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Linking to the Appropriate Copy

Report of a DOI-Based Prototype

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Introduction

There has been an explosive growth in the number of scholarly journals available in electronic form over the Internet. As e-journal systems move past the pains of initial implementation, designers have begun to explore the power of the new environment and to add functionality impossible in the world of paper-based journals. Probably the single most important such development has been reference linking, the ability to link automatically from the references in one paper to the referred-to articles.

Over the past several years, substantial effort has gone into building an environment to support linking between the rapidly growing number of journal articles available on the web. As this environment developed, it became clear that the initial linking model required refinement to reflect the full range of service arrangements found across the information landscape today. In particular, the model worked well for articles served exclusively through a single delivery system, but not for those replicated in multiple service environments. The complexity inherent in

having multiple online copies has become known as the "appropriate copy problem"; this paper describes a project demonstrating one solution to this problem.

DOI, CrossRef, and the General Linking Model

Early linking facilities between independent systems were largely built on bi-lateral agreements, and the link syntaxes they used were based on disparate specific local system configurations. By the late 1990s, however, it became clear that having to individually negotiate with and construct different links for each source did not scale, and that a generalized infrastructure was needed. Three relatively recent developments have helped to enable the emergence of this infrastructure: a series of workshops defined a general model for linking, the DOI system was implemented, and the CrossRef system was implemented.

Workshops. *A* widely-felt concern that the developing architecture of linking systems be as robust, as generalized, and as open as possible led to a series of meetings co-sponsored by the National Information Standards Organization (NISO), the Digital Library Federation (DLF), the National Federation of Abstracting and Indexing Services (NFAIS), and the Society for Scholarly Publishing (SSP). Following the model of an earlier series of workshops focusing on the Digital Object Identifier, these meetings brought together primary publishers, secondary publishers, librarians and researchers in an attempt to understand the functional requirements of linking systems and to begin to model linking systems that satisfied these requirements.

Two workshops and a smaller working meeting were held under these auspices between February and June of 1999. A summary of the conclusions of the participants was published in *D-Lib Magazine* [Caplan and Arms]. Essentially, by the summer of 1999, the basic parameters of a linking architecture were established. The accepted model posited that publishers would contribute bibliographic metadata associated with identifiers to a reference database, and that identifiers would be associated with locations (URLs) in a location database. Citations would be searched in the reference database to obtain identifiers, which would in turn be searched in the location database to return one or more locations in a process known as resolution. The preferred location would then be used to obtain the desired content.

Although the model is simple, several of the underlying assumptions were not apparent at the time. There was much discussion over what identifiers should pertain to, particularly over whether they should identify works or manifestations of works. The need for identifiers (also called names) was another subject of debate, as algorithmically calculated linking keys were also popular. The workshop series established the consensus that a linking key must meet at least three functional requirements: it must be persistent, unique within a defined namespace, and capable of supporting resolution to multiple items. The last requirement came from an understanding that multiple copies of a work may exist, and that it must be possible to get to all copies or the subset of copies most appropriate for the user.

DOI (Digital Object Identifier). The DOI was initially developed by the Association of American Publishers (AAP), but rapidly turned into an international effort resulting in the formation of the International DOI Foundation (IDF) in 1997 (see <http://www.doi.org>). The aim of the DOI effort was to create an identifier and associated resolution system to aid in the management of intellectual property on the Internet.

The DOI may be considered a form of URN (Uniform Resource Name). It provides two

critical functions: 1) it is a unique identifier of an object, and 2) it provides a mechanism for locating a copy of the named object on the Internet.

The DOI syntax is ANSI/NISO standard Z39.84 [Z39.84]. It is an essentially opaque identifier, meaning that one cannot reliably tell from the string itself the location or bibliographic identity of the object it is identifying. The resolution system for the DOI is the Handle System, developed at the Corporation for National Research Initiatives (CNRI) (see <http://www.handle.net>). The Handle System is a comprehensive system for assigning, managing and resolving persistent identifiers, such as the DOI, for digital objects and other resources on the Internet.

