

April 16, 2015

Ex Parte

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: *Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems, IB Docket No. 13-213, RM-11685*

Dear Ms. Dortch,

On April 15, 2015, Rob Alderfer and Vivek Ganti of CableLabs, and Paul Caritj of Harris, Wiltshire & Grannis LLP, and I on behalf of the National Cable & Telecommunications Association (“NCTA”) spoke with Mark Settle and Patrick Forster of the Office of Engineering and Technology, Patrick Donovan of the Wireless Telecommunications Bureau, and Jose Albuquerque, Chip Fleming, Lynne Montgomery, and Robert Nelson of the International Bureau.

We discussed the results of CableLabs’ report on the potential impact of Globalstar’s proposed TLPS service on Wi-Fi operations in the 2.4 GHz unlicensed band, which we have attached to this letter. CableLab’s analysis demonstrated that “Wi-Fi downlink throughput was reduced by as much as 65% in the presence of TLPS, with the scale of the impact dependent on the type of Wi-Fi device, and even more significant impact observed in the presence of additional interferers.”¹ A copy of that report is attached.

We also explained that, due to flaws in Globalstar’s own demonstration, it would be arbitrary to rely on its demonstration results in taking action on Globalstar’s petition. The TLPS devices demonstrated, and the environment in which Globalstar demonstrated these devices, are simply too different from the rules sought by Globalstar to form a reasoned basis for Commission action. At the Commission’s request, we further explain these deficiencies below.

The demonstration did not test whether a TLPS system adhering to the technical rules Globalstar has sought in this docket would degrade the experience of Wi-Fi consumers. Instead, the demonstration used TLPS devices with operational parameters far more limited than those

¹ See Letter from Rob Alderfer, Principal Strategist, CableLabs, to Marlene H. Dortch, Secretary, FCC, Attachment, IB Docket No. 13-213 (filed Apr. 14, 2015).

Globalstar seeks authority to use in commercial deployment. Furthermore, Globalstar's demonstration employed deeply flawed methodologies, rendering it not only unrepresentative of Globalstar's proposed TLPS operations, but also an unreliable demonstration even of the technology Globalstar exhibited.

- **The demonstration TLPS access point operated at far lower power than Globalstar has requested for actual deployments which masks the true potential interference impact.** The TLPS access point Globalstar demonstrated was set to operate at 200 mW E.I.R.P., 5% of the 4 W power level Globalstar plans to use.² Globalstar has refused to commit to use only the power level it tested.
- **Globalstar demonstrated only the most “polite” protocol, so the FCC has no information on the impact of the more interfering protocols that Globalstar could deploy.** Globalstar's demonstration illustrated only the interference impact of 802.11-compliant transmissions and ignored the other protocols that Globalstar could deploy, such as LTE, which cause significantly more interference to Wi-Fi. Globalstar has refused to commit to use only the protocol it demonstrated.
- **Globalstar's demonstration used only highly advanced, enterprise Wi-Fi access points, ignoring the impact of TLPS on typical, far-more-common consumer devices.** In reality, Globalstar's TLPS service will operate alongside many different types of Wi-Fi access points and clients, including personal Mi-Fi hotspots, reasonably priced consumer access points, and Internet-of-things devices.³ Interference to advanced, enterprise-grade access points is only a single, non-representative best-case scenario. Globalstar ignored this impact on the typical consumer.

² Petition for Rulemaking of Globalstar, Inc. at 40-41, RM-11685 (filed Nov. 13, 2012). Globalstar has suggested that this drastically reduced power level accounts for the close quarters of the demonstration environment. But in deploying Wi-Fi networks, it is reasonable for client devices and access points to operate at the tested distances from each other. In fact, the FCC has noted that testing at full power is appropriate at distances shorter than Globalstar's 4m. *See, e.g., Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands*, Report and Order, FCC 13-88, 28 FCC Rcd. 9483, ¶ 142 (2013).

³ Although Globalstar has criticized the Bluetooth Special Interest Group's use of a broadcast-based mesh networking technology in its demonstration, such architectures are likely to be typical of both Wi-Fi and Bluetooth Internet-of-things deployments. *See* Letter from Regina M. Keeney, Counsel to Globalstar, to Marlene H. Dortch, Secretary, Federal Communications Commission, at 1-2, IB No. 13-213 (filed Mar. 13, 2015).

- **Globalstar’s demonstration used only TLPS access points that were carefully designed to minimize interference to Wi-Fi rather than typical access points.** Globalstar’s demonstration TLPS access points were modified enterprise-grade Wi-Fi access points which cost over a thousand dollars each, and incorporate advanced interference-prevention technologies such as adaptive beamforming and dynamic antenna polarization. In fact, the data sheet on the device Globalstar used states that it enables up to a “50 percent reduction in interference to neighboring APs.”⁴ These features are not typical. Globalstar has not committed to use the types of devices it demonstrated in a commercial TLPS deployment.
- **Globalstar only demonstrated downlink throughput, ignoring other crucial performance metrics such as uplink throughput, latency, and jitter.** These metrics are particularly important for popular applications such as Wi-Fi calling, two-way video, and gaming. Uplink throughput, in particular, is a frequent challenge in deployment of high-capacity Wi-Fi networks given the often limited transmit power of Wi-Fi client devices.
- **Globalstar demonstrated only indoor access points.** The interference characteristics of an outdoor TLPS system remain entirely unexplored under any set of technical parameters. While Globalstar only demonstrated indoor devices, it has refused to commit to deploy only indoor devices.

It is critical that Globalstar explain whether these demonstration parameters indicate that it will now accept Commission rules limiting its terrestrial operations to 100 mW, requiring the use of 802.11 protocols that incorporate aggressive interference-avoidance features, requiring that its base stations incorporate interference prevention features similar to those used in its demonstration, permitting only indoor operation, and incorporating the other limitations described below. If it will not accept such rules, then the unrepresentative operating parameters of the Globalstar devices alone render the demonstration meritless.

The FCC simply cannot base regulatory action on a demonstration of devices and scenarios that are fundamentally different from Globalstar’s commercial operations. Globalstar’s demonstration likely would bear little resemblance to future commercial TLPS deployments under the rules Globalstar has requested.

In addition, Globalstar’s demonstration ignored important interference considerations and failed to adhere to basic scientific norms, which require controlled conditions and a transparent methodology:

⁴ RUCKUS WIRELESS, INC., *ZoneFlex Data Sheet*, at 1 (2012) available at <http://en.ruckuswireless.com/assets/pdfs/products/zoneflex-7982.pdf>.

- **Globalstar’s test set-up was biased.**
 - Globalstar’s demonstration scenarios were not designed to provide any useful information on the potential impact of TLPS on the 2.4 GHz Wi-Fi band. Their claim that TLPS is a “good neighbor” appears to rely entirely on their observation that adding an additional channel to the same number of test clients results in an increase in aggregate throughput. This is a basic networking principle that bears no relation to Globalstar’s petition, and overlooks the fact that this additional channel will not be open to all consumers, but will be limited to those who pay for Globalstar’s proprietary service.
 - Globalstar arranged client devices to ensure that each client device was significantly closer to the access point with which it was associated than to other access points, which would tend to reduce the impact of interference from other access points.
 - Client devices were carefully separated by channel of operation and remained stationary, meaning that Globalstar’s demonstration failed to account for the impact of spatially overlapping signals. This oversight is especially significant given the beamforming technology used in Globalstar’s demonstration access points.
 - Globalstar’s client devices were divided by a metal structure that was a part of the display furniture installed by the Commission in the Technology Experience Center. This metal structure further insulated the client devices from the two interfering access points on the other side of the metal structure.
- **The Commission’s Technology Experience Center is appropriate for a demonstration but not an interference test.**
 - The ambient radiofrequency environment contained several interfering signals. While Commission officials worked hard to disable FCC hotspot access points inside the Technology Experience Center, they were unable to disable other nearby access points or Mi-Fi devices used by Commission employees and visitors. On multiple occasions, NCTA observed access points operating on Channel 11, and other channels being used in the demonstration, at significant power levels.
 - Despite the efforts of FCC staff, the nature of the room made it impossible to control the demonstration environment. Consequently, it was impossible to maintain a consistent environment for tests because of variable positioning of people (often many people), furniture, and equipment. As a result, the FCC cannot have confidence in the reliability or reproducibility of any interference data.

