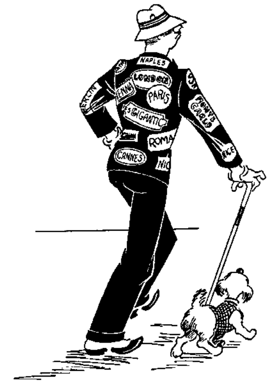
A Prototype Platform for Policy-Based Archival Replication



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Overview

Many threats to preservation are ameliorated through replication of the materials to be preserved by independent *institutions,* combined with regular auditing of that replication.[2] **Data-PASS** partners, as well as others who archive social science data, are prototyping a "syndicated storage" platform that would assist them in such preservation-oriented replication. This system will serve two institutional goals. First, it will help each institution insure against media, software, hardware, and physical failure, since geographically distributed partners will keep separate archival copies. Second, it will help the partnership insure against institutional failure, since if one partner should suffer institutional failure, the partnership as a whole will still retain copies of the holdings of that failed partner, and will be able to redistribute those copies. Many "single points of failure" are eliminated when the institutions involved are diversified with respect to the legal regimes and economic models under which they operate, and the technical preservation strategies that they employ.

Another institutional issue we plan to address is the asymmetrical nature of storage needs among current and potential partners. How do we construct systems that serve both the technology and the business needs for a collective when some members may require an order of magnitude more resources than others? Our institutional policies are asymmetric; some institutional members contribute more resources, or have larger holdings, than others, as illustrated in Figure 1 below.

At this point we have built a prototype that allows us to audit a replication network to determine whether it conforms to our stated replication policies. This prototype system is built around a core of **Private LOCKSS**[3] **Networks (PLN)** technology; a schema to encapsulate inter-archival replication commitments; an automated schema-driven service that audits **PLN's**; and **Open Archives (OAI-PMH)**[4] clients to harvest data collections from the **Dataverse Network**[5] **(DVN)** and other repositories using the **Data Documentation Initiative**[6] **(DDI)** schema.

This work is conducted by the **Data Preservation Alliance for the Social Sciences** (**Data-PASS**). Five major American social science data archives have created the **Data-PASS** partnership to ensure the long-term preservation of our holdings and of materials as yet un-archived.[7] The partners are the **Inter-university Consortium for Political and Social Research**, **The Roper Center for Public Opinion Research**, **The Howard W. Odum Institute for Research in Social Science**, the electronic records custodial division of the **National Archives and Records Administration (NARA)**; and **The Henry A. Murray Research Archive**, with strong technology support from the **Harvard-MIT Data Center**.[8] We seek to acquire and preserve data at-risk of being lost to the research community, such as opinion polls, voting records, large-scale surveys, and other social science studies; develop joint best practices for data preservation; and develop open shared infrastructure for digital preservation.[9]

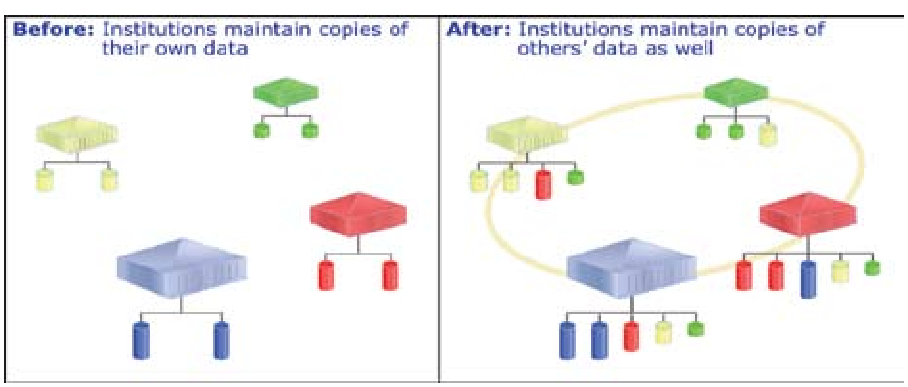

Figure 1: Conceptual Representation of Asymmetric Replication

Design Goals

Our design has three main goals: The first goal is to *automate policy* — the behavior of the syndicated storage system should be automatically auditable by reference to archival policy. We describe these policies formally, using a metadata schema. These formal policies include systematically describing the commitment of resources each of the archives has made to preserve the contents of the other partners; the auditing commitments each has made to its depositors; and the legal policies supporting access to the data by other partners in the case of institutional failure. The system acts on this metadata by auditing the actual state of the replication network, and reporting any deviations from policy. These auditing reports are also schematized, so that they can be used manually (now) or automatically (in future) to initiate corrective action by hosts in the network in response to deviations from policy.