In its most commonly used form, the DOI is embedded in a URL, where the server name given in the URL is that of a service (in this case a Handle System resolver) that looks up the DOI in a database and returns information on the object, including one or more addresses. Thus, as long as the database is kept current, objects identified by a DOI can be moved from system to system, and from owner to owner, without the DOI ever "breaking".

CrossRef. CrossRef has its origins in the DOI-X project, a collaborative effort among journal publishers to use the DOI for reference linking [Atkins et al.]. The success of that effort led to the creation of PILA, the Publishers International Linking Association, and its CrossRef initiative early in 2000 (see <http://www.crossref.org>).

The CrossRef system is intended to enable the automated large-scale assignment of DOI links to references [Pentz]. When a publisher assigns a DOI to a journal article, a standardized metadata record for that article is associated with that DOI and deposited in the CrossRef database. Then, when subsequent articles are being prepared for electronic publication, the references in those articles can be used to search the metadata in the CrossRef database, and the matching DOI retrieved and included as a link in the article. While the name (clickable anchor text) for such links varies from one online system to another, most services simply label the link "CrossRef, and these links will be called "CrossRef links" in the remainder of this paper.

Appropriate Copy Problem

The workshop model called for a reference database for obtaining identifiers and a location database for resolving identifiers to locations. The CrossRef system provides the former, while the DOI and its Handle System resolution service provides the latter. In this way the DOI/CrossRef infrastructure provides a very powerful and generalized mechanism for linking to electronic journal articles across a large number of independent and heterogeneous publisher systems.

However, in the current technical environment this architecture suffers a significant limitation. When a DOI link is "clicked", the DOI is sent to the resolver, and the URL found in that database is returned to the browser as an HTTP redirect. The mechanism in its general form is therefore limited to supporting a one-to-one relationship between DOIs and URLs. This would be fine if there existed only a single copy of each e-journal article. For a number of reasons, however, there are many instances when more than one legitimate copy of an article is available:

"Local Loading". Copies of e-journal articles are loaded in local systems to service institutional (e.g., the University of Toronto) or consortial (e.g., OhioLINK) populations.

Aggregator databases. Services such as EBSCO, Ovid, and OCLC's Electronic Collections Online load e-journal articles into aggregated databases that are available via subscription.

Paper copies. Currently, most e-journals are also published in paper form, with copies widely held. For such journals, a reference refers as much to the paper copy as it does the electronic one.

Mirror copies. For reasons of network performance or expense, mirror sites for content are increasingly common.

In each of these cases, the address to which the DOI should appropriately resolve depends on the location or affiliation of the user who is making the resolution request. This issue of which of multiple possible copies should be addressed in response to a resolution request is commonly referred to as the "appropriate copy problem" [Caplan and Flecker].

The limitation of one-URL-per-DOI was recognized as a significant issue from the beginning of the DOI implementation, and in fact the Handle System technology does allow multiple URLs to be associated with each DOI. However, even if multiple addresses were registered for a DOI, there is nothing in the current architecture of linking that could select among these multiple addresses to provide the appropriate one for a given user. As was recognized quickly in the various workshops on linking, selecting the appropriate copy when multiples exist is essentially a "localization" process, and is best carried out at the institutional (library or consortial) level. The local institution is best placed to keep a record of holdings and licensed services and determine the services users should be offered. The "appropriate copy" problem, then, is essentially the issue of where and how to insert localization into the linking process.

OpenURL Framework

At the same time the discussions of appropriate copy resolution were taking place, Van de Sompel was defining the OpenURL framework, based on his work on SFX [Van de Sompel and Hochstenbach 1999a, Van de Sompel and Hochstenbach 1999b, and Van de Sompel and Hochstenbach 1999c]. SFX, now marketed by Ex Libris, pioneered the ability to provide an appropriate set of extended services based on the context of a user and his request (see <http://www.sfxit.com>). Such services might include choices such as linking to an abstract rather than the full text, performing a citation search on the author or title, finding additional information about the author, or linking to related publications.

