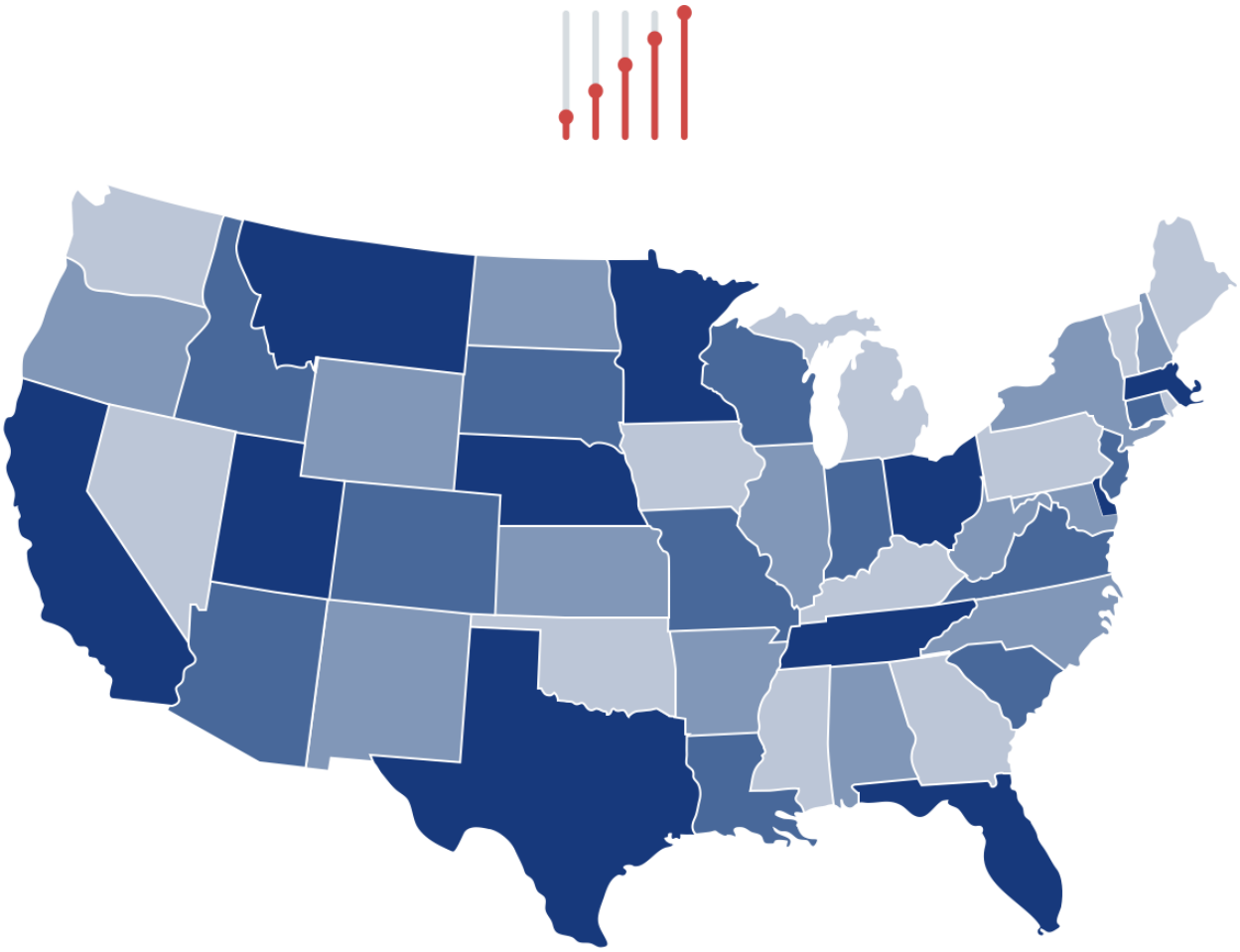

# Measuring Broadband America

## Technical Appendix to the Thirteenth MBA Report

FCC's Office of Engineering and Technology

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# 1 - INTRODUCTION AND SUMMARY

This Appendix to the Thirteenth Measuring Broadband America Report,[1] a report on consumer wireline broadband performance in the United States, provides detailed technical background information on the methodology that produced the Report. It covers the process by which the panel of consumer participants was originally recruited and selected for the August 2011 MBA Report, and maintained and evolved over the last twelve years. This Appendix also discusses the testing methodology used for the Report and describes how the test data was analyzed.

# 2 - PANEL CONSTRUCTION

This section describes the background of the study, as well as the methods employed to design the target panel, select volunteers for participation, and manage the panel to maintain the operational goals of the program.

The study aims to measure fixed broadband service performance in the United States as delivered by an Internet Service Provider (ISP) to the consumer's broadband modem. Many factors contribute to end-to-end broadband performance, only some of which are under the control of the consumer's ISP. The methodology outlined here is focused on the measurement of broadband performance within the scope of an ISP's network, and specifically focuses on measuring performance from the consumer Internet access point, or consumer gateway, to a close major Internet gateway point. The actual quality of experience seen by consumers depends on many other factors beyond the consumer's ISP, including the performance of the consumer's in-home network, transit providers, interconnection points, content distribution networks (CDN) and the infrastructure deployed by the providers of content and services. The design of the study methodology allows it to be integrated with other technical measurement approaches that focus on specific aspects of broadband performance (i.e., download speed, upload speed, latency, packet loss), and in the future, could focus on other aspects of broadband performance.

[1] The First Report (2011) was based on measurements taken in March 2011, the Second Report (2012) on measurements taken in April 2012, the Third (2013) through the Eleventh (2021) on measurements taken in September of the year prior to the Reports' release dates, and the Twelfth (2023) Report on measurements taken on September and October 2022.

## 2.1 - USE OF AN ALL VOLUNTEER PANEL

During a 2008 residential broadband speed and performance test in the United Kingdom,[2] SamKnows[3] had determined that attrition rates of an all-volunteer panel was lower than a panel maintained with an incentive scheme of monthly payments. Consequently, in designing the methodology for this broadband performance study, the Commission had decided to rely entirely on volunteer consumer broadband subscribers. Volunteers are selected from a large pool of prospective participants according to a plan designed to generate a representative sample of desired consumer demographics, including geographical location, ISP, and speed tier. As an incentive for participation, volunteers are given access to a personal dashboard which allows them to monitor the performance of their broadband service. They are also provided with a measurement device referred to in the study as a "Whitebox," consisting of an off-the-shelf commodity router configured to run custom SamKnows software.[4]

## 2.2 - SAMPLE SIZE AND VOLUNTEER SELECTION

The Thirteenth MBA Report relies on data gathered from 2,025 volunteer panelists across the United States. The methodological factors and considerations that influenced the selection of the sample and makeup include proven practices originating from the first MBA Report and test period, and adaptations beyond the first period. Both are described below:

- The panel of U.S. broadband subscribers was initially drawn from a pool of over 175,000 volunteers during a recruitment campaign that ran in May 2010. Since then, to manage attrition and accommodate the evolving range of subscriber demographics (*i.e.*, tiers, technology, population), additional panelists have been recruited through email solicitations by the ISPs as well as through press releases, a web page,[5] social media outreach and blog posts.
- The volunteer sample was originally organized with a goal of covering major ISPs in the 48 contiguous states across five broadband technologies: DSL, cable, fiber-to-the-home, fixed terrestrial wireless, and satellite.[6]

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[2] See https://files.samknows.com/~fcc_public/PM_Summer_08.pdf, (last accessed July 31, 2023).

[3] SamKnows is a company that specializes in broadband performance measurement and was retained under contract by the FCC to assist in this study. *See* http://www.samknows.com/.

[4] The Whiteboxes are named after the appearance of the first hardware implementation of the measurement agent. The Whiteboxes remain in consumer homes and continue to run the tests described in this Report. Participants may remain in the measurement project as long as it continues and may retain their Whitebox when they end their participation.

[5] https://www.measuringbroadbandamerica.com/

[6] At the request of, and with the cooperation of the Department of Commerce and Consumer Affairs, Hawaii, we are also collecting data from the state of Hawaii.

- Target numbers for volunteers were set across the four Census Regions—Northeast, Midwest, South, and West—to help ensure geographic diversity in the volunteer panel and compensate for differences in networks across the United States.[7]
- A target plan for allocation of Whiteboxes was developed based on the market share of participating ISPs. Initial market share information was based principally on FCC Form 477[8] data filed by participating ISPs for December 2020. This data is further enhanced by the ISPs who brief SamKnows on new products and changes in subscribership numbers which may have occurred after the submission of the 477 data. Speed tiers that comprise the top 80% of a Participating ISP's subscriber base are included. This threshold ensures that we are measuring the ISP's most popular speed tiers and that it is possible to recruit sufficient panelists.
- An initial set of prospective participants was selected from volunteers who had responded directly to SamKnows as a result of media solicitations, as described in detail in Section 2.3. Where gaps existed in the sample plan, SamKnows worked with participating ISPs via email solicitations targeted at underrepresented tiers.
- Since the initial panel was created in 2011, participating ISPs have contacted random subsets of their subscribers by email to replenish cells that were falling short of their desired panel size. Additional recruitment via social media, press releases and blog posts has also taken place.

The sample plan is designed prior to the reporting period and is sent to each ISP by SamKnows. ISPs review this and respond directly to SamKnows with feedback on speed tiers that ought to be included based on the threshold criteria stated above. SamKnows will include all relevant tiers in the final Report, assuming a target sample size is available. As this may not be known until after the reporting period is over, a final sample description containing all included tiers is produced and shared with the FCC and ISPs once the reporting period has finished and the data has been processed. Test results from a total of 2,025 panelists were used in the Thirteenth MBA Report. This figure includes only panelists that are subscribed to the tiers that were tested as part of the sample plan.

The recruitment campaign resulted in the coverage needed to ensure balanced representation of users across the United States. Table 1 shows the number of volunteers with reporting Whiteboxes for the months of September/October 2022 listed by ISP, as well as the percentage of total volunteers subscribed to each ISP. Tables 2 and 3 show the distributions of Whiteboxes

[7] Although the Commission's volunteer recruitment was guided by Census Region to ensure the widest possible distribution of panelists throughout the United States, as discussed below, a sufficient number of testing devices were not deployed to enable, in every case, the evaluation of regional differences in broadband performance. The States associated with each Census Region are described in Table 4.

[8] The FCC Form 477 data collects information about broadband connections to end user locations, wired and wireless local telephone services, and interconnected Voice over Internet Protocol (VoIP) services. *See* https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477 for further information.

by State and by Region respectively. This can be compared with the percentage of subscribers per state or region.[9]

## Table 1: ISPs, Sample Sizes and Percentages of Total Volunteers

| ISP | Sample Size | % of Total Volunteers |
|---|---|---|
| **CenturyLink** | 628 | 31.0% |
| **Charter** | 101 | 5.0% |
| **Cincinnati Bell DSL** | 41 | 2.0% |
| **Cincinnati Bell Fiber** | 120 | 5.9% |
| **Comcast** | 182 | 9.0% |
| **Cox** | 99 | 4.9% |
| **Frontier DSL** | 113 | 5.6% |
| **Frontier Fiber** | 62 | 3.1% |
| **Mediacom** | 73 | 3.6% |
| **Optimum** | 146 | 7.2% |
| **Verizon Fiber** | 103 | 5.1% |
| **Windstream** | 357 | 17.6% |
| **Total** | 2,025 | 100% |

[9] Subscriber data in the Thirteenth MBA Report is based on the FCC's Internet Access Services Report with data current to June 30, 2019. See Figure 33, Internet Access Services: Status as of June 30, 2019, Wireline Competition Bureau, Industry Analysis and Technology Division (rel. March 2022), available at https://docs.fcc.gov/public/attachments/DOC-381125A1.pdf

## Table 2: Distribution of Whiteboxes by State

| State | Total Boxes | % of Total Boxes | % of Total US Broadband |
|---|---|---|---|
| Alabama | 19 | 0.94% | 1.41% |
| Alaska | 0 | 0.00% | 0.22% |
| Arizona | 107 | 5.28% | 2.03% |
| Arkansas | 25 | 1.23% | 0.78% |
| California | 99 | 4.89% | 12.84% |
| Colorado | 80 | 3.95% | 1.73% |
| Connecticut | 31 | 1.53% | 1.12% |
| Delaware | 4 | 0.20% | 0.30% |
| District of Columbia | 0 | 0.00% | 0.27% |
| Florida | 115 | 5.68% | 6.78% |
| Georgia | 105 | 5.19% | 3.14% |
| Hawaii | 0 | 0.00% | 0.48% |
| Idaho | 23 | 1.14% | 0.49% |
| Illinois | 22 | 1.09% | 3.90% |
| Indiana | 25 | 1.23% | 1.88% |
| Iowa | 77 | 3.80% | 0.89% |
| Kansas | 10 | 0.49% | 1.35% |
| Kentucky | 62 | 3.06% | 1.32% |
| Louisiana | 12 | 0.59% | 1.42% |
| Maine | 2 | 0.10% | 0.39% |
| Maryland | 26 | 1.28% | 1.97% |
| Massachusetts | 25 | 1.23% | 2.29% |
| Michigan | 22 | 1.09% | 2.97% |
| Minnesota | 77 | 3.80% | 1.68% |
| Mississippi | 5 | 0.25% | 0.82% |
| Missouri | 56 | 2.77% | 1.77% |
| Montana | 9 | 0.44% | 0.29% |

| | | | |
|---|---|---|---|
| Nebraska | 26 | 1.28% | 0.53% |
| Nevada | 14 | 0.69% | 0.93% |
| New Hampshire | 3 | 0.15% | 0.41% |
| New Jersey | 84 | 4.15% | 2.92% |
| New Mexico | 47 | 2.32% | 0.58% |
| New York | 93 | 4.59% | 6.56% |
| North Carolina | 62 | 3.06% | 2.96% |
| North Dakota | 0 | 0.00% | 0.23% |
| Ohio | 197 | 9.73% | 3.51% |
| Oklahoma | 17 | 0.84% | 1.11% |
| Oregon | 36 | 1.78% | 1.26% |
| Pennsylvania | 69 | 3.41% | 3.90% |
| Rhode Island | 7 | 0.35% | 0.31% |
| South Carolina | 9 | 0.44% | 1.42% |
| South Dakota | 1 | 0.05% | 0.24% |
| Tennessee | 9 | 0.44% | 1.92% |
| Texas | 89 | 4.40% | 8.63% |
| Utah | 14 | 0.69% | 0.85% |
| Vermont | 1 | 0.05% | 0.19% |
| Virginia | 57 | 2.81% | 2.39% |
| Washington | 74 | 3.65% | 2.34% |
| West Virginia | 21 | 1.04% | 0.44% |
| Wisconsin | 54 | 2.67% | 1.66% |
| Wyoming | 3 | 0.15% | 0.17% |

The distribution of Whiteboxes by Census Region is found in the table on the next page.

