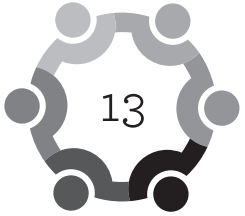

LOCKSS Networks

Community-Based Digital Preservation

Aaron Trehub, Corey Davis, Mark Jordan, Cinda May, and Sam Meister

Ten years ago, the landscape of working digital preservation (DP) solutions and networks was sparsely populated. Today, there is a wide variety of DP approaches and solutions to choose from. In 2013, the Digital POWRR project identified over sixty DP tools and services.[1] Today, that number has grown to include not just DP-related tools, but comprehensive DP networks and turnkey solutions. Institutions can outsource the preservation of their digital content to private companies that are active in the library, archives, and museum (LAM) market space. They can also take advantage of cloud services such as DuraCloud, Amazon Glacier, or Google Nearline/Coldline.[2] Academic institutions can join membership networks such as the Digital Preservation Network or the Academic Preservation Trust.[3] Or they can form other types of associations based on geographic proximity, institution type, or some other shared characteristic or interest.

One approach that has proven successful over time involves building community-based networks around the open-source LOCKSS (Lots of Copies Keep Stuff Safe) software application.[4] These networks have gone under various

From *Digital Preservation in Libraries: Preparing for a Sustainable Future*, edited by Jeremy Myntti and Jessalyn Zoom (Chicago: American Library Association, 2019).

names since their appearance in the early 2000s. For the sake of simplicity, we will refer to them here as Community LOCKSS Networks, or CLNs. Starting with the first Community LOCKSS Network—the MetaArchive Cooperative, in 2003–2004—CLNs have spread throughout the United States, Canada, Latin America, and Europe. There are currently at least 15 CLNs around the world, including networks in Belgium, Brazil, Germany, Sweden, Switzerland, and the United Kingdom.

Distributed Digital Preservation (DDP), LOCKSS, and CLNs

Digital preservation is the corollary to digital collections. Like many things having to do with infrastructure, it is mostly invisible, unglamorous, and absolutely necessary. It is also difficult to capture all of its facets in a single definition. As Thomas C. Wilson has written, "digital preservation is not just one thing; it is a cluster of many practices, policies, technologies and structures." Furthermore, it is "a game of probabilities," the goal being "to perform certain sets of actions that together mitigate the risks associated with digital objects." For these reasons, Wilson concludes, "there is a hierarchy of digital preservation needs," as well as of solutions.[5]

The overarching need for digital preservation is clear. Although precise figures are hard to come by, it is generally recognized that most of the world's information is currently being produced in digital form. In 2013, the website ScienceDaily reported that 90 percent of the world's data had been created in the previous two years.[6] Looking to the future, another study claims that the "digital universe" is growing by 40 percent each year, doubling every two years, and will reach 44 zettabytes (44 trillion gigabytes) by the year 2020.[7] This poses a serious challenge to libraries, archives, museums, and other cultural heritage organizations, as well as government agencies. Digital files are inherently susceptible to decay, corruption, destruction, and disappearance. Given the vulnerability of digital content to fires, floods, tornadoes, hurricanes, power blackouts, cyberattacks, and a variety of hardware and software failures, cultural heritage organizations need to start incorporating long-term digital preservation procedures for locally owned and created digital content into their routine operations, or risk losing that content irrevocably. In 2012, the then-head of the British Library's digital preservation program remarked that "if we're not careful, we will know more about the beginning of the 20th century than the beginning of the 21st century."[8] This danger has if anything become even more acute in the intervening years.

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Fortunately, a number of viable digital preservation solutions have emerged in the past decade. One successful approach combines distributed digital preservation (DDP) with LOCKSS, an open-source, peer-to-peer software application developed at the Stanford University Libraries in the late 1990s. The result is the Community LOCKSS Network, or CLN.

As its name implies, DDP is based on the idea of distributing copies of digital files to server computers at geographically dispersed locations in order to maximize their chances of surviving a natural or man-made disaster, power failure, or other type of disruption. DDP networks consist of multiple preservation sites that have been selected with the following principles in mind:

- Sites preserving the same content should not be within a 75–125-mile radius of one another.
- Preservation sites should be distributed beyond the typical pathways of natural disasters, such as hurricanes, typhoons, and tornadoes.
- Preservation sites should be distributed across different power grids.
- Preservation sites should be under the control of different systems administrators.
- Content preserved in disparate sites should be on live media and should be checked on a regular basis for bit-rot and other issues.
- Content should be replicated at least three times in accordance with the principles detailed above.[9]

LOCKSS was originally designed to harvest, cache, and preserve copies of e-journals for academic libraries, but it is also effective at harvesting, caching, and preserving multiple copies of locally created digital content for cultural heritage organizations of all types. LOCKSS servers typically perform the following functions:

- They collect content from target websites using a web crawler that is similar to those used by search engines.
- They continually compare the content they have collected with the same content collected by other LOCKSS boxes, and repair any differences.
- They act as a web proxy or cache, providing browsers in the library's community with access to the publisher's content or the preserved content as appropriate.
- They provide a web-based administrative interface that allows the library staff to target new content for preservation, monitor the state of the content being preserved, and control access to the preserved content.