The OpenURL framework is an architecture that allows for the building of localized, context-sensitive links based on metadata and identifiers for referenced works [Van de Sompel and Beit-Arie 2001a, Van de Sompel and Beit-Arie 2001b]. It defines a model for Open Linking, separating the identity of referenced items from specific linking addresses. In the OpenURL framework, a source system links to a local service component such as SFX rather than linking directly to the referenced work, and passes information identifying the bibliographic item.

The OpenURL itself is an HTTP request (GET or POST) that delivers metadata and/or identifiers of the referenced work to a local service component when clicked by the user. The

OpenURL draft specification was submitted to NISO in December 2000 and was accepted as a work item towards development as an American National Standard (see <http://www.niso.org/commitax.html>). A fundamental notion in the OpenURL architecture is that a referenced work can be identified by either an explicit set of metadata elements (e.g., ISSN, title, year, volume) or by one or more unique identifiers (e.g., DOI). The latter can be considered pointers to metadata since in many cases the service component will be able to use these identifiers to fetch additional metadata about the referenced work from resources that can accept identifiers as keys to metadata.

Demonstration Project

Prototype. A small group of interested parties agreed to prototype a solution to the appropriate copy problem based on the OpenURL framework. Participants consisted of representatives from CrossRef, Ghent University, Ex Libris, and CNRI.

In this prototype, a HTTP-to-Handle proxy server in front of the DOI resolver rerouted certain resolution requests to an alternate resolver, in this case an SFX implementation. The location of the alternate resolver was communicated to the proxy server via cookies stored on the user's browser using the SFX "CookiePusher" program (see <http://www.sfxit.com /openurl/cookiepusher.html>). The experiment provided practical answers to several of the issues raised earlier: where to insert localization (at a central spot in front of the default resolver), how to insert localization (information passed in cookies), and how to identify the appropriate location (using profile tables in the local server to associate subscription information with services).

The prototype was presented at a third linking workshop sponsored by NISO, the DLF, and CrossRef in July 2000 [NISO, Van de Sompel]. This meeting resulted in consensus on a new general model for linking based on the OpenURL framework. An actionable identifier found in any information service, when clicked, would go to a redirector at a central site for the identifier type. The redirector would check whether there was a cookie indicating an alternate service component, and if not, forward the identifier for resolution at the default resolver. If a cookie were found, the resolution request would be reformatted as an OpenURL addressing the alternate service component. The alternate service component might be an institutional or consortial resolver or some third-party service.

Institutional access to articles is generally by subscription to a journal title for some period of time. DOI identifiers, however, point to articles, not journals, and do not reliably contain information identifying the journal title, issue or date. Another important outcome of the workshop was the realization that the CrossRef database, originally intended to enable looking up a DOI from metadata in hand, could, with a small amount of programming, also be used to enable lookup of metadata from a DOI in hand. This "reverse lookup" facility in CrossRef would provide the additional metadata needed to determine the appropriate copy and/or deliver extended linking services to the user.

Project structure. Following this consensus on a general model for "localizing" reference links, a number of institutions agreed to conduct a larger demonstration of the proposed architecture. The project involved providing "appropriate copy" resolution of DOI links for three institutions, each of which has access to collections of locally loaded e-journal articles:

- the Research Library of the Los Alamos National Laboratory (LANL), which has access to over 4,000 electronic journal titles locally loaded into a Science Server system [1];

- the University of Illinois Grainger Engineering Library, which has access to a testbed of over 60,000 locally loaded full-text journal articles from 47 journals;

- the Ohio State University Libraries, which have access to over 4,000 electronic journal titles locally loaded in OhioLINK's Electronic Journal Center (EJC), also using the Science Server system.

