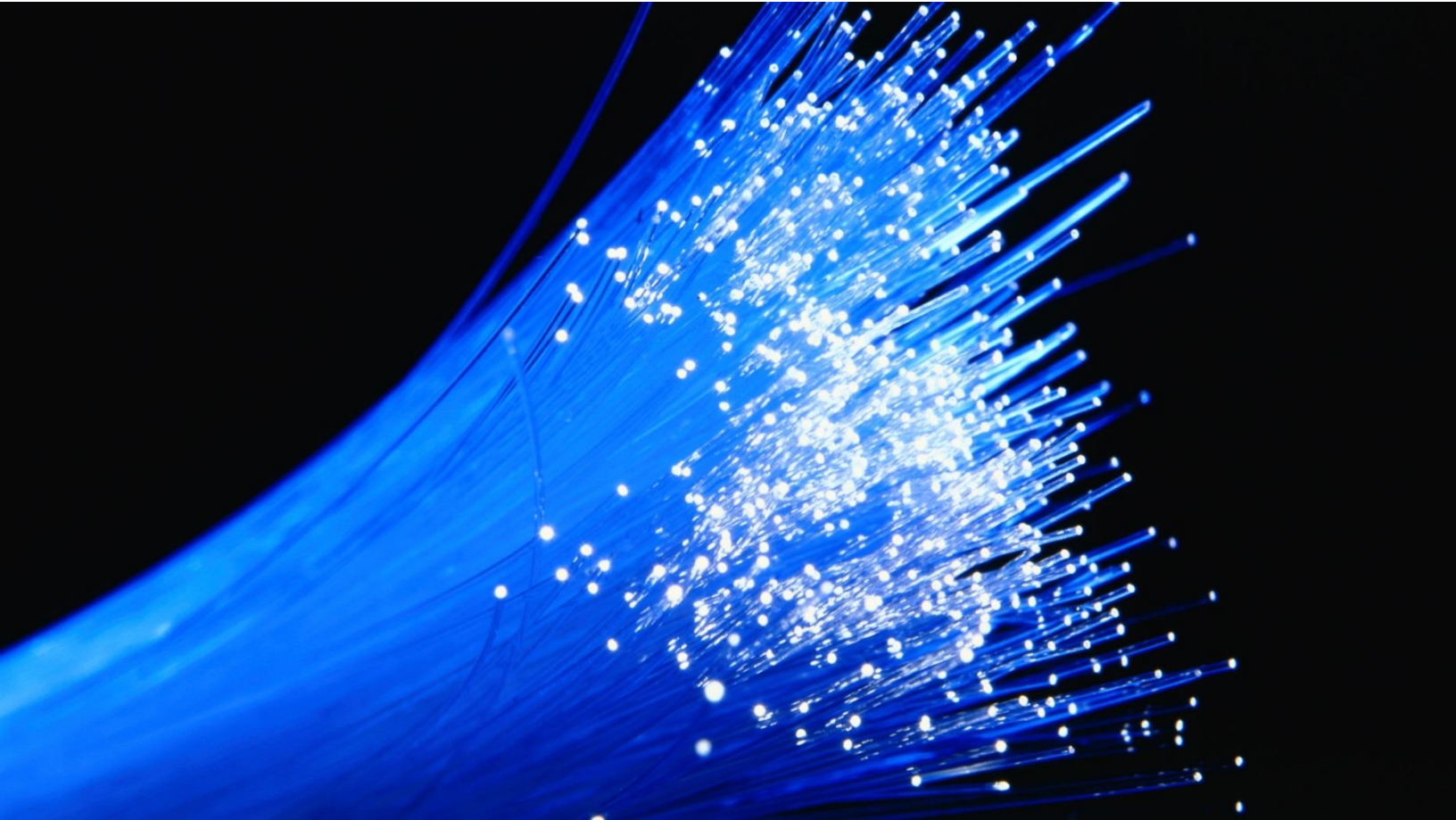# ctc technology & energy

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Connecting Libraries to the Future

Prepared for the John S. and James L. Knight Foundation
FINAL | October 2017

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1   Introduction

In the internet era, libraries use bandwidth as well as books to fulfill their historic mission of democratizing access to information and knowledge. High-bandwidth broadband is enabling libraries not only to meet a pressing societal need for access to the internet but also to shape the libraries' own futures.

Bandwidth at libraries should, ideally, be far greater than the connections citizens can access or afford in a coffee shop, at home, or elsewhere. But constraints on libraries' bandwidth hold back the ways in which library users can create, innovate, and prosper.

This document is intended to assist policy makers and library professionals to fully understand the importance of prioritizing bandwidth and internet access for today and the future. It describes how libraries currently use bandwidth to fulfill their mission; how that role is expanding and evolving; and how library professionals and policy makers can quantify the bandwidth libraries need to create an unfettered opportunity—not just to meet the public's information needs, but to incubate opportunity and innovation.

This report was prepared by CTC Technology & Energy under a grant from Knight Foundation. CTC is grateful to Knight Foundation for supporting our educational mission and for the leadership and vision Knight Foundation has shown in supporting the evolving technology and data needs of America's communities.

1.1   Internet Bandwidth Is an Essential Medium for Libraries

Today, more information—text, audio, and video—is accessible online than has ever been available in any individual local library. But the rise of "anywhere, anytime" access to information through the internet, including on mobile devices, has not diminished the central role of libraries; rather, the internet has expanded that role—creating an opportunity for libraries to embrace technology as a means of making more information and new services available to patrons. Modern libraries are evolving in ways that further the growth of their communities by providing access to massive amounts of data and learning through technology, as well as bandwidth to support entrepreneurs and innovation.

