Geospatial Data and Storage Resource Broker®

Online GIS Integration in ESRI Environments with SRB MapServer and Centera

White Paper

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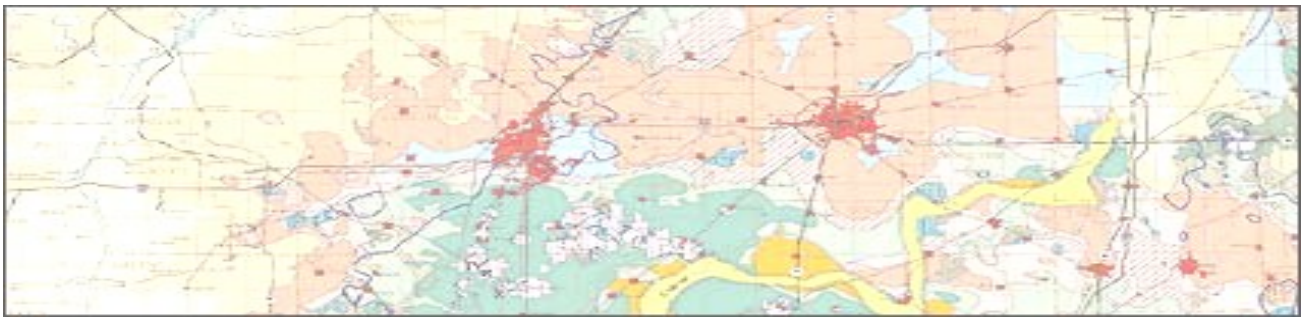


Introduction

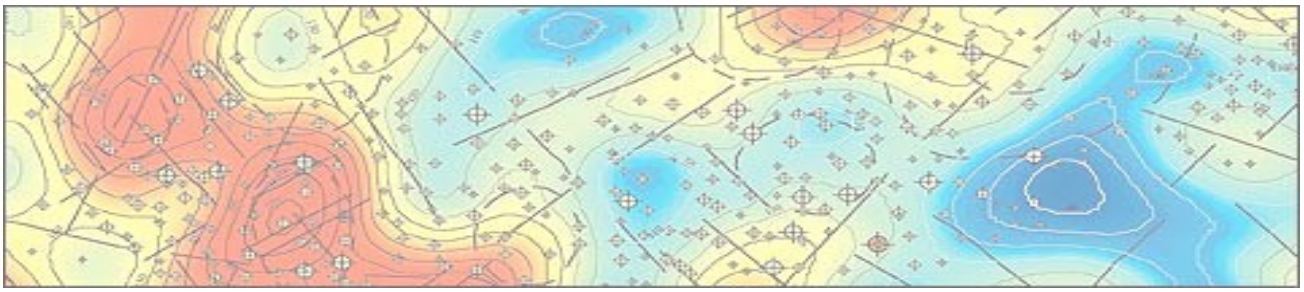
This paper investigates a solution for building, managing, and accessing online GIS data, especially when building and maintaining online archives combining historic images, maps, and data. The solution under investigation is the Image Storage Architecture (ISA) with integrated SRB® MapServer.

ISA is a complete online data storage solution designed to manage the growing cost of providing online geographic information services and improve the administration of massive online data repositories. ISA is pre-configured, pre-tested, and highly optimized for GIS environments and includes a complete package of integrated storage hardware, management software (the subject of this paper), and installation services.

SRB MapServer is a version of Nirvana's Storage Resource Broker, specially configured for use as a fully integrated component of ISA, along with EMC's Centera content addressed storage (CAS), the CLARiiON family, and the ESRI Arc family of products. Starting with a single SRB MapServer, the user can expand into an enterprise-wide, high-performance Storage Resource Broker (SRB) implementation and effectively address a variety of information storage requirements for fixed content, including digital image libraries, persistent archives, and data grids.

Within an ISA implementation, SRB MapServer provides applications and clients with a uniform interface and easy access to storage resources, including file systems, databases, and archival storage. When upgraded to its full potential, SRB can present an enterprise-wide, "Collection"-oriented hierarchical view of data, and enables discovery, presentation and management of distributed Data Collections. Leveraging its data abstraction and Global Namespace capabilities at an enterprise level, SRB can federate very complex planned environments, providing access to data on a wide variety of storage systems, and these capabilities will also be described.

Since 1995, SRB has been proven in the nation's most advanced supercomputing centers, as the basis for data grids, digital media libraries, and persistent archives. It has been implemented as the heart of over 100 data federations in some of the world's most demanding compute environments, to manage digitized & scanned maps, databases, GPS data, field-sampled attributes, remote sensing and aerial photographs, and other advanced digital imaging data. SRB MapServer builds on this experience with a product tailored specifically for today's ESRI environment, with scalability to support unlimited growth and complexity.



Case for SRB MapServer

From small map producers to large government agencies, GIS organizations struggle with the rapid growth and increasing complexity of large-scale GIS implementations. An integrated component of Image Storage Architecture (ISA), SRB MapServer enables easy access to EMC storage products and improved discovery, access and management of digital image files. Users and administrators alike benefit from an abstracted, independent view of all digital image data.

