doi Foundation

DOI HANDBOOK

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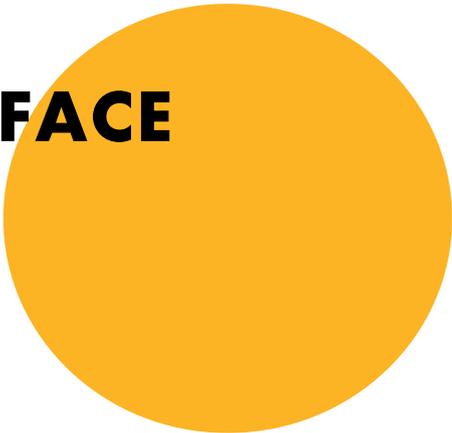
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PREFACE

ABOUT THIS HANDBOOK

The DOI Handbook is the main source of information about the DOI System[1]. It describes the DOI System at business and technical levels and assists the community in understanding the system and Registration Agencies (RA) in providing services based on the system.

Other information resources, such as factsheets and FAQs are available on the web site and are cited from this handbook where relevant.

AUDIENCE

This handbook is directed at anyone who is involved in services provided through the DOI System, or who is potentially interested in the DOI System: RAs, application designers and developers, RA communities.

ORGANIZATION

This handbook contains the following material:

- **Chapter 1: DOI System Overview** This chapter introduces the DOI System's history, purpose, basic principles, benefits and applications.

- **Chapter 2: DOI System Governance and Participation** This chapter describes the role and functions of the DOI Foundation and of Registration Agencies within the DOI System. It also summarizes the policies governing the DOI System and explains the policy formulation process.

- **Chapter 3: DOI Namespace** This chapter defines the syntax for a DOI name. It also explains the DOI name assignment principles and how other identifier schemes can be integrated into the DOI system.

- **Chapter 4: DOI Metadata** This chapter explains the basis for one of the main technical components of the DOI System, the DOI data model, and its ability to ensure interoperability of DOI name metadata assigned through metadata schemes.

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[1] DOI https://doi.org/10.1000/182 identifies the latest current version of the handbook

- **Chapter 5: DOI Identifier / Resolution Services** This chapter describes the identifier / resolution services included in the DOI System package.

- **Chapter 6: DOI Applications** This chapter discusses some of the ways in which resolution can be harnessed to provide applications with the ability to resolve a DOI name to the most appropriate content chosen from multiple DOI resolution options. These options can include pop-up menus offering manual selection, and consistent automated selection through content negotiation and Linked Data.

- **Chapter 7: Designing and Developing a DOI Application** This chapter assists business analysts and developers in designing and developing applications based on the DOI System.

- **Chapter 8: Defining RA and Registrant Policies** This chapter assists the Registration Agencies or registrants in defining their own policies.

- **Chapter 9: Operating and Maintaining the RA Services** This chapter assists the Registration Agency's service operations team in performing service operation tasks.

- **Appendix**

- **Glossary**

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STANDARD DOCUMENTS

The main standard documents related to the DOI are:

- ISO 26324:2022 "Information and documentation — Digital object identifier system"

- "Digital Object Identifier Resolution Protocol (DO-IRP) Specification" version 3.0 June 2022.
  https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf
  Notice: The DOI Foundation welcomes the publication of the Digital Object Identifier Resolution Protocol (DO-IRP). This specification is made available by DONA, a Swiss Foundation set up to govern the Handle System® (as used by the DOI infrastructure) and promote associated specifications. The Handle System was previously specified only in "informative" documents and the publication of proven, normative documents that remove features that were never implemented will increase the robustness and reliability of the DOI infrastructure. This infrastructure is used over 12 billion times a year to resolve over 300 million DOI names across the different sectors that rely on it. Most users access the DOI infrastructure through the resilient network of web proxies at https://doi.org and never encounter the Handle System directly, but this publication will ensure that the DOI System remains world-class into the future.

DOI SYSTEM OVERVIEW

This chapter introduces the DOI System's history, purpose, basic principles, benefits and applications.

In This Chapter

1.1 HISTORY AND PURPOSE OF THE DOI SYSTEM

The DOI® (Digital Object Identifier) System originated in a joint initiative of three trade associations in the publishing industry (International Publishers Association; International Association of Scientific, Technical and Medical Publishers; Association of American Publishers). Although originating in text publishing, the DOI System was conceived as a generic framework for managing identification of content over digital networks, recognizing the trend towards digital convergence and multimedia availability. The system was announced at the Frankfurt Book Fair 1997. In the same year, the DOI Foundation was created to develop and manage the DOI System.

From its inception the DOI Foundation worked with the [Corporation for National Research Initiatives](#) (CNRI[2]) as a technical partner, using the [Handle System](#)®[3] developed by CNRI as the digital network component of the DOI System. CNRI remains a technical partner of the DOI Foundation as the DOI technical support service provider.

From 1998 the Foundation worked closely with the INDECS project (1998-2000) and a number of subsequent and continuing initiatives building on this. The [INDECS framework](#)[4] underpins the DOI data model.

The DOI System provides a technical and social infrastructure on which organizations can build applications to provide services to users or communities of users. For example, the DOI System is used in internal processes in multiple industries, for publishing and reporting across corporate and national boundaries, and in the field of semantic web applications.

Because of the widespread implementation of the DOI System, the DOI Foundation was invited to propose it as an ISO standard. ISO 26324 was published in 2012 and updated in 2022. The ISO standard specifies the syntax and operation of the DOI while leaving implementation issues to the Foundation, which acts as registration authority for the standard. Note that the DOI Syntax was originally a National Information Standards Organization (US) standard, ANSI/NISO Z39.84-2010, first published in 2000 and withdrawn in 2017.

1.2 BASIC PRINCIPLE: INTEGRATION OF IDENTIFIER RESOLUTION AND SEMANTICS

The DOI System provides:

- an identification system of entities based on the Handle System, a globally distributed system for resolving identifiers
  Any entity (digital, physical, or abstract) can be identified by a global unique and persistent identifier called a DOI name. The DOI name can be resolved to a resource, such

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[2] https://www.cnri.reston.va.us/

[3] https://www.dona.net/handle-system

[4] https://www.doi.org/the-identifier/resources/factsheets/the-indecs-framework

as a web or internet resource, metadata describing the entity, a landing page with access to further resources, etc.

For example, a DOI name representing an article resolves to the web address of the HTML file version of the article.

- a metadata model based on the INDECS interoperable metadata framework
  Metadata must be assigned to each DOI name to describe the entity represented by the DOI name. Metadata interoperability is ensured through basic principles outlined by the DOI Foundation.

  Metadata is used to provide services to the users: it can be displayed to users to enrich an information resource; it can be used by users to search for a DOI name; etc.

The figure below illustrates the basic principle of the DOI System.
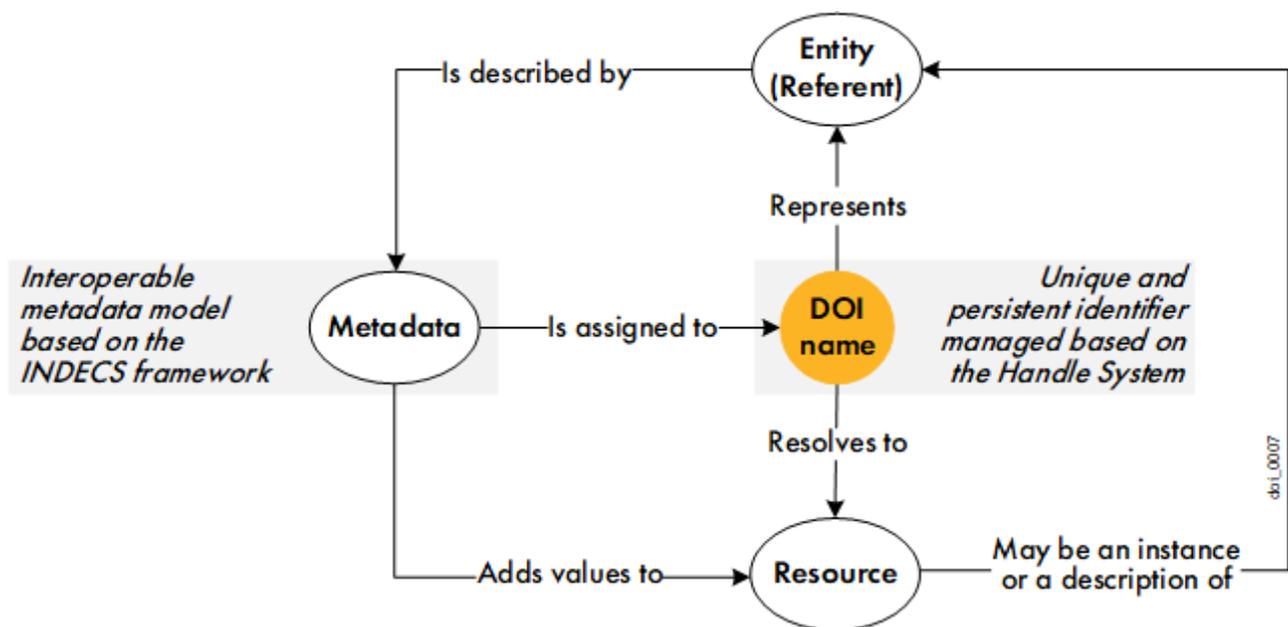
Figure 1 Basic principle: integration of identifier resolution and semantics

1.3 IDENTIFIER / RESOLUTION SYSTEM WITH THE HANDLE SYSTEM

For its resolution services, the DOI System is an implementation of the <u>Handle System</u>[5], a general-purpose distributed information system designed to provide an efficient, extensible, and secured global name service for use on networks such as the Internet.

1.3.1 DOI NAME: UNIQUE AND PERSISTENT IDENTIFIER

A DOI name is a global unique identifier of an entity (called the referent). The referent can be any digital, physical or abstract entity, and it can be defined on any granularity level of an entity depending on the requirements of the Registration Agency (RA); and a DOI name

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[5] https://www.dona.net/handle-system

may identify a specific edition of a novel, a novel chapter, a small piece of musical recording, etc. Referents can be intellectual property where examples would include inventions, literary and artistic works, ideas, symbols, names, images, designs, etc.

A DOI name can be resolved, through a Handle System service, to a set of elements, called the DOI record, as illustrated below. The DOI record usually contains a web address (or URL for Unified Resource Locator) representing an instance of the referent, and may contain services such as email, and one or more items of data about the referent (metadata).
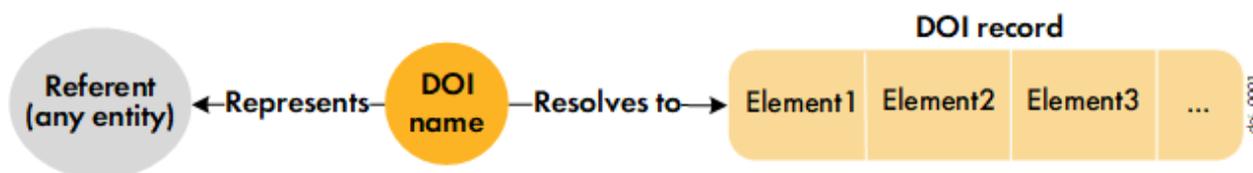
Figure 2 DOI name concept

The figure below shows an example where the referent is the specific edition of a novel. A referent could also be a chapter of the novel, etc.

Figure 3 DOI record example

The DOI name is persistent over time. Its persistence is provided by the independence of the identifier name from the element values, in particular from the entity localization or ownership. These elements can change over time: through the DOI name resolution, users will always get the up-to-date element values (This requires that the DOI record data be regularly maintained.).

NOTE Each element of the DOI record is assigned an explicit type (for example, "URL" (web address) or "email"). Predefined types exist in the Handle System and new types can be added by RAs, making the DOI resolution system extremely flexible and responsive to new requirements.

1.3.2   DOI NAME SYNTAX

The DOI syntax follows the Handle System's rules and is as follows:

`<prefix>/<suffix>`

where:

- prefix: refers to the DOI namespace (a namespace is allocated to a given service provider)
  The prefix can contain only numeric values and the "." character which is used to delimit a hierarchical level in the namespace allocation: a one-delimiter prefix (for example, "10.1000") derives from a zero-delimiter prefix ("10").
  In the Handle System, the prefix 10 is allocated to the DOI Foundation.

- suffix: is a unique local name in the namespace
  Any Unicode 2.0 character can be used in the suffix (there is no practical limitation on

the length of a DOI name). This unique string may be an existing identifier, or any unique string chosen by the Registration Agency or the registrant of the DOI name.

DOI name examples are: 10.1000/xyz-123; 10.1109/5.771073; etc.

NOTE DOI names may also be expressed as URLs: see 1.5.1.

For more information about the DOI name syntax, see Chapter 3.

1.4 STRUCTURED SEMANTICS BASED ON STRICT PRINCIPLES

The metadata describing an entity is provided by the registrants of the DOI names to the Registration Agency (RA) who provides the registration service. The metadata must follow strict rules which are guided by a set of principles derived from the INDECS (interoperability of data in e-commerce systems) project. The aim is to achieve metadata interoperability and the automated integration of metadata in the DOI System.

This section introduces the principles and tools of the DOI metadata system. For more information, see Chapter 4.

1.4.1 PRINCIPLES OF THE INDECS MODEL

The DOI Foundation is one of the organizations which funded the original INDECS framework and has continued to develop it further in partnership with an increasing range of organizations. Originally, the challenge for the DOI/INDECS project was to create a genre-neutral framework among rights-holders for electronic intellectual property rights trading so that companies can trade their creations in a coherent single marketplace.

In the INDECS model, an item of metadata is defined as "a relationship that someone claims to exist between two entities". This definition stresses the significance of relationships, which lie at the heart of the INDECS work.

The principles of the INDECS model are:

- unique identification
  Every entity must be uniquely defined within an identified namespace.

- functional granularity
  It should be possible to identify an entity whenever it needs to be distinguished.

- designated authority
  The creator of the metadata must be identified without doubts about its identity.

- application independence
  The metadata schema should be independent of the technology used.

- appropriate access
  Everyone must have access to the metadata needed. The consequence of this principle is that not all metadata must be accessible to everyone. In certain circumstances, some metadata would be inaccessible for certain users.

For more information, see **The INDECS Framework**[6].

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[6] https://www.doi.org/factsheets/indecs_factsheet.html

1.4.2 STANDARD METADATA DECLARATION

A standard metadata declaration must be made for every entity identified with a DOI name according to the following principles:

- The declaration must contain a minimum set of mandatory metadata called DOI Kernel. This kernel is designed to be as limited in scope as possible, and it is applicable to any entity identifiable by the DOI System.

- Additional metadata can be declared.
  It should be based on an agreed metadata exchange schema if metadata interoperability is required with other Registration Agencies (RA).

- All declared DOI metadata is based on a data dictionary which specifies all data elements and allowed values.

The DOI Kernel as well as the data dictionary are specified through the DOI Kernel Schema. This schema is extensible to whatever level of detail and granularity is required, and is neutral (it is independent of any business and any implementation technology). It allows the RAs to use any metadata scheme, yet still ensures semantic equivalence with DOI names assigned by others:

- Terms are added to the DOI Kernel Schema at the request of any RA.

- The DOI Kernel Schema provides the mappings to support metadata integration and transformations required for data exchange between RAs.

The figure below illustrates the metadata creation flow. The registrant of a referent provides the metadata describing the referent. The RA's metadata service creates the corresponding metadata declaration(s) according to the metadata schemas and assigns them to the respective DOI name.
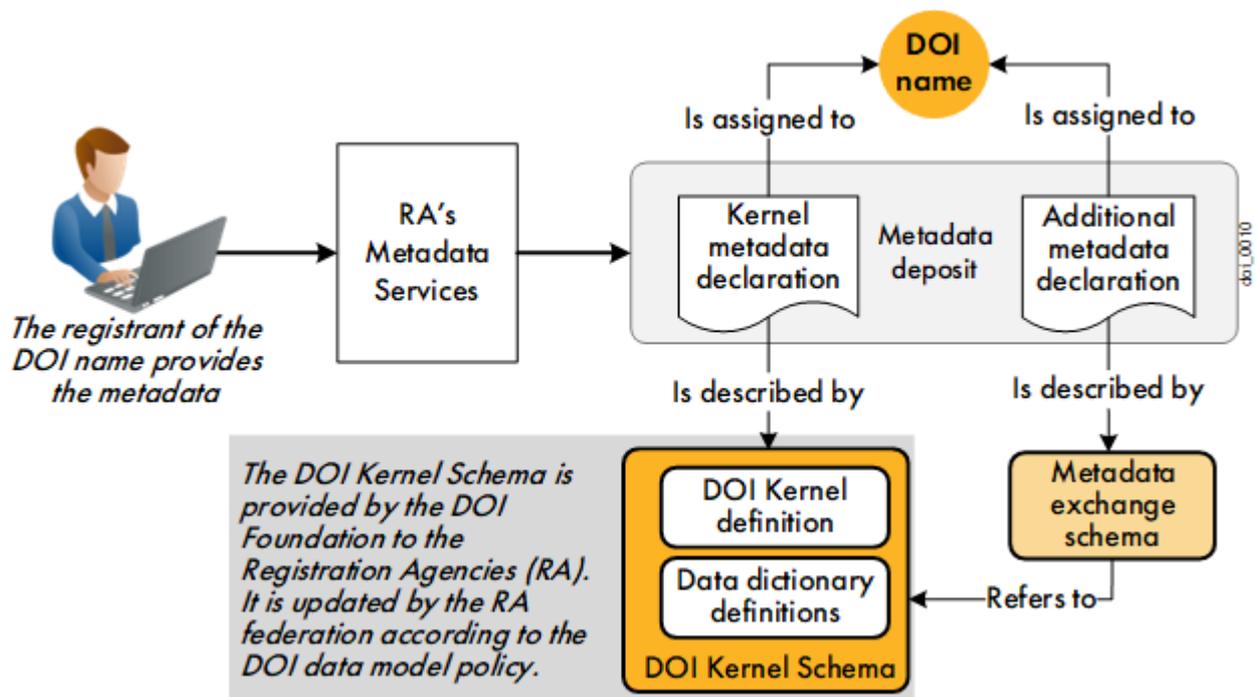
Figure 4 Metadata declaration

For more information, see Chapter 4.

1.5 BASIC RESOLUTION SERVICES PROVIDED BY THE DOI SYSTEM

The basic resolution function of the DOI System consists in redirecting a user to a web resource on resolution of a DOI name. The end-user can perform this basic resolution request from any standard web browser.

1.5.1 DIRECT REDIRECTION TO A WEB RESOURCE WITH THE DOI PROXY

The most common resolution function of a DOI name returns a single web address (or URL for Uniform Resource Locator) to which the user is redirected as illustrated below. This is done by using the HTTPS Proxy Server of the DOI System (https://doi.org). With the DOI Proxy, users can resolve DOI names from any standard web browser by using the URL syntax (A proxy server is a web server that understands the Handle System protocol, thereby acting as a gateway between the Handle System and HTTPS.). For example, the resolution of the DOI name "10.10.123/456" would be done from the address

"https://doi.org/10.123/456". That makes the DOI resolution service extremely easy to use.
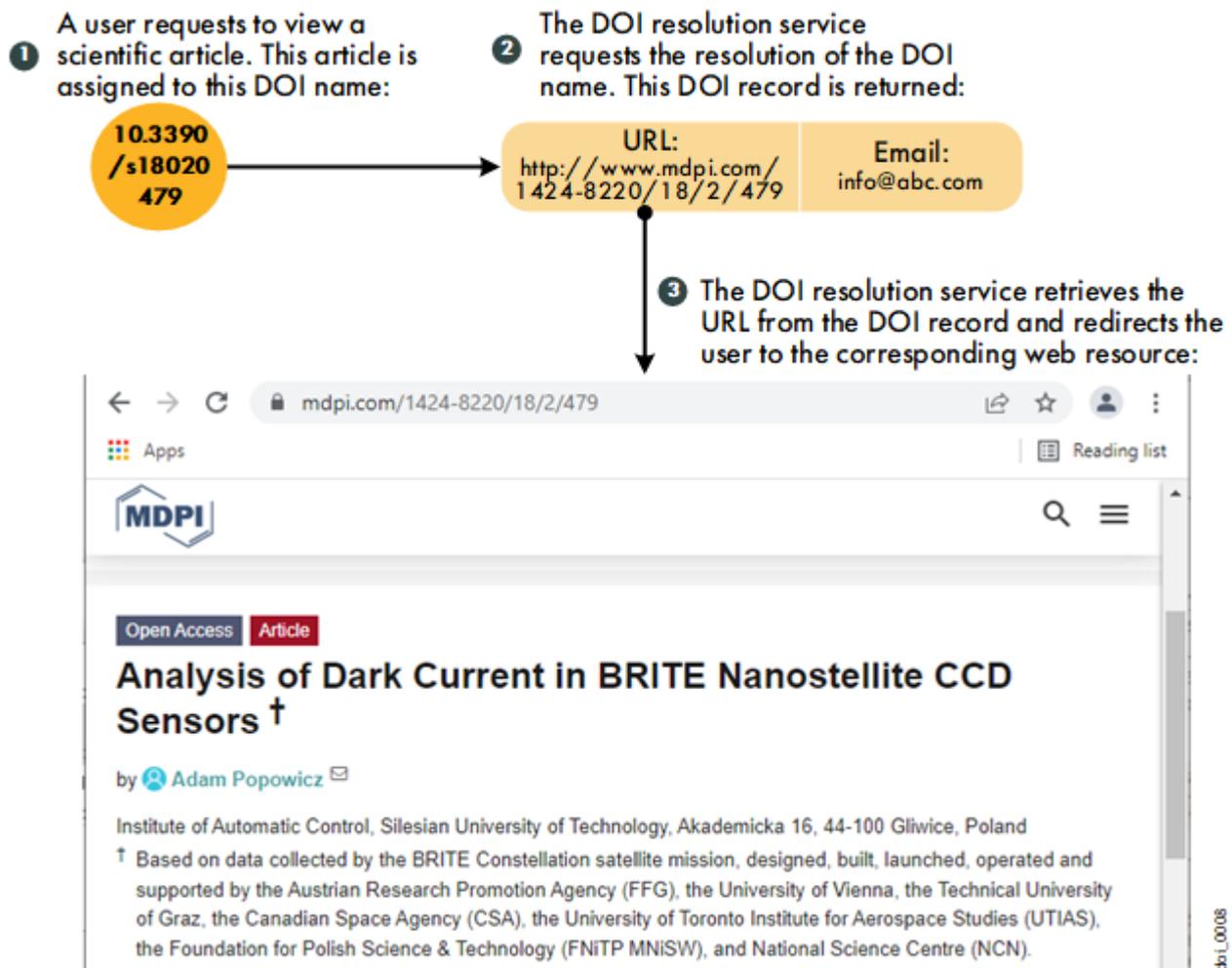
Figure 5 Direct redirection to a web resource

1.5.2 ADDITIONAL RESOLUTION SERVICES INCLUDED IN THE DOI SYSTEM

The following resolution services are included in the DOI System in addition to the main DOI resolution service:

- shortDOI
  The shortDOI Service creates shortened DOI names, as aliases for existing DOI names, which are often very long strings. Applications which resolve DOI names will treat a short DOI identically to the original.
  For more information, see 5.5.

- Which RA?
  This service returns the name of the DOI Registration Agency (RA) responsible for a specific DOI name, or group of DOI names.
  For more information, see 5.6.

1.6 VALUE-ADDED SERVICES A REGISTRATION AGENCY CAN BUILD ON THE DOI SYSTEM

Registration Agencies can provide various added-value services by using the multiple resolution request supported by the DOI resolution service. In contrast to the single resolution which can only return a single web address (URL) element, the multiple resolution allows making use of any useful information in any form returned in the DOI record. While the multiple resolution is typically used to acquire mulitple URLs, it is flexible enough to provide information for many other applications.

This section describes some examples of these added-value services.