In many communities—especially those in more rural areas—the public library is the only place for citizens to freely access the internet. Through this access, American citizens are able to take advantage of all that being online has to offer—both personally and professionally, and regardless of whether they live in a large urban community or a small rural one.

On any given morning, at the main branch of many urban public libraries (not to mention rural and suburban branches), one can arrive before the library opens and see people sitting on the front steps or lining up—holding laptops, tablets, and other devices—waiting for the doors to

open. The group may include students of all ages, entrepreneurs, small business owners, freelancers, job seekers, and, in many communities, homeless individuals. When the library opens, these patrons will enter, find a public computer terminal or a spot to sit and access the library's Wi-Fi on their own devices, and proceed with their days' activities.

1.2   Libraries Need More Bandwidth

But there is a problem. Even as libraries in urban, suburban, and rural settings serve an overwhelming societal need for bandwidth, surveys indicate that almost one-third of libraries (31.2 percent)[1] have broadband services that only rarely or sometimes meet patrons' needs. Further, 33.7 percent of libraries report that even if they need more bandwidth, the amount they have now is the maximum available.[2]

Recognizing libraries' singular role as enablers of knowledge, the Federal Communications Commission (FCC) set broadband connection standards of 100 megabits per second (Mbps) for libraries serving populations of less than 50,000 and 1 gigabit per second (Gbps) for libraries serving populations of more than 50,000.[3] In comments that the American Library Association (ALA) filed with the FCC, noting that "more granular bandwidth targets are needed for the library practitioner community," the ALA recommended the FCC adopt a standard of 1 Mbps per internet-connected device.[4] For example, if 10 patrons were using internet-connected devices at the same time, the library would need a connection speed of at least 10 Mbps.

Both the FCC's per-library standard and the ALA's per-device standard are clearly aspirational goals for the country: The ALA's most recent supplement to its "Broadband Quality in Public Libraries" report showed that less than half of libraries had connections of even 10 Mbps.[5]

This yawning gap between the connectivity that libraries need and the connectivity that they have (especially given that many library patrons arrive with multiple devices such as a laptop, a

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[1] Bertot, J.C., Real, B., Lee, J., McDermott, A.J., & Jaeger, P.T. (2015). 2014 Digital Inclusion Survey: Findings and Results, Figure 20. College Park, MD: Information Policy & Access Center, University of Maryland College Park.
http://digitalinclusion.umd.edu/sites/default/files/uploads/2014DigitalInclusionSurveyFinalRelease.pdf (accessed October 2017).

[2] Ibid., Figure 21.

[3] Federal Communications Commission, "Summary of the E-Rate Modernization Order," pp. 34-38, www.fcc.gov/general/summary-e-rate-modernization-order (accessed October 2017).

[4] "Comments of the American Library Association," GN Docket No. 16-245, September 2015, https://ecfsapi.fcc.gov/file/1090767678599/American%20Library%20Association%20Section%20706%20Comments%209_7_16.pdf (accessed October 2017).

[5] "Library broadband speed test shows increased capacity; room still for improvement," News Release, American Library Association, April 16, 2015, www.ala.org/news/press-releases/2015/04/library-broadband-speed-test-shows-increased-capacity-room-still-improvement (accessed October 2017).

smartphone, and a tablet) must be closed to not only protect libraries' critical role in society but also to enable libraries to meet their communities' needs.

But how much bandwidth do modern libraries really need to operate effectively today—and how much more will they need to enable the possibilities of tomorrow?

1.3   Recommendation 1: Calculate Libraries' Broadband Needs Based on Peak Utilization

Ensuring that a library has access to the broadband connectivity it needs requires an understanding first of how many simultaneous users will be accessing the library's network at peak times. Users at a given branch include the library staff, patrons using the branch's public computers, and patrons using the library's public Wi-Fi (many of whom connect multiple devices). To calculate a library branch's required broadband capacity, the staff must track the number of users at peak times.

1.4   Recommendation 2: Deliver at Least 1 Mbps per Simultaneous Library User—and Plan for Much Faster Service

We agree that the ALA's recommendation would allow many libraries to do a better job serving present needs. We also recommend that libraries plan for the future by setting significantly higher goals. Table 1 illustrates a tiered approach to establishing broadband requirements.

Table 1: Minimum, Adequate, and Aspirational Bandwidth per Library User

Standard of Broadband Needed	Bandwidth Needed per User (Current)	Bandwidth Needed per User (Future)
Minimum	1 Mbps	10 Mbps
Adequate	5 Mbps	50 Mbps
Aspirational	10 Mbps	100 Mbps

In this approach, "minimum" represents the lowest amount of bandwidth needed to meet users' basic needs, "adequate" is the amount of bandwidth needed to provide a good user experience, and "aspirational" is the amount of bandwidth at which users have no barriers.

We believe these recommendations represent minimum goals and that libraries should reevaluate their needs every three to five years—a time span that reflects the pace of technological change in broadband applications. Given that pace of change, today's aspirational bandwidth levels may become a minimum threshold in relatively short order.

1.5   Recommendation 3: Purchase Broadband Connectivity That Meets Peak Demand

The nature of internet traffic is changing with the rise of video-based and virtual reality applications that require sustained bandwidth. As a result, the historical practice of oversubscribing networks (that is, reducing costs by purchasing enough bandwidth for most needs but not enough to meet all users' needs simultaneously) should be supplanted by a practice of supporting peak demand for all users at all times without degradation of service, just as electrical utilities engineer their grids to support peak electrical demand for all customers at all times.