Other participants in the project included:

- the International DOI Foundation;

- the Corporation for National Research Initiatives, the technology provider for the DOI;

- CrossRef;

- Ex Libris, vendor of the SFX system;

- OhioLINK, which provides e-journals for the Ohio State University Libraries and other OhioLINK participants.

In addition, a number of other institutions served as observers and participated in the planning of the project:

- the Digital Library Federation;

- NISO;

- Elsevier Science;

- the American Institute of Phvsics.

Architecture. The project architecture followed closely on the July prototype. Key components of the architecture were:

Setting the local cookie. Cookies were to be used to indicate that a user had a local resolver available. This required that each of the three libraries implement a mechanism to cause the user's browser to go to the DOI site and get a cookie. Because obtaining the cookie should be transparent to the user, all three institutions used a script embedded in a web page image to"push" the cookie.

Filtering for local resolution. CNRJ, acting on behalf of CrossRef and the IDF, made a

small change to the HTTP-to-Handle proxy server to recognize and act on the resulting cookies. If a DOI resolution request was accompanied by a cookie naming a recognized local resolver, the resolution request was forwarded to the named resolver in the form of an OpenURL containing the DOI.

Local resolution. Two different local resolution systems were used in the project. Two of the three libraries used SFX; LANL already had a local SFX server for extended linking services, and Ex Libris set up an SFX service to be used by OhioLINK and Ohio State during the test. The University of Illinois wrote its own resolver specifically for the project (see APPENDIX A: Illinois Local Link Server).

The SFX and Illinois servers exemplify two different approaches to local resolution. In the first, SFX, approach, the local service component maintains institutional profile information used to determine the appropriate source(s) for a copy of an article and extended services that can be offered related to it. For example, the local resolver might store a set of profile tables indicating the preferred source for articles from a journal, given the journal title and date. When a DOI is redirected to the local resolver, the resolver uses the DOI to obtain the additional metadata needed to identify the containing journal issue. This can then be matched against the profile tables to determine the appropriate source for the article.

In the second, Illinois, approach, the local resolver uses two methods to identify the appropriate location. In the first method, the DOI passed in the resolution request is searched in a local database of DOIs for articles stored in the local collection. If found, the request is redirected to the local copy. In the second method, the passed DOI is used to obtain additional metadata, which is then searched in a bibliographic database (or catalog) describing locally held fulltext articles and their locations. Again, if found in the local database, the local address of the article is returned.

In both SFX and Illinois approaches, additional metadata was obtained by using the DOI to query the CrossRef database via the reverse lookup mechanism mentioned above. For more detail on this process, see APPENDIX B: Obtaining Metadata from CrossRef.

This architecture is illustrated in Figure 1.