1.6.1 MANAGEMENT OF A REFERENT WITH SEVERAL INSTANCES

In case a referent is linked to several web resources - for example, if an article is available in PDF and in HTML versions then two web addresses (URLs) are provided - then a resource selection mechanism must be implemented by the Registration Agency (RA). It may be:

- a manual selection
  When the user requests the referent's DOI name from the RA's application, the application generates a menu of options from which the user performs a manual choice.

- an automated selection
  The URL to which the user is redirected is automatically selected among a list of provided addresses according to predefined rules that may be based on parameters depending on the user (for example, the user's geographic location which would be determined through their IP address).

The menu options or the redirection rules are retrieved from the DOI record. In particular, redirection rules can be defined through a redirection graph element containing XML code which can be interpreted by the DOI resolution service as illustrated below.
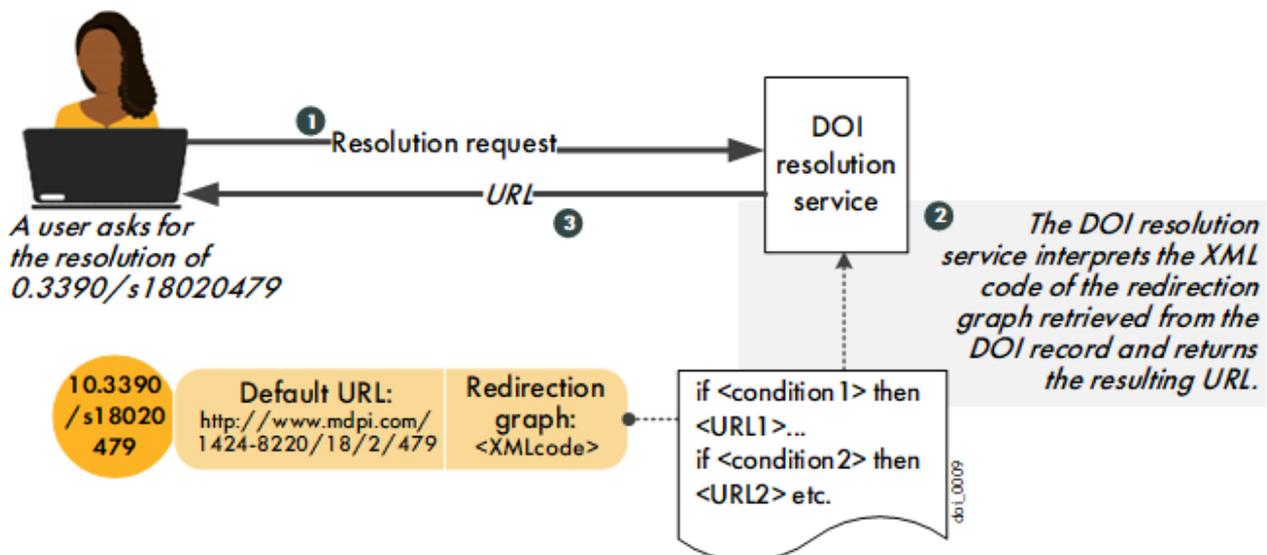
Figure 6 Management of a referent with several instances

1.6.2 DYNAMIC BUILDING OF A WEB PAGE ENRICHED WITH METADATA

On request of a user for a referent, Registration Agencies (RA) can dynamically build a web page displaying the metadata assigned to the respective DOI name. The metadata is provided by the RA's metadata service responsible for the respective DOI name. The address of this metadata service can be retrieved from the DOI record.

The figure below illustrates an application where each product of a building structure is identified through a DOI name which is printed on the physical product in the form of a QR code. When a user scans the QR code, they are redirected to a product landing page where they can quickly find all the most up-to-date information on a product.
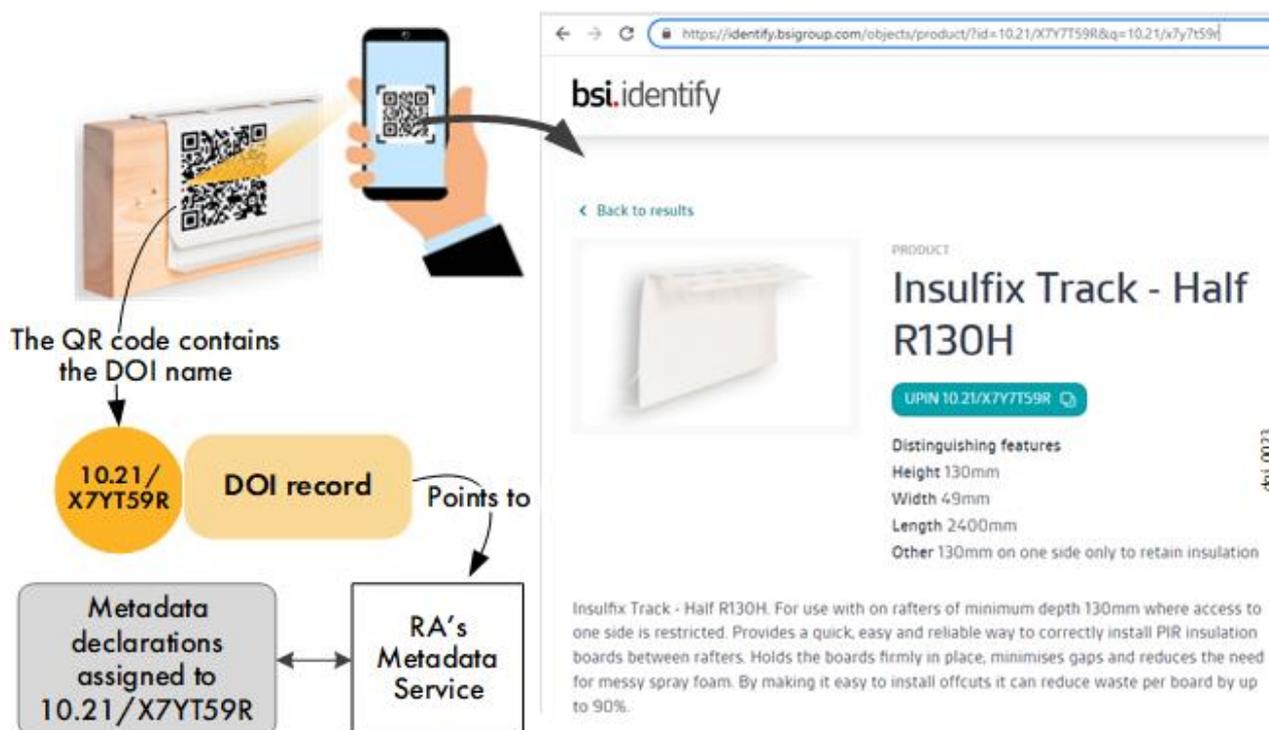
Figure 7 Dynamic building of a web page enriched with metadata

1.7 BUSINESS AND ORGANIZATIONAL MODEL OF THE DOI SYSTEM

The DOI System is deployed via Registration Agencies (RAs) who are empowered to assign DOI names for a community under the governance of the DOI Foundation.

1.7.1 FEDERATION OF REGISTRATION AGENCIES (RA)

The DOI System is implemented through a federation of Registration Agencies (RA) who provide services to users (registrants):

- Registration Agencies must comply with the policies and technical standards established by the DOI Foundation, but are free to develop their own business model for running their businesses.

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- Users can join a service offered by an RA by registering material with one of them, or developing a community to build an RA.
- Registrants ensure appropriate content management of their own material (maintenance of URLs and data), either directly or by contract (for example, with the RA).

1.7.2   FREE RESOLUTION SERVICE

The DOI Foundation maintains a DOI Proxy that can resolve all DOI names. Users can be any person or machine that wants to resolve a DOI. They do not have to be members of the DOI Foundation and may use the DOI Proxy as often as they like. DOIs are, and will always be, free to resolve.

1.7.3   GOVERNANCE ROLE OF THE DOI FOUNDATION

The DOI Foundation is the governance body of the DOI System:

- It safeguards (owns or licences on behalf of registrants) all intellectual property rights relating to the DOI System.
- It works with RAs and using the underlying technical standards of the DOI System components to ensure that any improvements made to the system (including creation, maintenance, registration, resolution and policymaking of DOI names) are available to any DOI name registrant, and that no third party licenses might reasonably be required to practice the DOI name standard.
- It provides agreed standards of governance, scope, and policy, and also a technical infrastructure (resolution mechanism, proxy servers, mirrors, back-up) and a social infrastructure (persistence commitments, fall-back procedures, cost-recovery (on a self-sustaining model), and shared use of the system).

1.7.4   DOI NAMESPACE ALLOCATION APPROACH

The DOI namespace allocation approach is as follows:

- The DOI Foundation allocates one or several prefixes derived from its top-level prefix (10) to an organization that wishes to register DOI names (a Registration Agency (RA)).
- The RA registers DOI names under their allocated prefix(es). If the RA allocates a separate prefix to each of their customers (registrants) then the combination of a prefix for the registrant and suffix provided by the registrant (which is unique within their prefix) avoids any necessity for the centralized allocation of DOI names.

The following figure illustrates the DOI namespace allocation approach.

Governance body of the Handle System

DONA

DOI System

Governance body of the DOI System
Is allocated the prefix "10" through the DONA-MPA (Multi-Primary Administrator) service agreement as defined by the DONA Foundation. Can allocate to itself or to third parties prefixes derived from its prefix.

doi Foundation
Prefix[1]: 10

Registration Agencies (RA)
An RA is allocated one or several prefixes by the DOI Foundation through the RA agreement. An RA provides registration services for DOI names under their allocated prefix(es). The RAs decide about the way they allocate their DOI namespace but it is recommended to allocate a separate prefix to each registrant.

Registration Agency (RA)
Prefixes: 10.11000 to 10.11999

Registration Agency (RA)
Prefixes: 10.13500 to 10.13600

Registrants (RA Customers)
A registrant registers DOI names with a Registration Agency with which they have an agreed relationship as a customer. If a registrant has multiple types of content or application requirements, they may choose to select several RAs.

Registrant
DOI names under Prefix 10.11005

Registrant
DOI names under Prefix 10.11012

Registrant
DOI names under Prefix 10.11064

1) A workflow for DOI names using prefixes other than 10 has yet to be established.

Figure 8 DOI namespace allocation approach

1.8   STANDARDIZATION OF THE DOI SYSTEM

The DOI System is ISO-standardized.

1.8.1   ISO 26324

The DOI System has been standardized through the International Organization for Standardization, ISO (within the responsibility of committee ISO TC46/SC9, Identification and

documentation) as [ISO 26324, Digital Object Identifier System](#)[7]. This International Standard specifies the syntax, description and resolution functional components of the DOI System, and the general principles for the creation, registration and administration of DOI names.

The DOI Foundation is ISO 26324 Registration Authority: as with other identifier standards, the creation of a public standard for the DOI System creates a controlled namespace which is populated through the Registration Authority.

ISO 26324 does not specify specific technologies to implement the DOI System. These are selected and implemented by the Registration Authority.

NOTE Norman Paskin wrote a history/case study of DOI standardization, ["The Digital Object Identifier: From Ad Hoc to National to International"](#)[8].

1.8.2   CONFORMANCE WITH RELEVANT EXTERNAL STANDARDS

The DOI System has also been developed to ensure conformance with relevant generic external formal standards, including URL.

It implements the Handle System which conforms with the DO-IRP protocol: see [Digital Object Identifier Resolution Protocol (DO-IRP) Specification](#)[9].

The DOI Foundation supports the [FAIR principles](#)[10] which provide guidelines to improve Findability, Accessibility, Interoperability and Reuse of digital assets. The FAIR principles emphasize machine-actionability (the capacity of computational systems to find, access, interoperate, and reuse data with none or minimal human intervention) because humans increasingly rely on computational support to deal with data as a result of the increase in volume, complexity, and creation speed of data. Note that FAIR principles may not be relevant to some use cases of the DOI System, for example EIDR.

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[7] https://www.iso.org/standard/81599.html

[8] https://www.doi.org/resources/DOI_Case_Study_Paskin.pdf

[9] https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf

[10] https://www.go-fair.org/fair-principles

1.9   PERSISTENCE AS A DESIGN FEATURE OF THE DOI SYSTEM

Persistence of DOI information is a key aim of the DOI System, and is guaranteed by the DOI social infrastructure through policies and agreements, and assisted by technology.

Table 1 Persistence considerations in the DOI System

Persistence aspect	Solution in the DOI System
Persistence of the access to data in case the referent location or ownership changes or in case the referent is no longer available	Through the DOI name resolution concept, DOI names resolve to information (DOI record) which may change over time (URL, object ownership, etc.) while the mapping of the DOI name to the entity persists. It is the responsibility of the registrant to maintain the data of the DOI record. In case the object identified by a DOI name is no longer available, the DOI name registrant can at minimum have the DOI name resolve to a response screen indicating that the object is no longer available.
Persistence of the access to data in case a Registration Agency (RA) is defaulting	RA membership imposes certain obligations on an RA to ensure transfer of appropriate records and enable continuity of DOI resolution in case the RA is defaulting. Membership of the DOI Foundation is predicated on the assumption that communities wish to work together to ensure long term persistence, beyond the interests of their own current applications. Should this assumption be false, the DOI agreements provide a fall-back position enabling persistence of resolution of the assigned DOI names. Note: Added-value services available through DOI resolution which are provided by a Registration Agency cannot be guaranteed to be maintained by the DOI Foundation in the event of the Registration Agency ceasing to exist. Such services may require additional material (for example, access to metadata look-up or workflow procedures). However, the DOI Foundation will make best efforts to transfer such services to another agency, or maintain such services itself, or encourage that services are transferred to a third party able to provide continuity where required. The aim will be to provide least disturbance to the community of users of those DOI records.
Persistence of the DOI System in case the DOI Foundation ceases to exist or the current technical implementation is unable to sustain its activities	In the event of the DOI Foundation ceasing to exist, agreements are in place to transfer the system to other parties. The DOI Foundation's agreement with technical support partners allows for reversion of all DOI System data, licenses, rights etc. to the DOI Foundation in the unlikely event of the current technical implementation closing or being unable to sustain its activities.

Persistence aspect	Solution in the DOI System
Persistence of the technical infrastructure technology	The DOI system uses a globally distributed multiple site network of servers and service sites overlain on the Handle System, which itself has similar distributed sites. These sites are at individual RA member locations, professional co-location hosting sites, and virtual (cloud computing) facilities, with resources to ensure 24x7 cover, mirroring machines to ensure against power outages, etc. The DOI Foundation also ensures that the doi.org domain is part of the persistent technical infrastructure, including mirroring and load balancing to ensure optimal availability for HTTPS requests to the DOI Proxy.
	The Handle System is governed by the DONA Foundation which is committed to ensure the system continuity. The Handle System is an open standard, so anyone can build/use a Handle service. Both source code and APIs are public.

1.10 BENEFITS OF THE DOI SYSTEM

The following paragraphs describe some of the benefits made possible by the DOI System.

1.10.1 IMPROVED CONTENT MANAGEMENT AND DISCOVERY

Benefits of implementing the DOI system include facilitating internal content management and enabling faster, more scalable product development, by delivering four key advantages in making it easier and cheaper to:

- know what you have
  Users are able to look at catalogues of content available throughout the enterprise.
- find what you want
  Users are able to search and browse for content to be used or re-purposed.
- know where it exists
  Users are able to see where the item exists within the organization.
- be able to get it
  Users and production tools are able to retrieve the content.

1.10.2 SOLUTION TO THE BROKEN LINK (PERSISTENCE)

The DOI System provides the means for a solution to the famous web issue of "http 404 not found" (broken link).

The problem is that a URL (Unified Resource Locator) is both an identifier and a locator for a resource on the Internet. The specific content of the URL that is its identifier is also the string that can be resolved into a location. This has the consequence that when a resource is moved from one service to another, from a server to another, or from a company to another, it will get a new URL that identifies the service, the server or the company that hosts it. Its old URL will most likely stop working and any previously made references to that resource using the old URL will no longer work.

With the DOI System, the identifier is persistent, whereas the metadata to which it resolves can change over time, in particular, the URL can be updated. For more information, see Chapter 3.

1.10.3 IDENTIFIER INTEROPERABILITY THROUGH A POWERFUL METADATA MODEL

Resources of interest in digital networks originate from a wide variety of sources, and may carry identifiers from different established public schemes, official standards, de facto schemes, or private cataloguing numbering. A key step in facilitating preservation, re-use and exchange of information is to enable users to re-use these identifiers (and their associated data) across different applications.

For example, where several Registry Agencies (RA) are issuing DOI names to journal articles from different publishers, it is likely that some RAs and publishers will want their DOI names to be included in journal-related services supported by other RAs. In a similar way, many RAs will want DOI names issued by other RAs to be available for inclusion in services they themselves are providing. Such interoperability is one of the principal benefits of the DOI System.

To achieve identifier interoperability in the DOI System, tools and policies are used: see 1.4.

1.10.4 COMPATIBILITY WITH OTHER IDENTIFIER SYSTEMS

The DOI System is not meant to replace existing identifier systems. Instead, it is designed for interoperability; that is to use, or work with, existing identifier and metadata schemes.

The DOI System explicitly recognizes other schemes. The ISO DOI specification (ISO 26324) sets out the specifications for recognizing existing schemes. At minimum, the DOI metadata must record the fact that another registry identifier exists. Additional optional steps are possible, including:

- a consistent way of including the other scheme in the DOI syntax
- a business relationship to facilitate this, by collaboration between the DOI Foundation and the relevant registry
  Where such collaboration is agreed, new potential may be unlocked: the ISBN-A application is an example of the linkage of DOI names to an existing registry. For more information, see [DOI System and the ISBN System](https://www.doi.org/factsheets/ISBN-A.html)[11].

1.10.5 SERVICE FLEXIBILITY AND EXTENSIBILITY

The DOI System supports any type of physical, digital or abstract entities, and of hierarchies and relationships between entities.

Through its scalable architecture, the DOI System is able to handle very large volumes of registrations and resolutions of DOI names. In fact, the DOI System is made up of Local Handle Services (LHS) of the Handle System (an LHS manages the DOI names under one or

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[11] https://www.doi.org/factsheets/ISBN-A.html

several prefixes): each LHS may be replicated into multiple service sites and each service site may consist of multiple computers (servers). It means that service requests targeted at any LHS can be distributed into different service sites, and into different servers within any service site.

1.10.6 PROTECTED AND TRUSTED INFORMATION

The Handle System - which is used for identification and resolution of DOI names - provides client and server authentication, data confidentiality and integrity, and non-repudiation based on Public Key Infrastructure (PKI):

- Any exchanged information between a client and a server of the Handle System can be encrypted using a session key.
- To ensure non-repudiation, clients may request digitally signed responses from any server.
- User access control is supported at DOI record and record element levels. Resolution requests for confidential data, as well as any administration requests (for example, creating or modifying a DOI record) require authentication of the user for proper authorization.
- The integrity of a DOI record's data is ensured by signing the DOI record. The digital signature is stored in the DOI record itself and can be validated through a chain of trust.

1.10.7 INFORMATION TRACEABILITY

Traceability is not provided by the DOI System but can be made available through the Digital Object Architecture (DOA) on which the Handle System is based (more precisely, through the DOA's Digital Object Interface Protocol (DOIP)).

Different actors may interact with the Digital Object (DO) (which represents the referent) throughout its life cycle. Each action is tracked in the DO itself and this information can be processed for various applications. For example, in the movie industry, this allows providing digital revenue reporting as well as detailed consumption metrics for individual assets.

1.11 APPLICATION EXAMPLES OF THE DOI SYSTEM

Many millions of DOI names have been assigned to date, through a growing federation of Registration Agencies worldwide. For example:

- Crossref manages DOI names for the scientific publishing industry. Its application is used by publishers and societies to enable cross-citation of scholarly publications.
- DataCite provides DOI name services for referencing and sharing research outputs and resources, primarily research data sets, text and samples.
- The Entertainment ID Registry (EIDR) provides identifiers and associated metadata that are used in the commercial film and video industry, from post-production through broadcast, digital distribution, and reporting.

- The British Standards Institution (BSI) Identify uses DOI names in building construction projects to identify the products used in the buildings (interior furnishing, lighting, etc.) and manage their supply chain information.

For more information, see [Registration Agencies - Areas of Coverage](https://www.doi.org/RA_Coverage.html)[12].

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[12] https://www.doi.org/RA_Coverage.html

DOI SYSTEM GOVERNANCE AND PARTICIPATION

This chapter describes the role and functions of the DOI Foundation and of Registration Agencies within the DOI System. It also summarizes the policies governing the DOI System and explains the policy formulation process.

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2.1   DOI SYSTEM GOVERNANCE BODY: THE DOI FOUNDATION

This section describes the status, roles, membership and governance of the DOI Foundation.

2.1.1   STATUS OF THE DOI FOUNDATION

The DOI Foundation is a non-stock membership corporation organized and existing under and by virtue of the General Corporation Law of the State of Delaware, USA, registered on 10 October 1997, registration number 2807134 8100. The DOI Foundation's corporate registered address is via CT Corporation: The Corporation Trust Company, Corporation Trust Center, 1209 Orange Street, Wilmington DE 19801, USA. The Foundation is controlled by a Board elected by the members of the Foundation. The Corporation is a not-for-profit organization, it means prohibited from activities not permitted to be carried on by a corporation exempt from US federal income tax under Section 501(c)(6) of the Internal Revenue Code of 1986 et seq. The operational address of the Foundation is: The DOI Foundation, c/o EDitEUR Limited, United House, North Road, London N7 9DP, UK.

Costs incurred by the DOI Foundation are recouped from operation of the system via a self-funding business model. The implementation of the DOI System adds value, but necessarily incurs some resource costs in data management, infrastructure provision, and governance, all of which contribute to persistence. Persistence is a function of organizations, not technology.

A Managing Agent is contracted by the DOI Foundation, who represents the DOI Foundation worldwide, and is responsible for the implementation of policies and management of all aspects of the affairs of the DOI Foundation. Functions such as technical operations, legal and financial services are outsourced.

2.1.2   OVERVIEW OF THE DOI FOUNDATION ROLES

The DOI Foundation is the DOI System registration authority and maintenance agency and the central body which governs the DOI System. It is the common management and co-ordination body for DOI Registration Agencies. It also manages those aspects of the DOI System that are put through external standardization procedures, as well as those aspects of the DOI System that are dealt with through internal policies and procedures. Responsibilities of the registration authority include:

- to promote the proper use of the DOI System (and ISO 26324, the ISO specification)
- to maintain the DOI System technical infrastructure and data in accordance with the needs of the users
- to establish guidelines regarding allocation, registration, maintenance and dissemination of DOI names
- to continuously adapt the DOI Handbook and guidelines to meet the needs of the market
- to respond to enquiries and information requests related to ISO 26324 in a timely manner
- to establish due diligence and quality assurance procedures of the DOI System

2.1.3 ISO 26324 REGISTRATION AUTHORITY

The DOI Foundation is the ISO 26324 Registration Authority, governed by an agreement between ISO and the Foundation. ISO 26324 specifies the duties of the Registration Authority: services to be provided and technical duties.

SERVICES TO BE PROVIDED BY THE REGISTRATION AUTHORITY

The ISO 26324 Registration Authority shall provide the following services:

- promote, coordinate and supervise the DOI System in compliance with the specifications of this International Standard
- supply technology and infrastructure for resolution, metadata and registration functionality in compliance with the specifications of this International Standard and ensure that any changes in selected technology will be compatible with earlier DOI applications
- allocate unique DOI prefixes to registrants and maintain an accurate register of the DOI prefixes that have been assigned
- secure the maintenance of DOI names and associated DOI resolution records through the maintenance of a single logical directory of all registered DOI names, the DOI directory
- enable the registration and mapping of DOI metadata through the maintenance of, or agreed use of, an appropriate data dictionary
- implement policies and procedures governing the process of DOI registration, including rules to aid persistence of DOI names and interoperability within networks of DOI users
- develop, maintain and make available documentation for users of the DOI system, including the provision of a User Manual for registrants which shall specify implementation details in conformance with this International Standard
- review relevant technology developments and maintain current information on appropriate syntax character encoding, resolution software implementations, etc.
- provide a unifying record for a referent in case multiple DOI names are assigned to the same referent (this may happen, for example, through assignment of DOI names by two different registrants)

TECHNICAL DUTIES OF THE REGISTRATION AUTHORITY

The ISO 26324 Registration Authority shall provide the following technical services by means of a User Manual:

- maintain a list of approved proxy servers (such as https://doi.org/ which resolve DOI names in web browsers)
- provide current information on appropriate encoding of characters
- provide current information on resolution technology
- maintain a list of representations used in other schemes
- provide information on common encodings
- specify, if required, more constrained rules for the assignment of DOI names to objects for services which make use of the DOI System

Where specified, these rules shall be compatible with the overall DOI System specification and shall not form part of this International Standard.

