



The Handle System®

What it takes to make a PID System Persist

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The Handle System as a PID System

- General Handle System Technology Overview.
- Attributes and characteristics of PIDs and PID systems.
- Handle System Persistence Features.
- Handle System User community.
- Handle System Governance body.
- Future Evolution.

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Handle System Origins

- The concepts were first elaborated in a 1995 white papers from Robert Kahn and Robert Wilensky “**A Framework for Distributed Digital Object**” as part of a DARPA funded research program and of the Computer Science Technical Report project, investigating questions on large-scale distributed digital libraries.
- The Handle System was designed to be a secure, scalable, distributed, extensible, network accessible identifier resolution system that abstracted its underlying implementation technology to facilitate persistence over time.
- The Handle System has evolved over time to answer user needs, adapt to technological changes, solve operational and political concerns, and to address digital sovereignty requirements from its various stakeholders.

A Few Dates..

- The first Handle System implementation dates from the mid 1990s.
- Today's Handle System, has been in constant operation since the late 1990s.
- First deployments: Library of Congress, US National Library of Medicine...
- The publishers where early adopters of the Handle System as handles solved their URL HTTP 404 Error. Led to the creation of the DOI Foundation.
- Used at industrial scale in China for the purpose of tracking and tracing and combatting counterfeit (2008).
- The DONA Foundation took over the operation of the Global Handle Registry® in late 2015 as it became a multistakeholder system.

Handle System Features

- The Handle System is a globally accessible and secure identifier administration and resolution infrastructure for the Internet.
- Resolves a digital object's identifier (aka handle) to that object's current state information as defined by its administrator.
- Associates to each handle 0 or more typed values, such as IP addresses, public keys, URLs, metadata.
- Has an integrated PKI capability for authentication and non-repudiation.
- Highly scalable, optimized for speed and reliability.
- Open, well-defined protocol, data model and namespace.
- Currently used across a wide wide of application domain, such as: Digital libraries, publishing, e-research, identity management, tracking and tracing of products and assets, combatting counterfeit, IoT, supply chains, etc...

Handle Identifier

55.1234/0101.ABCD.5678-#3

Handle Prefix **Handle Suffix**

- Character Set: **Unicode 2.0**
- Encoding: **UTF-8**
- Prefixes are currently allocated as numeric values with **2-3 digits**.
- Prefixes are derived by adding one or more “.” delimiters.
- Suffix: No restrictions but persistent PID characteristics should apply.
- A Handle is globally resolvable using DO-IRP(V3.0).

Handle Prefix

- **Handle Prefixes** are allotted to local handle service providers by MPAs.
- **Handle Prefixes** are themselves handles. Example 0.NA/20, 0.NA/10.500
- One delimiter (“.”) handle prefixes’ handle records are stored in the **Global Handle Registry**® (GHR®).
- Two or more delimiters (“.”) prefix handle records must be stored in Local Handle Service using **prefix delegation**.
- A **handle prefix** is typically resolved by the GHR into a **Handle Record** containing an IP address for a **Handle Resolution Service** such as at a **Local Handle Service**.

Handle Record

- A **Handle Record** has of 0 to n **Handle Values**.
- Each **Handle Value** includes:
 - A **Type-Value** pair. The type describes the value.

Examples of types: URL, HS_ADMIN, HS_SIGNATURE, 0.TYPE/TYPE etc...

- An integer **index** value (Differentiates handle values of the same type)
- Administrative **rights**. (Public Read Write and Admin Read Write)
- **Time last updated**.
- **Caching Period**. (in seconds)

