

PACHO—A Semantic P2P Network for Virtual-Reality-Based Heritage Objects and Resources

Martin White¹, Krzysztof Walczak², Wojciech Cellary², and Andrzej Prinke³

¹Department of Informatics
University of Sussex
Falmer, Brighton,
United Kingdom, BN1 9QT

²Department of Information Technology
The Poznań University of Economics
Mansfelda 4, 60-854 Poznań, Poland

³Department of Protection of Archaeological Heritage
Poznań Archaeological Museum
Ul. Wodna 27, 61-781 Poznań, Poland
M.White@sussex.ac.uk

Abstract

This paper proposes an innovative concept of an Internet-based system that will enable individuals and organizations to share digital heritage resources in the form of 3D models of artifacts accompanied by images, sounds, movies, catalogues, and archives. Semantic Web services will enable easy categorization and retrieval of digital heritage resources. User-friendly online tools will simplify widespread citizen access. The system will function similarly to the music and movies P2P sharing networks, but will be based on a legal and self-sustaining business model offering users a possibility to present their own archaeological and historical collections, scientific documentation, field research notes, etc., as well as the creation of thematic presentations. The digital library resources collected and maintained by the users will be subsequently aggregated into virtual museums. Ideally, the community of users can grow almost without limit, as its new members bring both demand and supply.

1 Introduction

Modern information and communication technologies (ICT), such as virtual and augmented reality, offer an appealing medium of presentation for cultural heritage, enabling reconstruction of both existing and lost artifacts, monuments, and historical sites, and facilitating flexible, fun, and engaging access to the citizen. Constant progress in both hardware and software systems is gradually decreasing the cost and effort required to create three-dimensional (3D) models and virtual exhibitions (Walczak et al. 2006). At the same time, quick expansion of the Internet, progressively replacing traditional forms of accessing information, strongly promotes an active role of users as creators, publishers, and players instead of passive readers, listeners, and viewers.

Museums can take advantage of these technical and societal opportunities by combining leading-edge presentation technologies such as virtual and augmented reality (Walczak et al. 2006) with the power and flexibility of knowledge-based peer-to-peer (P2P) (Wikipedia 2006a) networks and GRID computing (Wikipedia 2006b) systems. In this paper we propose a system that allows P2P access by the public to digital heritage objects (or artifacts) and resources through a semantic GRID digital library—we call this system PACHO, which is short for P2P Access by the Citizen to Heritage Objects and resources.

The proposed PACHO system progresses beyond the current state-of-the-art in the heritage domain by building highly innovative systems that will empower the citizen and any organization to create, semantically describe, maintain,

publish, exchange, and creatively exploit personal or organizational digital heritage resources such as images, sounds, movies, 3D models, catalogues, and archives—the key in our proposal is to empower the citizen (local history group, family tree group, metal detector society, archaeological service, small museum, etc.). PACHO services will be presented to end-users through user-friendly interfaces that will facilitate intuitive usage by individuals and organizations with different levels of computing expertise. But more importantly, PACHO will stimulate the development of a socio-economic culture that fosters a sharing and trading model of our digital heritage objects and resources, facilitating a revolution in cultural heritage access similar to the one in music and movie P2P networks, but based on a legal and self-sustaining cultural heritage business model.

Before we look at how we might implement a PACHO system, let's look a little more closely at an example scenario from the archaeologist's perspective. In a practical dimension, such a powerful instrument as PACHO can be applied following many different scenarios. One of the most obvious could be the construction of a PACHO Net on a regional scale that joins the following categories of partners/users.

1. A main archaeological museum in the region that can provide both its digital collection and expertise.
2. Other cultural institutions of similar profile (e.g., libraries, archives), but of different size and potential; they can supply additional data as well as make use of the products in the form of virtual exhibitions, e-publications, etc. in their own activities.

3. Schools of various types—as receivers of the products (i.e., to be used in e-learning applications).
4. Business enterprises (advertisements, public relations, tourism, etc.)—as the main users of the resources and products of the PACHO Net;
5. Individuals—both professionals (archaeologists, museologists, historians) and amateurs who share interests in the prehistory of the region and support its promotion in various forms (perhaps interested in publication of their research results, education of all types, tourist information, etc.).

According to the scale of the response, one may adjust the PACHO Net range to encompass regional, national, and international interests. But of particular interest is a chance to attract minority groups that are active in archaeology and cultural heritage—such a group might be the metal detector enthusiasts (sometimes referred to as “treasure hunters”) who often make amazing discoveries but do not have the tools, skills, or processes to report their discoveries. This is a very promising opportunity delivered by the PACHO Net allowing users to integrate their discoveries with the common heritage and make accessible much valuable information that is otherwise spread among amateur individuals who cannot apply professional verification methods to their finds. Thus, an additional gain for archaeology might be a possible change in the attitude of so called “treasure hunters” who nowadays devastate numerous archaeological sites using sophisticated and efficient metal detectors, and hardly ever contact any professional archaeologists or official heritage institutions. Their participation in PACHO Net could still guarantee that they stay anonymous, while at the same time enabling them to share knowledge on their discoveries, to provide them with a source of archaeological expertise, and, eventually, to bring their results into broader access.

