Wireless Services in Libraries

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Abstract

Since the turn of the 21st century, libraries of almost all types have been providing clients with access to the Internet through wireless networks. In the process, wireless networking has become an important part of the continuing effort to extend access to library services through networked information technologies. The expansion of the wireless access offered by libraries, now approaching ubiquity among academic and public libraries, has been driven by a number of factors, not the least of them being the tremendous growth in the numbers of so-called "smart" devices capable of connecting to wireless networks and the parallel increases in the bandwidth available via wireless networks.

Looking to the future, wireless access as provided libraries is vital to their function as public computing centers. The continued development of and improvements in mobile applications is also essential, but the construction of mobile-friendly Websites is probably far more important, given the evidence that mobile users are accessing content with increasing frequency and in progressively larger numbers. Similarly, the security and privacy of mobile applications and services must be ensured with the greatest possible vigor, inasmuch as the confidence of users is closely aligned with their continuing use of digital library resources.

Introduction

Since the turn of the 21st century, libraries of almost all types have been providing clients with access to the Internet through wireless networks. In the process, wireless networking has become an important part of the continuing effort to extend access to library services through networked information technologies. The expansion of the wireless access offered by libraries, now approaching ubiquity among academic and public libraries, has been driven by a number of factors, not the least of them being the tremendous growth in the numbers of so-called "smart" devices capable of connecting to wireless networks and the parallel increases in the bandwidth available via wireless networks; and it has been constrained by often inelastic budgets, confusion born of competing technologies and standards, and the other demands on the network bandwidth available to libraries.

Public libraries and academic libraries have been most active in the use of wireless networking as a means of extending services, but the provision of wireless access within the K-12 educational environment has also reached significant levels in terms of both installations and its effects on access to library resources.[1]

[1] Most of the wireless networks in place in libraries have been installed and managed locally, but lately at least a few libraries have begun to make wireless networking services available to clients through services provided by telecommunications companies such as Verizon. For example, the Seattle Public Library has initiated a program, underwritten by Google, through which the Library lends Wi-Fi hotspots, in the form of Verizon's 4G-compatible Jetpack MiFi, to clients. (In this instance, "mobile hotspots" refers to portable devices provide wireless Internet access, typically using mobile broadband service from cellular providers to provide 3G or 4G Internet access.) Under the program, a client may borrow the hotspot for up to three weeks, while enjoying unlimited data access to the Verizon network. The system has been very popular, and as a result, the City of Seattle has elected to assume financial responsibility for the program and provide funding that will place at least 1,000 hotspots into service. For additional information, see: Ridley, James. Seattle Public Library's free Wi-Fi hotspot program receives city funding, 450 more devices. Geekwire, December 2, 2015. http://www.geekwire.com/2015/seattle-public-librarys-free-wifi-hotspots-find-more-permanent-funding-as-google-grant-runs-out/. Last accessed February 20, 2016.

In the beginning, the foremost benefits of wireless networking were its comparatively low cost, the ease of implementation, and configurations that permitted the connection of personal devices, thus augmenting the local computing infrastructure. In recent years, it has become obvious that these benefits have been far exceeded by the impact that wireless technologies in general have had on access to and the use of library resources.

In the years between 2011-2015, mobile Internet usage increased by 394%, with tablet usage growing by more 1,700%, with mobile devices accounting for 60% of all digital media time. According to comScore:

> Across every age demographic, there is a substantially higher percentage of multi- platform and mobile-only internet users than the previous year. More than 3/4ths of all digital consumers (age 18+) are now using both desktop and mobile platforms to access the internet, up from 68 percent a year ago. Mobile-only internet usage is also becoming more prevalent, driven largely by the 21 percent of Millennials who are no longer using desktop computers to go online. Meanwhile, the 55-years-and- older consumer segment is actually the fastest growing faction of mobile users, increasing its combined multi-platform and mobile-only share of audience from 60 percent to 74 percent in the past year.[2]

[2] U.S. Digital Future in Focus 2015. comScore. U.S. Digital Future in Focus 2015. . Last accessed February 27, 2016. p. 4.

In 2015, it was reported that the number of mobile-only Internet users had exceeded the number of a desktop-only users.[3] [4] In addition, it was reported that mobile search, which includes queries conducted via mobile applications and mobile browsers, accounted for 29 percent of all search activity, with smartphones generating a much greater share (20 percent) than tablets (9 percent).[5] And, in specific regard to libraries, the 2014 Pew Research Center reported entitled Libraries at the Crossroads indicated that 50% of the users who accessed a public library Website did so through a smartphone or tablet computer using a wireless connection.[6]

The impact of the wireless installations? Within libraries themselves, wireless access has changed the relationship between libraries and users, mainly by enabling clients to connect personal devices, such as laptop computers, tablet computers, and smartphones, to the Internet through wireless access points provided by the libraries, thus augmenting the technologies made available by libraries for public use and expanding the role of public libraries as computer centers.

The ability of consumers to connect to the Internet through the use of mobile devices has been of even greater impact, compelling librarians to take those devices into account in the presentation of information and services via the World Wide Web. In the early days, most of the

[3] Mobile Internet Usage Skyrockets in Past 4 Years to Overtake Desktop as Most Used Digital Platform. ComScore. https://www.comscore.com/Insights/Blog/Mobile-Internet-Usage-Skyrockets-in-Past-4-Years-to-Overtake-Desktop-as-Most-Used-Digital-Platform Last accessed February 24, 2016.

