Technical Advisory Council
Federal Communications Commission
Summary of Meeting
June 9th, 2016

The Technical Advisory Council (TAC) for the FCC was convened for its twenty-first meeting at 12:30 P.M. on June 9th, 2016 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, all 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:

Shahid Ahmed, PwC	Steve Lanning, Viasat, Inc.
John Barnhill, Genband	Gregory Lapin, American Radio Relay League
Mark Bayliss, Virginia ISP Association and the West Virginia Broadband CO-OP	Brian Markwalter, Consumer Technology Association
Lynn Claudy, National Association of Broadcasters	Tom McGarry, Neustar
Marty Cooper, Dyna LLC	Lynn Merrill , NTCA
Brian Daly, AT&T	Ramani Pandurangan , XO Communications
Adam Drobot, OpenTechWorks	Mark Richer, Advanced Television Systems Committee, Inc.
Erik Ekudden, Ericsson	Marvin Sirbu, Special Government Employee
Jeff Foerster, Intel Corporation	Kevin Sparks, Nokia
Lisa Guess, Juniper Networks	Dennis Roberson, Wireless Network and Communications Research Center
Farooq Khan, PHAZR Inc.	

TAC members in attendance via teleconference:

Pierre De Vries, Special Government Employee	Jack Nasielski, Qualcomm Inc.
Dick Green, Liberty Global, Inc	David Tennenhouse, VMWare
Russ Gyurek, Cisco Systems	

FCC staff attending in addition to Walter Johnston and Julius Knapp included:

David Simpson
Michael Ha

NTIA Liaison

Rangam Subramanian

Meeting Overview

Dennis Roberson, TAC Chairman, began the meeting asking the TAC members to introduce themselves. He noted that the TAC was at the midway point when 'actionable recommendations' begin to take shape. He then began with each work group making its regular presentations. In response to the Mobile Device Theft Prevention work group, David Simpson, PSHSB/FCC asked if the group could identify what areas of cybersecurity are being focused on by individual Standards Development Organizations. He noted that as the FCC focuses on higher spectrum bands, this would be useful information for providing direction on cybersecurity issues.

The Spectrum and Receiver Performance work group highlighted its recent work on RF noise assessment. They described their current approach and focus which includes a review of relevant literature together with an examination of current device emissions in relation to RF limits. The group has decided to seek public comment on key issues associated with RF noise and put forward to the TAC a request to issue a Public Notice from the TAC to the public in this regard. The FCC would assist the TAC in this regard, issuing a PN notifying the public of the TAC inquiry and filing responses in a docket for review by TAC members. This proposal was approved unanimously by the TAC.

The final work group presentation was by the Implications of Mass Deployment of Aeronautical/Space Transmitters. They overviewed the work underway and presented the range of devices/applications currently being deployed in this area. They noted that the regulatory domain in this area overlaps both the FAA and the FCC and highlighted interference issues impacting Command/Control issues associated with these devices. They intend to develop these issues as work progresses.

Dennis Roberson ended the meeting thanking the participants noting that the TAC is expanding its scope by seeking comment from the public on its working issues, specifically RF noise issues, and noting that the work group members supporting the TAC have increased which has contributed enormously to the TAC meetings its goals. He noted that at the end of the meeting, there would be a demonstration of wireless charging. The meeting was adjourned.
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A copy of all presentations is attached herein.

Walter Johnston, Chief EMCD-OET
FCC

FCC Technological Advisory Council

June 9th, 2016

Agenda

• **Introduction**	12:30 PM
• **Mobile Device Theft Prevention Work Group**	12:40 PM
• **Cybersecurity Work Group**	12:55 PM
• **NG Internet Services Work Group**	1:25 PM
• **Future Game Changing Technologies Work Group**	2:05 PM
• **Spectrum and Receiver Performance Work Group**	2:45 PM
• **Implications for Mass Deployment of Aeronautical/Space Transmitters**	3:00 PM
• **Wrapup**	3:40 PM
• **Finish**	3:50 PM

Mobile Device Theft Prevention WG
Report to the FCC TAC

June 9, 2016

2016 MDTP WG

- The MDTP working group will continue its work on device theft prevention

- Work proposed for 2016 includes developing recommendations for:
  - Next generation anti-theft features,
  - Assessment of the effect of previous recommendations on device theft,
  - Development of recommendations for improvements in consumer outreach efforts,
  - Development of mechanisms to support easier access for law enforcement to IMEI information,
  - Examination of methods for carriers to provide more useful data related to device theft and for fostering greater global effectiveness of proposed solutions.

WG Participants

- Co-Chairs:
  - Brian Daly, AT&T
  - Rob Kubik, Samsung
- FCC Liaisons:
  - Walter Johnston
  - Charles Mathias
  - Chad Breckinridge
  - Elizabeth Mumaw
- Dennis Roberson, FCC TAC Chair
- Document Editor: DeWayne Sennett, AT&T

- Asaf Askenazi, Qualcomm
- Jay Barbour, Blackberry
- Alan Bersin, DHS
- Brad Blanken, CCA
- Matthew Bromeland, Metropolitan DC Police Department
- Craig Boswell, Hobi
- Eric Feldman, ICE/Homeland Security Investigations
- Thomas Fitzgerald, New York City Police Department
- Les Gray, Recipero
- David Dillard, Recipero
- Gunnar Halley, Microsoft
- Joseph Hansen, Motorola
- Jamie Hastings, CTIA
- Joe Heaps, National Institute of Justice
- Gary Jones, T-Mobile
- Steve Sharkey, T-Mobile
- Sang Kim, LG

- Jake Laperruque, Center for Democracy and Technology
- Irene Liu, Lookout
- John Marinho, CTIA
- Samuel Messinger, U.S. Secret Service
- James Moran, GSMA
- Jason Novak, Apple
- Kirthika Parmeswaran, iconectiv
- Greg Post, Recipero
- Deepti Rohatgi, Lookout
- Ogechi Anyatonwu, Asurion
- Mike Rou, eBay
- Kevin Harris, outerwall
- Paul Cashman, outerwall
- Christian Schorle, FBI
- David Strumwasser, Verizon
- Maxwell Szabo, City and County of San Francisco
- Ron Schneirson, Sprint
- Samir Vaidya, Verizon Wireless

MDTP WG 2016 Priorities

- Set up the common framework for collection of centralized data post July 2015 (e.g., through CTIA with input from OS providers, mobile operators, and law enforcement agencies) and framework for analysis of the data
  - (CTIA) Nielsen survey of consumers is in the field on the effectiveness of the theft prevention. Target is summer 2016.
  - (CTIA) Operator survey is currently underway to aggregate information.
  - Collection of data from LEA is being addressed.

- Continued studies to determine whether implementations post July 2015 have the desired effect on mobile device theft
  - Need to have data from CTIA and LEA from the above item before analysis can be performed.

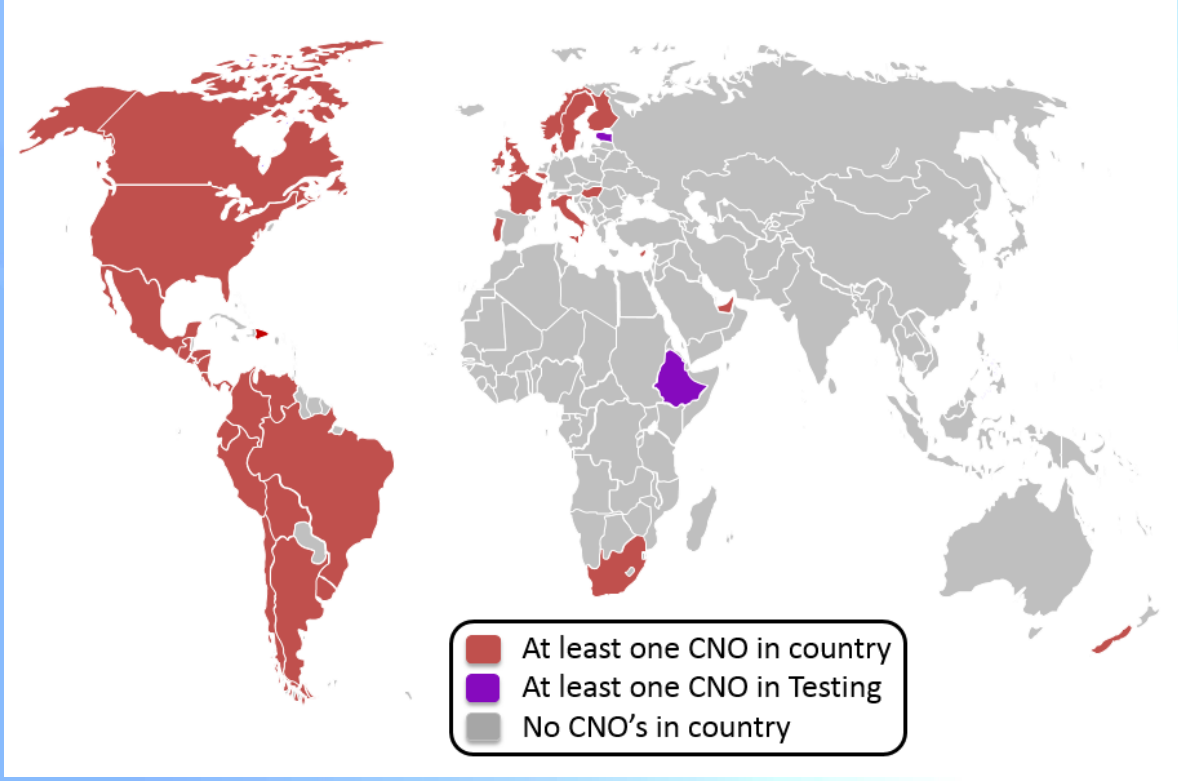
- Using the mechanisms being developed in ATIS and GSMA on enabling a mechanism for IMEI to be retrieved on disabled devices and educational outreach to law enforcement on using the mechanism
  - ATIS and GSMA best practices are in place.
  - Education outreach should be delayed until devices are available aligning with best practices.

- Consider a study on how to expand blacklisting to all US carriers, working with the GSM Association/GSMA North American Regional Interest Group and CTIA
  - GSMA/GSMA-NA are attempting to work with carriers in the region to encourage them to use the IMEI database.
  - CTIA joint meeting with GSMA addressed development of a plan to outreach to these other US carriers.

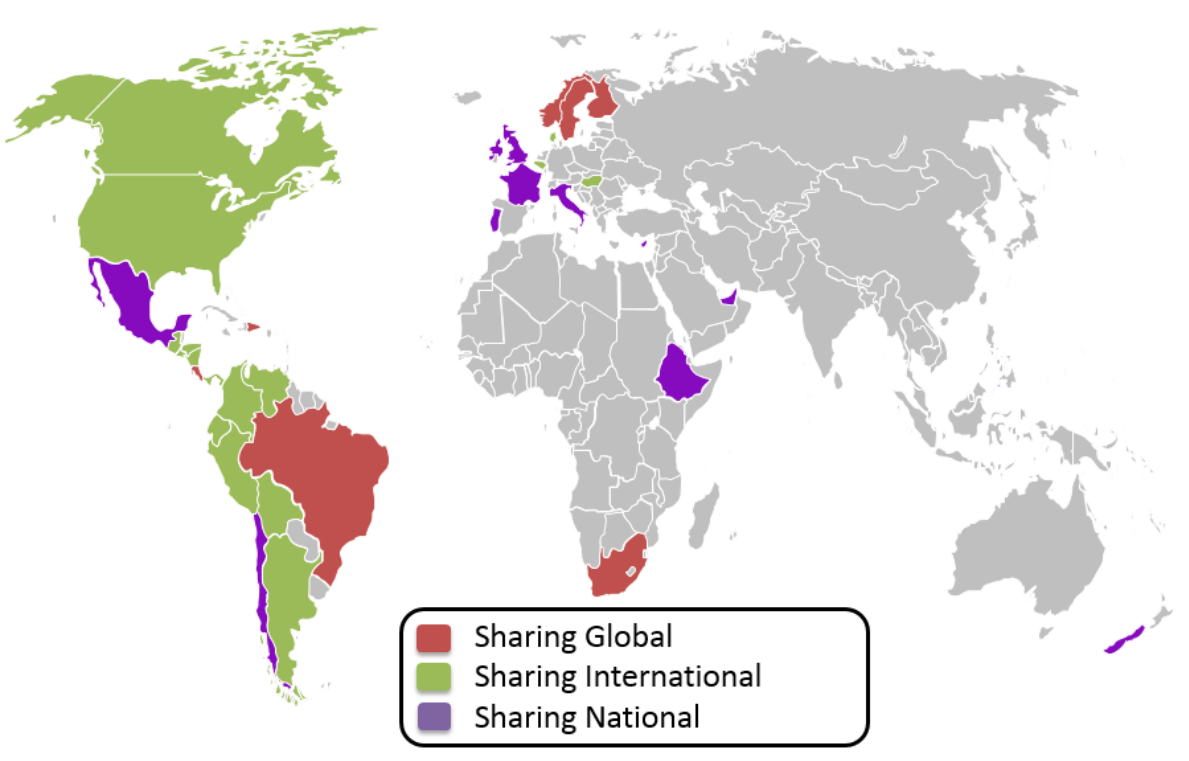
GSMA Stolen Device Data Sharing Report April 2016

- Describes the network operators participating in the exchange of IMEI data concerning devices reported lost or stolen
- Data is taken from the GSMA IMEI database and relates to operators with active live or test user accounts
- GSMA IMEI Database maintains a global blacklist collated from the data provided by the contributing operators
- GSMA provides the blacklist information on a 24/7 basis to the operators that have established connections to the IMEI Database for them to download and use within their own networks for device blocking purposes

Operators currently participating in lost and stolen blacklisting are active in the shaded countries



Rough overview of lost and stolen data sharing taking place between operators



Industry Initiatives Since March WG Report

- CTIA Device Information Portal:
  - Vendor evaluation is ongoing
  - Confident will meet phase 1 deadline – portal up and running by EOY2016

- Best Practices/Implementation Guideline for device blacklisting, device blocking, and data sharing
  - Best Practices has been completed & distributed to the GSMA-NA
  - In review cycle, to be complete by the end of June, 2016

