The EduSource Communication Language: Implementing Open Network for Learning Repositories and Services

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ABSTRACT
Interoperability is one of the main issues in creating a networked system of repositories The approaches range from simply forcing one metadata standard on all participating repositories to highly sophisticated semantic web based architectures with full semantic mapping capabilities between different schemas. The eduSource project in its holistic approach to building a network of learning object repositories in Canada is implementing an open network for learning services. Its openness is supported by an eduSource Communication Protocol (ECL) which closely implements the IMS Digital Repository Interoperability (DRI) specification and architecture, and by connection middleware that enables any service providers to join the network. EduSource is open to external initiatives as it explicitly supports an extensible bridging mechanism between eduSource and other major initiatives. This paper focuses on the design of ECL as an implementation of IMS DRI and supporting infrastructure and middleware. We also present two applications used in evaluating our approach: a gateway for connecting between eduSource and the NSDL initiative, and a federated search connecting eduSource, EdNA and SMETE.

Categories and Subject Descriptors
H.3.4 [**Information Storage and Retrieval**] Systems and Software – *information networks* H.3.7 [**Information Storage and Retrieval**] Digital Libraries – *standards, systems issues, dissemination*. D.2.12 [**Software engineering**] Interoperability

General Terms
Design, Standardization

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Learning object repositories, Interoperability

1. INTRODUCTION
When looking at the year 2003 through the eyes of a semantic web researcher one can be more than hopeful that a big vision of networked systems is at hand. Several crucial technologies and standards are already in place: XML and RDF have gained wide acceptance in the industry, and the Semantic Web group at W3C is finalizing the recommendation for next essential semantic web component the Ontology Web Language. Metadata are in use across all vertical layers of the systems and several large-scale initiatives are trying to build usable networked systems for object and knowledge sharing and to further our understanding of the related issues. All these activities promise to have systems that can discover and share information with other systems in place in the near future.

One of the leading areas where integration and sharing is in high demand is education, particularly in e-learning. The wholesale adoption of Internet technology as a channel for education and training has resulted in an abundance of learning resources in web-ready digital format. Typically, these digital learning objects (LO) [11] may be lesson content stored as text, audio-visual or interactive media files, or simply learning activity templates expressed in educational mark-up language EML [6]. Despite their apparent ubiquity, the locating and re-use of LOs is hampered by a lack of coordinated effort in addressing issues related to their storage, cataloguing and rights management. Strident efforts have been made to create portal repositories by communities such as Merlot, SMETE and, in Canada, by TeleCampus and CAREO. Not surprisingly, each entity produces a rather individual reflection of its own perceived organizational needs, and the concept of making all these repositories work together while laudable, has received less attention.

The e-learning community has seen fruitful initiatives in the standardization of learning object metadata by IEEE and towards the standardization of other aspects of learning objects and learning processes by organizations such as IMS and ADL. More recently, the e-learning community has been focusing on the ability to connect and use resources located in distributed and heterogeneous repositories. This process closely resembles the initiatives in the domain of digital libraries. In the next section we examine how the interoperability is handled in four major projects: the National Science Digital Library project, the IMS Digital Repository Interoperability group, our recent POOL project, and our current approach to interoperability in the eduSourceCanada project [8]. In Section 3 we describe the main

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drivers of the eduSource project as an infrastructure for connecting different types of networks and people. This provides us with main issues when creating large and open networks. In Section 4 we discuss the eduSource architecture, eduSource Communication Language and enabling middleware for easy connection to the network and between eduSource and other networks. In Section 5 we give a current status of the implementation and describe two uses cases providing validation of our approach.

2. MAJOR INTEROPERABILITY EFFORTS IN E-LEARNING

NSDL. The National Science Digital Library project (www.nsdl.org) is a major project funded by the National Science Foundation with the goal of building a digital library for education in science, mathematics, engineering and technology. The potential collections have a wide variety of data types, metadata standards, protocols, authentication schemes, and business models [1]. The aim of the NSDL interoperability is to build coherent services for users from technically different components. NSDL aims to support three levels of interoperability: federation, harvesting, and gathering.