[4] Number of Mobile-Only Internet Users Now Exceeds Desktop-Only in the U.S. comScore. https://www.comscore.com/Insights/Blog/Number-of-Mobile-Only-Internet-Users-Now-Exceeds-Desktop-Only-in-the-U.S. Last accessed February 26, 2016.

[5] U.S. Digital Future in Focus 2015. comScore. U.S. Digital Future in Focus 2015. . Last accessed February 27, 2016. p. 16.

[6] Horrigan, John. Libraries at the Crossroads: Pew Research Center, September 2015, Available at: http://www.pewinternet.org/2015/09/15/2015/Libraries-at-crossroads/ .

libraries responding to the presence of mobile devices focused on developing mobile Websites that were minimal in content, with the design predicated on the assumption that mobile device users employed them for simple tasks only. Under this view, a mobile website was treated as a companion to the full site, furnishing merely basic information, such as address, directions, contact information, hours of operation, etc., and with the expectation that mobile users would visit the full Website on a desktop or laptop computer for anything more than that.

That approach may have worked for a while, but it has been clear for some time that mobile users are no longer satisfied with simple mobile Websites. In 2012, it was reported that approximately 40% of undergraduate and graduate students used a smartphone on a daily basis, and that 54% of them the devices for academic purposes. In another study published two years later, investigators reported that 51% of the respondents used a mobile device to access library resources. Almost half of them used a smartphone or tablet to search research databases. Slightly less than half of the students indicated that they were "comfortable" reading articles, especially articles of shorter length, on their mobile devices.[7,8]

In addition, the mobile computing and networking capabilities of library users have inspired the creation of applications specially designed to support the use of library resources, e.g., online integrated library systems, databases, eBooks, etc., through tablet computers and smartphones. The mobile library applications have played a key role in

[7] Dresselhaus, A., and Shrode, F. (2012). Mobile technologies & academics: Do students use mobile technology in their academic lives and are librarians ready to meet this new challenge? Information Technology and Libraries. Retrieved from [http://works.bepress.com/angela_dresselhaus/8/]

[8] Caniano, William T., and Amy Catalano (2014) Academic Libraries and Mobile Devices: User and Reader Preferences, The Reference Librarian, 55:4, 298-317, DOI:10.1080/02763877.2014.929910

rendering libraries more visible and more useful on the mobile Web, but in the long run initiatives aimed at reformatting library content in accord with HTML5, CSS and its Media Queries capability, and the Web Accessibility Initiative's (WAI) Mobile Accessibility guidelines will prove much more important.[9, 10, 11]

In many parts of the world other than United States, the numbers of mobile users are high and continuing to climb. In many of the world's industrialized countries, the vast majority of libraries are connected to the Internet and offer Wi-Fi connections, either through the libraries or public Wi-Fi systems, such as those deployed in the Scandinavian countries. But in other locations across the world, where wired connectivity to the Internet is limited, since the physical infrastructure necessary for wired networking is lacking and economic factors argue against creating such facilities, wireless access to libraries is even more important. Many of those locations are in developing countries, but some are in more remote, less populous parts of industrialized nations. For example, in 2014 the Scottish government funded a program that provided 125 libraries with Wi-Fi capabilities and upgraded existing capabilities in 6 other libraries.[12,13] In the United States, the Federal Communications Commission's Broadband In Rural Areas program has provided $1.5 billion in order to provide broadband connectivity, including

[9] World Wide Web Consortium. HTML5: a vocabulary and associated APIs for HTML and XHTML. W3C Recommendation. (2014). http://www.w3.org/TR/html5/. Last accessed February 26, 2016.

[10] World Wide Web Consortium. Media Queries. W3C Recommendation (2012). https://www.w3.org/TR/css3-mediaqueries/. Last accessed February 26, 2016; and World Wide Web Consortium. Media Queries Level 4. W3C Working Draft. (2016). https://www.w3.org/TR/mediaqueries-4/. Last accessed February 26, 2016.

[11] See: World Wide Web Consortium. Mobile Accessibility. https://www.w3.org/WAI/mobile/. Last accessed February 25, 2016.

[12] Kingo Mchombu and Catherine Maggy Beukes-Amiss. "The Role of Libraries in Contemporary African Society." Library Trends 64, no. 1 (2015): 112-124. https://muse.jhu.edu/ (accessed February 26, 2016).

[13] Robertson, Iain. WiFi Projects in Scottish Libraries. Scottish Library & information Council. (2015).

wireless broadband services, to more than 7 million consumers in 45 states and the Commonwealth of the Northern Mariana Islands.[14]

Growth Rates

According to data produced by the Pew Internet Research Project in 2015, nearly two-thirds of the adult population in the United States owned a smartphone, and there are recent estimates that the number of mobile devices in use globally may already outnumber the total population.[15] For example, in 2014 it was noted that Hong Kong has a cellphone penetration rate of 237 percent, and it is anticipated that more than 7 billion new Wi-Fi devices will be enabled in the next 3 years.[16] [17] By 2020, it is predicted that 24 billion devices will be connected to the Internet, with the vast majority of them using some form of wireless connectivity for access to the Internet.