- Alternative Blacklist Data Exchange Mechanisms
  - At the May 2016 GSMA-NA NAFFSG meeting, discussed:
    - alternatives to remove barriers to operators currently not using the GSMA blacklist exchange
    - alternatives to offer incremental benefit to operators using the GSMA blacklist exchange

Lost/Stolen Device Trafficking Patterns Project

- Industry does not have good information on where lost or stolen devices are appearing on networks and whether any trafficking patterns can be detected
- GSMA indicated that there is an opportunity to gather new information to address this, ie
  - What levels of lost or stolen devices are being blocked on networks by taking blocking logs from carrier blocking solutions?
  - What levels of lost or stolen devices are appearing on networks not implement blocking by taking dumps of the IMEIs on such networks and comparing them to the blacklist?
- GSMA called for volunteers to participate in gathering this information to determine what we can learn, i.e.
  - can we establish how many stolen devices stay in-country vs leave?
  - do stolen devices migrate to non-blocking networks and to what degree?
  - when stolen devices are presented to a network, which networks do they come from?
- Such information could be useful to both carriers and the FCC
- Requires effort on the part of participating carrier's in gathering data
  - The data is sensitive and GSMA will respect any confidentiality requirements

Next Steps

- **Proposed scope/direction**
  - Leverage the valuable work produced by the 2015 TAC MDTP Working group
  - Review recommendations from the 2014 and the 2015 MDTP reports to identify impacts & gaps toward completing the actions specified

- **Key deliverables**
  - **September 2016:** Provide draft recommendations and report on impact 2014 & 2015 recommendations are having
  - **December 2016:**Provide final recommendations and industry updates for 2016 work items

Cybersecurity Working Group

Chairs: Shahid Ahmed, Paul Steinberg
FCC Liaisons: Jeffery Goldthorp, Padma Krishnaswamy, Ahmed Lahjouji

9-June-2016

Topics

1. 5G Security (Leaders: Amit Ganjoo, Tom McGarry)
2. Securing SDN (Leaders: Ken Countway, Michael Geller)
3. Cyber Software Defined Radio (Leader: Mike Bergman)

5G Security Subcommittee

- Amit Ganjoo – ANRA Technologies (co-chair)
- Tom McGarry – Neustar (co-chair)
- George Popovich – Motorola Solutions (co-chair)
- Mike Bergman – CTA
- Brian Daly – AT&T
- Martin Dolly – AT&T
- Adam Drobot – Open Tech Works
- Alex Gerdenitsch – Echo Star
- Dick Green – Liberty Global
- Katrina Hardy – Verizon
- Soo Bum Lee – Qualcomm
- Brian Russell – Cloud Security Alliance
- Christoph Schuba – Ericsson
- Paul Steinberg – Motorola Solutions
- John Yeoh – Cloud Security Alliance
- Padma Krishnaswamy – FCC
- Ahmed Lahjouji – FCC

2016 TAC 5G Security – Scope/Deliverables

- **Proposed scope/direction**
  - Start by leveraging the valuable work produced by the 2015 TAC IoT Working group
  - Focus on IoT applications of 5G technology, which can be categorized as; Automotive, Smart Society, Smart Grids, Healthcare, Industrial, and Logistics/Freight Tracking
  - Create a list of key security principles that should be built into the 5G IoT ecosystem
  - Identify the SDOs most active in developing 5G IoT specifications
  - Develop an action plan to use the TAC's 5G IoT key security principles into the standards development process
- **Key deliverables**
  - **June 2016:** Identify the SDOs most active in 5G IoT specifications
  - **September 2016:** Communicate the current list of key security principles
  - **December 2016:** Propose an action plan for integrating the principles into the standards development process and the final key security principles

2016 TAC 5G Security – Work Plan

- **Work Plan**
  - WHO – identify key SDO to provide input to
  - WHAT – identify the security principles we want to address
  - HOW – identify how we want to provide input to the SDO
  - Focus on SDOs involved in communications and leverage that process to expand to other aspects of 5G
  - Research and industry consultation has verified that there are security issues and feedback will be timely
- **Who – 3GPP**
  - 3GPP is instrumental in 5G standards and many TAC members work directly with 3GPP
- **What**
  - Research and industry consultation has identified issues that warrant further analysis
    - Denial of Service
    - Key management
    - Identity management
    - Encryption
    - Protecting the control plane
    - Isolation mechanisms
- **How – ATIS PTSC**
  - Submit an FCC TAC paper to ATIS
  - Many TAC members coordinate 3GPP input through ATIS
  - Martin Dolly Chair of ATIS PTSC

2016 TAC 5G Security – Schedule

- 3GPP SA3 Study on Architecture and Security for Next Generation System is targeted for completion December 2016
  - The SA3 objective is to study preliminary threats, requirements and solutions for the security of next generation mobile networks
- 5G Subcommittee must provide preliminary 3GPP recommendations to TAC at Sept TAC meeting
  - Need TAC approval to send recommendations to ATIS PTSC for review
  - TAC members companies to work with ATIS to create final recommendation
    - ATIS feedback brought to 5G Subcommittee
- 5G Subcommittee to provide final recommendations to TAC at Dec TAC meeting
  - TAC member companies to provide recommendations to 3GPP after Dec TAC

2016 TAC 5G Security– Preliminary Recommendations

- Denial of service
  - Resources for different classes of traffic, services or devices should be isolated. This resource isolation may apply to
    - Control plane vs. user plane traffic
    - High QoS traffic vs. low QoS traffic vs. best-effort traffic
  - The 5G network must be able to deauthorize an individual device (or multiple devices) in such a way as the device does not continue to utilize the control plane or media plane resources
- Key Management
  - Asymmetric keys
    - 5G networks must support asymmetric key approaches
      - To enable scalability, peer-to-peer authentication, distributed trust models, among other reasons
  - Enrollment process
    - 5G networks must support a bootstrapping and enrollment process that allows entities other than carriers to provision enrollment certificates to devices
      - Open discussion as to whether this applies only to non-3GPP access devices
  - Trust models
    - 5G networks must support new, flexible trust models that take into account new trust relationships between carriers, industry verticals such as critical infrastructure, and M2M communications

2016 TAC 5G Security – Preliminary Recommendations

- **Identity management**
  - **Transitive trust**
    - **The 5G network that provides access to a device must be able to uniquely identify, authenticate and authorize each individual device that accesses the network either directly or indirectly (e.g., via a gateway, virtual network)**
  - **Spoofing**
    - **An equipment or subscriber identity that is transported across networks and presented to a terminating device (e.g., telephone number) must be authenticated and authorized**
- **Encryption**
  - **To ensure integrity of contents of communication application layer encryption should be used**
  - **Require industry standard encryption techniques to protect data during transport**
    - **Avoid using proprietary encryption protocols**

2016 TAC 5G Security – Preliminary Recommendations

- Protecting the Control Plane
  - Integrity protection is mandatory to support and mandatory to use for both UE and CN endpoint, except for emergency calls
  - Confidentiality protection is mandatory to support for both UE and CN endpoint and is recommended to be used
- Isolation Mechanisms
  - Network Slicing
    - By having a properly implemented, high-assurance isolation mechanism to support slicing, it is possible to confine the impact of security requirements to single slices, rather than the whole network
  - Security mechanisms need to be pushed closer to the device, perhaps to the base station in some cases
  - Attacks to the control and media planes must be able to be isolated to smaller geographies

Topics

1. 5G Security (Leaders: Amit Ganjoo, Tom McGarry)
2. Securing SDN (Leaders: Ken Countway, Michael Geller)
3. Cyber Software Defined Radio (Leader: Mike Bergman)

Securing SDN Sub-Working Group

Mike Geller – Cisco (co-leader)
Ken Countway – Comcast (co-leader)
Martin Dolly – AT&T
Brian Daly – AT&T
Ramani Pandurangan – XO Communications
David Tennenhouse – VMWare
Dennis Moreau – VMWware
Christoph Schuba - Ericsson
Shanthi Thomas – Motorola Solutions
Kathrina Hardy – Verizon
Padma Krishnaswamy – FCC
Ahmed Lahjouji- FCC

FCC Direction: Securing SDN

- **FCC's Goal for the WG**

  "SDN is sometimes considered to carry significantly more cyber risk than traditional network architectures. Therefore, the need to manage cyber risk in the SDN centralized network's control plane and distributed dataplane seems essential. It would be worthwhile to build security in up-front as opposed to retrofitting it, and seeking to apply lessons learned from the long running efforts to secure existing control plane protocols such as BGP and DNS. To that end, we suggest the following approach: Leverage what has been learned during the first phase of this work to develop Best Common Practices (BCP) to mitigate cyber risk associated with SDN/NFV."

- **FCC's Questions**

  1. Identify existing BCPs that focus on securing programmable networks, particularly those that are based on SDN/NFC network architectures
  2. Develop BCPs that close the gaps identified.
  3. What effective mechanisms should be employed to keep these BCPs current, and relevant to the industry?
  4. How should the FCC and the industry, together, promote adoption of these BCPs?
  5. How should the FCC and the industry, together, assess the effectiveness of these BCPs?

Securing SDN

- **Proposed Scope / Direction**
  - For the TAC, last cycle, the Securing SDN group captured the industry landscape with respect to security challenges and opportunities, now we will build on that research to develop recommended best common practices based on our further analysis of the threat surface of SDN and NFV
  - We found it relevant and necessary to couple SDN and NVF together
  - Conduct research using industry resources (vendors, SPs, SDOs, Communities)
  - Consult - SDN / NFV Security SMEs from vendors, operators and communities (e.g. OPNFV, OpenDayLight)
- **Key Deliverables**
  - **June 2016:** a) Ecosystem Engagement and Strategy to Develop / Maintain BCPs with Industry, b) Confirm Prioritized Use Cases
  - **September 2016:** BCP Drafts developed for Prioritized Use Cases
  - **December 2016:** a) BCPs Finalized for Prioritized Use Cases, b) Promotion Activity

Progress From Last Update

- Team is finalized, engaged and meeting regularly
- Use cases and areas of focus finalized
- High level project plan developed
- Industry expert interviews are beginning

Dominant Use Cases

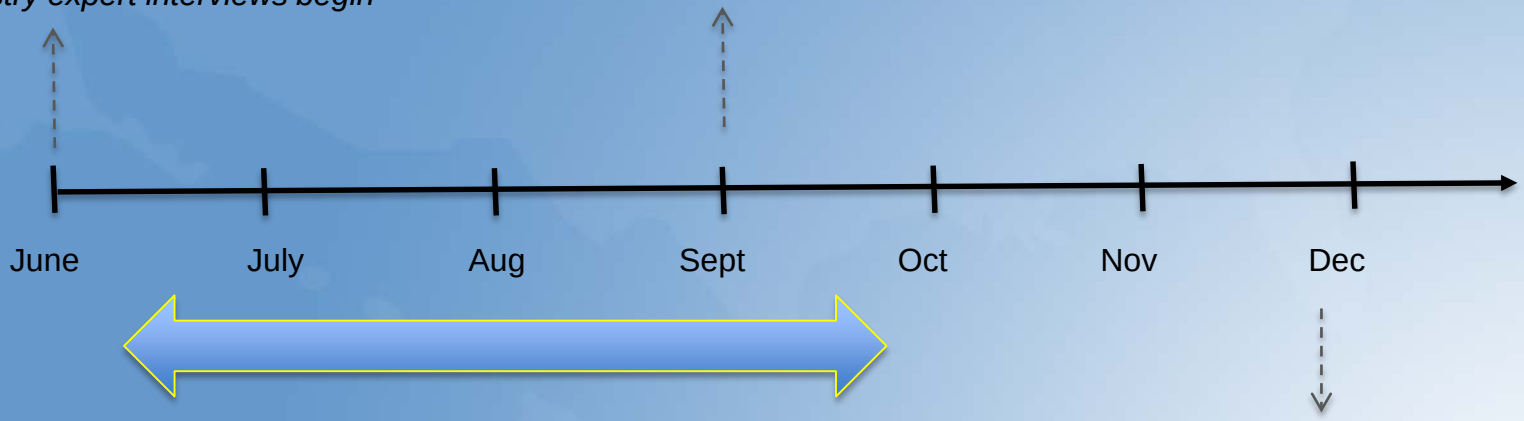
1. Service Provider SD WAN
   - Service Function Chaining
   - Virtualized Appliance and Cloud Networking
   - Virtual CPE
   - Centralized Controller Programming the Network

2. Using SDN to Mitigate DDOS Attacks

High Level Work Plan

- *Team finalized and engaged*
- *Use cases finalized*
- *High level project plan developed*
- *Industry expert interviews begin*

- *Begin writing BCP's*
- *Assign and distribute work across the team*
- *Bring in expert knowledge as needed*



- *Further refine Work Plan*
- *Key areas of focus under use cases begin to form/refine*
- *Adjust industry engagement as needed*
- *Build BCP structure and outline #1,2*
- *Draft BCP life cycle recommendations #3,4,5*

Final Draft BCP's and Life Cycle Recommendations to FCC

Topics

1. 5G Security (Leaders: Amit Ganjoo, Tom McGarry)
2. Securing SDN (Leaders: Ken Countway, Michael Geller)
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3rd Study Area in Cyber Security: Software Defined Radio (SDR)

- Issue: Freedom to overwrite SDR firmware means manufacturer frequency limits may be changed
  - E.g., TDWR interference problems
- Proposal: Additional sub group to study SDR cyber security options
  - "Cyber Security-SDR" Subgroup, CS-SDR
  - To study possible frequency security options for SDR, their likely effectiveness and impact
- Recommendations:
  - How to strike the appropriate balance between embedding frequency security mechanisms into Software Defined Radios while allowing innovation and the flexible addition of features.
- First meeting: Planned for Friday 2016-06-03 11am-12pm EDT
  - Some hardware manufacturers invited in addition to TAC participants

Next Generation (NG) Internet Service Characteristics & Features Working Group

Chairs: Russ Gyurek, Cisco
John Barnhill, Genband

FCC Liaisons: Walter Johnston, Scott Jordan, Alec MacDonell, Brian Hurley, Padma Krishnaswamy

Date: June 9, 2016

2016 Working Group Team Members

- Mark Bayliss, Visualink
- Brian Daly, AT&T
- John Dobbins, Earthlink
- Adam Drobot, OpenTechWorks
- Andrew Dugan, Level3
- Lisa Guess, Juniper
- Stephen Hayes, Ericsson
- Theresa Hennesy, Comcast
- Brian Markwalter, CE
- Milo Medin, Google
- ✓ Lynn Merrill, NTCA
- ✓ Al Morton, AT&T
- Jack Nasielski, Qualcomm
- Ramani Pandurangan, XO
- Mark Richer, ATSC
- Hans-Juergen Schmidtke, FB
- Steve Sharkey, T-mobile
- ✓ Marvin Sirbu, SGE
- Kevin Sparks, Nokia
- David Tennenhouse, VMware
- David Young, Verizon

+ Other Industry SME's

NG Internet Service Characteristics & Features Charter

2 Areas of Focus: General Improvements and Meaningful Metrics

1. Working across ISPs, the work group will seek to **identify achievable Internet improvements** that could **increase network efficiencies**, **security** or **otherwise improve the Internet ecosystem**;
2. Building on 2015, the work group will consider proposals to **extend data collection efforts**, both in terms of **efficiency** and **scale**, as well as **identifying network points** from which data should be available.
   - The possibility of end-to-end **measurements** will be examined together with the potential impact of **differentiated E2E QOS,** leveraging **alternative sources** of data (e.g. crowd sourcing), and **examining broadband bottlenecks** and **breakpoints**.