Handle Record Examples

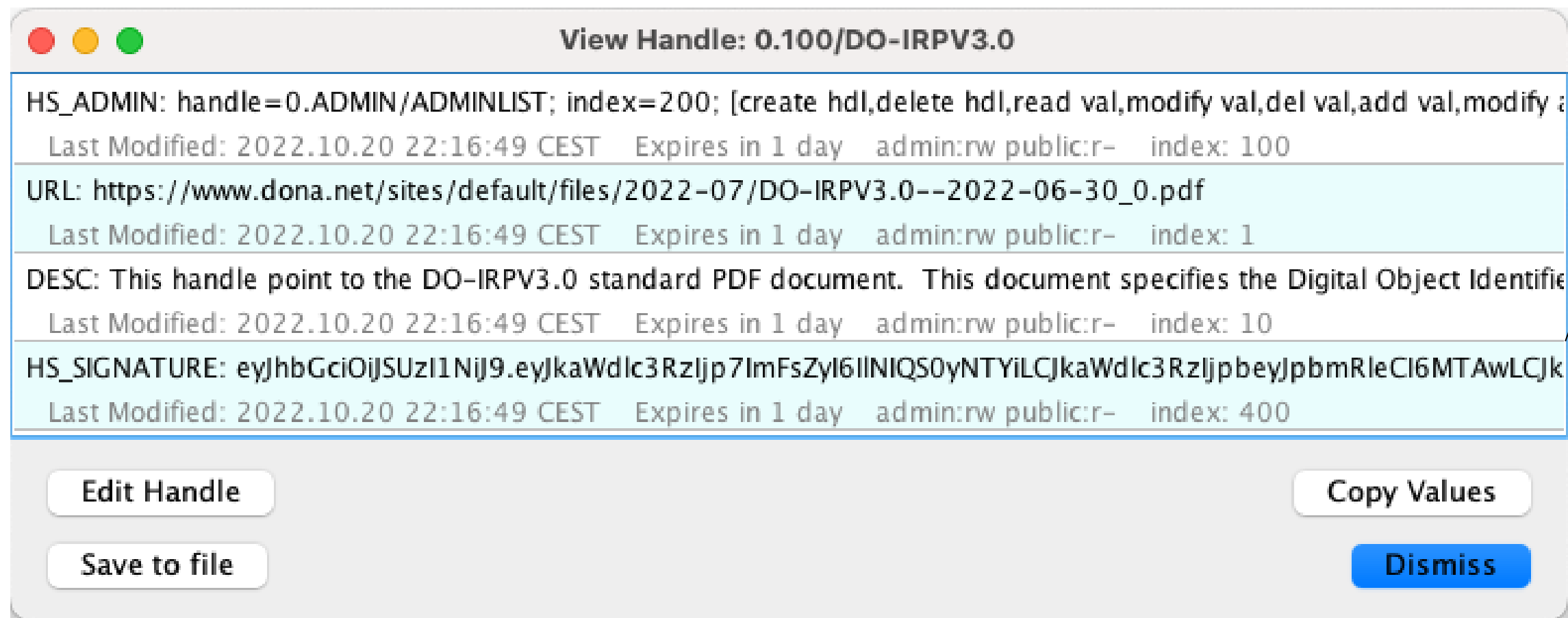
Web Proxy Resolver Client

Handle Values for: 0.100/DO-IRPV3.0

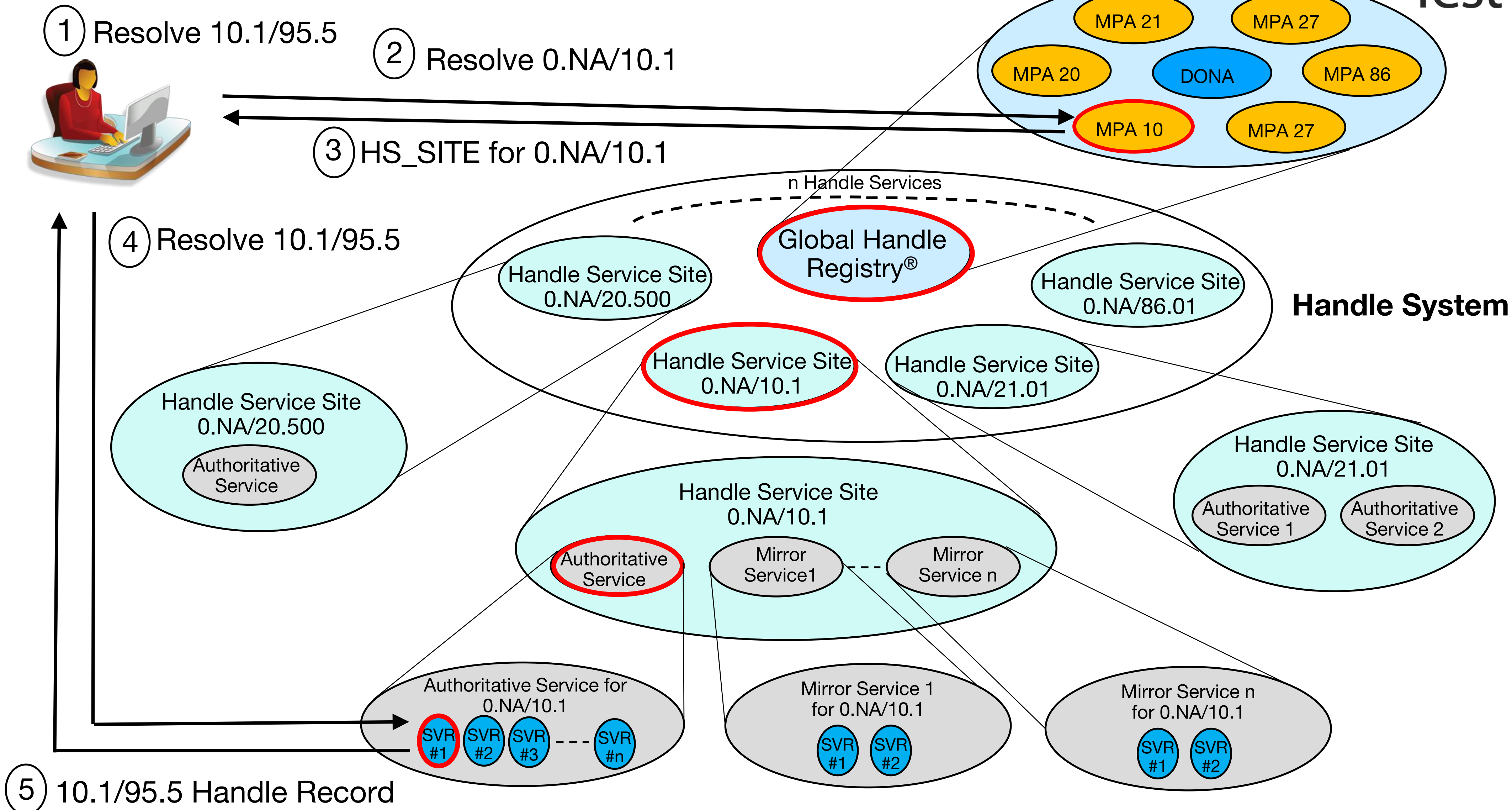
Index	Type	Timestamp	Data
100	HS_ADMIN	2022-10-20 20:16:49Z	handle=0.ADMIN/ADMINLIST; index=200; [create hdl,delete hdl,read val,modify val,del val,add val,mo
1	URL	2022-10-20 20:16:49Z	https://www.dona.net/sites/default/files/2022-07/DO-IRPV3.0--2022-06-30_0.pdf
10	DESC	2022-10-20 20:16:49Z	This handle point to the DO-IRPV3.0 standard PDF document. This document specifies the Digital Object Identifier Resolution Protocol (DO-IRP), that may be used to enable centralized or de-centralized, secure identifier resolution and administration in a computational environment such as the Internet. R
400	HS_SIGNATURE	2022-10-20 20:16:49Z	eyJhbGciOiJSUzI1NiJ9.eyJkaWdlc3RzIjpb7ImFsZyI6IlNIQS0yNTYiLCJkaWdlc3RzIjpbeyJpbmRleCI6Mw.p_XayQz7ArsWlZ8qqt7p27dN0sf4rcgXUX9Y0F0wkX6Eqwlup40ma7fmEA1vmdLxdAoAN3tq5LmNK



Java Handle Administration Client



Handle Resolution



Handle Service Site

- A **Handle Service Site** consists of:
 - 1 **Primary Handle Service**
 - 0 or more **Mirror Handle Service**.
- A **Handle Service** has 1 to many Handle Server(s).
 - More servers in a **Primary Handle Service** increases resolution and administrative performance.
 - More servers within a **Mirror Handle Service** increases resolution performance.
- Each server in a **Handle Service** is described by a **Service Information** value which include: IP address, public key, and the interfaces it supports. (query/admin on which ports).

