Naming and meaning of Digital Objects

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Abstract

Transacting digital content requires that the entities being managed have unique names denoting a specific referent. These names must have some agreed meaning so that one computer system knows what the names and attributes from another computer system denote. This paper discusses principles of naming and meaning on digital networks, and existing common naming mechanisms. It then describes the Digital Object Identifier (DOI) system for identifying content objects in the digital environment. DOI names may be assigned to any entity for use on any digital network using the internet protocol. DOI names build on the existing Handle protocols. The following areas of advanced development showing increased functionality are discussed: contextual resolution of identifiers (resolving an identifier in a way appropriate to the user); multiple resolution of identifiers (resolution offering additional management capabilities); a mechanism for semantic interoperability of identifiers (the expression of meaning); internationalisation of identifiers (use of non-Roman characters); and adding value through integration into Domain Name System resolution. Problems with the current internet approach to naming standards are discussed.

1.Naming and meaning on digital networks

Digital information needs to be a first class citizen in the networked environment. The fundamental characteristic of digital information is that it is processable data, enabling re-use and hence new forms of electronic commerce, creativity and social benefit. Managing these units of digital information, the "citizens" in the network, requires that they have unique *names* (or "identifiers") denoting a specific referent. Equally, these names have to have some agreed *meaning* so that one computer system knows what the names and attributes from another computer system denote. As applications become more sophisticated, objects may be representations of people, resources, licences, avatars, sensors, etc., which requires the ability to identify them by name and to have these names specify identity (what is named).

Naming is a prerequisite for management of digital information entities: as a means of storing, accessing, disseminating and exchanging them. Meaning is a prerequisite for enabling them to interact: as a means of interoperability and digital policy management[1]. It has long been recognised that unique identifiers are essential for the management of information in any digital environment. Identifiers assigned in one context may be encountered, and may be re-used, in another place (or time) without consulting the assigner, who cannot guarantee that his assumptions will be known to someone else. To enable such *interoperability* requires the design of identifiers to enable their use in services outside the direct control of the issuing assigner. The necessity of allowing interoperability adds the requirement of *persistence* to an identifier: it implies interoperability with the future. Further, since the services outside the direct control of the issuing assigner are by definition arbitrary, interoperability implies the requirement of *extensibility*: users will need to discover and cite identifiers issued by different bodies, supported by different metadata declarations, combine these on the basis of a consistent data model, or assign identifiers to new entities in a compatible manner. The DOI system, discussed below, is designed as a generic framework applicable to any digital object, providing a structured, extensible means of identification, description and resolution. The entity assigned a DOI can be a representation of any logical entity.

1.1 Naming mechanisms

The name assigned to an item of digital media we wish to manage should be a first class name: one that has an identity independent of any other item. The identity allows the item to persist when its attributes change,

and other items to claim relationships with the item. As a general rule, first class items represent things rather than relationships.

- A URL is not a first class name, but is an attribute: a location of a file on the WWW, currently based on the DNS (Domain Name System) – although the URL specification allows addressing by full path to host (IP address), this is rarely used. If the content, but not location, of the file is changed, a user may not know this; if the content of the file is moved, the URL link won't find it ("404 not found", or manual redirection, or automated redirection which may not persist). All URLs at one location have to be ultimately managed by the same domain name owner: the owner of the domain name has final control over all the URLs beginning with that name, which makes URLs especially brittle for any piece of content which could possibly change owners.
- a URN is a naming convention for the content of files on the internet. Although designed so that it is independent of any underlying technologies such as DNS, the only present technique of resolving URNs in the Internet is based on DNS. There are no widely standardised ways of using this: e.g. you can't type URNs into browsers except in certain special circumstances.
- URI is the collective name for URN and URL schemes.
- A Handle[2] is a name for entities, designed for use on IP (Internet Protocol) networks (i.e. the internet) which (a) can be used with the DNS, but is not DNS-based; (b) can redirect to a URL and is managed to be persistent even if the URL moves; (c) can have additional features of granularity of management, structured metadata, scalability, reliability, etc
- A Digital Object Identifier (discussed below) is a Handle system implementation with additional features designed for the management of intellectual property entities in digital networks.

