Broadband Enabled Fabric for Public Libraries in Canada

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ABSTRACT

Public libraries provide essential services to their communities through broadband Internet technologies. Broadband enables millions of people in these libraries to have access to e-government, employment, education, training, health, social networking and many other Internet-enabled services and resources. The public library service context is one in which multiple public access computers and mobile devices connected via the library's Wi-Fi are in continuous use as they access services and resources, often using the same connection.

In this work used to 1) estimate the required bandwidth per user in a public library through identifying applications used in different areas at public libraries. Then, estimate the bandwidth required for each target area; 2) recommend a systematic approach to determining the number of active users (in-branch cardholders or community member) to the resident population served by the library; 3) recommend best practice minimum and maximum bandwidth required to serve an individual library based on the population served.

The intent is to leverage these recommendations to broadband requirements for public libraries across North America, more specifically within the profile of Canadian libraries. The goal is to provide the library sector with a practical guide in determining broadband requirements that will support their digital roadmap.

Keywords: Public libraries, Bandwidth, Education, Estimation, Public service

1. INTRODUCTION

The use of public libraries is increasingly expanding in scope and have evolved beyond the traditional place to borrow books. They provide an inviting space for people to gather or pursue their interests and goals and they offer programs and spaces for recreation and cultural activities as well as learning and personal development [1]. Public libraries that offer internet access to their users face significant difficulties in ensuring legally compliant and non-offensive use of this facility whilst still adhering to the professional value of freedom of access to information. For example, in Ontario's public library boards have the authority to make decisions on the provision of library services (including internet use) to reflect their community's needs. Boards make policy on appropriate use of internet in the library and obtain the licenses/subscriptions for their digital products and service offerings.

It is becoming usual to use the internet on daily basis, the increase in broadband access across the nation has seen steady growth. There is a huge number of free access to high-quality digital resources providing on-line information for all library users in North America. For both boys and girls, there are games, movies, video chat…etc. Staying up to date with new technology is essential and for that, a large data pack is needed. As public library users, large amounts of data are needed for watching video, lectures, downloading slides and eBooks used for each lecture session, submitting homework and assignments and doing research. Therefore, library users need a high download bandwidth with consistency and reliability [2].

By understanding how library users connect to the Internet, administrators can make more informed planning decisions when developing and delivering web-based classes and content. A search of the available databases is very important to addressing broadband availability for libraries' users.

The addressed problem described in this paper was to estimate the required broadband access for a public library. The findings from this scientific research determined the percentage of the broadband services with high-speed access that can take full advantage of the online services offered.

In our previous work [3], we discussed and analyzed the network broadband requirements and recommended appropriate broadband ranges for K-12 taking into consideration a reasonable download wait time by students and school staff for different applications. In [4], the authors used the role of the digital divide

in the information society. This paper focuses on public libraries in Ontario to estimate the required broadband and define a common implementation methodology that includes, (a) anytime,

The remainder of this paper is organized as follows: First, a brief introduction to our methodology in estimating adequate broadband speed in Section 2. Section 3 summarizes types of applications and the suitable broadband speed for each internet application. Section 4 describes in detail the usage areas in public libraries in North America and estimates the required bandwidth for each area by estimating the bandwidth for each application. Section 5 gives a systematic approach to determining the number of in-branch active library Cardholder to the total resident population served by this library. Section 6 gives a proposed guide of required bandwidth for each library based on resident population served. Finally, Section 6 concludes and summaries the progressive results.

2. ESTIMATE ADEQUATE BROADBAND METHODOLOGY

Broadband can be defined as an advanced communications system capable of providing high-speed transmission of services such as data, voice, and video over the Internet and other networks [5]. Broadband refers to the size of the conduit in which the data is traveling within. Speed refers to the rate at which the data is traveling at. Using that definition, you can quickly see that larger broadband will permit more data to travel, which will also increase the rate at which it travels. However, this does not necessarily mean that the speed of your broadband connection will be the same as your broadband. Broadband simply refers to the size of the "pipe" in which data is traveling [6].