2 Building a Sustainable Semantic GRID Based Digital Library for Heritage Access

We propose an eight-step approach to building a sustainable semantic-GRID-based digital library for citizens’ access to digital heritage resources, including artifacts and other materials (Figure 1). These eight steps are designed to take into account issues focused on the citizen’s access to his or her heritage, but by default also contribute to preservation of digital cultural and scientific (heritage) resources through a shared digital library approach based on P2P networks similar to the P2P music networks. Such a highly innovative system aims at empowering the citizen and any organization to produce, publish, and maintain personal or organizational digital heritage resources such as images, sounds, movies, 3D models, catalogues, archives, etc., and to organize such resources in virtual museums or exhibitions.

Our proposed system’s underlying technology will be presented to the end-user through user interfaces that facilitate intuitive usage by any individual or organization with varying levels of computing expertise resulting from gender, age, and background variations, and drawing on the experiences of others, particularly in human-computer interface

design, and the design of virtual museums (Walczak et al. 2006; ARCO Project 2006; Sharp et al. 2002; Shiao et al. 2004; (Shneiderman et al. 1989; Shneiderman 1997).

Figure 1 illustrates the concept whereby small museums, local history groups, the citizen, and so on use a set of PACHO Semantic GRID Services to aggregate their digital heritage resources (3D models, images, text, videos, etc.) into distributed heritage repositories that are organized as collections or virtual museums and exhibitions.

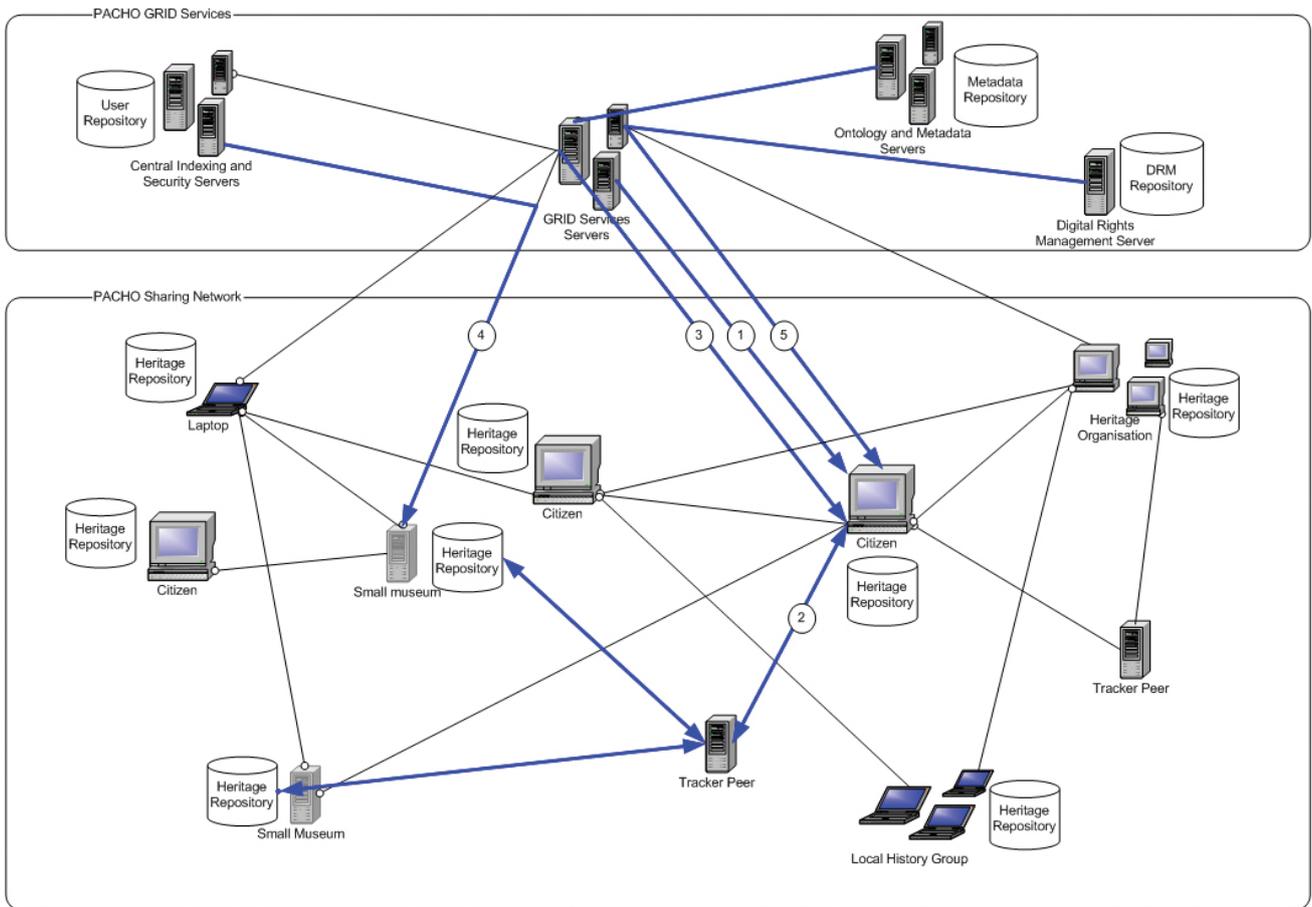
In summary, A PACHO Semantic GRID requires the definition and implementation of the following eight technological steps, which are described in detail in the following sections.

