Broadband Quality in Public Libraries

SPEED TEST HIGHLIGHTS

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Full Speed Test Findings and Results are available from the University of Maryland Information Policy and Access Center
http://digitalinclusion.umd.edu/

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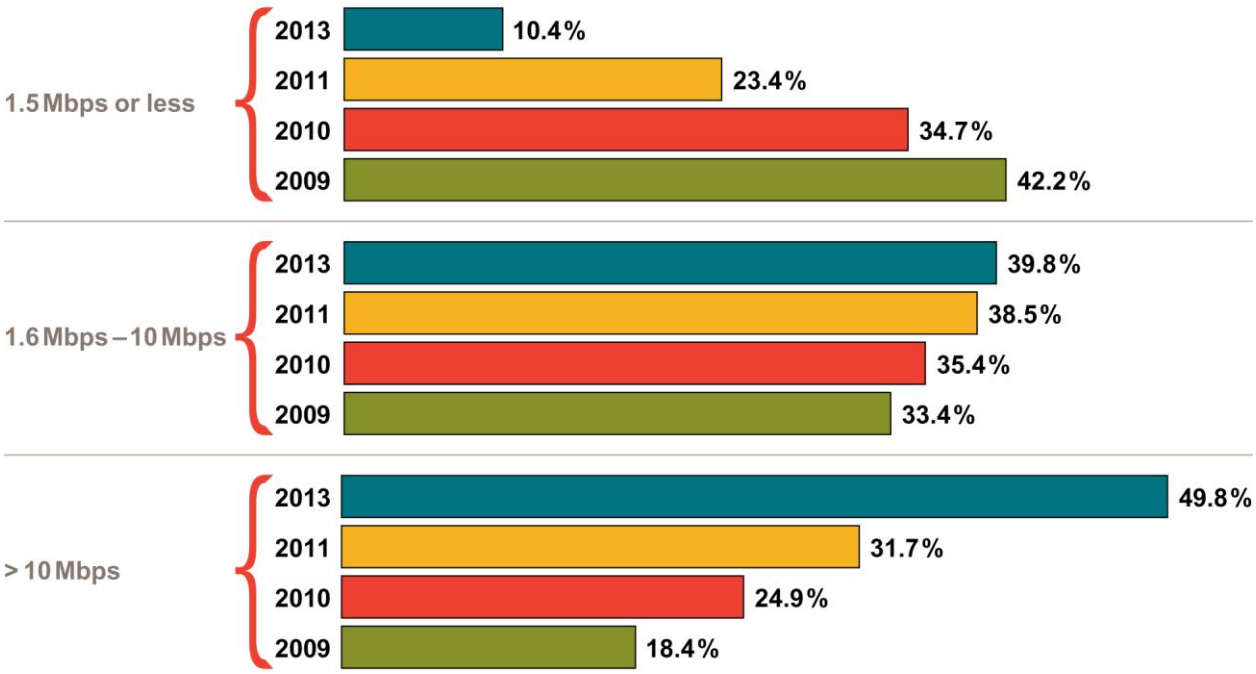
EXECUTIVE SUMMARY

From e-books to e-government services to distance learning, more of the information and services people seek and use in our nation's public libraries are delivered and shared via wired and wireless broadband networks. Documenting and analyzing public library technology infrastructure and how it is used to enable digital inclusion in communities nationwide is the central purpose of the Digital Inclusion Survey and related predecessor research efforts. This research subsequently informs library policy advocacy related to the federal E-rate program and other national broadband and technology efforts, as well as providing context for state and local digital inclusion planning.

In July 2014, the American Library Association (ALA) and the Information Policy and Access Center (iPAC) at the University of Maryland published the first report of the Digital Inclusion Survey, which is funded by the Institute of Museum and Library Services. Among its national findings, virtually all (98%) public libraries provide no-fee wi-fi access and an average of 20 computers.

Exhibit 1: Public Library Subscribed Internet Connectivity Speeds



Overall, libraries also report some progress in their public internet speeds (e.g., about 10% of libraries reported speeds of 1.5 Megabits per second or less, compared with 23% two years earlier), but still falling far short of goals established in the recent E-rate Modernization proceeding and in the National Broadband Plan (with about 2% of libraries with 1 Gigabit per second speeds). Only about half of all libraries reported subscribed internet download speeds greater than 10 Mbps, with city libraries generally skewing on the higher end (about 27% with subscribed speeds of 100 Mbps or higher) and rural libraries generally skewing on the lower end (about 3% with speeds of 100 Mbps or higher). Two-thirds of *all* libraries indicated they would like to improve their broadband speeds.