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In 2016, the LOCKSS program joined the Stanford University Libraries' Digital Library Systems and Services (DLSS) group in recognition of their complementary missions, competencies, communities, and infrastructures. As part of that transition, the LOCKSS development team has embarked on a major re-architecture of the LOCKSS software in order to better leverage solutions developed by the web archiving community and to facilitate the integration of LOCKSS technologies into new solutions. On the outreach side, the program is investing in the development of new LOCKSS networks to support an expanding set of content types and use cases. The LOCKSS program recently hired a full-time partnerships manager to assist with these efforts.

A Community LOCKSS Network (CLN) consists of a group of institutions that share a common dedication to community-based digital preservation and are bound by a common governance document and set of operating principles. From a technical standpoint, CLNs consist of geographically distributed servers (known as "caches" in LOCKSS terminology) that are configured to run the LOCKSS software. After a cache is up and running, it can continue to run even if it loses contact with the central server. This peer-to-peer technological structure has proven to be especially robust against failures, even cascading hardware failures. If any cache in the network fails, others can take over. If a cache is corrupted, any other cache in the network can be used to repair it. Since all caches are alike, the work of maintaining the network is truly distributed among all of the partners in the network. This is one of the great strengths of the LOCKSS-based DDP approach.

Since they are entirely community-designed, community-run, and community-oriented, CLNs represent community-based digital preservation in an especially pure form. This means that they are especially well-suited to building communities of practice—not only for relatively well-resourced institutions such as large research universities, but also for less-resourced institutions such as small colleges, middle-tier universities, public libraries, and institutions that serve historically underrepresented or marginalized communities—for example, historically black colleges and universities in the United States.

CLNs in North America

Although there are LOCKSS-based DDP networks in Europe (e.g., the UK LOCKSS Alliance and the Belgium-based SAFE network) and Latin America (e.g., the Cariniana network in Brazil), most of the CLNs are currently based in

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North America.[10] This chapter focuses on five of them: the MetaArchive Cooperative, an international preservation network which began in 2003–2004 with support from the U.S. Library of Congress's NDIIPP Program; the Alabama Digital Preservation Network (ADPNet), a statewide preservation network that began in 2006 with a two-year grant from the Institute of Museum and Library Services (IMLS), a federal funding agency; COPPUL WestVault, a network serving academic libraries in western Canada; the PKP Preservation Network (PKP PN), a global network preserving Open Journal Systems (OJS) content; and the Indiana Digital Preservation Network (InDiPres), a subsidiary consortial network within MetaArchive and the most recent addition to the list of CLNs in North America.[11]

Although they differ from each other in composition, focus, and administrative structure, all five of these CLNs have some features in common. These include a membership model that has low barriers to entry and that is flexible enough to serve large and small institutions alike; a shared governance structure that can respond to changing circumstances; a financial model that keeps costs low while ensuring that the network has a strategic reserve that can be used for network needs (e.g., new servers or additional storage); and a robust technical infrastructure consisting of at least five to six geographically dispersed LOCKSS servers with multiple terabytes of storage capacity, as well as web servers for staging digital content for ingest into the networks. Table 13.1 shows the current (2017–2018) cost categories and the number of copies for the five networks:

Table 13.1 • Cost categories and number of copies (2017–2018)

NETWORK	MEMBERSHIP FEE (ANNUAL)	STORAGE FEE (ANNUAL)	TECHNOLOGY FEE(S) (ANNUAL)	COPIES
MetaArchive Cooperative	$2,500–$5,500 per single member; Collaborative memberships also available	$.59/GB	$2,000 (for members not running a cache)	6-7
ADPNet	$300–$2,500 per member	$.25-$.50/GB	n/a	5-6
COPPUL WestVault	TBD	$2,000/TB (preliminary)	TBD	5-6
PKP PN	n/a	n/a	n/a	8
InDiPres	$2,500, divided among the members	$.59/GB	n/a	6-7

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MetaArchive Cooperative

The MetaArchive Cooperative is a community-owned, community-led network that preserves digital content for more than sixty member institutions. Its mission is to foster a better understanding of distributed digital preservation methods and to create enduring and stable, geographically dispersed "dark archives" of digital materials that can, if necessary, be drawn upon to restore collections at member organizations.

As the first CLN in North America, MetaArchive was founded in 2004 to develop a collaborative digital preservation solution for special collections materials, including digitized and born-digital collections. Working cooperatively with the Library of Congress through the NDIIPP Program, the founders sought to embed both the knowledge and the technical infrastructure of preservation within MetaArchive's member institutions. They selected the LOCKSS software as a technical framework that matched the cooperative's principles to promote the curation and preservation of digital special collections, including newspapers, electronic theses and dissertations, photographs, audio, video, datasets, and more. In doing so, they created a secure, cost-effective preservation storage solution that fosters ownership rather than the outsourcing of this core library/archive mission. MetaArchive moved to an open membership model in 2007 and has expanded in the past decade from a small group of six academic libraries in the southeastern United States to an extended community of more than sixty academic libraries, public libraries, archives, museums, and research centers in the United States, Brazil, and Spain.