Marlene H. Dortch

April 16, 2015

Page 5

In sum, while NCTA welcomed the opportunity to see Globalstar's TLPS technology in action, the demonstration did not produce results on which the Commission can rely. If you require any additional information, please contact the undersigned.

Sincerely,

A handwritten signature in cursive script, appearing to read "P. Margie".

Paul Margie
Counsel to NCTA

cc: meeting participants

Measuring the Potential Impact on Wi-Fi of Channel 14 Terrestrial Low Power Service

Abstract

The FCC is considering authorizing a new terrestrial service known as the Terrestrial Low Power Service (TLPS), as requested by Globalstar, Inc. The FCC invited CableLabs to attend a demonstration by Globalstar of its TLPS technology and to measure the potential impact on 2.4 GHz Wi-Fi systems, which are heavily used by wireless broadband consumers, immediately adjacent in frequency.

The only opportunity for measurement occurred as part of a demonstration of TLPS at the FCC headquarters in Washington, DC. Our observations were therefore constrained in scope and form, with results subject to ambient noise in an uncontrolled environment. We therefore caution that the demonstration is not a fully complete or representative set of tests; nonetheless, we present our most relevant findings in this report and make all data publicly available.

We observed a negative impact by TLPS on adjacent Wi-Fi networks in several of our measurement configurations. Wi-Fi downlink throughput was reduced by as much as 65% in the presence of TLPS, with the scale of impact dependent on the type of Wi-Fi device, and even more significant impact observed in the presence of additional interferers.

In other measurements, we observed results that we cannot reliably characterize. For example, though Wi-Fi throughput was generally highest in standalone cases, without interferers, in some instances the level of diminution was not proportionate to the level of interference added, as one would expect. Our measurements also yielded other inconsistent results, particularly as relates to the impact on Wi-Fi latency and jitter. These results are not likely to be replicable due to the limited and uncontrolled demonstration environment. Therefore, we anticipate that more fulsome testing in a controlled environment will yield results that better approximate the range of possible real world impact, should TLPS be authorized.

About CableLabs

CableLabs is the global nonprofit technology research and development consortium of the cable industry. CableLabs drives new technology innovation and serves to define interoperable solutions on behalf of major cable operators and their technology vendors. The organization promotes consistent high performance on a global scale through specification and testing of cable technologies, and actively advances wireless technologies through its laboratory facilities and by working with technology partners and standards bodies.

Table of Contents

- 1 INTRODUCTION7
- 2 TEST SETUP9
 - 2.1 Test Tool9
 - 2.2 Devices Used9
 - 2.2.1 Access Points9
 - 2.2.2 Clients10
 - 2.2.3 Other Devices11
 - 2.3 Test Layout11
 - 2.4 Test Procedure12
- 3 RESULTS13
 - 3.1 RF Channel Measurements13
 - 3.2 Residential AP and Smartphone CH 11 device pair14
 - 3.2.1 Results14
 - 3.3 Enterprise AP and Laptop CH 11 device pair16
 - 3.3.1 Results16
- 4 CONCLUSION18
- APPENDIX A: CABLELABS TLPS DEMONSTRATION PLAN19
- APPENDIX B: DEMONSTRATION MEASUREMENT DATA23
- APPENDIX C: CORRECTIONS TO FCC STAFF DEMONSTRATION OVERVIEW25

Table of Figures

FIGURE 1 - PROPOSED CHANNEL 14 TLPS..... 8

FIGURE 2 - TEST LAYOUT USED DURING CABLELABS TEST 11

FIGURE 3 - INSSIDER RF CHANNEL MEASUREMENT DURING CABLELABS TEST 13

FIGURE 4 - INSSIDER RF CHANNEL MEASUREMENT DURING CABLELABS TEST 14

FIGURE 5 - RESIDENTIAL AP AND SMARTPHONE PAIR CHANNEL 11 DOWNLINK THROUGHPUT PERFORMANCE WITH CHANNEL 6 AND CHANNEL 14 DEVICE PAIRS 15

FIGURE 6 - ENTERPRISE AP AND LAPTOP PAIR CHANNEL 11 DOWNLINK THROUGHPUT PERFORMANCE WITH CHANNEL 6 AND 14 DEVICE PAIRS.. ..17

Table of Tables

TABLE 1 - LIST OF WI-FI CHANNELS IN THE 2.4 GHZ FREQUENCY BAND 7

TABLE 2 - LIST OF ACCESS POINTS USED DURING CABLELABS TEST 9

TABLE 3 - LIST OF CLIENTS USED DURING CABLELABS TEST 10

DISCLAIMER

This document is furnished to the Federal Communications Commission (FCC) solely for the purpose of its use in the matter of *Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems, IB Docket No. 13-213, RM-11685*. This paper should not be used by others for any other purpose and neither CableLabs nor its members provides any representation or warranty, express or implied, regarding the use of this document for a particular purpose of this document for such other purposes.

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EXECUTIVE SUMMARY

At the invitation of the FCC, CableLabs attended a demonstration by Globalstar, Inc. (Globalstar) of its proposed Terrestrial Low Power Service (TLPS) and measured the potential impact on the 2.4 GHz Wi-Fi band. CableLabs coordinated its measurements with the Wi-Fi Alliance, the Wireless Internet Service Provider's Association, and the National Cable and Telecommunications Association.

In advance of the demonstration, CableLabs filed a measurement plan with the FCC, reproduced here as Appendix A, in which we cautioned that the demonstration environment was unlikely to yield conclusive results, and that inadequate time was provided for a fulsome exploration of impact on Wi-Fi. Nevertheless, we outlined a demonstration plan that we believed would provide some useful information for the FCC decision process. However, due to limitations imposed on CableLabs related to facility availability and space constraints, we were able to complete only an estimated 20% of all measurements necessary even within our reduced scope. Because of these constraints, the demonstration results do not provide CableLabs or the FCC with an adequate basis for determining that TLPS can operate without undermining existing 2.4 GHz Wi-Fi service. More fulsome testing is therefore required, and CableLabs stands ready to participate and, if needed, to host such testing in a controlled environment. Testing in a controlled environment would enable isolation of factors that influence results, and would permit the scientific standard of data replication, which was not possible for any of the demonstrations conducted by participants.

Nevertheless, the data we did collect during the demonstration leads us to conclude that TLPS channel 14 utilization can negatively impact adjacent Wi-Fi networks. We recorded channel 11 Wi-Fi downlink throughput reduction of as much as 65% in the presence of TLPS, with varying impact depending on the type of Wi-Fi equipment used, and even more significant degradation in the presence of additional interferers. We tested two access point / client pairs for Wi-Fi performance and found the most significant throughput reduction associated with a residential access point. As expected, we observed a less significant throughput reduction using an enterprise-grade access point.