- publish rules to aid persistence of identification (for example, requirements for maintenance of records, default resolution services)
- publish the DOI Kernel Metadata Declaration that specifies the metadata elements for each DOI name
- provide output metadata to support the services of the DOI System
- establish format and schema specifications for input and service metadata declarations
- provide a data dictionary as the repository for all data elements and allowed values used in DOI metadata specifications to facilitate interoperability across selected existing schemes
- provide a data dictionary as the repository for all data elements and allowed values (the items which may be used as values of each element) used in DOI metadata specifications
- provide the data dictionary mappings of other relevant schemes, as determined by the ISO 26324 Registration Authority (such as ISO codes for territories, currencies and languages)
- specify a set of allowed values of each kernel element
- specify an XML Schema of the DOI Kernel Metadata Declaration
- register sets of other metadata elements and sub-elements as needed
- prevent duplication of a DOI name once registered

2.1.4   REPRESENTATION TO STRATEGIC ORGANIZATIONS

A key role of the DOI Foundation is representation to organizations which are of strategic importance in the implementation of the DOI System. This includes:

- participation in governance and continuity activities of the Handle System whose central body is the DONA Foundation
  In addition, the DOI Foundation has contractual agreements for provision and persistence of the Handle System with the DOI technical support service provider (who is currently CNRI)
- maintenance of formal and informal alliances and liaisons with several other organizations
  A significant element of the work of the DOI Foundation lies in tracking standards developments in related areas, understanding their significance to the context within which the DOI System operates, and establishing working relationships with the responsible organizations and projects to ensure that appropriate co-operation is fostered to mutual benefit and that parallel developments do not remain in ignorance of one another.
- role as the formal Registration Authority of the ISO/IEC MPEG21 Rights Data Dictionary
  This standard is not a requirement for DOI System use. For further information, send questions to info@doi.org.

2.1.5 DOI FOUNDATION MEMBERSHIP

The activities of the foundation are controlled by its members, operating under a legal Charter and formal By-laws. Membership is open to all organizations with an interest in digital network publishing, content distribution, rights management, and related enabling technologies.

MEMBERSHIP OBLIGATIONS

By participating in membership of the DOI Foundation, members agree to:

- support the goals of the DOI Foundation, which ensure that the DOI System is an internationally adopted standard for digital object identification

- participate in the activities of the DOI Foundation

- comply with the Foundation's By laws, Agreements and Policies as these may be updated from time to time

- restrict access to the password-controlled portions of the Foundation's web site to members of the Foundation

- adopt the DOI brand identity
  The DOI Foundation provides members with the current identity information and with marketing materials.

- add the DOI Foundation to the circulation of all their press releases and news announcements, and notify the Foundation of forthcoming relevant events and activities
  Selected news about members' DOI activities may be carried on the DOI News page, with a link to the original announcement.

MEMBERSHIP CLASSES

There are four classes of membership:

- General Membership
  This membership is offered to any organization supporting the development of the DOI System that is not a Registration Agency. It is subject to a **signed agreement**[13].
  General membership is a pre-requisite for any organization applying to become a Registration Agency. If a General Member subsequently is appointed as a Registration Agency, their membership transfers from the General to the RA category.

- Registration Agency Membership
  This membership is only available to organizations who have successfully undergone the process of becoming a Registration Agency (RA) (see 2.2.5).
  The primary role of RAs is to provide services and applications to registrants by allocating DOI prefixes, registering DOI names and providing the necessary infrastructure to allow registrants to declare and maintain DOI metadata and DOI records. For more information about RAs, see 2.2.

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[13] https://www.doi.org/resources/GeneralMemberAgreement.pdf

- Charter Membership
  This membership was initially established for founding the DOI Foundation and is only offered to organizations whose main activities are in the creation or production and dissemination of intellectual property. The DOI Board reserves the right to determine eligibility for the Charter membership category.

- Affiliate Membership
  This membership is restricted to professional associations who have one or more of their current members in current membership of the DOI Foundation. Organizations outside this scope may be invited or admitted at the Board's sole discretion. Affiliate membership does not carry voting rights, and Affiliate members are not eligible for Board membership. Registration Agencies are not eligible for this category of membership.

General, Registration Agency and Charter members are entitled to vote in annual DOI Foundation's elections within their own category of membership (There are no differences in member rights and benefits between Charter and General.). Affiliate membership does not carry voting rights.

More information is available on the membership classes on the [DOI web site](https://www.doi.org/the-community/who-are-the-members-and-users)[14].

MEMBERSHIP FEES

This paragraph describes general statements about DOI Foundation membership fees.

The following rules apply:

- Membership fall due annually on the anniversary of joining.
- Membership reduction may be applied as follows:
  - General membership fee may be reduced at the sole discretion of the DOI Board.
  - Registration Agency membership fee is included as part of operational fees, allocated annually on a cost-sharing model (see 2.2.6).
- Criteria which will be considered for fee reduction include, in particular, any of the following:
  - organizations with a significant role in the creation or ongoing support of the DOI Foundation
  - not-for-profit organizations, depending on their annual revenue
  - for-profit organizations, depending on their annual revenue and other criteria
- If a General member subsequently is appointed as a Registration Agency (RA), their membership transfers from the General to the RA category, and any unexpired portion of the previous General membership fee is credited to their RA membership dues.

NOTE In general, it is likely that the cost of fees will be deductible as a business expense of the joining entity. The detailed question of deductibility is, however, a matter for the tax advisors of the entity that is joining, and it is not governed by DOI Foundation's status as a not-for-profit entity.

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[14] https://www.doi.org/the-community/who-are-the-members-and-users

MEMBER STRATEGY MEETINGS

Strategy meetings of the DOI Foundation members are held at least once a year, and usually one in mid-year and one at the end of the year, and are open to all members and non-member guests (by invitation only). Members are advised of forthcoming meetings by email.

DOI REPRESENTATIVE OF A MEMBER ORGANIZATION

Each member organization of the DOI Foundation must provide one named DOI representative, who will be responsible for the DOI matters. In particular, the DOI representative will represent the organization at all Board meetings and in voting issues. Members must ensure that the DOI Foundation is kept informed of any representative changes. Should the individual leave the member organization, or step down from the representation role, the organization will name a replacement.

Additional persons from the member organization may participate in all DOI activities.

TRIAL PREFIX

On joining the DOI Foundation, a unique DOI prefix is available for experimental purposes for each member. The number of DOI names allocated with this experimental prefix will be subject to review and may be limited at the discretion of the DOI Foundation. If further DOI prefixes are required for non-experimental purposes, members must work with one of the Registration Agency members. Trial prefix use is particularly intended for those members wishing to develop applications and move to later Registration Agency status.

Contact the DOI technical support service provider (doi-admin@doi.org) to request one, and discuss possible usage.

2.1.6   DOI FOUNDATION GOVERNANCE

The DOI Foundation is governed by its members, through an elected Board.

BOARD OF DIRECTORS

The Board is responsible for all aspects of management of the DOI System, including policy formulation and standards maintenance.

The Board consists of:

- Board officers: a Chair, Vice Chair, and Treasurer, each elected from the Board
- Board members
  Members of the DOI Foundation become Board members according to the following rules:
  o All Charter members are automatically members of the Board.
  o All Registration Agency (RA) members are automatically members of the Board after one full year of RA membership
  o General members are represented by one seat on the Board held for a three-year term, nominated from amongst the existing General members. Procedures for election in the event of more than one nomination are defined in the By-Laws.
  o Affiliate Members are not represented on the Board.

The Board reviews the number and distribution of Board seats from time to time.

NOTE   The members of the Board are not remunerated for their services to the DOI Foundation.

EXECUTIVE COMMITTEE

The Executive Committee is a subcommittee of the Board, elected by the Board, consisting of not fewer than three Directors and chaired by the Chairman of the Board. It may meet between Board meetings to deal with matters not requiring a meeting of the full Board, or requiring urgent discussion. In practice, the Executive Committee normally consists of the Chair, Vice Chair and Treasurer.

MANAGING AGENT

The Board of Directors of the DOI Foundation appoints a Managing Agent responsible for managing the DOI Foundation and carrying out policy formulated by the Foundation.

BOARD MEETINGS

The Board meets regularly. Issues which any member feels should be considered by the Board should first be brought to the attention of the Managing Agent or a Board member. Board meetings are open to all members who may attend as observers and participate but not vote, except for designated closed Executive Sessions.

The DOI representative of each organization will represent the organization at all Board meetings and in voting issues. Substitution of another individual from the organization at Board meetings is possible by advance agreement of the Chair of the Board.

2.2   DOI SYSTEM PARTICIPANTS: REGISTRATION AGENCIES AND REGISTRANTS

A Registration Agency (RA) (formally called Registration Agency Member) can be considered as a module of the DOI System, serving a constituency. New RAs can be added at any time, thereby allowing modular growth of the system by adding new communities of users and providing tailored services for them. A registrant is a person or organization who has requested and received the registration of a particular DOI name.

This section explains the role and function of Registration Agencies in the DOI System, including operational and technical requirements and policies. A list of current Registration Agencies and their areas of coverage is available on the [DOI web site](https://www.doi.org/registration_agencies.html)[15].

2.2.1   ROLES OF A REGISTRATION AGENCY

A Registration Agency (RA) provides services to one or several communities of users. A community is loosely defined, but could be any group of parties sharing a common application or interest, under any organizational structures (public, private sector, not-for profit, regulator, etc).

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15 https://www.doi.org/registration_agencies.html

The services an RA provides to their users include:

- allocating prefixes
- registering DOI names and providing the necessary infrastructure to allow registrants to declare and maintain DOI metadata and DOI record (in other words, use of the DOI System)
- services not directly involving the DOI System which add value, for example: management of a database of related data with facilities for look-up from metadata to DOI name

The role of an RA could also encompass any of the following activities:

- providing information and advice to the community
- providing applications, services, marketing, outreach, business cases etc. to introduce the DOI System to the community
- designing and implementing specific operational processes, for example: quality control of input data and output data
- integrating the community into other DOI related activities and services

2.2.2 BUSINESS MODEL FOR REGISTRATION AGENCIES

Registration Agencies (RA) must comply with the policies and technical standards established by the DOI Foundation, but are free to develop their own business model for running their businesses. There is no appropriate "one size fits all" model. RAs may be of any form (commercial, governmental, or not for profit). Examples of the functions of an organization which might become an RA include, but are not limited to:

- An organization is running a registry (of identifiers and related data) and wishes to add DOI functionality and services to its existing services.
- An existing aggregator of information wishes to use DOIs to improve their services and add new features.
- A new initiative is launched in a defined sector to meet specific needs or solve a problem, for example, an industry collaboration or effort to solve a common problem (examples of these including Crossref, DataCite and EIDR are amongst the most successful existing RAs).
- A start-up which has a business model suggesting a novel DOI application might be fruitful: in view of the importance of persistence, this is likely to require significant guarantees of continuity planning.

The costs of providing DOI registration may be included in the services offered by an RA provision and not separately distinguished from these. Examples of possible business models may involve:

- explicit charging based on the number of prefixes allocated or the number of DOI names allocated
- volume discounts, usage discounts, stepped charges, or any mix of these
- indirect charging through inclusion of the basic registration functions in related value added services
- cross-subsidy from other sources

Operational costs of the system are borne directly or indirectly by the registrants. The business model adopted by an individual RA is a matter for the RA alone, provided that it complies with the DOI Foundation's policies.

NOTE RAs may choose to provide other DOI System-related services to registrants, without limitation as long as they conform with DOI agreements and policies. These services may include any combination of value added services in, for example, data, content or rights management. RAs may also develop services that exploit the metadata that they collect.

RAs will typically register many thousands or millions of DOI names, and have multiple customers and services, thereby generating economies of scale. RAs for smaller scale applications will probably not be viable as stand-alone entities, though RAs may collaborate, for example to share back-office services to improve viability. Communities that cannot identify an acceptable RA should contact the DOI Foundation to discuss how the DOI System might be used, and whether a new RA application might be developed.

NOTE Once a DOI name is assigned, anyone may resolve that DOI name without charge. At least some information will always be available on resolution.

2.2.3   SERVICE NON-EXCLUSIVITY AND COMPETITION MATTERS

Exclusivity of DOI name registration rights covering either a specific geographic territory or a wide area of application in general (for example, audio) will not normally be granted to any Registration Agency (RA). Exceptions are possible, for example where the RA is mandated to operate as a service for an existing closed community and will not offer their registration services outside that community. DOI applications often overlap and in the digital world any number of categorisations are possible, which makes exclusive arrangements difficult. The only exception at present is an implementation for the Publications Office of the EU, covering DOI registration and management of official EU documents.

In order to maintain a persistent identifier, a DOI application normally provides more value than simply registering a DOI, by offering an added value service such as citation linking or metadata management. RAs operate as independent businesses on the basis of these added-value services and unique selling propositions they bring to offer to the market. In order to provide some coherence of DOI services, applications to become an RA are assessed in the context of likely business implications. Where there is an overlap of the expected market or services of RAs, each will be informed of the potential for overlap or competition and invited to address the problem in such a way as to encourage uptake of the DOI System as a whole whilst ensuring that legitimate business interests are met.

2.2.4   RA AGREEMENT

Registration Agencies (RA) enter into an agreement with the DOI Foundation. A copy of this generic agreement is available on the DOI web site (see RA Agreement[16]).

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[16] https://www.doi.org/resources/Master-DOI-Foundation-Agreement.pdf

The RA agreement covers a number of areas including:

1. Rights granted to the RA:
    o appointment as an RA having the authority to assign DOI names as part of the DOI System using the DOI prefix or prefixes that have been assigned to RA by the DOI Foundation
    o nonexclusive right and license to use DOI trademarks
    o sub-licenses to exercise all rights in the implementation technologies (such as the Handle System) required for the fulfillment of RA's rights and obligations as an RA under the DOI System

2. Obligations of the RA:
    o remain a fully paid member of the DOI Foundation, including adherence to all DOI agreements and policies
    o provide registration services and infrastructure
    o adopt procedures to assure quality
    o respect rights of other RAs

3. Obligations of the DOI Foundation:
    o maintain the DOI System, infrastructure and documentation
    o cooperate with RAs in setting policies and fees regarding RAs
    o participate in ISO and other relevant standards-setting bodies

4. Rights and intellectual property:
    o The DOI Foundation has the exclusive right to appoint RAs and to be the Registration Authority of ISO 26324.
    o Trademarks remain the property of DOI Foundation and are licensed to RAs.
    o RAs may assert patent or other proprietary rights in the RA services, but must comply with the DOI Patent and Trademark Policies.
    o In the event of the DOI Foundation ceasing to be the Registration Authority of ISO 26324, continuity must be ensured.

5. Change procedures, warranties, indemnities, and liability

6. Termination procedures, including:
    o considerations in the event of an RA leaving the DOI Foundation (for example, the transfer of registered DOI names to a successor)
    o considerations in the event of the DOI Foundation being unable to continue (for example, the orderly transition of the responsibilities of the DOI Foundation to a successor)

2.2.5   PROCESS OF BECOMING A REGISTRATION AGENCY

To become a Registration Agency (RA), an organization must:

1. become a General Member of the DOI Foundation
   Organizations interested in becoming a General Member of the DOI Foundation with a

view to developing an RA application are encouraged to contact the DOI Foundation for an exploratory discussion. See also the detailed DOI membership information in 2.1.5.

2. have made a successful application to the DOI Board to be appointed as an RA
   All appointments as an RA are made at the discretion of the Board of the Foundation. It is unlikely that an application simply to register DOI names without offering additional services utilising these registered DOI names will be acceptable or successful. Potential applicants are strongly encouraged to review one or more of the existing RAs for examples of services and operations. See also 2.2.2.

3. sign an RA Agreement with the DOI Foundation: see 2.2.4

2.2.6 FEE STRUCTURE FOR REGISTRATION AGENCIES

The DOI System is a cost-recovery system. ISO Council resolution 17/2012 "approves that fees can be charged on a cost-recovery basis by the DOI Foundation in the operation of the Registration Authority for ISO 26324". The cost of common DOI infrastructure (managed by the DOI Foundation on behalf of all Registration Agencies) is met by a charge made to each Registration Agency, whilst allowing each Registration Agency to adopt individual commercial models incorporating DOI name registration for their services.

2.2.7 REGISTRANT ROLES AND DUTIES

A registrant can be any individual or organization who wishes to uniquely identify entities using the DOI System.

A registrant:

* registers DOI names with a Registration Agency (RA)
  If a registrant has multiple types of content or application requirements, it may choose to use several RAs to provide services.

* ensures appropriate content management of their own material (maintenance of URLs and data), either directly or by contract (for example, with the RA)

* has an agreed relationship as a customer or client of an RA

* does not need to be a member of the DOI Foundation

2.3 DOI SYSTEM GOVERNING POLICIES

This section introduces the policies governing the DOI System.

2.3.1 POLICY FORMULATION PROCESS

Policies are developed within the context of the DOI Foundation's By-laws and Charter. Within this scope, formal agreements are in place between the DOI Foundation and its partners. Individual policies are then defined consistent with these agreements.

Policy development takes place through discussion at regular strategy and members meetings of the DOI Foundation, and sometimes through working groups tasked with reviewing specific areas. All proposed changes in the Core Specification or policies will be presented initially to the RA Working Group (RAWG) for discussion and approval under such quorum

and voting procedures as may be agreed by the RAWG members. Changes approved by the RAWG must then be approved by the DOI Foundation's Board.

2.3.2   LIST OF FORMAL DOI DOCUMENTS

The table below lists the approved policies and agreements governing the DOI System.

NOTE Policies are binding on all members of the DOI Foundation.

Table 2 Formal DOI documents

Formal document	Description	See
Antitrust policy	The DOI Foundation conducts their operations in strict compliance with the antitrust laws, regulations and guidelines of all jurisdictions where the Foundation conducts meetings, programs, or activities.	[Antitrust Policy](https://www.doi.org/resources/Antitrust_Policy.pdf)[17]
Conflict of interest policy	This policy protects the interests of the DOI Foundation when it is contemplating entering into a transaction or arrangement that might benefit the private interest of a Director or Officer of the Foundation.	[Conflict of Interest Policy](https://www.doi.org/resources/Conflict_of_Interest_Policy.pdf)[18]
Trademark policy	Guidelines for use of the trademarks which the International DOI Foundation owns. DOI®, DOI>®, DOI.ORG® and shortDOI® are registered trademarks of the International DOI® Foundation.	[Trademark Policy](https://www.doi.org/resources/130718-trademark-policy.pdf)[19]
Patent policy	Procedures relating to patent rights and claims among Registration Agencies (RA): to enable the DOI System to be available to all who want to use it on equal terms; to preserve and protect the collective investment in the DOI System and standard; and to allow RAs to develop added-value services and features. The DOI Foundation does not itself hold any patent rights in the DOI System.	[RA Patent Policy](https://www.doi.org/resources/RAPatentPolicy.pdf)[20]
Data policy	This policy concerns confidentiality of data such as usage statistics and information about individual DOI name resolution, for the DOI Foundation and the Registration Agencies.	[Data Policy](https://www.doi.org/resources/IDF_DataPolicyv3.pdf)[21]
RA collaboration policy	General requirements and procedures for resolving conflicts between Registration Agencies and encouraging collaboration, to the benefit of the DOI community.	[Collaboration Policy](https://www.doi.org/resources/IDF_RA_CollaborationPolicyv3.pdf)[22]
DOI Proxy implementation policy	Requirements for support and functionality of proxy servers by Registration Agencies, including those running instances of the DOI Proxy Server and their own local proxies, and support for the Default Proxy and the functionality of the Default Proxy.	[Proxy Policies](https://www.doi.org/resources/proxy_policies.html)[23]

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[17] https://www.doi.org/resources/Antitrust_Policy.pdf

[18] https://www.doi.org/resources/Conflict_of_Interest_Policy.pdf

[19] https://www.doi.org/resources/130718-trademark-policy.pdf

[20] https://www.doi.org/resources/RAPatentPolicy.pdf

[21] https://www.doi.org/resources/IDF_DataPolicyv3.pdf

[22] https://www.doi.org/resources/IDF_RA_CollaborationPolicyv3.pdf

[23] https://www.doi.org/resources/proxy_policies.html

Formal document	Description	See
Core specification	A technical specification relating to the description of the DOI System covered in the DOI Foundation's Registration Agency Agreement.	[DOI Core Specification](https://www.doi.org/resources/DOICoreSpecificationv1.pdf)[24]
Suspension and termination of an RA	This document outlines procedures for dealing with DOI names in the event of suspension or termination of an RA.	[RA Suspension and Termination Procedures](https://www.doi.org/resources/RA_Termination.pdf)[25]
General Member Agreement	This agreement governs the terms and conditions under which a General Member of the DOI Foundation agrees to participate in the DOI Foundation and use the DOI System.	[General Member Agreement](https://www.doi.org/resources/GeneralMemberAgreement.pdf)[26]
Registration Agency Agreement	This agreement governs the relationship between a Registration Agency (RA) and the DOI Foundation. The RA agreement provides equal terms to each RA, unless specific waivers or exceptions have been agreed to meet the needs of a specific community.	[RA Agreement](https://www.doi.org/resources/160101RA_Agreement.pdf)[27]
ISO 26324: Information and documentation — Digital object identifier system	ISO 26324 specifies the syntax, description and resolution functional components of the digital object identifier system, and the general principles for the creation, registration and administration of DOI names.	1.8.1

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[24] https://www.doi.org/resources/DOICoreSpecificationv1.pdf

[25] https://www.doi.org/resources/RA_Termination.pdf

[26] https://www.doi.org/resources/GeneralMemberAgreement.pdf

[27] https://www.doi.org/resources/160101RA_Agreement.pdf
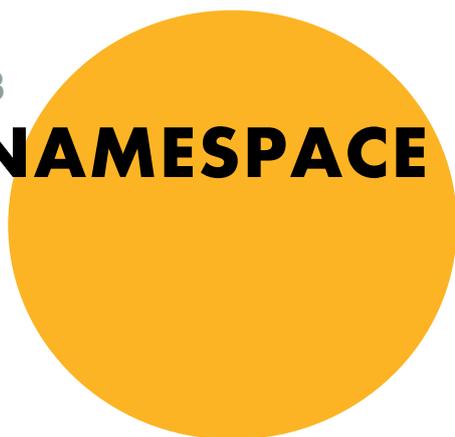
DOI NAMESPACE

This chapter defines the syntax for a DOI name. It also explains the DOI name assignment principles and how other identifier schemes can be integrated into the DOI system.

For information about the definition of prefix allocation and suffix naming policies, see Chapter 8.

In This Chapter

3.1 ASSIGNMENT PRINCIPLES OF THE DOI NAME

The following principles for assigning DOI names apply:

- A DOI name can be assigned to any object whenever there is a functional need to distinguish it from other objects.
  DOI names can be assigned at any desired degree of precision and granularity that a Registration Agency deems to be appropriate based on the needs of their community.

- Each DOI name shall specify one and only one referent in the DOI System.

- The assignment of a DOI name requires that the registrant provide metadata describing the object to which the DOI name is being assigned. The metadata shall describe the object to the degree that is necessary to distinguish it as a separate entity within the DOI System.

- No time limit for the existence of a DOI name shall be assumed in any assignment (see 1.9).

- A DOI name shall not be used as a replacement for other ISO identifier schemes.

NOTE While a referent can be specified by more than one DOI name, it is usually recommended that each referent has only one DOI name. But depending on the DOI application, there may be legitimate reasons to assign multiple DOIs to the same referent.

3.2 SYNTAX OF THE DOI NAME

The syntax of the DOI name is standardized as part of ISO 26324.