It is also interesting to note that according to the Pew study 19% of Americans rely primarily on a smartphone for accessing online services and information and for staying connected to the world around them, and they do so because they lack broadband access at home or have few, if any options for online access other than their smartphone. Of equal importance, Pew reports that smartphone-dependent users are four times more likely to be African-American or Hispanic than white, tend to be younger, and come from households with lower incomes and levels educational attainment. Indeed, 7% of Americans own a

[14] Mattey, Carol. A Milestone in Expanding Broadband to Rural America. FCC Blog. August 28, 2015. https://www.fcc.gov/news-events/blog/2015/08/28/milestone-expanding-broadband-rural-america. Last accessed February 26, 2016.

[15] Pew Research Center, April, 2015, "The Smartphone Difference" Available at: http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/. Last accessed February 24, 2016.

[16] Baker, David, and Evans, Wendy. Digital Information Strategies. Elsevier Science, 2015.

[17] 50 Incredible WiFi Tech Statistics That Businesses Must Know 02/12/2014 02:29 pm ET. Updated Apr 14, 2014. HuffPost Tech http://www.huffingtonpost.com/vala-afshar/50-incredible-wifi-tech-sb4775837.html

smartphone but have neither traditional broadband service at home, nor easily available alternatives for going online other than their cell phone. The Pew report documents the unique circumstances of this “smartphone-dependent” population, and also explores the ways in which smartphone owners use their phones to engage in a wide range of activities.

Taken together, these numbers suggest strongly that for public libraries in particular, and for many academic libraries as well, the quality of wireless access is of critical importance in building user populations of significant size and loyalty. The vast majority of these libraries already provide wireless access, but it is reasonable to presume that the quality of the access delivered is often inadequate to the needs of users. Studies showing that many libraries have no firm commitment to expanding or upgrading their wireless infrastructure suggest that qualitative problems leading to the dissatisfaction of users will become more acute as the speeds supported by new devices increases at what are expected to be dramatic rates.

The more pressing issue is the support that libraries provide for mobile users through applications designed for use on mobile devices and the refitting of Web pages to meet the requirements of devices, like, smartphones and tablet computers, with smaller screens and touch-based input. Many libraries have responded by creating mobile “apps” and making them available to users. Smaller numbers of libraries have revised top-level Web pages and the interfaces for key resources such as online catalogs for use on mobile devices, but most have not done so.

In K-12 education, the problems may be more severe. There appear to be many educators who believe, on the basis of adoption policies and sales figures, that mobile devices will soon be a ubiquitous element in primary and secondary education, that "by 2020, but probably during

the 2017–2018 school year — every student in every grade in every school in the U.S, will be using a mobile computing device, 24/7."[18] However, according to Tom Wheeler, the chairman of the Federal Communications Commission, nearly 60% of schools in America "lack sufficient Wi-Fi capability to provide students with 21st Century educational tools."[19] Many schools have no wireless network, and many of the schools that do have Wi-Fi do not have networks capable of meeting the capacity needs of students and teachers. A significant number of school districts have adopted "bring your own technology" (BYOT) programs to augment the numbers of connected devices, but in more than a few instances those programs may be taxing the capabilities of the existing wireless infrastructure. Nor is it clear how often or to what extent the "bring your own technology" programs in schools are supported by education or training.[20,21]

Mobile Apps

As noted in an issue of *Library Technology Reports* dedicated to the impact of computing on library services and users:

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[18] Norris, Cathleen A., and Elliot Soloway. "Mobile Technology in 2020: Predictions and Implications for K–12 Education." EDUCATIONAL TECHNOLOGY (2015): 12.

[19] Wheeler, Tom. Closing the Wi-Fi Gap in America's Schools and Libraries. https://www.fcc.gov/news-events/blog/2014/06/06/closing-wi-fi-gap-america%E2%80%99s-schools-and-libraries. Last accessed February 24, 2016.

[20] See: McCrea, Bridget. "9 IT Best Practices for BYOD Districts: Districts with Successful Bring Your Own Device Programs Share Their Key Strategies for Rolling out and Managing Student-Owned Devices in School." THE Journal (Technological Horizons in Education) 42, no. 1 (2015): 26; Grant, Michael M., Suha Tamim, Dorian B. Brown, Joseph P. Sweeney, Fatima K. Ferguson, and Lakavious B. Jones. "Teaching and learning with mobile computing devices: Case study in K-12 classrooms." TechTrends 59, no. 4 (2015): 32-45; and Gurung, Binod, and David Rutledge. "Digital learners and the overlapping of their personal and educational digital engagement." Computers & Education 77 (2014): 91-100.

[21] In the business sector, according to Deloitte, BYOT programs have been successful. In many instances, anticipated higher demands for technical support have not materialized, although only 20% of the companies with BYOT programs provide education or training for users.