Also as a matter of policy, this schematized approach is integrated with TRAC.[10] The schema can be used to document the TRAC criteria associated with particular commitments, and also to provide evidence in support of a number of criteria related to managing holdings.

A second goal of the design is to keep consistent with the model of trust already among collaborating archives: Each partner is trusted to hold the public content of the others, and not to disseminate it improperly. (Legal agreements among the archives reinforce this trust.) But, no partner is trusted to be a "super-user" and thus to arbitrarily delete content from the network. An implication of the decentralization is that harvesting assignments are completed by "request" — with approval by the local host administrator and not through a "super user" with privileges on all hosts.

The third goal is to accommodate asymmetries in the archival commitments:

- Partners may vary by policy in their commitment of storage for the syndicated storage network.
- Partners may vary by policy in the size of the holdings that they require to be replicated.

In practice, these two asymmetries imply a third — each partner need not replicate the entire network, but only a portion thereof.

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Use Cases

Use cases describe the fundamental desired behavior of a system. We have identified two essential use cases for syndicated storage:

1. Auditing

Compare the actual state of the network to the policy schema (instance), and report any deviations, such as inadequate number of replicas, infrequency of updates, etc.

2. Recovery

a. If a host fails, and is replaced (with a new host having the same credentials), the replacement should be able to use the network to recover all lost content.

b. Any member that was able to harvest the content in the past should be able to recover a copy of content from that time, at any time in the future.

Satisfying these use cases enables each archive to be assured that archival replication policies are being maintained, and that these replications are sufficient for future recovery of content.

We are also investigating automation of the configuration and reconfiguration of the system in order to reduce the effort of managing the network. In theory, these use cases, as well as off-the-path cases in which "requests" to a host node are refused, could be automated, and would eliminate most of the manual maintenance of the network:

1. Initialization

Given a policy schema (instance), send a set of harvesting requests to each host, so that when completed the network will conform to the replication policy.

2. Add replicated collections/hosts

Add new replicated collections and hosts to the networks.

3. Grow hosts/collections

Allow hosts and collections to grow in their resource commitments. (As a design assumption we assume that resources grow monotonically.)

However, given automated auditing, and the limited number of institutions participating in the network, these cases can be readily resolved manually, through communication with the administrators of each host.

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How it Works

The Syndicated Storage Platform (SSP) combines standard **LOCKSS** mechanisms; tools produced by the **LOCKSS** group for managing **PLN's**; and tools developed by the **Data-PASS** partners. An overview is shown in Figure 2 below.

Standard **LOCKSS** mechanisms and software are used for the harvesting framework (although like many others we have created our own plugin), integrity checks, and recovery. Harvesting is conducted by each host in the network using **LOCKSS** plugins. Hosts participate in polls of network content, and restoration occurs automatically when a host has a storage failure, or when a host fails entirely and is replaced with a new host that has the same configuration and credentials.

One should note that the limited trust model has a number of implications for implementation:

- For replication, hosts do not trust other single hosts to provide correct content, so each must be able to harvest its content directly from the source.
- For restores, hosts must have proven that they obtained the content previously, or be specially authenticated.
- No central authority can delete content from the network.
- No centralized authority can make arbitrary changes to any host, or access it through lower level (e.g., operating system) interfaces.
- The SSP also makes use of a **PLN** tool, the "cache manager," which is a tool supplied by the **LOCKSS** group for monitoring **PLN's**. The cache manager is used to gather information on the state of the network. To generate our auditing reports we run the cache manager and analyze the database it produces.