Handle Service Site Information

- A Handle Service Site is responsible for providing resolution for all handles under a specific prefixes. Example: 10.12345/*.
- A Handle service site is specified in a HS_SITE handle value in the prefix handle. Example: 0.NA/10.12345

Handle Service Site

Authoritative Service

SVR #1SVR #2

Mirror Service 1

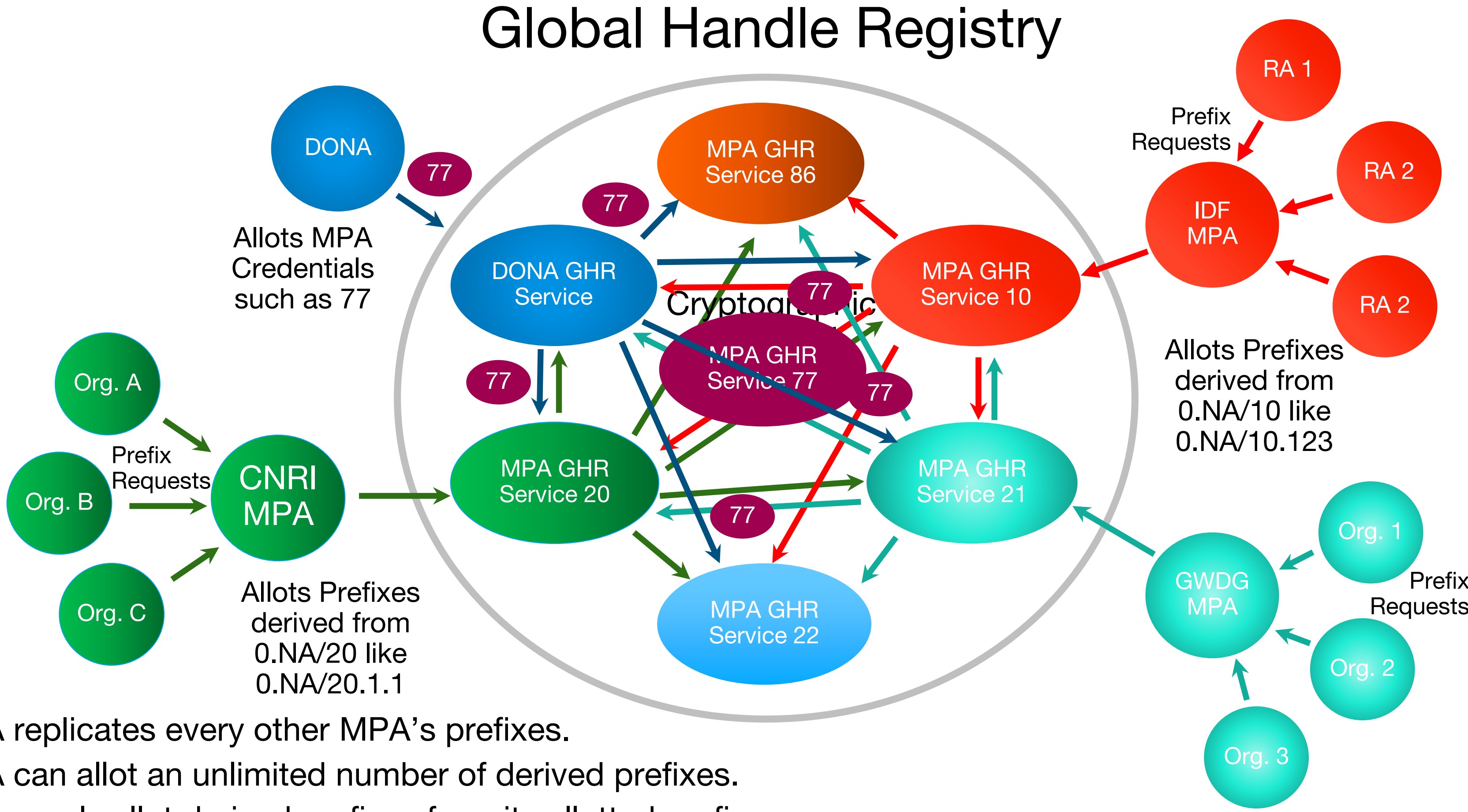
SVR #1SVR #2SVR #3

Mirror Service 2

SVR #1SVR #2

Handle Services	IP Addresses	Port Number	Public Key	...
Authoritative Service				
Service 1	12.34.45.67	2641	5ec6f944...	...
Service 2	12.34.56.68	2641	55fa26ca...	...
Mirror Service 1				
Service 1	12.45.67.71	2641	C77ee70...	...
Service 2	12.45.67.72	2641	22d81f1...	...
Service 3	12.45.67.73	2641	43a7a1f....	...
Mirror Service 2				
Service 1	32.23.23.12	2641	A80b56...	...
Service 2	32.23.23.13	2641	b56757...	...

Global Handle Registry



Handle System Security Features

- **Encryption:** Communications between handle clients and servers can optionally be encrypted.
- **Authentication:** Handle client and servers can authenticate each other using the built in PKI.
 - A client can be authenticated using the public key in its own Handle.
 - A server can be authenticate using the public key in its Server Info.
- **Authorization:** Handle System comes with a handle value level authorization controlling who can see and modify each value in a handle record.
- **Non-Repudiation:** Handle Client can require that the server cryptographically sign the handle records to guarantee their origins.

Handle System Protocols

- The Handle System implementation was described in
 - **RFC 3650** (Nov 2003): Handle System Overview
 - **RFC 3651** (Nov 2003): Handle System Namespace and Services
 - **RFC 3652** (Nov 2003): Handle System Protocol (V2.1) Specification
- **DO-IRPV3.0** (June 2022) replaces all 3 RFCs. (0.100/DO-IRPV3.0)
 - Digital Object Identifier Resolution Protocol – It is an implementation independent specification. The Handle System is a fully compatible.
- JSON over HTTP DO-IRP is available in the Handle.net LHS distribution.
 - Full Protocol implementation in Javascript libraries are available.
- Handle.net Web Proxy Handle Resolution supports both DO-IRPV3.0 and JSON over HTTP protocols.

The Handle System as a PID System

- General Handle System Technology Overview.
- Attributes and characteristics of PIDs and PID systems.
- Handle System's technology enabling Persistence.
- Handle System user communities enabling Persistence.
- Handle System Governance body.
- Future Evolution.

PID Characteristics

- PIDs should avoid semantics that can evolve over time.
 - Organization Name
 - Service related Information
 - Languages.
 - Others...
- PIDs need to be unique.
- PIDs need to map to a PID record.