In conjunction with EMC storage products, SRB MapServer has been tested with ESRI's Arc family of products and is ideally suited to the integration, management and access of digital image data in GIS applications. SRB MapServer and its enterprise parent, SRB, are the ideal vehicles for the support of large volumes of image and historical data in either a departmental or enterprise GIS production environment. SRB MapServer is an essential element of the Image Storage Architecture – a GIS data integration solution that combines storage hardware, management software and installation services. This optimized turnkey combination is a pre-configured, pre-tested, and highly GIS-optimized offering.

The Storage Resource Broker MapServer precisely addresses the needs of users of geospatial data: access to diverse, heterogeneous data, support for a wide variety of storage systems, and configuration flexibility to accommodate rapid growth and increasing complexity.

SRB MapServer is client/server middleware that connects GIS applications with diverse data resources including file systems on Storage Area Networks (SANs) or Network Attached Storage devices (NAS), and online Centera disk archives. Using SRB MapServer, many layers of data from disparate sources and formats can be assembled and grouped into logical Data Collections, for transparent access by GIS applications.

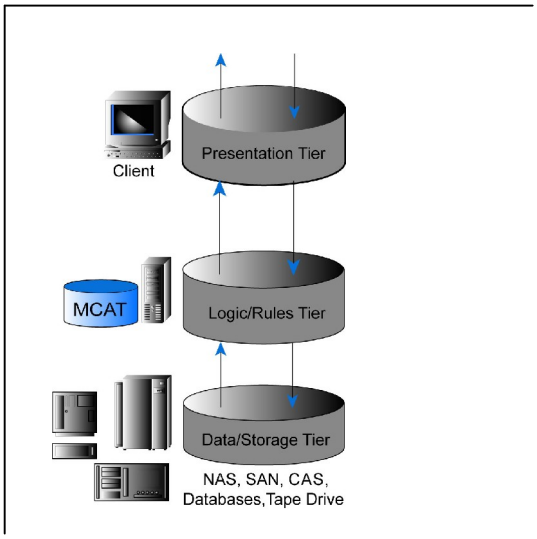
The result is an effective mechanism for managing rapidly-expanding GIS data stores. SRB MapServer, as part of the complete ISA offering, scales easily, from single storage subsystems to very large Collections, and provides multiple user interfaces, including Windows gateways and simple point-and-click Java applications. SRB MapServer is designed to access varied storage platforms, so it enables expanding GIS Operations at every level: departmental, organizational, community, state, and federal. And SRB MapServer can be easily scaled into a full SRB enterprise or enterprise-collaborative data grid implementation. It is a mature and stable product, under continuous development since 1995, and has been implemented at the core of some of the world's most advanced image repositories.

SRB MapServer Architecture

SRB MapServer Design

SRB MapServer offers a simple user presentation, in effect a "Collection hierarchy" – an extension of a standard directory hierarchy – of files residing on heterogeneous data sources. The SRB MapServer design can be described conceptually as three major layers: the SRB Clients (Presentation Tier), the Metadata Catalog or MCAT (Logic Tier), and the SRB Agents with drivers to the storage systems (Data Tier). This concept is illustrated as follows:

Figure 1: SRB MapServer Design



Terminology

Data Objects

Every piece of data managed or accessed through SRB MapServer is represented as a Data Object. Examples of Data Objects are: images, metadata files, databases, spreadsheets, database queries, URLs, or others. Data Objects can physically reside anywhere within an SRB Federation including file systems, tape drives, tape libraries, relational databases, or archives. A Data Object is not necessarily the same as a file, although it can be. Furthermore, Data Objects do not necessarily have a one-to-one relationship to the underlying

data. A Data Object can in fact point to several (replicated) pieces of data (a one-to-many relationship). Therefore, a Data Object can be viewed as a logical entity, whereas a file refers to a physical entity. There are numerous attributes automatically associated with each Data Object in SRB: name, data type, size, physical path, creation timestamp, modification timestamp, last access timestamp, custom attributes, etc.

Collections

An SRB MapServer Collection is (much like a folder or directory in a file system) an object that contains other Collections or Data Objects. A Collection is used to organize Data Objects into a logical hierarchy that is easily accessible and understood by both user and administrator. For example, a Collection named "Project X" can be used to store all the Data Objects related to project X, independent of where that data is physically stored or how it is physically structured. This logical Collection view is maintained transparently through SRB MapServer so that users do not need to keep track of the physical locations of their data. Collections in SRB MapServer possess the same attributes as Data Objects.

Global Namespace

The entire logical hierarchy comprising all Collections, Sub-Collections, and Data Objects is called a Global Namespace, also referred to as a *Logical Namespace*. By definition, a Global Namespace can span multiple heterogeneous and distributed storage systems and data centers.