The **Data-PASS** partners have built three supplementary tools to manage the SSP. First, a commitment schema describes institutional replication requirements and commitments. Second, a schema-based auditing tool automatically audits the network against the schema. Third, a specialized harvesting plugin gathers content based on the partners catalog interoperation standards.

The schema describes the network, hosts, and collections (archival units) being replicated. At the network level, the schema describes the number of copies to be maintained and the frequency of updates. At the host level, the schema describes each participating host, and the size of resource commitment it is making available for replication. At the collection level, the schema describes the plugin to use for harvesting, the storage commitment that the organization has made to the network, and the desired frequency of harvesting.

In support of this, the SSP schema provides elements that may be used to include text, or reference external text that documents evidence of compliance with TRAC criteria. Some fields document *how the SSP itself* supports relevant TRAC criteria, while others document how the virtual organization (in this case, the **Data-PASS** partnership) responsible for the SSP is compliant with additional TRAC criteria. Specific TRAC criteria are identified implicitly, and any TRAC criterion can be explicitly identified using schema attributes. The documentation describes each element's relevance to TRAC, and its mapping to particular TRAC criteria.

The auditing tool accesses the database maintained by the cache manager. It queries this database, aggregates the results, and compares them to the commitment schema. A report of all differences between actual and desired state is produced. This difference report can be presented in human-readable form and, more importantly, can serve as input to another stage of processing which outputs a set of changes to be made to the network.[11]

We have built a plugin to facilitate harvesting of content in our archives. Since the **Data-PASS** partners use OAI-PMH and DDI metadata to support a common catalog,[12] we have built upon this approach to replicate holdings. The DDI metadata is structural as well as descriptive, and contains links to each of the files in a research study. We have vastly updated and extended the OAI plugin so that it will handle this. In particular we have extended the plugin in the following ways:

- The plugin can now be configured to harvest a specific group of OAI "sets" corresponding to the archival units being shared by the partners.
- The plugin can now handle several sorts of authentication. HTTP "basic" authentication is now built-in, and other forms of authentication can be included via hooks to supplied libraries. Since many partners use the Dataverse Network,

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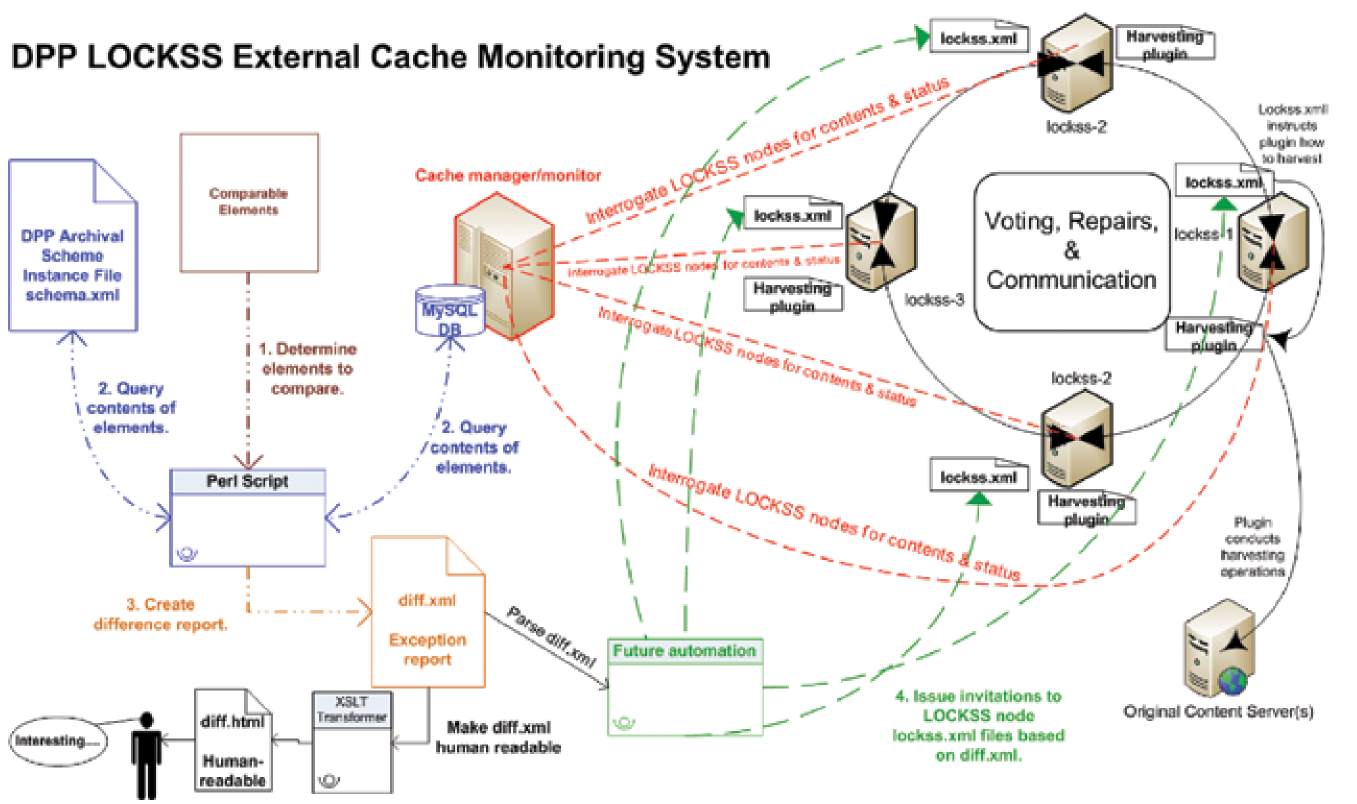