The ***federation*** implements the strong standards approach with libraries agreeing to use specific standards. The ***harvesting*** allows higher autonomy. The only requirement is to enable a limited set of services via a simple exchange mechanism. NSDL is using Protocol for Metadata Harvesting (PMH) developed by the Open Archive Initiative. To support the metadata harvesting from the repository a relatively simple wrapper communicated via PMH and providing metadata based on the Dublin Core standard has to be implemented. Thirdly, ***gathering*** uses the web crawler technique to collect information from the organizations that do not formally participate in the NSDL program.

NSDL has selected eight preferred metadata element sets for metadata storage. Preferably, libraries should store the metadata in their original format but they have to be able to serve the metadata in Dublin Core (www.dublincore.org) format. Effectively this solution establishes Dublin Core as the lowest common denominator for the NSDL.

IMS DRI. The IMS Digital Repository Interoperability Group, in its public draft specifications for the digital repository interoperability [5], provided a functional architecture and reference model for repository interoperability. Aiming at very broad application of the specification the document makes a recommendation only at a certain level leaving the resolution of more operational issues to the system implementers. Five basic functions defined by IMS DRI are: search/expose, gather/expose, submit/store, request/deliver, and alert/expose. For the *search* function, the specification recommends using XQuery (www.w3c.org/XML/Query) with SOAP protocol or Z39.50. For the *gather* function, the OAI's harvesting protocol is recommended. No recommendation is made for other functions in the current version of the specification. The IMS DRI in its current version does not explicitly deal with heterogeneity of the repositories and it is up to the implementers to ensure format compatibility. The DRI Group recommends development of a "search intermediaries" that will deal with multiple formats.

POOL. The POOL project ran from 1999 to 2002. One of its major goals was to build an infrastructure for connecting heterogeneous repositories into one network [4]. The infrastructure used a peer-to-peer model in which nodes could be individual repositories (called SPLASH) or community or enterprise repositories (PONDs). PONDs were connected to the POOL network using a specialized peer performing both functions of a gateway and wrapper. The POOL network used the JXTA peering protocol (www.juxta.org) and followed the CanCore/IMS metadata profile/specification to exchange metadata. Connected PONDs communicated using wrappers either via HTTP and CGI or XML-RPC protocol. The wrapper also performs the metadata schema translation functions that are needed. The network supported a high autonomy for the repositories, but this required creating a specialized wrapper translating between the metadata schemas and communication protocols.

ELENA/Edutella. This collaborative European project is creating Smart Spaces for Learning [9]. Smart learning spaces are defined as educational service mediators, which allow the consumption of heterogeneous learning services via assessment tools, learning management systems, educational (meta) repositories and live delivery systems such as video conferencing systems. ELENA builds a dynamic learner profile which is used as a basis for offering the learner with the choice amongst a variety of knowledge sources. ELENA forms a layer on top of a learning management network built on Edutella [10]. Edutella is an RDF based peer-to-peer (P2P) infrastructure that aims to connect highly heterogeneous educational peers with different types of repositories, query languages and different kinds of metadata schemata.

eduSourceCanada. The eduSource project (www.edusource.ca) brings together major Canadian LOR players to create an open infrastructure for linking interoperable LORs. The infrastructure will support a wide range of services and promises both ease of connecting and ease of using new and existing systems. For example, a repository using PMH protocol and Dublin Core metadata can either communicate with the eduSource network as a whole via gateway mechanism or can become a participant with access to wider range of services via the "semantic cobblestone" interoperability connector.

3. EDUSOURCE: AN OPEN NETWORK FOR CONNECTING COMMUNITIES

To achieve its goals the eduSource project is implementing IMS DRI specification as closely as possible. To understand the eduSource's strong requirements for interoperability we need to analyze the reality of the education space and the variety of communities that eduSource will serve.

