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White Paper (1)

Using Public Schools in Puerto Rico to Provide Broadband Accessibility in Underserved Communities

Purpose

The purpose of this white paper is to outline a plan to utilize PRDE's high-speed broadband infrastructure currently in place at each of its public schools to provide Internet service to public institutions, e.g., libraries, clinics, hospitals, municipal buildings, etc. and households that are situated in municipalities that do not currently have adequate Internet service. This plan would deliver service to these underserved entities without requiring extensive infrastructure improvements.

Background

In 2018 the Puerto Rico Department of Education (PRDE) entered into a task order with its Internet provider, Claro, to provide every public school in the Commonwealth with a broadband connection via fiber optic cable. The speed of this service is 750 Mbps. This buildout, funded with Re-Start monies from the U.S. Department of Education, is expected to be completed by the end of the first quarter of 2019.

This fiber optic broadband connection (see right side of Figure 1, below) is part of a larger infrastructure network used by PRDE. Figure 1 shows Claro acting as a dedicated Internet provider providing PRDE with a virtual private network. This network is separate from Claro's commercial network and connects the multitude of nodes that Claro has across Puerto Rico. Fiber optic connections are made to each of the PRDE schools from these nodes.

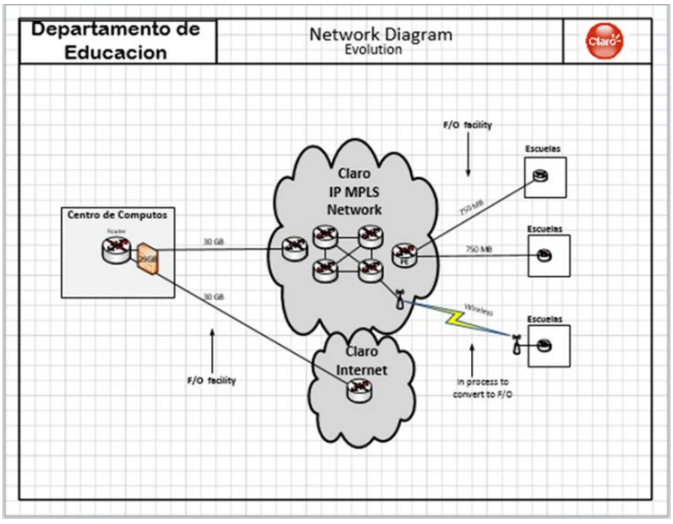

Figure 1 PRDE-Claro Internet Network Architecture

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(1) This white paper was prepared as a product of a Cornell Institute of Public Affairs winter term practicum in Puerto Rico in January 2019. The focus of this practicum was broadband in Puerto Rico. Participants in the practicum are master's degree candidates in public administration and regional planning, and included Gabriela Garcia, Elisabeth Lembo, Kate Long, Al Meghji, Sebastian Molina, Kiichi Ohshima, Katelyn Palumbo, Claudia n Poclaba, Noah Schumer, Peter Smet and Jiayang Yang. The faculty lead was John Foote. Questions should be sent to jhf25@cornell.edu.

The 857 public schools currently operated by PRDE are located throughout Puerto Rico. In some of these locations reliable, high speed broadband service is not available. In the most recent island-wide "census" of broadband availability (completed in 2014—see Appendix 1), there were sixteen (16) municipalities in which less than 50% of the household have Internet with speeds greater than 10 Mbps Download and 1.5 Mbps Upload. For the purpose of this white paper we will categorize these sixteen communities as "underserved". A map showing these municipalities is below. Note: The FCC "benchmark" for broadband connectivity is 25 Mbps Down and 3 Mbps Up.