## Table 3: Distribution of Whiteboxes by Census Region

| Census Region | Total Boxes | % Total Boxes | % Total U.S. Broadband Subscribers |
|---|---|---|---|
| **Midwest** | 567 | 28.0% | 20.6% |
| **Northeast** | 315 | 15.6% | 18.1% |
| **South** | 637 | 31.5% | 37.1% |
| **West** | 506 | 25.0% | 24.2% |

The distribution of states associated with the four Census Regions used to define the panel strata are included in the table below.

## Table 4: Panelists States Associated with Census Regions

| Census Region | States |
|---|---|
| **Northeast** | CT MA ME NH NJ NY PA RI VT |
| **Midwest** | IA IL IN KS MI MN MO ND NE OH SD WI |
| **South** | AL AR DC DE FL GA KY LA MD MS NC OK SC TN TX VA WV |
| **West** | AK AZ CA CO HI ID MT NM NV OR UT WA WY |

# 2.3 - PANELIST RECRUITMENT PROTOCOL

Panelists are recruited in the 2011- 2022 panels using the following method:

- Recruitment has evolved since the start of the program. At that time, (2011) several thousand volunteers were initially recruited through an initial public relations and social media campaign led by the FCC. This campaign included discussion on the FCC website and on technology blogs, as well as articles in the press. Currently volunteers are drafted with the help of a recruitment website[10] which keeps them informed about the MBA program and allows them to view MBA data on a dashboard. The composition of the panel is reviewed each year to identify any deficiencies with respect to the sample plan described above. Target demographic goals are set for volunteers based on ISP, speed tier, technology type, and region. Where the pool of volunteers falls short of the desired goal, ISPs send out email messages to their customers asking them to participate in the MBA program. The messages direct interested volunteers to contact SamKnows to request participation in the trial. The ISPs do not know which of the email recipients volunteer. In almost all cases, this ISP outreach allows the program to meet its desired demographic targets.

The mix of panelists recruited using the above methodologies varies by ISP.

A multi-mode strategy was used to qualify volunteers for the 2022 testing period. The key stages of this process were as follows:

1. Volunteers were directed to complete an online form which provided information on the study and required volunteers to submit a small amount of information.
2. Volunteers were selected from respondents to this follow-up email based on the target requirements of the panel. Selected volunteers were then asked to agree to the *User Terms and Conditions* that outlined the permissions to be granted by the volunteer in key areas such as privacy.[11]
3. From among the volunteers who agreed to the User Terms and Conditions, SamKnows selected the panel of participants,[12] each of whom received a Whitebox for self-installation. SamKnows provided full support during the Whitebox installation phase.

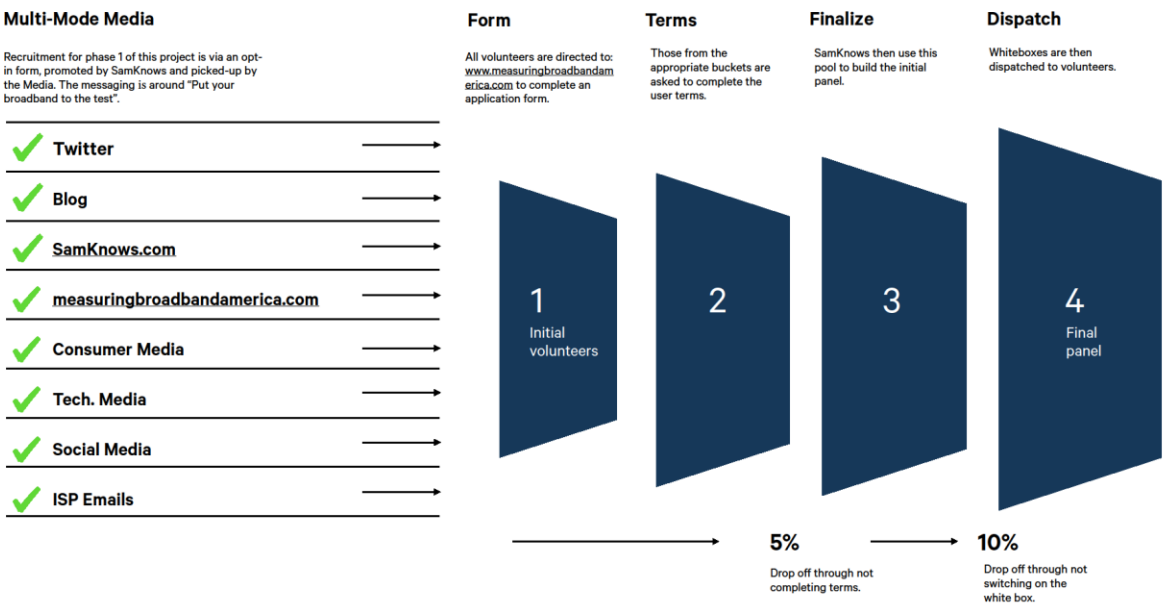
The graphic in Figure 1 illustrates the study recruitment methodology.

[10] The Measuring Broadband America recruitment website is: https://www.measuringbroadbandamerica.com/.

[11] The User Terms and Conditions is found in the Reference Documents at the end of this Appendix.

[12] Over 28,000 Whiteboxes have been shipped to targeted volunteers since 2011, of which 4,818 were online and reporting data from the months of September/October 2022.

*Figure 1: Panelist Recruitment Protocol*



## 2.4 - VALIDATION OF VOLUNTEERS' SERVICE TIER

The methodology employed in this study included verifying each panelist's service tier and ISP against the customer records of participating ISPs.[13] Throughput tests were used to initially confirm reported speeds, then further validated by the process described below.

The broadband service tier reported by each panelist was validated as follows:

- When the panelist installed the Whitebox, the device automatically ran an IP address test to check that the ISP identified by the volunteer was correct.
- Each ISP was asked to confirm the broadband service tier reported by each selected panelist.
- SamKnows then took the validated speed tier information that was provided by the ISPs and compared this to both the panelist-provided information, and the actual test results obtained, in order to ensure accurate tier validation.

SamKnows manually completed the following four steps for each panelist:

- Verified that the IP address was in a valid range for those served by the ISP.
- Reviewed data for each panelist and removed data where speed changes such as tier upgrade or downgrade appeared to have occurred, either due to a service change on the part of the consumer or a network change on the part of the ISP.
- Identified panelists whose throughput appeared inconsistent with the provisioned service tier. Such anomalies were re-certified with the consumer's ISP.[14]
- Verified that the resulting downstream-upstream test results corresponded to the ISP-provided speed tiers and updated accordingly if required.

Of the more than 28,000 Whiteboxes that were shipped to panelists since 2011, 4,392[15] units reported sufficient data in September/October 2022, with the participating ISPs validating

[13] Past FCC studies found that a high rate of consumers could not reliably report information about their broadband service, and the validation of subscriber information ensured the accuracy of expected speed and other subscription details against which observed performance was measured. See John Horrigan and Ellen Satterwhite, Americans' Perspectives on Online Connection Speeds for Home and Mobile Devices, 1 (FCC 2010), available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-298516A1.doc (finding that 80 percent of broadband consumers did not know what speed they had purchased).

[14] For example, when a panelist's upload or download speed was observed to be significantly higher than that of the rest of the tier, it could be inferred that a mischaracterization of the panelist's service tier had occurred. Such anomalies, when not resolved in cooperation with the service provider, were excluded from the Thirteenth Report, but will be included in the raw bulk data set.

[15] This figure represents the total number of boxes reporting during September/October 2022, the month chosen for the Thirteenth Report. Shipment of boxes continued in succeeding months and these results will be included in the raw bulk data set.

4,117 for the reporting period. A total of 2,025 validated units were part of download or upload tiers included in the sample plan and were ultimately included in this Report.

A total of 2,367 boxes were excluded for the following reasons:

- 1,192 belonged to users subscribed to plans that were not included in this study
- 545 Whiteboxes were legacy models that could not fully support the plan speeds
- 345 did not have enough data on reported testing days
- 127 were excluded due to local configuration issues or other technical constraints unrelated to the Whiteboxes
- 117 were excluded due to ambiguity remaining after the validation process as to which tier the user was subscribed to
- 41 belonged to users whose details or subscribed tier could not be successfully validated by the ISP

## 2.5 - PROTECTION OF VOLUNTEERS' PRIVACY

Protecting the panelists' privacy is a major concern for this program. The panel was comprised entirely of volunteers who knowingly and explicitly opted into the testing program. For audit purposes, we retain the correspondence with panelists documenting their opt-in.

All personal data was processed in conformity with relevant U.S. law and in accordance with policies developed to govern the conduct of the parties handling the data. The data were processed solely for the purposes of this study and are presented here and in all online data sets with all personally identifiable information (PII) removed.

A set of materials was created both to inform each panelist regarding the details of the trial, and to gain the explicit consent of each panelist to obtain subscription data from the participating ISPs. These documents were reviewed by the Office of General Counsel of the FCC and the participating ISPs and other stakeholders involved in the study.

# 3 - BROADBAND PERFORMANCE TESTING METHODOLOGY

This section describes the system architecture and network programming features of the tests, and other technical aspects of the methods employed to measure broadband performance during this study.

## 3.1 - RATIONALE FOR HARDWARE-BASED MEASUREMENT APPROACH

Either a hardware or software approach can be used to measure broadband performance. Software approaches are by far the most common and allow for measurements to easily and cost-effectively include a very large sample size. Web-based speed tests fall into this category and typically use JavaScript that execute within the user's web browser. These clients download content from remote web servers and measure the throughput. Some web-based performance tests also measure upload speed or round-trip latency.

Other, less common, software-based approaches to performance measurement install applications on the user's computer. These applications run tests periodically while the computer is on.

All software solutions implemented on a consumer's computer, smart phone, or other device connected to the Internet suffer from the following disadvantages:

- The software and computing platform running the software may not be capable of reliably recording the higher speed service tiers currently available.
- The software typically cannot know if other devices on the home network are accessing the Internet when the measurements are being taken. The lack of awareness as to other, non-measurement related network activity can produce inconsistent and misleading measurement data.
- Software measurements may be affected by the performance, quality and configuration of the device.
- Potential bottlenecks, such as Wi-Fi networks and other in-home networks, are generally not accounted for and may result in unreliable data.
- If the device hosting the software uses in-home WIFI access to fixed broadband service, differing locations in the home may impact measurements.
- The tests can only run when the computer is turned on, limiting the ability to provide a 24-hour profile.

- If software tests are performed manually, panelists might only run tests when they experience problems and thus bias the results.

In contrast, the hardware approach used in the MBA program requires the placement of the previously described Whitebox inside the user's home, directly connected to the consumer's service interconnection device (router), via Ethernet cable. The measurement device therefore directly accesses fixed Internet service to the home over this dedicated interface and periodically runs tests to remote targets over the Internet. The use of hardware devices avoids the disadvantages listed earlier with the software approach. However, hardware approaches are much more expensive than the software alternative, are thus more constrained in the achievable panel size, and require correct installation of the device by the consumer or a third party. This is still subject to unintentional errors due to misconfigurations, *i.e.*, connecting the Whitebox incorrectly, but these can often be detected in the validation process that follows installation. The FCC chose the hardware approach since its advantages far outweigh these disadvantages.