1. A digital heritage resource model based on a rich multimedia representation for the heritage artifact.
2. A set of Web/GRID service tools for managing digital heritage resources.
3. A set of Web/GRID service tools for interacting with digital heritage resources.
4. A set of Web/GRID service tools for publishing interactive digital heritage resources.
5. A network infrastructure ideally based on Open GRID and Web Services.
6. A distributed database systems that is self organizing.
7. A set of digital library services with semantic meaning thus creating a Semantic GRID.
8. A set of security services to protect the PACHO Semantic GRID.

2.1 Digital Heritage Resource, Artifact or Object Representations

Of foremost importance is the need to develop the most appropriate digital representations of our heritage resources, artifacts, or objects in the context of a digital library (Shiao et al. 2004). In this respect, a rich digital multimedia representational model should be specified (that also adheres to standards where appropriate) and into which the citizen can input digital information that describes an artifact, e.g., metadata, text, images, video, and 3D virtual reality digital content—in short, semantically rich data structures that are self explanatory and coded appropriately and intuitively in the user interfaces will be implemented. Semantic metadata based on cultural domain-specific ontologies should be used to enhance the descriptions, guide the automatic creation of new digital content, and create new knowledge using appropriate inference mechanisms.

Access to digital information will be controlled through a Web/GRID service that controls the input format to the PACHO digital library—the user, whether citizen or museum curator, simply follows a form-oriented approach to enter data. Implementation of P2P and GRID infrastructures, in the home and in our cultural and scientific heritage institutions, will be extended to include virtual and augmented reality heritage resources that augment current digital heritage object descriptions, thus building a semantically rich digital heritage object representation. Such a rich representation then allows “third parties” to create interactive



Key:

- (1) Citizen peer does a semantic search and finds an appropriate heritage data file;
- (2) Peer to peer search finds 2 small museum peers with the file (chooses one with fastest ping for download);
- (3) Citizen peer checks small museum peer and is authorized to provide data;
- (4) Small museum peer checks citizen peer and is authorized to receive data;
- (5) Citizen peer gets license to unlock media and uses it (perhaps even pays a fee!).

Figure 1. P2P and Semantic-GRID-based digital library of heritage objects and resources access by the citizen.

heritage experiences for learning about our worldwide heritage that uses the heritage content and metadata in interesting and clever ways to reinforce the learning of one's national heritage.

The PACHO digital library should take advantage of existing standards in its implementation—such as the Open GRID Service Architecture (OGSA) (Foster et al. 2001), the Web Services Resource Framework (WSRF) (OASIS 2006), and P2P technology—to determine the best way to implement the proposed system. The question of how existing P2P networks such as BitTorrent (BitTorrent 2006; Wikipedia 2006c) can be leveraged and moved beyond the state-of-the-art both at the heritage network file sharing and GRID levels should be resolved, including the issue of how best to resolve limitations such as digital rights management. That resolution will allow for the implementation of the underlying infrastructure of a PACHO digital library based on Semantic GRID concepts

2.1 Web/GRID Service Tools for Managing Digital Heritage Resources

A PACHO GRID implements a range of simple (for the citizen) Web/GRID service tools that allow citizens or cultural organizations to manage (import, edit, delete, etc.), for their heritage-stakeholder community, their digital heritage resources. These tools automatically package the accessioned digital resource into “learning objects” (based on a suitable learning object standard) to a sustainable digital library for community access and heritage learning. Such easy-to-use and intuitive tools are of paramount importance to allow novice technology users, whether the citizen or museum curator, to create the heritage repositories illustrated in Figure 1. As an example, we could think of these Web/GRID service tools as being analogous to a set of tools that allows the user to build a dynamic Web site, but with simple-to-use Web interfaces allowing the user to store or catalogue his or her digital heritage objects and to visualize these catalogues according to a set of predefined templates—a well-understood methodology.

A typical scenario would be where a citizen or museum

wishes to build a digital library composed of a collection of digital artifacts. The curator follows a simple two-step process. First, the curator accesses a PACHO Web service that guides the curator through a self certification process that qualifies him or her to use the PACHO digital library professionally, and accession resources to the library—this is essential for giving the “treasure hunter” “authority” to accession their discoveries to the PACHO Grid in a well-defined and auditable way. Second, the citizen then uses another PACHO Web service that guides them through the accession process. However, first the artifacts are assumed to be digitized, and if not, the citizen can chose to access a digitization service (if actual physical 3D digitization is required) or follow guidelines that set minimum standards for digitization (actual digital recording of the digital representations) accessed via another PACHO Web service.