2   How Broadband Powers the Libraries of Today

Before laying out a vision for connecting libraries to the future, we should first examine how much bandwidth libraries require to properly connect today. We consider three major types of users in this analysis: library staff, users of public computers, and users of public Wi-Fi.

2.1   Library Staff

Like any organization in the 21st century, a library requires robust access to the internet to manage its day-to-day operations. Library staff need adequate bandwidth for many "back office" applications.

Whether for basic uses like emailing, surfing websites, and transferring files, or more advanced applications like inventory management, secure access to data repositories, video security systems, and virtualized computing infrastructure, a modern library cannot function well unless its employees have sufficient internet access.

Library staff also may depend on robust internet connections to enable their own continuing education, which is often delivered via live or recorded webinar.

2.2   Public Computers

The ALA reports that public libraries have about 275,000 public access computers nationwide—and hosted 340.5 million user sessions on those computers—according to the most recent figures available.[6]

This demand reflects, in part, citizens' needs to access the range of government and educational services that are almost universally available online. These include filing federal and state tax returns, filing college financial aid applications, and applying for local economic development benefits.

Libraries' public computers play a vital role in bridging the digital divide. It has become increasingly difficult for anyone unable to connect to the online economy to succeed in the 21st century, and yet the barriers to entry are still too high. Providing free access to computers and the internet is essential to helping lower-income individuals and families gain wider access to information, opportunities, and services.

2.3   Public Wi-Fi

According to the ALA's most recent Digital Inclusion Survey, "[v]irtually all libraries (98 percent) offer free public Wi-Fi access."[7] Providing access to public Wi-Fi has become one of the most

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[6] "Internet Access and Digital Holdings in Libraries," American Library Association, www.ala.org/tools/libfactsheets/alalibraryfactsheet26 (accessed October 2017).

[7] "Internet Access and Digital Holdings in Libraries," American Library Association, http://www.ala.org/tools/libfactsheets/alalibraryfactsheet26 (accessed October 2017).

important services libraries provide to fulfill their role of democratizing access to knowledge through technology.

Free public Wi-Fi provides internet access to patrons who have their own devices, including those who cannot afford broadband or simply do not have access to it at home. (Despite advances in broadband adoption, this digital divide remains an issue for many Americans. [8])

In addition, in many parts of the country, the broadband services that residents can buy suffer from performance issues that limit their usability. And Americans who depend on their smartphones for internet access often face monthly data caps on their cellular contracts.

Free public Wi-Fi enables users to avoid these caps and also plays a key role in enabling libraries' support of small businesses—which require bandwidth to compete. In an era when start-up ventures often struggle to access and afford internet access, libraries are effective incubators for entrepreneurship.

Libraries' free public Wi-Fi is particularly important for children in communities where the public schools have incorporated online content in their curriculums and perhaps handed out laptops or tablet computers to students. While students often have adequate access to the internet at their schools, those who lack broadband access at home are at a severe disadvantage. Libraries fill that gap—as is clear to anyone who visits a library in the late afternoon and sees a big influx of students coming to do their homework.

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[8] In 2015 the Pew Research Center reported that 33 percent of households did not have internet access. This was an increase from the 30 percent of households reporting no access in 2013. See: Horrigan, John B. & Duggan, Maeve, December 21, 2015, "Home Broadband 2015," Pew Research Center, www.pewinternet.org/2015/12/21/home-broadband-2015/ (accessed October 2017).

3   How Broadband Powers Libraries of the Future

The foundational role libraries play in democratizing access to information over the internet is only the beginning. Early-adopter libraries are providing access to other new technologies made possible by broadband that will power the digital economy for the foreseeable future.

These technologies have higher barriers to universal participation than did mass media of the past—not only because of the higher costs of the related equipment and the training required to use them, but also because they require more robust broadband connections than many Americans can afford or have access to from home.

As a result, libraries stand perfectly positioned to continue serving their vitally important role as the democratizers of access by using their robust broadband connections (paired with other investments in emerging technologies) to expand the definition of what people can expect to find in their local library.

The sections below include an overview of some of the major categories of these technologies with specific examples of libraries that have deployed them and an introduction to the potential benefits that can be realized as a result of this access. In the final section, we describe how these technologies—and robust broadband connections—enable libraries to support entrepreneurs and other small businesses.

3.1   Telepresence

What is telepresence? Essentially, telepresence is videoconferencing on steroids. Rather than being limited to a laptop or phone's screen, telepresence relies on large monitors and sophisticated microphones that, when configured correctly, provide the sense that all the participants in the video call are in the same room. This means being able to do things like look people in the eye and converse as if everyone was sitting around the same table.

Another emerging type of telepresence is the telepresence robot, which puts a typical videoconferencing unit on wheels and allows the remote participant to drive around and interact with others as if they were there.

Where is it being used? Given that telepresence rooms are still prohibitively expensive and telepresence robots are still being developed both technologically and in terms of how to properly integrate them into organizations, most telepresence-type technologies are currently limited to universities. Western Michigan University's Waldo Library has been testing a

telepresence robot to communicate with patrons and librarians,[9] and the Brown Library at the University of Virginia has two rooms outfitted with telepresence systems.[10]

But as with all technology, what is expensive today will undoubtedly be affordable tomorrow to libraries and other institutions as this capacity sets a new standard for how people communicate.

What are the benefits? One of the biggest benefits of telepresence is that it enables seamless interaction among participants and offers a significantly more natural meeting and conversational experience. Thus this technology holds the possibility of saving money on travel for entrepreneurs and others because the experience so closely mimics real face-to-face meetings. And telepresence robotics can be liberating for anyone with mobility issues.