3.2.1 GENERAL CHARACTERISTICS OF THE DOI SYNTAX

The DOI syntax shall be made up of a DOI prefix and a DOI suffix separated by a forward slash.

There is no defined limit on the length of the DOI name, or of the DOI prefix or DOI suffix.

The DOI name is case-insensitive and can incorporate any printable characters from the legal graphic characters of Unicode. Further constraints on character use (for example, use of language-specific alphanumeric characters) can be defined for an application by the ISO 26324 Registration Authority.

NOTE The exact definition of case-insensitivity is expected to be clarified in an upcoming revision of the International Standard.

The DOI name is an opaque string for the purposes of the DOI system. No definitive information may be inferred from the specific character string of a DOI name. In particular, the inclusion in a DOI name of any registrant code allocated to a specific registrant does not provide evidence of the ownership of rights or current management responsibility of any intellectual property in the referent. Such information may be asserted in the associated metadata.

3.2.2 DOI PREFIX

The DOI prefix refers to the DOI namespace (a namespace is allocated to a given service provider): see 1.7.4.

The DOI prefix is <directoryIndicator>.<registrantCode>.

The following rules apply:

- The directory indicator can contain only numeric values. The directory indicator is usually 10 but other indicators may be designated as compliant by the DOI Foundation.

- The registrant code can contain only numeric values and one or several full stops which are used to subdivide the code. For example: 10.1000, 10.500.100, etc.
  If the directory indicator is 10 then a registrant code is mandatory.

3.2.3 DOI SUFFIX

Each suffix shall be unique to the prefix element that precedes it. The unique suffix can be a sequential number, or it might incorporate an identifier generated from or based on another system used by the registrant (for example, ISAN, ISBN, ISRC, ISSN, ISTC, ISNI; in such cases, a preferred construction for such a suffix can be specified, as in Example 2). No length limit is set to the suffix by the DOI System.

See also 8.3.

EXAMPLES

- Example 1
  10.1000/123456: DOI name with the DOI prefix "10.1000" and the DOI suffix "123456"

- Example 2
  10.1038/issn.1476-4687: DOI suffix using an ISSN
  To construct a DOI suffix using an ISSN, precede the ISSN (including the hyphen) with the lowercase letters "issn" and a period, as in this hypothetical example of a DOI name for the electronic version of the scientific journal Nature.

3.2.4 CHARACTER SET SUPPORTED IN THE DOI NAME

DOI Names may incorporate any printable characters from the Universal Character Set (UCS) of ISO/IEC 10646, which is the character set defined by Unicode. The Handle System at its core uses UTF-8, which is a Unicode implementation and so in its pure form has no character set constraints at all: any character can be sent to, stored in, and retrieved from a Handle server.

The character set encompasses most characters used in every major language written today (see also 10.2.1).

NOTE Some characters should be avoided: see 3.4.

3.2.5 CASE INSENSITIVITY OF THE DOI NAME

DOI names are case insensitive, using ASCII case folding for comparison of text. (Case insensitivity for DOI names applies only to ASCII characters. DOI names which differ in the

case of non-ASCII Unicode characters may be different identifiers.) 10.123/ABC is identical to 10.123/AbC. All DOI names are converted to upper case upon registration, which is a common practice for making any kind of service case insensitive. The same is true with resolution. If a DOI name were registered as 10.123/ABC, then 10.123/abc will resolve it and an attempt to register 10.123/AbC would be rejected with the error message that this DOI name already existed.

Although from a character encoding viewpoint suffixes are case sensitive, for example 10.123/ABC is different from 10.123/AbC and the two could be distinguished as different identifiers, the DOI Foundation decided to remove case sensitivity, after a detailed review of the consequences. The Handle System is configurable by service so as to be either case sensitive or case insensitive and therefore allows this. This restriction has been implemented from an early stage, and Registration Agencies have not introduced any cases of two DOI names distinguishable only by ASCII case resolving to the same thing.

The advantages of case sensitivity (librarian and publisher practice, human readability and expectations) were outweighed by considerations of data integrity. Case sensitivity practice across Internet applications varies: DNS is not, the rest of URLs are except sometimes they aren't (this depends on the server), Unix vs PC/Mac file names (Microsoft Windows in general is not case-sensitive, Unix operating systems are always case sensitive), markup language tags, etc. can all cause unexpected problems and one cannot guarantee that any particular piece of software will respect case sensitivity and not conflate two DOI names intended to be different. Some search engines and directories are partially case sensitive. Different web browsers may differ in case sensitive handling (web browser developers have advised that "authors should not rely on case-sensitivity as a way of creating distinct identifiers, unless they are designing solely for a truly standards-compliant browser").

This argued in favor of case insensitivity being the safer, and more robust, option for future evolution and development of the DOI System.

3.2.6 CONSIDERATIONS ABOUT THE USE OF CHECK DIGITS IN DOI NAMES

A DOI name is an opaque string. The DOI System does not itself make use of check digits. This is deliberate, for a number of reasons:

- ability to include an existing identifier string as a prefix in a DOI without any alteration: some common strings like ISO identifiers already have a check digit in them which act as aids to readability or keyboard data entry in the absence of any automated protocol correction;
- performance considerations if a check sum is calculated at each resolution;
- identifier schemes such as URL have no check digit: the underlying TCP/IP protocol they use has an error-correction component. This aids creation and use.

However, other applications may make use of check digits, so a checksum digit may be inserted into a DOI name if it would be useful for some other application. Use of checksums in a particular DOI System application can be introduced as a rule of that application by the Registration Agency concerned. An example is the EIDR application, where the check char-

acter is computed only over the DOI suffix. It does not include the prefix because if the prefix is wrong, it is highly probable that the DOI name will go to an incorrect resolution system anyway. The EIDR registry separately validates the prefix of any DOI name sent through its API.

3.3 PRESENTATION FORMATS OF A DOI NAME

A DOI name should be preceded by a lowercase "doi:" unless the context clearly indicates that a DOI name is implied. The "doi:" label is not part of the DOI name value. For example, the DOI name "10.1006/jmbi.1998.2354" is displayed and printed as "doi:10.1006/jmbi.1998.2354". This representation complies with the syntax f the IETF specification, RFC 3986, for a representation as a URI (Uniform Resource Identifier), in the same way as "ftp:" and "http:".

In a print version, to let the readers know that the DOI name is actionable, Registration Agencies may elect to print the DOI Proxy URL form (see 1.5.1). It is then advantageous to use some convention of showing both the plain DOI name and a way to resolve it online (a shorthand way of saying "the DOI name for this article is 10.1002/prot.999 and current information may be found on the web through https://doi.org/10.1002/prot.999" or "...available via https://doi.org/...").

NOTE If the URL form of a DOI name is represented by a button on a web page, the web browser will normally display the full DOI name when the cursor is moved over the button.

3.3.1 SPECIFIC PRESENTATION FORMATS OF A DOI NAME

Specific representations may be agreed to meet special technical requirements. For example, the joint ANSI / Society of Cable and Telecommunications Engineers standard "Digital Program Insertion Cueing Message for Cable" (SCTE 35:2013) defines (among other things) the standard method for cable TV systems to include EIDR DOI names in-band with the programs being broadcast. It uses a compact lossless EIDR representation rather than the full ASCII DOI string. This also makes use of the resolvability of DOI names, suggesting that IDs so carried can be resolved via an out-of-band mechanism to collect more data.

DOI names may also be presented in a shortened version via the shortDOI service: see 5.5.

3.4 CONSTRAINTS ON DOI NAME SYNTAX IN SPECIFIC CONTEXTS

If the DOI name is used in specific application contexts then there may be requirements or restrictions on the use of particular characters:

- When presented as above as an URL (Uniform Resource Locator) with the web proxy address prepended, some characters must be percent encoded (for example, # must be encoded because this character is used in a URL to indicate the beginning of a URL fragment).
- Characters which cannot be handled directly in a specific network or reference context, or where ambiguity can arise (for example, minus sign, the hyphen, and the en-dash all

look similar on the screen but carry different character values) should be avoided or encoded in an appropriate way (for example, for URLs: should be converted to UTF-8 and then hex-encoded).

The Unicode Standard imposes additional constraints on implementations of ISO/IEC 10646:2020, the Universal multiple-octet coded character set (usually referred to as the Universal Character Set, UCS). See [Unicode](https://home.unicode.org)[28] for more information.

3.5 INTEGRATION OF OTHER IDENTIFIER SCHEMES

A DOI name shall not be used as a replacement for other identifier schemes such as ISAN, ISBN, ISRC, ISSN, ISTC, ISNI and other commonly recognized identifiers, but when used with them it can enhance the identification functionality provided by those systems with additional DOI System functionality, and thus, provide interoperability with existing identifier schemes.

This section explains the different ways other identifier schemes can be integrated. For more considerations about identifier interoperability, see [Identifier Interoperability factsheet](https://www.doi.org/factsheets/Identifier_Interoper.html)[29] on the DOI web site.

3.5.1 SPECIFICATION OF ANOTHER IDENTIFIER IN THE DOI METADATA

The existence of other existing identifier(s) for a referent is incorporated into the DOI Metadata Kernel Declaration.

With this requirement, an existing legacy scheme can be used by any automated processes which pick up structured metadata from a DOI System service, using the DOI Kernel declaration of this referent.

3.5.2 INCORPORATION OF AN EXISTING IDENTIFIER INTO A DOI NAME

An existing identifier scheme can be included in the DOI syntax.

PURPOSES

DOI names can incorporate established identifiers (like ISBN, ISAN, ISWC, PII, or any proprietary identifier) to allow integration with existing systems. Use of DOI name allows ready interoperability with existing abstraction identifiers, with associated manifestation identifiers and other metadata; with rights metadata; and builds on what is practical in each sector.

CONSIDERATIONS TO BE TAKEN INTO ACCOUNT

Where syntax rules permit the incorporation of an existing identifier from another scheme as part of the DOI name, such rules do not form part of ISO 26324 but are documented

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[28] https://home.unicode.org
[29] https://www.doi.org/factsheets/Identifier_Interoper.html

separately by the registration authority. In such cases, attention is drawn to the following points.

- The same referent shall be denoted by both the DOI name and the included identifier string, to the degree that is necessary to distinguish it as a separate entity within each identifier scheme.

- Within the DOI System itself, the DOI name is an opaque string. No definitive information relating to the other identifier scheme should be inferred from the specific character string used for a DOI name, and the DOI name is not guaranteed to be usable in any non-DOI applications designed for the other identifier scheme.

- Specific syntax rules for the incorporation of an existing identifier from another scheme shall be maintained by the ISO 26324 Registration Authority.

EXAMPLES

Examples 1 and 2 show the incorporation of an ISBN and an ISSN into a DOI name. Other agreed syntaxes for integration are also possible. Example 3 shows that the DOI name is not a replacement for the other identifier scheme.

- Example 1
  10.978.86123/45678 shows a possible incorporation of an ISBN (978-86-123-4567-8) into a DOI prefix and suffix.

- Example 2
  10.1038/issn.1476-4687 shows a DOI suffix using an ISSN.

- Example 3
  10.97812345/99990 is a DOI name. It cannot be validly submitted to an ISBN point-of-sale ordering system, or converted to a GS1 bar code for use as an ISBN bar code. It does not conform to the ISBN syntax.
  978-12345-99990 is an ISBN. It cannot be validly submitted to a DOI resolution service; it does not conform to the DOI syntax.
  However both identifier strings have the same referent.

3.5.3   LINKAGE OF DOI NAMES TO ANOTHER REGISTRY

A business relationship can be built to facilitate the inclusion of another identifier scheme in the DOI syntax, by collaboration between the DOI Foundation and the relevant registry. Where such collaboration is agreed, new potential may be unlocked: the ISBN-A application is an example of the linkage of DOI names to an existing registry. For more information, see [DOI System and the ISBN System](https://www.doi.org/the-identifier/resources/factsheets/doi-system-and-the-isbn-system)[30].

3.5.4   COMPLEMENTATION OF OTHER IDENTIFIER SERVICES

The DOI System functionality can be offered to complement other identifier services which are available through other parties, for example, for the resolution of identifiers in a variety of contexts. Services using an identifier can be offered by multiple providers. Rules of

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[30] https://www.doi.org/the-identifier/resources/factsheets/doi-system-and-the-isbn-system

certain identifier systems can necessitate the use of only specified preferred service providers; in such cases, the application of the identifier shall follow the rules of the relevant registration authority. Each registration authority for an identifier scheme retains autonomy in determining rules for usage within its own scheme or community. The DOI Foundation maintains current information on agreed specific mechanisms for use with other identifier schemes.
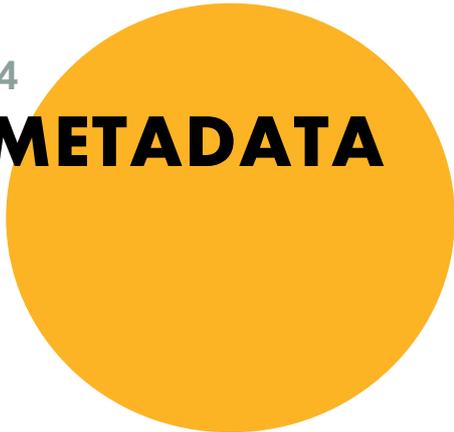
DOI METADATA

This chapter explains the basis for one of the main technical components of the DOI System, the DOI data model, and its ability to ensure interoperability of DOI name metadata assigned through metadata schemes.

In This Chapter

4.1 INTRODUCTION TO DOI METADATA

Without metadata, an identifier is of very little value. Metadata, which may be defined in this context as information about an identified referent, provides human beings or machines with the data they need to enable them to make use of that identified referent. Metadata may include names, identifiers, descriptions, types, classifications, locations, times, measurements, relationships and any other kind of information related to a referent.

There are two ways in which every Registration Agency (RA) is bound to deal with metadata as illustrated below:

- An RA will gather input metadata from referent providers (typically, descriptions of the referents and associated rights and policies).
- An RA will need to provide some level of output or service metadata to support DOI system services.
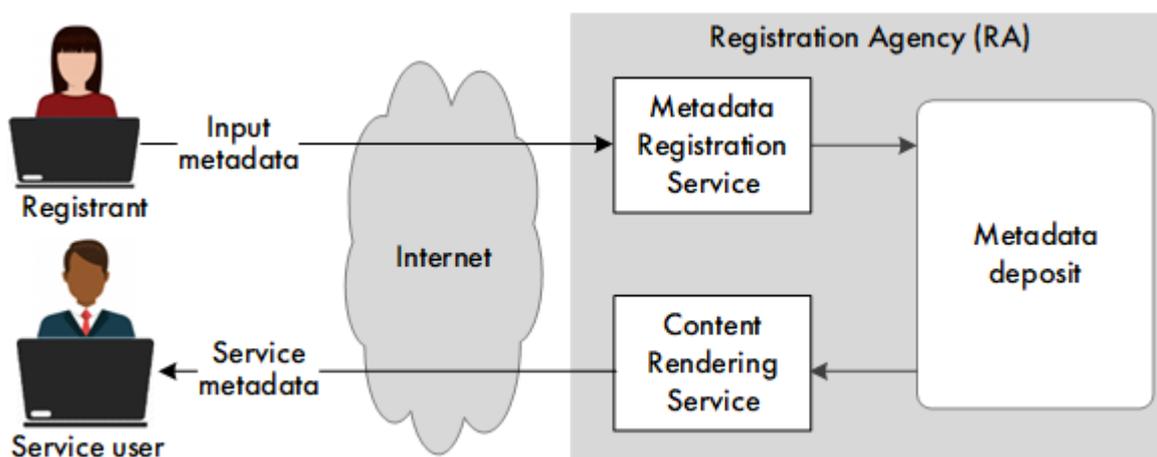
Figure 9 Input and service metadata

Input metadata will provide some, but not necessarily all, of the service metadata.

In some cases, a metadata declaration will itself be a complete DOI System service.

4.2 METADATA REQUIREMENTS ACCORDING TO ISO 26324

This section describes the requirements on DOI metadata specified in ISO 26324.

4.2.1 GENERAL REQUIREMENTS ON METADATA

According to ISO 26324, the referent shall be described unambiguously and precisely by DOI metadata, based on a structured data model that enables the referent of a DOI name to be associated with metadata of any desired degree of precision and granularity to support identification, description and services associated with a referent. This is designed to do the following:

- promote interoperability within networks of DOI users by enabling independent systems to exchange information and initiate actions from each other in transactions involving DOI names

Since DOI names can be assigned to any type of object, such interoperability can be across different types of content (for example, audiovisual, music and text).

- ensure minimum standards of quality of administration of DOI names by registrants, and facilitate the administration of the DOI system as a whole

4.2.2 REQUIREMENTS ON METADATA FUNCTIONS

According to ISO 26324, DOI metadata should support the following functions:

- generic mechanism for handling complex metadata for all different types of intellectual property
  For example, instead of treating sound carriers, books, videos, and photographs as fundamentally different things with different (if similar) characteristics, they are all recognized as creations with different values of the same higher-level attributes, whose metadata can be supported in a common environment.
- interoperability of metadata across applications, with reference to:
  - o media (for example, books, serials, audio, audiovisual, software, abstract works, visual material)
  - o functions (for example, cataloguing, discovery, workflow, and rights management)
  - o levels of metadata (from simple to complex)
  - o semantic barriers
  - o linguistic barriers
- functional granularity, making it possible to identify an object whenever it needs to be distinguished

4.2.3 REQUIREMENTS ON METADATA REGISTRATION

According to ISO 26324, metadata describing and identifying the referent to which the DOI name is being assigned shall be recorded promptly and accurately. In addition:

- Data elements and allowed values used in DOI metadata declarations shall be placed in a repository (data dictionary) to facilitate interoperability across selected existing schemes.
- The metadata shall meet the minimum requirements of the DOI Kernel Metadata Declaration.

4.3 DOI DATA MODEL

The DOI data model consists of a policy and various tools. It can be extended to meet the needs of the Registration Agencies.

4.3.1 DOI DATA MODEL POLICY

DOI metadata model policy is concerned with the internal management and exchange of metadata between Registration Agencies (RA) within the RA network, and is designed to:

- promote interoperability within the network of DOI system users

- ensure minimum standards of quality of administration of DOI names by RAs and facilitate the administration of the DOI System as a whole

POLICY ON DOI METADATA DECLARATION

A metadata declaration must be made for every entity identified with a DOI name according to the following principles:

- The declaration must contain a minimum set of mandatory metadata which is defined through the DOI Kernel Schema. This schema is designed to be as limited in scope as possible, and it is applicable to any entity identifiable by the DOI System.
- Additional metadata can be declared. They should be based on an agreed metadata exchange schema if metadata interoperability is required with other Registration Agencies (RA).
- All declared DOI metadata is based on an underlying ontology through the DOI Kernel Schema which specifies all data elements and allowed values.

DOI data model policy places no restrictions on the form and content of input and service metadata declarations of a Registration Agency (RA), except insofar as input metadata must support the minimum requirements implicit in the DOI Kernel. RAs may specify their own metadata schemes and messages, or use any existing schemes in whole or part for their input and service metadata declarations.

POLICY ON DOI NAME ADMINISTRATION

The second aim of DOI data model policy is to ensure minimum standards of quality of administration of DOI names by Registration Agencies (RA), and facilitate the administration of the DOI System as a whole. This aim may also be seen as supporting the first aim of interoperability, but it specifically addresses the need to ensure that a prospective RA is competent to issue DOI names responsibly and that ambiguous DOI names do not enter the network.

The policy provides a simple test of an RA's competence: the ability to make a DOI Kernel Declaration, which requires that the RA has an internal system which can support the unambiguous allocation of a DOI name, and is fundamentally sound enough to support interoperability within the network. In addition, the policy requires that RAs maintain a record of the date of allocation of a DOI name, and the identity of the registrant on whose behalf the DOI name was allocated.

The DOI data model policy also exists to support the future development of mechanisms for facilitating the administration of the DOI System as a whole. This might be done, for example, through the use of terms registered in the DOI Kernel Schema as types, to classify DOI names, or services.

4.3.2   DOI KERNEL METADATA

The assignment of a DOI name requires that the registrant provide metadata describing the object to which the DOI name is being assigned. At minimum, this metadata shall consist of a DOI Kernel Metadata Declaration.

The DOI Kernel is specified through the DOI Kernel Schema (see 10.1).

BASIC INFORMATION CONTAINED IN THE DOI KERNEL

The DOI Kernel Metadata Declaration should answer basic questions such as:

- What is the DOI name assigned to the referent?
- Is the referent commonly referenced with another identifier?
- What is the referent usually called?
- What is the primary type of the referent (examples: creation, party, event)?
- What is the structural type of the referent (for example, for a creation: physical, digital, performance, abstraction)?

It answers other questions about the referent depending on the primary type of the referent, and the following administrative questions:

- Which Registration Agency issued this DOI name?
- When was the declaration issued?
- Which Kernel version is it?

The data elements of the Kernel are specified by the DOI Kernel Schema (see 10.1 for more information).

NOTE Registration Agencies can add new values to open lists of allowed values of the DOI Kernel: see 4.3.6.

PURPOSE OF THE DOI KERNEL

The purpose of the DOI Kernel is to allow:

- recognition
  Recognition in this context means that the Kernel metadata should be sufficient to show clearly what kind of thing which is the DOI referent (by various classifications), and allow a user to identify with reasonable accuracy the particular thing (by various names, identifiers and relationships). These two are complementary, for it is possible to know that something is (for example) a movie or a DVD without knowing that it is "Casablanca", and vice versa. Recognition is required for the discovery of referents, and also to provide information to a user when a referent is discovered, whether by intent or accident. The user of metadata may be a person or a machine. The structure of the Kernel is often but not always sufficient to provide a unique description of a referent (disambiguation), and further specialized metadata elements may be required in some cases. A unique description can in fact always be achieved by adding additional descriptive text to a referent, but this is not a satisfactory way if the additional text is being used in place of a formal classification, measurement, identifier, time or other structured contextual metadata, as it undermines the second goal of interoperability.

- interoperability
  Interoperability in this context means that Kernel metadata from different DOI Registration Agencies may be combined or queried by the same software without requiring semantic mapping or transformation. Interoperability is achieved when data elements or their values are common to diverse metadata schemas. The Kernel provides this directly

by mandating a common set of core elements and classifications, but this of course supports only limited interoperability.

4.3.3   ADDITIONAL METADATA

Additional metadata can be declared. They should be based on an agreed metadata exchange schema if metadata interoperability is required with other Registration Agencies (RA). XML, RDF or JSON schemas may be used.

The DOI Kernel Schema specifies all data elements and allowed values of the metadata exchange schemas (see 10.1).

4.3.4   DATA DICTIONARY

A data dictionary specifies the data elements and allowed values of all declared DOI metadata. This data dictionary is defined through the DOI Kernel Schema (see 10.1).

Terms will be added to the dictionary at the request of any Registration Agency (RA): see 4.3.6.

Users need not understand the underlying concepts and construction of the data dictionary in order to make use of it. Key features of the dictionary are:

- The dictionary is extensible to whatever level of detail and granularity is required.
- The dictionary is neutral as to business model.
- The dictionary is independent of any implementation technology.
- The dictionary allows use of any existing metadata scheme.
- Multiple, different, specialized views can be made available.
- Local terms can be included.
  An RA can add all their own local data elements and names into the ontology, and use only those terms they need.
- The dictionary can include different terms from different internal systems and map them together.
- The dictionary incorporates external and standard schemes such ISO territory, currency and language codes, and sector specific external schemes, allowing them to be treated seamlessly alongside local terms.
- Any public terms are accessible to all RAs.

NOTE The data dictionary was previously specified through the DOI Data Dictionary file which is no longer actively updated. The last update of the DOI Data Dictionary was in 2015 and can be found on the [DOI web site](#)[31].

4.3.5   UNDERLYING ONTOLOGY

As described in 1.4, the DOI data model is based on the INDECS framework.