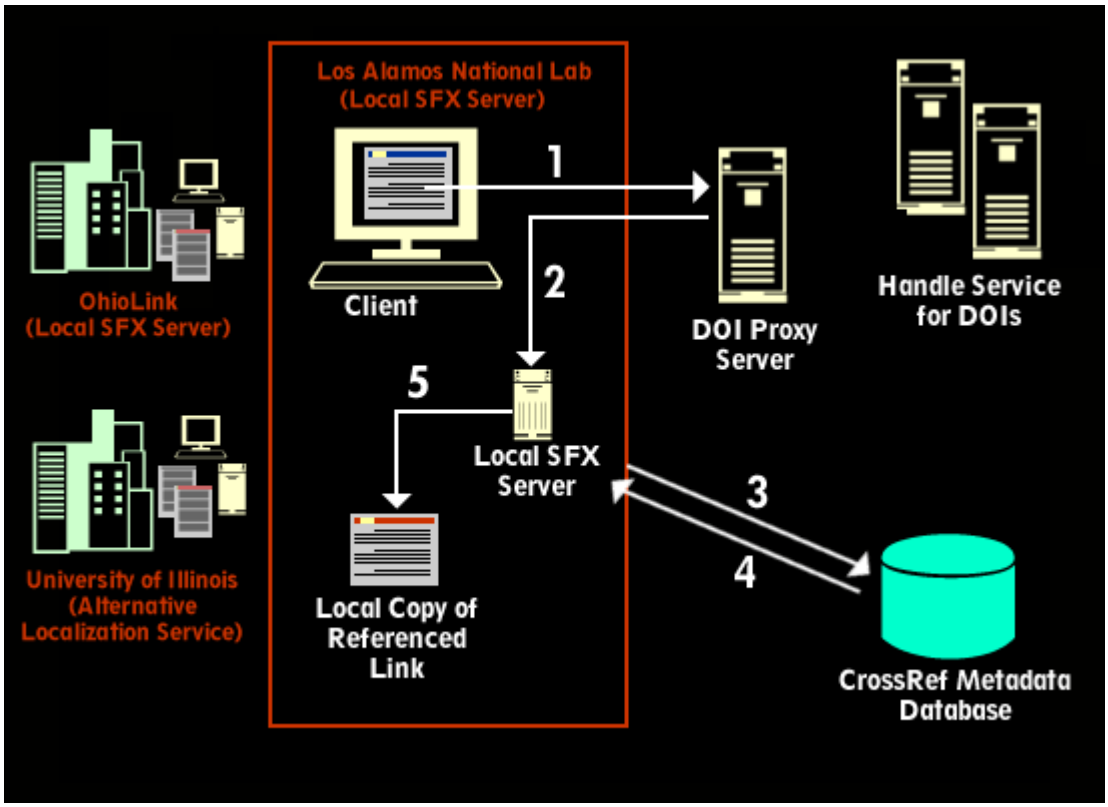

Figure 1: Process flow for the demonstration project.

1. A user reading an e-journal article "clicks" a DOI link in a reference. The DOI and the user's cookie (previously set
through the "CookiePusher" mechanism) are sent to the DOI HTTP-to-Handle proxy server.
2. The proxy recognizes the local resolver identified in the cookie, constructs an OpenURL containing the DOI, and sends this to the user's local resolver by way of an HTTP "redirect" to the user's browser.
3. The local resolver sends the DOI in OpenURL format to CrossRef.
4. CrossRef returns metadata for the item named by the DOI.
5. The local resolver recognizes this as a locally-held article, and constructs a URL pointing to the item, and sends this to the user's browser as a HTTP "redirect".

In addition to resolving an address for the item identified by a DOI, local resolution servers can also provide "extended services" based on the metadata derived from CrossRef. In the LANL implementation, clicking on a CrossRef link in a cited reference on a publisher's website would take the user to a complete SFX services screen, which included not only a link to the full text of the appropriate copy, but also links to extended services such as cited author searches and document delivery options. Illinois also experimented with extended services, providing a menu of links to targets including Compendex, INSPEC, and the local OP AC. Ohio State users were offered links to local holdings of the printed version of the journal as reflected in the OhioLINK union catalog, MyEmail (for authors' addresses), and Google (for searching keywords from the article title).

Participant Experience. Overall, all three implementations of local resolution were successful, and the proof-of-concept was amply demonstrated. No significant barriers were encountered during the project.

Usage of the test systems was unfortunately quite limited, for a number of reasons:

1. The number of publishers adding DOI links to references was limited at the time of the project, so there was a general paucity of links that users might encounter.

2. The Science Server systems run at OhioLINK and LANL create internal links from cited references to other locally held articles in the system. Therefore, the local resolution service becomes a factor only when there are cited references in an article *not* in the local e-journal collection, and these references contain DOIs that link to articles that *are* in the local e-journal collection. It was hard to find examples of this situation for the demonstration project.

3. The deployment of the cookie pushing mechanism was generally on a web page that not all journal collection users would encounter.