Telepresence will not solely be the domain of business applications. Telepresence at libraries could enable authors to present book talks, candidates to meet with voters, and elected officials to hold "town hall" meetings with constituents.

Applications like these could become commonplace. In an ideal world, as that transition takes place, libraries will continue to play their critical role in democratizing technology access to improve communication and knowledge transfer between people.

How does this use bandwidth? Telepresence is a bandwidth-intensive application; it requires a robust broadband connection that does not suffer from jitter or other degradation. Additionally, telepresence often uses multiple cameras and high-resolution video streams to provide the most realistic experience possible. Because of this, telepresence requires robust broadband networks that can guarantee performance rather than "best-effort" bandwidth that can result in degraded performance.

3.2 Makerspaces

What is a makerspace? A makerspace is a place where people can access tools to make physical things. While that can include non-technical tools for activities like sewing and knitting, the spaces' significance within the context of this report mainly has to do with networked-connected technologies like 3-D printers and robotics kits.

By doing something as simple as setting aside a room and providing access to these technologies, libraries can help students access educational opportunities and increase the odds that

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[9] Macy, S.K., & Baron, J., November 2015, "Library putting new twist on communicating with patrons," *WMU News*, https://wmich.edu/news/2015/11/28111 (accessed October 2017).

[10] "TelePresence Rooms," University of Virginia Library, www.library.virginia.edu/services/reserve-rooms/telepresence-rooms/ (accessed October 2017).

communities will be able to apply their ideas to and benefit from these evolutions in manufacturing technologies.

Where are there makerspaces? The Fayetteville (New York) Free Library has what it calls a Fab Lab with nine 3-D printers, a digitizer (for making 3-D scans of items), a laser cutter, a computer numerical control (CNC) milling machine, STEM learning kits, and Arduino boards, as well as computers with professional 3-D design software and access to education on 3-D design and programming, all available to the public.[11] Libraries in Detroit, Chicago, and other cities and towns are also operating makerspaces.

What are the benefits? Makerspaces foster experimentation, provide access to tools that allow people to build prototypes, and provide hands-on experience that can give people workforce skills.

These are not just tools for hobbyists but part of a trend that is changing how certain kinds of manufacturing gets done. Rather than using centralized assembly lines with giant machines geared toward producing massive quantities of the same thing over and over again, manufacturing is shifting to a more agile paradigm that is able to go from prototype to production much more quickly and that allows for more customization.

How does this use bandwidth? A 3-D model is required to build anything in a 3-D printer. While these models can be created from scratch, it is often more efficient to start with a preexisting model that needs to be downloaded from a website. The same is true of designs that can be used in CNC milling machines or laser etchers or engravers. Even someone who is starting from scratch may want to start the design at home and/or collaborate with friends, which requires transferring files between computers.

Additionally, a great deal of training is needed to truly master technologies like these, especially when it comes to robotics projects. As a result, robust connectivity to the internet is essential to enable online learning on how to use these tools.

3.3 Digital Recording Studios

What is a digital recording studio? Digital recording studios are places where people can access the tools they need to record and create the video, audio, or animated content that is the lifeblood of the digital economy. Such content is used widely in entertainment, education, health care, and many other fields.

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[11] "FFL Fab Lab," Fayetteville Free Library, www.fflib.org/fab-lab (accessed October 2017).

Where are there digital recording studios? In Charlotte, North Carolina, the ImaginOn center at the Charlotte Mecklenburg Library has created "Studio i"—a space for kids and teens that features a digital recording studio and tabletop animation equipment.[12] This center includes access to software such as GarageBand, iMovie, ICanAnimate, and apps from the library's digital devices. Patrons are encouraged to create animated movies and have the option of using clay, paper cutouts, or illustrations. They are also able to record podcasts and songs in a sound booth.

Another example is at the Skokie Public Library in Illinois, where a Digital Media Lab offers access to content creation tools that allow patrons to create and share video, music, photography, and design projects.[13] The lab features access to computers with editing software, cameras, camcorders, microphones, and musical keyboards, as well as a green screen wall for video projects.

What are the benefits? While media creation can be done on smartphones and consumer software is getting more powerful, digital recording studios generally offer communities access to more sophisticated, costly, and high-quality technologies that might otherwise be out of reach.

By democratizing access to the best digital technologies, libraries enable patrons to express themselves, hone skills they can use to obtain jobs, and create content they can sell or use to grow a business.

In the digital economy, content can be created anywhere and sold everywhere, which opens up tremendous opportunities for personal growth and local economic development.

How does this use bandwidth? The most basic way that digital recording studios use bandwidth is by transferring very large files; a single video, for example, may contain many gigabytes of data. And often these files must be shared multiple times among collaborators.

And, as is the case with 3-D printing, mastering the tools requires considerable education. A robust broadband connection enables new users to collaborate and gain access to resources such as training videos to help them more fully utilize these technologies.

3.4   Virtual Reality

What is virtual reality? Virtual reality (VR) uses powerful software to present 360-degree images and videos on computer displays—including traditional and head-mounted ones—in ways that allow the user to navigate through a real or computer-generated scene and feel "present" in it. Some versions of VR use head-mounted displays that block out all other visual stimuli, making

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[12] "ImaginOn: Studio i," Charlotte Mecklenburg Library, www.imaginon.org/studio-i (accessed October 2017).