It is through the active engagement and committed work of its members that MetaArchive has been able to achieve its current longevity and sustainability. MetaArchive members drive all governance decisions through their participation in the Steering Committee and targeted committees. Committees and working groups meet regularly, take on specific projects, and produce outputs that have a direct impact on network operations and/or local members' digital preservation practices. For example, committee members assisted in the process of conducting a Center for Research Libraries (CRL) Trustworthy Repositories Audit and Certification (TRAC) checklist audit in 2009 in order to assess the network's preservation capabilities.[12] As an Affiliated Community of the Educopia Institute, the MetaArchive Cooperative's activities are supported by a community manager and other staff who assist the members in setting and accomplishing project and strategic goals, as well as ongoing organizational and technical operations.

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With members located in multiple countries, MetaArchive is able to achieve the international-scale replication and distribution of its members' content. The current number of members hosting storage infrastructure has also created substantial capacity in the network that can scale up as needed in response to members' storage needs. To provide a view into the ongoing preservation operations managed by the LOCKSS software, the web-based Conspectus collections management tool was created. Members use the Conspectus to ingest, monitor, and audit content on demand. The Conspectus is regularly updated with new features and functionality in response to members' needs for content management. Currently, MetaArchive is in the early stages of a project to shift the cooperative's infrastructure to a SuperNode network model. This will entail designating a select number of member storage nodes to act as "supernodes" by expanding their total data storage capacity, as well as by incorporating additional "staging" server infrastructure in order to simplify the process for getting content into the network.

Developing and promoting an affordable entry point to digital preservation have been a primary motivation throughout MetaArchive's existence.[13] Soon after MetaArchive was launched as a membership organization, the Steering Committee created the Collaborative membership category in recognition of the need for a membership category that would allow multiple small organizations to band together to share and distribute the costs of membership in the network. Similarly, the organization has continually sought to lower the technical barriers (server-hosting and system administration) to joining and participating in the network. After a trial period of granting exceptions to the server-hosting requirement, MetaArchive has formalized this as an option where members can pay an annual technology fee as an alternative to hosting server infrastructure. In addition to evaluating and refining membership categories, the MetaArchive leadership has likewise regularly lowered the storage fees that members pay in relation to the total amount of data they have stored in the network. As a cooperative endeavor, MetaArchive is designed to be responsive to members' needs, especially those needs related to costs and affordability.

In addition to preserving its members' content, MetaArchive engages regularly with other digital preservation organizations and groups in research and development work to enable the interoperability of the MetaArchive network with other digital preservation approaches (e.g., Chronopolis, DPN, and APTrust). MetaArchive has also pursued research projects around a number of genre-specific curation and preservation issues, including digitized and born-digital newspapers (with National Endowment for the Humanities

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support) and electronic theses and dissertations (with Institute of Museum and Library Services support).

In recognition of its work in the digital preservation field, the MetaArchive Cooperative received the ALA ALCTS George Cunha and Susan Swartzburg Award in 2017.[14] This award pays tribute to individuals or groups that "foster collaboration for preservation" by demonstrating leadership, vision, and initiative in ensuring that libraries, archives, and historical institutions protect our cultural patrimony.

Alabama Digital Preservation Network

The Alabama Digital Preservation Network (ADPNet) is a statewide digital preservation network that serves cultural heritage institutions in Alabama. Its mission is to serve as a low-cost, low-maintenance, geographically distributed digital preservation network for libraries, archives, museums, and other cultural heritage organizations in Alabama. An emphasis on simplicity and cost containment is central to the network's mission. Alabama is a relatively poor state, ranking 46th and 47th out of the 50 states in median household income and per capita income, respectively.[15] The state is also vulnerable to hurricanes and tornadoes, especially along the Gulf Coast. On a more positive note, Alabama is home to a rich and growing array of digital collections at libraries, archives, and museums throughout the state, including AlabamaMosaic, a repository of digital materials on Alabama's history, geography, and culture.[16] This combination of circumstances—vulnerability to natural disasters, limited state funding, and rich digital collections—made Alabama an ideal test case for a simple, inexpensive, but effective digital preservation solution like LOCKSS.

Inspired in large part by Auburn University's experience with the MetaArchive Cooperative, ADPNet began in 2006 with a two-year National Leadership Grant from the Institute of Museum and Library Services (IMLS). The grant provided support to the founding institutions for equipment and associated expenses; crucially, it also covered those institutions' annual membership fees in the LOCKSS Alliance for the same period. For their part, the participating institutions split the equipment costs with the IMLS and contributed staff time and other in-house resources to the project. The goal was to transition from being a grant-funded project to a self-sustaining operation. The network met this goal in fairly short order. For the past ten years, ADPNet has been a financially self-sustaining program operating under the auspices of the Network of Alabama Academic Libraries (NAAL), a department of the Alabama Commission on Higher Education (ACHE) in Montgomery.[17] Achieving

technical independence from the LOCKSS support team took longer, but ADPNet became a fully self-managing LOCKSS network in 2015–2016.