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[31] https://www.doi.org/resources/DOI%20Data%20Dictionary%202015-03-23.pdf

The ontology logical data model, providing a consistent and logical world view, differs from the traditional taxonomic approach to knowledge representation in that it does not follow a rigid parent/child hierarchical structure. Terms may inherit meaning from more than one parent and a more complex relationship may be maintained. An interoperable data dictionary contains terms from different computerized systems or metadata schemes, and shows the relationships they have with one another in a formal way. An illustrative graphic of the high level concept model is provided on the DOI web site ([Data Model Underlying Ontology](https://www.doi.org/resources/DataModelUnderlyingOntology.pdf)[32]) and further documentation is available. Please consult the DOI Foundation for further information.

4.3.6   DATA MODEL EXTENSION AND MAINTENANCE

Registration Agencies can request:

- the addition of new terms to the DOI Kernel Schema, or the publication of additional metadata schemas
- the addition of new values to open lists of values of the DOI Kernel Schema

Authority to make changes in the existing DOI schemas lies with the Schema Working Group. A fundamental role of the DOI Foundation is to provide assurance to users that the changes have been peer-reviewed, tested in practical implementations, and are based on sound principles.

For more information, see 7.4.

4.4   METADATA INTEROPERABILITY

The first aim of DOI data model policy is to promote interoperability within the network of DOI name users. It does this by providing ways of achieving semantic compatibility between different Registration Agencies.

4.4.1   MOTIVATIONS FOR INTEROPERABILITY

Standardization of any kind is driven by a need for interoperability. If a Registration Agency (RA) is issuing DOI names for referents for use within a private domain where that RA is able to command all aspects of metadata gathering and output, then it has no need for standardization or conformance with DOI data model obligations. The RA will lay out its schemas and declarations, and its providers and users should conform to them. Such a situation is described as restricted use of the DOI System, and applies typically where an organization becomes an RA for the specific purpose of issuing DOI names for use only within its own private organization.

However, such isolation is unusual. Normally, when a DOI name is issued to a referent, one fundamental assumption may be made about interoperability: the RA or the referent provider may wish (now or in the future) that the DOI name should be available for use in services provided by other RAs. For example, where several RAs are issuing DOI names to

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journal articles from different publishers, it is likely that some RAs and publishers will want their DOI names to be included in journal-related services supported by other RAs.

In a similar way, many RAs will want DOI names issued by other RAs to be available for inclusion in services they themselves are providing. Such interoperability is one of the principal benefits of the DOI System.

As the RA network grows, such requirements are emerging, and where specific opportunities do not yet exist they are anticipated. In such circumstances neither the RA nor the referent provider wishes to issue a second DOI name for the referent, nor to provide and capture the input metadata all over again from its source.

4.4.2   ACHIEVEMENT OF INTEROPERABILITY

Any DOI name which is intended for interoperability — that is, which has the possibility of use in services outside of the direct control of the issuing RA — is subject to DOI metadata policy:

- The DOI Kernel Metadata ensures that the minimum set of metadata held by different RAs is consistent.
- The interchange provisions of the additional metadata exchange schemas and of the data dictionary ensure that an efficient and extensible means of interchange exists for transporting metadata between RAs (and in future other service providers).

The figure below shows how interoperability is achieved when the content rendering service of an RA (RA1) processes DOI names managed by another RA (RA2). In this example, the content rendering service of RA1 receives metadata about a DOI name managed by RA2. To be able to process this metadata, RA1's service uses, in addition to the DOI Kernel Schema, the metadata exchange schema agreed between RA1 and RA2.
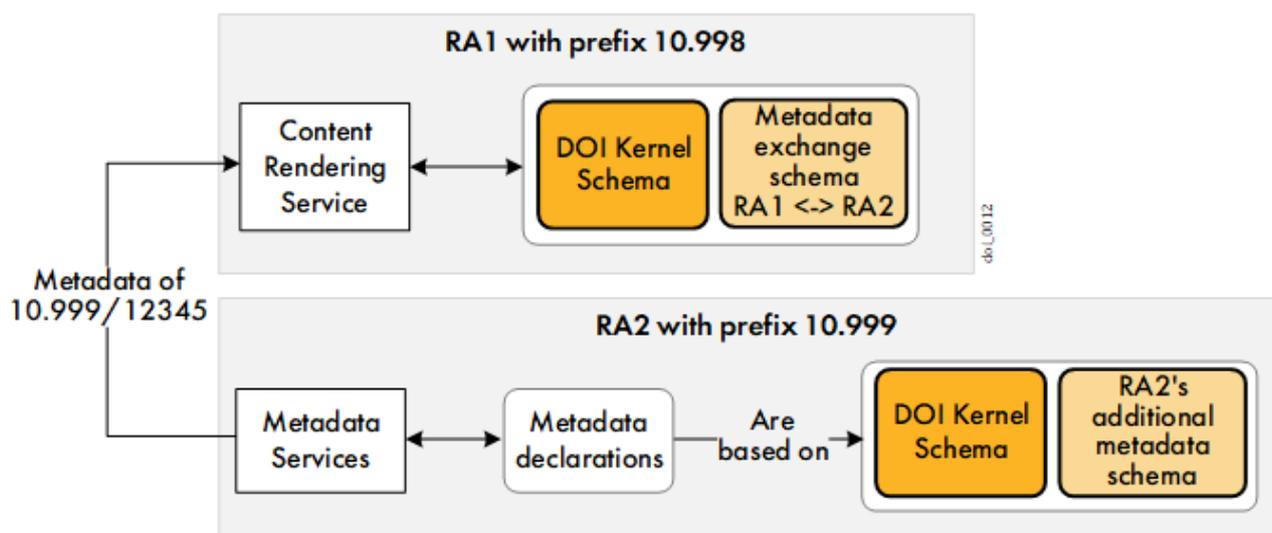

Figure 10 Achievement of interoperability

4.5   AUTOMATED INTEGRATION OF METADATA

The DOI Foundation recognizes that the automated integration of metadata is the key to re-alizing the full potential of the DOI System. This is also the underlying objective of the Se-mantic Web and Linked Data: that the Web should be seen as a medium for structured, in-terlinked and machine-processable information, as much as, in its current form, a network of documents presenting the information for human consumption.

The DOI Kernel Metadata and the data dictionary exist to provide a basis of good practice and a start point for the integration of metadata for different DOI referents. Initiatives such as Linked Open Data provide further essential infrastructure, but only in technology and syntax: they do not provide solutions at the level of shared meaning (semantic alignment) for the automated integration of different datasets which can allow services from different RAs and other parties to interact fully without human intervention or a plethora of one-to-one "silo" solutions.

The key to this is the development of well-structured metadata schemas and of services which make use of the semantic mapping capabilities of tools such as the DOI Kernel Schema. The DOI Foundation will provide support to their RAs where they choose to co-op-erate in the development of such services.

DOI IDENTIFIER / RESOLUTION SERVICES

This chapter describes the identifier / resolution services included in the DOI System package.

In This Chapter

5.1 IDENTIFIER / RESOLUTION SERVICES BASED ON THE HANDLE SYSTEM

The DOI System offers DOI identifier / resolution services through the Handle System which meets the functional requirements defined by ISO 26324.

5.1.1 ISO 26234 FUNCTIONAL REQUIREMENTS ON THE RESOLUTION SYSTEM

According to ISO 26234, the technology deployed to manage the resolution of the DOI name shall support the functions listed below:

- internet compatible: transmission via the global information system that is logically linked by a globally unique address space and communications
- first class naming: identifiers resolved by the system shall have an identity independent of any other object
- unique identification: the specification by an identifier string of one and only one referent
- functional granularity: separate resolution of an object whenever it needs to be distinguished
- data typing: The extensible definition of constraints placed upon the interpretation of certain data entries in a resolution record, such that data values with similar constraints can be grouped and treated in the same way.
- multiple resolution: the simultaneous return as output of several pieces of current information related to the object, in defined typed data structures
  Resolution requests should be capable of returning all associated values of current information, individual values or all values of one data type.
- designated authority: The administrator of an identifier shall be securely identified and capable of transfer.
- appropriate access to resolution records: Changes to a resolution record shall be recorded and shall be capable of providing access to the data on which the administrator depends and privacy and confidentiality from those who are not dependent on it.
- DNS independent but compatible: not reliant on the Domain Name System (DNS), but capable of working with DNS domain naming and resolution services
- granularity of administration: DOI names can be administered individually or in groups.
- scalability:
  - o efficient and infinitely scalable protocol
  - o no limitations on absolute number of identifiers assigned or length of identifier string
- unicode compliant

NOTE The regular update of the DOI records is crucial to maintain quality services.

5.1.2 INTRODUCTION TO THE HANDLE RECORD

With the Handle System, a Handle is resolved to a set of elements called the Handle Record (the DOI record in case of a DOI name). An element is a typed data. Predefined types exist

in the Handle System and new types can be added at any time (the process for adding new types is under development). For example, a DOI name could resolve to a Java servlet, or other dynamic mechanism.

An element inside a DOI record may be:

- a link to a resource: web address, IP address, etc.
- metadata: description, type, terms & conditions, ownership, etc. of the entity represented by the DOI name
- security information: public key, digital signature, etc.
- administration information: administrator of the DOI record with permissions
- state information: entity status, etc.

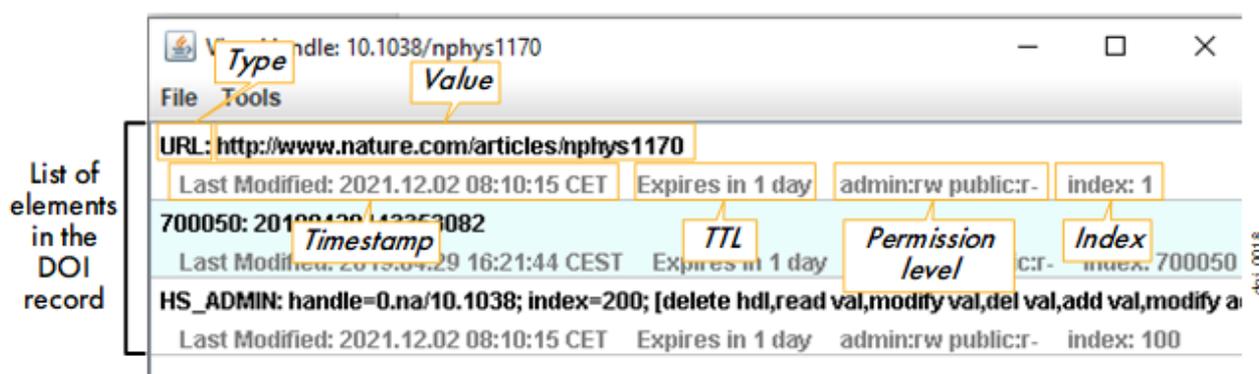The following figure shows a DOI record example.

Figure 11 DOI record example

An element consists of:

- an index: unique element identifier inside the DOI record
- a global and registered type (for example, URL, description, IP address, email address, etc.)
- a value (data)
- a permission level: specifies if the value is publicly available or not and if it can be changed by an authorized administrator
- a timestamp
- a Time To Live (TTL): specifies how long the element value can be cached before the information source should again be consulted

NOTE An element inside a Handle Record can point to one or several Handles or to one or several elements in the same or in another Handle Record.

5.1.3   HANDLE SYSTEM SERVICE ARCHITECTURE

This section introduces briefly the Handle System services. For more information, see Digital Object Identifier Resolution Protocol (DO-IRP) Specification[33].

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[33] https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf

The Handle System consists of a single distributed Global Handle Registry (GHR), and unlimited number of Local Handle Services (LHS):

- Identifiers (called Handles) are managed by LHSs. Handles under the same prefix are managed by the same LHS.
- The GHR stores the information necessary to locate the LHS responsible for any Handle in the system.

To resolve a Handle, a Handle System client will first connect to the GHR which will redirect it to the LHS responsible for the requested Handle.

To understand in more details how the GHR and LHS work, it is necessary to introduce first the prefix Handle concept.

INTRODUCTION TO PREFIX HANDLES (0.NA PREFIX)

Specific Handles are used in the Handle System to represent the prefixes:

- The Handle of a prefix is in the format "0.NA/<prefix>".
- The record of a prefix Handle (record returned by Handle resolution) contains administration data for managing the prefix. For example, 0.NA/10.100 record stores the location (service information) of the LHS responsible for the resolution of DOI names under 10.100 (see also a prefix handle example in section 10.6).

GLOBAL HANDLE REGISTRY (GHR)

The GHR is a distributed registry whose operation is managed collaboratively by the DONA Foundation and multiple organizations. An organization that is authorized by the DONA Foundation to participate in the distributed administration of the GHR is referred to as a Multi-Primary Administrator (MPA). Each MPA is "credentialed" and allotted a zero-delimiter prefix by the DONA Foundation. It operates its own GHR Service in accordance with the Foundation procedures, and coordinates it with the other MPAs and DONA on a multi-primary basis.

The DOI Foundation is an MPA and was allotted the prefix 10.

The GHR consists of:

- the GHR services of the MPAs called MPA GHR Services
- the GHR Service operated by the DONA Foundation

An MPA GHR Service provides:

- first-level resolution of Handles
  The GHR is the first access point for any client requesting a Handle resolution. Based on the prefix Handles hosted in the GHR, it redirects the client to the Local Handle Service (LHS) responsible for this Handle.
- administration for its assigned credential prefix
  The MPA GHR Service allows the creation and maintenance by an authorized administrator of the one-delimiter prefix Handles derived from the credential prefix. All prefix Handles managed in a GHR Service are automatically copied across all the other GHR Services.

The GHR stores only the records of zero- and one-delimiter prefix Handles (up to the limit of one million). The other prefixes are managed through LHSs.
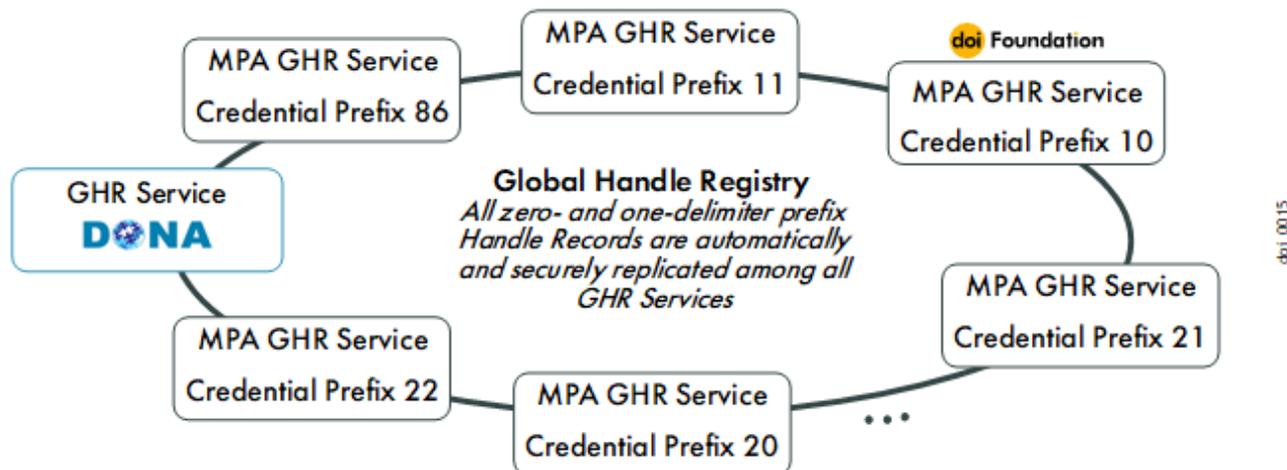
Figure 12 Global Handle Registry (GHR)

LOCAL HANDLE SERVICE (LHS)

 An LHS is operated independently by a service provider and is assigned one or several prefixes.

LHS INSTANCES: HANDLE AND PREFIX

There are two types of LHS instances:

- Handle LHS
  A Handle LHS hosts and provides resolution and administration of all Handles under a given prefix.
- Prefix LHS
  A Prefix LHS hosts and provides resolution and administration of prefixes derived from a given prefix.

NOTE Administration means creation, modification and deletion of the Handle Records. It requires administrator permissions. For more information, see Digital Object Identifier Resolution Protocol (DO-IRP) Specification[34].

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[34] https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf

The same LHS can provide both instances and can be responsible for any number of pre-fixes.

Handle LHS 10.500
Manages Handles under prefix 10.500
10.500/65_z8rt
10.500/84_t6gf

Prefix LHS 10.500
Manages prefixes derived from prefix 10.500
0.NA/10.500.80
0.NA/10.500.50

Figure 13 The two types of Local Handle Service (LHS)

Both these LHSs operate with the same LHS software and are configured the same way.

SERVICE SITES OF AN LHS

Handle System service components are scalable and extensible to accommodate any large amount of service load. An LHS may consist of multiple service sites, each hosting a full replica of the Handles managed by the service. A site may be a primary site (it means that it can be used for administrative operations: to create, modify or delete Handle Records stored in its database) or a mirror site (no administrative operation is possible). Each service site may also consist of a cluster of computers working together, each with a particular subset of the Handles managed by the service. Having multiple service sites avoids any single point of failure and allows load balancing among these service sites. Using multiple servers at any service site distributes the service load into multiple server processes and allows less powerful computers to be utilized for the name service.
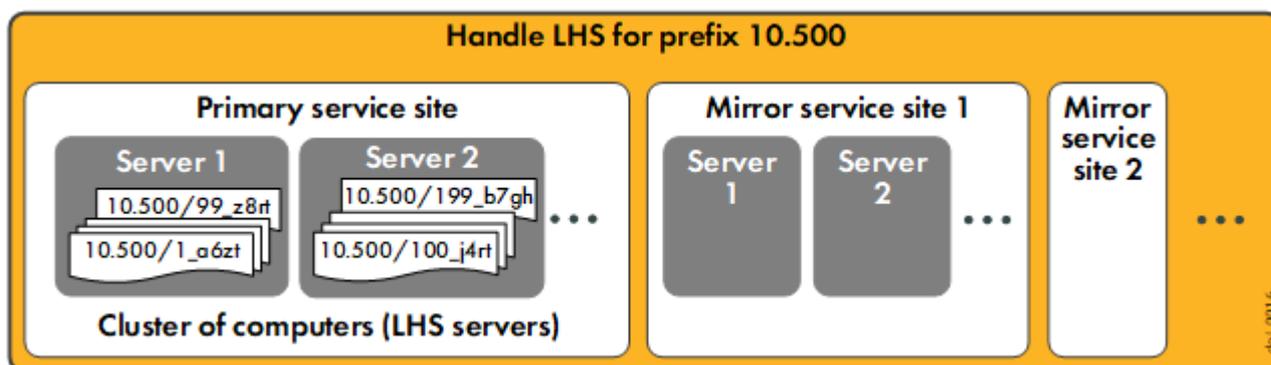

Handle LHS for prefix 10.500

Primary service site

Server 1
10.500/99_z8rt
10.500/1_a6zt

Server 2
10.500/199_b7gh
10.500/100_j4rt

Cluster of computers (LHS servers)

Mirror service site 1

Server 1
Server 2

Mirror service site 2

Figure 14 Service sites of an LHS

5.2   DOI DIRECTORY

The DOI Directory is a virtual service consisting of Handle System services (see 5.1.3) and web proxies located and configured to provide highly reliable resolution, administration, and backup for all DOI names, regardless of the varying administrative arrangements of the Registration Agencies (RA). This approach provides the flexibility RAs need to develop individual business models and meet customer requirements while guaranteeing reliable overall service.

The DOI names are stored in Local Handle Services (LHS) which are usually managed by the DOI technical support service provider but may also be operated by the RA.

NOTE All DOI names must be registered in the DOI Directory.

5.2.1   LOCAL HANDLE SERVICES (LHS) USED IN THE DOI SYSTEM

The DOI Foundation has contractual agreements for provision and persistence of the Handle System with the DOI technical support service provider who:

- provides technical and operational support for the DOI System
- usually manages the Local Handle Services used in the DOI System (DOI LHS). A Registration Agency (RA) can choose to install and use the Handle LHS responsible for their DOI names (A Prefix LHS will always be managed by the technical support service provider.).

5.2.2   DOI LHS OPERATED BY A REGISTRATION AGENCY

A Registration Agency (RA) can run the Local Handle Service(s) responsible for the DOI names of their registrants. This may the best choice for an RA who:

- wish to have immediate control of business-critical infrastructure components such as DOI registration
- plan to implement high performance standards for administration and resolution by choosing levels of performance appropriate to their application

In this case, the DOI technical support service provider will run a mirror service of this LHS so that they have a copy of the DOI name database managed by the RA. The DOI Foundation requires that RAs be responsible for modification of the configuration of their Handle servers to allow a secondary server installation at the DOI technical support service provider. In the illustration below, if the RA who was allocated the prefix 10.550 wants to run their own LHS, then the technical support service provider would run one of the mirror LHSs.
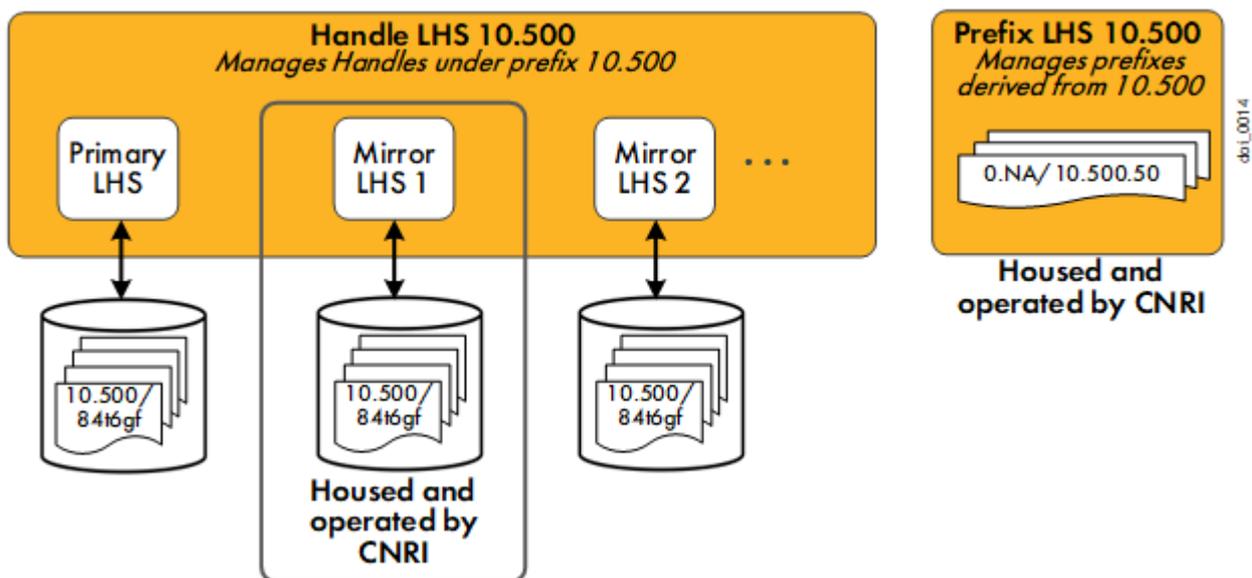

Figure 15 Handle LHS operated by a Registration Agency

5.3   DOI RESOLVERS

To be able to use the core resolution service of the DOI System, a DOI resolver is required. A DOI resolver is a client of the Handle System.

5.3.1   DOI PROXY

With the HTTPS Proxy Server of the DOI System (https://doi.org), users can resolve DOI names from any standard web browser by using the URL syntax. For example, the resolution of the DOI name "10.10.123/456" would be done from the address https://doi.org/10.123/456.

NOTE An earlier proxy address (https://dx.doi.org) is maintained but its use is discouraged.

DOI PROXY SERVICE CHARACTERISTICS

The DOI Proxy is accessible over IPv6, and supports DNSSEC.

The DOI Proxy consists of multiple servers running at multiple locations, with the load distributed evenly across all servers.

NOTE The core DOI name resolution service is used by the DOI Proxy but is not constrained by the DOI Proxy.

DOI PROXY RESOLUTION FUNCTION

The DOI Proxy supports the single and multiple DOI resolutions: see 5.4.

The resolution process is as follows:

1. The DOI Proxy receives an HTTPS or HTTP request from a requester for resolving a DOI name. The request is in the format https://doi.org/<doi-name>?<parameters>. For more information, see 10.3.