[13] "Digital Media Labs," Skokie Public Library, https://skokielibrary.info/services/computers-technology/digital-media-labs/ (accessed October 2017).

the experience particularly immersive. In the past several years, the evolution of hardware and software has made VR less costly. Today, VR is adding a powerful new dimension to the human-computer interface and providing new ways for people to interact with information.

Where is it being used? Public libraries like Arapahoe Libraries in Colorado[14] and the McAllen Public Library in McAllen, Texas,[15] are hosting interest groups for VR enthusiasts where anyone can try out head-mounted display technologies such as the Oculus Rift, Samsung Gear VR, and Microsoft HoloLens. And libraries like the Natrona County Library in Casper, Wyoming, are investing in technologies like this for the public to use.

But VR is also starting to expand the walls of libraries themselves. The Bibliotheque et Archives Nationales du Quebec in Montreal, Canada, featured a VR exhibition that re-created the interiors of libraries around the world.[16] Further innovation is under way at university libraries like the University of Oklahoma Libraries, which established a virtual academic laboratory for students.[17] Biochemistry students, for example, use VR to "fly" through chemical molecules.

And VR is not merely something that requires goggles or even special wall displays. It is becoming a more common way to experience online content on any computer or existing display, and works best when the user has plenty of bandwidth available. The websites of some news organizations are starting to offer VR-based storytelling, such as "Times 360" from the *New York Times*, which gives readers a visceral sense of being present in, for example, a remote war zone. And users can experience this even on their smartphones, by moving their phones around to "travel" through a 360-degree scene thanks to motion-detection hardware that is built into the phones.

What are the benefits? With VR, users are no longer limited by the size of their screens; they can, in effect, be immersed in visual information. While much of the initial adoption of VR occurred in gaming, the breadth of its impact could be profound in everything from education and health care to tourism and entertainment. That makes VR an important technology for libraries to accommodate.

How does this use bandwidth? Any VR experience requires users to download large software files. The most interesting things VR can do require a robust broadband connection to enable multi-user collaboration and to provide access to virtual worlds that outstrip the processing

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[14] "Show and Tech," Arapahoe Libraries, http://arapahoelibraries.org/show-and-tech/ (accessed October 2017).
[15] "Virtual Reality at the Library," June 2016, McAllen Public Library, https://mcallenlibraryblog.com/2016/06/10/virtual-reality-at-the-library/ (accessed October 2017).
[16] www.mcq.org/en/exposition?id=425961 (accessed October 2017).
[17] Enis, M., August 2015, "University of Oklahoma Expands Networked Virtual Reality Lab," *Library Journal,* http://lj.libraryjournal.com/2016/08/academic-libraries/university-of-oklahoma-expands-networked-virtual-reality-lab/ (accessed October 2017).

ability of any one personal computer. And even more so than telepresence, VR can require considerable bandwidth to generate a 360-degree visual immersion.

In this regard, VR illustrates the transformational benefits of high-speed internet connections. While gigabit connectivity may be more bandwidth than many common applications need today, such bandwidth is necessary for some VR applications. And this is a technology that would have been inconceivable, in practical terms, just a few years ago. Such bandwidth will enable other applications that we cannot yet imagine (or, even more likely, applications that we may imagine but that are impossible with the broadband connections that libraries have today).

3.5   Business Incubators

A Kauffman Foundation report highlights that nearly all net new job creation and almost 20 percent of gross job creation comes from new businesses.[18] Yet this same report shows that the rate at which new businesses are being created has been declining over the past few years.

The reason this is significant to discussions around the present and future of libraries is that increasingly, libraries are serving as informal co-working spaces and incubators for people starting new businesses.[19] At a library, an entrepreneur can find quiet space to work—and, often, training on the basics of how to use technology like the internet. Additionally, these library users may establish relationships with one another, which can lead to business opportunities.

As more forward-looking libraries are investing in new technologies like digital media studios, makerspaces, and VR, new businesses are able to access technologies that they may not yet be able to afford on their own. Underpinning all of these activities is the library's broadband connection. Whether or not a library provides access to technologies like telepresence, if it offers robust bandwidth, it can act as a business incubator. This is true whether libraries formally embrace the idea of serving start-ups or merely provide space.

These libraries are playing a vital role in the growth of their local economies. And increasingly, they can only fulfill this societal function if they are able to provide enough bandwidth for the entrepreneurs and small business owners who rely on those connections.

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[18] Wiens, J., & Jackson, C., September 2015, "The Importance of Young Firms for Economic Growth," www.kauffman.org/what-we-do/resources/entrepreneurship-policy-digest/the-importance-of-young-firms-for-economic-growth (accessed October 2017).

[19] See, for example, Hamilton, A., August 2014, "The Public Library Wants To Be Your Office," *Fast Company*, www.fastcompany.com/3034143/the-public-library-wants-to-be-your-office (accessed October 2017).

4   Defining Libraries' Broadband Needs Today

Calculating how much broadband a library needs today requires determining two key variables: the library's maximum number of concurrent broadband users and the amount of bandwidth each user needs.

Table 2: Equation for Defining Library's Broadband Needs

[Number of Peak Users] x [Bandwidth per User]

4.1   Calculating a Library's Peak Broadband Users

In terms of broadband planning, libraries must define the peak number of users who will potentially be online at the same time. The three categories of users defined earlier in this report—library staff, public computer users, and public Wi-Fi users—are the starting point for determining that number.

The number of staff working at a library is straightforward, as is the number of its public computers. We assume for this calculation that 100 percent of those staff members and public computers will be online at all times.