It is known that high-speed broadband is now a key component of a library's infrastructure, similar to electricity. Broadband is used to describe the technology that connects computers and users to the internet. It is measured in Megabits per seconds (Mbps), a measurement unit applied to digital data transfer rates. Gigabits per second (Gbps) is 1000 times Mbps.

Broadband requirements vary from one application to the other and from one network to another. Determining how many bits per second travel across the network and the amount of broadband each application uses is critical in identifying what broadband is required. The maximum broadband of a typical application is determined by [3]:

$$Throughput = \frac{R_{win}}{R_{tt}} \tag{1}$$

Where R_{win} is the Transmission Control Protocol (TCP) receive window and R_{tt} is the round-trip time for the path. The maximum TCP window size in the absence of TCP window scale option is 65,535 bytes [2].

The key factors to be considered when determining the required broadband for a user located in a shared network are:
1) What software applications are being used
2) What is the total bandwidth used per each user
3) What is a reasonable wait time for users
4) The number of concurrent users in the library
5) Technology and demand for broadband in the near future

Each item is addressed individually in the next sections.

anywhere access in and out of a library for all staffs, users and visitors; (b) a required number of hours for professional development for using different devices as learning tools.

3. SOFTWARE APPLICATION IN USE AND NETWORK BROADBAND REQUIREMENT

The application throughput is low when the round trip takes longer, Eq. 2. It is better to have the applications closer to the users, but it is not always possible. In 2016, 77% of all applications are hosted on the cloud, an increase from 39% in 2015 [2]. In public, all applications are only offered in the cloud. Today, web-based applications are widely used to download eBooks or participate in a collaborative learning session that is hosted in the cloud. Internet speed (broadband) influences the user's quality of experience. Based on the applications listed in Table 2, the required broadband ranges are from 0.5 Mbps to 100 Mbps per user. The usability of an application depends on the broadband, for example, most static websites are accessible at speed as low as 0.5 Mbps, while most collaboration application would not launch without at least 1.5 Mbps. The user experience is best interpreted analytically based on wait time i.e. the time between sending a request by clicking on a link to the time when results are returned.

Table 2 lists the expected wait time based on the user activity, where Nil refers to the inability to load. Download time calculation can be given by:

$$Time = \frac{file\ size\ in\ Mbyte\ \times 8\ (convert\ to\ bits)}{broadband} \tag{2}$$

Based on a technical analysis in TCP traffic profile being a minimum of 1.37 Mbps/user, whereas other [7] have argued that it should be greater than 2.0 Mbps sighting the increase in high broadband demand applications.
Libraries' adequate broadband is determined in the context of what is being downloaded and uploaded for different library area use within a reasonable wait time. While the specific use technology or broadband varies among activity, its primary use is to augment and enrich content delivery [8]. While this can lead to increasing levels of library user's engagement, participation, interest, and ultimately better outcome. It must be clear that the right-sizing technology (broadband) is just as important. Too little could have detrimental consequences. Blended learning can be used to support more equitable access to learning resources and discipline-specific expertise.

Table 1: Example of network speed and expected time to download various file size [9]

Bandwidth (Mbps)	Typical coursework notes (5 MB file)	Typical assignment with embedded images or drawing (500 MB file)	Typical single high-resolution image (1 GB)	Typical classroom media session (3 GB)
100	-	41 sec.	1.25 min	4.17 min
15	2 sec.	4.39 min	9.32 min	28.37 min
5	8 sec.	13.58 min	28.37 min	85.53 min
1	41 sec.	Nil	Nil	Nil
0.5	83 sec.	Nil	Nil	Nil

It may also engage libraries' users in a variety of online and offline activities that bring greater diversity to the learning

context. It may also hold value by employing certain technologies that help users to formative assess learning [7].

Library-based technology infrastructure must be robust and up-to-date, with equitable access, and the necessary resources (human and technology) must be made available to pedagogically support the blending. It is not tenable if Internet connectivity is unreliable or limited, or if there exists inequitable access to broadband or technology infrastructure in the library. Finally, if technical glitches are pervasive, or if the technical support is not available for users, then it is unlikely that blended learning will be a sustainable and successful concept [7].