2. The DOI Proxy requests the DOI name resolution from the GHR (or retrieves it from its cache, if the record is in its cache and no authoritative query is done) which redirects it to the responsible DOI LHS. Before sending the resolution request, the DOI Proxy decodes the percent-encoded DOI name if necessary (see 10.2.2).

3. The responsible DOI LHS returns the DOI record to the DOI Proxy.

4. The actions performed by the DOI Proxy depend on the query parameters. Typically:

   o If the DOI record contains a 10320/LOC element then the DOI Proxy interprets the XML code it contains and embeds the resulting URL in an HTTP(S) redirect, and sends it back to the requester (see 5.4.2).

   o Otherwise, the DOI Proxy redirects the requester to the first URL element it finds in the DOI record (see 5.4.1).

NOTE To speed resolution, the proxy servers cache DOI record values, with the TTL (Time To Live) set to one hour. This means that if a DOI record value is changed, it can take up to one hour before the new value is returned. This setting is specific to the current proxy system and different DOI software clients could be configured to behave differently. The default Handle Record TTL setting is 24 hours, which is a common TTL for Internet applications. While the one hour setting currently holds for the DOI proxy, it would be best to design various DOI workflows assuming the more conservative 24 hour period.

DOI PROXY MAINTENANCE COMMITMENT

The DOI technical support service provider and the DOI Foundation are committed to maintaining the DOI Proxy in perpetuity, as it is an essential component to maintaining the integrity of the millions of instances of DOI name-based web links. Maintaining the utility of those links over time will require maintaining both the core DOI System and the specific gateway service, doi.org, that those links reference and so use to gain access to the core DOI System. This, of course, is not at all unique and is just another variation on the Internet theme of layering services on top of one another. doi.org is itself dependent on the Domain Name System (DNS), which is itself dependent on IP addressing and routing, etc.

5.3.2   CUSTOM DOI RESOLVERS

Additional DOI resolvers can be built and additional methods can be used to access the core DOI name resolution system without interfering in any way with the ongoing operation of the DOI Proxy. For more information, see 7.5.

5.3.3   DOI REST API

The DOI REST API allows programmatic access to DOI name resolution services using HTTP(S). A REST API request can be made by performing a standard HTTP GET. The API returns JSON.

The DOI REST API provides specifications for using the Handle System but avoids the need for users to address the Handle System directly and in depth. The API ensures the portability of any code written to address DOI System services and applications.

For technical details, see 10.4.

NOTE In addition to Java, API libraries are available for Python, Perl, and C.

5.4   DOI RESOLUTION FUNCTIONS

This section describes the resolution functions provided through the DOI System. They are supported by the DOI Proxy and the DOI REST API.

5.4.1   SINGLE DOI RESOLUTION

The single resolution function of the DOI System consists in returning to the requester the location stored as an URL element in the DOI record. With the DOI Proxy, the requester is redirected to this URL through an HTTPS request (see 1.5.1). The process is as follows:

1. A user sends a DOI name resolution request to a DOI resolver.

2. The DOI resolver sends a resolution request of the DOI name to the GHR. The GHR redirects the resolver to the responsible DOI LHS which returns the DOI record to the resolver.

3. The DOI resolver retrieves the first URL element it finds in the list of DOI record elements and returns this URL to the requester.

5.4.2   MULTIPLE DOI RESOLUTION

With the multiple DOI resolution, multiple resources in potentially any format can be managed in the DOI record. The multiple resolution is typically used to manage several URLs of the same referent (see 1.6.1) or to select a different URL according to various criteria.

To manage multiple resources in the DOI record, an element of the predefined type 10320/LOC is used. This element allows specifying complex rules formatted in RDF/XML which can be interpreted by the DOI resolver to retrieve the resources to be returned to the resolution requester. For example, a resource may be selected according to the context of the request (in particular, to the country of the requester). For more information, see 10.5.

The following figure shows a DOI record containing a 10320/LOC element used to retrieve URL(s). The 10320/LOC element could also be stored at prefix level, thus applying to all DOI names under that prefix.
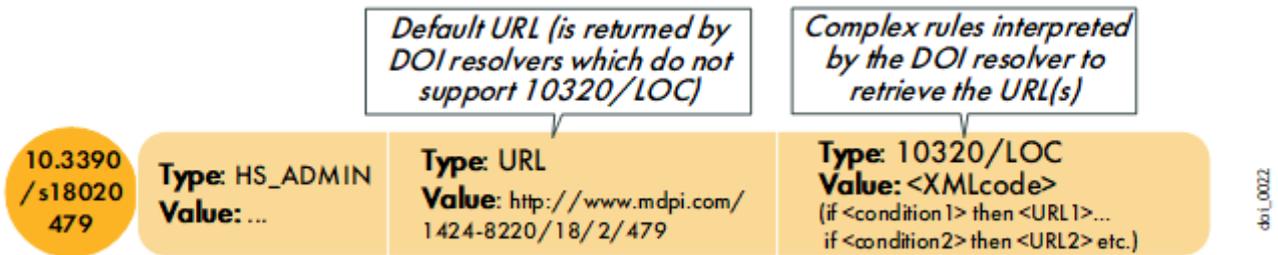

Default URL (is returned by DOI resolvers which do not support 10320/LOC)

Complex rules interpreted by the DOI resolver to retrieve the URL(s)

10.3390 /s18020 479

Type: HS_ADMIN
Value: ...

Type: URL
Value: http://www.mdpi.com/ 1424-8220/18/2/479

Type: 10320/LOC
Value: <XMLcode>
(if <condition1> then <URL1>...
if <condition2> then <URL2> etc.)

Figure 16 Multiple DOI resolution (multiple URLs)

The multiple DOI resolution process is as follows:

1. A requester (user or application process) sends an HTTP request to the DOI resolver.

2. The DOI resolver sends a resolution request of the DOI name to the GHR. The GHR redirects the resolver to the responsible DOI LHS which returns the DOI record to the resolver.

3. The DOI resolver recognizes the 10320/LOC element. Depending on the HTTP request features, the DOI resolver may interpret the code it contains and return the interpretation result (for example, an URL) to the requester; or it may return the raw XML code, or a list of possible resources (for example, a list of URLs).

If there are DOI resolvers (other than the DOI Proxy) that do not understand the 10320/LOC type, these resolvers would ignore it and simply apply a single DOI resolution request.

5.4.3 PARAMETER PASSING

With the parameter passing feature, information about the context of the request (for example, the particular user making the request) can be included in the DOI resolution request sent to the DOI Proxy. Different context expressed in the request may result in different resolution results. Changes in context are predictable, and do not require the original creator of the hyperlink to handcraft different URLs for different contexts.

Two URLs are involved in the parameter passing feature:

- the referrer URL: URL sent by the requester (referrer) to the DOI Proxy and containing the DOI name to be resolved and the context information
- the referent URL: URL registered in the respective DOI record (by the referent) and which may also contain parameters

The DOI Proxy combines the referrer URL with the referent URL to create the out-bound link. It supports two different methods :

- urlappend: simple method (see below)
- OpenURL: deprecated method (see Appendix)

PARAMETER PASSING WITH URLAPPEND

With urlappend, key-value pairs can be passed to the out-bound link by placing them in the referrer URL as follows:

```
https://doi.org/<doi-name>?urlappend=%3F<key1>=<value1>%26<key2>=<value2>...
```

The question mark (%3F) or the ampersand (%26) must be used before each key-value pair.

For example,
the referrer URL https://doi.org/10.1256/003590?urlappend=%3Fparam1=12345%26param2=6789
is combined with the referent URL https://www.publisher.org/resource9876
to create the out-bound link https://www.publisher.org/resource9876?param1=12345%26param2=6789

If the referent URL already contains parameters then they may conflict with the urlappend values. In the above example, the urlappend should start with an ampersand character rather than a question mark character.

5.4.4 CONTENT NEGOTIATION

Content negotiation refers to mechanisms defined as a part of HTTP(S) that make it possible to serve different representations of a resource at the same URL, so that the content rendering software can specify which version fits their capabilities the best. In the context of the DOI System, content negotiation allows making a request that favors content types specific to a particular Registration Agency (RA) but which will also degrade to respond with a more standard content type for other RAs.

A content negotiated request to a DOI resolver is much like a standard HTTP(S) request, except server-driven negotiation will take place based on the list of acceptable content types

a client provides. The request is done by using an HTTPS header "Accept" where the GET includes several content types that are acceptable to the requesting client process (those that it knows how to parse), each content type with a specific preference level (quality factor).

For example, Crossref RA uses content negotiation to redirect all requests which are not for the content type "text/html" to the metadata service managing the requested DOI name. To do so, the 10320/LOC element (which corresponds to the content type "application/rdf+xml") is used in the DOI record to specify the redirection to the respective metadata service. If the DOI resolver does not support this content type then it will redirect to the URL defined in the URL element (content type "text/html"). This is illustrated in the DOI name example below.

Values for: 10.1525/bio.2009.59.5.9			
Index	Type	Timestamp	Data
1	URL	Fri Apr 1 2022 13:32:18 EST	https://www.sciencemag.org/cgi/doi/10.1126/science.169.3946.635
1000	10320/LOC	Mon Jun 27 2021 14:28:25 EDT	<locations chooseby="locatt,country,weighted"> <location weight="0" http_role="conneg" href_template="https://data.crossref.org/10.1126/science.169.3946.635" /> </locations>

Figure 17 DOI record example with RDF XML content type

Shown below is an Accept header for the content negotiated request, listing both "application/citeproc+json" and "application/rdf+xml", and the metadata returned by the metadata service. The requesting client wishes to receive citeproc JSON if it is available, but can also handle RDF XML if citeproc JSON is unavailable. A preference level ("q" factor) is used in the request to specify the preferred choice.

```
$ curl -LH "Accept: application/rdf+xml;q=0.5, application/vnd.citationstyles.csl+json;q=1.0" http://dx.doi.org/10.1126/science.169.3946.635

{
  "volume" : "169",
  "issue" : "3946",
  "DOI" : "10.1126/science.169.3946.635",
  "URL" : "http://dx.doi.org/10.1126/science.169.3946.635",
  "title" : "The Structure of Ordinary Water: New data and interpretations are
          yielding new insights into this fascinating substance",
  "container-title" : "Science",
  "publisher" : "American Association for the Advancement of Science AAAS (Science)",
  "issued" : { "date-parts" : [ [ 1970,8,14 ] ] },
  "author" : [ { "family" : "Frank", "given" : "H. S."} ],
  "editor" : [],
  "page" : "635-641",
  "type" : "article-journal"
}
```

Figure 18 Content negotiated request with response

5.4.5   HANDLING OF RESOLUTION ERRORS IN THE DOI SYSTEM

Actions which result in an attempted resolution not being successful result in error messages. These can be provided by Registration Agencies, or by the DOI System centrally.

The error page provided by the DOI System directs the user to DOI help address (doi-help@doi.org) which is managed by the DOI technical support service provider:

- If the problem is with the Handle System, the DOI technical support service provider responds to the sender appropriately.
- If the DOI name is not found, a special handling is performed (see below).

"DOI NOT FOUND" AND "DOI PREFIX NOT FOUND" ERRORS

The entered DOI name or DOI prefix may not be found, for example, when resolution requests for DOI names are incorrectly formatted or the DOI names do not exist. In that case, a response page is displayed with:

- details about the error
  To further assist users, the error response system checks to see if a user has attempted to resolve a DOI prefix only, or a DOI that contains multiple slashes or a trailing slash which might be causing the error, and advises the user accordingly.
- the possibility for the user to send a report to the responsible RA
  If required by an RA, the technical support service provider can configure the DOI Proxy to automatically report the error message to the responsible RA.

5.5   SHORTDOI SERVICE

The shortDOI service is a public service (https://shortdoi.org/), open to anyone, that creates shortcuts to DOI names which are often very long strings. The shortDOI service provides a function similar to that which URL shortening services do for URLs. The service creates short DOI names of the form 10/abcde and enables short HTTPS URIs of the form https://doi.org/abcde that are ideal for use in email, blogs, mobile messaging and more. (Note that shortDOIs are not themselves DOI names and therefore do not conform to the ISO standard syntax and other requirements. A shortDOI can only be created for an existing DOI name.)

The shortDOI service proxy server only resolves the shortcuts, identically to the way the DOI Proxy only resolves full DOI names. The service will either create a new shortcut, or return the existing shortcut if one has already been created.

For automated purposes, the shortDOI service can also be used by simply appending the original DOI name to the URL for the service. A format parameter can be used to specify how information is to be returned. For further information, see the shortDOI service web page[35].

5.6   WHICH RA? SERVICE

Which RA? is a simple service that has been built to examine the type/value pairs returned from Handle resolution and provide specific information that is available from the DOI

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[35] https://shortdoi.org

Proxy. This service returns the name of the DOI Registration Agency (RA) responsible for a specific DOI name, or group of DOI names.

The service is requested by using the command

```
https://doi.org/doiRA/<doi-names>
```

where:

- <doi-names>: single DOI name or a list of DOI names separated by commas
  If a DOI name contains commas, then the commas must be percent encoded (see 10.2.2).
  Note that shortDOI names are not supported.

A bit of JSON specifying the name of the RA is returned.

For example, resolving https://doi.org/doiRA/10.5240/B1FA-0EEC-C316-3316-3A73-L will return:

```
[
  {
    "DOI": "10.5240/B1FA-0EEC-C316-3316-3A73-L",
    "RA": "EIDR"
  }
]
```

A full list of RA names and abbreviations can be found on the [web site](36). Possible error states include "Invalid DOI", "DOI does not exist" and "Unknown".

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[36] https://www.doi.org/registration_agencies.html

DOI APPLICATIONS

This chapter discusses some of the ways in which resolution can be harnessed to provide applications with the ability to resolve a DOI name to the most appropriate content chosen from multiple DOI resolution options. These options can include pop-up menus offering manual selection, and consistent automated selection through content negotiation and Linked Data.

In This Chapter

6.1　INTRODUCTION TO DOI APPLICATIONS

In order to maintain a persistent identifier, an active management service in collaboration with registrants is required. To justify that management service, a DOI application normally provides more value than simply registering a DOI — typically a Registration Agency offers an added value service, such as citation linking or metadata management.

DOI names can identify many types of content, and may resolve to more than just a permanent, indirect link to that content. They can also provide or point to any useful information about the object when that information has been provided by the registrant or a third party. This information can include any type of descriptive metadata and any type of service related to the object, such as rights clearance, alerting services, data visualization or any other associated information or service. The information can be used in many ways by DOI applications customized to meet users' needs.

NOTE No ability to search from metadata to DOI name (reverse look-up) is provided by the DOI System. It may be offered by Registration Agencies or other services as a value-added feature. A variety of technologies are in use for this purpose among the RAs, including the Cordra37 registry system as well as custom applications.

6.2　USE AND EXTENSION OF THE RESOLUTION FUNCTIONS

At the most basic level, all DOI applications query the DOI System by resolving a DOI name. The request can be structured to ask for all of the DOI record elements associated with that DOI name, or all of the elements of a specific type and/or index, etc. (see DOI Proxy Query Command Format). Applications are built to understand one or more of the element types, and parse, evaluate, and take action based on the corresponding element values.

The DOI record that is associated with a DOI name is stored in the DOI System in type/value pairs (see 5.1.2). This is extremely flexible and open: new types can be added at any time, and the values can be of arbitrary complexity. Type/value pairs can be administrative (creation date, permissions, etc.), well known and standardized (URL, email, 10320/LOC, etc.), or created by a Registration Agency for a specific application purpose (for example, a custom type with a value that is binary data or a specially formatted string). There can be many type/value pairs associated with a DOI name, and multiples of the same type.

Associating XML, or other machine readable data with a DOI name, expands the utility of multiple resolution even further, adding features, and offering more options for negotiating content, and facilitating the creation of Linked Data applications.

NOTE New types should, but are not required to, be registered in the Handle System as Handles. As a general rule types containing a slash (for example, 10320/LOC) should be considered full Handles and those without a slash (for example, URL) should be assumed to be suffixes under the 0.TYPE prefix (with the previous example: 0.TYPE/URL). The type Handle Record may define the

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[37] https://www.cordra.org/

syntax, structure, possible semantics, or any other necessary descriptive characteristics of the corresponding value field. For more information, see the [Digital Object Identifier Resolution Protocol (DO-IRP) Specification](#)[38].

6.3   APPLICATIONS OF THE 10320/LOC ELEMENT

The 10320/LOC element can be used if multiple resolution is required.

6.3.1   CHOOSE-BY MECHANISM

Multiple resolution with 10320/LOC element (see 5.4.2) is useful for building applications where the required evaluation is to choose from a set of possible outcomes based on some criteria. An application developer could create a type in which to store values used by a client to generate a menu of options for a user when the user resolves a DOI name. In the case of a document, the user might be given the option to view the document, view document metadata, share the document by emailing the URL to an associate, visit the author's blog, etc. For a dataset, the choices offered to the user on the landing page may include viewing the complete dataset, viewing only selected data, or some other choice of interaction with the dataset based on the information made available to a client via resolution of the DOI name.

For example, scholarly journal articles are assigned one DOI name, but they can be available from multiple web sites, and readers may wish to download an article from a service to which they are subscribed. Crossref uses multiple resolution to enable users to resolve an article's DOI name, and choose which version of an article they wish to view, as illustrated below.

Figure 19 Choose-by mechanism example

6.3.2 AUTOMATED SELECTION OF AN URL ACCORDING TO VARIOUS CRITERIA

Multiple resolution with 10320/LOC element (see 5.4.2) can be used to enable a DOI resolver to choose what the outcome of resolving a DOI name will be for a specific user, based on a given criteria. The figure below shows (non-administrative) elements associated with DOI name 10.1525/bio.2009.59.5.9. When this DOI name was registered it had a single URL element (type of URL and value, aka data, equal to a JSTOR URL). A 10320/LOC type was added to provide instructions for offering other resolution options (see 10.5.1 for information about the XML attributes used in 10320/LOC element). When this record is returned to the DOI Proxy, it recognizes the 10320/LOC type and, if asked to do so, performs an evaluation of the location values based on a given criteria.

Values for: 10.1525/bio.2009.59.5.9			
Index	Type	Timestamp	Data
1	URL	Sun Jan 02 2022 13:32:18 EST	https://www.jstor.org/stable/25502450
1000	10320/LOC	Mon Jul 27 2020 13:18:25 EDT	<locations chooseby="locatt,country,weighted"> <location id="1" cr_type="MR-LIST" href="https://mr.crossref.org/iPage?doi=10.1525%2Fbio.2009.59.5.9" weight="1" /> <location id="2" cr_src="unca" label="SECONDARY_BIOONE" cr_type="MR-LIST" href="https://www.bioone.org/doi/full/10.1525/bio.2009.59.5.9" country="gb" weight="0" /> </locations>

Figure 20 10320/LOC example

The DOI Proxy may be required to (see also 10.3):

* ignore type 10320/LOC
  In that case, the DOI Proxy would resolve 10.1525/bio.2009.59.5.9 and select the URL value https://www.jstor.org/stable/25502450. This action would be performed by any DOI resolver not knowing the type 10320/LOC.

* resolve 10.1525/bio.2009.59.5.9 and return to the user both of the URLs in the cr_type attributes in the 10320/LOC value, letting the user choose the next action (choose-by mechanism)

* resolve 10.1525/bio.2009.59.5.9?locatt=country:gb
  In that case, the DOI Proxy would determine the user's geographic location from their IP address. It would then select the URL https://www.bioone.org/doi/full/10.1525/bio.2009.59.5.9 for users in the UK ("gb" code), and would perform a random selection for all others.

* resolve 10.1525/bio.2009.59.5.9?locatt=id:1
  In that case, the Crossref metadata service at https://mr.crossref.org/iPage?doi=10.1525%2Fbio.2009.59.5.9 would be selected.

6.4 REDIRECTION TO LINKED DATA SERVICES

Linked Data is the general term for a set of best practices for exposing data in machine-readable form using the content-negotiation feature of the standard HTTP(S) web protocol. These best practices support the development of tools to link and make use of data from multiple web sources without the need to deal with many different proprietary and incompatible application programming interfaces (APIs), and use of HTTP(S) to request data in structured form meant for machines instead of human-readable displays.

In Linked Data applications, evaluation of the HTTP(S) request that comes in to the proxy service determines if it is a request for content of form application/rdf+xml, or one of a few similar types that are commonly understood to be a request for Linked Data. These requests for special content types would come from automated processes or special "linked data" browsers and would not normally come from end users. The utility of this, of course, is that it allows outside developers to query the extensive and reliable set of metadata records held by Registration Agencies (RA) to build value-added services.

Some RAs are using this approach for all of their DOI names, offering services that return metadata in a common machine-readable format. A significant advantage of applying Linked Data principles and technologies to DOI-registered material is that it is "data worth linking to": it is curated, value-added, data, which is managed, corrected, updated and consistently maintained by RAs. It is also persistent, so avoiding "bit-rot". In practice, the quality of Linked data implementations is only as good as the data you are linking to, and the meaning and contextualization of the link you use. The DOI System can offer "curated data", it means consistent, managed, linking so you can link to other "quality data" with confidence, while still using the standard Linked Data technologies.

The following figure shows a redirection to the metadata service managing the DOI name. The 10320/LOC element information can be stored at prefix level (see 10.5.3): should an

RA at some point need to change their approach to linked data and point to a different service or use different parameters, the change could be made to a single DOI prefix and it would apply to all of the millions of DOI names automatically.
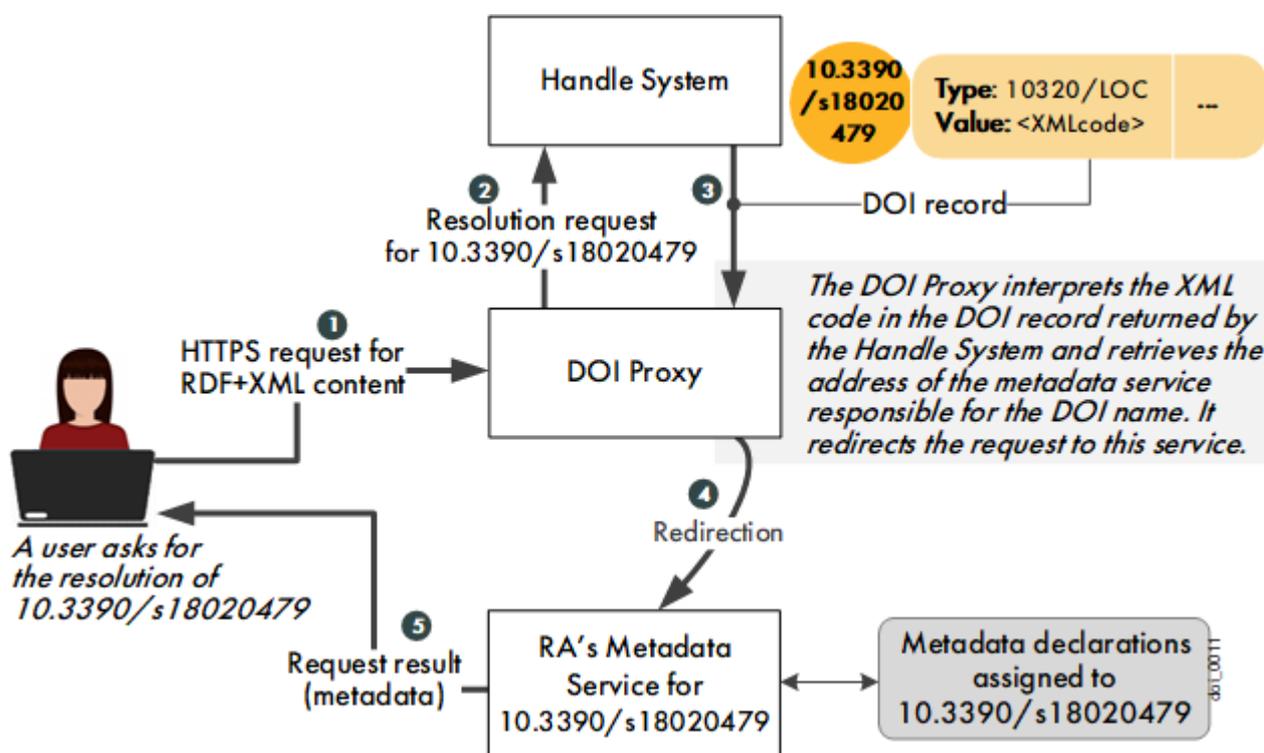

Figure 21 Dynamic building of a web page enriched with metadata

For more information, see 5.4.4.

