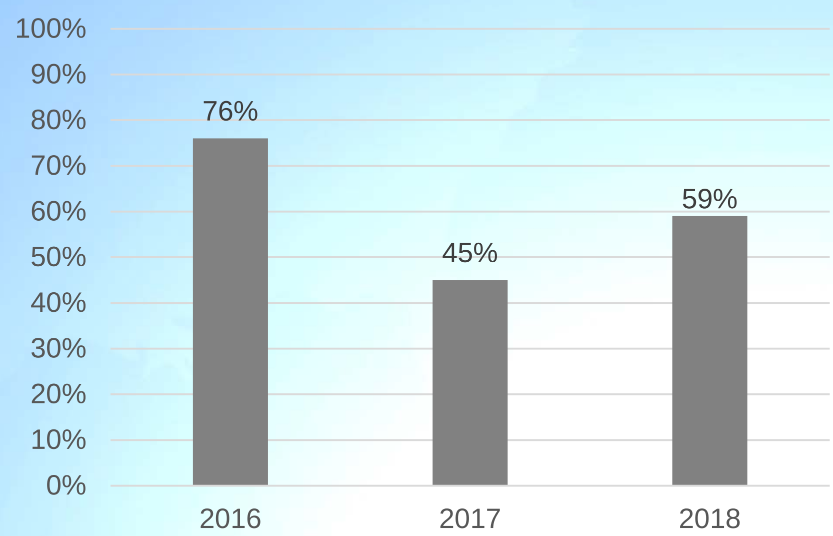
2018 CTIA Harris Poll Results

Smartphone Loss and Recovery

Recovery of Misplaced Smartphones



Recovery of Stolen Smartphones



2018 CTIA Harris Poll Results

Key Takeaways

- Number of respondent smartphone owners reporting having “find my phone” capabilities is hovering around 57%.

- Respondents reporting lost or stolen phones are down overall – and devices confirmed stolen (as opposed to lost) is also down.