Server-type repositories. Figure 1 shows a schematic infrastructure of eduSource network. Top left quadrant represents *server-type repositories*. The communities served by these repositories vary and can include governmental, academic, business or special interest groups. Some of these repositories were created and are managed by an organization expressly to serve their communities. For example, a university repository primarily serves its community of university students and professors; similarly a provincial Ministry of Education might

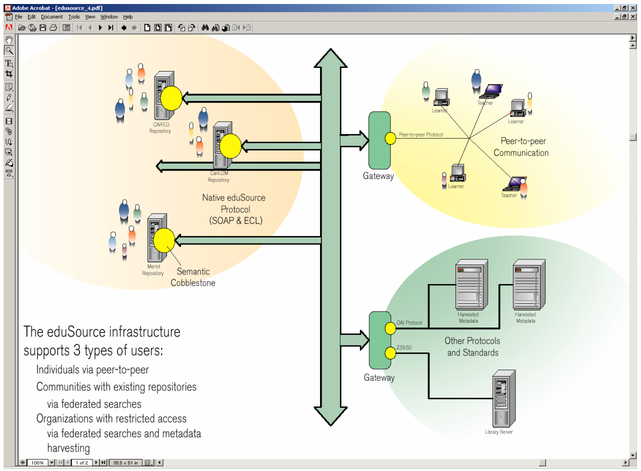

Figure 1. EduSource infrastructure supports three types of communities

operate a repository of learning resources for K-12 schools within its jurisdiction. Another type might be a commercial repository that licenses their content or charge fees per use. Another common type is informal repositories that are not tied to any formal organization but were simply set up by the community members themselves and are managed to further the community goals. In all these cases the repositories can be either public, or restricted to serve only the community, or can provide mixed access with a blend of privileges depending upon user identity and role.

The server-type repositories generally provide access to their functionality through a web portal. This includes search and create functionality for metadata and view functionality for the resources. The metadata schema is determined by the repository developer and cannot be easily changed. One example of an interesting repository is CAREO which in addition to web forms for metadata creation also provides a specialized application, ALOHA, for metadata creation and uploading of metadata and learning objects to the appropriate repository.

Peer-to-peer Repositories. Top right part of the Figure 1 represents a network of individual repositories which communicate on a peer-to-peer basis. SPLASH [4] is an example of a peer to peer repository that was developed in POOL. Individual SPLASH repositories provide the storage and management functions for the learning objects used or collected by an individual user. SPLASH also enables its users to create metadata for the learning objects residing either on the individual's file system or on the web. SPLASH uses peer-to-peer protocol to search for learning objects on other peers[2] and provides file swapping functionality to transfer learning objects between peers.

Peer-to-peer repositories serve the needs of the individual users (both instructors and learners) who may not have repository support from their organizations or communities or they object to the loss of control over their resources and imposed limitations when using centralized repositories, or they may be test sites for objects under construction. These repositories enable each individual to be included and contribute towards the community resources with minimal technical requirements. Peer-to-peer repositories may lack the system support of the server-type-repositories but they often provide their users with additional object management functions and facilitate cross-repository searches. A side benefit typical of peer-to-peer systems is their potential scalability when high demand for a particular type of object occurs.

Repositories of Harvested Metadata. Metadata harvesting is an alternative to federated searches - instead of constantly sending search requests out to all the primary repositories, harvesters collect metadata into a centralized location and searches scan the centralized collection. To be efficient, a search engine might harvest metadata from previous searches, and only conduct new searches when necessary. In another scenario, a harvester might continually poll repositories for new metadata records. Harvesting works well for repositories that use the same or easily-mapped metadata schemas as the queries are typically specified in one schema only.

It is important to note that not all primary sources (repositories) allow harvesting of their metadata. This is especially true of commercial repositories where their business model depends on the users visiting their repository directly. Some repositories only allow harvesting of certain metadata fields. In general, proprietary repositories prefer federated searches which generate results that direct potential users to the company's own website.

Outside Repositories and Networks. eduSource places an emphasis on connecting to other significant initiatives and networks. This connection is bi-directional enabling both eduSource users to search beyond the eduSource network and outside users to access resources inside the network. Alternatively, as the eduSource is an open network, the outside repository can use preconfigured middleware to connect to the eduSource network.

4. ECL: EDUSOURCE COMMUNICATION LANGUAGE

A communication protocol plays an important role in each of the major initiatives listed in the previous section. It allows members of the initiative to achieve its goals by allowing communication between its members, tools, and services. EduSource is a broad network as it aims at the wide spectrum of services it wants to support. On the other side, for eduSource to become an open network it has to build its protocol on existing standards and recommendations. EduSource defines its *eduSource Communication Language* (ECL) as an implementation of the IMS DRI specification. However, IMS DRI recommendation is not specific enough for direct implementation and the current penetration of recommended technologies is not as widespread as assumed in the specification. This makes the implementation both challenging and exciting endeavor.