2.3 Web/GRID Service Tools for Building Interactive Heritage Experiences

So far, we have outlined what is needed to both digitally represent and effectively manage digital heritage resources on the PACHO network or GRID. This allows us to visualize through predetermined templates in a catalogue fashion our digital resources, which is great for researchers. But, we want to learn more about these resources and use the new technologies such as virtual and augmented reality and other multimedia visualization types to interact with these resources. Thus, PACHO will also implement a range of simple (for the citizen) Web/GRID service tools that allow the citizen or heritage organizations to build new forms of highly interactive, multimedia-based, heritage experiences incorporating graphics, sounds, and 3D virtual reality representations where appropriate. The citizen or cultural organizations will be able to assemble digital heritage objects into interactive experiences using a set of citizen-oriented Web/GRID services that guide the citizen through the process of linking digital heritage objects and resources into learning scenarios based on appropriate learning technology standards. Such interactive experiences may require the distributed resources of the PACHO GRID including file sharing and server-side compute resources to render efficiently over broadband connections. These Web/GRID service tools will build into the interactive experience the features needed to exploit the GRID properties of the PACHO network to generate enriched collaborative access to virtual and augmented reality cultural heritage experiences. For example, if a creative experience is built for a photo-realistic tour of an archaeological site, which is then rendered in a museum display environment, the rendering process will exploit the compute resource inherent in the museums’ PACHO network.

2.4 Web/GRID Service Tools for Publishing Interactive Heritage Experiences

We can now encode our digital heritage resources in a semantically rich way, catalogue them into the PACHO

digital library, index and access them, and build interactive heritage experiences, all through a set of user-oriented Web/GRID services. But we now need to publish these experiences online to a variety of audiences. To accomplish this, PACHO will also implement for the PACHO digital library a range of simple Web/GRID service tools. These tools will employ knowledge technologies that allow the citizen to publish easily accessible experiences based on enriched representations of heritage resources using several innovative access modes (individual or collaborative) through the Web or in local museums. PACHO will use existing ICT infrastructure such as broadband, home computers, displays, and webcams to visualize the new digital heritage resource medium. This medium is a multimedia representation that enhances heritage access and learning, including virtual and augmented reality experiences. Further, it takes advantage of these new experience technologies (virtual reality, for example) that are enabled through broadband access. The citizen, facilitated by broadband access to a PACHO network or GRID, will be able to share and visualize these innovative experiences in the home or the local cultural institution simply by accessing over the Internet an appropriate PACHO digital library service for online viewing or download.

2.5 The PACHO Network or GRID Infrastructure

For PACHO to work, we need to build the network infrastructure, and for this PACHO proposes to implement a citizen-focused, access-sharing network based on the Open GRID Services Architecture (OGSA) and Web Services Resource Framework (WSRF) coupled with a P2P file sharing network technology similar to something like BitTorrent—we call this the PACHO GRID. The PACHO GRID will provide three main functionalities: resource sharing, authorized access to resources, and a compute infrastructure where appropriate for implementation of the PACHO digital library (Gioldasis et al. 2004).

The PACHO GRID will define a layered architecture starting with the PACHO digital library application layer that implements Web/GRID service tools (i.e., tools that allow the citizen to produce, present, and access heritage resources). This layer in effect characterizes the concept of a PACHO-based digital library service to which a citizen or organization can contribute and access digital heritage resources. The next layer is a service-oriented layer built upon the OGSA and WSRF specifications. This service-oriented layer defines such functions as presentation of heritage resources for visualization, access to heritage data services, and core services (such as discovery and information retrieval services). Services provide access to the underlying PACHO GRID resources, such as security services, digital rights management services, metadata services for semantic markup, a self-organizing XML database system, and semantic search services. The final layer is the PACHO GRID physical and logical resources layer composed of appropriate servers, storage, and networking (P2P). This layered implementation of an Open GRID Services Architecture over a server-supervised P2P network will

provide the optimum implementation of the PACHO digital library service that allows citizens and organizations to cooperate in production and distribution of digital heritage objects (based on a learning object paradigm) at a national and international level. The P2P access infrastructure is based on a sustainable digital libraries model that increases incentives for PACHO network members to access heritage content in a way that is also socio-economically optimal.

2.6 A Self-Organizing XML-enabled Database System

One of the most important features of the PACHO system is the distributed heritage repositories and how they are managed and accessed. Clearly, PACHO is a community concept and thus all its facilities and utilities are planned to be managed by the community similar to many other Open Source initiatives. One idea we have to keep maintenance of the heritage repositories to a minimum is for PACHO to develop a highly innovative, self-organizing XML-enabled database system (that requires zero maintenance from the “heritage community”) that allows users to index, categorize, retrieve, aggregate, use, and creatively exploit heritage resources and their integration into a sustainable digital library service.