Estimating how many patrons will be using Wi-Fi at any one time is somewhat more complicated. For most libraries, a realistic estimate is 50 percent of the number of peak patrons. This estimate, which we call the Wi-Fi Utilization Ratio, reflects the percentage of patrons who bring their own laptops with the intent of using Wi-Fi and those who bring devices like smartphones and use them incidentally while they are at the library for other reasons.

Multiplying the the number of peak patrons at the library by the Wi-Fi Utilization Ratio yields an estimated number of Wi-Fi users. Adding that number to the number of library staff and public computers gives a total number of broadband users.

Table 3: Equation for Calculating Library's Peak Broadband Users

Library Staff + Public Computers + (Peak Patrons * Wi-Fi Utilization Ratio)

As an example of how this formula works, let's say a library has 10 staff members, 10 public computers, 50 peak patrons, and a Wi-Fi Utilization Ratio of 50 percent. That would lead to the following calculation: 10 + 10 + (50 * 50%) = 45 peak simultaneous users.

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4.2   Calculating Bandwidth Needed per User

The second variable in the equation—bandwidth per user—is not calculated per individual library but based on how much bandwidth a person requires to use the internet today.

Given current broadband applications, **the minimum bandwidth required per user is 1 Mbps**. If users have 1 Mbps, then they can check their email, surf the web, watch low-resolution videos, and use most online applications.

Admittedly, 1 Mbps is not enough bandwidth to quickly upload or download large files or to use bandwidth-intensive internet applications like streaming higher quality video for an online classroom discussion. But 1 Mbps is enough to enable users to effectively access the internet.

Large files will take longer to download over a 1 Mbps connection than most home broadband connections would require; a library user with a 1 Mbps connection will need 14 minutes to download a 100 MB file and more than two hours to download a 1 GB file.[20] (Given the time limits that many libraries impose on public computer sessions, this may mean that a user cannot actually download such large files.)

Table 4: Time to Download Files

Broadband Speed	100 MB File	1 GB File
1 Mbps	14 min.	2.2 hrs.
5 Mbps	3.5 min.	35 min.
10 Mbps	1.5 min.	15 min.
25 Mbps	30 sec.	5 min.
100 Mbps	8 sec.	1.2 min.

Video streamed over a 1 Mbps connection will not be high resolution, although 1 Mbps does exceed the minimum standard of 500 Kbps that is shared by Netflix[21] and YouTube.[22]

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[20] "Download time," www.download-time.com/ (accessed October 2017).

[21] "Internet Connection Speed Recommendations," Netflix, https://help.netflix.com/en/node/306 (accessed October 2017).

[22] "System requirements," YouTube, https://support.google.com/youtube/answer/78358?hl=en (accessed October 2017).

Table 5: Bandwidth Required to Stream Video

Minimum	500 Kbps
Standard Definition (Recommended)	3 Mbps
High Definition (Recommended)	5 Mbps
Ultra-High Definition (Recommended)	25 Mbps

If a library wants to provide its users with enough bandwidth to take fuller advantage of what the internet has to offer today—what we call "adequate" bandwidth—we believe the standard should be set at 5 Mbps per user. At 5 Mbps, high-definition (HD) video can be streamed, most online applications should work well, and a 1 GB file can be downloaded in about half an hour.

Increasing per-user bandwidth to 10 Mbps—what we call "aspirational" bandwidth for most libraries—will enable an even better user experience, with faster downloads of large files and potentially seamless access to streaming video.

4.3 Calculating a Library's Bandwidth Needs

Applying either of the two numbers calculated above, a library can determine its minimum bandwidth requirements to meet today's needs:

Table 6: Equation for Calculating a Library's Minimum Broadband Needs

(Library Staff + Public Computers + (Peak Patrons * Wi-Fi Utilization Ratio)) * Minimum Bandwidth Requirement

The same formula can be used to determine a library's total broadband need assuming adequate bandwidth per user (5 Mbps) or an aspirational level of bandwidth per user (10 Mbps). The following table illustrates these levels for a library with 45 peak users:

Table 7: Sample Calculation—Bandwidth Required for 45 Library Users (Current)

Standard of Broadband Needed	Bandwidth per User	Total Simultaneous Users	Total Bandwidth Required
Minimum	1 Mbps	45	45 Mbps
Adequate	5 Mbps	45	225 Mbps
Aspirational	10 Mbps	45	450 Mbps

5 Defining Libraries' Broadband Needs Tomorrow

The internet is such a fertile place for innovation that it is impossible to predict what applications or technologies may be invented that will require significantly more bandwidth than we can imagine today. Twenty years ago—when many libraries still had dial-up modem access—few could have imagined all of the ways the internet was to evolve; we may be saying the same thing 20 years hence.

At the same time—given that deploying broadband infrastructure often requires years of planning—libraries do not have the luxury of sitting back and waiting to determine how much bandwidth they might need in the future. Decisions being made today about how to invest in broadband infrastructure may empower or hinder a library's ability to enable its community to fully participate in the online economy of tomorrow.

From a practical standpoint, then, we recommend that libraries revisit their broadband needs every three to five years. As a point of comparison, the State Educational Technology Directors Association (SETDA) released groundbreaking bandwidth recommendations for K–12 schools in 2012 and published an updated report in 2016.[23]

To help further this visioning process, there are two primary factors to be considered when trying to define a future goal for libraries' broadband connections. The first is simply to estimate how much to increase the amount of bandwidth available on a per-user basis from the equation explained in the last section. The second is to consider how the nature of internet traffic itself is evolving and what impact that evolution will have on libraries' networks.

5.1 Libraries Will Need a Minimum of 10 Mbps per User in the Near Future

Libraries will require at least 10 Mbps per user as a minimum standard in the near future. This increase reflects the many variables that will have an impact on bandwidth requirements.