Figure 2 Municipalities with less than 50% of households having more than 10 Mbps Down and 1.5 Mbps Up

The Plan

The plan is to use selected schools in these underserved municipalities as base stations to transmit and receive Internet signals to public institutions, e.g., libraries, clinics, hospitals, municipal buildings, etc. (referred to as "community anchor institutions, or CAIs) and households that are in proximity to the selected schools. There are several technologies that can be employed to do this, including

- Educational Broadband Service (EBS). Users of this technology are required to have a license and must be an accredited educational institution or nonprofit educational organization.
- TV white space (TVWS). Signals are transmitted via empty channels that are used to transmit TV signals. This part of the radio spectrum is unlicensed and is therefore available to anyone with the equipment to use it. While speeds are lower than that afforded by fiber optics connection, TVWS is wireless and can transmit over and through obstacles with a maximum range of 10km.
- Citizen Broadband Radio Service (CBRS). This band of spectrum has both licensed and unlicensed portions and represents a new band of spectrum that the FCC has recently opened. While this portion of spectrum shows promise for creating private high-speed internet networks it is still undergoing trials.

We have selected TVWS as the appropriate enabling technology to implement this plan. There are several reasons for this choice:

- TVWS does not require FCC approval or licensure.

- TVWS was deployed in Puerto Rico during the Hurricane Maria recovery (see https://blogs.microsoft.com/on-the-issues/2017/11/20/using-tv-white-space-technology-in-puerto-rico-and-the-us-virgin-islands/).
- TVWS has been used in similar circumstances and for similar purposes as what we envision in this plan—see Appendix 3.
- While the speed offered by TVWS may be below the FCC benchmark, it is a significant improvement over the current Internet service in the target municipalities.

Appendix 2 includes a technical description of TVWS. Appendix 3 includes links to examples of the use of TVWS. Appendix 4 is a discussion of regulatory issues.

A schematic of the proposed system is shown in Figure 3, below. In this picture a library is shown as the base station. In Puerto Rico, a public school would fill this role. The school would be responsible for providing a location on its premises for the installation of the tower for the antenna and electric power for the equipment. {Note: The base station could be powered by a solar/battery unit.)

The fiber optic connection that is in place at the school would "feed" the base station. The quality of the school's internet service would not be affected. (Note: The fiber optic connection at each school has unused, or dark, fiber that could be used as the last mile connection to the base station. Further, it is our understanding that this dark fiber is the property of Claro and therefore Claro would be the Internet service provider to households and CAI's—shown in Figure 3 as "HotSpots". Claro could also lease this fiber to another service provider.)