Next Gen Internet – *The End-to-End QoS Fork in the Road*

Undifferentiated Internet

Current Internet, massively scaled

- Ever higher BW applications enabled
- QoE still not predictable

Differentiated Internet

Paid QoS Internet

- For subset of traffic only
- Predictable QoE for wider range of uses

Unpaid QoS Internet

- Who gets differentiation?

Best Effort ⟵ ⟶ **Transactional**

Team Agenda 2016 – 2Q Focus Areas

- Measuring QoS- BIAS
  - *What, where, how to execute the 2015 recommendations*
- E2E QoS
  - *Continued work from 2015: "Fork in the Road"*
- Internet improvements and efficiencies
  - *New topic for WG in 2016*

June 2016 Deliverables

- Summary of QoS/ QoE Work in other standards bodies
  - ETSI, ITU, 3GPP, BiTAG, ATiS, etc.
- Identify Quality of Service/ Experience factors by traffic type
- Identify Industry efforts to improve in-home performance

NG-I WG Definitions

Quality of Service (QoS)

Quality of Service is an objective set of measurements used to describe the technical performance of a network.

Typical measurements include throughput, latency, jitter, bit error rate, availability and packet loss and are typically specified in service level agreements.

The network service provider typically proivdes layer 1-3. Higher layer services may also be offered by the network service providers, application providers or users, who in turn, may provide layer 1-3 services that inverface with the network service provider services.

Different applications have varying sensitivity to these performance factors which contribute to application Quality of Experience (QoE). From the viewpoint of the end user application, QoS metrics trade off against each other and should be interpreted in the context of improving user experience. (See BITAG recommendations)

Quality of Experience (QoE)

Quality of Experience is a subjective measurement of a consumer's perception of an application.

Many factors play a role in this subjective evaluation. These include network throughput, network latency, jitter and packet loss which are ususally measured as QoS parameters.

Origin and delivery route of content and/or applications also has an impact on perceived network performance.

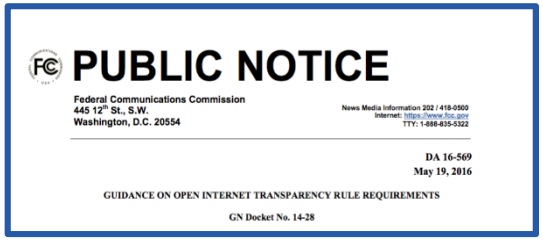
Additionally, non-service provider factors such as the user's network, devices, device configuration, user interface design, the applications that are running, the subscribed broadband tier, and the environment in which services are consumed play important roles.

Reliable QoE measurements need to copature data for all of the items listed above to compute a "realistic" QoE measurement. Adding contextual data removes many of the factors that can lead to incorrect perceptions and measurements.

Quality Metrics - QoS

Commission Driven Metrics

Open Internet Transparency Guidance



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DA 16-569
May 19, 2016

GUIDANCE ON OPEN INTERNET TRANSPARENCY RULE REQUIREMENTS

GN Docket No. 14-28

DA 16-569
May 19, 2016

MBA Metrics	AT&T/ Direct TV Merger
Download speed	
Upload speed	
Web browsing	
Voice over IP	
UDP latency	Latency Definition
UDP packet loss	Packet Loss Definitio
UDP latency/loss under load	Latency Definition -
UDP contiguous loss	
DNS resolution	
FTP throughput	
Peer-to-peer	
Email Relaying	
Video streaming (Generic)	
Video Quality of Experience	
Multicast IPTV	

Broadband Facts

15 Mbps Internet Download
Upload Speed 1.5 Mbps

Up to 50 gigabytes (GB)
Per Month **$39.99**

Extras

$10.00	Per additional 50 GB
$4.99	Equipment Rental
$3.99	Federal USF Fee
$1.99	State Deployment Fund
$49.99	Early Termination Fee

Performance*

99%	Availability
99%	Latency - Average
95%	Latency - Typical Peak
95%	Packet Loss
95%	Jitter

Standards Driven Metrics

ITU

IETF

BITAG
Broadband Internet Technical Advisory Group

atis

3GPP
A GLOBAL INITIATIVE

ETSI

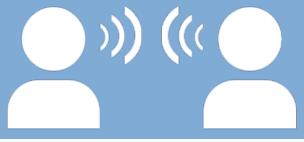
ANSI

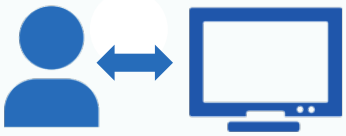
Private Initiatives

Various Parties Developing Instrumented Clients

Infrastructure focus, Human Factors Needs More Work

Services Matrix for Real-Time Services - QoS

	Real-Time	Non Real-Time
Person-to-Person 	• Multimedia Communication • Video Communication • Avatar Communication • Text Communication • Real-Time Games	• VideoMail • VoiceMail • Email • Text Chat

Person-to-Machine 	• Television
	  • TV over PC
	  • TV over Mobile
	• Real-Time Games
	• Avatar Communication
		• Web Surfing
		• Media on Demand
		  • TV over Mobile
		  • TV over PC
		  • Music

AN APPLICATION APPROACH – Tolerances Vary by Service

Source: ETSI TR 102 643 V1.0.1 (2009-12)

Human Factors; Quality of Experience requirements for real-time communication services

Service or Application	End to End delay (Seconds)		Audio-Video Asynchrony or Lip-asynchrony (Seconds)	Audio or Video arriving first	Source
	Preferred	Limit			
Example	N. S.	N. S.	0.04 s	N. S.	ETR 297 [i.17]
	N. S.	N. S.	< 0.08 s	Video	ANSI TI.552 [i.1]
Video Communication	0.1 s	0.4 s	0.1 s	N. S.	ITU-T Series H, Suppl. 1 [i.30](note)
	0.1 s	0.4 s	N. S.	N. S.	ITU-T Y.1541 [i.38]
	< 0.15 s	0.4 s	< 0.1 s	N. S.	TS 122 105 [i.22]
	< 0.15 s	0.4 s	< 0.08	N. S.	ITU-T. G.1010 [i.36] (see note)
	N. S.	N. S.	< 0.2 s	Audio	EG 202 534 [i.15]
Television	N. S.	N. S.	< 0.185 s	Video	ITU-R. BT.1359-1 [i.29]
	N. S.	N. S.	< 0.09 s	Audio	ITU-R. BT.1359-1 [i.29]
	< 0.1 s	0.4 s	N. S.	N. S.	ITU-T Y.1541 [i.38]
Surveillance, real-time video	< 10 s		N. S.	N. S.	TS 122 105 [i.22]

N. S. = Not Specified

Summary of IP Performance Metrics and Measurement Methods

IETF and ITU-T SG 12

- Good coverage of fundamental Packet Transfer aspects
  - Delay, Loss, Reordering, Duplication,
  - Many Special-purpose metrics derived from fundamentals
- More Metrics needed/under-development:
  - Registered Metrics with Less flexibility = Ease of comparison
  - Revised Service Availability Function (Loss-based, SG 12)
  - Metrics of Service Activation (DHCP, DNS, Address family/type)
  - Metrics for Transport Capacity (that meet IETF/SG12 reqmts)
- Growing Methods of Measurement (RFC 7799)
  - Active with synthetic traffic, Passive observations
  - Various Hybrids of Active and Passive emerging.

Summary of IETF Metrics/RFCs
(Relationship to ITU-T SG12 Recommendations)

	IETF IPPM RFCs	ITU-T Recs.
Framework	2330	Y.1540 cl 1 thru 5
Sampling & Streams	2330 Poisson 3432 Periodic	Some info in Y.1541
Loss	7680 STD-81 6673 (Round Trip)	Y.1540 cl 5.5.6
Delay	7679 STD-82(1way) 2681 (Round Trip)	Y.1540 cl 6.2
Delay Variation	3393 5481(PDV & IPDV)	Y.1540 cl 6.2.2 G.1020 (short term)
Availability	2678 (Continuity)	Y.1540 cl 7 (rev'16)
Loss Patterns	3357	Some in G.1020

Summary of Metrics/RFCs (Continued)
(and Relationship to ITU-T Recommendations)

	IETF IPPM RFCs	ITU-T Recs.
Reordering	4737	Y.1540 cl 6.6
Duplication & Replication	5560	Y.1540 cl 6.8 & 6.9
Stream Repair	----	Y.1540 cl 6.10
Spatial and Multiparty	5644	Y.1544
Conceptual Capacity	5136 (Links only, Informational)	Y.1540 cl 6.11
Requirements for Capacity M&M	MBM-draft sec4	Y.1540 cl 6.12, Appendix IX
Exp Methods	MBM-draft	
Numerical Object.	----	Y.1541

ITU-T SG 12 Service Availability and Related Metrics

- "Always On" model of Internet Access (Information Transfer Y.1540)
  - Packet Loss-based Service Availability Function, metrics only valid when Available
  - Proposal to use >20% loss ratio over 1 minute as transition to Unavailable state

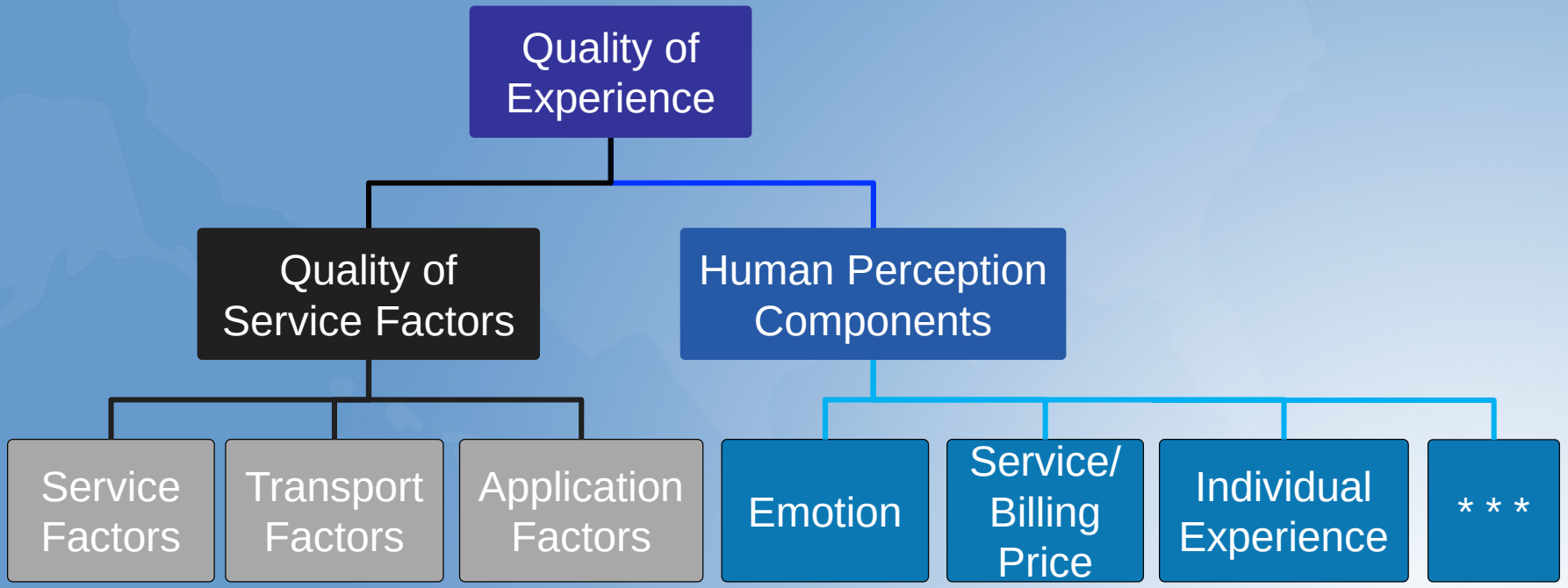
- Metrics for On-demand Service Activation (Link layer, DHCP, DNS)
  - Initial set of metrics in ITU-T SG 12, Rec Y.1546

Criteria / Function	Speed	Accuracy	Dependability
Access	Successful sub-IP attach time Successful IP activate time	Incorrect sub-IP attach ratio Incorrect IP activate ratio	Failed sub-IP attach ratio Failed IP activate ratio

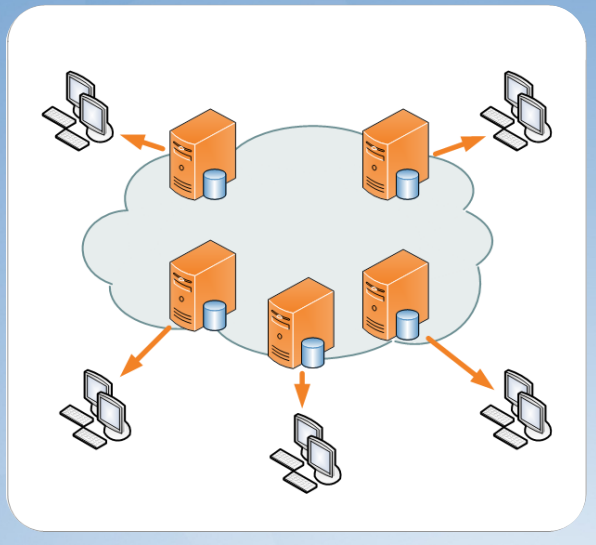
Continuing Study on Quality of Experience