Variability in our results, described in more detail in this paper, is difficult to causally determine given the limits of the demonstration as a forum for measurement. The physical configuration of the measurement setup, features of the TLPS and Wi-Fi equipment, and ambient noise (including an active FCC Wi-Fi network) may all have influenced results.

Furthermore, and critically, all of the measurements taken at the demonstration – both those taken by CableLabs and those taken by Globalstar – are relevant only to the extent that they reflect the characteristics of TLPS systems that are likely to be deployed. Unfortunately, neither the FCC nor CableLabs has reliable information about the characteristics of a potential commercial TLPS deployment.

As of this writing, CableLabs has not seen a lab-based measurement of the TLPS equipment used in the demonstration (e.g., to detect the spectral mask and other relevant RF properties), as we noted as necessary in our test plan, although we understand that the FCC may soon release this information.¹

Equally importantly, neither the FCC nor CableLabs know that the TLPS equipment used in demonstrations is representative of that which may be deployed, either in performance or technology. The TLPS units provided by Globalstar for our measurements were enterprise-grade 802.11 access points with a number of features designed to spatially isolate signals and

¹ We understand that the FCC may have performed such measurement in their lab, but we have not seen the data.

reduce interference; it is unclear that TLPS units likely to be deployed would have such features. In addition, deployment of LTE-based TLPS would bear no relation to the measurements taken in the FCC demonstration, which used 802.11-based TLPS. If Globalstar plans to use equipment other than the enterprise-grade Wi-Fi equipment tested, if it plans to operate in an outdoor environment, or if other elements of the demonstration do not reasonably reflect a commercial TLPS deployment, then the demonstration performed does not provide the FCC with representative or complete information.

Therefore, while the measurements presented herein may provide some useful information, we do not expect that they are determinative, and we anticipate that the FCC would benefit from further technical study on which it may base its decision making.

We also note that our work did not measure the potential impact to Bluetooth, Broadcast Auxiliary Service, Broadband Radio Service / Educational Broadband Service, or Globalstar's own in-band Mobile Satellite Service, though these factors may also be relevant to the FCC.

As part of this report, we provide public access to all measurement data. See 0 for more information.

In addition, FCC staff recently placed on the record their observations of the demonstration setup. Their observations do not properly describe several aspects of the CableLabs measurement configurations. In the interest of clarifying the public record, Appendix C contains our corrections to the FCC staff observations of the demonstration setup.

1 INTRODUCTION

The 2.4 GHz unlicensed frequency band used by Wi-Fi today, allocated as the Industrial, Scientific, Medical (ISM) band, extends from 2400 MHz to 2483.5 MHz. Devices do not require a license to operate in this frequency band but do need to comply with the Part 15 rules under Title 47 of the Code of Federal Regulations (47 CFR 15). Other devices that operate in this band are Bluetooth and microwave ovens, for example. In the United States, currently there are 11 channels that are used in Wi-Fi, each 22 MHz wide. Out of these 11 channels, only 3 are non-overlapping (1, 6, and 11); these three channels are widely used, whereas other adjacent or overlapping channels are not generally utilized by Wi-Fi equipment due to the greater potential for interference. Table 1 below provides a list of the channels in the 2.4GHz frequency band.

Table 1 - List of Wi-Fi channels in the 2.4 GHz frequency band

CHANNEL NUMBER	LOWER FREQUENCY (MHz)	CENTER FREQUENCY (MHz)	UPPER FREQUENCY (MHz)
1	2401	2412	2423
2	2406	2417	2428
3	2411	2422	2433
4	2416	2427	2438
5	2421	2432	2443
6	2426	2437	2448
7	2431	2442	2453
8	2436	2447	2458
9	2441	2452	2463
10	2446	2457	2468
11	2451	2462	2473
12	2456	2467	2478
13	2461	2472	2483
14	2473	2484	2495

The FCC currently forbids public use of Channel 14. The ISM band extends up to 2483.5 MHz, which includes only the lower half of Channel 14. The upper half of Channel 14, which is outside of the ISM band, is licensed to Globalstar for satellite communications services. Channels 1, 6, and 11 used in Wi-Fi today have a separation (guard band) of 3 MHz with their neighboring non-overlapping channel. As shown in Figure 1 below, there is no separation between Channel 14 and Channel 11.

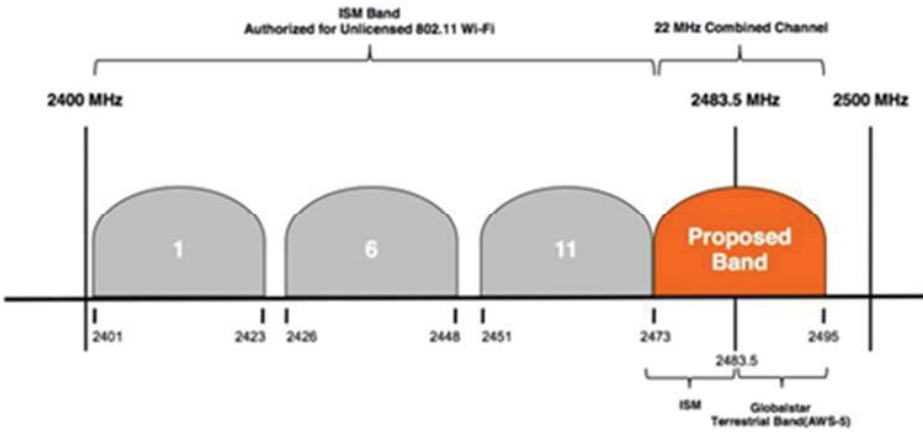


Figure 1 - Proposed Channel 14 TLPS²

Globalstar has requested that the FCC authorize exclusive terrestrial use of the upper half of Channel 14 to create a Terrestrial Low Power Service (TLPS). Globalstar has stated that TLPS would likely utilize 802.11 equipment on Channel 14, including the lower half that is within the ISM band. We base our analysis and measurement on these statements, however we know of no commitment by Globalstar to limit itself to 802.11 technology. It is possible that Globalstar may deploy other technologies, such as LTE, which may be permitted under Part 15 and which would significantly change the parameters of measurement and potential impact to ISM. If Globalstar plans to use LTE technology, the FCC must perform additional testing, as the results of the recent demonstration would be invalid.

Within the time and space constraints of the FCC demonstration environment, our goal was to measure the impact of TLPS on the performance of channel 11³ Wi-Fi, using different grade Access Points and clients. To do so, we sought to characterize downstream and upstream throughput, latency, and jitter, comparing to baseline standalone channel 11 performance as well as the use of both TLPS and channel 6.

² Figure taken from Globalstar presentations. See, e.g., June 21, 2013 ex parte filing of Globalstar, available at: <http://apps.fcc.gov/ecfs/document/view?id=7520924121>

³ Our primary assessment focus was the impact to channel 11 since it is directly adjacent to potential channel 14 TLPS operations. Given adequate time, we would have also assessed the impact to other Wi-Fi channels in the ISM band; however, given time constraints associated with the demonstration, were not able to complete a broader set of measurements.

2 TEST SETUP

CableLabs conducted TCP throughput and RTP latency and jitter tests in both uplink and downlink directions using a combination of access points (APs) and clients (STAs), measuring the impact to Wi-Fi channel 11 as a function of different TLPS interference scenarios. While our advance plan proposed a string of tests to be conducted, reflecting different interference scenarios through variation of transmit power, physical configuration, and number of AP / client pairs, because FCC facility time was limited CableLabs was able to perform only a fraction of the planned tests. We therefore preface our review of the test setup by noting that a more fulsome exploration of interference scenarios is required for comprehensive testing.