As a summary, software applications are only considered in the context of their network broadband requirement based on their input and output file types and size. It is assumed that software applications add no significant delay to transmission between the times it receives a request to the time it returns results on the network. Table 2 lists the common application types used by libraries' users and the recommended broadband [3, 10].

Table 2: Bandwidth needed per device for various applications

Applications used in public library	Bandwidth Required (Mbps)
Basic e-mail, web browsing, VoIP	< 1.5
Streaming music, telecommuting, standard-definition video	1.5 - 3
File-sharing for small and medium files	3 - 6
Online gaming, video on demand	6 - 10
Telemedicine, remote education, high-definition video	10 - 25
HD video surveillance	25 - 50
Video conferencing for multiple users, remote super-computing	50 -100
Real-time data collection	>100

4. USES OF PUBLIC LIBRARY INTERNET CONNECTIONS

Computers and Internet access in public libraries have become an expected service to patrons and fulfill many purposes. Interview participants and survey respondents were asked about their use of library computers and wireless networks to pursue activities in seven use areas, which were defined as follows [11, 12]:

- **Education:** Interacting with services related to education, including K-12, colleges or universities, continuing education, and the pursuit of learning for personal enrichment.
- **Employment and entrepreneurship:** Seeking work and gaining job-related skills or other activities related to maintaining employment, or to engage in business or self-employment activities.
- **Health and wellness:** Seeking information or accessing services related to individual or family health care.
- **Government and legal services:** Accessing online government services, retrieving information and assistance in legal and regulatory questions.
- **Community engagement:** Identifying and addressing issues of public concern, including efforts to work with others in a community to solve problems or interact with the institutions of representative democracy.
- **Managing finances:** Buying and selling goods and/or services using the Internet; managing household financial matters.
- **Social connection:** Pursuing personal or socially meaningful ends including connecting with family and friends, finding support for an issue or problem, and enjoying other social activities such as watching videos, pursuing hobbies, or maintaining blogs and personal websites.

Use of library technology across the seven activity areas varied considerably, ranging from a maximum of 60% of users engaged in social activities to just 7% engaging in entrepreneurial activities, Table 3. This will be useful to know the application used in these activities and then estimate the bandwidth required for each application.

In next subsections, we describe in detail each use area listed in Table 3, to determine the type of application used (video, text, audio…etc.) then estimate the required bandwidth for each use area.

Education

Over 42 percent of library technology users are engaged in activities related to education. Activities associated with education can be divided into [13]:

- Educational programs applied to K-12, colleges and universities' students: including doing homework, learning about programs, taking online classes, and applying for financial aid or programs.

Table 3: Ranking of use areas by the availability of alternative access users

Use area	Access user %
Social connection	60%
Education	42%
Employment and entrepreneurship	40%
Health and wellness	37%
Government and legal services	34%
Community engagement	33%
Managing finances	25%
Entrepreneurship	7%

- Educational programs applied to adults include, professional license or certificate, two and four-year degree and graduate degree.

Table 4 shows the educational applications and the recommended broadband required per each device based on application vendors [3, 12, 14].

As an average 5.6-11.4 Mbps is the requirement for education if the library user uses 100% of his time in education.

Table 4: Educational applications hosting location and networks require capacity

Application Type	% of users	Recommended broadband (Mbps)
Web browsing applications: online web-based learning, applied for financial aid, …etc.	39%	< 1.5
Download small file and a digital document including eBooks	22%	1.5 - 3.0
HD Video surveillance: YouTube and others	17%	25 - 50
Cloud application (like Google drive and Microsoft office 365)	14%	3 - 6
Online education games	8%	6 - 10

Employment and Entrepreneurship

In addition, 7 percent of the users use the library for activities related to starting or managing a business of their own. This includes:

- Preparing a resume, from learning how to create a resume to keeping it updated and written for specific jobs;

- Searching for job opportunities, using both internal library-developed and external online resources;
- Doing work to support job-related activities, including using software and other tools and library resources to carry out tasks as a requirement of one's job or profession;
- Getting job-related training, including learning software and applications, tools, and skills; and
- Starting or running a business, including how to write a business plan, find customers, and carry out activities in support of the enterprise.