- Quality of Experience (QoE) is the degree of delight or annoyance of the user of an application or service. (Qualinet/ITU-T SG 12)
- Factors that Influence QoE:
  - QoS, application, content, context, culture,
  - User expectations with respect to the system or service and their fulfilment
  - socio-economic issues, psychological profiles,
  - an expanding number of additional factors -> research

Quality of Experience – The ITU-T Approach

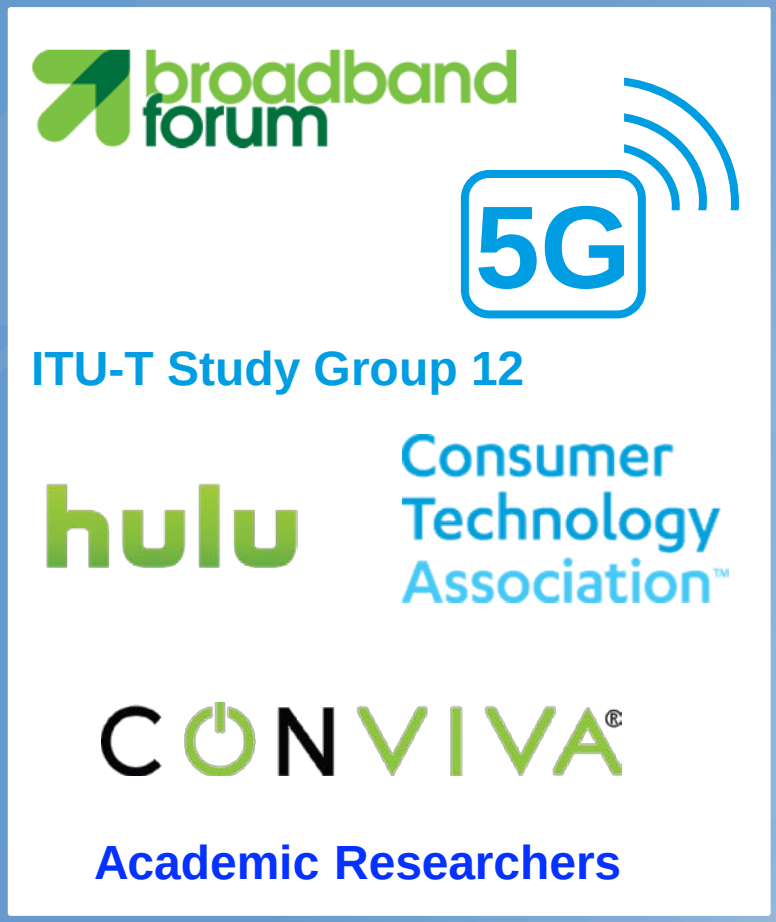


QoE Assessment stronger when more factors included



INDUSTRY INITIATIVES

Interviews and Guest Speakers



- Findings
  - Market-based Solutions are emerging to deliver improved experience for Video
  - Proprietary, client-based data gathering techniques and data allow content providers to improve the QoE provided to their users
  - Enables fine tuning of QoS
  - Enables faster decisions on content delivery path to consumer
  - No alternative path for last mile
- Q3 Target Interviews
  - You Tube, Apple, Amazon,

5.3 Connected Devices per US Household

Graphic: Laura Stanton and Tobey - The Washington Post. Published Oct. 11, 2011.

Lynn Merrill

IN-HOME NETWORKS

Source: http://www.chetansharma.com/connectedconsumer15.htm

TAC NGI WG IN-HOME NETWORK SUB WG

QoS/QoE In Home Network – Finding: BBF/ CTA

- Modern service delivery dependent on quality of in-home networks
  - In-home ”managed” by consumer, often with no experience or tools
- No public data is available on current measurements within the Home
- Few industry resources available for in-home measurement or self testing
- FCC does not have access to measurements beyond residential gateway
- Measurements within the home would help FCC, Service Providers and consumers understand constraints and additional needs for improvement
  - Unlicensed spectrum requirements (FCC)
  - Wi-Fi interference (Consumer, SP, FCC)
  - Impact due to number of devices or legacy equipment (Consumer, SP, FCC)
  - Evolution of services for future policy needs (FCC & Standards Bodies)
  - Reduce cases of trouble (Consumer, SP)

Coordination by Sub Groups with other Organizations

QoS/QoE In Home Network – Finding: BBF/ CTA

- CTA-R7 Home Networking Meeting
  - Determine Service Targets
    - Identify or work around for devices underperforming
    - SP provide assistance without truck roll
  - Design Constraints
    - WiFi challenge with added hot spots
    - Legacy and number of devices in home affect QoS
  - Customer satisfaction is improved by enhancing experience and safeguarding personal data

Coordination by Sub Groups with other Organizations- cont.

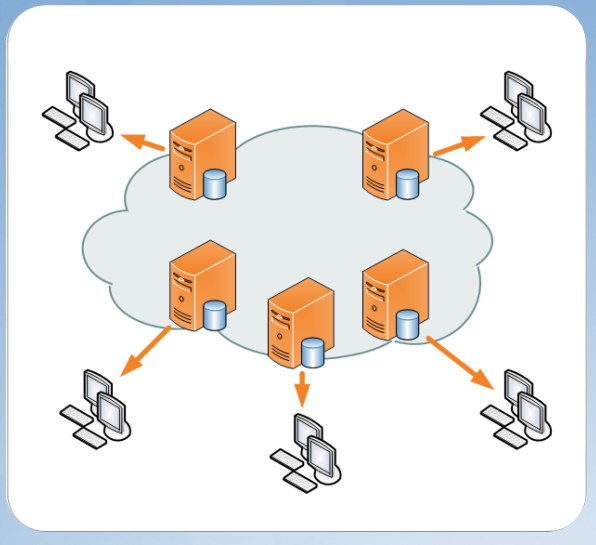
QoS/QoE In Home Network – Finding: BBF/ CTA

- CTA-R7 to provide input from members on:
  - What manufacturers are doing to perform measurements
  - Common set of metrics used to measure QoS/QoE: BBF TR069 TR304
  - Devices In Home use Open Source or Proprietary SW for measurements
  - Impact of CTA's members to implement a model to collect data
    - Concerns on increasing cost of product and data privacy
  - Members willingness to share experience and generic data
    - Response: One company provided an interest and still coordinating

Coordination by Sub Groups with other Organizations- cont.

QoS/QoE In Home Network – Finding: BBF/ CTA

- Broadband Forum
  - TR 069 for Gateway communications to SP and into the home
    - TR 304 for measurement collection for throughput, delay and availability
  - BBF to continue discussions with TAC on: QoE, NFV/SDN and IOT
- Contact Standards bodies for In-Home data collection: IETF, ITU, ETSI
- Contact others for information for In-Home data collection techniques: Service Provider, Software Providers, Content Providers, Others; Apple, Microsoft and Google



Marvin Sirbu

CONTENT DELIVERY NETWORKS

CDNs and QoS/QoE

- MBA measures performance to monitoring points in backbone
- Majority of content (esp video) is delivered from CDNs, often directly connected to BIAS network
- Need to monitor CDN performance to consumer
  - Quality Metrics
    - Startup latency
    - Average bit rate
    - Frequency of rebuffering events
    - Ratio of rebuffering to (playing + rebuffering)
    - Metrics are interdependent (higher bit rate ➔ more rebuffering)
  - Engagement as a measure of Quality of Experience
    - What fraction of a video is viewed
    - Affected by quality metrics
  - https://www.sandvine.com/downloads/general/whitepapers/measuring-internet-video-quality-of-experience.pdf

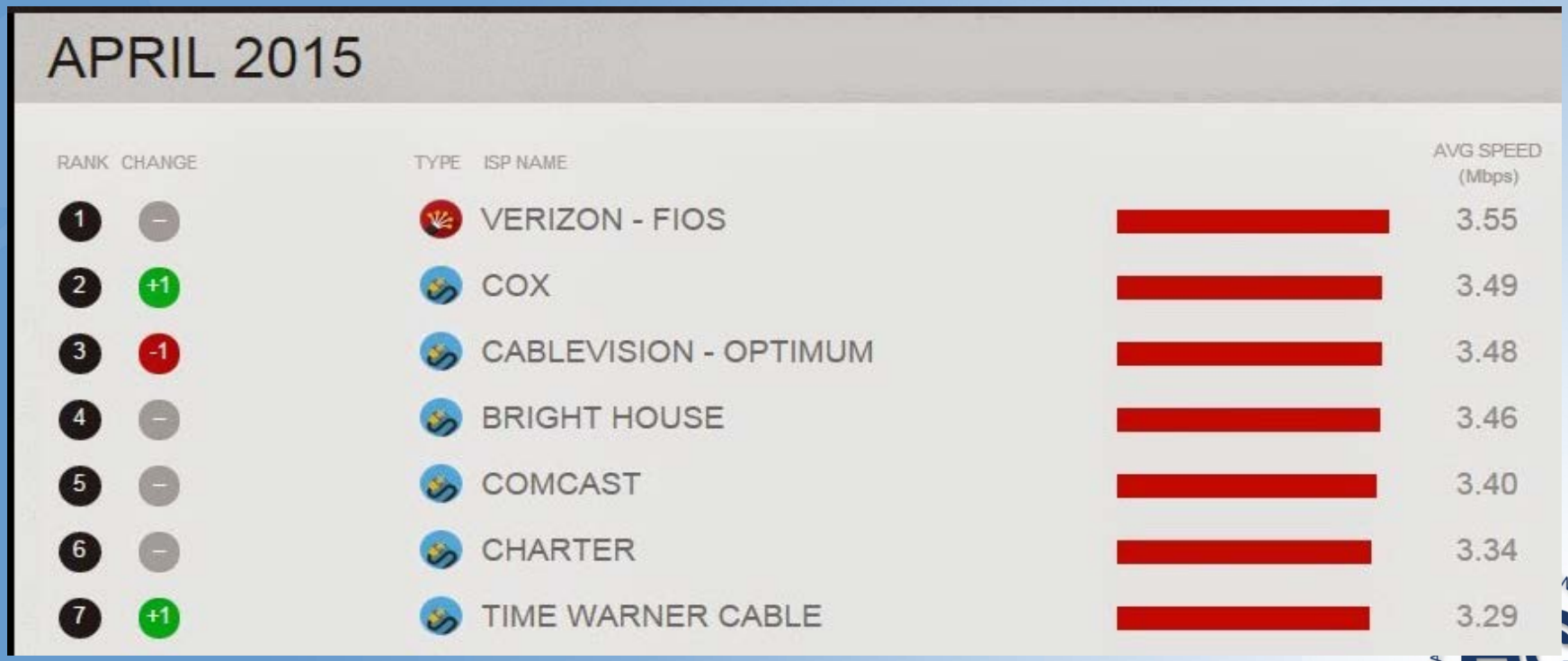
CDN Performance Data

- Some publishers, as well as 3rd parties, such as Conviva, collect extensive data on video quality
  - Instrument video players
- How can we use publisher or 3rd party data to present a picture of Internet and CDN health?
- Dimensions of the data
  - CDN
  - BIAS provider
  - Content
  - Device
  - Player
  - Time
  - Location
  - Publisher

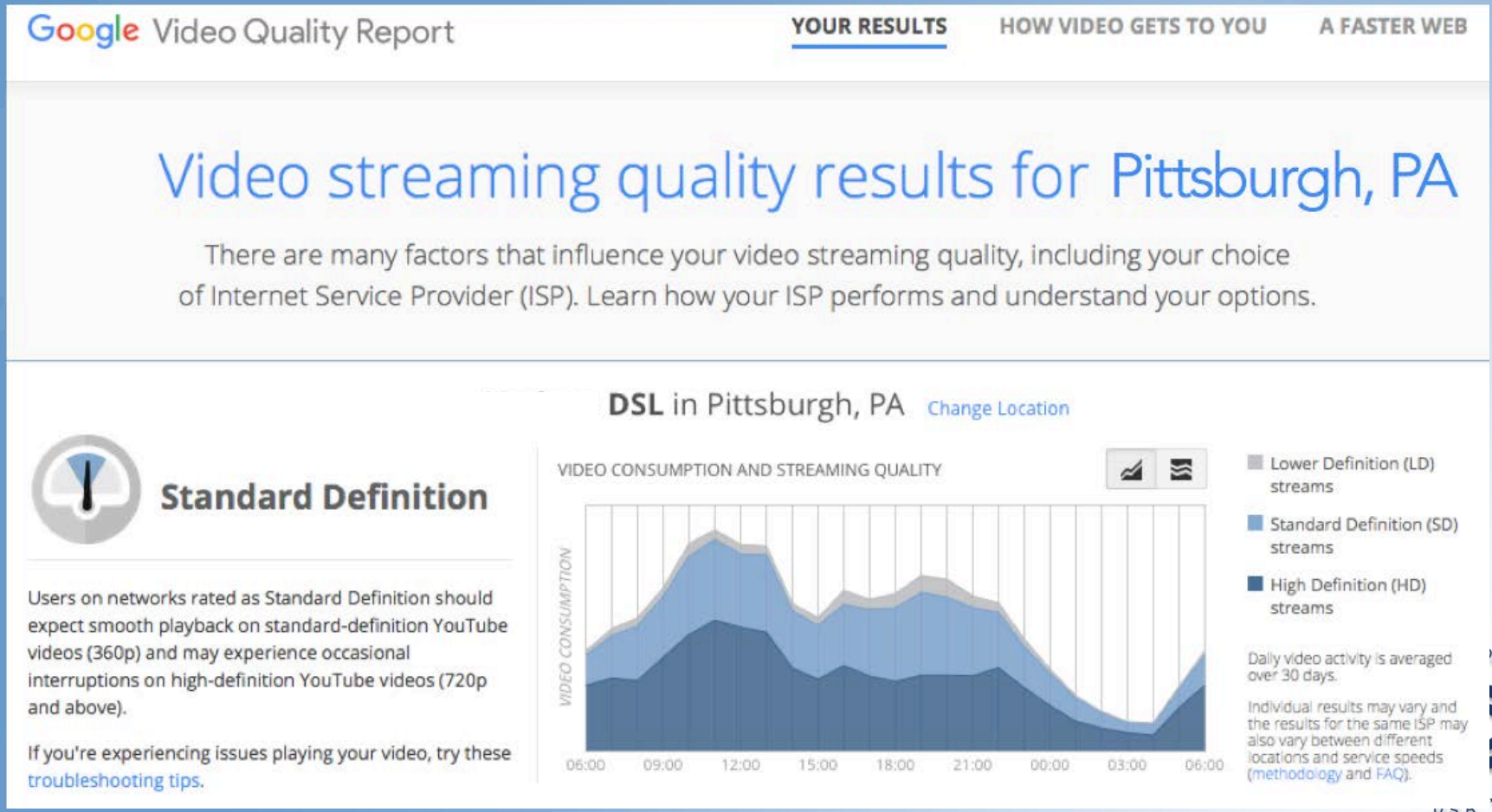
Type of Data Currently Available from Publishers