> ..... today's mobile users are no longer satisfied with simple mobile websites with only a small fraction of the information and features that are available on desktop websites. The small screen size of a mobile device may make performing certain tasks more tedious or cumbersome, but mobile users do expect to perform more and more tasks on their mobile devices.[22]

Mobile applications have been an element of library service on the World Wide Web since 2010, and one whose perceived importance has grown in accord with the rise of mobile devices as a means of accessing library content and services. According to the 2015 Library Edition of the NMC Horizon Report:

> Increasingly, these online [library] services and resources are being accessed via mobile devices as people expect to study and conduct research any time, anywhere. Thus, academic and research libraries must not only have a rich mobile presence through apps and responsive design approaches, but also understand the evolving landscape of smartphone and tablet delivery.[23]

Leadership groups within librarianship are working to meet the need for mobile applications and Websites based on principles of responsive design by facilitating the exchange of effective use cases and guidance.[24] For example, the International M-Libraries Conference convenes experts in the field to share their knowledge and experience

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[22] Bohyun Kim. Library Technology Reports. Aug/Sep2013, Vol. 49 Issue 6, p. 15-28.

[23] New Media Consortium (NMC). *NMC Horizon Report: 2015 Library Edition*. (2015). p. 7.

[24] Responsive Web design is an approach to Web design that aims at providing optimal viewing and interaction experience — reading and navigation with a minimum of resizing, panning, and scrolling — across a wide range of devices. Sites based on responsive design typically adapt layouts to the viewing environment by using fluid, proportion-based grids, images sized in relative units, and CSS3 media queries. Responsive Web design now accounts for more than half of total Internet traffic — see "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014–2019 White Paper". Cisco. January 30, 2015. Retrieved August 4, 2015 — a trend now so prevalent that Google has begun to

with mobile-centric innovations for academic and research libraries. M-Libraries was established in 2007 by the Open University and Athabasca University to promote the delivery of library services using mobile devices, when such developments were in their infancy. Conferences have been held every two years, beginning in 2009, focusing on "smart" libraries and users, sustainability, innovation, and data and intelligence. Library Success, a so-called "best practices wiki, invites library professionals to contribute to the M-Libraries forum, which provides comprehensive lists of academic libraries that have mobile interfaces, apps, collections, tours, and SMS services, as well as guidance about how to develop and deploy mobile services.[25] In the United Kingdom, JISC in particular has supported the development of mobile applications and mobile-friendly content for libraries, the JISC Mobile Infrastructure for Libraries Program and the Mobilizing Academic Content Online project, which was launched to establish a best practices toolkit.[2627]

The rapid growth of mobile technology has underscored the importance of understanding the behaviors and needs of users as a means of informing the design of serviceable Websites, and there are a number of frameworks for research and development that have emerged. There is, for example, the service design methodology that was developed at Finland's Aalto University; this method leverages employs user profiles and focus groups as a basis for developing new

boost the ratings of sites that are mobile-friendly if the search was made from a mobile device.

[25] M-Libraries Forum, http://www.libsuccess.org/M-Libraries. Last accessed February 27, 2016.

[26] JISC, formerly known as the Joint Information Systems Committee, is a public body in the United Kingdom that supports higher education and research, including research related to digital resources and technology services.

[27] See Mobilizing Academic Content Online. http://www.open.ac.uk/blogs/macon/. Last accessed February 27, 2016.

services.[28] The World Wide Consortium (W3C) sponsors a Mobile Web Initiative, supporting the development of mobile Web applications that can take full advantage of the Open Web Platform in accord with its Standards for Web Applications on Mobile. This support includes W3C widgets, which provide a packaging format to distribute Web-based applications; the Mobile Web Best Practices and the Mobile Web Application Best Practices, which offer guidance to developers on how to create content and applications that work well on mobile devices; and the mobileOK Checker.[29,30,31,32]

Examples of mobile Websites developed in the service of libraries and readers are now abundant. The M-Libraries Wiki, at http://www.lib-success.org/M-Libraries, offers an extensive and classified list that can be helpful in identifying exemplary sites and developmental trends.

Digital Inclusion and Libraries

According to 2013 Digital Inclusion Survey, which surveyed 1669 public libraries, 97.5% offered public wireless Internet access. Specifically,

[28] See: Kekolahti, P., & Karikoski, J. (2013). Analysis of Mobile Service Usage Behaviour with Bayesian Belief Networks. *Journal of Universal Computer Science*; and Soikkeli, T., Karikoski, J., & Hämmäinen, H. (2013). Characterizing Smartphone Usage: Diversity and End User Context. *International Journal of Handheld Computing Research*. vol. 4, no. 1, pp. 15-36.

[29] World Wide Web Consortium. *Standards for Web Applications on Mobile; Current State and Roadmap*. http://www.w3.org/Mobile/mobile-web-app-state/. Last accessed February 27, 2016.

[30] World Wide Web Consortium. Mobile Web Best Practices 1.0 Basic Guidelines. W3C Recommendation 29 July 2008. http://www.w3.org/TR/mobile-bp/. Last accessed February 27, 2016.

[31] World Wide Web Consortium. Mobile Web Application Best Practices. W3C Recommendation 14 December 2010. http://www.w3.org/TR/mwabp/. Last accessed February 26, 2016.

[32] See World Wide Consortium. MobileOK Checker. https://validator.w3.org/mobile/. Last accessed February 20, 2016.

99.2% of the urban libraries polled and 95.3% of the rural libraries accounted for offered Wi-Fi services. Slightly more than one-third of the libraries in the survey supported wireless printing.[33]

In terms of the speed of connectivity, data presented in Broadband Quality in Public Libraries: Speed Test Findings and Results indicates that in urban libraries the median speed of a download based on a Wi-Fi connection during light usage is 19,618 Kbps (19.16 Mbps) versus 1,009 Kbps (.99 Mbps) during heavy usage, whereas he median upload speed for a Wi-Fi connection during light usage is 10,517 Kbps (10.27 Mbps), as opposed to 291 Kbps (.28 Mbps) during heavy usage.