4. Part of the experiment was conducted over the summer, when library usage is lower.

The amount of feedback received from actual users was low, not only because usage was low, but because the resolution process was transparent to users. Participating staff noticed two minor problems:

First, as noted above, most services displaying reference links to users use something generic, such as a highlighted title, or the anchor text "CrossRef to indicate the clickable link. At least one online service, however, attempted to determine the target of the CrossRef link, and displayed the name of the target service to the user, e.g., "Access full text of this article from XYZ site". Redirecting the link from XYZ to the local e-journal collection was a source of potential user confusion. All project participants felt that explicitly identifying the target of a link was bad practice and should be discouraged.

Second, LANL and Illinois found that the metadata returned from CrossRef varied. For example, a reference with several authors might return only the first author with the metadata, limiting the extended services that could be made available. (Since CrossRef collects only the basic metadata necessary for matching references to article DOIs, submitting more than the first author for an article is optional.)

Outstanding Issues

Cookies. The use of cookies in this project tried to address a problem that is not specific to the proposed architecture, but rather is a universal problem related to checking user credentials in a distributed networked environment. Throughout, the use of cookies was problematic, and clearly only a short-term solution. One problem with the cookie mechanism was finding a method for setting cookies on every user's machine, and then resetting them regularly as they

expired. The general approach to this was to utilize a web page that library users could be expected to visit regularly to activate the cookie-pushing process. Such mechanisms are necessarily somewhat scattershot, and some users may not have the cookie set at the point at which they encounter a DOI.

Another issue with cookies is setting them inappropriately. Generally, the web pages used for initiating the cookie setting are available to outside as well as institutional users. Therefore, it is important that either the cookie-setting process be filtered to eliminate non-local users, or that the localization process check for non-local users and implement cookie "unsetting" when outside users are encountered. The JavaScript that LANL used to push the cookie did check to ensure it was set only for users within correct IP ranges.

A third issue concerned users with multiple affiliations (for example, university department and government research laboratory). Using the cookie mechanism, such users would have different access rights depending on the context of a particular server connection.

The only alternative to the use of cookies considered during the project was having the DOI HTTP-to-Handle proxy filter users directly based on IP address. All users from a given range of IP addresses would be routed to the local resolver for the associated institution. This is, of course, the mechanism used to control access for most commercial services to which libraries subscribe today. However, this option was rejected as administratively too difficult in the short term, as the DOI service does not currently have a business relationship to the institutions requiring localization.

In the long-term, better solutions than cookies will be needed to support localization. Many hope that digital certificates will help here, as they may in the general problem of authenticating users to remote information services. When better solutions become available, they can be easily substituted for local resolution without damage to the overall architecture.

Publisher "opt-out". From the earliest linking meetings there was discussion of a mechanism for publishers to "opt-out" of localization; that is, DOIs for a particular publisher would not be redirected to a local server. Some publishers, in particular society publishers that do not allow "local loading" or other arrangements resulting in institutions having alternative copies (except, of course, for print), may want their identifiers to resolve only to the location registered by the publisher. For some journals there may be no options for extended access that could even be offered by a localization server. Localization also introduces the possibility that links could be redirected to illegal copies of an article (perhaps as a result of honest configuration errors, or lack of awareness of license terms) or to document delivery suppliers that don't pay the copyright fee to publishers.

The most effective way to implement the opt-out option would be for a "no redirection" flag to be recorded for each of a publisher's DOIs in the central DOI directory. It was decided that, while possible, it was not practical to do this during the project.

It is not clear whether any publishers would actually choose to opt-out, based on the value localization brings to end users and librarians, but it may be important to have this alternative for localization to be fully accepted.