Storage Resources

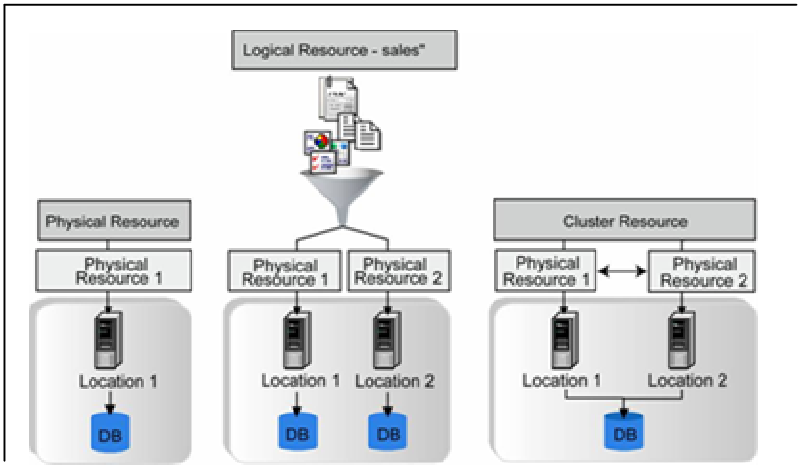
Every piece of data must ultimately be on a physical storage system. In SRB MapServer, the mapping between those storage systems and the Data Objects is done using Resources. There are three types of Resources: *Physical Resources*, *Logical Resources*, and *Cluster Resources*.

Physical Resources represent abstractions of places where Data Objects are physically stored. Such “places” include file systems on UNIX, Linux, or Windows; relational databases like Oracle, Sybase, or DB2; tape drives and libraries; Content Addressable Storage (CAS) systems; web or FTP servers etc.

Logical Resources are used to group one or more Physical Resources together, making it transparent to the SRB MapServer user where data is physically stored. Logical Resources can be useful for many reasons: (a) data can be transparently stored to several underlying resources simultaneously (replication), (b) Resources can be switched out or added, (c) load balancing can be managed among several Resources, and (d) SRB Containers can be used as a mechanism to automatically archive and stage the data in the correct archival or cache resource –- and all this can be accomplished transparently to SRB MapServer users.

Cluster Resources enable the efficient management of clustered file systems. To any SRB MapServer Client a Cluster Resource shows up as a Physical Resource. Behind the scenes, the Cluster Resource might in fact have many Physical Resources attached. When data is read or written on the Cluster Resource, the Cluster will iterate through its attached Physical Resources until it finds a working Resource. Cluster Resources provide SRB with an elegant automatic fail-over from one server to the next if those servers are seeing the same data.

Figure 2: Comparison of SRB MapServer Resources



Components

SRB MapServer is implemented as a distributed software layer using a client / server architecture. The combination of all SRB Servers, Clients, and storage systems is called a Federation. Every Federation must have a central master server connected to a Metadata Catalog (MCAT). SRB Agents can be installed optionally on other servers besides the master server. The client interfaces provide easy administration, navigation, and access to all the data within the Federation. Each SRB MapServer configuration contains an MCAT and a number of client interfaces.

MCAT

The Metadata Catalog (MCAT) includes attributes required for the implementation of the Global Namespace and the mapping of Data Objects to Storage Resources within the Federation. The MCAT is used to determine where a given Data Object is physically located, and which drivers handle and access the data of interest. Furthermore, the MCAT contains all file attributes, metadata, access control lists, Storage Resource information, and user data, and also handles queries.

Agents / Locations

Optionally, an SRB MapServer Federation maintained in MCAT can be expanded to span multiple servers within a department, the entire enterprise, or even beyond the enterprise and across administrative domains. This is achieved by installing additional software called **SRB Agents** on the respective servers. These Agents can either reside on an existing or (for performance reasons) on a dedicated server. An Agent provides a full range of services such as data handling, load balancing, data discovery, legacy systems integration, and proxy services.

Each SRB Agent is listening to a unique IP address and port number combination (a **Net Address**) on the server machine for requests from other Agents or SRB Clients. The combination of a unique port number and IP address (or hostname) is called an **SRB Location**. Therefore, several SRB Locations (or unique port number/IP address combinations) can coexist on a single server machine if they are monitoring different port numbers or IP addresses. SRB Locations are hierarchically organized.