For suburban public libraries, the data indicates that the median download speed for a Wi-Fi connection during light usage is 16,198 Kbps (15.81 Mbps), and 9,017 Kbps (8.80 Mbps) during heavy usage. The median upload speed during light usage is 7,617 Kbps (7.44 Mbps) versus 3,445 Kbps (3.36 Mbps) during heavy usage. For town libraries, the median speed during light usage is 9,783 Kbps (9.55 Mbps) versus 7,293 Kbps (7.12 Mbps) during heavy usage. The median upload speed during light usage is 3,056 Kbps (2.98 Mbps) versus 2,569 Kbps (2.51 Mbps) during heavy usage. And, for rural libraries, the median download speed during light usage is 9,783 Kbps (9.55 Mbps) versus 7,293 Kbps (7.12 Mbps) during heavy usage, and the median speed during light usage is 3,056 Kbps (2.98 Mbps) versus 2,569 Kbps (2.51 Mbps) during heavy usage.[34]

In all instances, there is substantial variance from location to location. More than a quarter of the users of city libraries experience average Wi-Fi download speeds in the 10.1Mbps-24.9Mbps range, whereas slightly more than 20% have access at speeds below 1.5Mbps. More

[33] Bertot, John Carlo, et al. 2013 *Digital Inclusion Survey: Survey Findings and Results*. Information Policy & Access Center, University of Maryland. 2014.

[34] Berto, John Carlo, et al. *Broadband Quality in Public Libraries: Speed Test Findings and Results*. Information Policy & Access Center, University of Maryland. (2015.) pp. 10-20.

than one-third of the suburban libraries included in the survey provide download speeds in the 10.1Mbps-24.9Mbps range.

The speeds delivered by town and rural libraries tend to be much slower. Almost half of the town libraries survey provided wireless services in the range of 1.6Mbps-10Mbps range for downloads. Almost half of the rural libraries are in the same range for downloads, but rural libraries fall substantially behind town libraries in terms of Wi-Fi upload speeds, with more than half of them reporting upload speeds of 1.5Mbps or less, whereas slightly less than half of the town libraries reported average upload speeds in the 1.6Mbps-10Mbps range. (The study also considers the "drop off" between subscribed speed and actual speed of network connections. The data presented indicate that the differences are considerable, and certainly great enough to have a significant impact on many types of Internet use — for example, upload speeds drop off by 47% for city libraries, 55% in suburban libraries, 67% in town libraries, and by 76% in rural libraries — but the data are based on wired connections only and do not take Wi-Fi connectivity into account.[35])

Unfortunately, the aforementioned report offers almost no information about the more specific nature of the Wi-Fi deployments in those libraries or the quality of services that are delivered through wireless connections. The report does suggest, however, that slightly more than half of the librarians surveyed in this study believe that the bandwidth provided by their respective libraries for patrons is not adequate, with the majority of them of the view that the costs of increasing bandwidth were the foremost constraint.

[35] Berto, John Carlo, et al. Broadband Quality in Public Libraries: Speed Test Findings and Results. op cit. pp. 26.

Types of Wireless Networks and Relevant Standards

Owing mainly to standardization, the technical framework in terms of which wireless networks function has remained stable since the mid-1990s, with changes and developments running by general agreement through processes attending IEEE 802.11, the set of standards for wireless local area network (WLAN) computer communication, as developed by the IEEE LAN/MAN Standards Committee (IEEE 802), for use in the 2.4 GHz and 5 GHz public spectrum bands.[36]

There are two types of wireless networks. The first type is a so-called "ad hoc," or peer-to-peer network, consisting of two or more computers each equipped with a wireless networking interface card. Each computer may communicate directly with all of the other wireless-enabled computers on the peer-to-peer network. The computers on the network can share files and other resources, such as a printer, under this configuration, but they may not be able to access resources on a wired LAN, unless one of the computers in the peer-to-peer network also acts as a bridge to the wired LAN. A wireless network may also use a physical access point, commonly referred to as a base station. In this configuration, the access point acts as a network hub, providing connectivity for the wireless computers. The main purpose of the access point is to provide a link (or "bridge") from a wireless LAN to a wired LAN, thus allowing wireless computer access to LAN resources, such as file servers or an existing Internet connection. This second type of network is the one used almost universally by public libraries offering wireless services.

There are two types of access points. The first and most commonly employed is the dedicated hardware access point. It is a wireless device that handles all the network traffic to and from its associated clients, usually within a range of about 300 feet and with the option of a

[36] See IEEE Web Portal at http://standards.ieee.org/findstds/standard/802.11-2012.htmlfor additional information about the IEEE and the 802.11 standard.

coded radio frequency for secure transmissions. In the vast majority of installations, the hardware access point is connected to a traditional, "wired" Ethernet network, thereby acting as bridge between the wired and wireless networks.[37] In many instances, because the wired LAN is connected to the Internet, shared access to the Internet is available to the clients connecting through the wireless access point. The second type of wireless access point is the software access point. A software access point is an application that runs on a computer equipped with a wireless network interface card configured for use in an ad hoc or peer-to-peer wireless network. Typically, the application is a software router that provides external connectivity through the Point-to-Point Protocol over Ethernet (PPPoE) specification.