## 3.2 - DESIGN OBJECTIVES AND TECHNICAL APPROACH

For this test of broadband performance, as in previous Reports, the FCC used design principles that were previously developed by SamKnows in conjunction with their study of broadband performance in the U.K. The design principles comprise 17 technical objectives:

### Table 5: Design Objectives and Methods

| # | Technical Objectives | Methodological Accommodations |
|---|---|---|
| 1 | The Whitebox measurement process must not change during the monitoring period. | The Whitebox measurement process is designed to provide automated and consistent monitoring throughout the measurement period. |
| 2 | Must be accurate and reliable. | The hardware solution provides a uniform and consistent measurement of data across a broad range of participants. |
| 3 | Must not interrupt or unduly degrade the consumer's use of the broadband connection. | The volume of data produced by tests is controlled to avoid interfering with panelists' overall broadband experience, and tests only execute when consumer is not making heavy use of the connection. |
| 4 | Must not allow collected data to be distorted by any use of the broadband connection by other applications on the host PC and | The hardware solution is designed not to interfere with the host PC and is not dependent on that PC. |

| | | |
|---|---|---|
| | other devices in the home. | |
| **5** | Must not rely on the knowledge, skills and participation of the consumer for its ongoing operation once installed. | The Whitebox is "plug-and-play." Instructions are graphics-based and the installation process has been substantially field tested. Contacts for support are also provided and the outreach once a Whitebox has been dispatched and activated. |
| **6** | Must not collect data that might be deemed to be personal to the consumer without consent. | The data collection process is explained in plain language and consumers are asked for their consent regarding the use of their personal data as defined by any relevant data protection legislation. |
| **7** | Must be easy for a consumer to completely remove any hardware and/or software components if they do not wish to continue with the MBA program. | Whiteboxes can be disconnected at any time from the home network. As soon as the Whitebox is reconnected the reporting is resumed as before. |
| **8** | Must be compatible with a wide range of DSL, cable, satellite and fiber-to-the-home modems. | Whiteboxes can be connected to all modem types commonly used to support broadband services in the U.S., either in a routing or bridging mode, depending on the model. |
| **9** | Where applicable, must be compatible with a range of computer operating systems, including, without limitation, Windows XP, Windows Vista, Windows 7, Mac OS and Linux. | Whiteboxes are independent of the PC operating system and therefore able to provide testing with all devices regardless of operating system. |
| **10** | Must not expose the volunteer's home network to increased security risk, *i.e.*, it should not be susceptible to viruses, and should not degrade the effectiveness of the user's existing firewalls, antivirus and spyware software. | The custom software in the Whitebox is hardened for security and cannot be accessed without credentials only available to SamKnows. Most user firewalls, antivirus and spyware systems are PC-based. The Whitebox is plugged in to the broadband connection "before" the PC. Its activity is transparent and does not interfere with those protections. |
| **11** | Must be upgradeable remotely if it contains any software or firmware components. | The Whitebox can be completely controlled remotely for updates without involvement of the consumer, providing the Whitebox is switched on and connected. |

| | | |
|---|---|---|
| **12** | Must identify when a user changes broadband provider or package (*e.g.*, by a reverse look up of the consumer's IP address to check provider, and by capturing changes in modem connection speed to identify changes in package). | Ensures regular data pool monitoring for changes in speed, ISP, IP address or performance, and flags when a panelist should notify and confirm any change to their broadband service since the last test execution. |
| **13** | Must permit, in the event of a merger between ISPs, separate analysis of the customers of each of the merged ISP's predecessors. | Data are stored based on the ISP of the panelist, and therefore can be analyzed by individual ISP or as an aggregated dataset. |
| **14** | Must identify if the consumer's computer is being used on a number of different fixed networks (*e.g.*, if it is a laptop). | The Whiteboxes are broadband dependent, not PC or laptop dependent. |
| **15** | Must identify when a specific household stops providing data. | The Whitebox needs to be connected and switched on to push data. If it is switched off or disconnected its absence is detected at the next data push process. |
| **16** | Must not require an amount of data to be downloaded which may materially impact any data limits, usage policy, or traffic shaping applicable to the broadband service. | The data volume generated by the information collected does not exceed any policies set by ISPs. Panelists with bandwidth restrictions can have their tests set accordingly. |
| **17** | Must limit the possibility for ISPs to identify the broadband connections which form their panel and therefore potentially "game" the data by providing different quality of service to the panel members and to the wider customer base. | ISPs signed a Code of Conduct[16] to protect against gaming test results. While the identity of each panelist was made known to the ISP as part of the speed tier validation process, the actual Unit ID for the associated Whitebox was not released to the ISP so specific test results were not directly assignable against a specific panelist. Moreover, most ISPs had hundreds, and some had more than 1,000, participating subscribers spread throughout their service territory, making it difficult to |

[16] Signatories to the Code of Conduct are: CenturyLink, Charter, Cincinnati Bell, Comcast, Cox, Frontier, Mediacom, NCTA, Optimum, Verizon and Windstream. A copy of the Code of Conduct is included as a Reference Document attached to this Appendix.

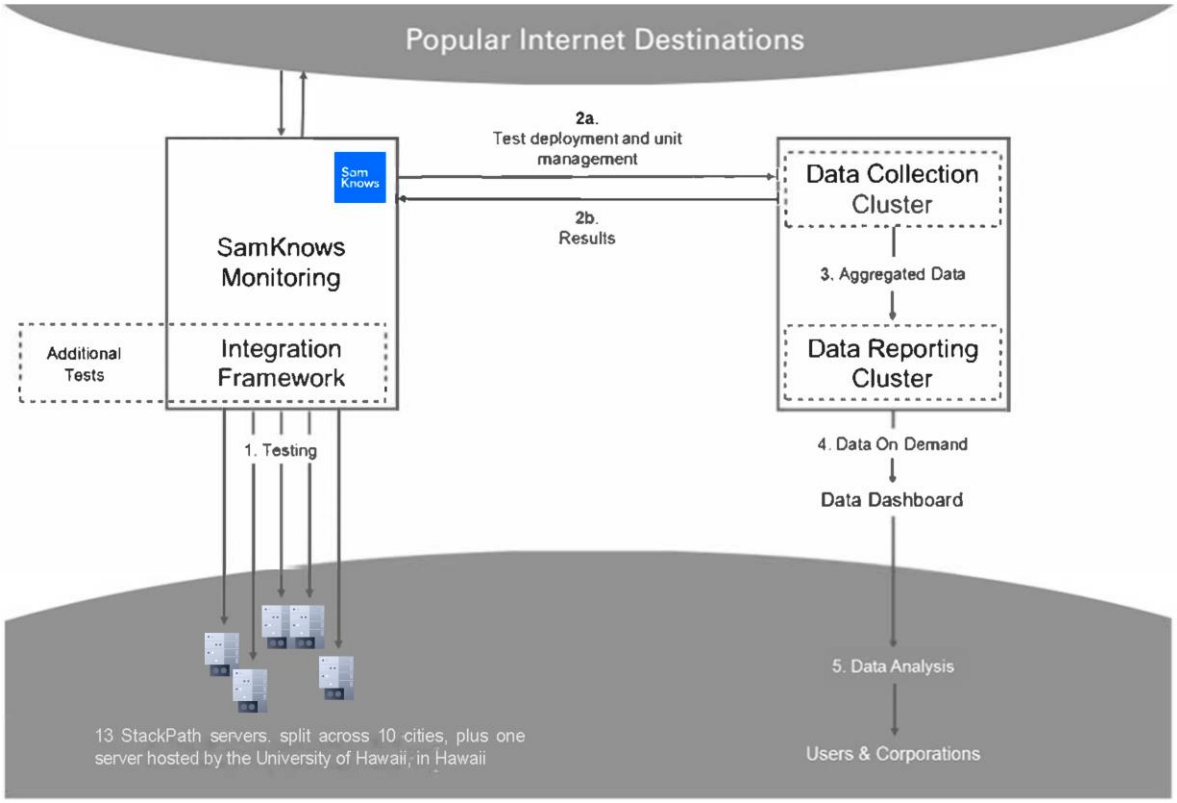
| | | |
|---|---|---|
| | | improve service for participating subscribers without improving service for all subscribers. |

# 3.3 - TESTING ARCHITECTURE

## Overview of Testing Architecture

As illustrated in Figure 2, the performance monitoring system comprises a distributed network of Whiteboxes in the homes of members of the volunteer consumer panel. The Whiteboxes are controlled by a cluster of servers, which hosts the test scheduler and the reporting database. The data was collated on the reporting platform and accessed via a reporting interface[17] and secure FTP site. The system also included a series of speed-test servers, which the Whiteboxes called upon according to the test schedule.

*Figure 2: Testing Architecture*




[17] Each reporting interface included a data dashboard for the consumer volunteers, which provided performance metrics associated with their Whitebox.

## Approach to Testing and Measurement

Any network monitoring system needs to be capable of monitoring and executing tests 24 hours a day, seven days a week. Similar to the method used by the television audience measurement industry, each panelist is equipped with a Whitebox, which is self-installed by each panelist and conducts the performance measurements. Since 2011, the project has used three different hardware platforms, described below. The software on each of the Whiteboxes was programmed to execute a series of tests designed to measure key performance indicators (KPIs) of a broadband connection. The tests comprise a suite of applications, written by SamKnows in the programming language C, which were rigorously tested by the ISPs and other stakeholders. The Thirteenth Report incorporates data from all three types of Whiteboxes and we use the term Whitebox generically. Testing has found that they produce results that are indistinguishable.

During the initial testing period in 2011, the Whitebox provided used hardware manufactured by NETGEAR, Inc. (NETGEAR) and operated as a broadband router. It was intended to replace the panelist's existing router and be directly connected to the cable or DSL modem, ensuring that tests could be run at any time the network was connected and powered, even if all home computers were switched off. Firmware for the Whitebox routers was developed by SamKnows with the cooperation of NETGEAR. In addition to running the latest versions of the SamKnows testing software, the routers retained all of the native functionality of the NETGEAR consumer router.

Following the NETGEAR Whitebox new models were introduced starting with the 2012 testing period. These versions were based upon hardware produced by TP-Link and then later manufactured by SamKnows and operate as a bridge rather than as a router. It connects to the customer's existing router, rather than replacing it, and all hardwired home devices connect to LAN ports on the TP-Link Whitebox. The TP-Link Whitebox / SamKnows Whitebox passively monitors wireless network activity in order to determine when the network is active and defer measurements. It runs a modified version of OpenWrt, an open source router platform based on Linux. All Whiteboxes deployed since 2012 use the TP-Link or SamKnows hardware.

SamKnows Whiteboxes (Whitebox 8.0), introduced in August 2016, have been shown to provide accurate information about broadband connections with throughput rates of up to 1 Gbps.

## Home Deployment of the NETGEAR Based Whitebox

This study was initiated by using existing NETGEAR firmware, and all of its features were intended to allow panelists to replace their existing routers with the Whitebox. If the panelist did not have an existing router and used only a modem, they were asked to install the Whitebox according to the usual NETGEAR instructions.

However, this architecture could not easily accommodate scenarios where the panelist had a combined modem/router supplied by their ISP that had specific features that the Whitebox could not provide. For example, some Verizon FiOS gateways connect via a MoCA (Multimedia over Cable) interface and AT&T IPBB gateways provide U-Verse specific features, such as IPTV.

In these cases, the Whitebox was connected to the existing router/gateway and all home devices plugged into the Whitebox. In order to prevent a double-NAT configuration, in which multiple routers on the same network perform network address translation (NAT) and make access to the SamKnows router difficult, the Whitebox was set to dynamically switch to operate as a transparent Ethernet bridge when deployed in these scenarios. All consumer configurations were evaluated and tested by participating ISPs to confirm their suitability.[18]

## Home Deployment of the TP-Link Based Whitebox

The TP-Link-based Whitebox, which operates as a bridge, was introduced in response to the increased deployment of integrated modem/gateway devices. To use the TP-Link-based Whitebox, panelists are required to have an existing router. Custom instructions guided these panelists to connect the Whitebox to their existing router and then connect all of their home devices to the Whitebox. This allows the Whitebox to measure traffic volumes from wired devices in the home and defer tests accordingly. As an Ethernet bridge, the Whitebox does not provide services such as network address translation (NAT) or DHCP.

## Home Deployment of the SamKnows Whitebox 8.0

The Whitebox 8.0 was manufactured by SamKnows and deployed starting in August 2016. Like the TP-Link device, this Whitebox works as a bridge, rather than a router, and operates in a similar manner. Unlike the NETGEAR and TP-Link hardware, it can handle bandwidths of up to 1 Gbps.

## Internet Activity Detection

No tests are performed if the Whiteboxes detect wired or wireless traffic beyond a defined bandwidth threshold. This ensures both that testing does not interfere with consumer use of

[18] The use of legacy equipment has the potential to impede some panelists from receiving the provisioned speed from their ISP, and this impact is captured by the survey.

their Internet service and that any such use does not interfere with testing or invalidate test results.

Panelists were not asked to change their wireless network configurations. Since the TP-Link Whiteboxes and Whitebox 8.0 attach to the panelist's router that may contain a built-in wireless (Wi-Fi) access point, these devices measure the strongest wireless signal. Since they only count packets, they do not need access to the Wi-Fi encryption keys and do not inspect packet content.

## Test Nodes (Off-Net and On-Net)

For the tests in this study, SamKnows employed thirteen core measurement servers as test nodes that were distributed geographically across ten locations, outside the network boundaries of the participating ISPs. These off-net measurement points were supplemented by additional measurement points located within the networks of some of the ISPs participating in this study, called on-net servers. The core measurement servers were used to measure consumers' broadband performance between the Whitebox and an available reference point that was closest in roundtrip time to the consumer's network address.

On-net secondary reference points operated by broadband providers provided additional validity checks and insight into broadband service performance within an ISP's network. In total, the following 122 measurement servers were deployed for the Thirteenth Report:

## Table 6: Overall Number of Testing Servers

| Operated By | Number of Servers |
|---|---|
| **AT&T** | 9 |
| **CenturyLink (inc Qwest)** | 19 |
| **Charter (inc TWC)** | 18 |
| **Comcast** | 37 |
| **Cox** | 2 |
| **Frontier** | 5 |
| **Hawaiian Telecom** | 1 |

| | |
|---|---|
| **Mediacom** | 1 |
| **Optimum** | 3 |
| **StackPath (off-net)** | 13 |
| **University of Hawaii (off-net)** | 1 |
| **Verizon** | 5 |
| **Windstream** | 8 |

## Test Node Locations

### Off-Net Test Nodes

The StackPath nodes were located in the following major U.S. Internet peering locations:

- Ashburn, Virginia (two locations)
- Atlanta, Georgia (one location)
- Chicago, Illinois (two locations)
- Dallas, Texas (one location)
- Los Angeles, California (one location)
- New York City, New York (two locations)
- San Jose, California (one location)
- Seattle, Washington (one location)
- Denver, Colorado (one location)
- Miami, Florida (one location)

### On-Net Test Nodes

In addition to off-net nodes, some ISPs deployed their own on-net servers to cross-check the results provided by off-net nodes. Whiteboxes were instructed to test against the off-net StackPath and the on-net ISP nodes, when available.