Terms and Conditions for Use of Metadata. Publishers who deposit metadata in the CrossRef system are naturally concerned about who uses that data, and for what purposes. Publishers have a legitimate interest in how links to content they publish are presented to users. The terms and conditions for the delivery and use of metadata for localization still need to be

finalized, but it is likely that publishers will want CrossRef Library Affiliates to sign agreements that:

- a link to the publisher's site will always be presented on intermediate screens, even when a user doesn't have a subscription to full text, because abstracts and document delivery options may be available from the publisher;

- libraries will only provide links to legal document delivery suppliers;

- link options presented to users will not violate the terms of license agreements the institution has signed with publishers.

Content Licensing. Practically all publishers offering electronic access today require subscribing institutions to sign license agreements governing the terms of access and use. There was disagreement among the participants as to whether changing the ultimate destination of a DOI link provided in a publication could be interpreted as changing the publication itself in which the link was found. Some user licenses prohibit such changes.

Scalability/Performance. The performance effects of redirecting links at the DOI Proxy, and of reverse lookup in the CrossRef reference database must be assessed. Also, publisher opt-out or other options that might require changes to the Handle System service may have an effect on the performance of the central DOI directory.

Locating metadata. During the project, local resolvers simply assumed that metadata for all DOIs could be retrieved from the CrossRef database. That is a valid assumption today, as all current DOIs are for material for which CrossRef is the DOI registration agency. However, other registration agencies have already been established, and the metadata look-up process will need to be made more flexible. A logical elaboration on the general architecture of the project is to add to the DOI database information about what registration agency holds the metadata for a given DOI.

This architecture is illustrated in Figure 2.

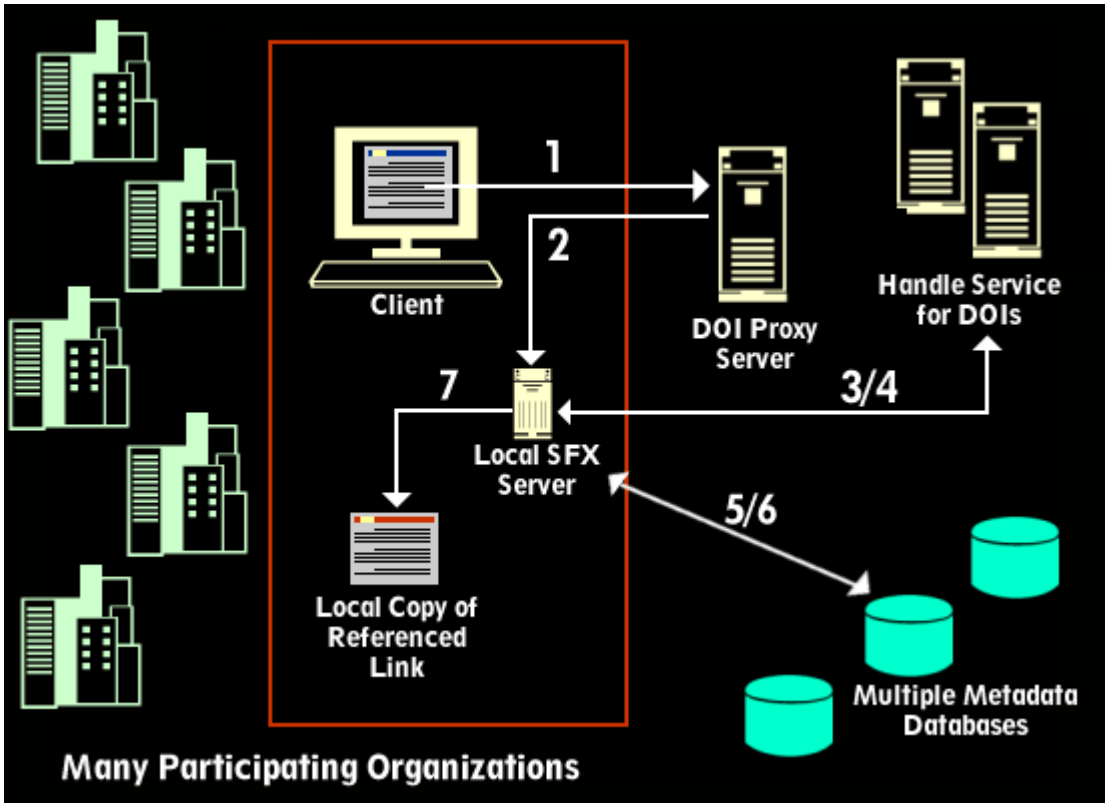

Figure 2: Possible architecture for locating metadata services.