Some existing and emerging applications have successfully managed information in the form of digital objects which are stored, accessed, disseminated and managed. A digital object is a data structure whose principal components are digital material, or data, plus a unique identifier for this material[3]. A digital object architecture provides naming conventions for identifying and locating digital objects, a service for using object names to locate and disseminate objects, and access protocols, forming an infrastructure that is open, and which supports a large and extensible class of distributed digital information services. Digital libraries are one example of such services; numerous other examples of such services may be found in emerging electronic commerce applications. The Digital Object Identifier System is an application of digital object architecture together with tools to ensure semantic interoperability.

The comparison of DOI and/or Handle internet identifiers to 'other web identifiers' such as URI is in some ways misleading. DOI and Handle systems are agnostic as to technology (web, mobile, P2P, etc) and assume only the existence of IP (the internet protocol). The World Wide Web is a communication medium and a highly successful one; but it is not an information management system (for example, it hasn't made databases obsolete). The DOI System, especially as it has evolved, has much more in common with an information management system or inventory system or distributed database than it does with web publishing. It is easy to misunderstand this because what is primarily managed at the moment is the web publishing aspect (if you want to get that article on the web, which will naturally involve using web protocols, go here). But the goal is to provide a management framework for the identified entities. Making them available on the web will naturally involve using web tools and protocols, which is unsurprisingly what is now happening.

2. Digital Object Identifier (DOI) System

The International DOI Foundation has developed DOI names (Digital Object Identifier names)[4] [5] as actionable persistent identifiers for content-related entities. A Digital Object Identifier (DOI) name can be assigned to an entity on digital networks. The system then provides for persistent and actionable identification and interoperable exchange of managed information on digital networks. Note that "DOI" is construed as *"digital identifier of an object"* (not "identifier of a digital object"); and the term *"object"* here is used in the accepted ontology sense of an entity which may be abstract, physical or digital[6], since all these forms of entity are of relevance in content management (e.g. people, resources, agreements) and may be manifested in, or compounded within, a particular object. It is an

implementation of the Handle system, one of the four components of the system. The DOI system as a whole is currently undergoing standardisation through ISO TC46/SC9.[7] The components are:

- *Numbering syntax*: rules for assigning an alphanumeric string (a number or name) to the intellectual property entity that the DOI name string identifies; a syntax standardised as ANSI/NISO Z39.84-2006. The number may incorporate any existing identifier scheme (thereby retaining its construction, check digits, etc.) though for the purpose of the system the string is "opaque" or meaningless. DOI names are not case-sensitive and have no fixed field length.
- *Description* of the entity that has been identified with a DOI name, through associated metadata. The DOI data model is based on a contextual ontological architecture developed from the <indecs> framework[8], and provides a data dictionary to precisely define referents, and a grouping mechanism (Application Profiles) to relate sets of DOI referents with common properties.
- *Resolution*: the internet technologies that make the identifier "actionable" on digital networks, by providing resolution services, currently using the Handle System.
- *Policies*: the rules that govern the operation of the system, in a social infrastructure. The social infrastructure defines the funding and ongoing operational requirements of the system as well as its day-to-day support and management. One of the key features of the DOI system is a co-funded social infrastructure to ensure consistency and quality. This also ensures a fair distribution of funding for the required technical and social infrastructure needed for the system. As with other identifiers such as ISBN, ISSN, etc, the only persons permitted to register DOI® identifiers are Registration Agencies that have been authorized by IDF, or persons acting under the authority of Registration Agencies

The DOI system is unique in bringing together all four components in a fully implemented and managed system[9].