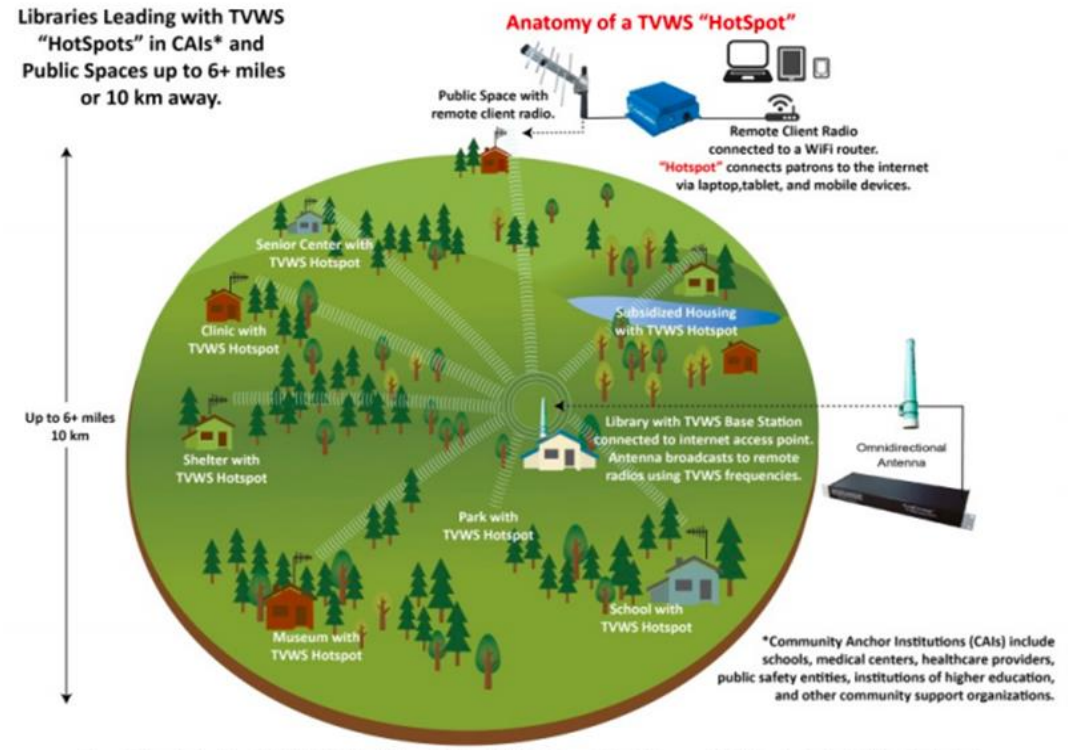

Figure 1. Libraries Leading with TVWS. Modified Infographic from TVWS Equipment Manufacturer and Collaborator Carlson Wireless Technologies

Figure 3

In the development of this plan, we have had discussions with Adaptrum which is an Internet hardware provider specializing in TVWS systems (see http://www.adaptrum.com/). (Note: Adaptrum is a partner in the Microsoft Airband Initiative the objective of which is to "to extend broadband access to 2 million unserved people living in rural America by July 4, 2022". See https://blogs.microsoft.com/uploads/prod/sites/5/2018/12/MSFT-Airband_InteractivePDF_Final_12.3.18.pdf.)

Discussions with Adaptrum have focused on the a) technical feasibility of the plan, b) the design of the TVWS "system", and c) the cost of the various components of the "system". According to Adaptrum, the capabilities of TVWS are:

- With the base station receiver above the tree line, the maximum range of TVWS signal is 10 km. This signal range will be smaller depending topography. The FCC restricts tower heights to 100ft.
- The base station and the client (hotspot) require power; 30W per base station and 20W per client.
- Typically, one tower can have three base stations mounted on it, each covering an angle of 120 degrees and each capable of a throughput of 18Mbps.
- The abovementioned throughput is shared among all users of the base station.

The estimated cost of building out the system depicted in Figure 3 is:

- Base station, including transmitter/receiver, antenna and tower, and installation (it is assumed power will be supplied by the school)—$10,000.
- Hotspots, including receiver/transmitter, antenna and router—$500 per hotspot.

Business Model

The base station will be connected to the Internet via a fiber optic connection to Claro's network. This fiber optic connection is already in place as a consequence of the PRDE network upgrade. As previously mentioned, it is assumed that there is unused capacity in this connection, i.e., the schools are not using all of the fiber in the actual cable.

Claro, as the ISP, would make the service charge determination, but it is hoped that this service charge would the not include a capital charge given the service is leveraging existing infrastructure. (Note: It is our expectation that the base station equipment would be paid for from available community/rural development grants.)

The schools in this plan are passive participants, i.e., they host the base station and also provide power to the base station.

The Case for PRDE's Participation

PRDE, through its contract with Claro and for its own purposes, has put in place a broadband infrastructure that has the capability to provide broadband Internet service to underserved communities in which its schools are located. As mentioned above, this infrastructure can be utilized without impacting the existing broadband service used by the schools. A school's responsibility will be only to provide a location for an antenna and power to the base station equipment.

This initiative, in which PRDE can be a visible partner, would immediately connect critical community institutions, e.g., libraries, health centers, community centers, to the Internet. Further, this system could provide Internet service to students to address the "homework gap."