6.5   DYNAMIC IDENTIFICATION OF THE FRAGMENTS OF AN ENTITY

In some cases, applications may require the identification of fragments of an entity, rather than the full entity. Each such fragment may be assigned a separate DOI name if it is practical and useful to do so (for example, if a specific table within a book is likely to be re-used many times). However, this may not always be possible: there are also cases where one wishes to identify in principle any fragment of this entity as it becomes needed on the fly. For such cases, use may be made of Template Handles (see section 11 in the [Handle.net Technical Manual](#)[39]): a single template DOI Handle can be included in the form of a base formula that allows any number of extensions to that base to be resolved as full DOI Handles, according to a pattern, without each such Handle being individually registered. This would allow, for example, the use of DOI names to reference an unlimited number of ranges within a video without each potential range having to be registered with a separate Handle. If the pattern needs to be changed, for example, the video moves or a different kind of server is used to deliver the video clips, only the single base DOI name (Handle)

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[39] http://www.handle.net/tech_manual/HN_Tech_Manual_9.pdf

needs to be changed to allow an unlimited number of previously constructed extensions to continue to resolve properly.

DESIGNING AND DEVELOPING A DOI APPLICATION

This chapter assists business analysts and developers in designing and developing applications based on the DOI System.

Before starting the design or development of a DOI application, you should have read the previous chapters of the Handbook.

See also 10.7.

In This Chapter

7.1 CHECKLIST FOR DESIGNING A DOI APPLICATION

The DOI System has the flexibility to meet identification and resolution requirements of any application domain. However, these don't come "in a box": someone needs to build the specific social and technical structures to support the particular requirements of a community, and provide applications which offer value to that community. In designing a DOI System application several questions need to be considered.

Table 3 Checklist for designing a DOI application

Question	Description	See
What are we identifying with this identifier?	The rules about what is identified, and whether two things being identified are "the same thing", are made at the level of a specific application of the DOI System, and this is a role of Registration Agencies (RA). This deceptively easy question (usually known as "granularity") is one of the most difficult encountered in all discussions about identifiers (but the one most commonly overlooked) and an answer is often much more difficult than it might at first appear. The answer to when two things are "the same thing" is entirely contextual, it means what a specific application will need to distinguish.	
What are we resolving to from this identifier?	A DOI name can resolve to anything. At minimum, it will resolve to a URL, but there may be multiple URLs or it can be configured to return multiple other data types.	Chapter 5
What metadata are we associating with this DOI name?	Without an explicit structured metadata layer, an identifier essentially can have no meaning at all outside a specific application. Most DOI names are not yet used for widespread interoperability, but are used within specific applications. They do not need to reveal explicit structured metadata, but RAs maintain Kernel metadata and additional application metadata which may be delivered in a number of ways.	Chapter 4
What are the interoperability requirements?	The DOI System has a mechanism for interoperability with other standards. If the application is in a sector where other identifiers or metadata schemes are already in use, an RA will need to work out an implementation of this in detail that is practical for the community that they serve.	4.4
How will the DOI application be paid for?	A cost is associated with managing persistence and with assigning identifiers and data to ensure long-term stability, because of the need for human intervention and support of an infrastructure. In the DOI System the way in which these costs are recouped depends on the application. RAs are free to establish their own business model for the allocation of DOI names. The services offered by a DOI RA will include more than simple provision of a DOI name: these value added services may include data, content or rights management. There is no single business model applicable to all DOI RAs (and consequently no single answer to the question of how a DOI name is paid for and what it costs).	2.2.2

7.2 DESIGN CONSIDERATIONS

Flexibility and scalability are important features of well-designed DOI-enabled services.

The most flexible and scalable approach is to use the DOI System as a lightweight redirection mechanism, resolving identifiers to well-structured data. This approach can be used to provide DOI-related services beyond that of a single level of redirection. In addition to simply resolving a DOI name and getting back a single URL, DOI registration agencies may offer multiple resolution services, linking a DOI name to multiple options about the content (for example, bibliographic metadata), and those options may include requests for particular representations of metadata, or metadata useable only for particular contexts.

Developers may choose to put all or most of the information provided by the service in the DOI System itself, such that the DOI system is the primary service provider, or alternatively, use the DOI System to point to one or more external services to provide the desired information and functions. For example, the DOI System may be used to store all of the data required to display a simple menu of labelled options for a user to pick from, but redirecting to an external service that stores large quantities of scientific data for visualization tools, or multiple image files, might be preferable to storing that data in the DOI System.

Developing applications that store, use, and share high-quality machine-readable data in a standardized format is a further design consideration. DOI applications can be designed to conform to the best practices of Linked Data, a well-known concept of exposing data in machine-readable form, using the content negotiation feature of the standard HTTP web protocol.

NOTE The use of HTTPS over HTTP is highly recommended.

Creating services that take advantage of DOI structured data to create consistency across RA applications is encouraged. Collaboration is encouraged whenever possible. Third party application developers not part of the DOI Foundation are also encouraged to be part of the process of creating services that take advantage of DOI structured data.

A sampling of DOI application services based on multiple resolution and content negotiation are described in Chapter 6. New services may be created at any time. Questions can be sent to info@doi.org.

7.3 DEFINING AN IDENTIFIER SCHEME

If you need to define a new identifier scheme, consider the following:

- Avoid re-inventing the wheel: if it appears that you need to devise a new identifier scheme, examine whether the problem can be avoided by re-using existing identifiers.
- If a new scheme is needed, consider if an existing protocol or identifier registry can be harnessed to implement your scheme.
- Register your scheme with an appropriate public namespace declaration.
- Provide easy links for semantic mapping by specifying a well-formed metadata scheme and publishing it.
- Consider the community and business implications for others who may need to use your scheme.
- Provide clear guidance on rights and obligations of use of your scheme.

- Adopt identifiers with a mechanism for ensuring persistence.

7.3.1   INTEGRATING ANOTHER IDENTIFIER SCHEME

Where syntax rules permit the incorporation of an existing identifier from another scheme as part of the DOI name, such rules shall not form part of ISO 26324. In such cases, attention is drawn to the following points.

- The same referent shall be denoted by both the DOI name and the included identifier string, to the degree that is necessary to distinguish it as a separate entity within each identifier scheme.

- Within the DOI System itself, the DOI name is an opaque string. No definitive information relating to the other identifier scheme should be inferred from the specific character string used for a DOI name, and the DOI name is not guaranteed to be usable in any non-DOI applications designed for the other identifier scheme.

- Specific syntax rules for the incorporation of an existing identifier from another scheme shall be maintained by the ISO 26324 Registration Authority.

7.4   MANAGING DOI METADATA SCHEMAS

Schemas are used to specify Kernel and additional metadata (see 4.3). You may want to update existing schemas or create new ones.

7.4.1   CREATING OR UPDATING A METADATA SCHEMA

Authority to make changes in the existing DOI schemas lies with the Schema Working Group. Any member of the DOI Community may make proposals for updates to a schema, or for introducing a new schema, at any time. Implementing the changes will be the responsibility of the DOI Foundation's selected technical provider as managers of the schemas, who will acknowledge each proposal and give an estimated deliverable time according to the scope and complexity of the proposed changes.

The procedure is:

1. initial proposal
   DOI RA member submits suggestions for changes to a schema, or for a new schema, to the Schema Working Group. These may be in the form of specific proposals (for example, the addition of a new allowed value or element) or of requirements (for example, a request to introduce a way of identifying the owner of a proprietary ID scheme in the Kernel). Others on the list may comment.

2. proposal agreed
   If necessary, request for clarifications or comments and suggestions for implementation will be made, allowing time for anyone else on the list to respond. The aim is to reach consensus before going ahead to implement the change, and so the time period to reach agreement will vary according to the proposal: some will be very quick, other proposals may be abandoned if there is no agreement.

3. draft implementation
   Once the proposal or requirement is clear, an estimated time will be provided for the update, and then issuance of new drafts of the appropriate schema(s) in the time frame, letting the Schema Working Group know in advance if there is going to be delay for any reason.

4. review updated or new draft schema
   The group will be given an opportunity (typically a working week for routine changes) to make any comments on the drafts. If further revision is then needed, steps 3 and 4 will be repeated.

5. release of updated or new schema
   When the updated schema is agreed, it will be put on the web site accessible to DOI Foundation members.

NOTE RAs wishing to develop de novo schemes and new metadata applications are also encouraged to contact the DOI Foundation for advice.

7.4.2   ADDING TERMS TO THE DOI KERNEL SCHEMA

Terms will be added to the DOI Kernel Schema at the request of any Registration Agency (RA) by the modification of the Metadata Kernel and/or its Allowed Values, or the publication of other DOI message schemas in addition to the Metadata Kernel. Any RA may add new values to the open Allowed Value Sets (AVS) by registering them with the DOI Foundation. To do so, the procedure is as described in 7.4.1.

7.5   DEVELOPING A DOI RESOLVER

For your DOI application, you may use the DOI Proxy (see 5.3.1). Additional DOI resolvers can be built and additional methods can be used to access the core DOI name resolution system without interfering in any way with the ongoing operation of the DOI Proxy. For example, you may:

- set up your own web-to-DOI-name proxy server
- use the DO-IRP protocol to query the DOI System directly: see 7.5.1
- use the DOI REST API to access to DOI name resolution services using HTTPS: see 5.3.3

NOTE The resolution functionality might also be delivered to a browser by means of a scripting feature, such as JavaScript. However, this method is not recommended since languages are likely to evolve faster than protocols.

As resolution is freely available, you can develop your DOI resolver entirely independently of the DOI Foundation, but we encourage developers to let us know about their applications in order that we may: let others know about it if it is public; work with developers to improve their understanding of the DOI System and thus the success of their efforts.

7.5.1 DEVELOPING HANDLE SYSTEM CLIENT SOFTWARE

An organization or individual developing Handle System client components is encouraged to use the CNRI client software and the standard interfaces supplied with it: the [Handle.Net® Software Client Library Java™ Version](#)[40] is freely available and can be used to develop new resolution clients as needed, either for individual applications or for use in completely separate systems. In particular, the Handle System client shall not interfere with the normal operation of a Local Handle Service (LHS) or other client applications in interacting with the Handle System client software or the GHR (see 5.1). In the event an organization or individual wishes to use its own interface software, it is their responsibility to ensure that these interfaces remain compatible with the current Handle System interface specification.

NOTE The `net.handle.apps.simple` package has a number of examples of how to use the Handle client library. Contact the Handle.Net Registry Administrator at hdladmin@cnri.reston.va.us for information.

7.6 CONFIGURING THE RESOLUTION ERROR MESSAGE HANDLING

Actions which result in an attempted resolution not being successful result in error messages. These can be provided by Registration Agencies (RA), or by the DOI System centrally. RAs may use similar wording and procedures in their own services as the DOI System.

In addition, an RA can request the DOI technical support service provider to configure the DOI Proxy to report a "DOI Name Not Found" error message to you in case the entered prefix is your prefix.

See 5.4.5.

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[40] https://www.handle.net/client_download.html

DEFINING RA AND REGISTRANT POLICIES

The DOI Foundation defines high-level operational policy and assigns the execution of this policy to the Registration Agencies (see 2.3). The Registration Agencies enforce their own operational policies, specific to their community of interest. These specific policies will be consistent with the DOI Foundation's high-level policies.

This chapter assists the Registration Agencies or registrants in defining their own policies.

In This Chapter

8.1 DEFINING A PREFIX ALLOCATION POLICY

As a Registration Agency (RA), you may choose to assign prefixes to your customers (see 1.7.4). To do so, you should define a prefix allocation policy.

The DOI Foundation allots to each RA prefixes as a block of sequential numbers that have no special meaning (prefixes are created by the DOI technical support service provider). No reserved prefixes may be requested.

Some RAs will manage all assignments themselves and can operate under a single prefix. Others will want to delegate assignment to customers and in this case, it is recommended that prefixes are assigned at an appropriate level to deal with business requirements. Typically, a Registration Agency (RA) may issue one prefix per customer, but it might also be appropriate to issue a prefix per brand, or to some recognizable cluster of products (for example, a publisher imprint). The choice is the RA's, but the DOI Foundation and/or other RAs can discuss requirements and make recommendations.

NOTE In case DOI names must be transferred from one RA to another, the foremost technical issue in this transfer is the one-to-one relation of prefix to Local Handle Service (LHS). In this perspective, RAs should allocate at least one separate prefix for each customer, and where appropriate more than one, since the fundamental constraint is that all DOI names under a given prefix must reside in the same LHS (this general architecture is a logical and efficient approach to a distributed service and is far from unique to the Handle System).

8.2 DEFINING A DATA MAINTENANCE POLICY

The effective operation of the DOI System depends on accurate resolution of a DOI name to the appropriate URL or other data type. To maintain quality services, it is also crucial that metadata assigned to a DOI name be regularly updated. Therefore, the maintenance of URLs and data about a DOI name should be subject to a policy. In particular, the policy should specify who, between the Registration Agency (RA), the registrant or a service organization acting with the authority of the registrant, is responsible for the data maintenance.

8.3 DEFINING A DOI NAME REGISTRATION POLICY

You must define a policy which specifies:

- that all DOI names must be registered in the DOI Directory (see 5.2)
- who, between the Registration Agency or the registrant, generates the DOI names
- the general scheme of the suffix to be followed, if any (for example, if another identifier scheme is integrated in the DOI name syntax)
- the rules governing the suffix syntax (see also 3.2) with possible constraints from outside the DOI System on the suffix, for example:
  - on the character set: see 3.4
  - on the suffix length
- etc.

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OPERATING AND MAINTAINING THE RA SERVICES

This chapter assists the Registration Agency's service operations team in performing service operation tasks.

In This Chapter

9.1 DEFINING OPERATIONAL PROCESSES

This section describes a DOI name registration process workflow example.

NOTE If you want to allow DOI name administration from a local web server, you may use CNRI's `net.handle.apps.admin_servlets`. Contact the Handle.Net Registry Administrator at hdladmin@cnri.reston.va.us for information.

9.1.1 DEFINING THE DOI NAME REGISTRATION PROCESS

Registration Agencies (RA) support registration of DOI names with an associated metadata declaration. Individual RAs develop their own workflow and procedures for the management of DOI name registration, and metadata deposit and maintenance, and provide their own information to their community of registrants.

The service provided by each RA must include quality assurance measures, so that the integrity of the DOI System as a whole is maintained at the highest possible level (delivering reliable and consistent results to users). This includes ensuring that the DOI record is accurate and up-to-date and that the DOI metadata is consistent and complies with both DOI Kernel and appropriate DOI data model standards.

The general steps of the DOI name registration process are:

1. The registrant sends to the RA data of DOI names to be registered.
2. The RA creates the DOI names by registering them in the Handle System.
3. The RA adds the appropriate registrant data to their metadata service. (At the current time there is no metadata database or mechanism for depositing metadata in a service run by the DOI technical support service provider.)
4. The RA sends to the registrant the registration process results.

9.2 MANAGING THE USER ACCESS RIGHTS

Each Registration Agency administers the access rights and permissions for the DOI name registrants that form their community. They must provide adequate security to ensure that only the registrant (or someone acting with the registrant's permission) is able to maintain both metadata and DOI record data.

For information about the user access right management in the Handle System, see the [Digital Object Identifier Resolution Protocol (DO-IRP) Specification](#)[41].

9.3 ISSUING PREFIXES TO REGISTRANTS

An authorized Registration Agency issues prefixes to registrants where relevant and requests the DOI Directory Manager to register such new prefixes in the Handle System. The RA maintains the systems environment for storing a minimum set of descriptive metadata that can be provided and may be integrated with the Handle System.

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[41] https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf

9.4 MAINTAINING THE RESOLUTION SERVICES

The Registration Agency (RA) is responsible for taking the necessary steps to ensure the proper maintenance of their DOI prefixes and DOI names, including the following:

- An administrator must be designated for each prefix (or set of prefixes): the prefix administrator can create DOI names under their prefix.
  The DOI technical support service provider also maintains administrative permission for the prefix. This is intended as backup for administration. Note that the creation of derived prefixes can only be done by the technical support service provider.

NOTE The technical support service provider configures the prefix administrators in the prefix Handle (see 10.6).

- Secure maintenance of private keys must be ensured by each administrator.
- Service configuration changes must be timely reported to the DOI technical support service provider.
- The RA must inform the technical support service provider and the DOI Foundation in the event of any major operation on the DOI names that could possibly interrupt the mirroring mechanism.
- Additional requirements apply to RAs who operate their own LHS: see 9.5.3.

9.4.1 TROUBLESHOOTING RESOLUTION PROBLEMS

The DOI technical support service provider provides technical and operational support for the DOI System as a contractor. Further details of the relevant Agreement for Technical Services are available to potential and current Registration Agencies.

If you receive an error message forwarded by the DOI technical support service provider, you must take the appropriate action. See the handling of resolution errors in the DOI System in 5.4.5.

9.5 OPERATING YOUR OWN LHS

If a Registration Agency (RA) chooses to implement and operate a Local Handle Service (LHS) for their DOI names (see 5.2.2), the DOI technical support service provider will provide the RA with the necessary technical guidance to help them install and administer their LHS. The technical support service provider is responsible for the scalability of the system and, in consultation with the DOI Foundation, for implementing future developments leading to its growth and any improvement to its technical sophistication.

9.5.1 INSTALLING THE LHS

For information about the LHS installation, see [Handle.Net Technical Manual](42).

The installation process will create a file called `sitebndl.bin` that will contain the service information for the LHS. As per the instructions in the distribution, you will need to send the

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[42] https://www.handle.net/tech_manual.html

file to the DOI technical support service provider at doi-admin@doi.org. Name, organization name, and the fact that the request is coming from a DOI RA is important so that the technical support service provider knows to create prefixes that begin with 10.

9.5.2   SETTING UP THE LHS

You are responsible for modification of the configuration of your LHS to allow a secondary server installation at the DOI technical support service provider. The secondary server will house a complete database of the your DOI names. This requires a minor change in the server's configuration file. This will be coordinated by the technical support service provider. After setup is complete a regularly executing task (for instance, a cron job) will be created to check to see if the secondary server is able to connect to your server. If there is problem with the connection (for example, your server is shut down) you will be notified by email and expected to correct the problem as soon as possible.

For more information about LHS setup, see [Handle.Net Technical Manual](https://www.handle.net/tech_manual.html)[43].

9.5.3   LHS OPERATION REQUIREMENTS

Maintaining overall integrity of the Handle System entails ensuring that each of the following conditions is met by administrators, who must agree to operate their resolution services during the period while the authorization is in effect. The term "system" as used below refers to those components run by each administrator, and the interaction of these components with the Global Handle Registry (GHR) and the users of the Local Handle Service (LHS). Operational goals for administrators include:

- Ensuring compatibility and smooth interaction among system components
- maintaining consistency and reliability in service performance
- conducting proper system management and performance tracking
- offering non-interrupted access to the GHR
- taking adequate system security measures

It is also the responsibility of the Registration Agency to inform the DOI technical support service provider of any configuration changes in their LHS.

NOTE A number of utilities for low-level maintenance of a Handle server are available such as `net.handle.apps.tools` and `net.handle.apps.site_tool`. Contact the DOI technical support service provider at doi-admin@doi.org.

9.6   TRANSFERRING DOI NAMES FROM ONE REGISTRANT TO ANOTHER

If a compilation of multiple assigned DOI names (for example, a journal containing a collection of articles; an imprint; a recording catalogue; etc.) is transferred from one registrant to another (both registrants being related to the same Registration Agency (RA)), the DOI names within that compilation are transferred as well. Each RA will develop appropriate

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[43] https://www.handle.net/tech_manual.html

procedures for proper transfers. Transfers may be a sale, or any form of exchange, commercial or otherwise. If the new owner is not already a registrant, special arrangements may have to be made appropriate to the case. Consult the DOI Foundation for guidance if necessary.

The individual DOI names stay the same, it means that what the DOI name identifies is not changed. This is a fundamental requirement. The DOI name prefix does NOT change (recall that a prefix is not meaningful, but is initially assigned to a registrant for convenience in generating DOI names only; no reverse look-up can be inferred to a prefix). The administrative value is changed in order for the new owner to modify its data elements (most likely the URL element). Both registrants involved in the transfer need to send email to the DOI technical support service provider at doi-admin@doi.org giving permission for the transfer. The technical support service provider will assist RAs to ensure an efficient and successful outcome.

9.7 TRANSFERRING DOI NAMES FROM ONE REGISTRATION AGENCY TO ANOTHER

Moving an entire prefix worth of DOI names from one Registration Agency (RA) to another is easy. Splitting control of a prefix between two administrative bodies who both use the same Handle service (it means, when it has not been possible to foresee a split by issuing separate prefixes) is also possible but more complex. In general, there are two solutions:

1. leave it with one or the other service (or the DOI default Handle service run by the DOI technical support service provider on behalf of the DOI Foundation) and split up the administration, such that the managers of one service allowed the 'foreign' admins access

2. alias all the DOI names under the old prefix to DOI names under a new prefix controlled by the new RA
   The old DOI names do not have to be maintained other than ensuring resolution to the new DOI names.

All of the above is strictly from a DOI System point of view and does not address any internal workflow issues or value-added services that the RAs provide that interact with Handle administration, which would of course be specific to the RA.

Chapter 10
APPENDIX
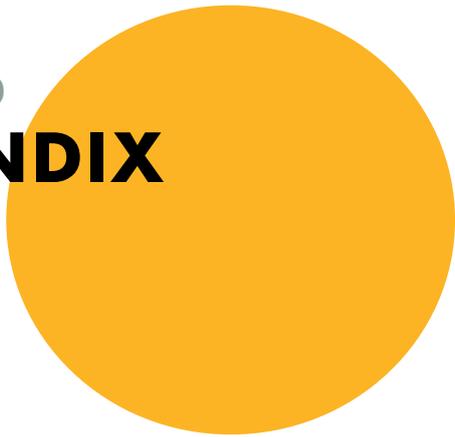
In This Appendix

10.1 DOI KERNEL SCHEMA

The DOI Kernel Schema is an XML schema (also called DOI Kernel XML Schema). It specifies the DOI Kernel Metadata and all data elements and allowed values (data dictionary) of the metadata exchange schemas. It is maintained by the DOI Foundation.

It consists of two files available on the DOI web site:

- [DOI Schema](44)
- [DOI Schema AVS](45) (Allowed Value Sets)

10.1.1 DOI KERNEL ELEMENTS

This section describes the elements of the DOI Kernel. These descriptions are based on the extensible kernel contained in ISO 26324. Additional terms beyond those stated in ISO 26324 may be listed but only for terms which are open lists for which new items may be registered.

DESCRIPTIVE ELEMENTS

The table below lists the descriptive elements used in DOI Metadata Kernel.

Table 4 DOI Kernel: descriptive elements

Kernel element	Occurs	Description
DOI name	1	Specific DOI name allocated to the identified referent.
referentIdentifier(s)	0-n	Other identifier(s) referencing the same referent (examples: ISAN, ISBN, ISRC, ISSN, ISTC, ISNI). This element contains a type element appropriate to the primaryReferentType. The schema at present recognises a creationIdentifierType and partyIdentifierType, which are open lists[1].
referentName(s)	0-n	Name(s) by which the referent is usually known (example: title). This element contains a type element appropriate to the primaryReferentType. The schema at present recognises a creationNameType and partyNameType, which are open lists[1]. This element also contains a language element, for which the allowed value list is the ISO 639-2 code list.
primaryReferentType	1	The primary type of the referent (examples: creation, party, event). This is an open list[1].