2.1 DOI system benefits

A DOI name persistently identifies an entity of relevance in an intellectual property transaction and associates the entity with relevant data and services. An entity can be identified at any arbitrary level of granularity. DOI names can be used to identify, for example, text, audio, images, data[10], software, etc., and in future could be used to identify the agreements and parties involved, though initial implementations have focussed on "creations". While the scope of intellectual property transactions is quite broad, it is unlikely that DOI names would be appropriate for identifying entities such as people or natural objects or trucks unless they are involved in such a transaction. DOI names can be used to identify free materials and transactions as well as entities of commercial value. Benefits include:

- *Persistence* – DOI names resolve to information (metadata) about the referent (identified object) in a manner that persists over changes in location, ownership, description methods, and other changeable attributes. If the object ceases to be available, the DOI name at minimum indicates a valid but now defunct identifier.
- *Granularity:* names may be assigned at arbitrarily fine granularity with administrative control at the same level of granularity (each DOI name may have independent management)
- *Interoperability* – providing tools to enable the use of the identified referent in services beyond the assigner's direct control, which enables rich interlinking with related content, so as to increase the content's usefulness and visibility;
- *Extensibility* - the ability to later add new features and services
- *Efficiency* - Through single management of data for multiple output formats (platform independence) and class management of applications and services, efficiency is gained;
- *Dynamic updating* - metadata, applications and services need to be quickly and easily updated.

The benefits of this functionality, because it is essentially generic and so rather abstract, needs to be translated into specific illustrations that make sense for a particular community. For example, DOI names in enterprise content management convey the benefits of knowing what you have and being able to find and use it efficiently[11] [12]. DOI names for publishers provide improved discoverability, longer shelf life for access, and linking to related offerings[13]. DOI names for

citations improve the ability to create cross-links in the publishing production process[14 15].

The initial simple implementation of DOI names as persistent names linked to redirection continues to grow, with over 25 million assigned to date, from several hundred organisations through a number of Registration Agencies in USA, Europe, and Australasia, supporting large scale business uses. Implementations of more sophisticated applications (offering associated services) have been developing well but on a smaller scale. A number of issues remain to be solved: these are no longer technical in nature, but more concerned with perception and outreach to other communities. Persistent, actionable identifiers with a fully managed sustainable infrastructure are not appropriate for every activity; but they are suitable for many, and where they are used, the key to providing a successful and widely adopted system is encouraging economy of scale (and so, where possible, convergence with other related efforts), flexibility of use, and a low barrier to use.

The DOI system is built using several existing standards-based components brought together and further developed to provide a consistent system. The DOI system was developed as a cross-industry, cross-sector, not-for-profit effort managed by an open membership collaborative development body, the International DOI Foundation (IDF) founded in 1998. The DOI system forms a key feature of applications such as scientific primary publishing as part of the CrossRef system[16] (providing a pre-publication processing tool enabling cross-references to be persistent and not rely simply on URLs and bibliographic citation matching). DOI names are being adopted for use in government documents (notably by the Office of Publications of the European Community) and in non-document applications such as scientific data sets.

2.2 Deployment of DOI naming technologies

Handle clients can be embedded in end user software (e.g. a web browser) or in server software (e.g. a web server). The choice is one of embedding functionality in individual clients (which puts it closer to the end user, and simplifies the architecture, but means that you have to deploy and maintain the software using plug-ins etc.) versus simpler maintenance of a centralized piece of middleware (which means that the users must all then talk to that middleware). Handle client software libraries in both C and Java are freely available.

CNRI runs a proxy server system, a collection of web servers that understands the handle protocol and knows how to talk to the Handle System[17]. Many implementations of the Handle System intended to help manage web content use handles embedded in URLs on web pages, and for the convenience of their customers, use the proxy server (or a similar implementation) for resolution. A growing ecology of other tools for handles is developing, both from CNRI and from outside parties: examples include integration into next generation technologies such as GRIDs[18]; "Sente" a Mac OS X application that incorporates the handle resolver for any handles and DOI names that it finds[19]; discussions to get a built-in handle/doi client for Acrobat 9 (requirements gathering is about to start); a demonstration plug-in is already available for Adobe Acrobat which embeds native handle functionality into links within PDF documents.