TESTING BROADBAND QUALITY

Using this nationwide survey and a smaller subset of libraries that provided both subscribed internet speeds and measured speed test data in fall 2013, the ALA and iPAC sought to provide insights into the broadband connectivity quality of service that users experience in public libraries through the use of speed test tools. The summer 2014 supplementary study was in the field July 14 to August 15, 2014, and a total of 2,251 library locations participated.

While this new speed test data should not be interpreted as a proxy for *actual* network speeds, the data suggest several findings relevant to broadband access and modern library services:

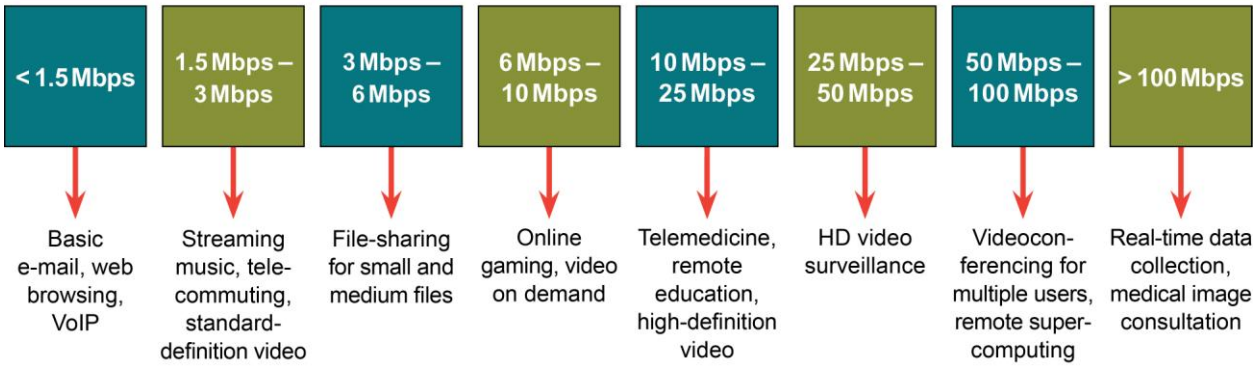
- Median download speed tests show libraries offering better than anticipated broadband quality based on subscribed internet speeds[1]—with city libraries "clocking in" at 30 Mbps wired and 13 Mbps wireless speeds, and rural libraries reading 9 Mbps and 6 Mbps speeds, respectively.
- However, there is *significant* variation in these two metrics: 1) The captured speed data among libraries of all sizes, and (2) the captured speed data for direct (wired) and wi-fi connections. City and suburban public libraries provide greater quality of service at the device level compared with town and rural libraries, and there is wide variation across libraries. Directly connected devices exhibit the greatest download and upload speeds.
- At a given time, the median captured speed delivered to individual users' devices is significantly less than the subscribed network speed.
- In most cases, quality of service degrades at peak use times, sometimes dramatically;
- While city and suburban libraries generally report higher speeds in their testing instances than town and rural library counterparts, they also see proportionally greater degradation during heavy internet usage times;
- Captured (and subscribed) upload speeds lag download speeds considerably, impacting libraries' ability to support emerging services like digital media labs and other user content creation and dissemination; and
- While the trend for library internet speeds continues to improve, the quality of public access to the internet still lags targets for modern library services.

These speed test findings suggest libraries have more work ahead to improve their base subscribed broadband speeds, wireless networks and overall network management to bring a more consistent quality of service to communities nationwide. A gap remains between current speeds of public library networks and the recent gigabit goal for libraries and schools adopted by the Federal Communications Commission (FCC).

[1] Bertot, J.C., Jaeger, P.T., Lee, J., Dubbels, K., McDermott, A.J., Real, B. (2014). 2013 Digital Inclusion Survey: Survey Findings and Results. College Park, MD: Information Policy & Access Center, University of Maryland College Park. Available at http://ipac.umd.edu/. Figure 5.