- Netflix
  - video bit rate by BIAS provider
    - Averaged over time, location, video content, device, and CDN
- YouTube
  - Fraction of video streams that are “high quality”
    - By BIAS, location (city), and time
    - Single CDN (Google)

Netflix US Data



Example YouTube Data



https://www.google.com/get/videoqualityreport/

Generating Maximum Coverage of Access, Devices, Networks

Instrumented Video Players Generate Service Quality Measurements

One App

HBO GO

NETFLIX

hulu

amazon

Many Devices

Web Browsers

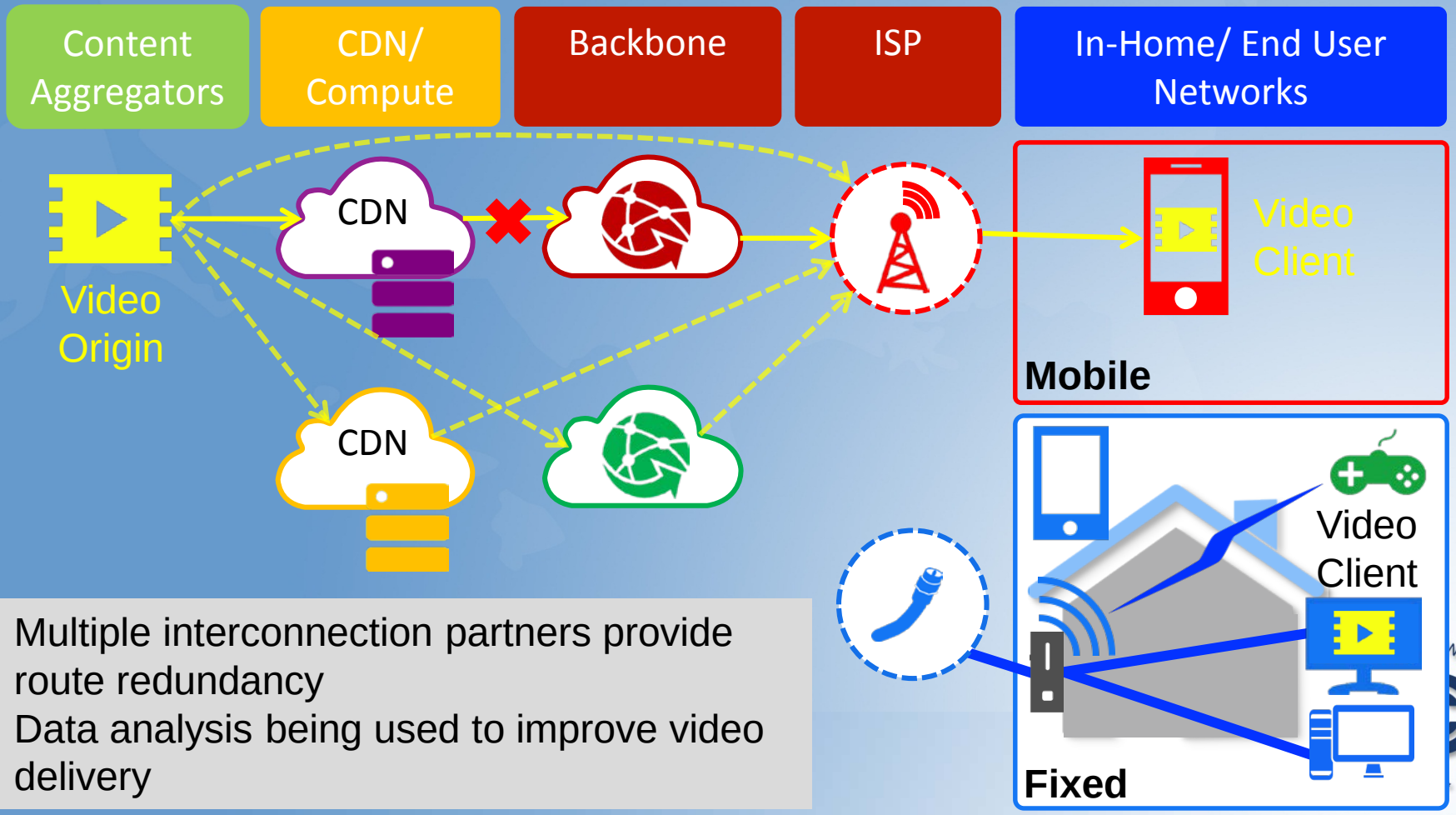
Streaming Media Players

Game Systems

Smart TVs

Mobile Devices

Data from Instrumented Video Apps Enabling Improved Route Delivery Identification



- Multiple interconnection partners provide route redundancy
- Data analysis being used to improve video delivery

What Data Reports would be useful to the FCC?

- Availability of data collected from instrumented video players
- Possible reports:
  - Bit rate by CDN and BIAS provider
    - Averaged over location, content, device, time
      - We would expect lower bit rate for wireless vs wireline
    - Averaged over location, content, device and peak hour
  - Buffering ratio by CDN and BIAS provider
    - Averaged over location, content, device, time
    - Averaged over location, content, device, peak hour
  - Percentage of locations receiving data above some bit rate threshold
    - By CDN, BIAS provider
    - By Urban vs Rural
    - Averaged over content, device, time.
- Conviva whitepaper
  - https://www.usenix.org/conference/nsdi15/technical-sessions/presentation/ganjam

3Q2016 Work Group Focus

- Plan additional focus on interviews with industry participants
- Explore opportunities with content providers and client developers for data sharing with Commission as an approach to bridging the end-to-end quality gap
- Additional Focus on Implications of Mobility and 5G
- Explore Work being done on QoE
- Focus on 2016 New Item:
  - Internet improvements and efficiencies

THANK YOU!

BACK-UP MATERIAL

Today: E2E QoS Only Available via Managed Services

Managed Connectivity	**Enterprise VPNs** **ISP Video Services** **ISP Voice Services**	▪ Managed End-end QoS/SLAs ▪ Coordinated between network operators ▪ Essential for ensuring the integrity of ISPs' own services & many "mission critical" enterprise uses ▪ Applicable to fairly high end users/uses, given cost
Internet	**Skype** **OTT Video** **OTT Voice** **Internet VPN's** **Web Browsing**	▪ User flows undifferentiated (best effort) ▪ Shared resource = universally accessible ▪ Low cost = universally applicable ▪ Enabler of unrestrained innovation & rapid/viral adoption of new services

Should the range of type & quality of services expand in the NG Internet?

AN APPLICATION APPROACH – Tolerances Vary by Service

Source: ETSI TR 102 643 V1.0.1 (2009-12)

Human Factors (HF); Quality of Experience (QoE) requirements for real-time communication services

Medium	Service or application	End-to-End one-way delay (seconds)		Audio-Video asynchrony or Lip-asynchrony (seconds)	Audio or Video arriving first	Source (see note)
		Preferred	Limit			
Text	Real-time text	< 1 s	2 s	Not applicable	Not applicable	ITU-T F.700 [i.33] (see note)
Audio	Audio communication	< 0,15 s	0,4 s	Not applicable	Not applicable	TS 122 105 [i.22] ITU-T. G.108 [i.34] ITU-T. G.114 [i.35]
		0,1 s	0,4 s	Not applicable	Not applicable	ITU-T Y.1541 [i.38]
	High Quality streaming	< 10 s		Not applicable	Not applicable	ITU-T. G.1010 [i.36]
	Speech, mixed speech and music, medium and high quality music	< 10 s		Not applicable	Not applicable	TS 122 105 [i.22]
Video	Video communication	Not specified	Not specified	0,04 s	Not specified	ETR 297 [i.17]
		Not specified	Not specified	< 0,08 s	Video	ANSI TI.552 [i.1]
		0,1 s	0,4 s	0,1 s	Not specified	ITU-T Series H, Suppl. 1 [i.30] (see note)
		0,1 s	0,4 s	Not specified	Not specified	ITU-T Y.1541 [i.38]
		< 0,15 s	0,4 s	< 0,1 s	Not specified	TS 122 105 [i.22]
		< 0,15 s	0,4 s	< 0,08	Not specified	ITU-T. G.1010 [i.36] (see note)
		Not specified	Not specified	< 0,2 s	Audio	EG 202 534 [i.15]
	Television	Not specified	Not specified	< 0,185 s	Video	ITU-R. BT.1359-1 [i.29]
		Not specified	Not specified	< 0,09 s	Audio	ITU-R. BT.1359-1 [i.29]
		< 0,1 s	0,4 s	Not specified	Not specified	ITU-T Y.1541 [i.38]
	« One-way »	< 10 s	Not specified	Not specified	Not specified	ITU-T. G.1010 [i.36] (see note)
	Movie clips, surveillance, real-time video	< 10 s		Not specified	Not specified	TS 122 105 [i.22]

Medium	Service or application	End-to-End one-way delay (seconds)		Audio-Video asynchrony or Lip-asynchrony (seconds)	Audio or Video arriving first	Source (see note)
		Preferred	Limit			
	Bulk data transfer/retrieval, playout and synchronization information, still image	< 10 s		Not applicable	Not applicable	TS 122 105 [i.22]
NOTE:	The source is contained in an appendix or a supplement (informative) rather than the body or annex(es) of the Recommendation document.					
Data	Real-time games	< 75 ms	Not specified	Not applicable	Not applicable	TS 122 105 [i.22]
	Interactive games	< 200 ms		Not applicable	Not applicable	ITU-T. G.1010 [i.36] (see note)
	Telnet	< 200 ms	Not specified	Not applicable	Not applicable	ITU-T. G.1010 [i.36] (see note)
		< 250 ms	Not specified	Not applicable	Not applicable	TS 122 105 [i.22]
	Telemetry - two-way control	< 250 ms	Not specified	Not applicable	Not applicable	TS 122 105 [i.22]
	Bulk data transfer/retrieval, still image	< 15 s	< 60 s	Not applicable	Not applicable	ITU-T. G.1010 [i.36] (see note)

N. S. = Not Specified

Building User Satisfaction – ETSI Approach

Human Factors (HF); Quality of Experience (QoE) requirements for real-time communication services

Technology Centric ***User Centric***

Usability:
Effectiveness
Efficiency
Satisfaction

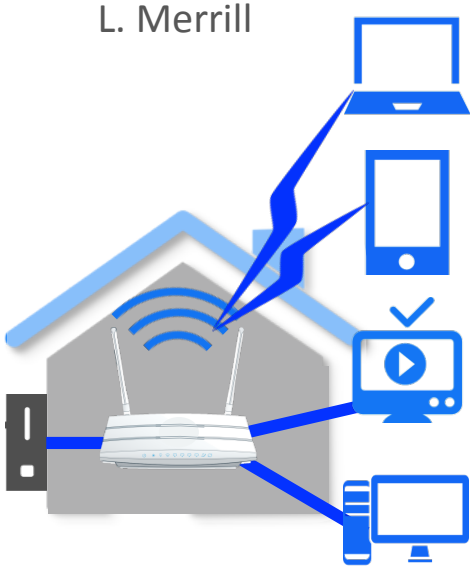
Communications Service Preformance:
User-Perceived QoS
QoE

User Experience:
Enjoyment
Appeal
Engagement

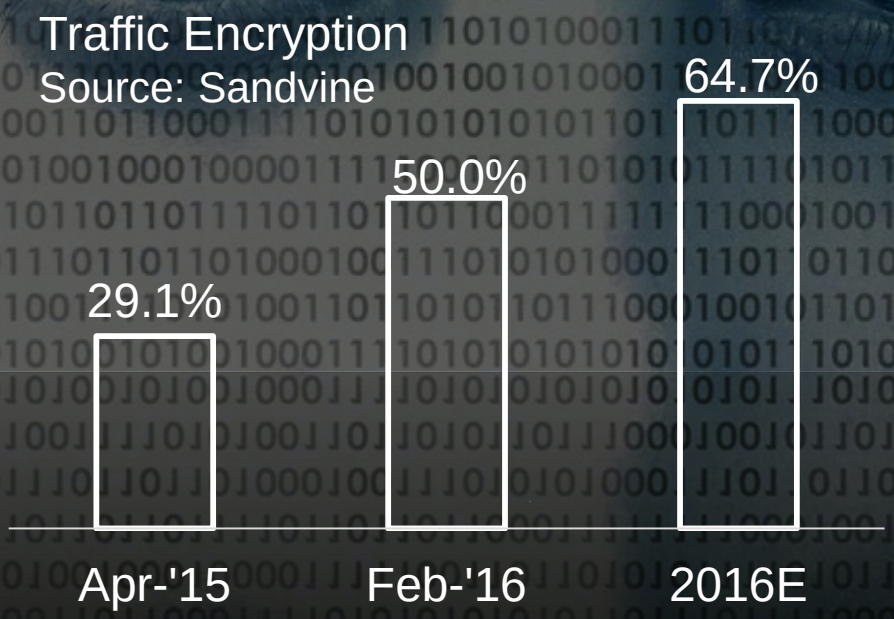
https://www.etsi.org/deliver/etsi_tr/102600_102699/102643/01.00.01_60/tr_102643v010001p.pdf