2.1 Test Tool

IxChariot Console version 7.30 SP1 was used to conduct all tests. IxChariot Endpoint was downloaded and installed on all clients.

TCP throughput tests were conducted using the default 'High Throughput' script that sends a 10MB file from Endpoint 1 to Endpoint 2, where the two endpoints are configured to be the sender and receiver of data in uplink and then reversed for downlink directions.

MetaGeek Chanalyzer was used to record ambient channel usage and signal strength. Also, MetaGeek InSSIDer was used to visualize the RF environment. Both are commercially available, commonly used tools for Wi-Fi spectrum analysis and measurement.

2.2 Devices Used

Several devices were used for testing which included Wi-Fi access points, clients, and other devices. Details are provided in the following sections. We note that Wi-Fi equipment has wide variability in performance across form factors, brands, and market segment, and that these factors will impact how equipment may perform in the presence of TLPS. Ideally, a generally representative set of Wi-Fi equipment would be measured to determine the range of likely impact to Wi-Fi in the real world if TLPS is authorized. While we measured channel 11 performance on two AP / client pairs to obtain a basic sense of variability across the Wi-Fi ecosystem, due to the constraints of the demonstration we were not able to characterize a broader subset of equipment as we expressed interest in doing in advance. Therefore we do not believe that the equipment used provides a full picture of the range of Wi-Fi performance in the presence of TLPS.

2.2.1 Access Points

Table 2 provides a list of Access Points that were used during the CableLabs test.

Table 2 - List of Access Points used during CableLabs test

Access Point	FCC ID	TX POWER SETTING	CHANNEL	MIMO
Netgear R6200	PY3124000218	Default	6	2x2
Ruckus R700	S9G-MPE2N33A	Full	11	3x3
Belkin N150	K7SF9K1001V5	Default	11	2x2
Ruckus 7982	S9G-MPE2N33A	Full	14	3x3

All the above APs were set to their default settings⁴ (no special QoS configurations, etc.) and used a 20 MHz channel in the IEEE 802.11n mode.

The Netgear R6200, used in our measurements as the channel 6 AP, is a high-performing residential access point used commonly in homes in the United States. This AP has beamforming capabilities and is capable of 2x2 MIMO.⁵ Two separate APs were used as channel 11 test subjects in our measurements, a Belkin N150 and a Ruckus R700. The Belkin N150 AP uses 2x2 MIMO and 802.11n features and the Ruckus R700 is a high-performing enterprise AP with beamforming, adaptive polarization diversity, and interference mitigation features. The intention was to test the potential impact on networks operating in channel 11 using both a common residential access point (Belkin N150), as well as a full-featured AP used in an enterprise environment (Ruckus R700). While the two APs may vary in performance and price, they are both commonly used access points in their respective categories, home and enterprise.

The Ruckus 7982 access points operational in channel 14 were provided by Globalstar, and have interference mitigation techniques, adaptive polarization diversity, and transmit beamforming capabilities.⁶

2.2.2 Clients

Table 3 provides a list of clients that were used during CableLabs observations. Our channel 11 test subjects included a Samsung Galaxy S5 smartphone and an Apple MacBook Pro laptop, both common devices in residential and enterprise environments.

Table 3 - List of clients used during CableLabs test

CLIENT	FCC ID	MODEL	CHANNEL
Dell Laptop	PD97260H	Inspiron 15R (P28F Processor)	6
Apple Laptop	QDS-BRCM1052	MacBook Air (Early 2012)	6
Samsung Smartphone	A3LSMG900F	Galaxy S5 (SM-G900F)	11
Apple Laptop	QDS-BRCM1055	MacBook Pro (A1286; Early 2011)	11
Asus Tablet	MSQK008	Nexus 7 (K008)	14
Asus Tablet	MSQK008	Nexus 7 (K008)	14

⁴ User guides with complete default configurations for the APs are included below:

Netgear R6200: http://pl.netgear.com/images/R6200v2_DS_20Jun1318-52074.pdf

Belkin N150: http://cache-www.belkin.com/support/dl/MAN_F9K1001v5_N150v5_Router.pdf

Ruckus R700: <https://support.ruckuswireless.com/products/60-zoneflex-r700#documents>

Ruckus 7982: <https://support.ruckuswireless.com/products/38-zoneflex-7982>

⁵ See the data sheet for full specifications: http://pl.netgear.com/images/R6200v2_DS_20Jun1318-52074.pdf

⁶ See the data sheet for full specifications: <http://a030f85c1e25003d7609-b98377aee968aad08453374eb1df3398.r40.cf2.rackcdn.com/datasheets/ds-zoneflex-7982.pdf>

2.2.3 Other Devices

- HP Laptop (IxChariot Console): solely used for management of traffic streams using the IxChariot application. Not used to generate any traffic.
- IBM Lenovo laptops (Traffic Generators): Two laptops were used to solely act as IxChariot endpoints and connected to the APs in operation for test (via the switch) to exchange traffic with the STAs.
- Cisco SG-102-24-NA Gigabit Switch: All APs in operation, IxChariot console along with the traffic generator endpoints were connected to a flat network on the switch.

2.3 Test Layout

Each client was placed at a distance of 5 feet from the AP to which it was associated. APs and clients were turned on and off depending on the test being conducted. The test layout replicated a dense, controller-less multi-AP multi-dwelling unit architecture comprised of several APs in close range to each other. As noted previously, we have no knowledge of Globalstar’s deployment plans for TLPS. The demonstration architecture depicted below is one possible interference scenario that may be encountered if TLPS is authorized. We note that other scenarios are also possible but could not be explored in the demonstration environment due to space and time constraints. Further testing and measurement reflecting different scenarios may therefore yield additional insights.

Figure 2 provides a logical configuration of the APs and clients used in the CableLabs test, with the measurement subject channel 11 AP/client pair reflected in blue.

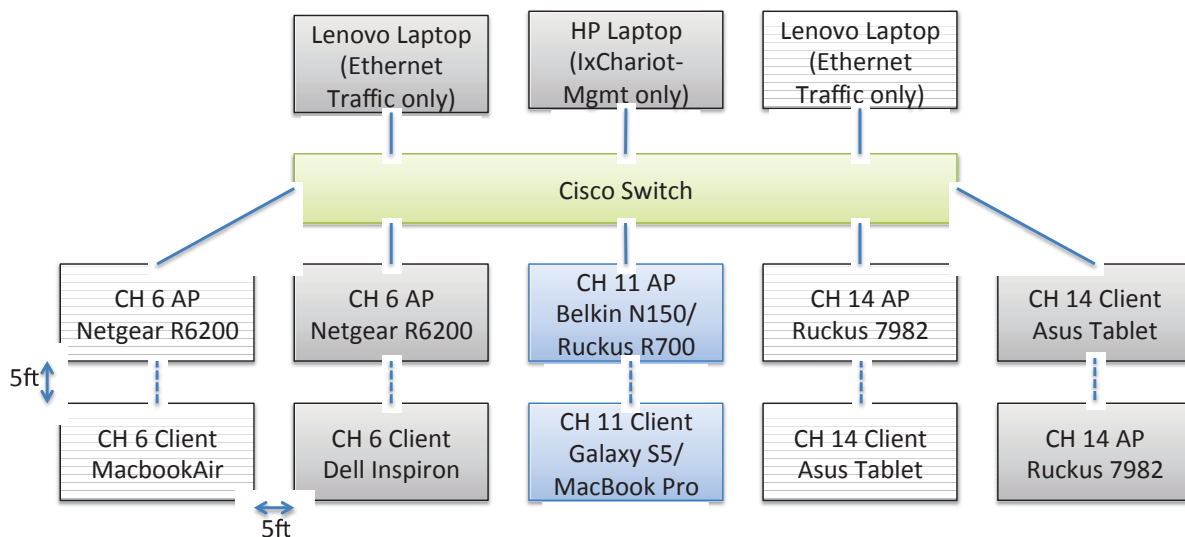


Figure 2 - Test Layout used during CableLabs test

All access points were connected to a flat network on the Cisco switch. The IxChariot console and two other traffic generator endpoints were also connected to the same switch to generate and receive traffic on behalf of the access points being used in the test.