1. A user reading an e-journal article "clicks" a DOI link in a reference. The DOI and the user's cookie (previously set through the "CookiePusher" mechanism) are sent to the DOI HTTP-to-Handle proxy server.
2. The proxy recognizes the local resolver identified in the cookie, constructs an OpenURL containing the DOI, and sends this to the user's local resolver by way of an HTTP "redirect" to the user's browser.
3. The local resolver looks up metadata locations.
4. The Handle system returns the identity (address) of the metadata source.
5. The local resolver sends the DOI in OpenURL format to the identified metadata source. 6. The metadata source returns metadata for the item named by the DOI.
7. The local resolver recognizes this as a locally-held article, and constructs a URL pointing to the item, and sends this to the user's browser as an HTTP "redirect".

(A possible variation on this sequence would involve the proxy server querying the Handle System for metadata locations and returning the metadata location on its initial trip back to the local resolver.)

Large-scale test. As discussed above, there was very little actual use during the project. More links and increased use of the resources containing them will be required to assess the validity and utility of the architecture.

Next Steps

The participants and observers in this project are convinced that:

• The tested architecture is valid. The combination of the OpenURL Framework and the DOI resolution system provides one viable and practical solution to the appropriate copy problem. The three key components of this architecture are:

- o Local resolvers with the requisite knowledge to match a query (identifier) to an appropriate copy, given sufficient information about the item identified in the query.
- o A unified general or global resolution system with the ability to redirect a query to the correct local resolver, given a method for the originator of the query to identify the appropriate local resolver.
- o A source of well structured metadata about the requested item, sufficient for the local resolver to match the query to the appropriate copy.

• The tested architecture solves a real problem in the current environment.

• The use of local resolvers will become increasingly practical as an increasing number of commercial alternatives enter the market [2].

• Moving from a prototype to a full production system will take continued collaboration. The prototype was primarily an analysis of the technical feasibility of localized linking and it has been very successful, within limited parameters. However, while non-technical issues were discussed, resolution of the business issues was not part of the prototype. The various parties need to discuss and determine the business terms governing localized linking.

It is currently the intention of the participants in this prototype to continue working together on the issues raised in this paper. While the business terms and policies are being discussed and resolved, the current implementation can be kept running and even extended, with the agreement of the current participants. It would be useful to test the system with greater usage and heavier loads and investigate solutions to issues that have been identified. Further user feedback, when many more CrossRef links are in place, will also be valuable.

In the online world collaboration, network effects and standards are all critical factors. Under network effects, the more computers that join a network, the more valuable it becomes. Similarly, the more that the various parties in the online scholarly information chain collaborate, the more valuable the whole system becomes for everyone. Network effects are not possible without standards at all levels, from HTTP to metadata encoded in XML. It is unusual but necessary to have trade associations like CrossRef and the DLF, publishers, standards organizations, libraries and library systems vendors all working together on a common solution to a problem.

The end result of this collaboration will be to make robust, open reference linking possible across all legal copies of articles, which will serve the best interests of scholars, libraries and publishers.

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Chris Shillum, Elsevier Science/ScienceDirect

Notes

[1] ScienceServer is a software product for loading and searching local journal collections, marketed by ScienceServer LLC.

[2] In addition to SFX, resolution systems are under development by OCLC Open Name Services <http://www.oclc.org/strategv/preservation/opennames> and Endeavor Information Systems <http://www.endinfosys.com/prods/linkfinderplus.htm>.

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