Membership in ADPNet is open to any Alabama cultural heritage institution that creates publicly available digital assets and whose activities and objectives are consistent with the Alabama Digital Preservation Network's mission and principles. This includes but is not limited to universities, libraries, museums, historical societies, and state and municipal government agencies. ADPNet currently has eleven members: the Alabama Department of Archives & History (ADAH) in Montgomery, Auburn University, the Birmingham Public Library (BPL), the Huntsville-Madison County Public Library, Troy University, Tuskegee University, The University of Alabama (UA), the University of Alabama in Birmingham (UAB), the University of Alabama in Huntsville (UAH), the University of North Alabama (UNA), and the University of Montevallo. Like the MetaArchive Cooperative, ADPNet is a member-run network with a formal governance policy. There are two standing committees: the Steering Committee and the Technical Policy Committee (TPC). The Steering Committee holds monthly conference calls to which all members are invited. The TPC meets as needed. The chair of the Steering Committee is selected by the members and typically serves a one-year term. The chair's responsibilities include convening and setting agendas for the conference calls, calling votes on network business, and reporting on the network to the NAAL directors. ADPNet's governance and membership documents have been revised multiple times since the network's inception in response to changing circumstances and opportunities. The most recent revisions took place in 2016–2017 and focused on streamlining the network's membership model to make it simpler and more affordable.

ADPNet has transitioned over the years from being a LOCKSS-managed CLN to operating as a self-managed network. This means that the CLN's members themselves manage the harvesting of content into the network and provide technical support and troubleshooting as needed, although LOCKSS personnel may be called in to assist as a last resort. ADPNet is technologically interesting in that the network configuration server itself is treated as a preservation object and is replicated on the nodes in the network, thus reducing external dependencies and adding another layer of resiliency.[18] The network currently has six preservation nodes and a total storage capacity of approximately 200 terabytes. At the time of writing it contained over 3,200 archival units with over 30 terabytes of content.

As befits a network in a relatively poor state, ADPNet was designed to be as inexpensive as possible. Institutions can join ADPNet in one of two ways: by joining the LOCKSS Alliance (annual fees currently range from $2,489

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for baccalaureate institutions to $12,460 for very large research universities), or by joining ADPNet directly and paying into the ADPNet reserve account, which is managed at The University of Alabama. There are two membership levels in ADPNet: Participant, for $300 per year; and Host, for $2,500 per year. Network storage fees are $.50 per gigabyte/$500 per terabyte for Participant institutions and $.25 per gigabyte/$250 per terabyte for Host institutions. Host institutions maintain a LOCKSS cache and have one full vote on the ADPNet Steering Committee; Participant institutions are not required to maintain a LOCKSS cache and are represented on the ADPNet Steering Committee by a single elected member. In 2016–2017, ADPNet instituted a hardware subsidy program for institutions that would like to acquire a new LOCKSS server or that need to replace an old server. The program is tied to the ADPNet membership year (October 1–September 30) and offers up to $6,000 from the ADPNet reserve account towards the purchase of a new server by up to two institutions in the course of the year. To date, one institution—Auburn University—has taken advantage of the new program.

COPPUL WestVault

The Council of Prairie and Pacific University Libraries (COPPUL) in western Canada is a membership-based academic library consortium representing 22 institutions that collectively serve over 400,000 students and faculty. While the consortial licensing of electronic resources remains the core function of the consortium, the collaborative mechanisms developed to enable this have been leveraged to enable cooperation in other domains, of which digital preservation is one.

COPPUL's digital preservation initiatives have a complex history.[19] The story began in late 2007, when the directors of COPPUL libraries established the COPPUL Private LOCKSS Network, or COPPUL PLN, as a two-year pilot project. The eight founding members of the COPPUL PLN were Athabasca University, Simon Fraser University, and the universities of Alberta, British Columbia, Calgary, Manitoba, Saskatchewan, and Winnipeg. In 2012, COPPUL established the Digital Preservation Working Group (DPWG) to support its strategic focus on digital preservation. In 2015, the DPWG established the COPPUL Digital Preservation Network (COPPUL DPN), with the intention of transforming COPPUL's digital preservation activities into a set of comprehensive, flexible, scalable, and sustainable services. The COPPUL DPN created a Steering Committee in 2017 and, through COPPUL

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membership fees, funds a full-time coordinator position to oversee the day-to-day operations of the network.

The COPPUL PLN laid the groundwork for helping members address the challenges of digital preservation. However, the network itself lost momentum over time because of difficulties getting content into the network, scalability problems (e.g., quickly adding storage to accommodate new content), and the fact that not all the members had the resources to host and run a LOCKSS cache. These issues and others led to significant underutilization of the original network and therefore to a lack of effective geographically replicated preservation storage for COPPUL members.