Individual traffic streams were generated for each AP/client pair for throughput, latency, and jitter tests in the downlink and uplink directions.

2.4 Test Procedure

Tests were conducted on two channel 11 device pairs to measure throughput, latency, and jitter in the presence of channel 14 and channel 6 device pairs. The two channel 11 device pairs included a residential AP with a smartphone and an Enterprise AP with a laptop.

Baseline tests using individual device pairs were conducted on each channel (6, 11, and 14) before performance tests using simultaneous device pairs on separate channels were run. The duration of each individual test was 90 seconds and run two times. The test results reported in this document are the average of the two runs.

The following provides an overview of the combinations of device pairs tested:

- CH 11 device pair only (baseline), using residential AP (Belkin N150) and smartphone (Samsung Galaxy S5)
- CH 11 device pair only (baseline) using enterprise AP (Ruckus R700) and laptop (MacBook Pro)
- CH 6 device pair only (baseline), using Netgear R6200 and laptop (Dell Inspiron/ MacBook Air)
- CH 14 device pair only (baseline), using Ruckus 7982 and Asus tablet
- CH 11 + CH 14 device pairs, using equipment noted above
- CH 6 + CH 11 + CH 14 device pairs, using equipment noted above

3 RESULTS

Using the device orientation and configuration described in the previous section of this report, the RSSI of the devices were in the range of -25 to -35 dBm.

Results of the testing are provided in the following sections. As part of this report, we provide public access to all measurement data. See Appendix B for more information.

3.1 RF Channel Measurements

During the demonstration a number of other Part 15 devices were active, constituting ambient noise in the environment. Results of RF channel measurements that are representative of the channel usage and RF signal strength during the CableLabs testing are shown below. Figure 3 and Figure 4 show that two FCC Hotspots were operating in Channel 11 during testing at levels of approximately -61 to -72 dBm (the orange FCC Hotspot in Figure 4) and -76 to -81 dBm (the yellow FCC hotspot in Figure 4). A FCC Hotspot was also operating on Channel 6 in the approximate range of -86 to -88 dBm. A FCC Hotspot was also operating on Channel 1 as seen below.⁷

MAC Address	SSID	RSSI	Channel	Vendor	Security	Max Rate
00:15:62:a9:ef:10	FCC HotSpot Network	-84	1	Cisco Systems	WPA2 Personal	54
2c:3f:38:c1:27:40	FCC HotSpot Network	-89	6	Cisco Systems	WPA2 Personal	130
2c:3f:38:f6:fe:b0	FCC HotSpot Network	-87	6	Cisco Systems	WPA2 Personal	130
84:db:2f:1b:f5:0f	ctech	-59	2	Sierra Wireless Inc	WPA2 Personal	65
a8:b1:d4:9c:3a:70	FCC HotSpot Network	-84	1	Cisco Systems	WPA2 Personal	130
a8:b1:d4:c5:71:f0	FCC HotSpot Network	-79	1	Cisco Systems	WPA2 Personal	130
a8:b1:d4:c5:ee:80	FCC HotSpot Network	-76	11	Cisco Systems	WPA2 Personal	130
a8:b1:d4:c5:f0:30	FCC HotSpot Network	-61	11	Cisco Systems	WPA2 Personal	130
a8:b1:d4:c5:f0:3f	FCC HotSpot Network	-75	36	Cisco Systems	WPA2 Personal	144
a8:b1:d4:c5:f4:a0	FCC HotSpot Network	-87	6	Cisco Systems	WPA2 Personal	130
ec:1a:59:a8:4b:51	Belkin	-38	11	Belkin International Inc.	Open	144
f2:8d:8c:94:84:a7	Verizon vs980 4g 079a	-78	1		Open	65

Figure 3 - InSSIDer RF channel measurement during CableLabs test

⁷ These measurements were taken in close proximity to the Channel 11 STA measurement location with a commonly used Wi-Fi spectrum analyzer called InSSIDer.



Figure 4 - InSSIDer RF channel measurement during CableLabs test

This ambient noise present throughout the duration of the testing likely influenced both our observations and those of other demonstration participants, though the direction and magnitude is difficult to quantify. Testing in a controlled environment would better enable isolation of factors that influence results, and promote the scientific standard of data replication, which was not possible in the demonstration environment.

3.2 Residential AP and Smartphone CH 11 device pair

The residential AP used for testing was a Belkin N150. This AP uses 2x2 MIMO transmitting at default RF power in the 802.11n-only mode using a 20 MHz channel bandwidth. The STA used was a Samsung Galaxy S5 smartphone. This is also a 2x2 MIMO device.

3.2.1 Results

Channel 11 throughput measurements were taken in five configurations: (1) channel 11 device pair only (baseline measurement), (2) in the presence of one channel 14 TLPS device pair, (3) in presence of two channel 14 TLPS device pairs, (4) in presence of one channel 14 TLPS device pair and one channel 6 device pair, and (5) in the presence of two channel 14 TLPS device pairs and two channel 6 device pairs.

Figure 5 shows the results of downlink throughput of the residential AP and smartphone channel 11 device pair in the configurations noted above. Results generally show a reduction in channel 11 Wi-Fi downlink throughput as TLPS is introduced. In particular, we observed a 65% decrease in channel 11 Wi-Fi downlink throughput when two channel 14 TLPS device pairs are operating, and a 71% decrease in channel 11 Wi-Fi throughput when two channel 14 TLPS and two channel 6 device pairs are operating. Throughput diminution can also be conceived of as a decrease in Wi-Fi spectral efficiency, or the amount of throughput per unit of bandwidth. A 71%

decrease in channel 11 Wi-Fi throughput is equivalent to a 71% decrease in channel 11 spectral efficiency.

We note that channel 11 performance in the presence of two channel 6 and two channel 14 AP / client pairs was slightly better than in the presence of only one channel 6 and one channel 14 AP / client pair, which is counterintuitive. While this may be due to the ambient noise present from other active hotspots in the environment, we cannot conclusively explain this result, which is worth further investigation under more scientific conditions.

Ambient channel usage and signal strength recorded during measurements show that there were two hotspots on channel 11 at signal levels in the range of -60 to -80 dBm.