Figure 2: How the Syndicated Storage Platform Works

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these hooks are designed to interface with the Dataverse libraries in order to navigate the click-through style authentication used in the DVN.

- The plugin can process metadata schemas other than OAI-DC, when an appropriate library is supplied. We have supplied a library for DDI version 2.0 metadata. This preserves the metadata, and harvests any URI's listed as resources in it. We have also included performance enhancements for handling portions of large metadata objects.

Discussion

The ability to express replication requirements and inter-archival replication commitments using a formal schema, and to automatically audit a **LOCKSS** network for dynamic consistency with these requirements is a significant advance. This provides an organization with automatic, continuous and compelling evidence that accurate, timely, and complete replicas are being maintained. Moreover this approach does not require a central administrator or homogenous configuration of the **LOCKSS** network, or create a single point of failure, either in terms of individual machines or entire institutions.

This work is in a prototype stage, and two questions remain before it could be used in production: First, the **LOCKSS** cache manager, which plays a much more prominent role in a **PLN** than it does it in the public **LOCKSS** network, is still in a "beta" stage, and in our experience, must be manually triggered regularly in order to update its state — this can trigger "false alarms" when the state of the cache manager database becomes stale, and does not reflect the actual network state. It is unclear when the cache manager will be robust enough to support automated auditing. Second, we are investigating the extent to which the **PLN** architecture can support reconfiguration of host nodes by a source that is not completely trusted.

In future work, we plan to investigate how the network might adapt automatically to changes to commitments through harvesting requests to participating hosts to perform additional harvesting. We also intend to identify ways to make the network self-repairing, so that deviations from policy commitments are repaired using the same request mechanism. That said, having the ability to audit the network against a formal policy is a useful innovation on its own. Our prototype serves as a proof-of-concept of the ability of **LOCKSS** to accommodate the institutional needs of archives as well as libraries. For more information on **Data-PASS's** approach to archival replication, including our policies and practices, software,[13] and schemas see the **Data-PASS** Website: *http://data-pass.org*.

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against the grain people profile

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WHERE DOES MICAH SEE THE INDUSTRY IN FIVE YEARS: The next five years will see a further application of **Melvin Kranzberg's** second law of technology: "Invention is the mother of necessity." We are now seeing a flood of new inventions for the individual and social creation, recording, and dissemination of knowledge. Information is becoming ambient — continually created, and recorded. Libraries, by necessity, will need to take a larger role in integrating with the workflows around this knowledge, and especially around tagging, social annotation, and other forms of social creation of secondary data.

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