The database system should take into account existing multimedia metadata standards, e.g., MPEG-7 (Martínez 2004), in order to provide a framework for describing the digital heritage resources—the first issue outlined above concerns appropriate conceptualization and representation of the digital heritage resource. Existing standards must be extended, e.g., using MPEG-7 DDL (Martínez 2005), to provide support for defining specific features of 3D, virtual reality, and augmented reality objects and experiences, with particular emphasis on their interactivity and dynamism, as well as new classification schemes based on museum and educational metadata standards to enable unambiguous definition and interpretation of metadata values (Tsinaraki et al. 2004). Digital heritage resources registered in the database can be automatically organized using multi-level dynamic categorization hierarchies based on the complex metadata descriptions of the resources. The categorization hierarchies should be connected to an ontology service allowing both complex searches and advanced browsing paradigms.

For example, a picture described as taken in Paris in July 2005 will be automatically accessible in categories such as Paris, France, Europe, World, and also 2005, 21st century, Summer, as well as Summer in Paris in the last three years, without the author even knowing that such categories exist in the database. End-users will be able to define new categories as complex predicates on multiple metadata fields including both discrete and quasi-continuous data types and the ontology services.

A software environment will be created allowing the management of domain ontologies necessary for the indexing of digital content residing in PACHO peer repositories. The metadata descriptions of a particular digital object or part of an object may use multiple ontologies covering different domains. State-of-the-art ontology-based retrieval languages and inference mechanisms by the Semantic Web

Community will also facilitate and influence the work on the user querying. Semantic annotation, and the associated tools to make use of this annotation, will make PACHO a Semantic GRID.

2.7 Creating the PACHO Semantic GRID

PACHO will develop protocols to convert the citizen-focused PACHO GRID into a virtual heritage access organization that allows coordinated digital library resource sharing. This means extending the Open GRID Services Architecture to a point where both the digital heritage resources and the Web/GRID services tools that facilitate access are given a well-defined meaning in the context of digital library services. In other words, we convert the PACHO GRID into the PACHO Semantic GRID, and we do this by developing appropriate ontology and metadata-based middleware focused on existing standards such as RDF or OWL schemas (Tsinaraki et al. 2005; Tsinaraki et al. 2004a, 2004b). To give the PACHO GRID semantic meaning in the context of a digital library service, we will develop an ontology that allows intuitive and natural resource discovery of digital cultural and scientific resources using Web/GRID Services. We propose to do this using the W3C standard Web Ontology Language (OWL) and/or the Resource Description Framework (RDF), thus moving PACHO beyond the state-of-the-art (i.e., the Semantic Web) into a PACHO Semantic GRID that effectively supports resource sharing and interoperability (i.e., effective integration of heterogeneous resources) (Tsinaraki et al. 2003).

This will allow citizens and organizations to format their digital heritage data in a standards-conformant way, thus facilitating aggregation of similar resources into a sustainable digital library service. Thus, we will develop a set of Web/GRID services based on the notion of the Semantic GRID that allows the citizen to discover (index, retrieve, aggregate, use, and creatively exploit), reuse, and enrich existing digital cultural and scientific resources, in effect multiplying complex objects for access by the citizen. Further, by doing this, we enable the preservation and interoperability of heritage resources, discovery through Web/GRID services, presentation of resources to the citizen, sharing of resources across networks, and management of the digital resources. In effect, digital libraries thus created can aggregate into digital or virtual museums that are in effect curated by the citizen.

2.8 Securing the PACHO Digital Library

PACHO will develop two main GRID security services. The first service implemented will be a standards-based, interoperable, digital rights management (DRM) model that is integrated with the PACHO Semantic GRID, and which is a basic requirement to protect ownership of heritage intellectual property (IP) (raw digital heritage resources and subsequent enriched heritage objects). The second security service is concerned with securing the actual GRID infrastructure by controlling access and distribution of PACHO

heritage resources through sustainable digital library services that facilitate exploitation through contents-based business models. These security services are seen as crucial to enabling the future of sustainable heritage digital library services. Thus, PACHO implements first a GRID-based DRM while at the same time ensures the GRID infrastructure is secured.

The PACHO Semantic GRID can be thought of as a P2P network where a group of PACHO members are browsing collections and archives. But when PACHO members are accessioning, discovering, and enriching digital content, they interact with a GRID-based service that provides DRM, indexing, and security functions. In the former case, a GRID security service will be developed that enforces a strict PACHO usage policy starting with the concept that all PACHO end-users will become certified to professionally use the PACHO digital library service—thus bringing the “treasure hunter” in from the cold. Access to the network is thus controlled and followed by different levels of certification that allows the PACHO member controlled access to network files. In the latter case, the PACHO Semantic GRID will also have security servers to manage standard network security issues. For example, a written GRID security policy will be drafted to ensure integration of a new PACHO member’s computing resource to the PACHO GRID has the appropriate firewall, password access, anti-virus software, etc.