The Commission goals reflect the multi-user library environment, as well as the growing demands of high-bandwidth applications and services and the explosion of mobile devices. From photo-laden websites to streaming media to high-definition interactive videoconferencing, library patrons are connecting to more information and resources in more formats—both as consumers and as creators. Better broadband also enables library functions such as transitioning telephony to voice over IP (VoIP) and greater use of cloud computing and data storage.

Exhibit 2: Bandwidth Needed for Various Applications



The FCC's E-rate modernization proceeding addresses the most pressing capacity gaps libraries have today: the lack of high-capacity broadband *to* the building and *within* the building. Libraries without adequate capacity are thwarted in the kinds of services they can provide their communities. Alternately, the well-connected 21st century library is the quintessential community access point for completing education, jumpstarting employment and entrepreneurship, fostering individual empowerment, and encouraging community engagement. Broadband is the crucial foundation on which *The E's of Libraries™* are built.

STUDY BACKGROUND

The study collected speed test data via direct connect devices (e.g., public access computer using a library's hardwired infrastructure), via a public library's wireless (wi-fi) connected device (e.g., a laptop computer); and via a public library's wireless (wi-fi) mobile-connected device (e.g., a smartphone, tablet).[2] This small study supplement was conducted within the context of the 2013 Digital Inclusion Survey data collection effort conducted by iPAC at the University of Maryland in partnership with the ALA and the International City/County Management Association (ICMA) and funded by the Institute of Museum and Library Services.

[2] The mobile device data collection was experimental and in part a proof of concept test that used speedof.me as its speed capture tool. The tool is an HTML5-based product, and thus iPAC researchers were able to build a mobile device interface that did not require an app download and was not flash-based and thus could work with iOS (iPhone and iPad devices).

The speed test was in the field from July 14, 2014, through August 15, 2014. The survey licensed an instance of Ookla[3] and built a custom data collection and capture tool around the utility. A total of 2,251 library locations (outlets/branches) spread across 49 states participated in the speed test (Figure 1)[4]. In all, the study captured 6,207 instances of the speed test that included 3,458 direct connect instances, 2,160 wi-fi instances, and 589 mobile instances.

Figure 1: Total Public Library Outlet / Branch Speed Test Participation

	Total Public Library Participation (number of library branches / locations)			
Locale Code	**Direct Connect**	**Wireless**	**Mobile**	**Total**
City	391	75	61	527
Suburban	290	80	94	464
Town	323	128	72	523
Rural	371	254	112	737
Overall	**1,375**	**537**	**339**	**2,251**

As part of the speed test, iPAC asked participating libraries to:

- Run the speed test multiple times—when the library was closed, when usage was light, typical, and heavy (these were self-identified determinations).
- Indicate whether the test was via a directly connected computer or wi-fi (the mobile test was separate; thus that determination was automatic).
- Indicate the library's subscribed download and upload broadband speeds.
- Indicate the number of public access computers available at the location/branch.

KEY SURVEY FINDINGS AND RESULTS

The 2014 supplemental data collection adds detail to a body of research from the Digital Inclusion Survey that includes interactive mapping tools, infographics, issue briefs and state-level data summaries. The narrative that follows will focus on data from the direct connection (wired) and wi-fi instances of the supplemental data collection. The full report of the supplemental data collection, as well as other survey-related materials are available, from the Information Policy and Access Center (iPAC) at the University of Maryland online and the ALA Office for Research & Statistics at www.ala.org/ors.

[3] Ookla is the underlying speed test capture tool in the www.speedtest.net website that many organizations use to measure the speed of their connection.

[4] For general speed test data, the research team opened up the speed test tool to all libraries (excluding U.S. territories, bookmobiles and books by mail locations, there are 16,715 library locations in total).

This highlights report provides:

- Median download and upload speed test results for direct connections (wired) and wi-fi by locale (city, suburban, town and rural)[5];
- Median speed test results by network load (light, typical or heavy) and locale;
- Comparisons of subscribed speeds with speed test results for wired and wi-fi by locale; and
- Correlational analysis between speed test data, numbers of public access computers, and the basic and advanced categorizations of library services provided to the public.