Recent Developments in WLAN Standards

The newest generation of Wi-Fi signaling in popular use is IEEE 802.11ac.[38] It utilizes dual band wireless technology and channel binding, supporting simultaneous connections on both the 2.4 GHz and 5 GHz Wi-Fi bands to increase the bandwidth available to compatible devices. Offering backward compatibility to 802.11b/g/n, 802.11ac is rated up to 1300 Mbps on the 5 GHz band and up to 450 Mbps on 2.4 GHz.

The previous versions of the 802.11 standards have typically used 20 MHz channels, although 802.11n used up to 40 MHz wide channels. The 802.11ac standard uses channel bandwidths up to 80 MHz wide as

[37] Most hardware access points cannot communicate with each other on the basis of a wireless connection. Typically, an access point can communicate only with its wireless clients. The exception is the wireless repeater, a device that receives a signal and retransmits it at a higher level and/or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances without degradation. What is more important, wireless access points cannot be used to bridge wireless LANs.

[38] The 802.11 family of standards specifies an over-the-air interface between a wireless client and a base station or between two wireless clients. The IEEE accepted the specification in 1997.

standard with options of 160MHz or two 80MHz blocks. According to the IEEE, 802.11ac raises data throughput rates attainable on Wi-Fi networks to a minimum of around 1 Gbps, with speeds up to 6.93 Gbps possible. There are bottlenecks, however. Routers based on 802.11ac generally use multiple antennas to increase overall data rates, but when a user with a single-antenna 802.11ac-compatible smartphone connects to such a router, the data rate is likely to be somewhere between 400Mbps — the theoretical maximum — and 200Mbps.

Efforts to extend 802.11ac are already well under way. For example, IEEE 802.11ad is an amendment that defines a new physical layer for 802.11 networks to operate in the 60 GHz millimeter wave spectrum -- this frequency band has different propagation characteristics than the 2.4 GHz and 5 GHz bands, where Wi-Fi networks normally operate -- IEEE 802.11af is another amendment, that allows WLAN operation in the so-called "TV white space spectrum," which is situated in the VHF and UHF bands between 54 and 790 MHz, and IEEE 802.ah, which offers, owing to the favorable propagation characteristics of the low frequency spectra, improved transmission range when compared with the conventional 802.11 WLANs operating in the 2.4 GHz and 5 GHz bands.

The deployment of the newer standards is likely to occur over the next few years -- routers supporting 802.11ac are readily available at this writing -- but available information about replacement schedules devised by libraries, or the lack thereof, suggest that the capabilities of 802.11ac and its amendments are unlikely to have any broad effect in the short term on the wireless services offered by libraries, particularly services based on local installations. According to the *Public Library Technology Landscape* report from 2012:

> Overall, a majority of public libraries (63.2 percent) do not have replacement schedules and replace their work-

> stations only as needed. There is a stark difference between the replacement policy schedules of urban and rural libraries. The majority of urban libraries (57.3 percent) have an established replacement policy, whereas the majority of rural libraries (69.5 percent) do not. The majority of suburban libraries (53.4 percent) had a replacement schedule in 2010-2011, but this percentage decreased to 41.9 percent in 2011- 2012.[39]

Security Issues

The security vulnerabilities of wireless local networks fall within the following areas:

- Passive monitoring;
- Unauthorized access; and
- Denial-of-service attacks

Wireless LANs radio signals that often go beyond the limits of the area an organization physically controls. For instance, radio waves easily penetrate building walls and can be received from the facility's parking lot and possibly a few blocks away. As a result, it is possible for an unauthorized person to gain access to a wireless network, use licensed resources on an illicit basis, and even passively retrieve sensitive information about configurations, licenses and other permissions, or legitimate users. How difficult is it to engage in passive monitoring? A hacker with a wireless laptop and so-called "packet sniffer" could capture data streaming across a library's wireless network from a park bench across the street from their town's public library and then, for example, extract sensitive information, including passwords. The method for resolving issues of passive monitoring is to implement secure connections between all client devices and the access points through encryption. An encryption scheme alters the information bits

[39] American Library Association. *Public library technology landscape*. (2012). p. 22.

in each frame of data transmitted by using encrypted keys. The goal is to make data captured via passive monitoring unusable. However, some of encryption schemes are much more effective than others. The Wired Equivalent Privacy (WEP) scheme, which was part of the original 802.11 standard, is relatively easy to crack, whereas other encryption methods, such as Wi-Fi Protected Access (WPA), are much more difficult to break and therefore offer much stronger security.[40]

The extent to which unauthorized access to a wireless network is a problem depends largely on the skill with which wireless networks and connected wired networks are managed where security is concerned. Many organizations lock down servers and applications effectively, close unused ports, and apply software patches and updates regularly to guarantee the integrity of their networks, but many other organizations are considerably less vigilant, even when confronted with abundant evidence of the problems that can arise in a poorly secured network. Perhaps more to the point, any network that permits external access is potentially vulnerable. The objective of security regimes is to reduce the number of unauthorized intrusions to a minimum.