Next Steps

1. Obtain PRDE and Claro buy-in of the concept
2. Identify and prioritize selected schools. The criteria include:
    a. Located in underserved communities in terms of broadband service.
    b. Located within 10 km of one or more community institutions (e.g., libraries, health centers, community centers, etc.) that currently do not have broadband service)
3. Select one or two pilot locations, and develop, in conjunction with Adaptrum, a
    a. system design and budget
    b. installation plan
    c. an operating and maintenance plan
    d. a post-installation monitoring and evaluation framework to measure benefits and impact.

    Items a and b would be developed in conjunction with Adaptrum. Item c would require Claro's direct involvement.
4. Identify funding sources for the capital costs (equipment and installation).

Appendix 1-- Broadband Availability by Municipality

Broadband Availability by Municipality (Includes cable, DSL, fixed wireless and fiber platforms. Excludes mobile platforms)

Source: https://www.connectpr.org/sites/default/files/connected-nation/pr_gigabit_plan_020915_final.pdf

	Municipality	Household Density**	Number of Households	----% of Households Served---- At > 3 Mbps Down/ 768 Kbps Up	At > 10 Mbps Down / 1.5 Mbps Up	Library
1	Vieques	13.9	3,666	43.2	0.0	1
2	Culebra	4.4	749	48.7	0.0	0
3	Maricao	62.5	2,289	33.6	0.2	1
4	Aguas Buenas	333.6	10,040	75.4	31.5	1
5	Naranjito	366.3	10,163	80.1	34.0	1
6	Adjuntas	102.1	6,851	47.0	34.2	1
7	Las Marias	76.6	3,561	40.1	34.5	1
8	Orocovis	122.5	7,812	83.4	37.1	2
9	San Lorenzo	277.2	14,746	99.8	38.1	1
10	Ciales	97.2	6,487	59.0	38.5	1
11	Lares	181	11,154	55.8	40.2	2
12	Aibonito	298.9	9,367	63.4	40.6	1
13	Utuado	103.3	11,885	64.6	42.8	1
14	Corozal	292.3	12,446	73.2	43.3	2
15	Yabucoa	162.3	13,507	77.7	46.1	1
16	San Sebastian	225.3	16,047	59.0	48.9	1
17	Barranquitas	297.3	10,191	63.5	50.6	1
18	Cidra	415.2	15,135	96.0	50.6	1
19	Comerio	248.8	7,097	69.9	53.5	1
20	Jayuya	125.1	5,569	64.4	55.9	1
21	Toa Alta	889.5	24,515	95.9	57.2	1
22	Camuy	205.8	12,752	75.2	61.1	1
23	Las Piedras	414.8	14,058	100.0	62.3	1