The same suite of tests was scheduled for these on-net nodes as for the off-net nodes and the same server software developed by SamKnows was used regardless of whether the Whitebox

was interacting with on-net or off-net nodes. Off-net test nodes are continually monitored for load and congestion.

While these on-net test nodes were included in the testing, the results from these tests were used as a control set; the results presented in the Report are based only on tests performed using off-net nodes. Results from both on-net and off-net nodes are included in the raw bulk data set that will be released to the public.

## Test Node Selection

Each Whitebox fetches a complete list of off-net test nodes and on-net test nodes hosted by the serving ISP from a SamKnows server and measures the round-trip time to each. This list of test servers is loaded at startup and refreshed daily. It then selects the on-net and off-net test nodes with lowest round trip time to test against. The selected nodes may not be the geographically closest node.

Technical details for the minimum requirements for hardware and software, connectivity, and systems and network management are available in the **5.3 - Test Node Briefing** provided in the Reference Document section of this Technical Appendix.

## 3.4 - TESTS METHODOLOGY

Each deployed Whitebox performs the following tests.[19] All tests are conducted with both the on-net and off-net servers except as noted, and are described in more detail in the next section.

### Table 7: List of Tests Performed by SamKnows[20]

| Metric | Primary Metric(s) |
|---|---|
| **Download speed** | Throughput in Megabits per second (Mbps) utilizing eight concurrent TCP connections |
| **Upload speed** | Throughput in Mbps utilizing eight concurrent TCP connections |
| **Web browsing** | Total page fetch time and all its embedded resources from a popular website |
| **UDP latency** | Average round trip time of a series of evenly spaced UDP packets distributed over a long timeframe |
| **UDP packet loss** | Fraction of UDP packets lost from UDP latency test |
| **Voice over IP** | Upstream packet loss, downstream packet loss, upstream jitter, downstream jitter, round trip latency |
| **DNS resolution** | Time taken for the ISP's recursive DNS resolver to return an A record[21] for a popular website domain name |
| **DNS failures** | Percentage of DNS requests performed in the DNS resolution test that failed |
| **ICMP latency** | Round trip time of five evenly spaced ICMP packets |
| **ICMP packet loss** | Percentage of packets lost in the ICMP latency test |
| **UDP Latency under load** | Average round trip time for a series of evenly spaced UDP packets sent during downstream/upstream sustained tests |

## 3.5 - TEST DESCRIPTIONS

The following sub-sections detail the methodology used for the individual tests. As noted earlier, all tests only measure the performance of the part of the network between the Whitebox and the target (*i.e.*, a test node). In particular, the VoIP tests can only approximate the behavior of real applications and do not reflect the impact of specific consumer hardware,

[19] Specific questions on test procedures may be addressed to team@samknows.com.

[20] Other tests may be run on the MBA panel; this list outlines the published tests in the Report.

[21] An "A record" is the numeric IP address associated with a domain name such as www.fcc.gov.

software, media codecs, bandwidth adjustment algorithms, Internet backbones and in-home networks.

## Download Speed and Upload Speed

These tests measure the download and upload throughput by performing multiple simultaneous HTTP GET and HTTP POST requests to a target test node.

A stream of binary, non-zero content with no maximum size—herein referred to as the payload—is provided by the SamKnows HTTP server application on the target test node. The test operates for a fixed duration of 10 seconds. It records the average throughput achieved during this 10 second period.

The test uses eight concurrent TCP connections (and therefore eight concurrent HTTP requests) to ensure that the line is saturated. Each connection used in the test counts the numbers of bytes transferred and is sampled periodically by a controlling thread. The sum of these counters (a value in bytes) divided by the time elapsed (in microseconds) and converted to Mbps is taken as the total throughput of the user's broadband service.

Factors such as TCP slow start and congestion are taken into account by repeatedly transferring small chunks (256 kilobytes, or kB) of the target payload before the real testing begins. This "warm-up" period is completed when three consecutive chunks are transferred at within 10 percent of the speed of one another. All eight connections are required to have completed the warm-up period before the timed testing begins. The warm-up period is excluded from the measurement results.

Downloaded content is discarded as soon as it is received, and is not written to the file system. Uploaded content is generated and streamed on the fly from a random source.

## Web Browsing

The test records the average time taken to sequentially download the HTML and referenced resources for the home page of each of the target websites, the number of bytes transferred, and the calculated rate per second. The primary measure for this test is the total time taken to download the HTML front page for each web site and all associated images, JavaScript, and stylesheet resources. This test does not measure against the centralized testing nodes; instead, it tests against actual websites, ensuring that the effects of content distribution networks and other performance enhancing factors can be taken into account.

Each Whitebox tests against the following eight websites:[22]

- **http://www.edition.cnn.com/**
- **http://www.apple.com/**

[22] These websites were chosen based on a list by Alexa, http://www.alexa.com/, of the top twenty websites in October 2010.

- http://www.bing.com/
- http://www.msn.com/
- http://www.bbc.com/
- http://www.ebay.com/
- http://www.m.imdb.com/help/
- http://www.google.com/policies/

The results include the time needed for DNS resolution. The test uses up to eight concurrent TCP connections to fetch resources from targets. The test pools TCP connections and utilizes persistent connections where the remote HTTP server supports them.

The client advertises the user agent as Mozilla Firefox 54. Each website is tested in sequence and the results summed and reported across all sites.

## UDP Latency and Packet Loss

These tests measure the round-trip time of small UDP packets between the Whitebox and a target test node.

Each packet consists of an 8-byte sequence number and an 8-byte timestamp. If a response packet is not received within three seconds of sending, it is treated as being lost. The test records the number of packets sent each hour, the average round trip time and the total number of packets lost. The test computes the summarized minimum, maximum, standard deviation and mean from the lowest 99 percent of results, effectively trimming the top (*i.e.*, slowest) 1 percent of outliers.

The test is configured to send packets at a constant frequency, periodically reporting summarized results from the most recent window of testing. Approximately two thousand packets are sent within a one-hour period, with fewer packets sent if the line is not idle.

This test is started when the Whitebox boots and runs permanently as a background test.

## Voice over IP

The Voice over IP (VoIP) test operates over UDP and utilizes bidirectional traffic, as is typical for voice calls.

The Whitebox handshakes with the server, and each initiates a UDP stream with the other. The test uses a 64 kbps stream with the same characteristics and properties (*i.e.*, packet sizes, delays, bitrate) as the G.711 codec. 160 byte packets are used. The test measures jitter, delay, and loss.

Jitter is calculated using the Packet Delay Variation (PDV) approach described in section 4.2 of RFC 5481. The 99th percentile is recorded and used in all calculations when deriving PDV.

## DNS Resolutions and DNS Failures

These tests measure the DNS resolution time of an A record query for the domains of the websites used in the web browsing test, and the percentage of DNS requests performed in the DNS resolution test that failed.

The DNS resolution test uses the nameservers provided by the panelist's home gateway. In the majority of cases, home gateways either provide the ISP's own nameservers via DHCP or are configured as DNS forwarders that forward requests on to the ISP's nameservers themselves.

## ICMP Latency and Packet Loss

These tests measure the round-trip time (RTT) of ICMP echo requests in microseconds from the Whitebox to a target test node. The client sends five ICMP echo requests of 56 bytes to the target test node, waiting up to three seconds for a response to each. Packets that are not received in response are treated as lost. The mean, minimum, maximum, and standard deviation of the successful results are recorded. The number of packets sent and received are recorded too.

## Latency Under Load

The latency under load test operates for the duration of the 10-second downstream and upstream speed tests, with results for upstream and downstream recorded separately. While the speed tests are running, the latency under load test sends UDP datagrams to the target server and measures the round-trip time and number of packets lost. A packet is sent every 100 milliseconds (ms), and a three second timeout is used. The test records the mean, minimum, and 99$^{th}$ percentile round trip times in microseconds. The number of lost UDP packets is also recorded.

This test represents an updated version of the methodology used in the initial August 2011 Report and aligns it with the methodology for the regular latency and packet loss metrics.

## Traceroute

A traceroute client is used to send UDP probes to each hop in the path between client and destination. Three probes are sent to each hop. The round-trip times, the standard deviation of the round-trip times of the responses from each hop and the packet loss are recorded. The open source traceroute client "mtr" (https://github.com/traviscross/mtr) is used for carrying out the traceroute measurements.

## Lightweight Capacity Test

This test measures the instantaneous capacity of the link using a small number of UDP packets. The test supports both downstream and upstream measurements, conducted independently.

In the downstream mode, the test client handshakes with the test server over TCP, requesting a fixed number of packets to be transmitted back to the client. The client specifies the transmission rate, number of packets and packet size in this handshake. The client records the arrival times of each of the resulting packets returns to it.

In the upstream mode, the client again handshakes with the test server, this time informing it of the characteristics of the stream it is about to transmit. The client then transmits the stream to the server, and the server locally records the arrival times of each packet. At the conclusion of this stream, the client asks the server for its summary of the arrival time of each packet.

With this resulting set of arrival times, the test client calculates the throughput achieved. This throughput may be divided into multiple windows, and an average taken across those, in order to smooth out buffering behavior.

This test uses approximately 99% less data than the TCP speed test and completes in a fraction of the time (100 milliseconds versus 10 seconds). The lightweight capacity test achieves results are within 1% deviation from the existing speed test results on fixed-line connections tested on average.

## Table 8: Estimated Total Traffic Volume Generated by Test

| Test Name | Test Target(s) | Test Frequency | Test Duration | Est. Daily Volume |
|---|---|---|---|---|
| **Web Browsing** | 8 popular US websites | Every 2 hours, 24x7 | Est. 30 seconds | 80 MB |
| **Voice over IP** | 1 off-net test node | Hourly, 24x7 | Fixed 10 seconds at 64k | 1.8 MB |
| | 1 on-net test node | Hourly, 24x7 | Fixed 10 seconds at 64k | 1.8 MB |
| **Download Speed (Capacity – 8x parallel TCP connections)** | 1 off-net test node | Once 12am-6am, Once 6am-12pm, Once 12pm-6pm, Once 6pm-8pm, Once 8pm-10pm, Once 10pm-12am | Fixed 10 seconds | 75 MB at 10 Mbps |
| | 1 on-net test node | Once 12am-12pm, Once 12pm-12am | Fixed 10 seconds | 25 MB at 10 Mbps |
| **Upload Speed (Capacity – 8x parallel TCP connections)** | 1 off-net test node | Once 12am-6am, Once 6am-12pm, Once 12pm-6pm, Once 6pm-8pm, Once 8pm-10pm, Once 10pm-12am | Fixed 10 seconds | 7.5 MB at 1 Mbps |
| | 1 on-net test node | Once 12am-12pm, Once 12pm-12am | Fixed 10 seconds | 2.5MB at 1 Mbps |
| **UDP Latency** | 1 off-net test node | Hourly, 24x7 | Permanent | 2.9 MB |
| | 1 on-net test node | Hourly, 24x7 | Permanent | 2.9 MB |
| **UDP Packet Loss** | 1 off-net test node | Hourly, 24x7 | Permanent | N/A (uses above) |
| | 1 on-net test nodes | Hourly, 24x7 | Permanent | N/A (uses above) |
| **Consumption** | N/A | 24x7 | N/A | N/A |
| **DNS Resolution** | 8 popular US websites | Hourly, 24x7 | Est. 3 seconds | 0.3 MB |
| **ICMP Latency** | 1 off-net test node<br>1 on-net test node | Hourly, 24x7 | Est. 5 seconds | 0.3 MB |
| **ICMP Packet loss** | 1 off-net test node<br>1 on-net test node | Hourly, 24x7 | N/A (As IMCP latency) | N/A (uses above) |

| Test Name | Test Target(s) | Test Frequency | Test Duration | Est. Daily Volume |
|---|---|---|---|---|
| **Traceroute** | 1 off-net test node<br>1 on-net test node | Three times a day, 24x7 | N/A | N/A |
| **Lightweight Capacity Test – Download (UDP)** | 1 off-net test node | Once 12am-6am,<br>Once 6am-12pm,<br>Once 12pm-6pm,<br>Hourly thereafter | Fixed 100 packets | 9MB |
| **Lightweight capacity test – Upload (UDP)** | 1 off-net test node | Once 12am-6am,<br>Once 6am-12pm,<br>Once 12pm-6pm,<br>Hourly thereafter | Fixed 100 packets | 9MB |

Download/upload daily volumes are estimates based upon likely line speeds. All tests will operate at maximum line rate so actual consumption may vary.

Tests to the off-net destinations use the nearest (in terms of latency) server from the StackPath list of test servers. These tests are also performed to the closest on-net server, where available.

## Consumption

This test was replaced by the new data usage test. A technical description for this test is outlined here: https://transition.fcc.gov/oet/mba/Data-Usage-Technical-Methodology_2018-08-24_Final-v1.3.pdf

## Cross-Talk Testing and Threshold Manager Service

For up to 30 seconds prior to and during the testing period, a background traffic monitor on the Whitebox monitors the inbound and outbound traffic across the WAN interface to calculate if a panelist is actively using the internet connection. The threshold for traffic is set to 200kbps downstream and 200kbps upstream. Metrics are sampled and computed every 5 seconds. If either of these thresholds is exceeded, the test is delayed for 5 seconds and the process repeated. If the connection is being actively used for an extended period of time, this pause and retry process continues for up to six times before the test is abandoned.