Drivers

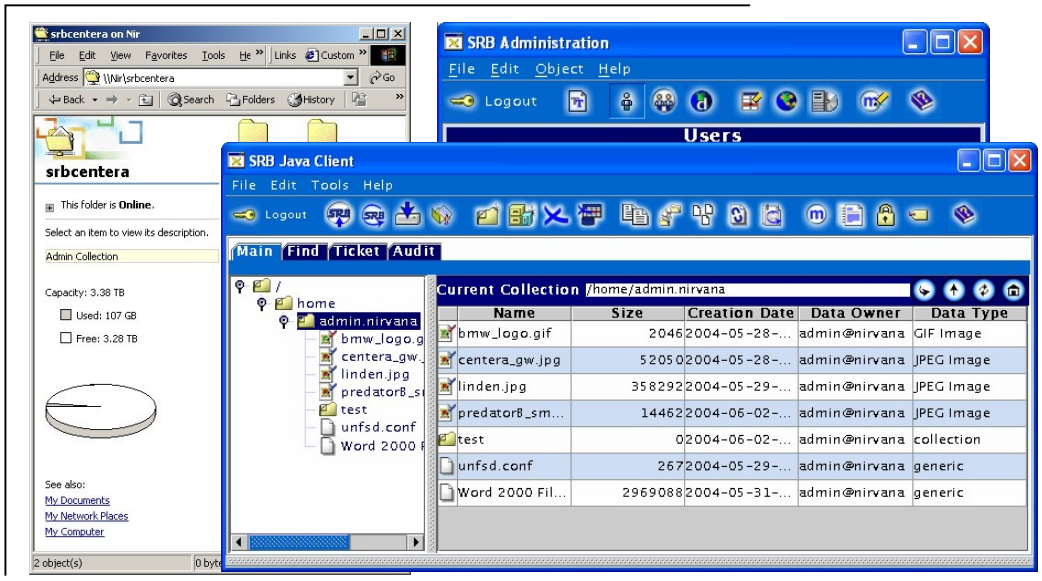
The MCAT or an SRB Agent may contain any number of drivers to interface with various storage systems. SRB MapServer is configured with drivers to EMC Centera and a number of file systems. Additional drivers are separately available and new drivers are continually under development. As GIS data stores grow, and as the complexity of a data store increases (due to reorganization, collaboration, acquisition, etc.), SRB MapServer and SRB enable continuing data transparency. SRB MapServer and SRB also greatly simplify migration to new storage formats and media technologies.

Client Interfaces

SRB MapServer includes the following interfaces:

- Windows (CIFS) Gateway
- UNIX/Linux (NFS) Gateway
- Java Admin
- Java Client
- Mcommands

Figure 3: SRB User Interfaces



GIS applications will mainly access their data using the Windows (CIFS) Gateway, which essentially creates a Windows network share using a Samba server with an SRB Module in the backend. The CIFS Gateway makes it completely transparent to GIS applications where the GIS data is physically stored.

For applications running on UNIX/Linux the NFS Gateway will provide the same functionality as the CIFS Gateway on Windows. It enables the mounting of SRB Collections as a local directory on any UNIX/Linux workstation or server.

The entire administration of SRB MapServer can be performed through a central console (Java Admin) and allows for such tasks as the creation of new Storage Resources, the changing of access permissions, user management, Metadata Scheme customization, etc.

A user may also interface with SRB MapServer through a Java Client that can be installed on any of the supported platforms. The GUI looks familiar to anyone who has used a file manager to copy and move files and folders. Compared to the gateways it has additional SRB-specific functionality like data migration, data discovery, or the viewing of audit trails.

The Mcommands are utilities used for the maintenance of MCAT and are usually only necessary during the installation or upgrade process of MCAT.

A number of additional clients are available as an option (see Expanding into the Enterprise).

SRB MapServer installations typically start on a single server with one or two storage systems attached. EMC Centera can serve as an online archive in such an environment. MapServer can then easily be expanded through the addition of SRB Agents.

Metadata

The MCAT at the heart of an SRB MapServer Federation keeps track of several different metadata attributes. They are generally grouped into system-level and user-level attributes.

System-level attributes are automatically maintained by MCAT and are mostly queried, displayed, and used for data management. System-level attributes are maintained on all SRB Objects including Data Objects, Collections, Storage Resources, Locations, Users, Groups, and Domains. Examples for system-level attributes are file path, Data Object size, resource type, etc.

User-level attributes are created and maintained by applications or users and can be attached to both Data Objects and Collections. They also are useful for query, display, and data management purposes. User-level attributes are access controlled on a per-attribute-basis so that SRB MapServer Administrators can create access policies such as “Engineering can modify the revision attribute, Analysts can read it, and the Public can not even see it”. Other examples for user-level attributes are latitude, longitude, keywords, projects, etc.

Data discovery is made much easier through SRB MapServer’s metadata attributes. Additionally, Collection metadata can ease discovery of Data Collections with attributes such as author or project name. SRB MapServer keeps access control lists in every user-level metadata attribute, ensuring a high level of security. Different access levels such as ‘read’ or ‘write’ are supported, assuring that metadata is only viewed and modified by users authorized to do so.

Metadata Schemes

To make SRB MapServer management easier, administrators can group different metadata attributes into SRB Metadata Schemes. Metadata Schemes provide “attribute groupings” that may be specific to certain types of Data Objects or specific user groups within the organization. One example might be a Metadata Scheme called ‘DEMs’ that contains ‘Capture Method’, ‘Creation Date’, ‘Resolution’, and ‘Layer’.

SRB MapServer Features

SRB MapServer Highlights

SRB MapServer is configured to provide an affordable entry point compatible with the requirements of most ESRI operating environments, and complementary to EMC online storage options. At every step, users pay only for what they need. The SRB MapServer configuration includes the following features:

- 20TB maximum capacity MCAT
- 3 SRB Users (super + 2 custom)
- Centera driver
- Disk driver (for UNIX/ Linux/ Windows file systems)
- Windows (CIFS) and UNIX/ Linux (NFS) gateways
- Java Admin
- Java Client
- Mcommands (for MCAT maintenance)

SRB MapServer provides Windows, UNIX and Linux gateways to Centera and other storage systems, Access Control, Read and Write access for data and metadata on Centera, and an integrated query engine for secure data discovery based on attributes.