In order to address these challenges, COPPUL has reorganized the network from the ground up. Among other things, the new network enables drag-and-drop ingest for generic content packages; uses a storage-as-a-service model with "supernode" caches at selected member institutions, thereby eliminating the need for every institution to run a LOCKSS cache; and has created governance structures to simplify network operations and make it easier to add capacity as needed.

The organizers call this new instantiation of their Community LOCKSS Network WestVault.[20] As currently envisioned, COPPUL WestVault provides a high-redundancy peer storage network spread across all four western Canadian provinces. WestVault can also monitor content health, repair damage, and recover from data loss events, and addresses a range of threat scenarios, such as major natural disasters and multiple simultaneous cyberattacks. It also mitigates against human error by preventing any one person from deleting or altering content. WestVault also enables participants to "drag-and-drop" digital content into the geographically distributed storage network, ensuring the longevity, integrity, and accessibility of critical digital content over the long term.

WestVault is overseen by a Working Group for Preservation Storage Infrastructure to be overseen by the COPPUL DPN Steering Committee, with responsibility to advise the COPPUL DPN on infrastructure and best practices for preservation storage, especially as they relate to the development, deployment, and sustainability of the WestVault service. The Working Group will also participate in discussions with the preservation storage community in Canada and internationally, including the LOCKSS network community of practice, and will monitor and advise the COPPUL DPN about preservation storage infrastructure developments as they relate to and impact the WestVault service. The Working Group will also be tasked to oversee the WestVault service and provide support for implementation, operation, and assessment; evaluate

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WestVault operations on an annual basis and make recommendations for enhancements and improvements; and identify potential projects and partnerships to increase preservation storage infrastructure capacity within COPPUL.

As currently envisioned, WestVault runs at campus data centers at five to six COPPUL institutions. This enables all COPPUL members to participate in the service without having to host infrastructure, while at the same time providing the flexibility to meet future storage demands. Libraries from each campus with a participating data center invoice COPPUL for the annual costs of running the necessary software and storage. These total costs are then used to calculate service fees. Pricing is governed by agreements with partner institutions, but is anticipated to be approximately $2,000 per terabyte per year. This pricing includes content-staging and deposit support.

Public Knowledge Project

The Public Knowledge Project (PKP) is based at Simon Fraser University (a member of COPPUL). Established in 1998, the PKP is a multi-university initiative that is developing (free) open source software and conducting research in order to improve the quality and reach of scholarly publishing. Its best-known product is Open Journal Systems (OJS), an open source platform for publishing e-journals. In 2016, the PKP developed a Private LOCKSS Network (PLN) to digitally preserve OJS journals. The PKP PLN was subsequently renamed the PKP Preservation Network (PKP PN). The PKP PN ensures that journals that are not part of the Global LOCKSS Network (which primarily preserves content from larger publishers and vendors) and are not part of an existing CLN (which preserves small numbers of OJS journals hosted by member libraries) can be preserved using the LOCKSS program.[21]

The PKP PN is a free service that uses open-source software and a network of partners to create a "dark archive" of OJS journals. Journals preserved in the network will become "bright" again and be available to the reading public long after their original OJS website is gone. To make this possible, the network of eight partner institutions stores identical copies of each issue, mitigating against loss from natural disaster or human activity. Copies are currently stored across Canada, in the United States, and in Europe.

The distinctive characteristics of the PKP PN are that preparing content for preservation, and ingesting it into the network, has been completely automated, and that the network's membership and governance models are designed to be very lightweight. For instance, to be preserved in the PN, a journal only needs to accept a set of terms of service via a web form within

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OJS, and preservation nodes accept a simple memorandum of understanding with PKP that outlines each party's obligations. The network has an Advisory Panel, whose members represent PKP, the preservation nodes, and allied organizations such as LOCKSS, DOAJ, and the Keepers Registry.

As of July 2018, 22,373 issues from 880 OJS journals had been collected and preserved in the network. Publishers of OJS journals represented in the network include commercial publishers, scientific institutes associated with universities, libraries, and scholarly societies. Many publishers have only one journal in the network, but there are several publishers that have over thirty journals in it. A forthcoming issue of *Digital Library Perspectives* will feature a full-length article on the PKP PN.

Indiana Digital Preservation (InDiPres)

The mission of Indiana Digital Preservation (InDiPres) is to collaboratively manage and sustain a low-cost, secure, and geographically distributed archive for the long-term preservation of locally created digital resources in Indiana.

Between 2007 and 2014, the Indiana State Library (ISL) awarded more than $1,276,000 in Library Services Technology Act (LSTA) digitization grants, resulting in 386,000 digital files. Applicants struggled with questions regarding the sustainability of master files, prompting the ISL to adopt the delivery of a statewide digital preservation solution as one of its strategic directions. In May 2008, stakeholders from across the state attended a Digital Preservation Summit at Indiana State University (ISU). The desired outcome was to identify institutions that were willing to form a Community LOCKSS Network (CLN) in Indiana. Unfortunately, beyond a few initial conversations, the idea did not come to fruition. Three years later, the ISL held a Digital Preservation Planning and Policy Creation workshop and offered funding to jump-start a CLN. Despite this gesture, an insufficient number of institutions agreed to participate. Although these attempts to establish a statewide CLN in Indiana were not successful, the desire to participate in a CLN did not wane. It evolved into the idea of leveraging the collective resources of interested organizations to join an existing CLN.