- A PID's record need to be extensible.

PID System Characteristics

- Should globally and securely resolve any registered PID into its associated PID record.
 - Verifies the existence and global uniqueness of the PID.
 - Provides information about the digital object identified by the PID.
- Should make the PID record easily accessible, readable, extensible and secure.
- Should provide built in integrity solutions for its PID and associated PID record.
- Flexible: Integrate with existing systems, accommodate new applications and use cases.
- Scalable, redundant / fault tolerant.
- Independent from the underlying PID System's implementation technology.
- Open standards / Open source.
- Should have a transparent and open governing body.

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Handle System - Resolution

- The Handle System provide resolution for all its registered Handles.
 - Verifies the existence / guarantees the uniqueness of all handles globally.
- The Handle System has built in Handle integrity and validation mechanism.
 - Values returned from a Handle Server can be signed by the key of that host server.
 - Handle values can be hashed and the value stored in the Handle.
 - Handle Hashes can be signed using the keys of entities identifier by a Handle.
 - The Handle System has support for Key Certificates to specify handle policies.
- Prefixes are managed by organization credentialled by DONA.

Handle System - Extensible

- Handle System is Extensible:
 - New Types (Identified as handle) can be created and globally unique and reused.
 - A PID Record can include any number of values of any type. (within reason)
 - PIDs can be made to expire and can be “**Tomb Stoned**” when no longer needed.
- Flexibility: The handle system can be adapted to fit existing service needs:
 - Easy Integration with existing application.
 - Web Resolution Proxies. Example: Handle.net’s Handle Web Proxy, DOI’s Web Proxy.
 - Multiple protocols.
 - **Handle Templates** provide synthetic / operation specific resolutions capabilities
 - Provide powerful resolution / integration / persistence solutions

Handle System - Scalability Redundancy

- The Handle System's architecture make the Handle System easily scalable accommodate very large administration and resolution needs.
- The Handle System has a high degree of implementation abstraction.
- Can be used with emerging technologies to easily increase its server deployment (AWS and Docker) and increase its storage with distributed storage solutions (MongoDB).
- The Handle System can use Cloudflare for load balance between is services.
 - Example: DOI Resolution Per month:
 - March 2000: 60,000. 4 FTE
 - March 2024: 1,700,000,000 4 FTE
- Hardware and network technology evolution has greatly increased in performance.