2016 Work Team Progress – Primary Focus on CDN/ In-Home

Content	CDN/ Compute	Backbone/ ISP	5G - Mobile/ ISP	In-Home/ End User Networks
Facebook Google Hulu Netflix Apple	M. Sirbu A. Dugan K. McElearney	M. Browne M. Dolly K. McElearney R. Pandurangan M. Richer	J. Nasielski B. Daly M. Browne	W. Johnston A. MacDonnell B. Markwalter M. Medin L. Merrill



Encryption



Storage

Browsing

Devices

Future Game Changing Technologies Working Group

Chairs: Kevin Sparks and Adam Drobot
FCC Liaison: Walter Johnston

9-June-2016 Washington, DC

Working Group Members

- WG Chairs: Kevin Sparks, Nokia
  Adam Drobot, OpenTechWorks
- FCC Liaison: Walter Johnston
- Members:
  - Kumar Balachandran, Ericsson
  - John Barnhill, Genband
  - Mark Bayliss, Visualink
  - Lynn Claudy, NAB
  - Brian Daly, AT&T
  - Hans-Juergen Schmidke, Facebook
  - Jeffrey Foerster, Intel
  - Dick Green, Liberty Global
  - Ramani Panduragan, XO Communications
  - Jack Nasielski, Qualcomm

Working Group Members Cont'd

- Russ Gyurek, Cisco
- Brian Markwalter, CEA
- Paul Misener, Amazon
- Lynn Merrill, NTCA
- Mark Richer, ATSC
- Marvin Sirbu, SGE
- Paul Steinberg, Motorola Solutions
- Lisa Guess, Juniper Networks
- Nomi Bergman, Brighthouse Networks
- Michael Browne, Verizon
- Steve Lanning, Viasat
- J Pierre de Vries, Silicon Flatirons
- Marty Cooper, Dyna LLC
- Charla Rath, Verizon
- Dewayne Sennett, AT&T

FGCT Working Group Charter for 2016

The work group will continue its focus on seminal technical areas for 2016:

i) Concentrate on identifying the technical challenges in developing 5G and what can to be done to ensure rapid deployment in the U.S;

ii) Examine potential new business models and service regimes that could be enabled by future programmable networks. The work group will also address the adoption of dynamic, virtualized networks and the implications for current FCC rules and policies;

iii) Address how the FCC can better anticipate rapid changes in technology and an approach to rules and policies that have the best outcome for rural and urban settings.

iv) Finally, the work group will continue its efforts to identify key new and emerging technologies

FGCT WG Tracks and Products for 2016

Sub-Working Groups (SWGs):

- 5G Adoption – White Paper
  Chairs: Brian Daly & Charla Rath
- Programmable Networks: Business Models, Rules, and Policies – White Paper
  Chairs: Mark Bayliss & __
- Education – Briefing, Presentation
  Chair: Nomi Bergman
- New and Emerging Technologies – Briefing, Presentation
  Chairs: Kevin Sparks and Adam Drobot

SME Presentations and Discussions

April 28th "Network Latency in LTE" Ericsson
May 20th "3GPP Low Latency Requirements" Intel – Nageen Hymayat
May 20th FCC Wire-line and Wireless Bureaus Discussion
May 27th "5G" Nokia – Volker Ziegler
May 27th "Programmable Networks" VmWare - Dharma Rajan
June 3rd "5G Cutting the last Cord" Phazr – Farooq Khan
June 3rd "Futurescapes" Institute for the Future – Mike Liebhold

August 12th "The 4P Project" Stanford U. – Prof. Nick McKeown

5G SWG – White Paper Overview

Purpose

- Identify technical challenges in developing 5G and ensuring leadership and rapid deployment in the U.S

Scope

- Outline benefit of moving to 5G, such as area coverage, high throughput even with intense use, capacity, cost, hyper-connectivity, latency, enabling new applications.
- Review main technical challenges to rapid 5G deployment, such as small cells and siting, spectral efficiency, coverage, availability of sufficient spectrum, automation and optimization, softwarization (cloud infrastructure and NFV)
- Identify other non-technical challenges to rapid deployment, but not review in detail, such as privacy and security, state and local ROW, competition policy

Timing

- Final report and recommendations complete for December TAC meeting

5G White Paper – Outline

- Section 1 contains the **report overview** including the introduction, the mission statement, the scope of the report, a description of the methodology used to develop this report, the FGCT 5G subgroup membership, and the structure of this report.
- Section 2 defines **what is 5G**.
- Section 3 provides a survey of **5G activities**.
- Section 4 discusses the **timeline for 5G**.
- Section 5 identifies any considerations for **privacy and security for 5G**.
- Section 6 reviews **regulatory considerations for 5G**.
- Section 7 discusses **spectrum considerations for 5G**.
- Section 8 provides **recommendations related to 5G**.
- Section 9 summarizes the **conclusions of this report**.
- Appendix A is the Glossary.

Programmable Networks SWG – White Paper Overview

Purpose

- Characterize the innovation benefit potential of programmable networks, and identify how the FCC can impact (negatively and/or positively) the realization of these benefits

Scope

- Focus is on network programmability *between* entities (e.g. network operators, application/content providers, virtual operators, enterprises)
- Benefits of network programmable implementations within a single network are out of scope

Timing

- Complete by or before December TAC meeting

Programmable Networks White Paper – Draft Outline

1. Introduction and Background – scope, purpose, and precursors
2. What are 'programmable networks'?
3. How might programmable networks be disruptive?
    1. Changes in network design
    2. New business models and the economics of PNs
    3. Altering relationship between players
    4. New functionality
    5. Use of resources (spectrum, power, computing, storage, etc)
4. What technologies underpin programmable networks?
    1. SDN/NFV
    2. Orchestration & Network APIs
    3. Enablement of programmability in network hardware equipment (fixed and wireless)
    4. Impact of Open Source software
    5. Distributed resource sharing
    6. Security

Programmable Networks White Paper – Draft Outline

5. Existing examples of operational programmable network services
    1. Cloud, Mist, and Fog services
    2. Networking services
    3. MVNOs
6. Prospective programmable networks use cases [functionality, timing, benefits]
    1. Virtual operators
    2. Roaming between mobile networks
    3. Enterprise/vertical network slicing
    4. 3rd party vNF-aaS providers
7. FCC rules, regulations, & processes that could impact PN innovation
    1. Who owns the regulatory charter and framework for new types of PN-enabled players?
    2. PNs and PN services
    3. Technology neutral approaches based on Function not Form
    4. Convergence and integration of capabilities needed to support end-end functions/apps/services
8. Recommendations

Analysis of FCC Rules, Regulation, & Processes

Context:

If SDN/NFV programmable networks lead to:

- converged wireline/wireless network providers,
- service convergence (access neutral service platforms), &
- disaggregation of service vs. network providers …

Thrust of analysis:

- What current rules, regulation, & processes might be barriers to these innovations?
- What changes to rules, regulation, & processes might encourage these innovations?

Method of analysis:

- Goal is to analyze impact on anticipated innovative business models, in the context of multi-entity use cases
- Initial discussion with FCC Wireline and Wireless Bureaus held May 20th

Analysis of FCC Rules, Regulation, & Processes

Areas of industry innovation identified for WG analysis:

- When non-communication services companies integrate communications services, impact on distribution of resources and obligations (PSAP access, CALEA, etc.) between service and infrastructure providers?
- As network slices with different characteristics (QoS, priority, mixed intranet/Internet, …) are offered over the same infrastructure, what is the impact on Internet QoS obligations?
- If infrastructure provider controlled distributed CDN/compute becomes critical to delivering quality services/content, what transparency needs or barrier to entry issues may result?
- What is the impact of access technology agnostic (wired/wireless/mobile) service platforms?
    a) 5G fixed access to the residence, which becomes mobile when subscriber leaves the home
    b) the same small cell infrastructure serves other nearby mobile/nomatic users
- Impact of dynamic 'affinity networks', for temporary large scale entertainment or sports events
- Extension of market presence of companies across other physical networks via SDN/NFV
- Insights on potential use cases that would require (or benefit from) the decoupling of spectrum owner from network infrastructure owner

Programmable Networks & 5G Use Cases

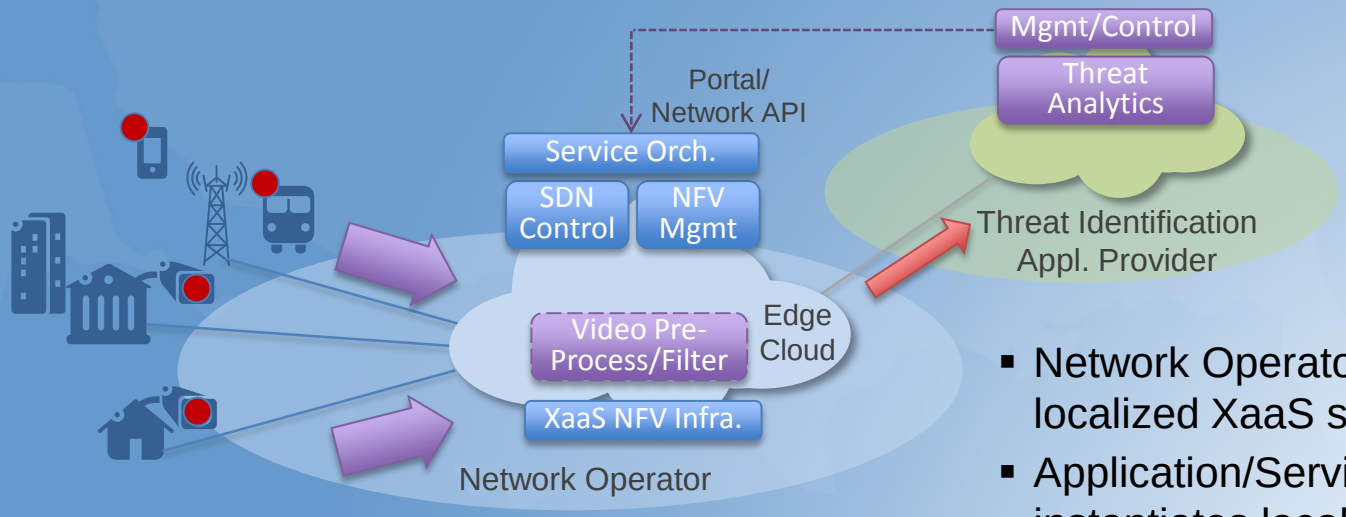
- **IoT virtual operator**
  - fleet management, IoT-specific MVNO
- **Converged wireless & wireline carrier**
  - voice, video, & content – common service environment for fixed and mobile endpoints
  - virtualized content delivery across multiple access domains
- **Network slicing** for providing QoS (that the Internet does not)
  - enterprise prioritized 'specialized' services
  - Netflix with bundled network access
- **Low latency 'tactile Internet' services**
  - programmable IaaS for 3rd parties to run low-latency apps on ISP infra
  - vehicular/cloud automation, drones,
- **Multi-connected devices**, spanning network/service entities

Programmable Networks & 5G Use Cases (continued)

- **Roaming** - more robust/uniform and efficient roaming capabilities across home & visited networks
  - service functions, security functions, obligations
- **Cooperative, cloud-based CDN arrangements** - leveraging distributed network resources
  - transparency and/or barrier to entry issues?
- **Efficient enterprise voice/collaboration arrangements** – service provider based tenant slices
  - issues with network segmentation for different network slices?
- **Composing services on the fly** from multiple entities (companies)
  - ATIS NFV Forum example: service function chains with third party VNF application providers
  - how to divide up responsibilities

Acknowledgement: Use cases on this page adopted from ATIS NFV Forum

Use Case Example - IoT Vertical Application Provider



- Network Operator provides localized XaaS services
- Application/Service Provider instantiates local functions via APIs
- Both parties benefit from performance and efficiency gains

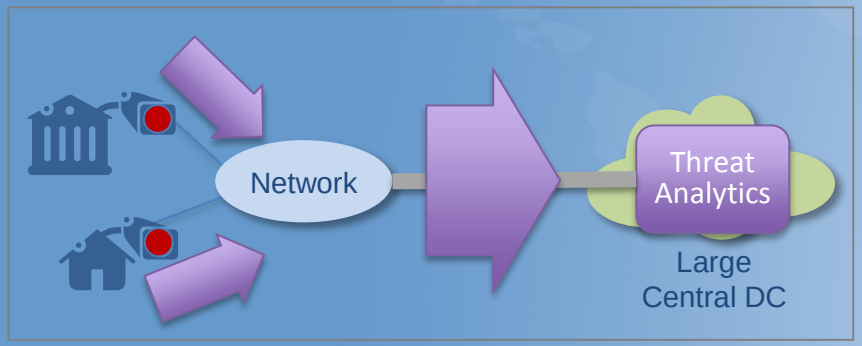
Video Pre-processing Use Case – 'Before & After' Example

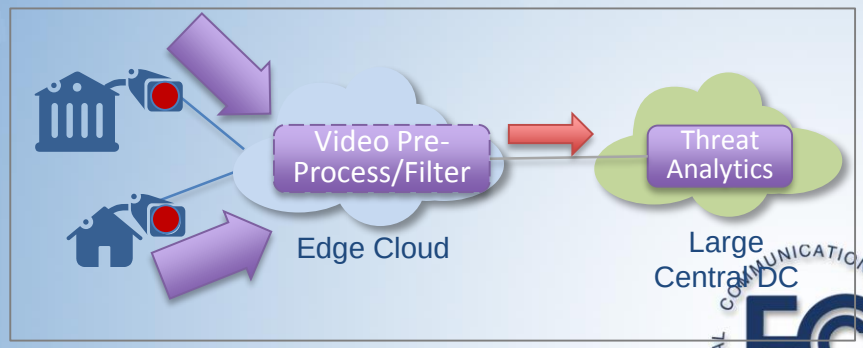
With only conventional cloud processing

- Long high BW backhaul to central DC
- Encourages local pre-filtering & storage at camera site (higher cost)
- Discourages use of highest resolution
- Discourages cross-correlation of feeds
- Limits scale & utility of security infrastructure investment

With distributed pre-processing

- Much lower transport/peering load
- Facilitates use of high resolution feeds
- Makes cross-feed correlation practical
- Efficient cloud-based archiving
- Encourages larger scale, higher utility deployments
  - enhanced security





Education SWG Summary

Objective: Address how the FCC can better anticipate rapid changes in technology and an approach to rules and policies that have the best outcome for rural and urban settings.