3 PACHO GRID Concept

Figure 2 illustrates the PACHO GRID concept, which is composed of three architectural layers: the GRID application layer implementing Web/GRID service tools, the WSRF GRID services oriented layer, and the GRID/P2P physical and logical resources layer. The first layer in effect implements the PACHO digital library, the second implements functionality such as security, ontologies, digital rights management, and so on, while the final layer provides the network infrastructure based on P2P and GRID technologies, and is where the heritage data are stored. Think of the final layer as the physical infrastructure, i.e., the citizens’ and museums’ computing networks and broadband supplemented by appropriate PACHO GRID services (security, ontology, DRM, and other servers).

The implementation of PACHO over a P2P “sharing” network and GRID Infrastructure (Figure 3 shows both an architectural and technology view) is also based on a digital libraries model that leverages the Semantic GRID by providing semantic search services and is also focused on sustainability allowing the heritage community to share the cost of access to heritage resources and repositories, including production, presentation, and maintenance costs on the P2P sharing network. PACHO will thus allow cooperative community access in a manner that can grow almost without limit, because new citizens or organizations accessing their heritage through PACHO bring both demand and supply. The more popular a PACHO digital library (and there

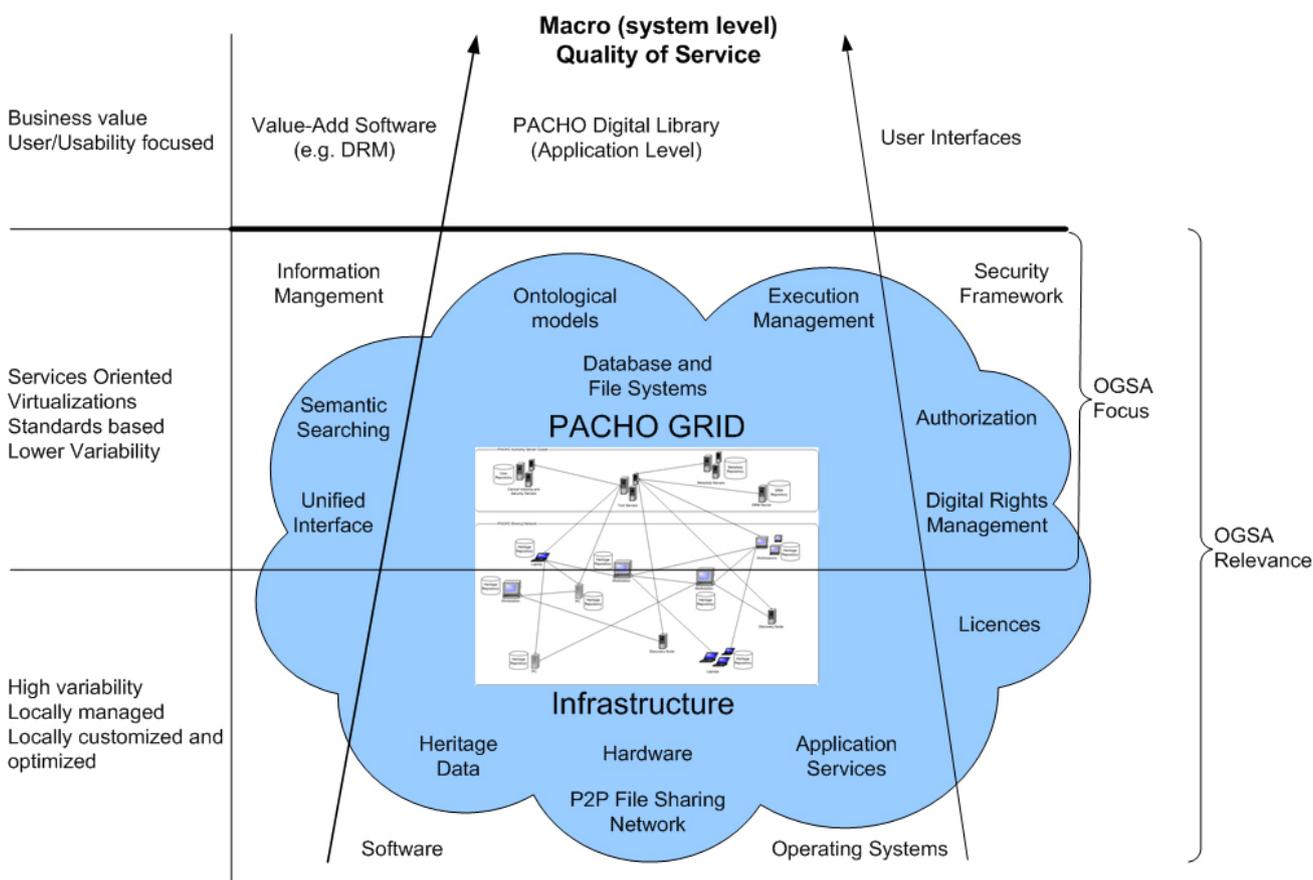


Figure 2. Conceptual PACHO GRID.

are many types, e.g., art history, local history, archaeological, scientific collections, virtual museum exhibitions, and so on) becomes, the more new users join (i.e., citizens or organizations) bringing new resources to these community-based heritage repositories (digital library archives). These new users contribute to these repositories by accessioning and managing their own digital cultural resources to a community-based PACHO digital library managed by themselves for themselves, while at the same time bringing more access bandwidth (through their own broadband connections) and storage media.