# 4 - DATA PROCESSING AND ANALYSIS OF TEST RESULTS

This section describes the background for the categorization of data gathered for the Thirteenth Report, and the methods employed to collect and analyze the test results.

## 4.1 - BACKGROUND

### Time of Day

Most of the metrics reported in the Thirteenth Report draw on data gathered during the so-called peak usage period of 7:00 p.m. to 11:00 p.m. local time[23]. This time period is generally considered to experience the highest amount of Internet usage under normal circumstances.

### ISP and Service Tier

A sufficient sample size is necessary for analysis and the ability to robustly compare the performance of specific ISP speed tiers. In order for a speed tier to be considered for the fixed line MBA Report, it must meet the following criteria:

(a) The speed tier must make up the top 80% of the ISP's subscriber base;
(b) There must be a minimum of 30 panelists that are recruited for that tier who have provided valid data for the tier within the validation period; and
(c) Each panelist must have a minimum of five days of valid data within the validation period.

The study achieved target sample sizes for the following download and upload speeds[24] (listed in alphabetical order by ISP):

**Download Speeds:**

CenturyLink DSL: 1.5, 7, 10, 12, 15, 20, 25, 40, 60, 80 and 100 Mbps tiers;
Charter Cable: 300 and 400 Mbps tiers;
Cincinnati Bell DSL: 50 Mbps tier;
Cincinnati Bell Fiber: 250 and 500 Mbps tiers;
Comcast Cable: 50, 100, and 800 Mbps tiers;
Cox Cable: 250 and 500 Mbps tiers;

[23] This period of time was agreed to by ISP participants in open meetings conducted at the beginning of the program.

[24] Due to the large number of different combinations of upload/download speed tiers supported by ISPs where, for example, a single download speed might be offered paired with multiple upload speeds or vice versa, upload and download test results were analyzed separately.

Frontier DSL: 12, 18 and 24 Mbps tiers;
Frontier Fiber: 500 Mbps tier;
Mediacom Cable: 200 and 400 Mbps tiers;
Optimum Cable: 100, 200, 300 and 400 Mbps tiers;
Verizon Fiber: 75, 100, and 200 Mbps tiers;
Windstream DSL: 10, 12, 15, 25, 50, and 100 Mbps tiers.

**Upload Speeds:**

CenturyLink DSL: 0.512, 0.768, 0.896, 1.5, 2, 5 and 10 Mbps tiers;
Charter Cable: 10 and 20 Mbps tiers;
Cincinnati Bell DSL: 5 Mbps tier;
Cincinnati Bell Fiber: 100, and 125 Mbps tiers;
Comcast Cable: 10 and 20 Mbps tiers;
Cox Cable: 10 Mbps tier;
Frontier DSL: 1 and 1.5 Mbps tiers;
Frontier Fiber: 500 Mbps tier;
Mediacom Cable: 10 and 30 Mbps tiers;
Optimum Cable: 35 Mbps tier;
Verizon Fiber: 75, 100, and 200 Mbps tiers;
Windstream DSL: 0.768, 1, and 1.5 Mbps tiers.

A file containing averages for each metric from the validated September/October 2022 data can be found on FCC's Measuring Broadband America website.[25] Some charts and tables are divided into speed bands, to group together products with similar levels of advertised performance. The results within these bands are further broken out by ISP and service tier. Where an ISP does not offer a service tier within a specific band or a representative sample could not be formed for tier(s) in that band, the ISP will not appear in that speed band.

Results from tests run on speed tiers of 1Gbps were not included in the Thirteenth Report. This was due to concerns from ISPs that the Whitebox 8.0 could not measure these speeds accurately. An investigation was conducted to establish if this was the case, or if speeds of 1Gbps could be reliably reported on.

Following investigation and testing with one of the ISPs which takes part in the program this conclusion was reached:

The network of the ISP concerned was quite "bursty" in nature, with servers on a 1Gbps network sometimes bursting to 3Gbps. This caused small amounts of packet loss which

[25] See: https://www.fcc.gov/general/measuring-broadband-america-measuring-fixed-broadband.

negatively affected overall speed test results. However once implementing new traffic shaping rules restricting traffic from the server to 1Gbps consistent high speeds were recorded by the Whitebox. The other solution to this specific problem was seen when using a very large number of parallel TCP connections. This investigation established that there is not an issue with the Whitebox 8.0 measuring speeds up to 1Gbps consistently.

# 4.2 - DATA COLLECTION AND ANALYSIS METHODOLOGY

## Data Integrity

To ensure the integrity of the data collected, the following validity checks were developed:

1. *Change of ISP intra-month*: By checking the WHOIS results once a day for the user's IP address, we found units that changed ISP during the month. We only kept data for the ISP where the panelist was active the most.
2. *Change of service tier intra-month*: This validity check found units that changed service tier intra-month by comparing the average sustained throughput observed for the first three days in the reporting period against that for the final three days in the reporting period. If a unit was not online at the start or end of that period, we used the first or final three days when they were actually online. If this difference was over 50 percent, the downstream and upstream charts for this unit were individually reviewed. Where an obvious step change was observed (*e.g.*, from 1 Mbps to 3 Mbps), the data for the shorter period was flagged for removal.
3. *Removal of any failed or irrelevant tests*: This validity check removed any failed or irrelevant tests by removing measurements against any nodes other than the US-based off-net nodes. We also removed measurements using any off-net server that showed a failure rate of 10 percent or greater during a specific one-hour period, to avoid using any out-of-service test nodes.
4. *Removal of any problem Whiteboxes*: We removed measurements for any Whitebox that exhibited greater than or equal to 10 percent failures in a particular one-hour period. This removed periods when the Whitebox was unable to reach the Internet.

## Legacy Equipment

In previous Reports, we discussed the challenges ISPs face in improving network performance where equipment under the control of the subscriber limits the end-to-end performance achievable by the subscriber.[26] Simply, some consumer-controlled equipment may not be capable of operating fully at new, higher service tiers. Working in open collaboration with all service providers we developed a policy permitting changes in ISP panelists when their installed modems were not capable of meeting the delivered service speed that included several conditions on participating ISPs. First, proposed changes in consumer panelists would only be considered where an ISP was offering free upgrades for modems they owned and leased to the consumer. Second, each ISP needed to disclose its policy regarding the treatment of legacy modems and its efforts to inform consumers regarding the impact such modems may have on their service.

[26] See pgs. 8-9, 2014 Report, pg. 8 of the 2013 Report, as well as endnote 14. http://www.fcc.gov/measuring-broadband-america/2012/july.

While the issue of DOCSIS 3 modems and network upgrades affect the cable industry today, we may see other cases in the future where customer premises equipment affects the achievable network performance.

## Collation of Results and Outlier Control

All measurement data were collated and stored for analysis purposes as monthly trimmed averages during three time intervals (24 hours, 7:00 p.m. to 11:00 p.m. local time Monday through Friday, 12:00 a.m. to 12:00 a.m. local time Saturday and Sunday). Only participants who provided a minimum of five days of valid measurements and had valid data in each of the three time intervals were included in the September / October 2022 test results. In addition, the top and bottom 1 percent of measurements were trimmed to control for outliers that may have been anomalous or otherwise not representative of actual broadband performance. All results were computed on the trimmed data.[27]

Data was only charted when results from at least 30 separate Whiteboxes was available for individual ISP download speed tiers. Service tiers of 50 or fewer Whiteboxes were noted for possible future panel augmentation.

## Peak Hours Adjusted to Local Time

Peak hours were defined as weekdays (Mondays through Fridays) between 7:00 p.m. to 11:00 p.m. (inclusive) for the purposes of the study. All times were adjusted to the panelist's local time zone. Since some tests are performed only once every two hours on each Whitebox, the duration of the peak period had to be a multiple of two hours.

## Congestion in the Home Not Measured

Download, upload, latency, and packet loss measurements were taken between the panelist's home gateway and the dedicated test nodes provided by StackPath. Web browsing measurements were taken between the panelist's home gateway and nine popular United States-hosted websites. Any congestion within the user's home network is, therefore, not measured by this study. The web browsing measurements are subject to possible congestion at the content provider's side, although the choice of eight popular websites configured to serve high traffic loads reduced that risk.

## Traffic Shaping Not Studied

The effect of traffic shaping is not studied in the Thirteenth Report, although test results were subject to any bandwidth management policies put in place by ISPs. The effects of bandwidth management policies, which may be used by ISPs to maintain consumer traffic rates within advertised service tiers, may be most readily seen in those charts in the 2016 Report that show

[27] These methods were reviewed with statistical experts by the participating ISPs.

performance over 24-hour periods, where tested rates for some ISPs and service tiers flatten for periods at a time.

## Consistency of Speed Measurements

In addition to reporting on the median speed of panelists, the MBA Report also provides a measure of the consistency of speed that panelists experience in each tier. For purposes of discussion we use the term "80/80 consistent speed" to refer to the minimum speed that was experienced by at least 80% of panelists for at least 80% of the time during the peak periods. The process used in defining this metric for a specific ISP tier is to take each panelist's set of download or upload speed data during the peak period across all the days of the validated measurement period and arrange it in increasing order. The speed that corresponds to the 20$^{th}$ percentile represents the minimum speed that the panelist experienced at least 80% of the time. The 20 percentile values of all the panelists on a specific tier are then arranged in an increasing order. The speed that corresponds to the 20$^{th}$ percentile now represents the minimum speed that at least 80% of panelists experienced 80% of the time. This is the value reported as the 80/80 consistent speed for that ISP's tier. We also report on the 70/70 consistent speed for an ISP's tier, which is the minimum speed that at least 70% of the panelists experience at least 70% of the time. We typically report the 70/70 and the 80/80 consistent speeds as a percentage of the advertised speed.

## Latencies Attributable to Propagation Delay

The speeds at which signals can traverse networks are limited at a fundamental level by the speed of light. While the speed of light is not believed to be a significant limitation in the context of the other technical factors addressed by the testing methodology, a delay of approximately 5ms per 1000 km of distance traveled can be attributed solely to the speed of light (depending on the transmission medium). The geographic distribution and the testing methodology's selection of the nearest test servers are believed to minimize any significant effect. However, propagation delay is not explicitly accounted for in the results.

## Limiting Factors

A total of 116,770,480,992 measurements were taken across 253,337,175 unique tests throughout 2022. This includes under measurements; all individual download, upload, jitter, and web get tests, as well as all latency packets sent. For unique tests the number includes; all download, upload, latency (tests considered as a whole), jitter and web get tests.

All scheduled tests were run, aside from when monitoring units detected concurrent use of bandwidth.

Schedules were adjusted when required for specific tests to avoid triggering data usage limits applied by some ISPs.

## 4.3 DATA PROCESSING OF RAW AND VALIDATED DATA

The data collected in this program are made available as open data for review and use by the public. Raw and processed data sets, mobile testing software, and the methodologies used to process and analyze data are freely and publicly available. Researchers and developers interested in working with measurement data in raw form will need skills in database management, SQL programming, R programming, and statistics, depending on the analysis. A developer FAQ for database configuration and data importing instructions for MySQL and PostgreSQL are available at https://www.fcc.gov/general/database-setup-and-importing-measuring-broadband-america-data-april-2012.

The process flow below describes how the raw collected data was processed for the production of the *Measuring Broadband America Report*. Researchers and developers interested in replicating or extending the results of the Report are encouraged to review the process below and supporting files that provide details.

| | |
|---|---|
| **Raw Data:** | Raw data for the chosen period is collected from the measurement database. The ISPs and speed tiers that panelists were on are exported to a "unit profile" file, and those that changed during the period are flagged. 2022 Raw Data Links |
| **Validated Data Cleansing:** | Data is cleaned. This includes removing measurements when a user changed ISP or tier during the period. Anomalies and significant outliers are also removed at this point. A data cleansing document describes the process in detail. 2022 Data Cleansing Document Link |
| **SQL Processing:** | Per-unit results are generated for each metric. Time-of-day averages are computed and a trimmed median is calculated for each metric. The SQL scripts used here are contained in SQL processing scripts available with the release of each Report. 2022 SQL Processing Links |
| **Unit Profile:** | This document identifies the various details of each test unit, including ISP, technology, service tier, and general location. Each unit represents one volunteer panelists. 2022 Unit Profile link |
| **Excluded Units:** | A listing of units excluded from the analysis. 2022 Excluded Units Link |
| **Unit Census Block:** | This step identifies the census block (for blocks containing more than 1,000 people) in which each unit running tests is located. Census block is from 2020 census and is in the FIPS code format. We have used block FIPS codes for blocks that contains more than 1,000 people. For blocks with fewer than 1,000 people we have aggregated to the next highest level, *i.e.*, tract, and used the Tract FIPS code, provided there are more than 1,000 people in the tract. In cases where there are less |

| | |
|---|---|
| | than 1,000 people in a tract we have aggregated to Regional level. 2022 Unit Census Block Link. |
| **Excel Tables & Charts:** | Summary data tables and charts in Excel are produced from the averages. These are used directly in the Report. 2022 Statistical Averages Links |

The raw data collected for each active metric is made available by month in tarred gzipped files. The files in the archive containing active metrics are described in table 9.