Most of these applications are a web-browsing application, which required < 1.5 Mbps bandwidth.

Entrepreneurship

About 7 percent used the library to start or manage a business, this includes: starting their own business, managing an existing business, performing business-related research…etc. Most of these applications are related to web browsing and cloud applications with <1.5 Mbps as a recommended bandwidth.

Health and Wellness

Most prevalent users use library resources for health and wellness needs as summarized in Table 5. As an average, the required bandwidth should be 1.5- 3.81 Mbps / device.

Table 5: Health and Wellness applications hosting location and networks require capacity

Application Type	% of users	Recommended broadband (Mbps)
Improving health by locating information about diet and fitness (web, videos)	37%	1.5 - 5
Learning about medical conditions and treatments, medications, and medical procedures (web, videos)	29%	1.5 - 5
Finding and using health care providers, including locating support groups for medical concerns (web)	21%	< 1.5
Accessing health insurance or locating information about drug discount plans (web)	13%	< 1.5

Accessing Government and Legal Services and Information

Accessing government information activities includes:
Learning about government programs or services (web and video application);
- Getting help from a government official or agency (web browsing);
- Obtaining government forms (web);
- Learning about laws and regulations (web);
- Learning about permits and licenses (web); and
- Looking for assistance with a legal question or problem (web).

In general, 1.5 Mbps is the recommended bandwidth for such use.

Community Engagement

The study shows that 33 percent of the users take advantage of library computers to participate in community life.
- Organizing and managing community groups;
- Participating in political and social activities; and
- Keeping up with news and current events.

Most of it web-based application with 1.5 Mbps as a recommended speed required.

Managing Finances

This includes:
- Managing household finances, including doing online banking, paying bills, managing investments, and managing debt; and
- Comparing and purchasing goods and services, which consists of comparing products and services, and buying and selling online.

Most of it web-based application with 1.5 Mbps as a recommended speed.

Social Connections

Nearly 60 percent of social and recreational users used library internet to communicate with friends or family. This includes:
- Keeping families strong (communicating with family and friends, doing something online with family or friends, finding support for a personal or family issue, and exploring family genealogy);
- Building social networks (visiting social network sites such as Facebook, getting in touch with old friends, making new friends, and maintaining a blog or website); and
- Exploring the world (pursuing skills and hobbies; finding, attending, and organizing events and activities for oneself and others; travel; spirituality; and entertainment).

Libraries also play a key role in helping to integrate newcomers to Canada for example, delivering over 10,000 programs in more than 60 Ontario communities. Programs include English and French language instructions, settlement support, and help with professional accreditation [Salam6].

Most of these applications related to online telepresence, video streaming, audio applications and file downloading. 1.5-3 Mbps are the requirement for such applications.

Based on previous descriptions of each library area use, Table 3 can be updated to include the percentage use and the total bandwidth in each area use, as shown in Table 6. Table 6 shows also the estimated interactive access areas use. This has been done through the expected multi-area use at the same time, either through the use of multi-devices or using the same device. In such situation, the user can use the stationary computer provided by the library for a specific task, meanwhile, he can use his own device in a different area (like running a music application).

From Table 6, 2.6-4.2 Mbps is the estimated bandwidth required for each user in the library.

5. NUMBER OF LIBRARY USERS

In a typical library, broadband is shared between all users and staff, stationary and mobility devices. This presents an advantage since the expected number of concurrent users (devices) is generally less than the total number present. However, the main problem is the large increase in the total number of users.

All libraries have a Bring Your Own Device (BYOD) policy or a guest network. This allows many users to bring one or more devices of their own to the network. Currently, every user will have at least one device, 3 out of 4 users prefer tablets over textbooks. This trend is expected to continue in the same direction, where every user will have an average of 2.6 devices by 2018 [15].