An important issue will be that of digital rights management (DRM), which will pose challenges for the digital content communities expected to benefit from PACHO. Cultural and scientific institutions are actively taking up DRM technologies, and several working groups concerned with DRM now exist. PACHO monitors these activities to determine a suitable strategy for compliance with DRM strategies. PACHO is expected to produce virtual communities of digital heritage content through its GRID-based digital libraries, which will require DRM architectures to manage IP asset creation and capture, IP asset management (this is particularly important for memory institutions as an exploitation route), and IP asset usage. But open archival standards are also an issue here, so attention is given to the OAIS Reference Model (CCSDS 2002), PREMIS (PREMIS

2006), and the like.

4 Potential impact of PACHO

The PACHO system is aimed at allowing cultural and scientific institutions and other heritage stakeholders (e.g., museums, galleries, and historical/scientific/cultural societies) to build digital heritage objects, resources, and interactive experiences based on multi-origin digital heritage archives and multimedia, 3D, virtual and augmented reality learning environments, all accessible from P2P based GRID systems. The development of PACHO is based on the integration of semantic GRID access technologies with digital library repositories focused on access by the citizen to interactive heritage experiences in the domains of cultural and scientific heritage and their reuse through adoption of emerging international standards using a service-oriented architecture and Web/GRID services.

New Web/GRID service tools for building digital heritage objects and interactive heritage experiences will be integrated with digital libraries and allow them to publish their own multimedia heritage experiences through the Web or in local museums using existing ICT infrastructure such as broadband, home computers, displays, and webcams. Such Web and GRID services will integrate interactive