As context for the findings that follow, the research team notes that a speed test is essentially a point in time measure rather than a true measure of actual network speed. Speed test results can be affected by a number of factors, including the design of the speed test tool, a library's local network configuration, user device and its configuration, a library's internet service provider arrangement (e.g., allowing for bursting or not), overall internet traffic, and the number of external "hops" to the physical location of the speed test server. As such, speed test data are best viewed as an approximate simulation of an individual's experience via a library's public access network.

SPEED TEST FINDINGS, OVERALL

Direct Connection

- City public libraries reported a median captured **download** speed of 30.5 Mbps, with a minimum captured speed of 560 Kilobits per second, and a maximum captured download speed of 821.8 Mbps.
- Suburban public libraries reported a median speed of 18.8 Mbps, with a range from 480 Kbps to 791 Mbps.
- Town public libraries reported a median speed of 10.5 Mbps, with a range from 160 Kbps to 777 Mbps.
- Rural public libraries reported a median speed of 9 Mbps, with a range of 20 Kbps to 487.8 Mbps.

Figures 2 and 3 provide a different look at the direct connection captured speed data. For download, about 40% of libraries are below 10 Mbps. A similar "curve" across the captured upload speeds, but with greater disparities between city and rural libraries, is found in Figure 3.

[5] Library outlets are assigned locale codes by the Institute of Museum and Library Services based on the geocoded latitude and longitude values of their street addresses, using the same methodology that is used to assign public schools locale codes in the National Center for Education Statistics' Common Core of Data datasets. The locale coding system classifies areas into four major types—city, suburban, town, and rural. For more information, please see Public Libraries in the United States data documentation: http://www.imls.gov/research/pls_data_files.aspx.

Figure 2: Public Library Outlets Grouped Speed Test Direct Connect Download Speeds, by Locale

	Direct Connect Download Speeds					
Locale Code	**1.5 Mbps or Less**	**1.6 Mbps – 10 Mbps**	**10.1 Mbps – 24.9 Mbps**	**25.0 Mbps – 49.9 Mbps**	**50 Mbps – 99.9 Mbps**	**100 Mbps – 1Gbps**
City	4.4% (n=43)	17.4% (n=170)	29.6% (n=289)	13.8% (n=135)	27.0% (n=264)	7.8% (n=76)
Suburban	3.6% (n=26)	33.1% (n=241)	24.2% (n=176)	17.7% (n=129)	16.5% (n=120)	4.9% (n=36)
Town	7.0% (n=55)	41.5% (n=324)	27.5% (n=215)	12.8% (n=100)	9.7% (n=76)	1.4% (n=11)
Rural	13.3% (n=129)	42.4% (n=412)	25.1% (n=244)	7.6% (n=74)	10.7% (n=104)	0.9% (n=9)
Overall	**7.3% (n=253)**	**33.2% (n=1,149)**	**26.7% (n=924)**	**12.7% (n=438)**	**16.3% (n=565)**	**3.8% (n=133)**

Figure 3: Public Library Outlets Grouped Speed Test Direct Connect Upload Speeds, by Locale

	Direct Connect Upload Speeds					
Locale Code	**1.5 Mbps or Less**	**1.6 Mbps – 10 Mbps**	**10.1 Mbps – 24.9 Mbps**	**25.0 Mbps – 49.9 Mbps**	**50 Mbps – 99.9 Mbps**	**100 Mbps – 1Gbps**
City	11.7% (n=114)	29.6% (n=289)	26.2% (n=256)	8.6% (n=84)	17.4% (n=170)	6.6% (n=64)
Suburban	13.5% (n=98)	41.9% (n=305)	22.8% (n=166)	8.8% (n=64)	10.6% (n=77)	2.5% (n=18)
Town	30.7% (n=240)	48.1% (n=376)	10.5% (n=82)	4.7% (n=37)	50% (n=39)	0.9% (n=7)
Rural	43.3% (n=421)	37.2% (n=362)	9.7% (n=94)	4.4% (n=43)	4.7% (n=46)	0.6% (n=6)
Overall	**25.2% (n=874)**	**38.6% (n=1,335)**	**17.3% (n=598)**	**6.6% (n=228)**	**9.6% (n=332)**	**2.7% (n=95)**

- City public libraries reported a median **upload** captured speed of 25.2 Mbps, with a minimum captured speed of 160 Kbps, and a maximum speed of 792.5 Mbps.
- Suburban public libraries reported a median upload speed of 8.9 Mbps, with a range of 200 Kbps to 651.2 Mbps.