The MetaArchive Cooperative adopted a Collaborative membership category in 2010. ISU applied for LSTA funding in 2015 and 2016 and partnered with the ISL to create Indiana Digital Preservation (InDiPres), a community-based and -governed organization, for the sole purpose of joining the MetaArchive Cooperative's CLN. Library Services and Technology Act funding covered the initial collaborative membership fees and purchased the server.

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Individuals from Indiana libraries, MetaArchive, and ADPNet assisted with the development of a membership agreement, a governance structure, workflows, and local ingest pathways. ISU and the ISL promoted InDiPres through open digital preservation forums held across the state. Ingests of InDiPres content began in March 2017 with a membership of twelve institutions: the American Legion Auxiliary, Butler University, DePauw University, Knox County Public Library, Lebanon Public Library, Rockville Public Library, Rose Hulman Institute of Technology, the Sisters of Providence of St. Mary-of-the-Woods, Sullivan County Public Library, Vigo County Historical Society, and the Vigo County Public Library. The Indiana State Library is the lead institution, the Indiana State Library Foundation is the fiscal agent, and the Indiana State University Library is serving as the initial host and manager of the NAS and LOCKSS servers until an InDiPres member is able to assume this role. Participating institutions are assessed annual fees that are held in escrow in order to accumulate the necessary monies for InDiPres to be self-sustaining by 2020. Any Indiana institution that is creating digital assets and whose activities and objectives are consistent with Indiana Digital Preservation's mission and principles may join InDiPres.

Charter members gathered for a foundational governance meeting on May 17, 2016, and further developed the InDiPres administrative structure. Using the procedural documents of the MetaArchive Cooperative, ADPNet, Evergreen, and the Indiana Memory DPLA Service Hub for guidance, the representatives drafted a policy that provided for a steering committee with a chair, a chair-elect, a communication officer, and four standing committees—finance, membership/outreach, technology, and nomination. Duties and responsibilities were set; quorums, rules of order, nominations and voting procedures were determined; and decision-making authority was defined. At their August 2016 meeting, the membership approved the Governance Policy, elected officers, and appointed committees. The governance apparatus is intentionally light in acknowledgment of the demands on members' time and to allow participants to focus more on the selection and preparation of their digital content for preservation.

InDiPres seeks to accommodate the needs and resources of a variety of institutional types and sizes; and it offers two ingest pathways to its members—the transfer of data directly to the InDiPres NAS Staging Server and the collection of data on-site using a portable hard drive. The choice of method is left up to the individual members. Content is ingested into the MetaArchive network through a staging area located on the NAS (with 9 terabytes of storage space, divided into an InDiPres folder and a MetaArchive folder).

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Indiana Digital Preservation requires minimal expenditures by its members. The annual membership fee is based on four factors: members pay $100 per year to participate in InDiPres; members share the cost of the MetaArchive Collaborative Membership ($2,500 per year with a three-year minimum); members share the cost of the server housed at Indiana State University (approximately $6,000, with a three-year replacement cycle); and members pay for individual storage needs ($0.59 per gigabyte per year). For example, the membership fee would be $325 per year plus the cost of individual storage, based on twenty members. Membership fees are due July 1, and new members joining during the fiscal year pay a pro-rated amount.

Advantages

The chief advantages of Community LOCKSS Networks are affordability, transparency, mutual support, innovation, diversity, resiliency, security, and local control.

Affordability. The CLN approach allows members to maintain control over the cost of the network and its major inputs (e.g., network storage). CLN members typically review the network's preservation work annually and are fully in charge of setting the costs for continued operations. CLNs are committed to making distributed digital preservation affordable for all kinds of cultural heritage institutions, not just large research universities.

Transparency. Transparency is built into the CLN governance structure. From hardware and software to pricing and budget decisions, CLNs operate in an open-source way. Every member institution in the network has a voice, either through a direct vote on the network executive bodies or (in the case of consortial members) through elected representatives. Other participants—for example, the OJS journals in the PKP PN—are represented on the network's advisory groups.

Mutual Support. Members of CLNs are able to draw on support from other members of their networks and from the larger LOCKSS community. There have been annual CLN Community Meetings every year since 2010 at which representatives from CLNs around the world gather to share updates, policies, apps, ideas, and technical solutions. Collaboration among CLNs and with the LOCKSS Program at the Stanford University Libraries has been strengthened by the hiring of a full-time LOCKSS partnerships manager in 2017.