## Table 9: Test to Data File Cross-Reference List

| Test | Validated Data File Name |
|---|---|
| **Download Speed** | curr_httpgetmt.csv — IPv4 Tests<br>curr_httpgetmt6.csv — IPv6 Tests |
| **Upload Speed** | curr_httppostmt.csv — IPv4 Tests<br>curr_httppostmt6.csv — IPv6 Tests |
| **Web Browsing** | curr_webget.csv |
| **UDP Latency** | curr_udplatency.csv — IPv4 Tests<br>curr_udplatency6.csv — IPv6 Tests |
| **UDP Packet Loss** | curr_udplatency.csv — IPv4 Tests<br>curr_udplatency6.csv — IPv6 Tests |
| **Voice over IP** | curr_udpjitter.csv |
| **DNS Resolution** | curr_dns.csv |
| **DNS Failures** | curr_dns.csv |
| **ICMP Latency** | curr_ping.csv |
| **ICMP Packet Loss** | curr_ping.csv |
| **Latency under Load** | curr_dlping.csv – Downstream latency under load results<br>curr_ulping.csv – Upstream latency under load results |

## Table 10: Validated Data Files - Dictionary

The following Data Dictionary file describes the schema for each active metric test for row level results stored in the files described in table 9.[28] All dtime entries are in the UTC timezone. All durations are in microseconds unless otherwise noted. The location_id field should be ignored.

| curr_dlping.csv | |
|---|---|
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **target** | Target hostname or IP address |
| **rtt_avg** | Average RTT |
| **rtt_min** | Minimum RTT |
| **rtt_max** | Maximum RTT |
| **rtt_std** | Standard deviation in measured RTT |
| **successes** | Number of successes |
| **failures** | Number of failures |
| **curr_dns.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **nameserver** | Name server used to handle the DNS request |
| **lookup_host** | Hostname to be resolved |
| **response_ip** | Field currently unused |
| **rtt** | DNS resolution time |
| **successes** | Number of successes (always 1 or 0 for this test) |
| **failures** | Number of failures (always 1 or 0 for this test) |
| **curr_httpgetmt.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |

[28] This data dictionary is also available on the FCC Measuring Broadband America website, located with the other validated data files available for download.

| | |
|---|---|
| **target** | Target hostname or IP address |
| **address** | The IP address of the server (resolved by the client's DNS) |
| **fetch_time** | Time the test ran for |
| **bytes_total** | Total bytes downloaded across all connections |
| **bytes_sec** | Running total of throughput, which is sum of speeds measured for each stream (in bytes/sec), from the start of the test to the current interval |
| **bytes_sec_interval** | Throughput at this specific interval (*e.g.*, Throughput between 25-30 seconds) |
| **warmup_time** | Time consumed for all the TCP streams to arrive at optimal window size |
| **warmup_bytes** | Bytes transferred for all the TCP streams during the warm-up phase |
| **sequence** | The interval that this row refers to (*e.g.*, in the US, sequence=0 implies result is for 0-5 seconds of the test) |
| **threads** | The number of concurrent TCP connections used in the test |
| **successes** | Number of successes (always 1 or 0 for this test) |
| **failures** | Number of failures (always 1 or 0 for this test) |
| **curr_httppostmt.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **target** | Target hostname or IP address |
| **address** | The IP address of the server (resolved by the client's DNS) |
| **fetch_time** | Time the test ran for |
| **bytes_total** | Total bytes downloaded across all connections |
| **bytes_sec** | Running total of throughput, which is sum of speeds measured for each stream (in bytes/sec), from the start of the test to the |

| | |
|---|---|
| | current interval |
| **bytes_sec_interval** | Throughput at this specific interval (*e.g.*, throughput between 25-30 seconds) |
| **warmup_time** | Time consumed for all the TCP streams to arrive at optimal window size |
| **warmup_bytes** | Bytes transferred for all the TCP streams during the warm-up phase. |
| **sequence** | The interval that this row refers to (*e.g.*, in the US, sequence=0 implies result is for 0-5 seconds of the test) |
| **threads** | The number of concurrent TCP connections used in the test |
| **successes** | Number of successes (always 1 or 0 for this test) |
| **failures** | Number of failures (always 1 or 0 for this test) |
| **curr_ping.csv** | ICMP based |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **target** | Target hostname or IP address |
| **rtt_avg** | Average RTT |
| **rtt_min** | Minimum RTT |
| **rtt_max** | Maximum RTT |
| **rtt_std** | Standard deviation in measured RTT |
| **successes** | Number of successes |
| **failures** | Number of failures |
| **curr_udpcloss.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished in local time. |
| **ddate** | Date test finished in local time. |
| **duration** | The duration of the outage/disconnection event in microseconds. |
| **target** | The hostname we experienced the outage to |
| **address** | The IP address of the host we experienced the outage to |

| | |
|---|---|
| packets | |
| curr_udpjitter.csv | |
| unit_id | Unique identifier for an individual unit |
| dtime | Time test finished |
| target | Target hostname or IP address |
| packet_size | Size of each UDP Datagram (bytes) |
| stream_rate | Rate at which the UDP stream is generated (bits/sec) |
| duration | Total duration of test |
| packets_up_sent | Number of packets sent in upstream (measured by client) |
| packets_down_sent | Number of packets sent in downstream (measured by server) |
| packets_up_recv | Number of packets received in upstream (measured by server) |
| packets_down_recv | Number of packets received in downstream (measured by client) |
| jitter_up | Upstream Jitter measured |
| jitter_down | Downstream Jitter measured |
| Latency | 99th percentile of round trip times for all packets |
| successes | Number of successes (always 1 or 0 for this test) |
| failures | Number of failures (always 1 or 0 for this test) |
| curr_udplatency.csv | UDP based |
| unit_id | Unique identifier for an individual unit |
| dtime | Time test finished |
| target | Target hostname or IP address |
| rtt_avg | Average RTT |
| rtt_min | Minimum RTT |
| rtt_max | Maximum RTT |
| rtt_std | Standard deviation in measured RTT |
| successes | Number of successes (note: use |

| | |
|---|---|
| | failures/(successes + failures)) for packet loss) |
| **failures** | Number of failures (packets lost) |
| **location_id** | Internal key mapping to unit profile data |
| **curr_ulping.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **target** | Target hostname or IP address |
| **rtt_avg** | Average RTT |
| **rtt_min** | Minimum RTT |
| **rtt_max** | Maximum RTT |
| **rtt_std** | Standard deviation in measured RTT |
| **successes** | Number of successes |
| **failures** | Number of failures |
| **curr_webget.csv** | |
| **unit_id** | Unique identifier for an individual unit |
| **dtime** | Time test finished |
| **target** | URL to fetch |
| **address** | IP address used to fetch content from initial URL |
| **fetch_time** | Sum of time consumed to download HTML content and then concurrently download all resources |
| **bytes_total** | Sum of HTML content size and all resources size (bytes) |
| **bytes_sec** | Average speed of downloading HTML content and then concurrently downloading all resources (bytes/sec) |
| **objects** | Number of resources (images, CSS, …) downloaded |
| **threads** | Maximum number of concurrent threads allowed |
| **requests** | Total number of HTTP requests made |
| **connections** | Total number of TCP connections established |
| **reused_connections** | Number of TCP connections re-used |

| | |
|---|---|
| **lookups** | Number of DNS lookups performed |
| **request_total_time** | Total duration of all requests summed together, if made sequentially |
| **request_min_time** | Shortest request duration |
| **request_avg_time** | Average request duration |
| **request_max_time** | Longest request duration |
| **ttfb_total_time** | Total duration of the time-to-first-byte summed together, if made sequentially |
| **ttfb_min_time** | Shortest time-to-first-byte duration |
| **ttfb_avg_time** | Average time-to-first-byte duration |
| **ttfb_max_time** | Longest time-to-first-byte duration |
| **lookup_total_time** | Total duration of all DNS lookups summed together, if made sequentially |
| **lookup_min_time** | Shortest DNS lookup duration |
| **lookup_avg_time** | Average DNS lookup duration |
| **lookup_max_time** | Longest DNS lookup duration |
| **successes** | Number of successes |
| **failures** | Number of failures |

# 5 - Reference Documents

## 5.1 - USER TERMS AND CONDITIONS

*The following document was agreed to by each volunteer panelist who agreed to participate in the broadband measurement study:*

## End User License Agreement

**PLEASE READ THESE TERMS AND CONDITIONS CAREFULLY. BY APPLYING TO BECOME A PARTICIPANT IN THE BROADBAND COMMUNITY PANEL AND/OR INSTALLING THE WHITEBOX, YOU ARE AGREEING TO THESE TERMS AND CONDITIONS.**

**YOUR ATTENTION IS DRAWN PARTICULARLY TO CONDITIONS 3.5 (PERTAINING TO YOUR CONSENT TO YOUR ISPS PROVIDING CERTAIN INFORMATION AND YOUR WAIVER OF CLAIMS), 6 (LIMITATIONS OF LIABILITY) AND 7 (DATA PROTECTION).**

1. Interpretation

1.1. The following definitions and rules of interpretation apply to these terms & conditions.

Broadband Community Panel: the participants to the Service / Program who voluntarily provide access to their connection equipment from the Whitebox in order to produce test results.

Connection: the Participant's own broadband internet connection, provided by an Internet Service Provider ("ISP").

Connection Equipment: the Participant's broadband router or cable modem, used to provide the Participant's Connection.

Intellectual Property Rights: all patents, rights to inventions, utility models, copyright and related rights, trademarks, service marks, trade, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database right, moral rights, rights in confidential information (including know-how and trade secrets) and any other intellectual property rights, in each case whether registered or unregistered and including all applications for and renewals or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

ISP: the company providing broadband internet connection to the Participant during the term of this Program.

Participant/You/Your: the person who volunteers to participate in the Program, under these terms and conditions. The Participant must be the named account holder on the Internet service account with the ISP.

Open Source Software: the software in the Whitebox device that is licensed under an open source license (including the GPL).

Participant's Equipment: any equipment, systems, cabling or facilities provided by the Participant and used directly or indirectly in support of the Services, excluding the Connection Equipment.

Parties: both the Participant and SamKnows.

Party: one of either the Participant or SamKnows.

Requirements: the requirements specified by SamKnows as part of the sign-up process that the Participant must fulfil in order to be selected to receive the Services.

SamKnows/We/Our: the organization providing the Services and conducting the Program, namely:

SamKnows Inc of 1775 Tysons Blvd, Tysons, VA 22102, USA

Services / Program: the Federal Communications Commission (FCC) Measuring Broadband America Program's measurement of the performance certain broadband and Internet characteristics of fixed consumer broadband Internet connections using the Participants equipment.

Software: the software that has been installed and/or remotely uploaded onto the Whitebox, by SamKnows as updated by SamKnows, from time to time, but not including any Open Source Software.

Test Results Information concerning the Participant's ISP connection results.

Whitebox: the hardware supplied to the Participant by SamKnows with the Software.

**1.2.** Headings in these terms and conditions shall not affect their interpretation.

**1.3**. A person includes a natural person, corporate or unincorporated body (whether or not having separate legal personality).

**1.4**. The schedules form part of these terms and conditions.

**1.5**. A reference to writing or written includes faxes and e-mails.

**1.6**. Any obligation in these terms and conditions on a person not to do something includes, without limitation, an obligation not to agree, allow, permit or acquiesce in that thing being done.

**2. SamKnows' Commitment to You**

**2.1 Subject to the Participant complying fully with these terms and conditions, SamKnows shall use reasonable care to:**

(a) provide the Participant with the Measurement Services under these terms and conditions;

(b) supply the Participant with the Whitebox and instructions detailing how it should be connected to the Participant's Connection Equipment; and

(c) comply with all applicable United States, European Union, and United Kingdom privacy laws and directives, and will access, collect, process and distribute the information according to the following principles:

Fairness: We will process data fairly and lawfully;

Specific purpose: We will access, collect, process, store and distribute data for the purposes and reasons specified in this agreement and not in ways incompatible with those purposes;

Restricted: We will restrict our data collection and use practices to those adequate and relevant, and not excessive in relation to the purposes for which we collect the information;

Accurate: We will work to ensure that the data we collect is accurate and up-to-date, working with Participant and his/her ISP;

Destroyed when obsolete: We will not maintain personal data longer than is necessary for the purposes for which we collect and process the information;

Security: We will collect and process the information associated with this trial with adequate security through technical and organizational measures to protect personal data against destruction or loss, alteration, unauthorized disclosure or access, in particular where the processing involves the transmission of data over a network.

**2.2 In addition, SamKnows shall:**

(a) provide Participant with access to a Program-specific customer services email address, which the Participant may use for questions and to give feedback and comments;

(b) provide Participant with a unique login and password in order to access to an online reporting system for access to Participant's broadband performance statistics.

(c) provide Participant with a monthly email with their specific data from the Program or notifying Participant that their individual data is ready for viewing;

(d) provide Participant with support and troubleshooting services in case of problems or issues with their Whitebox;

(e) notify Participant of the end of the FCC-sponsored Program and provide a mechanism for Participant to opt out of any further performance/measuring services and research before collecting any data after termination of the Program;

(f) use only data generated by SamKnows through the Whitebox

**2.3** While SamKnows will make all reasonable efforts to ensure that the Services cause no disruption to the performance of the Participant's broadband Connection, including only running tests when there is no concurrent network activity generated by users at the Participant's location. The Participant acknowledges that the Services may occasionally impact the performance of the Connection and agrees to hold SamKnows and their ISP harmless for any impact the Services may have on the performance of their Connection.

**3. Participant's Obligations**

**3.1** The Participant is not required to pay any fee for the provision of the Services by SamKnows or to participate in the Program.