Table 6: Ranking of use areas by the availability of alternative access users

Use area	Access user %	% Interactive Access Probability	Recommended broadband (Mbps)
Social connection	60%	20%	1.5-3
Education	42%	33%	5.6-11.4
Employment and entrepreneurship	40%	12%	<1.5
Health and wellness	37%	4%	1.5- 3.81
Government and legal services	34%	7%	< 1.5
Community engagement	33%	9%	< 1. 5
Managing finances	25%	2%	< 1.5
Entrepreneurship	7%	1%	< 1.5

This provides more avenues and opportunities for devices to connect to the network and unfortunately increase the overhead of the network bandwidth. The available network broadband is divided among all connected users or the total concurrent users. Determining the number of concurrent users in a library network can only be done empirically. These approximated were used to compute the effective broadband or throughput at a library, where the libraries are connected directly to the internet.

In this section, we estimate the percentage of concurrent library users to a number of Cardholder in a library. This is achieved by:
- Estimating the concurrent percentage of in-branch users per month (regular library users).
- Estimating the percentage of library in-branch users to the resident population served.

In both cases, this research will focus on library users who visit in-branch and use library resources. It does not include visitors who use virtual resources by accessing the library's website.

Percentage of Concurrent Use

In this section, the percentage of concurrent use for people who visit the library will be estimated based on real data from a survey result of 87,975 people, who used the library in the following categories [12]. Where 86,067 (98%) of survey respondents visited the library at least once in the past 12 months. Of those who did,
1) 34,803 (40%) visited the library once a week or more frequently;
2) 32,852 (38%) visited the library about 1-3 times a month;
3) 18,412 (21%) visited the library less than once a month.
4) Based on that we can estimate the number of visits per month through:
5) For 3 visits per week, the total number of visiting the library per month will be 3×4×40,
6) For 1-3 visit per month, the total number will be 2×38 as average.
7) For 1 visit per month, it will be 1×20

The sum of the three percent above will give the percentage of a concurrent visitor to a total number of in-branch visitor to be 576% per month.

Percentage of In-branch Visits to Resident Population

In Toronto, according to Toronto libraries statistics from 2011 to 2015, the average use of virtual resources is about 60% while the average use of in-branch resources is 40%. Also, it shows that, in 2015, 18% of Torontonians visit their local library per week. This mean about 1,102,302 out of total Greater Toronto Area (GTA) population 6,123,900 [9] in 2015. According to that, we can estimate the number of total in-branch visit equal to 1,102,302 × 40%.

We did the same analysis to Ontario [10] public libraries statistics in 2015. In this data, the number of active library cardholders was 4,538,193 and a total number of population was 13,551,704.

By multiplying the number of the active Cardholders (4,538,193) in Ontario by our estimated percentage (576%) we will get 787,881 of Ontario resident population use in-branch library resources. This is approximately 18% of the total number of the active cardholder.

Though this example we use three different biggest library surveys and we prove that our estimation of concurrent use is used to give a percentage of the in-branch user for any library to a number of resident in North America.

6. RECOMMENDED BROADBAND

Library broadband requirements can fairly compare a student's broadband bandwidth needs to the bandwidth needs of a user. By comparing library users to the well-researched education sector, we can lay some ground rules for bandwidth demands today and in the future. The main three differences are:

- In schools or education institution we know a number of users, while in the library we should estimate that number based on resident served by this library.
- This estimation is useful in North America, where it depends on services provided by the library to the communities which may differ from country to other.
- The applications used are very diverse because the user is different in their age and culture and interesting, unlike in school where most of the student in specific ages and use almost the same applications and resources.

Table 7, represents a guide to required practical bandwidth based on the population served by this library. Where each in-branch library user (cardholder or community member benefit from library service) will need 2.6 Mbps / user as a minimum, and 4.2 Mbps / user as a maximum bandwidth required. The relation between population size and the estimated number of in-branch active library cardholder (active user) can be given by:

$$Estimated\ No.of\ In - branch\ active\ user = 0.1736\ Population \tag{3}$$

While the estimated practical bandwidth for a library related to population severed by this library can be shown in figure 1.
In Table 7, minimum practical bandwidths proposed to be 10 Mbps or higher, even for very small communities, this came from a librarian current experience, where libraries with service of 5 Mbps or less, report difficulties using online/distance education programs and government systems like Grants Ontario due to their internet timing out.