For example, there is the ever-increasing quality of streaming video. Already a transition from standard definition to HD is starting to happen, but on the horizon is the transition to QuadHD (which has four times the resolution of HD) and even SuperHD, which promises 16 times the resolution of HD.

While it is relatively easy to show how much more bandwidth these applications require today, it is hard to say how much bandwidth they will require tomorrow. In order for this higher resolution video to be adopted, a great deal of equipment—including cameras, monitors, and

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[23] "Equity of Access," SETDA, http://www.setda.org/priorities/equity-of-access/broadband-imperativeii-2016/ (accessed October 2017).

computing power—will need to be upgraded, which means it is hard to judge when it will become ubiquitous.

Additionally, one could argue that users already need 10 Mbps today if they want to avail themselves of all the internet offers. With 10 Mbps, a user can multitask online—watching a video while researching information on a website and downloading a file in the background. As such, 10 Mbps is a reasonable estimate of how much bandwidth will be a bare minimum standard in the not too distant future.

Defining an adequate amount of bandwidth for fully participating in the online economy of 10 years from now is much more difficult. If QuadHD and SuperHD video become ubiquitous, streaming a single video to a single user, or sharing such a file between collaborators, could require 25 Mbps or more of bandwidth.[24] And if the file sizes that software companies and businesses are using continue to increase, then 25 Mbps probably will not be enough bandwidth, because downloading a single 1 GB file over that connection would take more than an hour. Indeed, it is possible to imagine a future in which each user requires 100 Mbps.

Such considerations give a sense of how much further there is to go if libraries want to keep up and offer adequate access in the future.

Table 8: Bandwidth Required for Library Users (Future)

Standard of Broadband Needed	Bandwidth per User
Minimum	10 Mbps
Adequate	50 Mbps
Aspirational	100 Mbps

5.2 Libraries' Broadband Connections Must Meet Peak Demand at All Times

The second important point to be considered for the future is the changing nature of internet traffic and the impact that is having on library network oversubscription, or the practice of subscribing to less bandwidth than is required by all users. Oversubscription is a common approach because not all patrons will be using bandwidth at the same time. It is a standard practice in home broadband networks to oversubscribe a network by a factor of 10 or even 100.

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[24] "Internet Connection Speed Recommendations," Netflix, https://help.netflix.com/en/node/306 (accessed October 2017).

If, for example, a broadband provider has 100 customers who purchase service with speeds up to 10 Mbps (for a total capacity of 1,000 Mbps, or 1 Gbps), the provider might not actually deliver 1 Gbps in internet connectivity to support those customers; instead, the provider may have only 100 Mbps or, in extreme cases, as little as 10 Mbps—recognizing that not every customer will be online simultaneously.

While this industry practice can cause congestion during periods of peak demand, such as when kids get home from school and go online, it has worked reasonably well in large part because of the nature of most internet traffic. When users go to a web page, they are really only using bandwidth when they first open the page. Once they are reading the page, very little data is being transferred. And given that it is not often that everyone is hitting the button to go a web page at the same time, broadband providers can get away with oversubscribing their networks.

This practice has been common in libraries too; some entire libraries have been run off T1 lines that offer only 1.5 Mbps. And while bandwidth in these environments is rarely adequate, libraries have been able to get by.

But a day of reckoning is coming. The nature of internet traffic itself is changing and putting enormous new stresses on this practice of oversubscription. For example, video, especially live and higher-quality video, requires a steady amount of bandwidth, not the bursty bandwidth that has historically been required to surf web pages. Watching video requires continuous bandwidth for smooth playback. And video is utilized across so many different types of applications that it alone is changing the nature of how well networks can work if they are oversubscribed.

Libraries need to start thinking about bandwidth more like electricity. Electricity networks are built to support peak demand—the highest amount of capacity that might be needed. If everyone turns on air conditioning at the same time on a hot July day, the energy-guzzling compressors all need to kick on and stay on. Ultimately, broadband networks need to operate the same way. If every user decides to click on a YouTube video at the same time, libraries cannot afford for their networks to only work some of the time for some of the users—or, perhaps even worse, to not work well for anyone in moments of peak demand.

That is why, rather than offering a sophisticated approach to oversubscribing their broadband networks, libraries need to make sure their bandwidth is always sufficient for whatever uses may reasonably be expected.

To truly be connected to the future, libraries need to apply the minimum (or even aspirational) standard bandwidth per user to the peak total number of simultaneous users, not just to some fraction of users.

SIDEBAR 1: How to Determine Whether a Library Has Enough Bandwidth Today

When discussing their bandwidth needs, it is helpful for libraries to gain a better understanding of how well their current broadband capacity meets the current needs of their employees and patrons.

From a quantitative perspective, libraries should be regularly examining how much they are using their current broadband connections. For example, it is important to understand how often they are using all of their current capacity—that is, how many times a day or week, and for what duration, they are using all the bandwidth they have available.

If they find that they are never maxing out their broadband connections, then they may have opportunities to create internal benefits (by optimizing operations) or to enable patrons to do more online.

Conversely, if libraries are maxing out their broadband connections, then it is important to understand whether that is happening just every once in a while or whether it is a chronic issue that is impeding the functioning of the library.

Gaining a more granular understanding of how well a broadband network is performing depends in part on the type of broadband connection a library has.

If a library has a cable modem, DSL, or other "small business" service that has a monthly price tag of a couple of hundred dollars or less, then the broadband provider likely will not offer any tools to measure utilization. However, if the library has a service level agreement (SLA), then the service provider will often offer network monitoring services accessible through an online portal that provide reporting on SLA metrics like connection availability and average utilization.