**3.2 The Participant agrees to use reasonable endeavors to:**

(a) connect the Whitebox to their Connection Equipment within 14 days of receiving it;

(b) not to unplug or disconnect the Whitebox unless (i) they will be absent from the property in which it is connected for more than 3 days and/or (ii) it is reasonably necessary for maintenance of the Participant's Equipment and the Participant agrees that they shall use reasonable endeavors to minimize the length of time the Whitebox is unplugged or disconnected;

(c) in no way reverse engineer, tamper with, dispose of or damage the Whitebox, or attempt to do so;

(d) notify SamKnows within 7 days in the event that they change their ISP or their Connection tier or package (for example, downgrading/upgrading to a different broadband package), to the email address provided by SamKnows;

(e) inform SamKnows of a change of postal or email address by email; within 7 days of the change, to the email address provided by SamKnows;

(f) agrees that the Whitebox may be upgraded to incorporate changes to the Software and/or additional tests at the discretion of SamKnows, whether by remote uploads or otherwise;

(g) be an active part of the Program and as such will use all reasonable endeavors to complete the market research surveys received within a reasonable period of time;

(h) not publish data, give press or other interviews regarding the Program without the prior written permission of SamKnows; and

(i) contact SamKnows directly, and not your ISP, in the event of any issues or problems with the Whitebox, by using the email address provided by SamKnows.

**3.3** You will not give the Whitebox or the Software to any third party, including (without limitation) to any ISP. You may give the Open Source Software to any person in accordance with the terms of the relevant open source licence.

**3.4** The Participant acknowledges that he/she is not an employee or agent of, or relative of, an employee or agent of an ISP or any affiliate of any ISP. In the event that they become one, they will inform SamKnows, who at its complete discretion may ask for the immediate return of the Whitebox.

**3.5** THE PARTICIPANT'S ATTENTION IS PARTICULARLY DRAWN TO THIS CONDITION. The Participant expressly consents to having their ISP provide to SamKnows and the Federal Communications (FCC) information about the Participant's broadband service, for example: service address, speed tier, local loop length (for DSL customers), equipment identifiers and other similar information, and hereby waives any claim that its ISPs disclosure of such information to SamKnows or the FCC constitutes a violation of any right or any other right or privilege that the Participant may have under any federal, state or local statute, law, ordinance, court order, administrative rule, order or regulation, or other applicable law, including, without limitation, under 47 U.S.C. §§ 222 and 551 (each a "Privacy Law"). If notwithstanding Participant's consent under this Section 3.5, Participant, the FCC or any other party brings any claim or action against any ISP under a Privacy Law, upon the applicable ISPs request SamKnows promptly shall cease collecting data from such Participant and remove from its records all data collected with respect to such Participant prior to the date of such request, and shall not provide such data in any form to the FCC. The Participant further consents to transmission of information from this Program Internationally, including the information provided by the Participant's ISP, specifically the transfer of this information to SamKnows in the United Kingdom, SamKnows' processing of it there and return to the United States.

**4. Intellectual Property Rights**

**4.1** All Intellectual Property Rights relating to the Whitebox are the property of its manufacturer. The Participant shall use the Whitebox only to allow SamKnows to provide the Services.

**4.2** As between SamKnows and the Participant, SamKnows owns all Intellectual Property Rights in the Software. The Participant shall not translate, copy, adapt, vary or alter the Software. The Participant shall use the Software only for the purposes of SamKnows providing the Services and shall not disclose or otherwise use the Software.

**4.3** Participation in the Broadband Community Panel gives the participant no Intellectual Property Rights in the Test Results. Ownership of all such rights is governed by Federal Acquisition Regulation Section 52.227-17, which has been incorporated by reference in the relevant contract between SamKnows and the FCC. The Participant hereby acknowledges and agrees that SamKnows may make such use of the Test Results as is required for the Program.

**4.4** Certain core testing technology and aspects of the architectures, products and services are developed and maintained directly by SamKnows. SamKnows also implements various technical features of the measurement services using particular technical components from a variety of vendor partners including: NetGear, Measurement Lab, TP-Link.

**5. SamKnows' Property**

The Software will remain the property of SamKnows. The Whitebox shall become the property of the Participant upon receipt of the Whitebox by the Participant.

**6. Limitations of Liability - THE PARTICIPANT'S ATTENTION IS PARTICULARLY DRAWN TO THIS CONDITION**

**6.1** This condition 6 sets out the entire financial liability of SamKnows (including any liability for the acts or omissions of its employees, agents, consultants, and subcontractors) to the Participant, including and without limitation, in respect of:

(a) any use made by the Participant of the Services, the Whitebox and the Software or any part of them; and

(b) any representation, statement or tortious act or omission (including negligence) arising under or in connection with these terms and conditions.

**6.2** All implied warranties, conditions and other terms implied by statute or other law are, to the fullest extent permitted by law, waived and excluded from these terms and conditions.

**6.3** Notwithstanding the foregoing, nothing in these terms and conditions limits or excludes the liability of SamKnows:

(a) for death or personal injury resulting from its negligence or willful misconduct;

(b) for any damage or liability incurred by the Participant as a result of fraud or fraudulent misrepresentation by SamKnows;

(c) for any violations of U.S. consumer protection laws;

(d) in relation to any other liabilities which may not be excluded or limited by applicable law.

**6.4** Subject to condition 6.2 and condition 6.3, SamKnows' total liability in contract, tort (including negligence or breach of statutory duty), misrepresentation, restitution or otherwise arising in connection with the performance, or contemplated performance, of these terms and conditions shall be limited to $100.

**6.5** In the event of any defect or modification in the Whitebox, the Participant's sole remedy shall be the repair or replacement of the Whitebox at SamKnows' reasonable cost, provided that the defective Whitebox is safely returned to SamKnows, in which case SamKnows shall pay the Participant's reasonable postage costs.

**6.6** The Participant acknowledges and agrees that these limitations of liability are reasonable in all the circumstances, particularly given that no fee is being charged by SamKnows for the Services or participation in the Program.

**6.7** It is the Participant's responsibility to pay all service and other charges owed to its ISP in a timely manner and to comply with all other ISP applicable terms. The Participant shall ensure that their broadband traffic, including the data pushed by SamKnows during the Program, does not exceed the data allowance included in the Participant's broadband package. If usage allowances are accidentally exceeded and the Participant is billed additional charges from the ISP as a result, SamKnows is not under any obligation to cover these charges although it may choose to do so at its discretion.

**7. Data protection - the participation's attention is particularly drawn to this condition.**

**7.1** The Participant acknowledges and agrees that his/her personal data, such as service tier, address and line performance, will be processed by SamKnows in connection with the program.

**7.2** Except as required by law or regulation, SamKnows will not provide the Participant's personal data to any third party without obtaining Participant's prior consent. However, for the avoidance of doubt, the Participant acknowledges and agrees that subject to the privacy polices discussed below, the specific technical characteristics of tests and other technical features associated with the Internet Protocol environment of architecture, including the client's IP address, may be shared with third parties as necessary to conduct the Program and all aggregate statistical data produced as a result of the Services (including the Test Results) may be provided to third parties.

**7.3** You acknowledge and agree that SamKnows may share some of Your information with Your ISP, and request information about You from Your ISP so that they may confirm Your service tiers and other information relevant to the Program. Accordingly You hereby expressly waive claim that any disclosure by Your ISP to SamKnows constitutes a violation of any right or privilege that you may have under any law, wherever it might apply.

**8. Term and Termination**

**8.1** This Agreement shall continue until terminated in accordance with this clause.

**8.2** Each party may terminate the Services immediately by written notice to the other party at any time. Notice of termination may be given by email. Notices sent by email shall be deemed to be served on the day of transmission if transmitted before 5.00 pm Eastern Time on a working day, but otherwise on the next following working day.

**8.3** On termination of the Services for any reason, SamKnows shall have no further obligation to provide the Services.

**8.4** Notwithstanding termination of the Services and/or these terms and conditions, clauses 1, 3.3 and 4 to 14 (inclusive) shall continue to apply.

**9. Severance**

If any provision of these terms and conditions, or part of any provision, is found by any court or other authority of competent jurisdiction to be invalid, illegal or unenforceable, that provision or part-provision shall, to the extent required, be deemed not to form part of these terms and conditions, and the validity and enforceability of the other provisions these terms and conditions shall not be affected.

**10. Entire agreement**

**10.1** These terms and conditions constitute the whole agreement between the parties and replace and supersede any previous agreements or undertakings between the parties.

**10.2** Each party acknowledges that, in entering into these terms and conditions, it has not relied on, and shall have no right or remedy in respect of, any statement, representation, assurance or warranty.

**11. Assignment**

**11.1** The Participant shall not, without the prior written consent of SamKnows, assign, transfer, charge, mortgage, subcontract all or any of its rights or obligations under these terms and conditions.

**11.2** Each party that has rights under these terms and conditions acknowledges that they are acting on their own behalf and not for the benefit of another person.

**12. No Partnership or Agency**

Nothing in these terms and conditions is intended to, or shall be deemed to, constitute a partnership or joint venture of any kind between any of the parties, nor make any party the agent of another party for any purpose. No party shall have authority to act as agent for, or to bind, the other party in any way.

**13. Rights of third parties**

Except for the rights and protections conferred on ISPs under these Terms and Conditions which they may defend, a person who is not a party to these terms and conditions shall not have any rights under or in connection with these Terms and Conditions.

**14. Privacy and Paperwork Reduction Acts**

**14.1** For the avoidance of doubt, the release of IP protocol addresses of client's Whiteboxes are not PII for the purposes of this program and the client expressly consents to the release of IP address and other technical IP protocol characteristics that may be gathered within the context of the testing architecture. SamKnows, on behalf of the FCC, is collecting and storing broadband performance information, including various personally identifiable information (PII) such as the street addresses, email addresses, sum of data transferred, and broadband performance information, from those individuals who are participating voluntarily in this test. PII not necessary to conduct this study will not be collected. Certain information provided by or collected from you will be confirmed with a third party, including your ISP, to ensure a representative study and otherwise shared with third parties as necessary to conduct the program. SamKnows will not release, disclose to the public, or share any PII with any outside entities, including the FCC, except as is consistent with the SamKnows privacy policy or these Terms and Conditions. See https://www.measuringbroadbandamerica.com/privacy/. The broadband performance information that is made available to the public and the FCC, will be in an aggregated form and with all PII removed. For more information, see the Privacy Act of 1974, as amended (5 U.S.C. § 552a), and the SamKnows privacy policy.

**14.2** The FCC is soliciting and collecting this information authorized by OMB Control No. 3060-1139 in accordance with the requirements and authority of the Paperwork Reduction Act, Pub. L. No. 96-511, 94 Stat. 2812 (Dec. 11, 1980); the Broadband Data Improvement Act of 2008, Pub. L. No. 110-385, Stat 4096 § 103(c)(1); American Reinvestment and Recovery Act of 2009 (ARRA), Pub. L. No. 111-5, 123 Stat 115 (2009); and Section 154(i) of the Communications Act of 1934, as amended.

**14.3** Paperwork Reduction Act of 1995 Notice. We have estimated that each Participant of this study will assume a one hour time burden over the course of the Program. Our estimate includes the time to sign-up online, connect the Whitebox in the home, and periodic validation of the hardware. If you have any comments on this estimate, or on how we can improve the collection and reduce the burden it causes you, please write the Federal Communications Commission, Office of Managing Director, AMD-PERM, Washington, DC 20554, Paperwork Reduction Act Project (3060-1139). We will also accept your comments via the Internet if you send an e-mail to PRA@fcc.gov. Please DO NOT SEND COMPLETED APPLICATION FORMS TO THIS ADDRESS. You are not required to respond to a collection of information sponsored by the Federal government, and the government may not conduct or sponsor this collection, unless it displays a currently valid OMB control number and provides you with this notice. This collection has been assigned an OMB control number of 3060-1139. THIS NOTICE IS REQUIRED BY THE PAPERWORK REDUCTION ACT OF 1995, PUBLIC LAW 104-13, OCTOBER 1, 1995, 44 U.S.C. SECTION 3507. This notice may also be found at https://www.measuringbroadbandamerica.com/paperwork-reduction-act/.

**15. Jurisdiction**

These terms and conditions shall be governed by the laws of the state of New York.

**SCHEDULE**

**THE SERVICES**

Subject to the Participant complying with its obligations under these terms and conditions, Measuring Broadband America records test results that include, but aren't limited to, the following information:

1. Web browsing

2. Video streaming

3. Voice over IP

4. Download speed

5. Upload speed

6. UDP latency

7. UDP packet loss

8. Consumption

9. Availability

10. DNS resolution

11. ICMP latency

12. ICMP packet loss

In performing these tests, the Whitebox will require a variable download capacity and upload capacity per month, which will be available to the Participant in motion 2.3. The Participant acknowledges that this may impact on the performance of the Connection.

1. SamKnows will perform tests on the Participant's Connection by using SamKnows' own data and will not monitor the Participant's content or internet activity. The purpose of this study is to measure the Connection and compare this data with other consumers to create a representative index of US broadband performance.