7. CONCLUSION

In this work, a scientific process to estimate the required broadband for a public library based on a number of resident population served by this library has been proposed. It comes with a guide for minimum and maximum bandwidth required for each library in North America based on several population. This has been done through the review of all expected applications that may be used in North America libraries and estimation of the required network speed for each area use. This work has been done based on real data statistics provided for the largest libraries and institutions in North America to estimate the number of In-branch active user's resident population served by a library. As

case study presented, the analysis of results indicates that the subjected model for estimating the required broadband for the public is very attractive regardless of the use of the Internet whether for entertainment and communication or different public library purposes.

Though this study, several points not covered and required further attention as future work, these can be summarized as:

- Changing in technology and demand for broadband in the near future should be taken into consideration. This work focusses on the present needs of the population or technology minimum requirements.
- This study used to identify the broadband required for current libraries, future work should include the effect of increasing in library users and support capacity, e.g. adding new workstations, computers and digital resources, which may continue to drive the number of in-branch users upwards.
- The required bandwidth for staff needs should be included. Staff need like Integrated Library Systems, online catalogs, or Business Intelligence tools that may be in use to generate reports and collect library statistics.

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Table 7: Proposed practical minimum and maximum public library required bandwidth guide based on the number of resident population

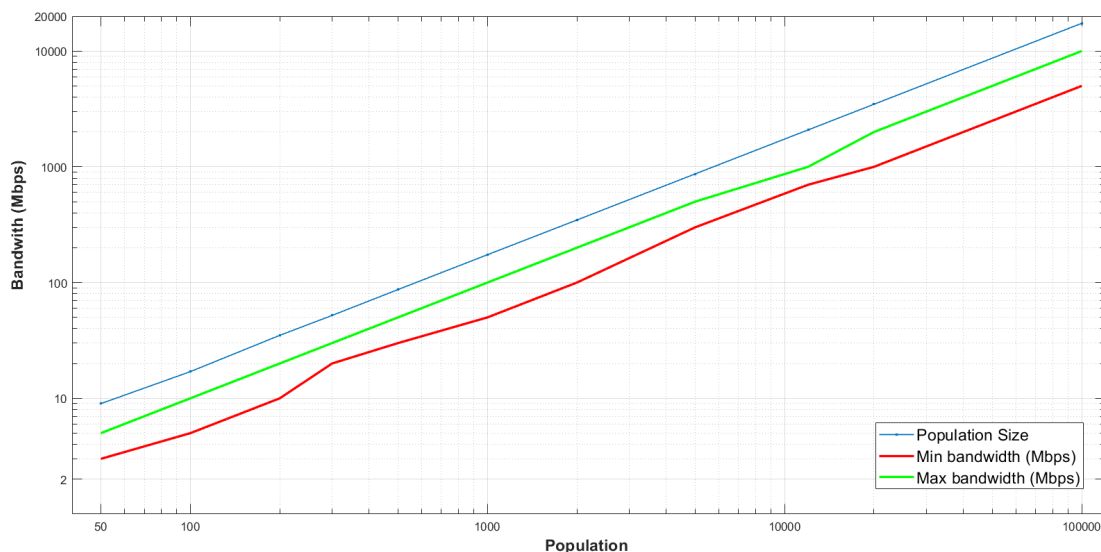| Population Served by the library	Estimated No. of In-branch Active Cardholder	Practical Min Bandwidth (Mbps)	Practical Max Bandwidth (Mbps)
50	9	10	10
100	17	10	10
200	35	10	20
300	52	20	30
500	87	30	50
1000	174	50	100
2000	347	100	200
5000	868	300	500
12000	2,083	700	1000
20000	3,472	1000	2000
100000	17,361	5000	10000

Figure 1: Population size vs practical bandwidth required for a library