Innovation. CLNs have developed tools and techniques that build on LOCKSS and make it easier to implement. One example of this is the MetaArchive Conspectus collections management tool, which allows member

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institutions to monitor their content in the network. Another example is LOCKSS-O-Matic.[22] Developed at Simon Fraser University, LOCKSS-O-Matic helps to automate the ingestion of content into a CLN; it also monitors the network to ensure that all member boxes are online and operating normally. The LOCKSS-O-Matic web application acts as the "admin server" for the CLN, which means that the LOCKSS boxes in the network use it as the source for the configuration files that govern what content they harvest and preserve. LOCKSS-O-Matic derives these configuration files from its interaction with other applications (known as content providers) or from people registering content to be preserved using a set of in-browser tools. LOCKSS-O-Matic implements the SWORD protocol to communicate with content providers. The first two content providers to go into production with LOCKSS-O-Matic are the Open Journal Systems plug-in that enables journals to join the PKP PN, and the OwnCloud deposit interface developed by COPPUL. Archivematica (Artefactual Systems Inc.) also has an option to store Archival Information Packages in a LOCKSS Network using LOCKSS-O-Matic.[23] However, LOCKSS-O-Matic is designed to be used with any content management system or other type of application that produces content to be preserved in a LOCKSS network.

Diversity. Openness regarding membership is a distinguishing feature of Community LOCKSS Networks. Most CLNs welcome different types and sizes of organizations, from large research universities to small public libraries. For example, the MetaArchive Cooperative's membership includes academic libraries (including the Atlanta-based HBCU Library Alliance), public libraries, museums, library consortia, and archives. ADPNet's membership includes large research universities, mid-range institutions, public libraries, and the state archives.

Resiliency. CLNs are designed to ensure that digital content will survive an array of threats, ranging from natural or man-made disasters to hardware and software failures. The members of the MetaArchive Cooperative and ADPNet have over the years designed and performed periodic disaster-recovery exercises to test their networks' robustness. Basically, these exercises fall into two categories: exercises for restoring a damaged or destroyed LOCKSS node in the network, and exercises for restoring content from nodes in the network to a server at a member institution. MetaArchive carried out a successful recovery exercise for the first scenario, and ADPNet was able to restore inadvertently deleted content in the second scenario. The networks have also successfully recovered from unplanned failures, and they have incorporated lessons learned from these failures into their ongoing operations.[24] In this respect, CLNs strive to embody the principles of "highly resilient organizations (HROs)."

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Security. As recent national events have shown, even large companies and government agencies are vulnerable to being hacked. LOCKSS was designed from the ground up with this danger in mind. CLNs are dark archives. Access is limited to selected IP numbers and is closely monitored. In 2014, the CLOCKSS Archive—a joint venture of LOCKSS, research libraries, and academic publishers—won the first-ever perfect score in the Technologies, Technical Infrastructure, and Security category of the Center for Research Libraries' (CRL) TRAC audit.[25] No system is hack-proof, but LOCKSS networks offer a high degree of security.

Local Control. Control is key. CLNs are member-owned, member-operated, member-governed, and member-driven. The member institutions make the rules and set the membership fees (if any) and other costs. They can also adjust them if needed. And they maintain complete control over their own content in the network. As recent acquisitions of widely used content-management solutions by commercial publishers have shown, institutions that do not control the tools for managing their information ecosystem are almost entirely at the mercy of external, and often unfavorable, events. Local control of the governance structure, the technology, and the content itself mitigates that risk.

Challenges

Of course, running a CLN also presents challenges. These challenges include ensuring active participation by the members; maintaining institutional commitment; identifying and retaining staff members with the necessary technical expertise; dealing with scalability issues (e.g., the need to add storage capacity quickly if necessary); and keeping costs as low as possible in order to retain existing members and attract new ones, while at the same time building up a strategic reserve that can be used for new hardware and/or storage capacity. A recent National Digital Stewardship Alliance (NDSA) survey has shown that institutions engaged in digital preservation consistently underestimate the amount of storage they will need in order to simply keep pace with the growth in digital content that needs to be preserved.[26] Whether on-site or cloud-based, storage costs money. The larger and more active the network, the more it costs. This can be a barrier to participation, especially by smaller or less-resourced institutions.

Perhaps the most serious challenge to CLNs and other community-based DP solutions is the putative low cost of commercial cloud-based storage services such as Amazon Glacier and Google Archival Cloud Storage (Nearline and Coldline). The LOCKSS program's chief scientist David Rosenthal has

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researched the economics of digital preservation for over a decade, focusing in particular on the comparative cost of various preservation solutions. In 2012, using then-current information on the increasing data density and decreasing cost of magnetic disk storage (also referred to as the Kryder rate), Rosenthal demonstrated that it would be considerably less expensive to preserve eight terabytes of data for four years in a do-it-yourself network of three geographically distributed servers than it would be to preserve the same data for the same period in DuraCloud or Amazon S3.[27] The Kryder rate has slowed down since then, however, and cloud storage has become even cheaper. Surveying the same landscape in 2016, Rosenthal predicted that "increasing technical difficulty and decreasing industry competition will continue to keep the rate at which the per-byte cost of bulk storage media decreases well below pre-2010 levels," leading to "a very large increase in the total cost of ownership of long-term data" over the next decade or two.[28] The implication is that commercial cloud storage services will continue to represent an attractive alternative to community-based DP networks, especially for very large data sets. Local control of the preserved content and of the network remains a key advantage of community-owned solutions, however.