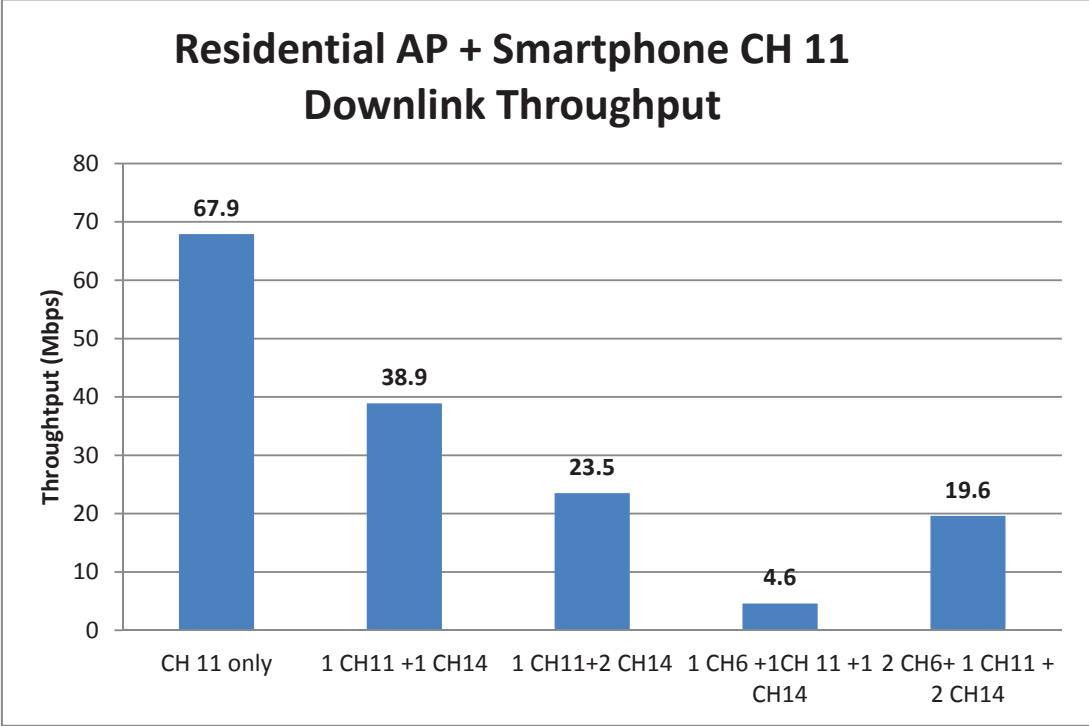


Figure 5 - Residential AP and Smartphone Pair Channel 11 Downlink Throughput Performance with Channel 6 and Channel 14 Device Pairs

Uplink throughput measurements also generally show a reduction in channel 11 Wi-Fi uplink throughput as TLPS is introduced. However, there was some variability across scenarios, which again would benefit from further exploration. For example, results show a 70% decrease in uplink throughput when one channel 14 TLPS AP/client pair is introduced, but only a 31% decrease in throughput when two channel 14 device pairs are operating. This result is counterintuitive, and may be due to the limitations of the test environment described above. We suggest further testing on this point.

Latency and jitter measurements were inconsistent, and not conducive to firm conclusions.

Ambient channel usage and signal strength recorded during measurements show that there were two hotspots on channel 11 at signal levels in the range of -60 to -80 dBm.

3.3 Enterprise AP and Laptop CH 11 device pair

The Enterprise AP used for testing was a Ruckus R700. This AP uses 3x3 MIMO with proprietary beamforming, adaptive polarization diversity, RF interference cancellation, and a high performance receiver. The AP was transmitting at full power in the 802.11n-only mode using a 20 MHz channel bandwidth. The laptop used for testing was a MacBook Pro. This is a 2x2 MIMO device.

3.3.1 Results

Channel 11 throughput measurements were taken in five configurations: (1) channel 11 device pair only (baseline measurement), (2) in presence of one channel 14 device pair, (3) in presence of two channel 14 device pairs, (4) in the presence of two channel 14 device pairs and one channel 6 device pair and (5) in the presence of two channel 14 device pairs and two channel 6 device pairs.

Figure 6 shows the results of channel 11 downlink throughput of the enterprise AP and laptop device pair in the presence of channel 6 and 14 device pair configurations. In general, results show reduced channel 11 Wi-Fi downlink throughput as interferers are introduced; however, degradation was not as severe as in the residential AP/client measurements discussed in the previous section of this report. Results show a roughly linear reduction in throughput as one and then two channel 14 TLPS AP/client pairs are introduced, up to a 55% decrease in channel 11 throughput. Again, this throughput diminution can also be conceived of as an equivalent decrease in spectral efficiency.

However, performance improves (but remains below channel 11 standalone baseline) as channel 6 AP/client pairs are introduced. That channel 11 performance would improve merely because of the presence of a channel 6 AP is counterintuitive, and likely due to the limitations of the testing environment. Again, this points toward the need for additional testing.

Ambient channel usage and signal strength recorded during measurements show that there were two hotspots on channel 11 at signal levels of greater than -60 dBm.

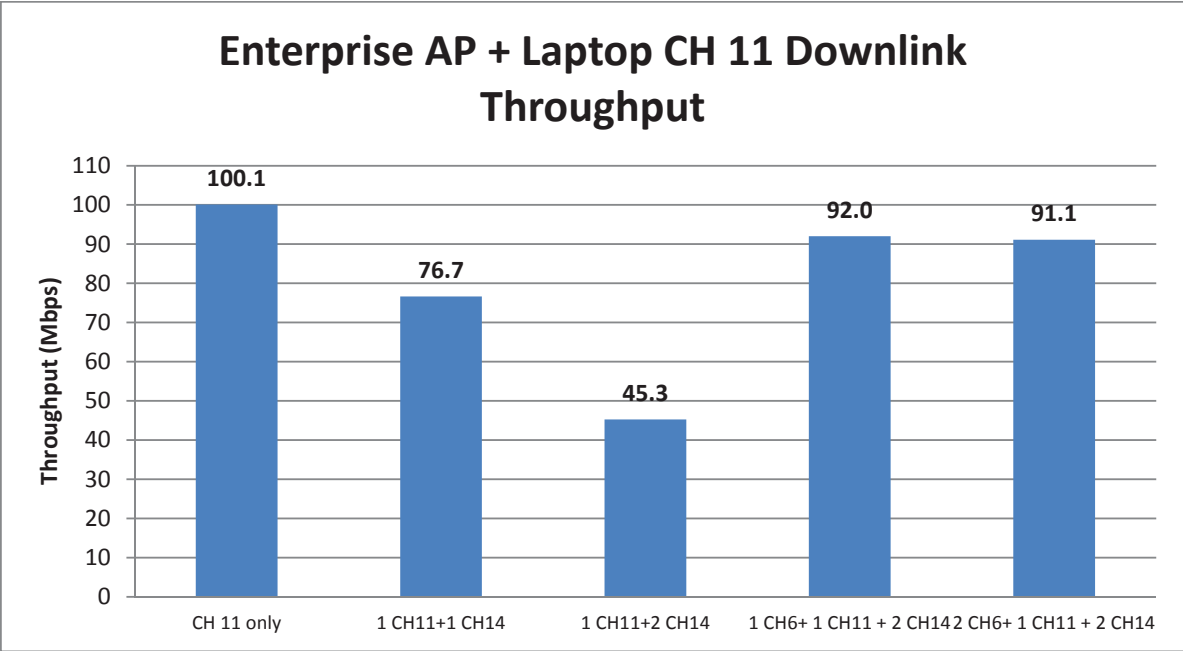


Figure 6 - Enterprise AP and Laptop Pair Channel 11 Downlink Throughput Performance with 2 Channel 6 and 2 Channel 14 Device Pair

Uplink throughput measurements are generally inconsistent, and show an 18% decrease and 20% increase in throughput when one and two channel 14 device pairs are operating, respectively. Results also show a 7% decrease and 22% increase in throughput when one and two channel 6 device pairs are operating with two channel 14 pairs, respectively. These results warrant further study.