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Handle System Community - MPAs

- MPAs operate their own respective MPA GHR Service as part of the GHR and can manage their prefix space according their own policies and procedures, respecting their own organization and countries' laws.
- The MPAs, along with DONA, collaborate to maintain the integrity, quorum and persistence of prefixes in the GHR.
- The DOI Foundation MPA has established agreements between Registration Agencies to guarantee the continuation of Handle Services for a derived 10 prefix should a registration agency fail.
- The Coalition MPA in China has garnered the Chinese government's support to make the Handle System a recognized technology to be used at large scale their industrial Internet.

Handle System Community - Adopters

- The community of adopters has promoted the use of the Handle System while maintaining its overall interoperability and availability.
- Organizations using the Handle System have developed new applications and use patterns:
 - Integration with manufacturing chains.
 - Distributed semaphores.
 - Identity System.
- Adopter have defined their own types and associated functionality.
- Adopters define the persistence of its PIDs according to their requirements.

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DONA Foundation

- Based in Geneva Switzerland for neutrality.
- Operates the GHR in collaboration with Multi-Primary Administrators.
- Provide coordination, software, and other strategic services for the technical development, evolution, application, and other uses in the public interest around the world of the Digital Object Architecture (DOA) with a mission to promote interoperability across heterogeneous information systems.
- Promote the DO-IRP, DOIP and X.1255 standards and the adoption of the DOA across different countries, domains, and industries.
- Consider new MPA candidates with diverse geographical location, a wide range of industries, organizations that can persist.

Handle System Governance

- The Global Handle Registry was operated by CNRI Until December 2015.
- The DONA Foundation based in Geneva, in collaboration with organizations credentialled by DONA as MPAS started in December 2015 operating the GHR in a multistakeholder manner.
- DONA allots a credential to an MPA for their exclusive use. (10 for the DOI Foundation, 20 for CNRI, etc).
 - MPAs Provides scalability, redundancy, and availability around the globe.
 - MPAs can operate their Handle Service according to their local laws, and policies and procedures.
- MPAs are the only entities that can create derived prefixes from their 2 digit prefix.
- Within the GHR, the DONA GHR replication policies and procedures are enforced cryptographically across all MPAs insuring a consistent quorum, and valid prefixes.
- MPAs and DONA collaborate together on the evolution of the Handle System and the DO-IRP standard as well as on the GHR operations, policies and procedures.

The Handle System as a PID System

- General Handle System Technology Overview
- What are the various requirements and attributes of persistence
- What aspects of the Handle System's technology enable Persistence
- How Handle System user communities enable Persistence
- The role of the Handle System Governance bodies.
- Future Handle System Evolution.

Future Evolution of the Handle System

- Keep the Handle System's evolution focused on what it is good at.
- Keep it simple and add new features only if absolutely necessary.
- Use a Kaizen approach – Continuous small Improvement.
 - Prefix Delegation
 - Multistakeholder GHR
 - Multi-Primary to reduce single point of failure for administration
 - OverwriteWhenExists
 - HTTP JSON protocol and libraries.
- Key the standards as minimal as possible.

Summary

- The development and evolution of the Handle System® is the product of infrastructure research, research projects, software and standards development, industry adoption, adaptation to technological changes, changing business models, policies and politics.
- The Handle System was designed from the ground up as a secure, distributed, scalable, extensible, network accessible identifier resolution system to provide persistent identification system for decades to come.
- The Handle System's architecture and technical attributes facilitate the task of making handles PID, but the organizations that operate and use the system, design applications and service, develop policies and procedures and develop communities of users play a huge role in making the Handle System a PID system and Handles PIDs.

Thank you!