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structuralType	1	The primary structuralType of a referent. For creations, there are four mutually exclusive creationStructuralTypes (physical, digital, performance, abstraction) that allow classification according to overall form. Where structuralTypes may be contained within one another, the referent's structuralType is defined by the overall form (for example, a CD (physical) may contain files (digital) which contain recordings of performances of songs (abstractions)), and elements of content can be further classified if necessary under referentType. For parties there are three mutually exclusive partyStructuralTypes (person, animal, organization). These lists are closed[2].
mode	0-n	For creations only, the principal sensory mode(s) by which a referent is intended to be perceived (audio, visual, tangible, olfactory, tasteable, none). Mode identifies only the principal intended modes of perception. Most physical resources are perceivable with all five senses, but some of these perceptions may be trivial. For example, a printed book may be touched or smelled, but these are supplementary or incidental to visual mode, the intended function as a content carrier. For a Braille book, however, tangible would be a principal mode. This list is closed[2].
character	0-n	For creations only, a fundamental form of communication in which the content of a referent is expressed. There are four values: music, language, image, other. This list is closed[2].
referentType	0-n	Specification of type(s) of referent for parties: author, composer, book publisher, library, university, financial institution, film studio. For creations, the abstract nature of the content of a referent, irrespective of its creationStructuralType, is typically described by creationType, which may be extended as needed to include format and genre elements (examples: audio file, scientific journal, musical composition, dataset, serial article, eBook, PDF). For parties, referentType is a role with which the party is associated and is described by associatedPartyRole (examples: Composer, Author, BookPublisher, JournalPublisher). This is an open list[1].
linkedCreation	0-n	For creations only. Another creation with which a referentCreation is associated. This element contains a creationRoleToCreation element, which is an open list for which new allowed values may be registered.
linkedParty	0-n	For parties only. Another party with which a referentParty is associated. This element contains a partyRoleToParty element, which is an open list[1].
principalAgent	0-n	For creations only, the entity or entities principally responsible for the creation or publication of the referent. This element contains an agentRole element which specifies the particular role played (examples: Creator, Author, BookPublisher). This is an open list[1].
dateOfBirthOrFormation	0-1	For parties only, the date of birth (for an individual or animal) or formation (for an organization) of the referentParty.

Kernel element	Occurs	Description
dateOfDeathOrD-issolution	0-1	For parties only, the date of death (for an individual or animal) or dissolution (for an organization) of the referentParty.
associatedTerritory	0-n	For parties only, a territory with which the referentParty is associated (examples: a territory of birth, nationality or residence). The allowed value list is the ISO 3166a2 territory code list.

1) Registration Agencies can request the addition of new allowed values to open lists (see 4.3.6).

2) No new values can be added to closed lists.

ADMINISTRATIVE ELEMENTS

The table below lists the descriptive elements used in DOI Metadata Kernel.

Table 4 DOI Kernel: administrative elements

Kernel element	Occurs	Description
registrationAuthorityCode	1	Code assigned to denote the name of the agency (authorized by the ISO 26324 Registration Authority) that issued this DOI name.
issueDate	1	Date when this DOI name was issued.
issueNumber	0-1	Number or other designation associated with the specific version of the DOI Kernel Metadata Declaration.

10.2 DOI NAME ENCODING

This section contains various information related to DOI name encoding.

10.2.1   UTF-8 ENCODING OF NON-ASCII CHARACTERS

UTF-8 is a Unicode encoding that allows characters to be encoded in terms of one to six octets. UTF-8 encoding plays a role when non-ASCII characters are used. For example, the Japanese word "nihongo" is written as:

日本語

The Unicode sequence representing the Han characters for "nihongo" is: 65E5 672C 8A9E. These may be encoded in UTF-8 as follows: E6 97 A5 E6 9C AC E8 AA 9E.

For further information on UTF-8 see RFC 3629.

10.2.2   DOI NAME ENCODING RULES FOR URL PRESENTATION

Hex-encoding must be used when presenting a DOI name as a Uniform Resource Locator (URL) if the DOI name contains characters that are not allowed, or have other meanings, in the URL application context. Hex-encoding consists of substituting for the given character its hexadecimal value preceded by percent. For example, # becomes %23 and https://doi.org/10.1000/456#789 is encoded as https://doi.org/10.1000/456%23789 (Thus, the browser does not now encounter the bare #, which it would normally treat as the end of the URL and the start of a fragment, and

so sends the entire string off to the DOI network of servers for resolution, instead of stopping at the #.).

The table below lists the mandatory and recommended hex-encoding rules (the recommendation was established based on a practical experience of the current web browsers).

Table 5 DOI name encoding rules

Character	Encoding
Mandatory Rules	
%	%25
"	%22
#	%23
SPACE	%20
?	%3F
Recommended Rules	
<	%3C
>	%3E
{	%7B
}	%7D
^	%5E
[	%5B
]	%5D
`	%60
|	%7C
\	%5C
+	%2B
, (only necessary in a Which RA service request context)	%2C

NOTE The web browser treatment of /./ and /../ can be inconsistent. It is recommended that one of the slashes be percent encoded, for example, /./ is changed to /.%2F and /../ to /..%2F.

NOTE To enable the use of DOI names in workflows that have already standardized on URNs, the DOI proxy servers understand the substitution of a colon in place of the initial slash in a DOI name. DOI names may therefore be expressed as URNs in the doi.org domain by writing, for example, the DOI name 10.123/456 in the form https://doi.org/urn:doi:10.123:456. However, a DOI suffix is allowed to contain other slashes, and where these occur they must be hex-encoded rather than replaced with a colon: for example, the DOI name 10.123/456ABC/zyz would become https://doi.org/urn:doi:10.123:456ABC%2Fzyz, with the final slash character encoded as %2F.

10.3 DOI PROXY QUERY COMMAND FORMAT

The format of a resolution query command to the DOI Proxy (see 5.3.1) is as follows:

```
https://doi.org/<doi-name>?<param_1>&<param_2>&..
```

where:

- <doi-name>: DOI name to be resolved
- <param_i>: parameter i passed to the DOI Proxy

Example: `https://doi.org/10.1000/1?noredirect&type=URL`

NOTE HTTP instead of HTTPS as well as dx.doi.org instead of doi.org are still supported (but not recommended).

The following table lists the native parameters supported in a query sent to the DOI Proxy. (Other parameters may be passed through the proxy using the urlappend parameter.)

Table 6 DOI Proxy: query parameters

Parameter	Description	See
noredirect	Do not redirect using URL or 10320/loc type elements. Display the elements instead.	
ignore_aliases	Ignore HS_ALIAS elements. The HS_ALIAS element is used to specify a Handle that should be resolved instead of the input Handle.	
auth	Authoritative query. The DOI Proxy bypasses its cache and sends its resolution request to an authoritative Handle service (it means to a primary service, not to a mirror service).	
cert	Certified query. The DOI Proxy requires an authenticated response from the Handle service (it means that the DOI Proxy asks the Handle service to sign its response and the Proxy will check the signature before accepting it).	
index=<value>	Resolve the DOI record element at the specified index value and do not resolve the other elements except if otherwise required. May be repeated to resolve multiple indexes.	5.1.2
type=<value>	Resolve the DOI record element of the specified type value and do not resolve the other elements except if otherwise required. May be repeated to resolve multiple types.	5.1.2
urlappend=<value>	Append the value of this parameter to the end of the URL used for redirection.	
locatt=<key>:<value>	In case of a multiple resolution: use this key:value pair for the interpretation of the 10320/LOC element.	5.4.2
action=showurls	In case of a multiple resolution: return an XML representation of the possible redirect locations stored in the 10320/LOC element.	5.4.2

All combinations of parameters are accepted (not all are useful). For example, if the index and type query parameters are used together then any element which matches any of the specified indexes or types is returned.

10.4 DOI REST API REQUEST AND RESPONSE FORMATS

The DOI Proxy REST API allows programmatic access to DOI name resolution using HTTP(S).

10.4.1 REST API REQUEST FORMAT

A REST API request can be made by performing a standard HTTPS GET of /api/handles/<doiName>:

`https://doi.org/api/handles/<doiName>?<param_1>&<param_2>&..`

where:

- <doiName>: DOI name to be resolved

- <param_i>: parameter i passed to the DOI Proxy REST API

Example: `https://doi.org/api/handles/10.1000/1?type=URL&callback=processResponse`

The table below lists the parameters supported in a query sent to the DOI Proxy REST API.

Table 7 DOI API query parameters

Parameter	Description
callback	Use JSONP callback (instead of CORS headers).
pretty	Pretty-print the JSON output.
auth	Authoritative query. The DOI Proxy bypasses its cache and sends its resolution request to an authoritative (primary) Handle service.
cert	Certified query. The DOI Proxy requires an authenticated response from the Handle service (it means that the DOI Proxy asks the Handle service to sign its response and the Proxy will check the signature before accepting it).
index[1]	Resolve the DOI record element at the specified index and do not resolve the other elements except if explicitly required. May be repeated to resolve multiple indexes.
type[1]	Resolve the DOI record element of the specified type and do not resolve the other elements except if explicitly required. May be repeated to resolve multiple types.

1) The index and type query parameters can be used together: any element which matches any of the specified indexes or types is returned.

10.4.2 REST API RESPONSE FORMAT

The REST API response is a JSON object which includes a response code, an echo of the resolved Handle identifier, and either a list of DOI record elements or, in the case of an error, an optional message which is a string describing the error. The figure below shows a response example.

```
{
  "responseCode": 1,
  "handle": "10.1000/1",          ← Identifier of the resolved DOI name
  "values": [
    {
      "index": 100,
      "type": "HS_ADMIN",
      "data": {                     ← Element at index 100
        "format": "admin",
        "value": {
          "handle": "0.NA/10.1000",
          "index": 200,
          "permissions": "011111111111"
        }
      },
      "ttl": 86400,
      "timestamp": "2000-04-13T15:08:57Z"
    },
    {
      "index": 1,
      "type": "URL",
      "data": { "format": "string", "value": "https://www.doi.org/index.html" },
      "ttl": 86400,
      "timestamp": "2004-09-10T19:49:59Z"
    }
  ]
}
```

List of elements in the DOI record

dbi_0019

Figure 22 REST API response example

RESPONSE CODE

The response code is an integer referring to a Handle System protocol response code. The most common response code values are:

- 1 : Success. (HTTP 200 OK)
- 2 : Error. Something unexpected went wrong during DOI name resolution. (HTTP 500 Internal Server Error)
- 100 : Handle Not Found. (HTTP 404 Not Found)
- 200 : Values Not Found. The Handle Record exists but the required elements do not exist.

ELEMENT DATA

An element consists of:

- an index (an integer): unique element identifier inside the Handle Record
- a type (a string): for example, URL, description, IP address, email address, etc.
- a value (a data object): see table below
- a timestamp (an ISO8601-formatted string): date and time of the last data update
- a Time To Live (TTL; an integer, or, in the rare case of an absolute expiration time, an ISO8601-formatted string): specifies how long the element value can be cached before the information source should again be consulted

The table below describes the "value" property depending on the "format" property of the element data object. For more information about HS_ADMIN, HS_VLIST and HS_SITE data, see [Digital Object Identifier Resolution Protocol (DO-IRP) Specification](#)[46].

Table 8 Element value ("data" object)

"format" property	"value" property
"string"	Is a string representing the data as a UTF-8 string.
"base64"	Is a string, with a BASE64 encoding of the data.
"hex"	Is a string, with a hex encoding of the data.
"admin"	Is an object representing an HS_ADMIN element (Handle administrator) with the properties: "handle": identifier of the Handle used to identify the administrator "index": index of the element in the administrator's Handle Record storing the administrator's public key "permissions": access rights to the Handle Record granted to the administrator
"vlist"	Is an object representing an HS_VLIST element (refers to a list of administrators (public keys in Handle Records)).
"site"	Is an object representing an HS_SITE element (Handle service site information).

10.5 10320/LOC ELEMENT

This section contains details about the 10320/LOC element used in the multiple DOI resolution (see 5.4.2).

10.5.1 10320/LOC: XML ATTRIBUTES

The 10320/LOC type is used in a DOI record to describe complex location selection rules in XML format. The following table lists the XML attributes supported in these rules.

Table 9 10320/loc: XML attributes

Attribute	Description	Mandatory
chooseby	Identifies a comma-delimited list of location selection methods: the DOI resolver will iterate over the selection methods in the specified order. For each applied selection method: If one and only one location is selected then the DOI resolver will redirect to this location. Otherwise, the DOI resolver will apply the next selection method. If no selection method is left then the DOI resolver will apply the weighted method which guarantees to return a single location. If no chooseby attribute is specified then the default ("locatt,country,weighted") is assumed. Possible location selection methods: locatt: Only locations from an attribute passed in the Proxy/DOI name-URL link are selected. Example: With doi:10.123/456?locatt=id:1, the resolver will return the locations that have an "id" attribute of 1. country: Only locations that have a country attribute matching the country of the requester are selected. If no matching locations are found then locations that have no country attribute are selected. Note: The https://hdl.handle.net and https://doi.org Proxies determine the country of the requester using a **GeoIP**[47] lookup. weighted: A single location is selected based on the weight assigned to each location: A location with no weight attribute is assumed to have weight one. A higher weight is selected first. If several locations have the same weight then a random choice is performed. If the weighted selection method is applied to locations that all have non-positive weights, then this method selects one of the remaining locations randomly while disregarding location weights. Note: The weighting allows for a very basic load balancing, but is also a way to ensure that some locations can only be addressed directly (for example, by country or locatt/attributes).	No
href	The URL for the location.	Yes

---

[46] https://www.dona.net/sites/default/files/2022-06/DO-IRPV3.0--2022-06-30.pdf

[47] https://www.maxmind.com/en/geoip2-services-and-databases

Attribute	Description	Mandatory
weight	The weight (a floating point between zero and one) that should apply to this location when performing a weighted selection.	No
country	Country of the requester. Possible values: two-letter country codes according to ISO 3166-1.	No

10.5.2   10320/LOC: EXAMPLE

The table below shows the DOI record returned for doi:10.123/456.

Table 10 DOI record with redirection graph

Index	Type	Data
1	URL	https://www.defaultexample.com

1000	10320/LOC	\<locations\>
		    \<location id="0" href="https://uk.example.com/" country="gb" weight="0" /\>
		    \<location id="1" href="https://www1.example.com/" weight="1" /\>
		    \<location id="2" href="https://www2.example.com/" weight="1" /\>
		\</locations\>

With this example, the DOI resolver will apply the default selection method order - it means: 1) locatt; 2) country; 3) weighted - as illustrated below. If the DOI resolver does not understand the 10320/LOC element type (or is requested to ignore it), then it will select the URL element type: https://www.defaultexample.com.

Table 11 Resolution request examples with result

Resolution request	Selection method	Result
10.123/456 from a requester located in the UK	1. The locatt method does not apply. 2. The resolver applies the country method. It selects https://uk.example.com/ and stops (single matching selection).	https://uk.example.com/
10.123/456 from a requester located outside of the UK	1. The locatt method does not apply. 2. The resolver applies the country method: no URL can be selected. 3. The resolver applies the weighted method to https://www1.example.com/ and https://www2.example.com/. They have the same weight, it selects one of these two URLs randomly.	https://www1.example.com/ or https://www2.example.com/
10.123/456?locatt= id:1	1. The resolver applies the locatt method with id="1". It selects https://www1.example.com/ and stops (single matching selection).	https://www1.example.com/
10.123/456?locatt= id:0	1. The resolver applies the locatt method with id="0". It selects https://uk.example.com/ and stops (single matching selection).	https://uk.example.com/

Resolution request	Selection method	Result
10.123/456?locatt=country:gb	1. The resolver applies the locatt method with country="gb". It selects https://uk.example.com/ and stops (single matching selection).	https://uk.example.com/
10.123/456?locatt=country:us with requester located in US	1. The resolver applies the locatt method with country="us": no URL can be selected. 2. The resolver applies the country method with the country of the requester: no URL can be selected. 3. The resolver applies the weighted method to https://www1.example.com/ and https://www2.example.com/. They have the same weight, it selects one of these two URLs randomly.	https://www1.example.com/ or https://www2.example.com/

10.5.3   10320/LOC AT PREFIX LEVEL

Any location information (information specified through a 10320/LOC element) that applies to all or most DOI names under a prefix can be stored at prefix level: this information applies to all DOI names under that prefix. If specific location information is stored at DOI name level then this information overrides information stored at prefix level.

Location information is stored at prefix level by using the HS_NAMESPACE element in the record of the prefix Handle (0.NA/<prefix>): the HS_NAMESPACE element points to another Handle or DOI name which will store a 10320/LOC element. Typically, this element will contain URL templates. For more information about the HS_NAMESPACE element, see the [Handle.net Technical Manual](#)[48].

---

[48] https://www.handle.net/tech_manual/HN_Tech_Manual_9.pdf

The following figure shows the example of the prefix Handle 0.NA/10.5237 where the 10320/LOC element is stored in the prefix record.

Figure 23 10320/LOC at prefix level

10.6 PREFIX HANDLE EXAMPLE

The figure below shows the record of the prefix Handle 0.NA/10.1009.

Figure 24 Prefix Handle Record example

The table below describes the elements of the 0.NA/10.1009 record.

Table 12 0.NA/10.1009 elements

	Type	Index	Description
1	HS_ADMIN	100	RA or registrant's prefix administrator: can create Handles (DOI names) under prefix 10.1009. This administrator is identified1) by 200:0.NA/10.1009 which points to the index 200 in this identifier (HS_VLIST).

	Type	Index	Description
2	HS_ADMIN	101	Prefix administrator of the DOI technical support service provider: can create and delete Handles (DOI names) under prefix 10.1009; can create and delete prefixes deriving from 10.1009.
3	HS_SERV	1	Points to the 10.SERV/CROSSREF Handle which locates the Local Handle Service (LHS) sites managing the DOI names under prefix 10.1009.
4	HS_VLIST	200	List of administrators (list of public keys).
5	EMAIL	3	Email address.
6	HS_SIGNA-TURE	400	Signature over the prefix Handle.

1) An administrator is identified in the Handle System by a public key stored in a Handle Record (in this example, the public key is at index 200 of 0.NA/10.1009 record). User authentication is performed by a Handle System service through a PKI challenge-response.

10.7 SYSTEM TOOLS

The DOI technical support service provider provides servlets and tools that some users and programmers may find useful. The table below lists some of them. Contact the DOI technical support service provider at doi-admin@doi.org for information.

Table 13 Handle tools

Name	Description
net.handle.batch.DOIBatch	A batch loader for DOI names.
net.handle.apps.admin_servlets	The servlets used for administering Handles via the web, useful if you want to allow DOI name administration from a local web server.
net.handle.apps.simple	If you do decide to roll your own Handle software, this package has a number of examples of how to use the Handle client library.
net.handle.apps.tools, net.handle.apps.site_tool	A number of utilities for low-level maintenance of a Handle server. Make sure to check there before writing anything along these lines yourself.

GLOSSARY

This section contains terms which are relevant to the document content. The terms marked * are as specified in ISO 26324.

A

actionable
Capable of resolution by a system on the Internet. For example, in an Internet Web browser, an actionable identifier can be "clicked on" and some action takes place.

allowed value*
An item which may be used as a value of an element.

API
Application Programming Interface. A way for two or more computer programs to communicate with each other. It is a type of software interface, offering a service to other pieces of software. A document or standard that describes how to build or use such a connection or interface is called an API specification. A computer system that meets this standard is said to implement or expose an API. The term API may refer either to the specification or to the implementation.

D

Data Dictionary*
A repository for all data elements and allowed values of those elements used in DOI metadata declarations.

DO
Digital Object. A sequence of bits, or a set of sequences of bits, that is used to represent a digital, physical or virtual entity in the Digital Object Architecture (DOA).

DOI Directory
A virtual service consisting of Handle System services and web proxies located and configured to provide highly reliable resolution, administration, and backup for all DOI names.

DOI metadata

Metadata associated with a referent within the DOI System, based on a structured data model that supports unambiguous description and services.

DOI name*

A string that identifies a unique object within the DOI System.

DOI Proxy

A web server that understands the Handle System protocol (DO-IRP), thereby acting as a gateway between the DOI System and HTTPS, enabling resolution of a DOI name in the URL https:// syntax. Any standard browser encountering a DOI name represented in this form will be able to resolve it without the need to extend the web browsers capability.

DOI record

The set of elements to which a DOI name can be resolved.

DOI syntax*

Rules for the form and sequence of characters comprising any DOI name, specifically the form and character of a prefix element, separator and suffix element.

DOI System*

Social and technical infrastructure for the assignment and administration of DOI names as identifiers in computer-readable form through assignment, resolution, referent description, administration, etc.

G

GHR®

Global Handle Registry. A component of the Handle System which provides first-level resolution of Handles. Stores the information necessary to locate the LHS responsible for any Handle in the system.

H

Handle

Actionable identifier concept underlying the Handle System.

Handle System®

The technology used as the resolution component of the DOI system. The Handle System is a general-purpose distributed information system designed to provide an efficient, extensible, and secured global name service for use on networks such as the Internet. The Handle System is a particular implementation of the DO-IRP (Digital Object - Identifier / Resolution Protocol) which is part of the Digital Object Architecture (DOA).

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HTTP

Hypertext Transfer Protocol. An application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems. HTTP is the foundation of data communication for the World Wide Web, where hypertext documents include hyperlinks to other resources that the user can easily access, for example by a mouse click or by tapping the screen in a web browser.

HTTPS

Hypertext Transfer Protocol Secure. An extension of HTTP. It is used for secure communication over a computer network, and is widely used on the Internet. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL).

I

INDECS

INteroperability of Data in E-Commerce Systems. A project, set of principles, and tools, resulting in a framework, derived from a multi-participant project conducted 1998-2000. Provides the analytical basis for the DOI System's approach to metadata.

interoperability*

Ability of independent systems to exchange meaningful information and initiate actions from each other, in order to operate together to mutual benefit.

International Organization for Standardization (ISO)

Standards setting organisation with National Standards Bodies as members which publishes international standards and other documents.

ISO 26324

ISO 26324 Information and documentation — Digital object identifier system. The international standard published by ISO which specifies the DOI System. The 2022 document is the second edition and revises the original document published in 2012.

K

Kernel metadata

A compulsory, small standardized set of metadata elements assigned to each DOI name.

L

LHS

Local Handle Service. A component of the Handle System which provides resolution and administration services for Handles belonging to a given namespace.

Linked Data

Structured data which is interlinked with other data so it becomes more useful through semantic queries. It builds upon standard Web technologies such as HTTP, RDF and URIs, but rather than using them to serve web pages only for human readers, it extends them to share information in a way that can be read automatically by computers.

M

metadata*

Specific data associated with a referent within the DOI System based on a structured data model that enables the referent of the DOI name to be associated with data of any desired degree of precision and granularity to support identification, description and services.

multiple resolution

Resolution of a DOI name returning multiple resources.

O

opaque string*

Syntax string that has no meaning discernible by simple inspection. (To discover meaning, metadata is required.)

P

persistence*

Existing, and able to be used in services outside the direct control of the issuing assigner, without a stated time limit.

R

RA

Registration Agency. An RA provides DOI-based services to one or several communities of users. An RA can be considered as a module of the DOI System, serving a constituency.

RDF

Resource Description Framework. A World Wide Web Consortium (W3C) standard originally designed as a data model for metadata. It has come to be used as a general method for description and exchange of graph data.

RDF / XML

A syntax defined by the W3C to express (serialize) an RDF graph as an XML document.

referent*

Entity identified by a DOI name.

registrant

The registrant of a DOI name provides and maintains the metadata assigned to the DOI name. They may also assign the DOI name suffix.

registration authority

Entity appointed by ISO to manage the allocation of names to codes under the auspices of an international standard. A registration authority agreement between ISO and the registration authority sets out the obligations and responsibilities of each.

resolution*

Process of submitting a DOI name to a network service and receiving in return one or more pieces of current information related to the identified object such as a location (URL) of the object or an email address, etc.

REST

REpresentational State Transfer. An architectural style that defines a set of constraints to be used for creating web services. REST API is a way of accessing web services in a simple and flexible way.

S

single resolution

Resolution of a DOI name returning a single URL.

U

URL

Uniform Resource Locator. Colloquially termed a web address, is a reference to a web resource that specifies its location on a computer network and a mechanism for retrieving it. URLs occur most commonly to reference web pages but are also used for file transfer, email, database access, and many other applications.

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