- Town public libraries reported a median speed of 3.3 Mbps, and a range from 73 Kbps to 531.4 Mbps.
- Finally, rural public libraries reported a median speed of 2.1 Mbps, with a range of 20 Kbps to 466.5 Mbps.

Wi-Fi Connections

- City public libraries reported a median captured wi-fi **download** speed of 13.4 Mbps, with a range from 400 Kbps to 815.8 Mbps.
- For suburban public libraries, it was a median speed of 14.4 Mbps, with a range from 150 Kbps to 483.2 Mbps.
- Town public libraries reported a median speed of 9.3 Mbps, and a range from 20 Kbps to 394.1 Mbps.
- Rural public libraries reported a median download captured speed of 6.3 Mbps, and a range from 20 Kbps to 480.9 Mbps.

Figures 4 and 5 below provide another view of wi-fi captured speed data. For download, a majority are below 10 Mbps.

Figure 4: Public Library Outlets Grouped Speed Test Wi-Fi Download Speeds, by Locale

	Wi-Fi Download Speeds					
Locale Code	**1.5 Mbps or Less**	**1.6 Mbps – 10 Mbps**	**10.1 Mbps – 24.9 Mbps**	**25.0 Mbps – 49.9 Mbps**	**50 Mbps – 99.9 Mbps**	**100 Mbps – 1Gbps**
City	20.6% (n=102)	19.2% (n=95)	27.1% (n=134)	12.1% (n=60)	14.9% (n=74)	6.1% (n=30)
Suburban	5.2% (n=26)	31.7% (n=158)	36.1% (n=180)	13.1% (n=65)	11.8% (n=59)	2.0% (n=10)
Town	6.1% (n=29)	48.1% (n=230)	30.5% (n=146)	6.3% (n=30)	7.7% (n=37)	1.3% (n=6)
Rural	20.3% (n=140)	44.7% (n=308)	24.7% (n=170)	5.5% (n=38)	4.1% (n=28)	0.7% (n=5)
Overall	**13.8% (n=297)**	**36.6% (n=791)**	**29.2% (n=630)**	**8.9% (n=193)**	**9.2% (n=198)**	**2.4% (n=51)**

- City public libraries reported a median captured wi-fi **upload** speed of 6.3 Mbps, with a range from 10 Kbps per second to 679.8 Mbps.
- Suburban public libraries reported a median speed of 5.9 Mbps and a range from 107 Kbps to 104.8 Mbps.

- Town public libraries reported a median upload speed of 2.9 Mbps, ranging from 70 Kbps to 375.8 Mbps.
- Rural public libraries reported a median upload of 1.4 Mbps and a range from 10 Kbps to 364.2 Mbps.

Figure 5: Public Library Outlets Grouped Speed Test Wi-Fi Upload Speeds, by Locale

	Wi-Fi Upload Speeds					
Locale Code	**1.5 Mbps or Less**	**1.6 Mbps – 10 Mbps**	**10.1 Mbps – 24.9 Mbps**	**25.0 Mbps – 49.9 Mbps**	**50 Mbps – 99.9 Mbps**	**100 Mbps – 1Gbps**
City	28.5% (n=141)	36.2% (n=179)	19.2% (n=95)	5.1% (n=25)	6.1% (n=30)	5.1% (n=25)
Suburban	19.3% (n=96)	42.4% (n=211)	28.3% (n=141)	6.4% (n=32)	2.8% (n=14)	0.8% (n=4)
Town	37.0% (n=177)	45.4% (n=217)	10.5% (n=50)	3.6% (n=17)	3.1% (n=15)	0.4% (n=2)
Rural	54.6% (n=376)	35.7% (n=246)	6.2% (n=43)	1.2% (n=8)	1.7% (n=12)	0.6% (n=4)
Overall	**36.6% (n=790)**	**39.5% (n=853)**	**15.2% (n=329)**	**3.8% (n=82)**	**3.3% (n=71)**	**1.6% (n=35)**

SPEED TEST RESULTS BY NETWORK LOAD

Librarians were asked to indicate whether the speed test was being conducted when the library was closed, or usage was light (e.g., only a small number of people using the computers and wi-fi), typical (e.g., the use of computers and/or wi-fi is about what we typically get during the day), or heavy (e.g., most or all of our computers are in use, there are many people using the library's wi-fi). Though these were self-reported perceptual indicators, they provided a useful way to classify and analyze the impact of network load and usage on reported speeds at the device level and thus an indication of what a user might experience during peak versus lighter times.