24	Villalba	226.1	8,373	71.5	63.2	1
25	Maunabo	116.2	4,446	76.1	63.2	1
26	Catano	1434.9	10,108	99.9	65.5	1
27	Cayey	340.3	17,681	94.0	66.2	1
28	Florida	295.2	4,494	78.8	66.3	1
29	Canovanas	502.3	16,579	96.1	66.7	1
30	Morovis	279	10,859	79.8	67.5	1
31	Coamo	183	14,281	72.6	68.8	1
32	Patillas	96.6	7,271	72.8	70.8	1
33	Gurabo	556.4	15,753	99.5	70.8	3
34	Yauco	220	15,138	73.0	72.1	1
35	Guayanilla	116.8	7,503	76.8	72.2	1
36	Naguabo	135	9,755	97.9	73.0	1
37	San German	248.4	13,542	79.4	73.3	1
38	Salinas	99.9	11,400	89.2	73.9	1
39	Hatillo	261.8	15,386	88.3	74.2	7
40	Penuelas	115.9	7,863	78.9	74.4	1
41	Vega Baja	312.9	21,335	88.9	74.5	0
42	Vega Alta	371.3	13,925	93.2	75.2	?
43	Arecibo	213.7	36,579	89.2	75.8	1
44	Juncos	540.4	14,382	100.0	75.8	1
45	Caguas	901.9	53,273	99.1	77.2	1
46	Trujillo Alto	1259.7	26,935	98.0	77.8	2
47	Rio Grande	210.8	18,869	85.4	78.0	1
48	Manati	230.7	16,309	85.3	78.3	1
49	Humacao	305.1	21,780	97.7	79.1	1
50	Toa Baja	780.2	32,617	99.9	79.5	2
51	Anasco	243.6	10,942	83.1	80.1	1
52	Luquillo	156.9	7,302	82.0	80.3	1
53	Dorado	248.4	13,342	99.3	81.2	4
54	Sabana Grande	261.5	9,372	85.8	82.0	1
55	Santa Isabel	106.9	8,225	90.8	82.1	1
56	Guayama	152.1	16,244	87.0	82.3	1
57	Guaynabo	1347.1	37,402	97.0	82.9	2
58	Loiza	154.4	10,130	98.8	83.5	1
59	Ceiba	32.8	5,213	89.0	83.7	1
60	Rincon	110.2	5,998	87.8	84.2	1
61	Juana Diaz	161	17,252	93.7	85.1	0
62	Lajas	95.6	9,670	87.9	85.6	2
63	Arroyo	201.7	7,191	88.3	85.8	1
64	Moca	285.1	14,360	88.2	86.2	2
65	Guanica	90.9	7,223	91.2	86.8	1
66	Cabo Rojo	111.7	19,816	91.3	87.4	1
67	Quebradillas	274.9	9,442	92.8	89.0	4
68	Bayamon	1726.1	76,834	98.1	89.1	1
69	Fajardo	132.2	13,922	89.9	89.4	1
70	Barceloneta	296.5	9,165	94.6	90.4	1
71	Ponce	310.2	60,049	96.8	90.4	1
72	Isabela	185.9	17,072	91.5	91.0	0
73	Carolina	1113.9	67,192	98.0	91.6	1
74	Aguada	332.8	15,156	94.4	92.3	1
75	Hormigueros	601.3	6,821	97.0	93.3	1
76	Mayaguez	130.6	35,805	96.3	93.9	1
77	Aguadilla	311.6	23,552	98.4	98.1	2
78	San Juan	2148.2	165,316	100.0	99.0	4
	**Household density = average households per square mile in Municipality.					99