4.1 General approach

The eduSource architecture uses the web services approach in which services communicate using the ECL protocol (Figure 2) [7]. Although choosing the web services approach was a

[2] In the POOL network SPLASH also searches server types repositories which were connected to the POOL network. In the eduSource network this functionality is being replaced by the more generic ECL approach.

Table 1 eduSource services

ECL Service	Description
Expose	When asynchronous messaging is required, this service will be called by service providers to return the responses for search, gather, and alert.
Gather	Repositories wanting to provide gather service must implement gather service handler.
Gateway Gather	A type of gather service. It allows EduSource members to make gather requests to repositories external to eduSource. By default, the results are converted to IEEE LOM format or alternatively they remain in the format used in external repository Gateway gather service providers must specify a repository type and protocol (e.g. OAI).
Search	As recommended by IMS DRI, ECL protocol uses XQuery. To enable connection of the repositories that do not support (full) XQuery a set of XQuery templates is used. The repositories register their Search Service with an indication of supported templates or full XQuery search capability.
Alert	IMS DRI recommends Alert for push gather.Whenever repository has new metadata matching subscribe parameters, it sends an alert message to the subscribers.
Submit	It is a function for moving an object (metadata and learning object) to a repository.
Store	When asynchronous messaging is required, this service is called by service providers to return the results of submit function.
Request	It provides a function to ask to deliver objects to a client. The transfer protocol could be a successive SOAP request to download the object or FTP transfer protocol
Deliver	When asynchronous messaging is required, this service will be called by service providers to return the chunked of results.

straightforward decision, selecting associated technologies needed more consideration. The criteria for the protocol and its development process that affected our approach included:

- eduSource is a heterogeneous network consisting of existing and future institution repositories, peer-to-peer network, individual small repositories, and application interfaces.
- ECL will be evolving over time of the project which makes all the parallel activities vulnerable to changes in the protocol.
- ECL supports many new services non-existing in the current systems. Some of these services require asynchronous communication, such as search through peer-to-peer network or alert.
- ECL is a complex protocol. To achieve its fast and easy adoption it has to be supported with pre-configured middleware.
- A solution for connection between eduSource and other initiatives has to be easy to maintain and easy update if there is a change in the protocol used by the other initiative.

After thorough development team discussion we had to reject WSDL as a language for defining services for several reasons. First, ECL protocol is much richer than WSDL. Although eduSource uses WSDL for basic communications between clients and service providers, WSDL of itself does not provide enough coverage for eduSource as a heterogeneous network. Specifically,

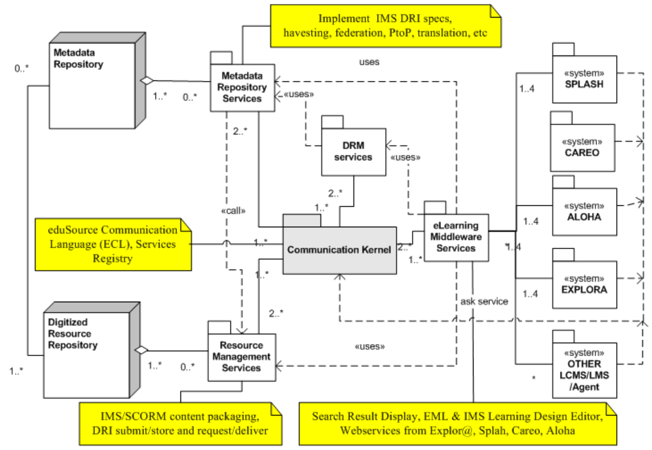

Figure 2 Edusource functional architecture

the support for the asynchronous messaging is difficult to achieve using WSDL and ECL implements a whole set of new services possible, such as 'push gather', 'subscribe', 'alert'. Connecting peer-to-peer network into eduSource also needs asynchronous messaging as the search results from the broadcasted search will become available in batches. This is also true when processing large amounts of data where it is more manageable to have asynchronous messaging deliver results in batches.

ECL closely follows IMS DRI specification and uses SOAP as a communication layer. IMS DRI core functions are defined and implemented as eduSource services (Table 1). Repositories or tools connected to the eduSource network can implement some of these services and register them in an eduSource maintained registry (such as UDDI). Registration is a preferred way for discoverability of permanent services. However, in many cases user tools connected to the network will not register any service[3]. This was made possible by declining WSDL as the only way of implementing services in eduSource.