Wireless networks are particularly vulnerable to denial-of-service attacks.[41] Today, most wireless networks in place rely on the 2.4 Ghz band. In the United States, under Federal Communications Commis-

[40] WEP is used at the two lowest layers of the OSI (Open Systems Interconnection) model - the data link and physical layers -- and therefore does not offer end-to-end security. (The OSI model, which divides a communication system into seven abstract layer, is a conceptual framework that characterizes and standardizes the communication functions of a telecommunication or computing system independent of its underlying internal structure and technology, with the aim of promoting interoperability by means of standard protocols.)

[41] A denial-of-service attack (DoS) is an explicit attempt to prevent legitimate users of a service from using that service. There are two general forms of DoS attacks: those that are designed to crash services and those are intended that flood services with data packets and thus render them unable to respond to other requests for service.

sion's regulations, the 2.4 Ghz band provides only three non-overlapping channels -- channels 1,6, and 11 -- which means that targeting and directing a denial-of-service attack on a wireless network can be relatively simple, since an attacker needs only to cause enough interference into those three channels to cause a serious service interruption.[42] In addition, denial of service attacks can launched in concert with the use of a so-called "rogue access point." The rogue access point can be setup in a channel not used by a legitimate access point. Then, a denial of service attack may be launched at the channels currently in use on the legitimate access point, causing endpoint devices to re-associate with a channel in use on the rogue access point and creating conditions under which users may unwittingly reveal confidential information of various types, e.g., userID, password, address, telephone numbers, credit card numbers, Social Security number, etc.

There is no foolproof method of thwarting denial-of-service attacks, but packet filtering, a firewall technique used to control network access by monitoring outgoing and incoming packets and allowing them to pass or halt based on source and destination Internet Protocol (IP) addresses, protocols and ports, is probably the most effective and most widely used of the means available. The use of Media Access Control (MAC) address filtering can also be effective under circumstances sufficiently controlled to permit its implementation.[43]

[42] A non-overlapping channel is one that does not share frequency space, meaning in this case that the use of the channels is restricted to devices supporting wireless networking, and that other devices, e.g., microwave ovens, telephones, etc., designed to operate within the 2.4 Ghz band, are not licensed to use these specific channels.

[43] A MAC address, also called physical address, is a unique alphanumeric string separated by colons, e.g., 00:02:D1:1A:2D:12, that is used to identify networked devices as they send and receive data over the network. MAC addresses are used as a network address for most IEEE 802 network technologies, including Ethernet and Wi-Fi.

Bluetooth, or Wireless Personal Area Networks

An increasing number of wireless devices also support a short-range data transfer technology known as Bluetooth. Bluetooth, a standard developed by a telecommunications industry consortium, is a so-called "WPAN (wireless personal area network) technology" that is designed to connect personal devices within a small area. Although library technologists have focused mainly on 802.11-based networking technologies, Bluetooth-based devices are important in many settings, and they may play a much larger role in the years ahead.

The purpose of Bluetooth technology is to develop and deploy a standardized, low-powered radio chip that may be used to connect devices within a wireless network with a range of 10 meters extending in all directions. The Bluetooth chip is designed to replace cables by taking the information normally carried by cables to and from devices such as printers, keyboards, mice, and PDAs and transmitting it to a radio receiver.

Bluetooth chips are commonly placed in computers, printers, keyboards, and mice, replacing short-range cables. They are also found in a wide variety of other devices, including smartphones and tablet computers.[44] Recent versions of the Bluetooth specification include the use of a collocated 802.11 link running at data traffic (Version 3.0 and 4.0 of the Bluetooth Core Specification), a privacy layer and IP connectivity, including IPv6 connections, to support connected buildings and other IoT implementations (Bluetooth v4.2).[45]

[44] The Bluetooth specification was originally conceived by Ericsson in 1998, before a number of other companies began to collaborate and eventually launched the Bluetooth Special Interest Group.

[45] Bluetooth uses the microwave radio frequencies in the 2.402- 2.480 GHz range. USB 3.0 devices, ports and cables interfere with Bluetooth devices, owing to the close operating proximity of Bluetooth and USB 3.0 usage in the radio spectrum. The conflicts can result in a drop in throughput or complete connection loss of the Bluetooth device/s connected to a computer. Solutions range from increasing the distance of USB 3.0 devices from any

The future of Bluetooth may turn largely on its support for a technology called "beamforming," which concentrates data transmission so that more data reaches the targeted device instead of radiating out into the atmosphere. Beamforming is also supported by IEEE 802.11ac. At present, Bluetooth's support for beamforming is a key element in new technologies that support remote charging of wireless devices, but it also holds the prospect of being to connect a mobile device to Bluetooth-compatible display devices at rates high enough to sustain high-resolution pictures.[46]

RFID

Another aspect of wireless technology in libraries is the use of radio-frequency identification, or RFID, and wireless sensors.[47] Activities that can benefit from the use of RFID include circulation, inventory management, and item processing. In addition to making each of these labor-intensive activities more efficient, RFID installations also guard against the loss of physical items through misplacement or theft. [48] [49]

Bluetooth devices to purchasing USB cables with higher-quality shielding to applying additional shielding to the internal Bluetooth components of a computer.