Even then, without knowing the average time interval for these measurements and the types of applications in use, the reporting may not indicate much about the user experience for many types of applications. Network performance really depends on the applications the network supports, their relative criticality, and whether or not the customer (or the service provider on behalf of the customer) is employing any type of quality of service (QoS) mechanisms to prioritize certain types of traffic.

For example, if a library has a 10 Mbps connection supporting voice over internet protocol (VoIP), video streaming from Netflix, and basic web browsing, the library might expect to see just over 50 percent average utilization over a five-minute window during which patrons are watching an HD video, talking on a VoIP call, and surfing a web page. In general, the video will be fine because it is buffered and only needs about half of this capacity. Similarly, web surfing will function well because browsing requires short bursts of capacity, generally for only a few seconds. However,

this can spike to the full capacity of the 10 Mbps connection at any given time. When this happens, a VoIP call, which averages less than 32 Kbps but does not tolerate much packet loss (because there is little to no buffering involved), would suffer noticeable degradation.[25]

There are too many variables to say that a connection is or is not overutilized unless it is always at 100 percent, but in a real-world scenario, libraries should start to be concerned when they see 50 to 75 percent utilization for any significant amounts of time.

A wide range of standards-based network monitoring solutions can collect and report on utilization on a per-interface basis for any number of network switches, routers, and firewalls. SolarWinds, What's Up Gold, and HP Open View are some of the better enterprise platforms; for basic utilization statistics, numerous free and open source software utilities are available. Generally, these all use simple network management protocol (SNMP).

Libraries can also assess network performance qualitatively by surveying employees, patrons, and members of the wider community to gain a fuller understanding of their needs and experiences.

Querying a small group of library employees is a relatively straightforward task. It is also relatively straightforward to query existing library users about their needs, given that they visit the building. Ideally, however, a library will want to understand the needs of the wider community, including those who rarely visit the library and may have low levels of digital literacy and thus might benefit the most from library services.

Surveying a community about its needs requires more planning in order to capture a representative sample of the local population, not only the people who regularly visit the library and/or who are already internet-connected. The best way to survey a community is to generate a random list of residential addresses and then perform telephone or in-person interviews with occupants. But if such a survey is not feasible, libraries can come up with more informal ways of trying to achieve the same thing, such as approaching people at community events, at schools, and in public spaces. Online surveys can be helpful but it is important to understand that such surveys will, by definition, only reach people who are online.

When surveying employees, patrons, and members of the wider community, it is important to remember to:

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[25] If a library were to employ QoS over this link, then the VoIP traffic would always be prioritized and the problem would be solved.

1) Use good methods. If libraries want to understand community needs, their surveys need to be carried out in a reasonably scientific way to capture a representative segment of the community.

2) Use good questions. Survey questions are tricky animals. Done well, they will elicit useful, accurate answers. We have provided sample questions below as a starting point.

Sample Survey Questions for Library Staff

- Do you feel that you always have fast-enough internet to perform your duties effectively and efficiently? [Yes, No]

- [Comments:_____]

- Are there any things you feel like you cannot do well at your job because of a lack of adequate internet access? [Yes, No] If yes, describe what they are in the comments box.

- [Comments:_____]

- Do you feel that the internet access the library provides to patrons through public computers and public Wi-Fi is adequate? [Yes, No]

- [Comments:_____]

- Are there any internet-powered technologies or services that the library is not currently using that you think we could benefit from adopting? [Yes, No] If yes, please describe further in the comments box.

- [Comments:_____]

For Patrons and Members of the Community

The following sample questions are presented as a script that a survey taker would read to a member of the public over the phone or in person. These questions are derived from Pew Research Center surveys, which are professionally designed. [26] *The list can be shortened as needed to address specific areas of concern at your library.*

"I have some questions about your local library, and in particular about using computers and the internet at public libraries. Please answer yes or no.

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[26] See: http://www.pewinternet.org/question-search/?keyword=library&x=0&y=0 (accessed October 2017). Pew has given permission for use of their database of questions. The questions below were derived from their database. We also recommend utilizing the Pew Research Center "Question Search" to find additional sample questions written by survey experts.

In the past 12 months, have you …

…. used computers, the internet, or a public Wi-Fi network at a public library for any reason? *(If they say no, skip past the specific questions about what they used it for.)*

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…. used a public library computer or Wi-Fi connection to check or send email or texts?

… used a public library computer or Wi-Fi connection to visit a social media site, such as Facebook, Twitter, or Instagram?

… used a public library computer or Wi-Fi connection to take an online class or complete an online certification program of some kind?

… used a public library computer or Wi-Fi connection to get health information online?

… visited a public library in person to search online for a job or apply for a job online?

… visited a public library in person to use a 3-D printer or other new high-tech device?

Do you think your local public library provides you with the help you need to use the internet?

If you use a public computer at the library, do you think it provides you with the internet connection speeds you need, or not?

If you use Wi-Fi at the library, do you think it provides you with the connection speeds you need, or not?

Have you ever connected to the library's Wi-Fi when the library building itself was closed?

Do you think your local public library contributes a lot, some, not too much, or nothing at all when it comes to providing a trusted place for people to learn about new technologies?

Please tell me if each of the following is something you, personally, think the public library should definitely do, should maybe do, or should definitely not do.

How about … buy 3-D printers and other digital tools to allow people to learn how to use them to make different kinds of objects?

How about … offer programs to teach people, including kids and senior citizens, how to use digital tools such as computers, smartphones, and apps?