# 5.2 - CODE OF CONDUCT

*The following Code of Conduct, available at* http://data.fcc.gov/download/measuring-broadband-america/2020/Code-of-Conduct-fixed.pdf*, was signed by ISPs and other entities participating in the study:*

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## FCC MEASURING BROADBAND AMERICA PROGRAM

### FIXED TESTING AND MEASUREMENT

### STAKEHOLDERS CODE OF CONDUCT

**WHEREAS the Federal Communications Commission of the United States of America (FCC) is conducting a Broadband Testing and Measurement Program, with support from its contractor SamKnows, the purpose of which is to establish a technical platform for the Measuring Broadband America Program (MBA)'s Fixed Broadband Testing and Measurement and further the use of that platform for broadband data collection;**

**WHEREAS volunteer panelists have been recruited and agreed to provide broadband performance information measured on Whiteboxes to support the collection of broadband performance data, steps have been taken to protect the privacy of panelists while measuring broadband performance. WE, THE UNDERSIGNED, as participants and stakeholders in that Fixed Broadband Testing and Measurement, do hereby agree to be bound by and conduct ourselves in accordance with the following principles and shall:**

1. At all times act in good faith;
2. Act in accordance with the privacy policies of the program as provided [https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/measuringbroadband-america/fixed ];
3. Not act, nor fail to act, if the consequence of such act or omission is to enhance, degrade, or tamper with the results of any test for any individual panelist or broadband provider, except that:

   3.1. It shall not be a violation of this principle for broadband providers to:

3.1.1. Operate and manage their business, including modifying or improving services delivered to any class of subscribers that may or may not include panelists among them, provided that such actions are consistent with normal business practices, and

3.1.2. Address service issues for individual panelists at the request of the panelist or based on information not derived solely from the MBA Results;

4. Not publish any data generated by the tests, nor make any public statement based on such data, until such time as the FCC releases data, or except where expressly permitted by the FCC;

5. Cooperate with academic or research experiments on the MBA infrastructure as initiated under the FCC's MBA-Assisted Research Studies (MARS) program; and

6. Ensure that our employees, agents, and representatives, as appropriate, act in accordance with this Code of Conduct.

7. Renew participation in this Code of Conduct annually.

Signatories: _____

Printed: _____

Date: _____

## 5.3 - TEST NODE BRIEFING

Test Node Briefing

DOCUMENT REFERENCE:

SQ302-002-EN

TEST NODE BRIEFING

Technical information relating to

the SamKnows test nodes

August 2013

# Important Notice



## 1 - SamKnows Test Nodes

In order to gauge an Internet Service Provider's broadband performance at a User's access point, the SamKnows Whiteboxes need to measure the service performance (*e.g.*, upload/download speeds, latency, *etc.*) from the Whitebox to a specific test node. SamKnows supports a number of "test nodes" for this purpose.

The test nodes run special software designed specifically for measuring the network performance when communicating with the Whiteboxes.

It is critical that these test nodes be deployed near to the customer (and their Whitebox). The further the test node is from the customer, the higher the latency and the greater the possibility that third-party networks may need to be traversed, making it difficult to isolate the individual ISP's performance. This is why SamKnows operates so many test nodes all around the world—locality to the customer is critical.

### 1.1 Test node definition

When referring to "test nodes," we are specifically referring to either the dedicated servers that are under SamKnows' control, or the virtual machines that may be provided to us. In the case of virtual machines provided by StackPath, the host operating system is under the control of and maintained by these entities and not by SamKnows.

### 1.2 Test node selection

The SamKnows Whiteboxes select the nearest node by running round-trip latency checks to all test nodes before measurement begins. Note that when we use the term "nearest" we are referring to the test node nearest to the Whitebox from the point of view of network delay, which may not necessarily always be the one nearest geographically.

Alternatively, it is possible to override test node selection based on latency and implement a static configuration so that the Whitebox will only test against the test node chosen by the Administrator. This is so that the Administrator can choose to test any particular test node that is of interest to the specific project and also to maintain configuration consistency. Similarly, test node selection may be done on a scheduled basis, alternating between servers, to collect test data from multiple test nodes for comparison purposes.

### 1.3 Test node positioning—on-net versus off-net

It is important that measurements collected by the test architecture support the comparison of ISP performance in an unbiased manner. Measurements taken from using the standardized set of "off-net" measurement test nodes (off-net here refers to a test node located outside a specific ISP's network) ensure that the performance of all ISPs can be measured under the same conditions and would avoid artificially biasing results for any one ISP over another. Test nodes located on a particular ISP's network ("on-net" test nodes), might introduce bias with respect to the ISP's own network performance. Thus data to be used to compare ISP performance are collected using "off-net" test nodes, because they reside outside the ISP network.

However, it is also very useful to have test nodes inside the ISP network ("on-net" test nodes). This allows us to:

- Determine what degradation in performance occurs when traffic leaves the ISP network; and
- Check that the off-net test nodes are performing properly (and vice versa).
- By having both on-net and off-net measurement data for each Whitebox, we can have a great deal of confidence in the quality of the data.

### 1.4 Data that is stored on test nodes

No measurement data collected by SamKnows is stored on test nodes. The test nodes provide a "dumb" endpoint for the Whiteboxes to test against. All measurement performance results are recorded by the Whiteboxes, which are then transmitted from the Whitebox to data collection servers managed by SamKnows.

## 2 - Test Node Hosting and Locations

SamKnows test nodes reside in major peering locations around the world. Test nodes are carefully sited to ensure optimal connectivity on a market-by-market basis. SamKnows' test infrastructure utilizes nodes made available by various network operators, as well as under contract with select hosting providers.

## 2.1 Global Test Nodes

SamKnows has contracted with StackPath, a major CDN, to host virtual servers at its 10 US locations. Each location has at least one node with 25Gbps capacity (25Gbps redundant).

Table 1 below shows the locations of the SamKnows test node architecture supporting the Measuring Broadband America Program.[29] All of these listed test nodes reside outside individual ISP networks and therefore are designated as off-net test nodes.

| Location |
|---|
| **Atlanta, Georgia** |
| **Chicago, Illinois** |
| **Dallas, Texas** |
| **Los Angeles, California** |
| **Miami, Florida** |
| **New York City, New York** |
| **San Jose, California** |
| **Seattle, Washington** |
| **Washington, Virginia** |
| **Denver, Colorado** |

*Table 1: Test Node Locations*

SamKnows also has access to many test nodes donated by ISPs around the world. These particular test nodes reside within individual ISP networks and are therefore considered on-net test nodes.

ISPs have the advantage of measuring to both on-net and off-net test nodes, which allows them to segment end-to-end network performance and determine the performance of their own network versus third party networks. For example, an ISP can see what impact third party networks have on their end-users Quality of Experience ('QoE') by placing test nodes within their own network and at major National and International peering locations.

Diagram 1 below shows this set-up.

[29] In addition to the test nodes used to support the Measuring Broadband America Program, SamKnows utilizes a diverse fleet of nodes in locations around the globe for other international programs.

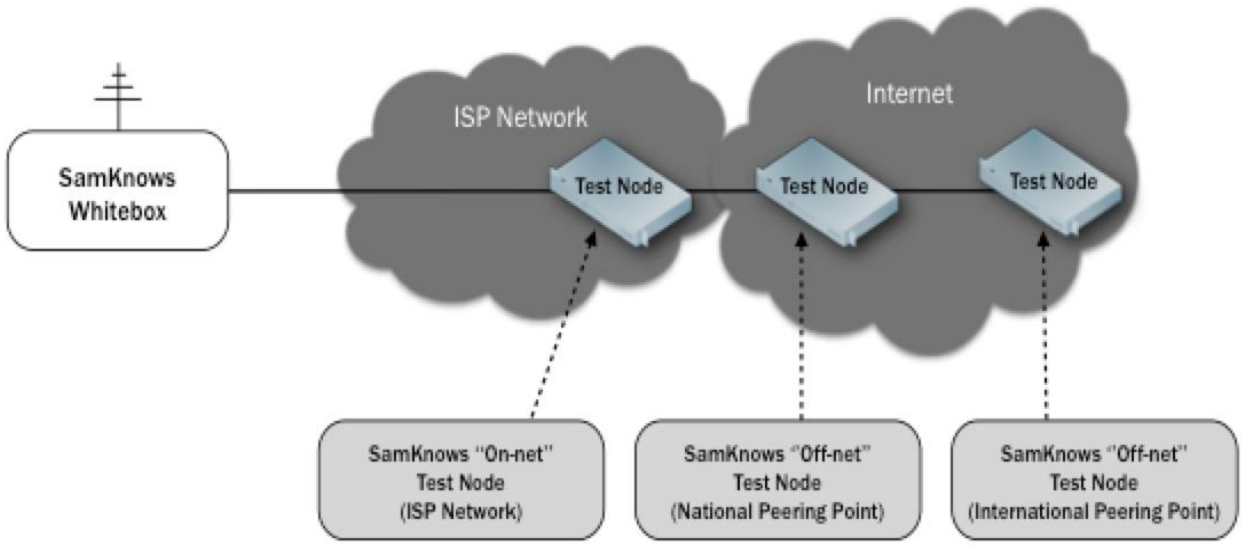


*Diagram 1: On-net and Off-net Testing*

Both the on-net and off-net test nodes are monitored by SamKnows as part of the global test node fleet. Test node management is explained in more detail within the next section of this document.

## 3 - Test Node Management

SamKnows test node infrastructure is a critical element of the SamKnows global measurement platform and includes extensive monitoring in place. SamKnows uses a management tool to control and configure the test nodes, while the platform is closely scrutinized using the Nagios monitoring application. System alerts are also in place to ensure the test node infrastructure is always available and operating well within expected threshold bounds.

The SamKnows Operations team continuously checks all test nodes to monitor capacity and overall health. Also included is data analysis to safeguard data accuracy and integrity. This level of oversight not only helps to maintain a healthy, robust platform but also allows us to spot and flag actual network issues and events as they happen. Diagnostic information also supports the Program managers' decision-making process for managing the impact of data accuracy and integrity incidents. This monitoring and administration is fully separate from any monitoring and administration of operating systems and platforms that may be necessary by hosting entities with which SamKnows may be engaged.

### 3.1 Seamless Test Node Management

SamKnows controls its network of test nodes via a popular open-source management tool called Puppet (**https://puppetlabs.com**). Puppet allows the SamKnows Operations team to easily manage hundreds of test nodes and ensure that each group of test nodes is configured properly as per each project requirement. Coded in Python, Puppet uses a low-overhead agent installed on each test node that regularly communicates with the controlling SamKnows server to check for updates and ensure the integrity of the configuration.

This method of managing our test nodes allows us to deal with the large number of test nodes without affecting the user's performance in any way. We are also able to quickly and safely make changes to large parts of our test node fleet while ensuring that only the relevant test nodes are updated. This also allows us to keep a record of changes and rapidly troubleshoot any potential problems.

### 3.2 Proactive Test Node Monitoring

While Puppet handles the configuration and management of the test nodes, Nagios (the most popular online monitoring application) is used by SamKnows to monitor the test nodes. Each test node is configured to send Nagios regular status updates on core metrics such as CPU usage, disk space, free memory, and SamKnows-specific applications. Nagios will also perform active checks of each test nodes where possible, providing us with connectivity information—both via "ping" and connections to any webserver that may be running on the target host.

## 4 - Test Node Specification and Connectivity

SamKnows maintains a standard specification for all test nodes to ensure consistency and accuracy across the fleet.

### 4.1 SamKnows test node specifications

All dedicated test nodes must meet the following minimum specifications:

- CPU: Dual core Xeon (2 GHz+)
- RAM: 4 GB
- Disk: 80 GB
- Operating System: CentOS/RHEL 6.x
- Connectivity: Gigabit Ethernet connectivity, with gigabit upstream link.

### 4.2 StackPath test node notifications

- CPU Dual Core Xeon (2 GHz+)

- RAM: 8 GB
- Disk: 25 GB root disk
- OS: CentOS 7
- Connectivity: 25 Gbps (with 25Gbps redundancy)

### 4.3 Test Node Connectivity

Measurement test nodes must be connected to a Tier-1 or equivalently neutral peering point. Each test node must be able to sustain 1 Gbps throughput.

At minimum, one publicly routable IPv4 address must be provisioned per-test node. The test node must not be presented with a NAT'd address. It is highly preferable for any new test nodes to also be provisioned with an IPv6 address at installation time.

It is preferred that the test nodes do not sit behind a firewall. If a firewall is used, then care must be taken to ensure that it can sustain the throughput required above.

### 4.4 Test Node Security

Each of the SamKnows test nodes is firewalled using the IPTables linux firewall. We close any ports that are not required, restrict remote administration to SSH only, and ensure access is only granted from a limited number of specified IP addresses. Only ports that require access from the outside world—for example TCP Port 80 on a webserver—would have that port fully open. SamKnows regularly checks its rulesets to ensure that there are no outdated rules and that the access restriction is up to date.

SamKnows accounts on each test node are restricted to the systems administration team by default. When required for further work, an authorized SamKnows employee will have an account added.

## 5 - Test Node Provisioning

SamKnows also has a policy of accepting test nodes provided by network operators providing that

- The test node meets the specifications outlined earlier
- Minimum of 1 Gbps upstream is provided and downstream connectivity to national peering locations

Please note that donated test nodes may also be subject to additional local requirements.

### 5.1 Installation and Qualification

ISPs are requested to complete an information form for each test node they wish to provision. This will be used by SamKnows to configure the test node on the management system.

SamKnows will then provide an installation script and an associated installation guide. This will require minimal effort from the ISPs involved and will take a very similar form to the package used on existing test nodes.

Once the ISP has completed installation, SamKnows will verify the test node meets performance requirements by running server-to-server tests from known-good servers. These server-to-server measurements will be periodically repeated to verify performance levels.

## 5.2 Test Node Access and Maintenance

ISPs donating test nodes are free to maintain and monitor the test nodes using their existing toolsets, providing that these do not interfere with the SamKnows measurement applications or system monitoring tools. ISPs must not run resource intensive processes on the test nodes (*e.g.*, packet captures), as this may affect measurements.

ISPs donating test nodes must ensure that these test nodes are only accessed by maintenance staff when absolutely necessary.

SamKnows requests SSH access to the test nodes, with sudo abilities. sudo is a system administration tool that allows elevated privileges in a controlled granular manner. This has greatly helped diagnosis of performance issues with ISP-provided test nodes historically and would enable SamKnows to be far more responsive in investigating issues.

[DOCUMENT ENDS]