The DOI system builds on this handle functionality, and deals with the problem of software distribution by making DOI names usable in both native protocols or by a common proxy: several DOI-specific tools are available. Many implementations of the DOI system intended to help manage web content use DOI names embedded in URLs on web pages, and for the convenience of their customers, use a proxy server implementation (dx.doi.org) which has the functionality of the general Handle System proxy but may have additional functionality added in the future. A DOI name takes the form of a URL when the proxy is involved (e.g. *doi: 10.1234/abcd* becomes *http://dx.doi.org/10.1234/abcd*) but this resulting URL will never change even if the actual content location changes. A growing number of specific DOI tools are becoming available[20]: some deploy native handle resolution, whilst others make use of proxies easier - e.g. Connotea, a free online reference management and social bookmarking service[21], recognises and stores DOI names, enabling bookmarking a DOI name directly in web browsers.

3. Contextual resolution of identifiers

The DOI System is already in widespread use with the OpenURL framework, a mechanism for transporting metadata and identifiers describing a publication, for the purpose of context-sensitive linking. A DOI name (identifier) is resolved to the appropriate copy of a

resource (e.g., a library user may be automatically directed to a local library holding instance of a file; a non-library user to a publisher site). DOI applications of OpenURL context-sensitive linking are used in for example the Crossref system for the persistent identification of scholarly content and cross-publisher citation linking to the full-text and related resources using the DOI technology.[22]

In Open URL contextual linking, the same resource is returned from different depending on rights. The Handle System has also been used to develop more sophisticated contextual resolution of identifiers, in which *different* results are obtained from the same identifier in different contexts: the DVIA Registry System provides contextual search, navigation and access for DTIC's Technical Reports[23]. This delivers powerful functionality: User A and User B receive different results from a resolution query about an object, dependent upon A and B's differing rights and access privileges etc in a federation of resources. The DVIA Registry and the Contextual Linking Service leverages CNRI's handle system, Digital Object Architecture and OpenURLs. DVIA Registries can harvest metadata from other registries, using OAI-PMH to publish and acquire metadata from each other. Federated registries behave as single unified registry and are uniquely identified by a handle; but the Context Linking Service can route queries addressed to the federation to the appropriate registry based on federation rules. DVIA Registries can act as a registry of registries by indexing registry level metadata; clients can search a registry of registries to choose which registry or registry federation to issues their queries.

4. Multiple resolution of identifiers

Another type of advanced application of DOI names is multiple resolution; rather than one DOI identifier simply resolving to one URL (as in many current implementations, delivering the basis of first-class persistent identification ion the face of changed location), in multiple resolution one DOI name resolves to *multiple* data types[24]. Some users of the DOI System are now experimenting with such applications (e.g. the CrossRef system[25]). A full implementation may combine multiple resolution and interoperable metadata.

The Handle system enables this by the ability of the resolution service to resolve to multiple state data, returning typed data to be processed by clients to determine applications. Resolution is the process in which an identifier is the input - a request - to a network service to receive in return a specific output of one or more pieces of current information (state data) related to the identified entity: e.g., a location (URL). The handle system returns, in response to a request, either all data types or all values of one data type. Multiple resolution is the return as output of *several* pieces of current information related to a DOI-identified entity - specifically at least one URL plus other defined data structures providing additional information. A client software can then process such data, and deliver an appropriate service. The data may include interoperable metadata, or references to it, allowing meaningful management of the resource. (Interoperable metadata refers to metadata elements and schemes that adhere to well-defined principles including a common ontology basis and so can be understood outside a particular metadata scheme). The basic approach to such full DOI system implementations uses a data model which encapsulates the concepts of DOI names, DOI Application Profiles (APs), and DOI Services. Each DOI name is associated with one or more AP, and each AP is associated with one or more defined Services.