Update: We completed discussions with Marina Gorbis and Mike Liebhold of The Institute For The Future (IFTF) to educate ourselves as to possible approaches we might consider. They have done much relevant work, capturing signals, making forecasts, and then building a perspective on roadmaps for future technologies. For example, they recently completed a project entitled, "When Everything is Programmable," and another entitled, "After Broadband."

Next steps: Debrief internally on our discussions with IFTF, to determine whether they can be of assistance to us, whether we might want to consider other partners or approaches, and most of all, how we want to move forward.

We welcome input from the broader TAC/.

FGCT WG Next Steps

- SME talks and use case analysis throughout the year
- Schedule for Key deliverables
  - September 2015
    - In progress versions of White Papers, Briefings, and Presentations
    - Early Recommendations
  - December 2015
    - Final White Papers, Briefings, and Presentations
    - Actionable Recommendations

Thank you!

Technological Advisory Council

Spectrum and Receiver Performance

Working Group

June 9, 2016

Spectrum and Receiver Performance Working Group

- **Chairs:**
  - Lynn Claudy, NAB
  - Greg Lapin, ARRL
- **FCC Liaisons:**
  - Julius Knapp
  - Robert Pavlak
  - Matthew Hussey
  - Ziad Sleem

- **Participants / Contributors:**
  - Pierre de Vries, Silicon Flatirons
  - Dale Hatfield, University of Colorado
  - Brian Markwalter, CTA
  - Geoff Mendenhall, GatesAir
  - Dennis Roberson, IIT
  - Michael Tseytlin, Facebook
  - Robert Dalgleish, Ericsson
  - David Gurney, Motorola Solutions
  - Bruce Judson, Qualcomm

RF Noise Assessment

- Research literature and measurements on RF noise floor changes
- Research FCC rules on RF emission limits
- Compare available measurement data from devices relative to current emission limits
- Research required noise floor for various radio service bands and assess RF environment contributions to noise floor(s)

RF Noise Assessment

- Broadband Spectrum Monitoring Studies by NTIA-ITS
  - Multiple cities were studied:
    Chicago, Denver, LA, San Diego, San Francisco
  - Denver and San Diego were studied twice, 7-8 years apart
- No clear trends about the noise floor were evident.
- Most ITS reports are interested in spectrum occupancy and not specifically noise
- Questions have been raised about the applicability of the techniques used to determine the noise floor

RF Noise Assessment

- In search of answers, we would like to issue a TAC Technical Inquiry that asks the public for detailed answers to the following broad questions:
  - Is there a noise floor problem?
  - Where do problems exist (spectrally, spatially, temporally)?
  - Is there quantitative evidence of harmful interference from noise?
  - How should a noise study be performed?
- We request TAC approval to publish the Noise Floor Technical Inquiry

THANK YOU

FCC Technological Advisory Council Working Group:

Implications for Mass Deployment of Aeronautical/Space Transmitters

June 9 2016

Working Group

Steve Lanning (ViaSat) co-chair
Michael Tseytlin (facebook) co-chair
Jeffrey Foerster (Intel)
Dale Hatfield (U Colorado)
Adam Drobot (OpenTechWorks)
Russ Gyurek (Cisco)
Lynn Merrill (NTCA, MRL&Co)
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Shaun Coghlan (Aeryon)

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Michael Marcus (Marcus Spectrum)

Cortney Robinson (AIA Aerospace)

Scott Kotler (Lockheed Martin)

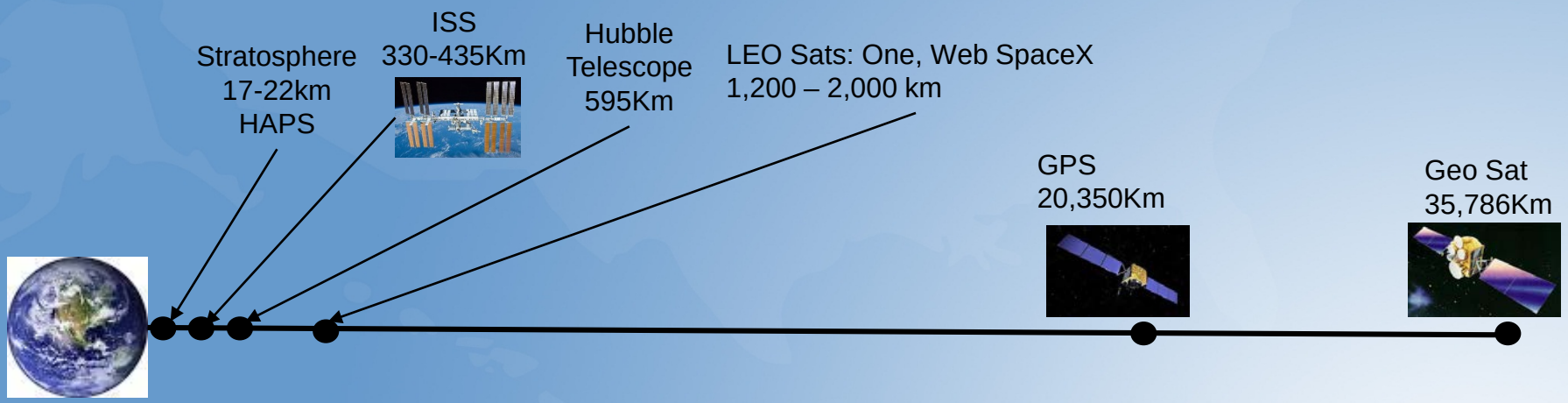
Alexander Gerdenitsch (EchoStar)

Earl Cox (Aerovironment)

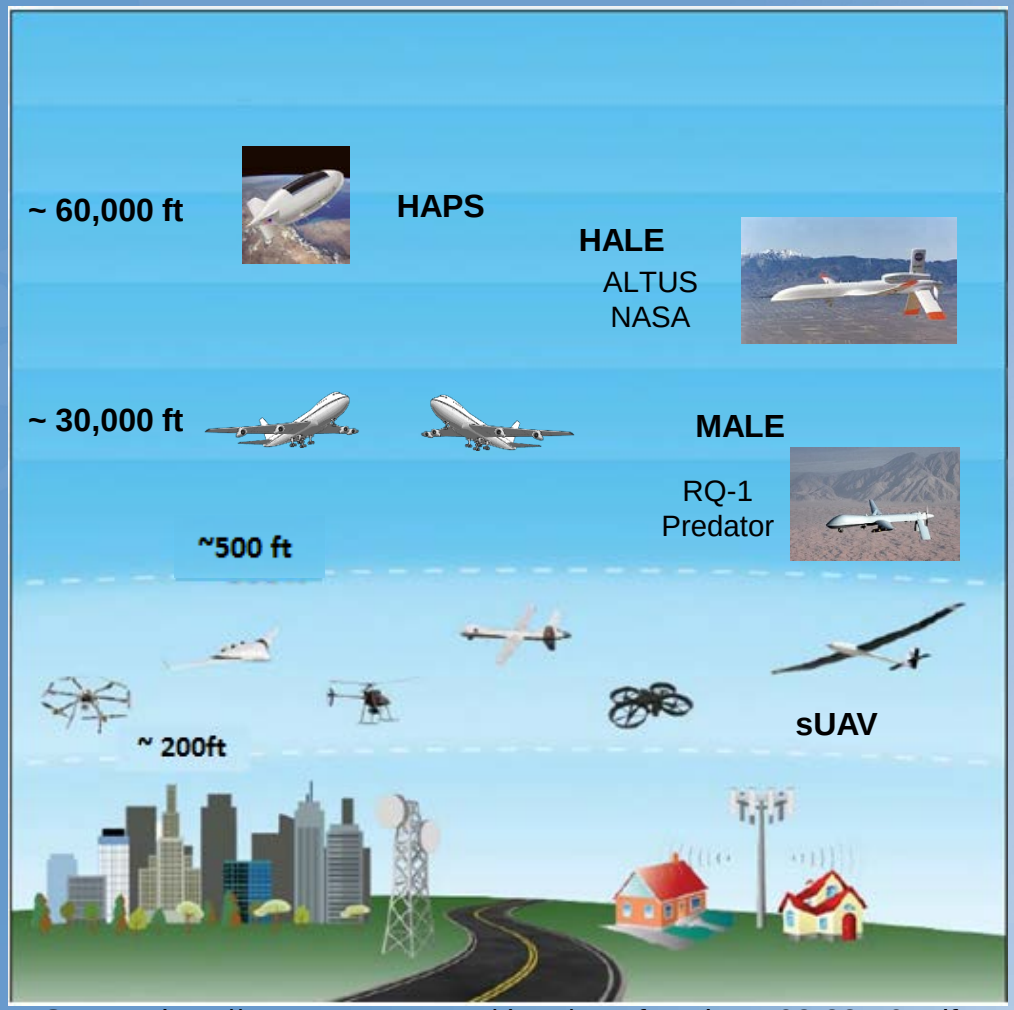
Planned Scope Of Work Adapted From Charter

Technological advances are enabling a potential expansion in the development and deployment of new types of aeronautical and space transmitters.
The aeronautical platform include manned and unmanned aircraft systems (UAS), aerostats, balloons, high altitude/long endurance platforms (HALE) and other aeronautical communications and controls emitters. The space transmitters consist of space communications, active and passive observations systems at GEO/MEO/LEO orbits. First focus on command and control of unmanned platforms as this represents the most critical new component. Payload spectrum issues remain in scope.
This working group will examine the implications these systems relative to FCC rules and policies, including identifying any spectrum issues and recommending how the Commission might address them.

Various Space/High Altitude Systems by Altitude



Note: This is not in scale



Source: http://utm.arc.nasa.gov/docs/utm-factsheet-02-23-16.pdf

UAV/HAPS under 60,000 ft (~20 km)

HAPS:
High Altitude Platform Stations

HALE:
High Altitude Long-Endurance UAV

MALE:
Medium Altitude Long-Endurance UAV

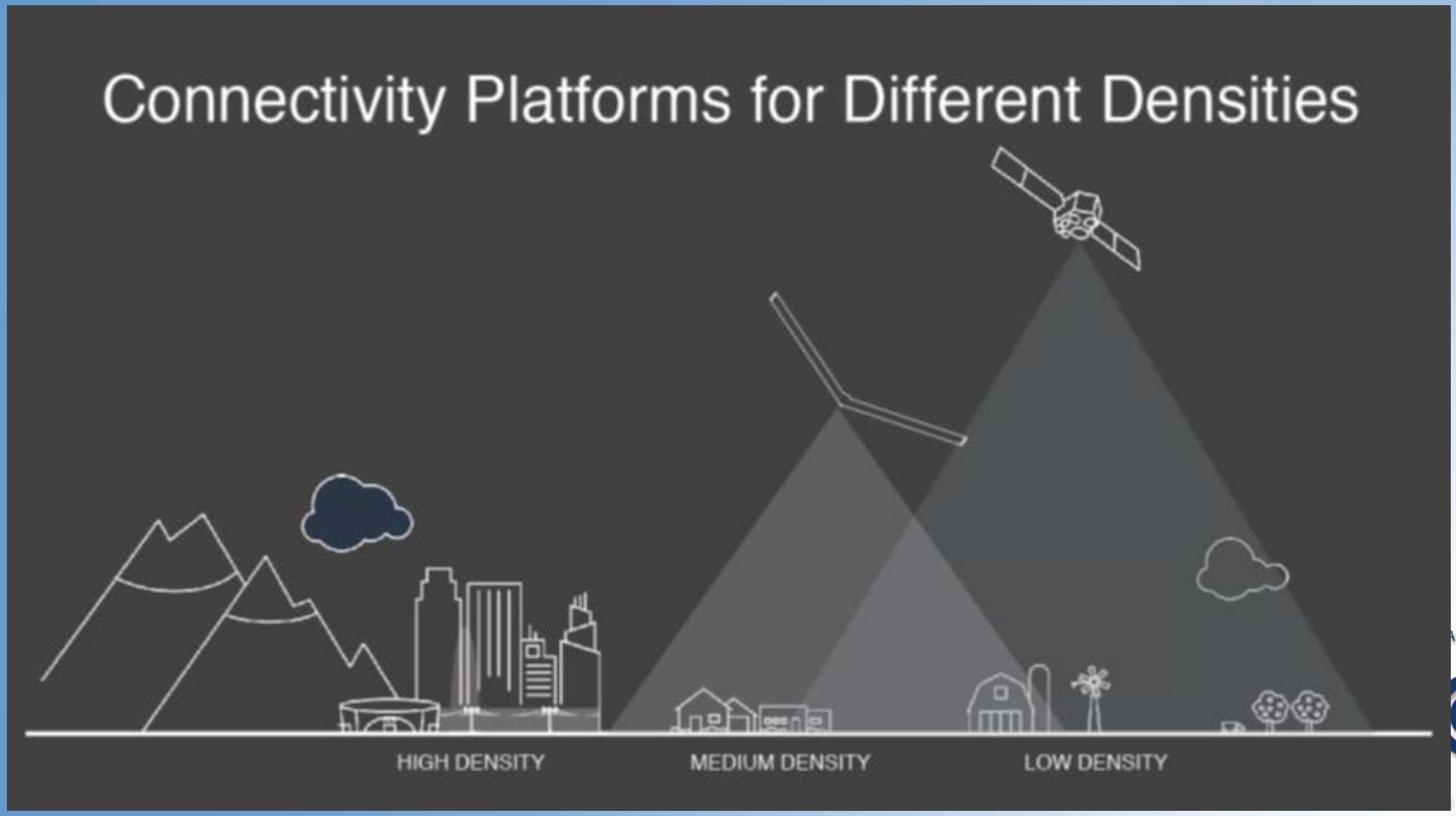
Low Altitude UAV:
Flies below 500’

Comparison of Capabilities

	GEO/LEO/MEO	Small RPAS	MALE	HALE	HAPS (fixed)
Primary Applications	Comms, Imagery	Imagery, deliverables	federal, imagery	federal	Comms. imagery
Altitude	160-2000km	Under 150ft	150-30.000ft	>30.000ft	>60000ft
Spectrum	ITU NGSO Allocations in Ku and Ka bands More allocation studied	No specific allocation	No specific allocation	No specific allocation	ITU HAPS Allocations in C, Ka and Q-bands. More allocation studied