ECL is a complex protocol with communication patterns that may be challenging to implement. To lower the technical barriers for service providers to join the network it was essential to have a solution that made the ECL easy to implement. Thus, as we develop the ECL we are building the eduSource connector - a middleware that exposes eduSource services in the form of handlers and hides all the complexity of properly encoding XML messages and communicating with other eduSource services.

4.2 ECL Connector

Since the complexity of the ECL protocol might be detrimental to its adoption, we are providing an eduSource connector which implements the ECL protocol. The connector provides a standard API to connect existing repository to the eduSource network. ECL protocol requires institution repositories or tools to implement connector handlers only for those services they want to expose to others (Figure 2), which is a far simpler than implementing and deploying every service in each institution. The connector also

[3] For example, a search application does not provide any services on its own but needs to implement 'deliver' service for asynchronous search results.

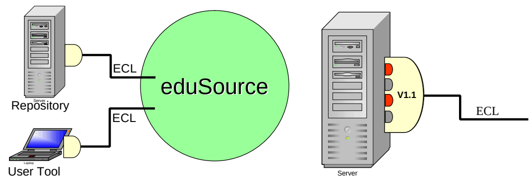

Figure 2. EduSource Connector

facilitates version synchronization during the protocol evolution. Changes in the protocol itself rarely propagate to the API level. In most cases, repositories do not have to worry about the change in the protocol, they only need to update the connector with a never version. Changes in the ECL protocol are detected by the newer version of the connector and are dealt with automatically. This feature makes the implementation of the ECL protocol very attractive, especially in this early development stage where the implementation is still evolving.

The connector hides the complexity of the communication between two eduSource nodes. This is especially advantageous in the case of the asynchronous messages that are very difficult to implement.

4.3 ECL Gateway

Although the eduSource internal protocol provides a flexible and efficient solution it is unlikely that well established repositories and initiatives will invest resources and convert their protocols to the ECL. However, an ability of the eduSource project to connect to other established protocols and major initiatives is of the utmost importance to the project participants. EduSource addresses the problem of outside interoperability by providing a second type of mediator simply called eduSource gateway. EduSource gateway is modeled after the design patter of an adapter [3] functioning at the network level. The main function of the gateway is to mediate between ECL and communication protocols used by the outside systems.

Figure 3 shows a schema of the eduSource gateway. One side of the gateway is formed by the ECL connector. The other side of the gateway provides a framework for defining a chain of handlers that perform a conversion between ECL protocol and the protocol of the external network. The gateway framework enables us to define the mapping between protocols at four levels:

L1. Communication protocol (HTTP, SOAP, XML-RPC, Peer-to-peer, etc.)

L2. Communication language (ECL, OAI, POOL, etc)

L3. Metadata (IMS, CanCore, Dublin core)

L4. Ontologies (vocabularies for metadata)

The eduSource Gateway is typically running on a dedicated computer and provides services for all participants in the eduSource network. The main benefit of placing the mapping functionality for an outside network onto a gateway instead of with each participant is that it can be easily updated if the change in the outside network protocol occurs. In such a case, a chain of mapping handlers is updated at the one place and all eduSource participants can continue to communicate with the gateway using ECL protocol without any change necessary. There can be several gateways for the same outside network if the traffic between the

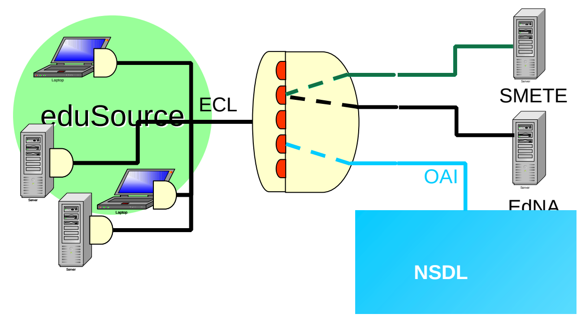

Figure 3. EduSource Gateway

two networks is high. One gateway can provide services for several other networks.