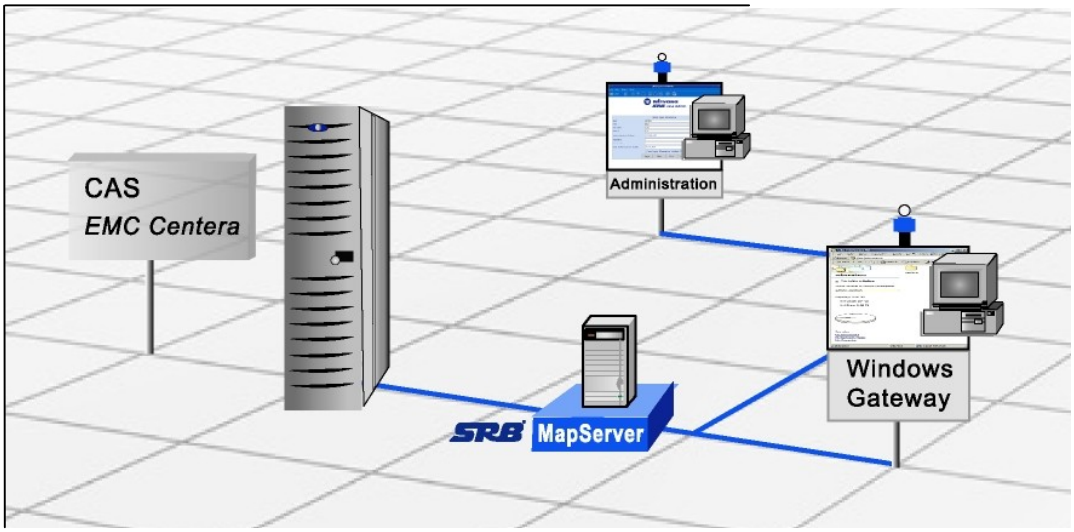
Virtually every component of the configuration is upgradeable, so the offering represents a scaleable path to very large (multi-petabyte) installations, with a wide variety of networked storage and server configuration options.

Supported Systems
SRB MapServer

- **Operating Systems**
  AIX, HP UX, SGI Irix, Linux, Mac OS X, Sun OS, Sun Solaris, Windows
- **File Systems**
  all supported operating systems
- **Archives / HSM**
  EMC Centera, DiskXtender 2000, DiskXtender UX (formerly Unitree)
- **Databases for MCAT**
  DB2, MSSQL, Oracle, Postgres, Sybase

SRB MapServer users can add SRB Agents, upgrade MCAT and server capacities, and also add optional Policy/HSM and synchronization daemons, as required. Also available are Web Client, Scommands (command-line client), Acommands (command-line administration), the SRB Software Development Kit with APIs in C and Java, SRB Container technology for reducing latencies and complexities, additional reporting mechanisms and MCAT reports, Ticketing for time- and access-count restricted access, bulk operations and the planned “zone” feature.

Figure 4: SRB MapServer Configuration



Virtualization

When using SRB MapServer, applications, clients, and administrators immediately benefit from the following levels of abstraction, which ease administration, data discovery, and data access:

Information Repository Virtualization

The information repository (or MCAT) where the Federation's metadata is stored is transparently accessed and managed by SRB. This allows for a seamless exchange of the underlying information repository over time. Currently there is support in SRB MapServer for many relational databases (see *Supported Systems SRB MapServer* above). The entire information repository can be exported and imported using XML. SRB dynamically generates SQL to perform various operations on the MCAT.

Storage Virtualization

The underlying technologies for storing data change every few years. SRB makes it transparent to its clients which particular storage technology underlies an SRB MapServer environment. For SRB MapServer Clients it is no longer necessary to remember a server's hostname, IP address, operating system, access protocol, or even whether a system is an archival storage system or a cache system. SRB MapServer hides those complexities and alleviates data storage complications by defining a common set of operations for manipulating data through its drivers.

Data Virtualization

Data within an SRB Federation is virtualized through a mapping mechanism from the physical path to a logical name within SRB MapServer. Every Data Object in SRB MapServer has its unique Global Identifier that is independent from the physical data path. SRB MapServer takes the approach of associating any metadata such as access control lists, audit trails, checksums, or user-level metadata with the logical name (or Global Identifier). This enables SRB MapServer to function across heterogeneous and distributed storage systems.

In the case that an SRB MapServer User does not know the logical name of a Data Object, data can be discovered and accessed solely through an object's attributes (creation date, size, frequency of access, latitude, longitude, keywords, projects, etc.).

Access Virtualization

The following mechanisms provide for a complete access transparency: 'single-sign-on' and access through one common set of APIs. Clients do not require previous knowledge of a system's APIs or security mechanisms.

Services

The MCAT and the Global Namespace enable the transitioning of services such as backup or migration from a local administrative domain into the enterprise-wide SRB Federation. The following paragraphs give an overview of the most important services implemented in SRB MapServer.