Again, latency and jitter measurements were inconsistent, not conducive to firm conclusions.

Ambient channel usage and signal strength recorded during measurements show that there were two hotspots on channel 11 at signal levels of greater than -60 dBm.

4 CONCLUSION

Though constrained in scope and form, our measurements show a negative impact on Wi-Fi resulting from channel 14 TLPS, with varying impact depending on the type of Wi-Fi equipment used. We observed more significant throughput degradation in a residential access point / client pair – up to 65% reduction to channel 11 downlink -- than we did in an enterprise access point / client pair.

We also observed inconsistent results in several other measurements, especially around latency and jitter effects. Many factors likely impacted our results, including the performance characteristics of the Wi-Fi and TLPS equipment, the physical configuration of the measurements, and ambient noise in the uncontrolled demonstration environment. These inconsistent results demonstrate the need for further testing in a controlled environment.

Finally, we note that both CableLabs' and Globalstar's measurements are useful only to the extent that they measured equipment and deployment scenarios that Globalstar would utilize if authorized. If Globalstar would be provided the flexibility to use LTE instead of 802.11 Wi-Fi technology, or the ability to operate outdoors, or otherwise deploy TLPS in a manner not represented in the demonstration, then the utility of the demonstration data is limited.

We hope that the information provided in this report is useful for the FCC as it considers the TLPS proposal; however, we do expect that further testing and measurement will yield additional insight.

Appendix A CableLabs TLPS Demonstration Plan

The following plan was filed at the FCC in advance of the March 2015 demonstration, and is appended here for reference.

TLPS Demonstration Plan Overview

At the FCC's request, CableLabs, WISPA and the Wi-Fi Alliance have developed a plan to assess the impact of Globalstar (GSAT) Terrestrial Low-Power Service (TLPS) on existing Wi-Fi devices operating at the 2.4 GHz ISM band. At the FCC's direction, such testing is to take place at their Washington, D.C. facility (an uncontrolled RF environment) and is subject to time constraints. These factors inherently limit the scope of what can be measured and the information that will be obtained, relative to what we would generally consider a "test". The parties continue to be willing to quickly create, implement and conduct a test that would produce more meaningful results than those that will result from these constrained circumstances.

Nevertheless, the plan outlined below is designed to provide a basic level of information regarding potential impact (or non-impact) of TLPS on unlicensed devices operating in the ISM band. We do not anticipate that the information gained through these procedures will be comprehensive, in part because real-world interference will be dependent on the deployment scenarios and configurations of TLPS and unlicensed devices, which are not known at this time. For instance, we understand that TLPS equipment to be used in the FCC demonstration relies on 802.11 technology; however, if TLPS were to be deployed as a LTE service, the impact on the ISM band would be categorically different. In addition, the procedures and resources described below reflect the constraints provided by the FCC, and are subject to modification as we learn more about the capabilities available on-site.

These procedures do not include tests that measure the potential impact to Bluetooth, Broadband Auxiliary Service, Broadband Radio Service / Educational Broadband Service, or Globalstar's own in-band Mobile Satellite Service, though these factors will also be relevant to FCC decision-making.

A.1 Test Objectives:

- a. Measure the power level, spectral mask and out-of-band emissions (OOBE) from TLPS channel 14 Access Points operating up to full traffic loads in order to characterize the TLPS devices being used in the demonstration. This step is necessary to ensure that the wireless performance of TLPS equipment that may be deployed at a later date is identical, or at least similar, to TLPS equipment used in the current FCC demonstration.
- b. Measure the impact on performance of channel 11⁸ Wi-Fi devices using different grade Access Points and clients, that results from the use of TLPS channel 14 Access Points and clients. To do so, we will characterize downstream and upstream throughput, latency, and jitter, comparing to baseline standalone channel 11 performance as well as the use of both TLPS and channel 6 (together). (Note that we do not include channel 1 activity in our procedures, though this is likely to be relevant to Bluetooth performance and should be considered as part of a demonstration.)

⁸ Our primary assessment focus will be the impact to channel 11 since it is directly adjacent to potential channel 14 TLPS operations. Given adequate time, we would also assess the impact to other Wi-Fi channels in the ISM band; however, given time constraints associated with FCC direction, we will not be able to complete a broader set of measurements.

A.2 Timeline:

- We understand that FCC staff has allocated four days of facility time for which CableLabs staff is available (March 5, 6, 9, and 10). This is significantly less time than is required to state with confidence that we can complete even the limited procedures outlined in this document. Accommodation for necessary tests, accepting the constraint of performing those tests at the FCC's facilities, can be accomplished by:
 - a. Performing baseline physical characterizations of TLPS units, including spectral mask, OOB, and transmit power levels, in advance of FCC facility demonstrations; and,
 - b. Allocating the entire week of March 9th for testing (the 9th through the 13th); and/or,
 - c. Providing access to FCC facilities over the weekend of March 7th and 8th.
- If none of the above accommodations are provided, we will work within the time constraints provided and attempt to complete the procedures. However, if we cannot complete them, we will conclude that the demonstration procedures do not provide sufficient information to support an FCC decision authorizing TLPS.
- In addition, we expect that we will need to verify the results of the demonstrations in a controlled RF environment, which FCC staff has indicated it is open to. To do so, we request the use of TLPS equipment, to be provided by Globalstar. Globalstar is welcome to join these follow-on tests, which we can accommodate as soon as the week following the FCC demonstration (March 16-20).
- Following the completion of testing, we will need three weeks to complete the data analysis and write up a test report. Based on this schedule, assuming no slippage, we expect to be able to provide a report during the week of April 13th.

A.3 Staff:

The following CableLabs, Wi-Fi Alliance and WISPA staff will participate in this effort:

- Mark Poletti, Lead Wireless Architect, CableLabs (lead point of contact for testing)
- Shlomo Ovadia, Lead Architect, CableLabs
- Vivek Ganti, Architect, CableLabs
- Steve Shearer, Wi-Fi Alliance
- Alex Phillips, WISPA

A.4 Equipment

The following devices and test equipment is needed for the testing. Globalstar is to supply TLPS equipment; WISPA is to provide fixed wireless broadband equipment; Wi-Fi Alliance to supply some Wi-Fi equipment; CableLabs to supply all remaining equipment. The parties may work together to ensure efficiency of effort.

- 4 TLPS clients and Access Points (APs), in order to assess the impact of different TLPS deployment densities
- At least two different 802.11n APs and two clients. Note that additional Wi-Fi APs and clients may be assessed if there is sufficient time to do so within the measurement period.
- Gigabit Ethernet switch and 802.11n bridge

- Two traffic generators – Spirent SMB-600 with at least 8 GbE ports, and 1 IxChariot server and 8 IxChariot clients, or similar
- RF chamber with spectrum analyzer for WLAN testing
 - CableLabs has such a chamber, and we understand that similar capability exists at the FCC labs. Characterization can be done at CableLabs, which would require shipping TLPS equipment to Colorado. Alternatively, we are open to using the FCC labs.

A.5 Procedures

A high-level description of the demonstration procedures to meet the objectives stated above is as follows.

Note that for each procedure in which TLPS is active, it is critical that information on its activity, such as data rate (e.g. MCS), transmit power level, Wi-Fi standard (e.g. 11n or 11g), TLPS AP controller management and SSID, as well as MAC layer performance such as CSMA and LBT algorithms, be available to all parties in order to properly assess the interaction with Wi-Fi. The below procedures were designed assuming a TLPS service based on 802.11 technology; if Globalstar may deploy a LTE-based TLPS service, additional procedures must be designed to measure the impact on the ISM band.