Source: Connect Puerto Rico inventory estimate as of June 30, 2014.

Appendix 2—Technology Description

TV White Space (TVWS) consists of the unused channel frequencies in the wireless spectrum band used traditional to transmit television signals. The part of the spectrum used for these signals has gaps between channels for buffering purposes—these "empty" channels can be used to deliver broadband internet.

Signals using this part of the spectrum can travel up to 10 kilometers, through vegetation, buildings, and other obstacles. Access to the network on tablets, phones and computers must be through a dedicated transmitter receiver via an antenna.

Several major companies such as Microsoft and Google are working on TV white space (TVWS) initiatives. Notably, Microsoft is worked on an initiative called Airband to close the rural broadband gap across the United States, and previously implemented TVWS in Puerto Rico and the U.S. Virgin Islands as part of post-Maria recovery efforts.[1] In addition, TVWS has already been implemented at scale: in 2013, the University of West Virginia commenced using TVWS on campus, benefitting more than 15,000 students.

Limitations to the use of TVWS are a) this part of the spectrum is used in other applications, and b) the speeds do not meet the FCC broadband definition. With respect to the former, medical monitors and sensors in hospitals communicate using a portion of this spectrum. As a consequence, scans of the local frequencies are required to ensure minimal interference.

In most cases, TVWS is a more cost-effective option than installing fiber optic cables which can cost $30,000 per mile or more if it is necessary to traverse difficult terrain. A white paper produced by Microsoft in collaboration with the Boston Consulting Group stated that a mixed-technology plan centered on TVWS could reduce initial capital and operating costs by 80 percent compared with the cost of using fiber cables, and by 50 percent compared with the cost of LTE fixed wireless technology.[2]

[1] https://www.axios.com/microsoft-uses-tv-white-space-to-provide-internet-in-puerto-rico-1513307063-da29c572-5939-4fc8-808e-e0c7395708d7.html

[2] "A Rural Broadband Strategy" (Microsoft White Paper). 2017. Retrieved from: https://blogs.microsoft.com/uploads/2017/07/Rural-Broadband-Strategy-Microsoft-Whitepaper-FINAL-7-10-17.pdf

Appendix 3—Example of TVWS In Use

There is precedent using TVWS in an application similar to what is described this white paper. One example is described below. (Excerpted from "A Rural Broadband Strategy", Microsoft 2017 https://3er1viui9wo30pkxh1v2nh4w-wpengine.netdna-ssl.com/wp-content/uploads/sites/289/2017/07/Rural-Broadband-Strategy-Microsoft-Whitepaper-FINAL-7-10-17.pdf .)

In 2017 Mid-Atlantic Broadband Communities Corporation (MBCI launched a free Internet service via TV White Space (TVWS) for students in Halifax and Charlotte Counties in southern Virginia. This deployment was in partnership with the public school districts in the two counties and was designed to address the "homework gap" arising from the inability of students in certain communities to access Internet outside of school.

To address this homework gap, MBC installed the necessary TVWS infrastructure to provide broadband access for education purposes to more than 1,000 rural households. The network included 18 base stations on towers operating at schools that already had broadband service delivered through fiber optic connections. The installation costs of this TVWS infrastructure was substantially lower than the cost associated with traditional broadband infrastructure such as fiber optic cables.

Before the TCWS service, students had to spend after school hours at school so they could keep up with assignments and other schoolwork. This is work they can now do at home.

The project in Virginia received support from the Virginia Tobacco Region Revitalization Commission. "Rural southern Virginia is now home to a highly innovative solution, which can serve as a model for other parts of the state, the U.S. and even around the world, to help young people succeed in school," says Virginia State Senator Frank Ruff, who co-chairs the Commission. "We are proud to help support and fund such an important project starting here in Charlotte and Halifax counties."

Other sources:

- http://tvwsvirginia.com/commonly-asked-questions/
- https://apps.fcc.gov/els/GetAtt.html?id=179331&x=
- https://www.daines.senate.gov/imo/media/doc/Daines%20Johnson%20Letter%20to%20FCC%20regarding%20TVWS%20proceedings%2011.27.18.pdf .

Appendix 4—Regulatory Issues

FCC Regulations—TVWS uses signals transmitted via empty channels that are used to transmit TV signals. This part of the radio spectrum is unlicensed and is therefore available to anyone with the equipment to use it. In 2010, the Federal Communications Commission (FCC) adopted rules to allow unlicensed transmitters to operate in the white spaces. The current legal framework and infrastructure regulation indicate that both fixed and personal/portable devices can operate in TVWS on an unlicensed basis (Source https://www.fcc.gov/general/white-space).

The primary method of preventing interference to TV and other services is the use of databases and geo-location functions of TVWS devices to identify vacant channels at specific locations. The FCC Office of Engineering and Technology (OET) has approved four TVWS databases and seven models of devices to power them. Google was one of the companies that has been certified to create and manage a national database. (https://www.techrepublic.com/article/white-space-the-next-internet-disruption-10-things-to-know)

Regulations relating to erecting antenna—The FCC's Antenna Structure Registration (ASR) program requires owners of antenna structures to register with the FCC any antenna structure that requires notice of proposed construction to the Federal Aviation Administration (FAA). The Antenna Structure Registration (ASR) System is an online system that stores the location, height, marking and lighting, and other information on all antenna structures that are registered with the FCC. Antenna structure owners must use the ASR system to file new antenna structure registrations (Source https://www.fcc.gov/wireless/support/antenna-structure-registration-asr-resources).