5. Semantic interoperability of identifier referents

How does one computer system know what the terms from another computer system mean? If A says "owner" and B says "owner", are they referring to the same thing? If A says "released" and B says "disseminated", do they mean different from a found identifier, or from a physical object in hand). A given instance of an object will encapsulate several related identifiers of different entities inherent in the intellectual property it represents, any of which might be exemplified in the object. For example, a pdf text file may embody a work; a particular publication edition of that work; and a format of that edition. Incorrect assumptions about the referent of the identifier will lead to error. Most objects of interest in intellectual property transactions have this compound form, simultaneously embodying from a found identifier, or from a physical object in hand). A given instance of an object will encapsulate several related identifiers of different entities inherent in the intellectual property it represents, any of which might be exemplified in the object. Therefore an identifier does not necessarily resolve to its referent, but may often resolve to something we understand to represent it as part of the compound object (akin to the literary figures of speech metonymy: the use of a word referring to an element or

attribute of something to mean the thing itself, as in "the kettle is boiling", and synecdoche: allusion to the part used to imply the whole).

The only way of unambiguously deciding if one term means the same as another, irrespective of what it is called, is by sharing a single frame of reference: a structured ontology (an explicit formal specification of how to represent the entities that are assumed to exist in some area of interest and the relationships that hold among them) with an underlying model that allows the generation of consistent new relationships, and a method of recording the agreement between the parties whose terms are included in it. The indecs project[26] considered logical definition for intellectual property entities through a *Model of Making*[27], relating the various types of creations which are the intellectual content of digital media: performances, fixations and abstractions. One phylum of development resulting from the indecs project, a contextual-based ontology approach for creating data dictionaries, is now well established and in practical use in several major applications. Context has a specific meaning in this analysis: "An intersection of *time* and *place*, in which *entities* may play roles". The most highly developed form of this analysis, the Contextual Ontologyx Architecture (COA)[28], is a generic ontology-based metadata framework comprised of a set of defined types of *Entity* and *Attribute*, and the *Relators* which link them within a contextual model structure. In this analysis every entity belongs to at least one of five primary classes: context, time, verb, place or resource. The underlying central ontology that COA builds is called Ontology_X. It is a proprietary data model, with origins in the development of the indecs metadata framework. It may be expressed in e.g. OWL (web ontology language) for use in Semantic Web applications. The origins of this approach in the indecs project, the methodology for producing contextual data dictionaries, and the widespread applications of the approach (in media commerce through ONIX, DDEX, MPEG-21, and in other areas) is described in detail elsewhere[29]. The DOI System has adopted this approach as the basis of its data model.

6. Internationalisation of identifiers

The internet is a global revolution in communication - as long as you use letters from the western alphabet. There is growing pressure for a net that recognises Asian, Arabic and Hindi characters, too. The DNS only recognizes ASCII characters A-Z, 0-9 and the hyphen, the characters used in primarily Latin-based languages; it does not recognize other character sets. Around 33% of the current online population are native speakers in non-Roman character language zones (Arabic, Chinese, Farsi, Hebrew, Japanese, Korean, Malay, Thai, Vietnamese) - an estimated 240 million people[30], a figure likely to grow especially as online transactions keep moving into traditional areas, e.g. finance and consumerism. Handles may consist of any printable characters from the Universal Character Set (UCS-2) of ISO/IEC 10646, which is the character set defined by Unicode v3.0. The UCS-2 character set encompasses most characters used in every major language written today. To allow compatibility with most of the existing systems, and to prevent ambiguity among different encodings, the Handle System protocol mandates UTF-8 to be the only encoding used for handles. The UTF-8 encoding preserves any ASCII encoded names so as to allow maximum compatibility with existing systems without causing naming conflict.