City

Importantly, if not surprisingly, performance (i.e., speed) degrades as usage increases in most cases—particularly for wi-fi connections. For city libraries, the degradation is significant—from 52.2 Mbps median download speed test for light usage of **direct connected** devices to 16.1 Mbps during heavy usage for download speeds. The median upload speed test result ranged from 19.6 Mbps for light usage to 7.7 Mbps during heavy usage. The median download speed test result for a **wi-fi** connection during light usage is 19.2 Mbps versus 1 Mbps during heavy usage. The median upload wi-fi speed test ranged from 10.3 Mbps to 291 Kbps during heavy usage.

Suburban

This trend is similar for suburban libraries. The median download speed test for a **direct connection** during light usage is 19.6 Mbps versus 9.6 Mbps during heavy usage. The median upload speed is 9.3 Mbps versus 5.4 Mbps during heavy usage. The median download speed test result for a **wi-fi** connection during light usage is 15.8 Mbps versus 8.8 Mbps. The median upload speed is 7.4 Mbps versus 3.4 Mbps for heavy usage.

Town

Speeds in town libraries are more variable. The median download speed test result for a **direct connection** during light usage is 11.6 Mbps versus 14.4 Mbps during heavy usage. The median upload speed test result for a direct connection during light usage is 3.6 Mbps versus 3.2 Mbps during heavy usage. The median download speed test result for a **wi-fi** connection during light usage is 9.6 Mbps versus 7.1 Mbps during heavy usage. The median upload speed test result is 3 Mbps versus 2.5 Mbps.

Rural

Captured speeds in rural libraries indicate that as usage increases, speeds at the device level decrease. The median download speed test result for a **direct connection** during light usage is 9.1 Mbps versus 6.7 Mbps during heavy usage. The median upload speed test result during light usage is 2.7 Mbps versus 1 Mbps during heavy usage. The median download speed test result for a **wi-fi** connection during light usage is 9.5 Mbps versus 7.1 Mbps during heavy usage. The median upload speed result is 3 Mbps for light usage and 2.5 Mbps during heavy usage.

SUBSCRIBED SPEED V. USER EXPERIENCE

Figures 6 and 7 show the difference between a library's reported median subscribed download and upload speeds and the median speed captured at the device level in a library. This is an indicator of the overall user experience as compared to the subscribed speeds, and should not be interpreted as a measure of actual speed. As noted earlier, speed test results can be affected by a number of factors, including a library's local network configuration, user device and its configuration, and the number of external "hops" to the physical location of the speed test server.

Figure 6: Public Library Outlet Subscribed Download Speed Compared to Captured Device-Level Speed, by Locale Code

Locale Code	Subscribed Median Speed	Direct Connect Speed Test (median)	Wi-Fi Speed Test (median)
City	35.2 Mbps (n=1,055)	30.5 Mbps (n=977)	13.4 Mbps (n=495)
Suburban	30.0 Mbps (n=904)	18.8 Mbps (n=728)	14.4 Mbps (n=498)
Town	16.0 Mbps (n=768)	10.5 Mbps (n=781)	9.3 Mbps (n=478)
Rural	10 Mbps (n=1,003)	8.9 Mbps (n=972)	6.3 Mbps (n=689)
Overall	**20.0 Mbps (n=3,822)**	**17.2 Mbps (n=3,458)**	**10.8 Mbps (n=2,160)**

Figure 7: Public Library Outlet Subscribed Upload Speed Compared to Captured Device-Level Speed, by Locale Code