Data Load

There are two mechanisms to load data into SRB MapServer: registration and ingestion. Registration leaves the data untouched and only registers a pointer to the data in MCAT without transferring any of the data contents. Ingestion is similar to Registration but also transfers the data to an SRB Storage Resource.

Data Retrieval

Data is as easily retrieved from SRB MapServer as it is loaded. It is completely transparent where the data is coming from because SRB MapServer and TCP/IP handle the routing of the data streams.

Replication

Data replication – the process of creating and maintaining synchronized copies of a Data Object throughout an SRB Federation – has a number of uses and benefits: it enables disaster protection with instantaneous failover from one replica to another one; caching is achieved by allowing clients to access a local replica rather than a remote one; and load balancing works by distributing synchronized replicas across multiple servers.

Persistent Migration

Using the Global Namespace as a logical view of federation-wide data, SRB MapServer Clients can migrate data to new Storage Resources without

affecting the way users see data organized in their Collections.

Backup

Unlike Replication, a backup is not automatically overwritten when the original data is modified. This protects against accidental or malicious destruction of data. A backup in SRB MapServer makes copies of Data Objects or entire Collections in designated backup Collections.

Restore

The restore process recovers deleted or wrongfully modified objects to an earlier point in time.

Secure Queries

A number of different objects can be queried through the MCAT: Resources, configuration information, Users, Groups, Domains, Locations, Data Objects, Collections, Containers, Tickets, Schemes, and Tokens. There are several hundred attributes that allow the creation of very complex SQL-style queries. At no point in time will SRB MapServer Clients gain access to any object/information for which they do not have at least 'read' access.

Security

SRB MapServer provides authentication schemes to protect data (Challenge Response Mechanism, Grid Security Infrastructure - GSI, Kerberos) enabling Single sign-on throughout the whole organization. SRB's authorization service maintains Access Control Lists (ACLs) on various SRB Objects: Data Objects, Collections, Resources, and Metadata Attributes. Support is also built in for data encryption (GSI, Kerberos), User management (users, groups, domains) as well as Audit trails.

Authentication

There are a number of built-in mechanisms that ensure the authenticity of an SRB MapServer User: challenge response mechanism (password is not sent across the network), Grid Security Infrastructure (using public and private keys), and Kerberos (sophisticated ticket management mechanism to provide single sign-on for multiple networked services). When using the CIFS and NFS Gateways, administrators are free to set up any supported authentication mechanism for their end-users, such as the integration with Microsoft Active Directory (AD) or Lightweight Directory Access Protocol (LDAP).

Authorization

Once users are authenticated to ensure that they really are who they claim to be, SRB performs authorization services on every SRB Object that is requested. This ensures that users gain access only to the appropriate objects. The level of access may vary depending on the Access Control List (ACL).

Users / Groups / Domains

Users within an SRB Federation have roles assigned to them and only one *Super User* has the power to do and see everything. Others can be designated to manage a subset of the Federation and users can be assigned to manage Data Collections or to be data readers.

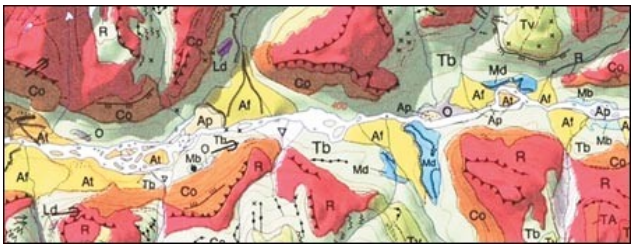
In order to ease the administration of an SRB Federation, MapServer administrators can create domains and groups of users. Access control lists can then be created referencing SRB Domains and Groups.

Access Control Lists

Access is controlled (authorization service) on Data Objects, Collections, Resources, and Metadata Attributes. There are various levels of access for each object ranging from 'null' (no access) to 'all' (full access). A fine-grained security mechanism enables access control on a per-user-level. In order to ease user and access control management, access can also be controlled for entire SRB MapServer Groups or Domains.

Audit Trails

Every transaction within an SRB MapServer Federation can be audited. An audit trail will typically contain information such as date of transaction, success or error code, user performing transaction, type of transaction, and notes. The audit trails are just like everything else stored inside MCAT and can therefore be easily queried and filtered.



SRB MapServer Performance

Before offering SRB MapServer as a part of ISA, ESRI tested SRB MapServer to determine that Centera online archive access performance would be acceptable relative to normal file server access. The results of the test are summarized below:

File Name	File Type	Pyramid File Size (MB)	Main File Size (MB)
North American	GRID	16.5	17.5
Palm Springs	IMG	81.6	958.1
Pyramids	TIF	48.0	573.9
Redlands	IMG	283.4	3,356.5
Redlands	TIF	99.1	1,186.5
Parcels	SHP	NA	40.4
Raster	TIF	35.5	212.1
World	SID	NA	85.0