Procedure 0: The total transmit power, and the in-band spectral power density of TLPS APs operating at channel 14 up to full traffic load conditions is measured inside an RF Anechoic chamber or equivalent controlled setup. Total transmit power compliance with FCC part 15 and compliance with the IEEE 802.11n spectral mask is verified. In addition, the Out-of-Band emission power levels of the TLPS APs are tested.

Procedure 0+1: In the uncontrolled demonstration environment, characterize the ambient in-band RF noise in the room before performing the procedures described below.

Procedure A – Measure the baseline performance (throughput, latency, jitter) of at least two different Wi-Fi APs exchanging client traffic on channel 11 up to full traffic load. This measurement should be taken in the absence of any interference (channel 14 TLPS and other interferers turned off). Measure the baseline performance (throughput, latency, jitter) of up to four different TPLS APs handling client traffic on channel 14 up to full traffic load. This measurement should be taken in the absence of any interference (channel 11 devices turned off). Measure the baseline performance (throughput, latency, jitter) up to four different Wi-Fi APs operating at channel 6 up to full traffic load. This measurement should be taken in the absence of any interference (channel 11 devices turned off).

Procedure B – The average, minimum, and maximum IPv4 downstream and upstream throughput, latency and jitter of at least two different Wi-Fi APs and clients operating at channel 11 is measured in the presence of one, two, three, and four TLPS APs operating at channel 14 using a traffic generator up to full traffic load.

Procedure C – The average, minimum, and maximum IPv4 downstream and upstream throughput, latency, and jitter of at least two different Wi-Fi APs and clients operating at channel 11 is measured in the presence of up to four TLPS APs operating at channel 14, and up to four Wi-Fi APs operating at channel 6 (simultaneous 6 + 11 + 14 operation) using a traffic generator up to full traffic load.

A.6 Other Notes

Reasonable modification to these procedures may be made based on what is learned on-site. If time permits, we will test the impact on additional iconic devices such as iPhone, Samsung 5S,

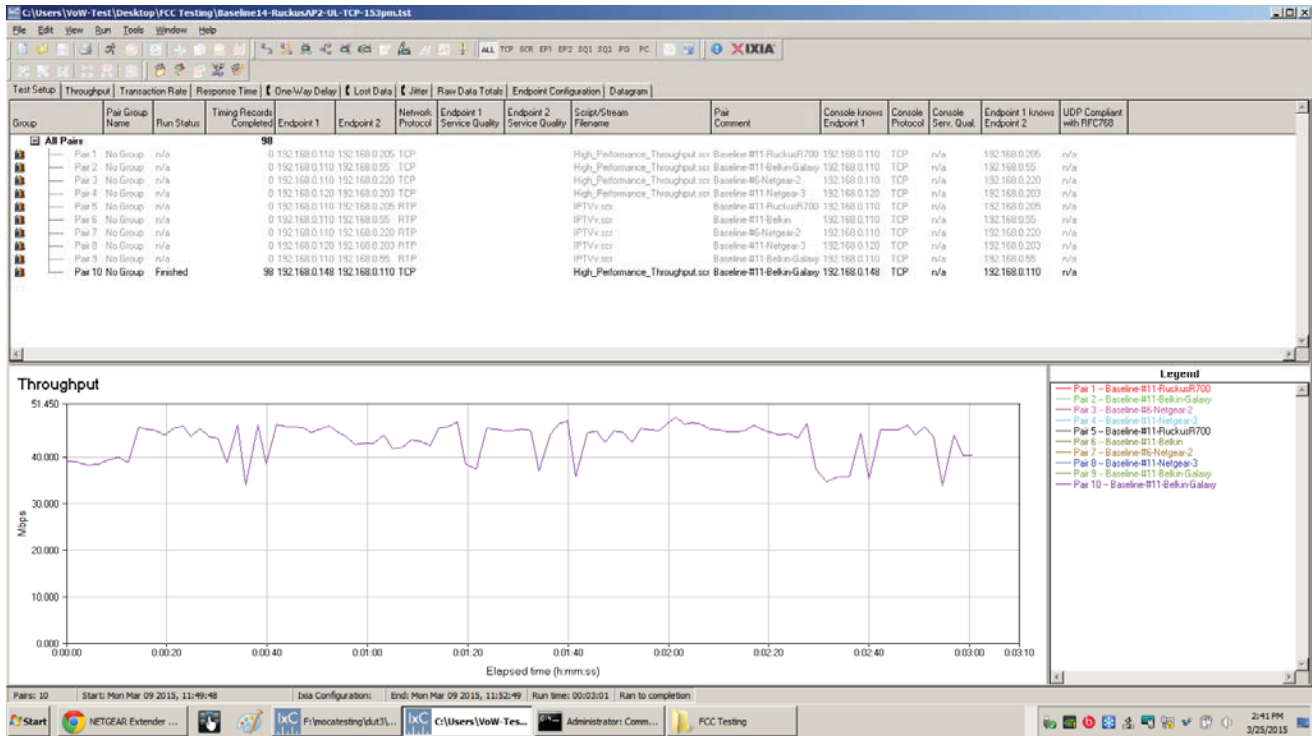
and Motorola X using similar procedures to those described above. As noted, CableLabs, WISPA, and Wi-Fi Alliance have constructed this demonstration plan under constraints provided by the FCC, and the parties do not view it as a substitute for more thorough and controlled measurement, which we are ready and willing to perform in an expeditious manner following this FCC demonstration. And, these procedures are relevant only to the extent that they approximate TLPS deployment. If TLPS density or use cases are markedly different, or if LTE technology is used instead of 802.11, the information gathered through this demonstration may have little or no relevance.

Appendix B Demonstration Measurement Data

We have made publicly available all measurement data from the March, 2015 demonstration, available to download here:

<https://owncloud.cablelabs.com/public.php?service=files&t=491a240129fc46ed2e1463b551a969f8>

The data is in the form collected via IxChariot, and organized into files according to the specific measurements taken. A sample of the data is provided below for reference.



Appendix C CORRECTIONS TO FCC STAFF DEMONSTRATION OVERVIEW

On March 27, 2015, FCC staff placed on the record an overview of the TLPS demonstration that took place March 6, 9, and 10 at the FCC headquarters. This document is titled, “Federal Communications Commission Office of Engineering and Technology Staff Report on Demonstrations of Globalstar, Inc.’s Proposed Terrestrial Low Power Service”, and was placed in IB Docket 13-213. The staff report documents the demonstration environment setup and does not provide any results from the various measurements taken. This document contains several errors, and as a result, the FCC staff report conflicts with elements of our description of the demonstration layout and procedures, included in Section 2 of this report. For the sake of clarity in the record, this Appendix notes where the FCC staff report was in error in describing CableLabs measurements.

In several places, the FCC staff report notes that one channel 11 access point used in measurements was a Ruckus N700. In fact, the Ruckus model used was the R700.

The diagram has an incorrect placement of the final Asus Nexus 7 client device, which was actually placed where the diagram represents the corresponding Ruckus 7982 access point, and vice-versa.

The staff report claims that the access points were set to transmit at 20 dBm (100 mW) conducted power, 31 dBm (1250 mW) EIRP. In fact, the Ruckus access points used in our measurements (both TLPS and ch.11 enterprise-grade) were adjusted to full transmit power.

The staff report also infers that two traffic generators were used by noting both the IxChariot and Spirent models. In fact, only the IxChariot was used to generate traffic for measurements.