Section 332(c)(7) of the Communications Act preserves state and local authority over zoning and land use decisions for personal wireless service facilities, but sets forth specific limitations on that authority. Specifically, a state or local government may not unreasonably discriminate among providers of functionally equivalent services, may not regulate in a manner that prohibits or has the effect of prohibiting the provision of personal wireless services, must act on applications within a reasonable period of time, and must make any denial of an application in writing supported by substantial evidence in a written record (Source https://www.fcc.gov/wireless/bureau-divisions/competition-infrastructure-policy-division/tower-and-antenna-siting).

Regulations limiting use of ReStart funded infrastructure—The legal codes specifying the regulations applicable to this funding are the Education Department General Administrative Regulation (EDGAR) 34 CFR parts 76, 77, 79, 81, 82, 84, 97, 98, 99 and the Cost Principles and Audit Regulations in 2 CFR 200 (Source https://www2.ed.gov/programs/restart/2018-938a.pdf). We have not found a regulation in these codes or in the ReStart program documentation that would prevent the use of the ReStart-funded fiber network for TVWS broadband provision to the community. However, most of the codes defer to the agreement made between the U.S. federal government and the grantee. PRDE's application to ReStart and their grant agreement would need to be reviewed to ensure that further restrictions were not put in place to prevent this use.

To receive funding from the Department of Education's Restart program, eligible state-level agencies applied and received funds to be distributed to help their local education agencies

(LEAs) or districts rebuild after the fall 2017 hurricanes (Source https://www2.ed.gov/programs/restart/eligibility.html). The applications included: a brief description of how the state will provide services or assistance with the Restart funds to eligible LEAs and non-public schools and a description of the state's plan to ensure accountability for the use of Restart funds, including how the state agency will monitor for compliance with applicable requirements (Source https://www2.ed.gov/programs/restart/2018-938a.pdf; pg 3). For each year of the funded program, which would have been specified in the state's application, the DoE requested reporting on how the state distributed the funds it received or provided services to eligible LEAs and non-public schools, the number and identity of public and non-public schools that received assistance or services, the uses of funds within the State, a description of the internal controls the State had in place to ensure that funds were used for allowable purposes and in accordance with cash management principles (Source https://www2.ed.gov/programs/restart/2018-938a.pdf; p. 4).

If we assume that the period of the ReStart grant ends before the launch of TVWS services, PRDE is not be required to receive prior approval for accommodating TVWS services or report this use of grant-funded assets to the DoE. The end-date for the grant period would be specified in the award documents.

Rules and Regulations around income generated by ReStart grant-funded assets— According to 2 CFR 200.307, there is no restriction on generating income from the grant program after the period of performance has ended, unless otherwise specified in the grant agreement between DoE and PRDE. The EDGAR code 34 CFR 75.618 does not allow students or school personnel to be charged for the ordinary use of equipment or supplies purchased with grant funds. As the provision of broadband services to the community using TVWS is unlikely to be considered "ordinary use" of the equipment, it is unlikely that it would be restricted under this code. However, the grant agreement for the funding may contain additional restrictions that would need to be followed. Review of this document would be needed to confirm that this program income is allowable.

Additional Challenges—Because the fiber network is owned by Claro, the contract between PRDE and Claro for construction or upgrades of the system and any leasing agreements would need to be reviewed to confirm that there are no restrictions that would prevent the existing fiber optic connections at the schools from being utilized in the TVWS service.

Television broadcasters have been challenging the use of TVWS, claiming that it causes interference to TV broadcast signals (Source https://www.fcc.gov/general/white-space). However, the "Dynamic Spectrum Alliance", including Google, Microsoft, and Facebook, are pushing to increase the use of TVWS for unlicensed broadband (Source https://www.broadcastingcable.com/news/spectrum-alliance-releases-new-white-space-rules-170967). As these interests continue to weigh in, further impediments to the proposed TVWS broadband solution may arise.