Figure 5: ArcMap Full Extent Test Results

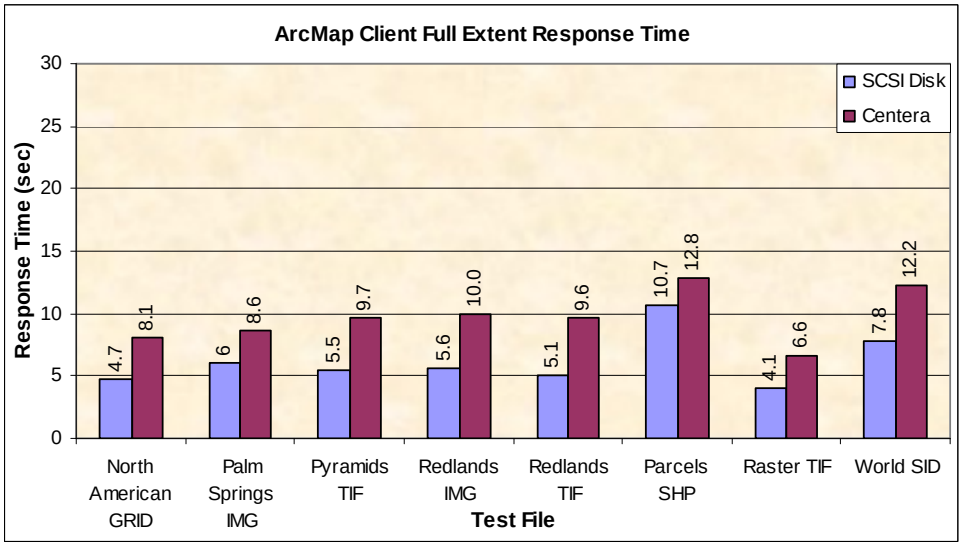
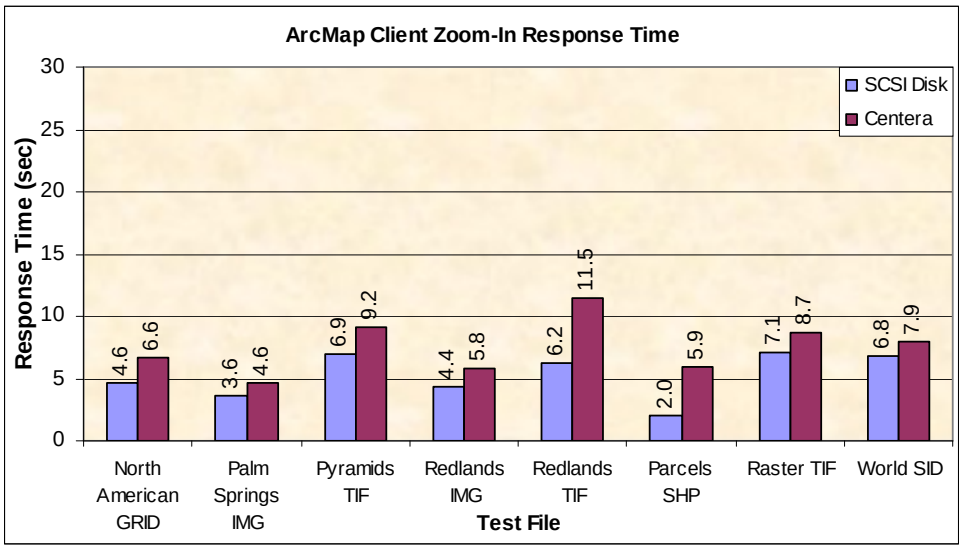