Recent proposals from OneWeb/SpaceX involves a fleet of several hundred LEO satellites to offer global coverage

Unmanned Aerial Vehicles Come In Many Shapes And Sizes Designed For A Wide Variety Of Uses – Commercial (non-military) UAVs In Infant Stage Of Development



FAA Proposed Rules For Command And Control Of Small Size UAVs

Any UAV that does not meet all 4 conditions must have safe channel for command and control

- 500’ or less
- 55 lbs (25 kg) or less
- One to one control
- Line of sight control

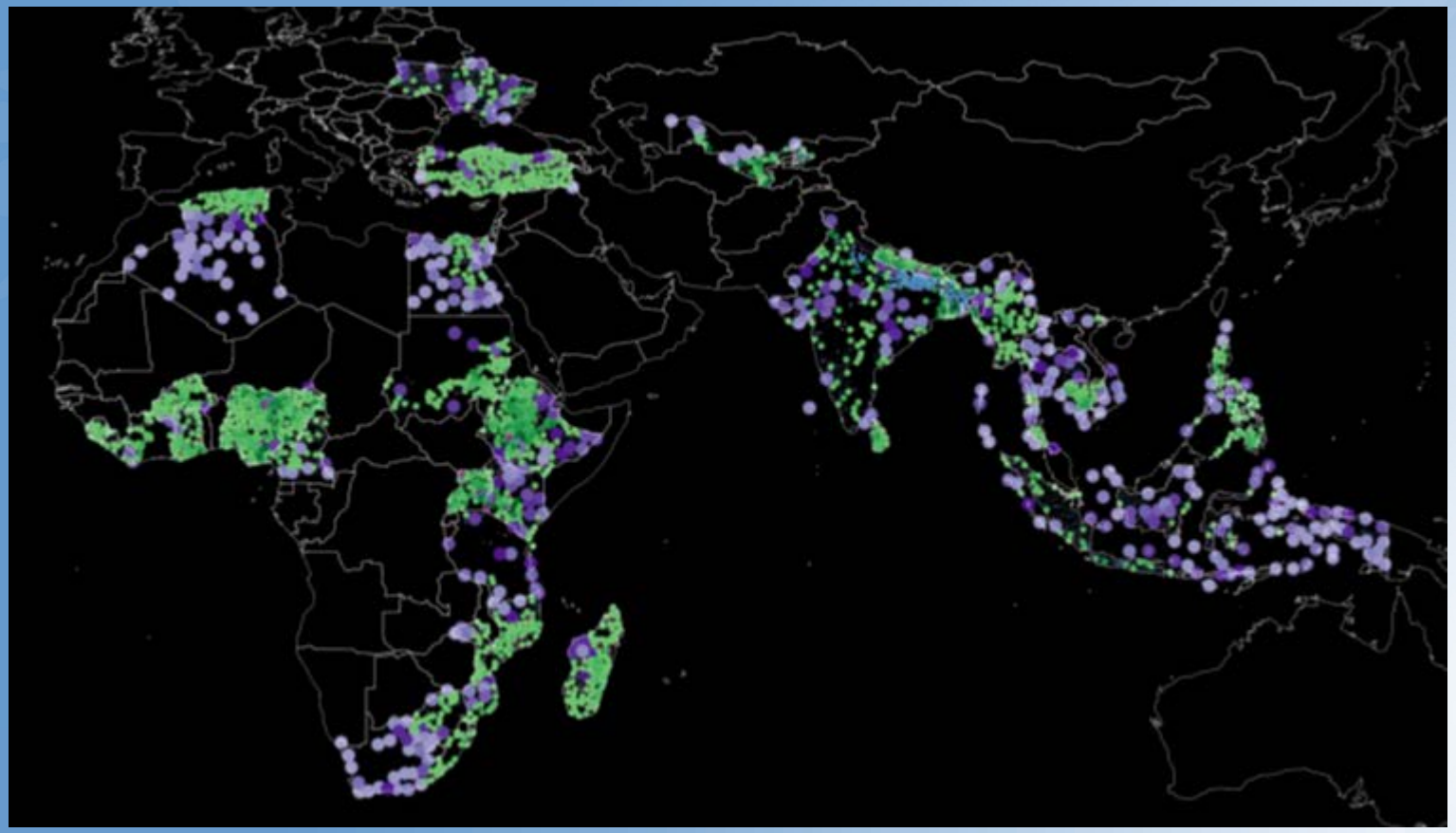
FAA To Issue Rules At End Of June

facebook – Project Aquila

Source: Facebook presentation

Large unmanned UAVs can support significant payloads at altitude of 20km
Deliver 10 GB service competitive with 3G towers under right conditions
With ongoing improvement overlay applications and coverage improve

Facebook: Mass deployment over sufficiently dense, low density areas are cost effective relative to wireless and satellite in 31 countries



Source: Facebook presentation

UAVs – cross many jurisdictional boundaries

- Government has been studying UAVs for years
  - International Telecommunication Union (ITU)
  - World Radio Conference (WRC)
  - Federal Aviation Agency (FAA)/NASA
    - Management of airspace for safety of life
  - ICAO
  - FCC/NTIA
    - Spectrum management for command and control and payloads for commercial and federal use
    - Consideration to harmonize with worldwide rules and regulations
  - Still gathering data from industry participants and stakeholders so what follows represents provisional findings
- Working group will focus on spectrum management as opposed to safety of live

Summary Of FAA Activities (details in back up)

- Section 333: over 5,000 Exemptions, But With Significant Limitations
- Notice Of Proposed Rulemaking On Small UAVs With Final Rules Expected Spring 2016
- April 2016: Micro-UAVs Aviation Rulemaking Committee Recommended further performance based regulatory framework for small UAVs and FAA to issue rule making proposal after reviewing the ARC's report in 18 – 24 months
- PathFinders Initiative: Partnership with industry to explore UAVs operations beyond those in small UAV rulemaking
- RTCA Special Committee 228: Draft Method and Procedures completed. First Phase scheduled to be completed July 2016

World Radio Conference Summary (details in backup)

Results of WRC 12

- Line of Sight (LOS) C2 spectrum allocated
- Beyond Line of Sight (BLOS) put on agenda for WRC 15/16
- SC-228 and ASTM working to develop standards to use LOS spectrum allocation

Results of WRC 15

- BLOS Spectrum “enabled”, but many source of potential interference

960–977 MHz (“L-band”) may be available in some, but not all of US

980–1020 MHz (“L-band“) May work for low-altitude below some radar interferers

5030–5091 MHz (“C-band”)

Use of FSS Ku/Ka bands resolution

Possible Interferers From Existing Users in “L-band”:

- Distance Measuring Equipment (DME), Tactical Air Navigation (TACAN), secondary surveillance radar (SSR), 1090-MHz Extended Squitter (1090ES), the Traffic Alert and Collision Avoidance System (TCAS), the Universal Access Transceiver (UAT), and the Joint Tactical Information Distribution System (JTIDS)

DoD systems need to co-exist in “L-band“ – often a source of confusion

Spectrum for command and control

ITU (Report ITU-R M.2271) says that the spectrum requirements for UAS are:

– 34 MHz for terrestrial systems,

– 56 MHz for satellite systems

Based on 10 UAVs per 70 mile radius cell operating at 18,000 feet

- Most UAVs expected to operate at considerably lower altitudes

General sentiment from those we have heard so far is that not nearly enough spectrum has been designated for command and control – maybe by as much as half what is needed has been designated

- ITU did not address sharing in order to leave as much flexibility for manufacturers as possible
  - Sharing and control of allocation for operations remains an open subject

Sample Of Regulatory Questions From Presentations

- How do FAA rules impact FCC rules and rule making?
- Options for managing spectrum for UAS
  - Should FCC auction spectrum or
  - Support spectrum assignment process
- How does ADS-B relate to this? Automatic Detection Surveillance – Broadcast
  - Certified, but really FAA call to adopt for UAV
  - Broadcast component might impose significant bandwidth requirements for command and control which may need to be handled in Ku and Ka bands by satellite
- Do BLOS requirements translate to satellite as most frequently used alternative
  - Radio line of sight vs visual LOS

Interference to and from UAS

- For Example: Model interference potential of Wi-Fi and LTE transmitters on drones; baselined against ground-level transmitters
- Deliverables
  - Interference model for low & medium altitude UAS's (ideally both C2 and access links)
  - Preliminary measurements to calibrate/test models
- Background
  - MATLAB code for interference studies widely available
  - Potential constraint: city models to generate propagation statistics
  - Should be able to extend prior work on "urban 3D" interference modeling
- Legal/regulatory questions (relevant but out of scope for engineering study)
  - Airborne unlicensed allowed by Part 15 rules?
  - Status of low altitude cellular mobile transmission?
- Next step: recruit research group(s), review research plan(s)

Work Plan Q3

- Q3
  - Summarize ITU activities
  - Complete Summarization Of FAA activities
  - Review small sats and LEO
  - Ongoing presentations from industry
  - Summarize architectural approaches
  - Identify list of what is needed by aerial platforms
    - Check off degree to which each item is addressed
    - Note which items FCC can address and which it needs to track
  - Part 15 Rules (unlicensed) and how aerial platforms using unlicensed bands might interfere with existing applications
  - Shape questions FCC needs to address regarding sharing

Work Plan Q4

- Capture working definitions
- Summarize assessments of viability
- Add catalog to basic internet service application
- Firm up provisional recommendations or propose what to track

Thank you

BACKGROUND DETAIL: FAA Activities

FAA Activities: Section 333 Exemptions

- The FAA has granted over 5,000 exemptions
- But exemptions have major limitations
  - Small UAS only (below 55 lbs.)
  - Visual LOS only
  - Below 400 feet
  - Licensed Pilot assisted by Visual Observer
  - Daytime Only (one nighttime has been granted – albeit with significant restrictions and in a very isolated case)
  - Flight restrictions near airports and over vehicles, nonparticipating people, and structures

FAA Activities:
Notice of Proposed Rulemaking (NPRM) on Small UAS

- Rules proposed for small UAS flights
- Proposed Limitations:
  - Weight under 55 lbs
  - Daylight and visual line of sight operations
  - May not operate over any persons not directly involved with operations
  - Maximum airspeed 100 mph
  - Maximum altitude 500 feet AGL
  - Operator must pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center.
- Final Rules expected Spring 2016
- FAA intends to follow with a NPRM for Beyond Visual Line of Sight rules

FAA Activities:
Micro-UAS Aviation Rulemaking Committee

- In April 2016, the FAA's Micro-UAS Aviation Rulemaking Committee recommended a further, performance-based regulatory framework for small UAS.
- The framework would be based on four small UAS categories, defined primarily by risk of injury to people below the flight path:
  - Category 1: aircraft <250 grams.
  - Category 2: aircraft >250 grams, but still presenting a <1% chance of "serious" injury to a person on impact.
  - Category 3: aircraft representing a <30% chance of causing serious injury upon impact with a person.
  - Category 4: aircraft representing a <30% chance of serious injury, but involving sustained flight over people.
- The FAA plans to issue a proposed rulemaking proposal after reviewing the ARC's report
- Despite the speed of commissioning and executing the ARC, the follow on rulemaking is expected to follow normal FAA timelines – 18 months – 2 years

FAA Activities:
PathFinders Initiative

- Partnership with industry to explore UAS operations beyond those in small UAS rulemaking
- Areas of focus:
  - **Airspace management system**
    - PrecisionHawk/Harris/DigitalGlobe/Verizon
    - Includes testing LTE networks for communications/command and control and sensing
  - **Visual line-of-sight operations in urban areas**
    - CNN/newsgathering
  - **Extended visual line-of-sight operations in rural areas**
    - PrecisionHawk/crop monitoring
  - **Beyond visual line-of-sight in rural/isolated areas**
    - BNSF Railway/rail system infrastructure inspection

FAA Activities:
RTCA Special Committee 228

- Empaneled by FAA to develop Minimum Operational Performance Standards (MOPS) for UAS.
- Two areas of primary focus:
  - **Command and Control (C2) data links:** Initial focus on L-Band and C-Band terrestrial data links; second phase would consider SATCOM C2 links in multiple bands.
  - **Detect and Avoid Radar:** Initial phase to examine civil UAS equipped to operate into Class A airspace under IFR flight rules. A second phase of MOPS development would consider DAA equipment to support UAS operations in Class D, E, and perhaps G, airspace.
- Draft MOPS have been completed. First phase scheduled to be finished in July of 2016.

Spectrum Status

- Spectrum for UASs is quickly becoming (or already is) the most critical issue for future UAS applications
- Spectrum allocation determined by World Radiocommunication Conference (WRC)
  - International forum for world agreement
  - Meetings previously held every 2 - 3 years, now extended to 4 years
  - Sets the world stage for future technological development
- National spectrum divided into two groups
  - NTIA: National Telecommunications and Information Administration
    - Federal Users
  - FCC: Federal Communications Commission
    - Non-Federal Users
- Results of WRC 12
  - Line of Sight (LOS) spectrum designated
  - Beyond Line of Sight (BLOS) put on agenda for WRC 15/16
  - SC-228 and ASTM working to develop standards to use LOS spectrum allocation
- Results of WRC 15
  - BLOS Spectrum “enabled”, but...

Current work in UAS Spectrum Management

- Official allocation for aeronautical mobile (route) service (AM(R)S)
- 960–977 MHz (“L-band”) may be available in some of US
  - USN Shipboard Tactical Air Navigation (TACAN) may interfere
- 980–1020 MHz (“L-band“)
  - May work for low-altitude below some radar interferers
- 5030–5091 MHz (“C-band”)
- Total: 67 MHz “L-band”, 61 MHz “C-band”
- Future CNPC Radio should handle both bands
- Existing Users in “L-band”:
  - Distance Measuring Equipment (DME), Tactical Air Navigation (TACAN), secondary surveillance radar (SSR), 1090-MHz Extended Squitter (1090ES), the Traffic Alert and Collision Avoidance System (TCAS), the Universal Access Transceiver (UAT), and the Joint Tactical Information Distribution System (JTIDS).
- DoD opinion on “L-band“ still unclear