[46] Wireless power system charges devices up to 20 feet away. ExtremeTech. January 6, 2015. http://www.extremetech.com/extreme/196868-wireless-power-system-charges-devices-up-to-20-feet-away. Last accessed February 26, 2016.

[47] RFID uses electromagnetic fields to identify and track tags attached to objects. The tags contain electronically stored information; passive tags collect energy from a nearby RFID reader's interrogating radio waves, whereas active tags have a local power source, such as a battery, and can operate at a considerable distance from an RFID reader.

[48] Hardgrave, Bill C., John Aloysius, and Sandeep Goyal (2009). "Does RFID improve inventory accuracy? A preliminary analysis". *International Journal of RF Technologies: Research and Applications* 1 (1): 45–56. doi:10.1080/17545730802338333.

[49] Suthar, Ashokkumar A. RFID: An Emerging Technology for Libraries. *Asian Journal of Multidisciplinary Studies*. 2 (7): 43-46.

A 2013 study suggests that if the quality of a RFID implementation is "good," the use of resources increases and user satisfaction is higher.[50] There are, however, concerns about the possibility of RFID implementations in libraries leading to the violation of the privacy of readers.

Efforts to secure RFID systems have been extensive, but concerns persist, owing to the nature of RFID implementations and the possibility of personally-linked information being collected and read.[51] There is, moreover, an interest, nascent at this writing, in using RFID, wireless sensors, and artificial intelligence in concert to automate aspects of the reader's advisory function and build digitally defined paths that users might follow in order to reach their particular objectives in the use of library resources. This use is certain to raise serious privacy concerns.

But precisely how librarians will respond is unclear. Another recent study of RFID implementations in libraries suggests that in many instances the analysis of potential ethical issues has not been a central part of the process of implementing RFID technology — in those cases, the consideration of ethical issues had either been delegated to local government or vendors, whose claims for privacy protection appear to have been taken at face value, and in other cases ethical issues had

[50] Dwivedia, Yogesh K., Kawaljeet Kaur Kapoorb, Michael D. Williams, and Janet Williams. RFID systems in libraries: An empirical examination of factors affecting system use and user satisfaction. *International Journal of Information Management* 33 (2013) 367–377.

[51] The International Organization for Standardization(http://www.iso.org/) has been active in the development of specifications aimed at securing RFID installations. For example, ISO/IEC 18000 and ISO/IEC 29167 use on-chip cryptography methods for tag and reader authentication, over-the-air privacy, and support of efforts to make the tags untraceable, and ISO/IEC 20248 specifies a digital signature data structure for RFID and barcodes providing data, source and read method authenticity. (This work has been done within the framework of ISO/IEC JTC 1/SC 31 Automatic identification and data capture techniques.)

been treated as peripheral, if at all.[52,53,54] In the long term, however, it is reasonable to expect that a continuation of the librarianship's longstanding commitment to the privacy of readers will shift perceptions and lead to the imposition of sharp limits on the extent to which these technologies are placed in the service of individual clients.

Conclusions

In summary, wireless access as provided by libraries is vital to their function as academic or public computing centers. In order to maintain effective function in that area, libraries must provide wireless services of high quality. Because there is not enough information currently available about the specific nature of deployments and support for relevant standards, it is impossible to know what might constitute the best prospects for maintaining these services at high levels, but the example of the Seattle Public Library and its use of mobile hotspots is one that should be considered carefully.

Mobile access is already of critical importance to libraries and their users, and the emergence of the 5G mobile networks in the next few years is likely to enlarge the demands for mobile services. The continued development of and improvements in mobile applications is essential, but the construction of mobile-friendly Websites is probably far more important, given the evidence that mobile users are accessing

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[52] Ferguson, Stuart, Clare Thornley, and Forbes Gibb. How do libraries manage the ethical and privacy issues of RFID implementation? A qualitative investigation into the decision-making processes of ten libraries. *Journal of Librarianship and Information Science* 2015, Vol. 47 (2) 117–130.

[53] R-Moreno, María D., Bonifacio Castaño, David F. Barrero, and Agustín M. Hellín. "Efficient Services Management in Libraries using AI and Wireless techniques." *Expert Systems with Applications* 41, no. 17 (2014): 7904-7913.

[54] Griol, David, Miguel Ángel Patricio, and José Manuel Molina. "The CALIMACO Multimodal System: Providing Enhanced Library Services Using Mobile Devices." In *Bioinspired Computation in Artificial Systems*, pp. 339-348. Springer International Publishing, 2015.

content with increasing frequency and in progressively larger numbers. And, suffice it to say, the security and privacy of mobile applications and services must be ensured with the greatest possible vigor, inasmuch as the confidence of users is closely aligned with their continuing use of digital library resources.

New technologies? The use of RFID and artificial intelligence as means of helping users locate and select resources is an intriguing possibility, but also one fraught with dangers. Librarians need to consider any technology that has the potential to reduce friction in the use of library resources, whether those resources are analog or digital, but they need to exercise great care in doing so.

In Pew's *Libraries at the crossroads*, the authors note that the number of Americans using libraries may be trending downward. [55]While the report is careful to note that there is not enough data available to draw broad conclusions, it seems reasonable to conclude that reversing this trend may well depend in large part on the extent to which libraries of all types come to grips with the needs and requirements of mobile users.

[55] Horrigan. *Op cit*, p. 2.