CLNs and DP Standards

How do Community LOCKSS Networks stack up against standards for digital preservation? Specifically, how do they rate when compared against the NDSA's Levels of Digital Preservation and the CRL's Trustworthy Repositories Audit and Certification (TRAC) checklist?

The NDSA Levels of Digital Preservation were first published in matrix form in 2013. They posit four ascending levels of preservation in five categories: Storage and Geographic Location, File Fixity and Data Integrity, Information Security, Metadata, and File Formats (a sixth category, Access, was proposed by Shira Peltzman in 2016).[29] The CLNs discussed in this chapter would score at level 4—the highest preservation level—in Storage and Geographic Location, File Fixity and Data Integrity, and Information Security. They would score at level 3 in Metadata and File Formats. CLNs are dark archives. They are designed for long-term preservation, not access. For this reason, they would not address the proposed additional category that deals with that question. Furthermore, there is an obvious tension between preserving digital content in its original form and allowing it to be modified retroactively to "redact personally identifiable information (PII) and other sensitive material."[30] Repairing bit-rot is one

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thing; the retroactive redaction of digital content is quite another. LOCKSS was specifically designed to prevent the latter. Finding the proper balance between ensuring the long-term integrity and authenticity of digital objects in DP networks while accommodating institutional concerns about personally identifiable information and network security is one of the more difficult issues facing the DP community and the information professions generally.

The MetaArchive Cooperative conducted a Center for Research Libraries TRAC audit in 2009.[31] The results of that audit are publicly available on the cooperative's website and show that the network "conform[ed] to all 84 criteria specified by TRAC and operat[ed] according to the standards of a trustworthy digital repository across each of TRAC's three major areas of activity and concern: Organizational Infrastructure, Digital Object Management, and Technologies, Technical Infrastructure and Security."[32] Although the audit results are specific to MetaArchive, they suggest that other CLNs that have been modeled on MetaArchive would also do fairly well on the TRAC audit.

A word of caution about standards and checklists is necessary here, however. As Thomas C. Wilson has pointed out, TRAC and other OAIS-based audit and certification standards have access-related criteria that "belie an assumption of a live repository that the (general) public would use to access digital materials." For this reason, argues Wilson, "a dark archive [e.g., a CLN] could not be certified as a trustworthy repository, when, in fact, it may actually achieve a more robust preservation strategy."[33]

Conclusion: Community, Continuity, Sustainability

For over a decade, the MetaArchive Cooperative and other CLNs in North America and Europe have demonstrated that it is possible to build community-based digital preservation networks that are affordable, flexible, and resilient. They have also shown that it is possible to build networks that serve a variety of institutions, from large research universities to public libraries. Robert Fox of the University of Notre Dame has identified a number of "key advantages" of peer-to-peer digital preservation networks such as CLNs, including "garner[ing] support from like-minded institutions and rais[ing] the awareness level regarding the preservation of key digital assets"; "the potential to increase the knowledge base required to maintain the preservation systems being used"; and "increas[ing] the opportunity for validity checking, especially in systems that use 'voting' as a mechanism for checking file integrity."[34] Distributed

digital preservation networks also offer excellent opportunities for international collaboration. The geographic separation of LOCKSS nodes is one of the core features of DDP, and the more far-flung the LOCKSS caches are, the more survivable the network will be. It is hoped that this chapter will help to persuade other institutions that LOCKSS-based DDP networks are a technologically viable option for preserving their digital content.

And they are an affordable one. Digital preservation is still widely perceived to be a complex and expensive undertaking, requiring years of planning and large infusions of money and other resources. As Fox put it in 2012, the issues surrounding long-term digital preservation "are daunting not only owing to the complexity of the topic, but also the time commitment that would be required to implement very robust preservation systems."[35] More recently, Tim Marconi and Sibyl Schaefer of the Chronopolis program at the University of California at San Diego Library pointed to a mood of "defeatism" in the information professions regarding the challenges of digital preservation: "There is a lot of talk in the digital preservation world that has a tone of a lack of hope: 'we're never going to be able to do this,' and 'it's so hard.'"[36] The decade-long experience of the CLNs in North America suggests that it is entirely possible to build robust, scalable, and economically sustainable preservation solutions with relatively modest resources. Moreover, it is possible to extend these solutions across different kinds of institutions in different states, provinces, and countries. Taken together, MetaArchive, ADPNet, COPPUL, PKP PN, and InDiPres represent working examples of technologically resilient solutions and offer proof that it is possible to create economically sustainable, community-based digital preservation networks at the state, national, and even international level.

Acknowledgments

The authors would like to thank Art Pasquinelli, Victoria Reich, Katherine Skinner, Bronwen Sprout, and Nicholas Taylor for their comments on successive drafts of this chapter.

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