7. DNS integration

CNRI have collaborated with the China Internet Network Information Center (CNNIC), the state network information center of China. CNNIC is China's domain name registry to operator and administrator of the ".CN" country code top level domain (ccTLD) and Chinese Domain Name (CDN) system. A Handle-DNS integration system has been developed to integrate Handle with DNS through the .cn domain. The International DOI Foundation, a Handle implementation, is discussing the establishment of a DOI Registration Agency in China.

The CNNIC/CNRI collaboration[31] takes advantage of the Handle System to provide a security service for the DNS namespace, including secured DNS resolution (whenever needed), discretionary administration & dynamic update, access control & privacy protection, delegation & real-time credential validation. This service may co-exist with the existing DNS operation: there is no need to change the DNS client.

The abstract Handle System is specified in RFC3650,3651,3652. CNRI have developed, and distribute, a reference implementation of the specification, available as Java through open source distribution. A perfectly compliant handle service built without using any of the reference implementation code would not by definition be distinguishable from the standard version from the outside: the global Handle

records give IP address, port numbers, public keys, etc., but nothing about the internals of the machinery with those handle service attributes. (However, the onus would be on the developer to ensure that this assertion of compliance was true). CNNIC developed a Handle Server in a new implementation in C/C++ (server/client) integrated with BIND 9.3.0 standard distribution, and additional modules offering improved performance. A prototype application offers secured DNS resolution via a Handle protocol interface. Further work will package the Handle-DNS software for public release; deploy the Handle-DNS server in ".cn" TLD registry and its subsidiaries; and establish an ENUM service and client software based on the Handle-DNS interface.

The DNS/Handle integration enables an identifier service for any digital resource over the Internet, with a distributed, scalable service infrastructure similar to DNS with additional features:

- Efficient name-resolution and administration, supporting both TCP and UDP.
- Built-in security options for both name resolution and administration.
- Secure handle resolution, including data confidentiality and service integrity checking
- Discretionary namespace and identifier attribute administration, independent from host-admin, which allows creation, deletion, and modification of identifier and/or identifier attributes (this level of granularity is a requirement for any truly sophisticated extensible management of digital media objects)
- Standard access control model per individual identifier attribute (essential for privacy protection applications).
- A mechanism for credential validation per individual handle attribute.

8. Internet naming standards

Internet naming standards do not yet specify a satisfactory approach for naming objects consistently[29]. Handles are capable of being used in any specification that is finally endorsed. Until a clear consensus is reached in the internet communities on which approach is to be preferred, handle applications remain agnostic as to formal registration as a generic scheme such as URI or URN, but useable and widely implemented for millions of objects. Ongoing debates about the nature of URIs, URNs, and URLs and an ill-defined "IETF architecture for identifiers" suggest that improved standards of clarity and process (e.g., what is the consensus?) would be beneficial to any development which, like the DOI system, attempts to build constructively on existing infrastructure.

There is a danger that the current dominance in internet governance and, perhaps more importantly, in internet funding, of organisations reliant on one naming mechanism, domain naming (a mechanism which makes it particularly difficult to identify digital content independent of location and at appropriate levels of administrative granularity) may be problematic in introducing complementary alternative naming mechanisms[32]. That some internet applications (e.g. peer-to-peer, or multiplayer games) do not rely on DNS demonstrates that DNS cannot be a necessary required component of any future development (for example, P2P, at its core, does not use DNS. There are probably entry point web sites for most services, some of which may be obvious and some of which may not, but e.g. your Skype identity is not based on a domain name, and that's not how Skype finds you; and in fact such systems are designed so that users never even see a recipients IP address). The internet is not DNS but the global information system that is logically linked by a globally unique address space and communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) suites and provides high level services layered on these (or successors)[33]. The Domain Name System and its disputes as to governance through recent WSIS summits have overshadowed the real issues of efficient naming here; DNS is receding in real importance at the same time that governance issues increasingly look at DNS as the thing to govern. There is a danger that the attempt to control uses of internet protocols too closely may impede the evolution of new technologies and even endanger the nature of the internet[34 35].

Note

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