The gateway also functions as a selector of internal eduSource services for the external requests. Currently, any request addressed directly to an eduSource node is forwarded to that node, while a request addressed to eduSource as a whole is distributed to all registered nodes providing the requested service. This is not the best way of distributing the requests and needs to be further addressed.

4.4 Pragmatics of following the recommendations

The following of recommendations from IMS DRI required making several pragmatic decisions. One major obstacle we faced was following the recommendation for using XQuery as a query language for search functionality. The reality is that there are very few products that currently support Xquery, indeed, many of the existing repositories of eduSource stakeholders do not support XQuery. Two possible solutions to address this problem were: 1. degrade query language to a less powerful but commonly supported language, such as XPath; or 2. use XQuery but provide a solution that will enable all repositories to participate in eduSource. Although first option looked attractive from the implementation point of view we opted for the second option mainly because of long-term benefits of having a solution following the recommendation from IMS. We have implemented several template XQueries to satisfy the requirements of the major stakeholder[4]. Participants without XQuery support may implement as many templates as they want to support and register these services with their explicitly specified supporting format. EduSource participants who support the full XQuery will support all defined templates through their XQuery engine.

5. IMPLEMENTATION

Designing and implementing eduSource architecture including ECL is just one of several goals that the eduSource project is attempting to achieve in a short period of 18 month with a $9M budget. This intense project requires simultaneous advancement of several interconnected development activities. We have opted for an iterative development process which saw the most

[4] Templates differ by their query capabilities and ways how they format their results. For example, one template specifies keyword based search and formulates results in brief format. Another template specifies keyword search and returns full IEEE LOM records.

important, most informing and riskiest functionality implemented in the first round. Our aim was to develop the frameworks for the connector and gateway for the most complex services. This enabled us to test the feasibility of our approach while address other issues such as the critical need for content in the eduSource network.

We have opted for the ‘gather’ function as our first ECL service. As IMS DRI recommends using OAI protocol we have implemented the OAI protocol commands into ECL communicating via SOAP messages. Gather functionality enabled us to implement first versions of both the connector and gateway. The gateway for mapping between ECL and OAI enabled us to connect to the large NSDL initiative that provided eduSource participants with access to NSDL resources.

The search functionality was the second ECL service to be implemented. Again, we have implemented search service in the connector and connected existing systems and tools used by eduSource partners. The search service in eduSource is peculiar as we are connecting server type of repositories via federated search and we connect to our SPLASH peer-to-peer system that uses a broadcast-relay search mechanism. To connect to the peer-to-peer system we have implemented another gateway translating between ECL and peer-to-peer protocol. To test the flexibility of our solution we have took a challenge to implement a federated search similar to the one presented by Merlot team at the Merlot 2003 conference [2]. We were able to implement two chains of handlers for EdNA (http://www.edna.edu.au) and SMETE (http://www.smete.org) into an existing ECL-OAI gateway and build a simple web based interface in 2 weeks time with one programmer. The federated search experiment is accessible available from the www.edusplash.net website.

The implementation of the ‘submit’ service required us to expand our SOAP implementation framework with SOAP attachments and introduction of IMS Packaging for submitting object and metadata to the repository. Another aspect of submit is that many repositories require some level of authorization for the submit operation. ECL does not provide a user registration service; instead the user registers with the specific repository directly. ECL uses a PKI mechanism to secure sensitive login information in the submit messages.

Achieving the fundamental functionality we have stopped the development of the protocol at this stage and now we are focusing on the registry and discovery of the service. We will finalize full ECL protocol development and implementation by December 2003.

6. CONCLUSIONS

In a perfect world there would be only one metadata protocol and we would need only one repository and one search mechanism. However, the reality of e-learning is a hodge-podge of legacy repositories, protocols, special interest groups and self-serving communities. Rather than preach conformance, the eduSourceCanada project focused on the common functions desired by the owners and user of learning object repositories and strived to intermediate between the technologies involved. Our previous experience with POOL, POND and SPLASH proved that heterogeneous repository types could and should co-exist and serve a global interest in the re-use of learning objects. Although the protocols described in this paper are but baby steps in that direction, they demonstrate that the technical barriers can be overcome and that robust solutions to interoperability are not far away. However, the ultimate challenges to interoperability remain political – we can only interoperate with those repositories that wish to do so.

7. ACKNOWLEDGEMENTS

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