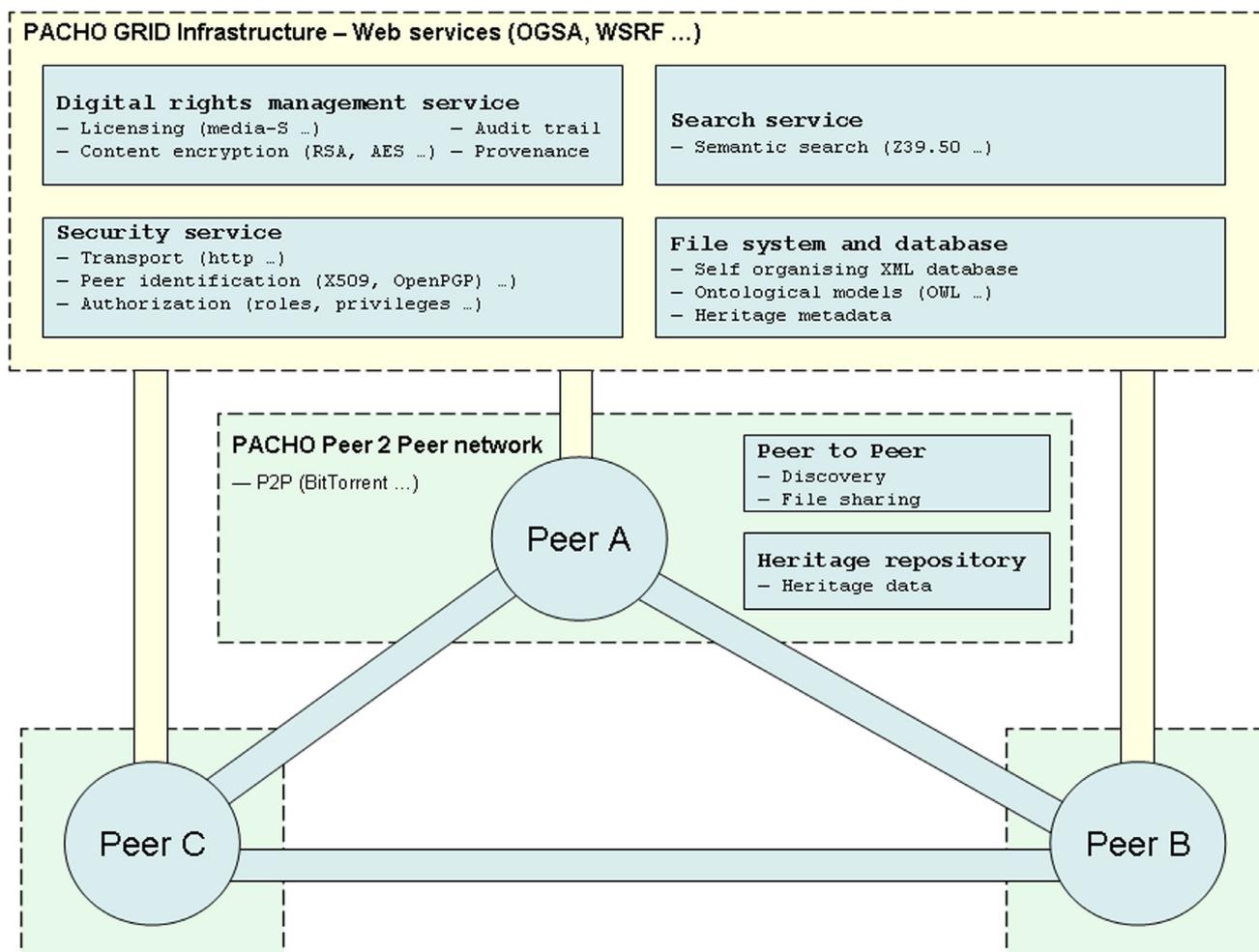


Figure 3. PACHO Technology.

multimedia with virtual and augmented reality cultural and scientific heritage contents.

Recognizing that for developing successful heritage access, PACHO technology needs to be integrated with strong didactic methodologies. A careful analysis of how the citizen accesses cultural and scientific resources in the traditional way, and how this can be mapped to online access patterns, should be performed in order to define the guidelines driving all the technical implementations. PACHO must also take account of the specific needs of all specific user communities and stakeholders, involving innovative scenarios of use. Main beneficiaries of the PACHO technology and new Web/GRID services will be cultural and scientific heritage institutions, which mainly belong to the public sector and do not typically have access to the financial resources available to private institutions. These institutions will have the possibility of extending the range of services offered, increasing their revenues by applying PACHO technology to build standardized and reusable digital cultural and scientific objects and experiences. On the other hand, educational institutions will have the great opportunity of offering to their students a new range of innovative resources integrating them in their pedagogical processes.

The use of PACHO technology will contribute to the enhancement of digital literacy among humanities and science experts. State-of-the-art technologies involving multimedia, virtual and augmented reality are perceived to be difficult and time-consuming to use. PACHO may demonstrate how these technologies can be made simple and useful, helping teachers and students to get closer to ICT.

PACHO may have a significant impact on cultural and scientific institutions and the way they implement their digital libraries. There will now be the choice for museums to build their own digital libraries based on GRID concepts, or encourage local heritage stakeholder communities to build their own digital libraries. Most importantly, any individual could be either invited by an organization or by their own initiative to produce and publish heritage material enriching a worldwide repository. New tools will be made available for these communities and individuals to build self-sustaining digital library heritage communities.

Cultural and scientific institutions will have access to a new range of tools that will allow them to package their digital objects and experiences for access and reuse benefiting from self-sustaining digital libraries. The main benefits for these institutions will be as follows.

- Ability to share (subject to appropriate DRM architectures) their digital cultural and scientific contents on a larger scale, thus significantly increasing their visibility. This will be particularly relevant for smaller heritage institutions, which do not have the financial resources to promote their activity beyond the local area. Thanks to the project's results, they will be able to reach a wider audience, even on an international scale.
- Possibility of introducing new innovative services based on several media, thus generating new revenue lines. For example, museums will be able to design new digital library services targeting both young and adult visitors, and to launch information services

based on heritage content from several standardized digital libraries. Market evidence shows that these kinds of services are becoming more and more important as revenue generators.

PACHO will give citizens belonging to societies such as local history groups the tools and means to build and manage their own heritage digital libraries, similar to the way citizens subscribe to music P2P computer networks operated by participants sharing computing power and bandwidth. Such societies will be able to share and trade their digital objects and experiences knowing they are safe and managed in a standardized way through PACHO digital library services by their own community. And the cost to them will be no more than what they already own: a PC, broadband, their digital heritage objects, and their time.

Heritage content publishers specialized in cultural and scientific content will improve and innovate their offering, thanks to the introduction of new digital cultural and scientific resources (e.g., interactive multimedia contents, virtual reality reconstructions, and simulations). As a result, their competitive position will be strengthened. This will be particularly relevant for smaller publishers, which today do not have the financial resources to introduce innovative services. We are certain that the PACHO concept may give a new impulse to the growth of this sector, which has suffered from stagnating growth rates during the last years.

5 Conclusions

In this paper, we have described an integrated approach to building a Semantic P2P Network for virtual reality heritage objects and resources called PACHO. We have outlined eight technological steps we believe are necessary to implement a PACHO semantic GRID based on the concept of digital library services, including the following: establishing a Digital Heritage Resource Model; providing Web/GRID services for managing, interacting, and publishing these digital resources; organizing the network infrastructure based on Open GRID and Web Services standards; providing a self-organizing database technology that is crucial for distributing digital resources across the network; developing digital library services with semantic meaning to allow intuitive and natural resource discovery of digital resources; and providing a security layer to protect the PACHO digital resources. An overriding focus of PACHO is that it should be implemented and organized in a similar manner to the way existing peer-to-peer networks access and share music files. In addition, it will take account of both the museums perspective on digital curation, while empowering the citizen, by, for example, encouraging the amateur or "treasure hunter" to engage in their regions heritage in a professional or at least semi-professional way.

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