Locale Code	Subscribed Median Speed	Direct Connect Speed Test (median)	Wi-Fi Speed Test (median)
City	29.3 Mbps (n=1,048)	25.2 Mbps (n=977)	6.3 Mbps (n=495)
Suburban	20.0 Mbps (n=846)	8.9 Mbps (n=728)	5.9 Mbps (n=498)
Town	10.0 Mbps (n=784)	3.3 Mbps (n=781)	2.9 Mbps (n=478)
Rural	8.9 Mbps (n=961)	2.1 Mbps (n=972)	1.4 Mbps (n=689)
Overall	**15.0 Mbps (n=3,636)**	**7.5 Mbps (n=3,458)**	**4.1 Mbps (n=2,160)**

As to be expected, the data show the device level measure of speed shows a drop-off as compared to subscribed speed. The drop-off can range substantially, however, from about 39% in rural and city libraries to nearly 54% in suburban public libraries (download speed, via directly connected devices). Upload speed drop-off is more pronounced, ranging from about 55% for city libraries to nearly 75% for suburban libraries.

SPEED TEST CORRELATIONS

The Information Policy and Access Center at the University of Maryland conducted additional analyses upon merging the speed test results, including the reported number of public access computers, with selected data on technologies, services, training, training types, and programming from the 2013 Digital Inclusion Survey (Bertot, et al., 2014). In doing this, the study team created a subset of data that included only libraries that participated in both the speed test and the 2013 Digital Inclusion Survey; and libraries that participated in the direct connect version of the speed test (not wi-fi or mobile). This approach created a dataset with 1,578 cases.

For extended analysis, the selected 2013 Digital Inclusion Survey data (technologies, services, training, training types, and programming) were categorized as being either basic or advanced library offerings. In addition, the captured and subscribed direct connect speeds from the speed test were divided into quintiles (see full report for further information). Correlational analyses were then conducted between the speed test data, the numbers of public access computers, and the basic and advanced categorizations of what libraries offer to the public.

In general, the correlational analysis did not show a statistical relationship between subscribed broadband speeds, speed test results, and the public access technology services offered by libraries to their communities.

- Generally, there were weak positive relationships between the captured or subscribed speeds and the basic/advanced categories, but lacked statistical significance.

- The strongest correlation was usually between the basic library offerings and the advanced. This may indicate that libraries that provide greater numbers of basic service offerings are also more likely to provide more advanced offerings.
- There was also a weak positive correlation between the number of public access computers (PACs) and the basic and advanced library offerings, with a greater positive relationship to advanced offerings. This may indicate that if a library is able to offer more computers as a resource, they are also more likely to be able to provide more advanced offerings.

In summary, the analysis as conducted did not show a statistically significant correlation between broadband connectivity and the digital services and/or resources provided by libraries to the communities that they serve. This may be a reflection of the approach taken with the analysis conducted. There is a need for greater empirical study of the relationship between broadband connectivity and public access technology services to more definitively explore the topic.

CONCLUSION

The supplementary speed test results confirm an overall trend from the Digital Inclusion Survey and its antecedents—library broadband speeds are improving, but these improvements are uneven across the country, and broadband capacity still falls far short of goals set by the Federal Communications Commission for public libraries to meet community digital inclusion needs.

There is a need, however, for more in-depth study and analysis of broadband connectivity in public libraries that ascertains the quality of broadband and network services. Using tools like those provided by the Digital Inclusion Survey or the Edge Initiative, America's public library leaders are becoming more knowledgeable about their technology infrastructure, but too many still report (roughly 30% of public libraries in the 2013 Digital Inclusion Survey) they don't know their subscribed or actual point-in-time broadband speeds.

Towards that end, the research team encourages the FCC to expand its *Measuring Broadband America* (2011-2014) research initiative to include community anchor institutions such as public libraries. Such research would provide a definitive assessment of the quality of broadband services in public libraries and facilitate further development of the E-rate program into the future.

We also encourage other researchers to take advantage of public data files released by the Digital Inclusion Survey to conduct their own analysis and/or use the tools and methodology to further build the body of knowledge available to policymakers and practitioners to identify and address library broadband gaps.

The Digital Inclusion Survey is funded by the Institute of Museum and Library Services **and conducted by the** ALA Office for Research & Statistics **and the** Information Policy & Access Center **at the University of Maryland. The** International City/County Management Association **and the** ALA Office for Information Technology Policy **serve as partners on the grant. Complete survey information is available online at:** http://digitalinclusion.umd.edu/.

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