Figure 6: ArcMap Zoom-In Test Results



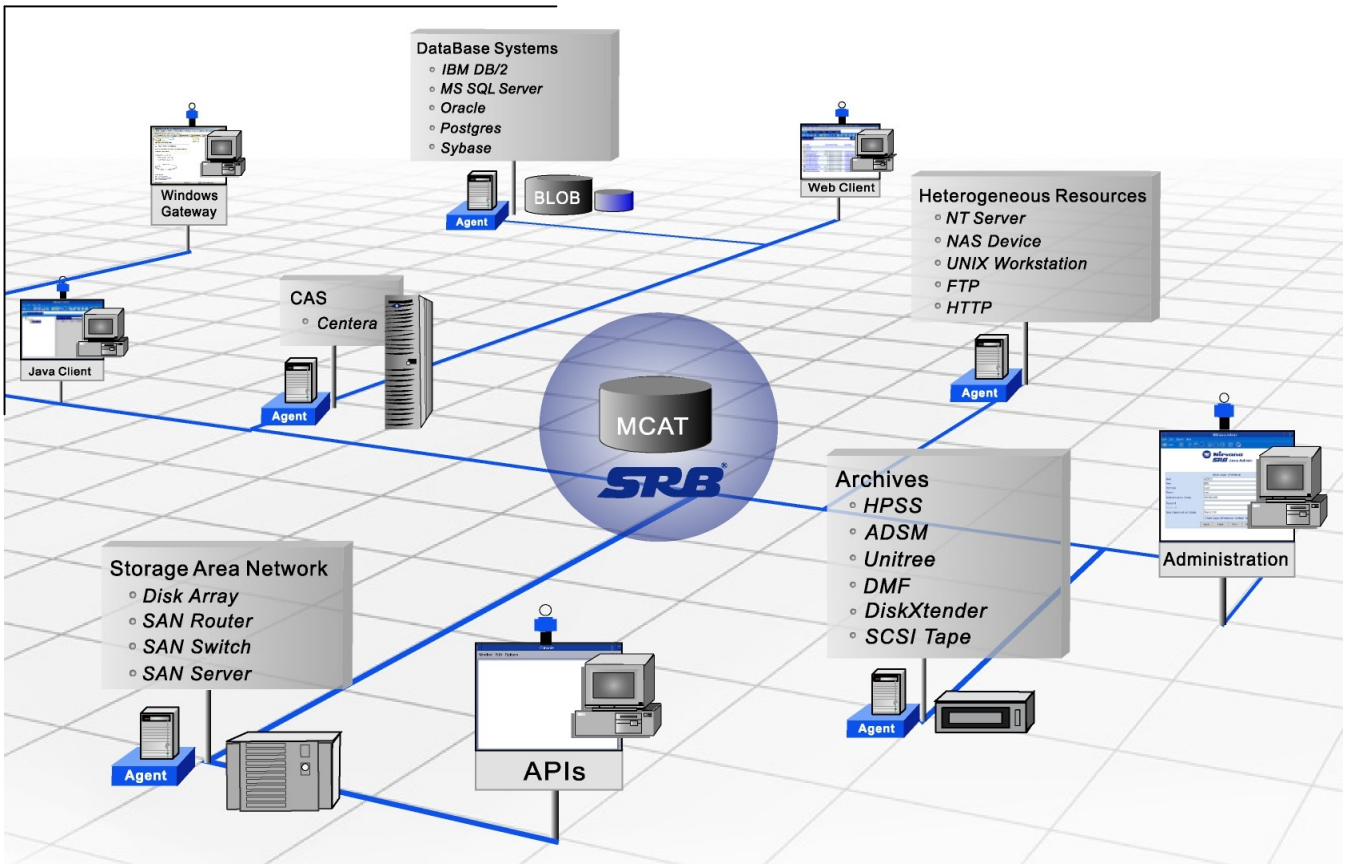
Parallel I/O

The SRB MapServer communication protocol is a thin protocol implemented on top of TCP/IP. This protocol supports parallel communications using multiple sockets and a single static port initiated by an SRB MapServer Client. This greatly enhances the utilization of bandwidth, especially when sending larger files across Wide Area Networks (WANs). SRB MapServer's parallel I/O mechanism can be configured to use a single static port through a firewall since the request is initiated by the client. Because the SRB Server (or rather its administrator) has a better understanding of the server's bandwidth availability and speed of the attached storage system, the server controls the number of parallel I/O streams. In SRB's parallel I/O mechanism not only Data Objects are transferred using the parallel mechanism but also any other data (like a large query result) is transported in parallel.

Expanding into the Enterprise

SRB MapServer can be gradually expanded into an entire enterprise-wide data grid. Capacity can be increased, more resource types and drivers can be added, additional servers (or Locations) can be attached, data management processes can be automated, and performance can be scaled. At every step, SRB users pay only for what they need.

Figure 7: SRB Enterprise Architecture



Data Collaboration and Management Suite

SRB is an advanced data grid implementation that enables simplified information management in ad hoc federations of users. Not only does it enable cross-platform access to data, but it also facilitates the discovery of the information residing on very different, usually incompatible, platforms going across administrative domains. SRB is a comprehensive solution for managing all the information in an organization. This includes table databases, LOBJ (Large Object) databases, file systems, tape drives, and archives. To allow viewing of table databases together with typical documents (spreadsheets, letters, forms), SRB can display customizable reports dynamically generated from database queries.

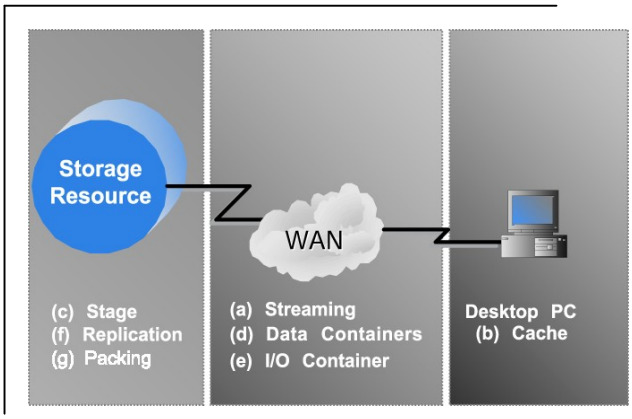
Performance

Numerous performance advantages include prefetch for Containers, support for a network of distributed caches, support for multiple archive resources in Containers, and Collection-based (hierarchical) management of distributed digital objects. Parallel I/O and bulk operations are also supported by SRB.

Latency Minimization

SRB features many different mechanisms to reduce latencies that occur during any data transfer:

Figure 8: Latency Management



(a) *Streaming*…is the continuous transfer and receipt of data without any noticeable lag time.
(b) *Caching*…keeps local copies of frequently accessed data on fast storage systems or memory.
(c) *Staging*…temporarily writes Data Objects stored on archival storage media to disk for faster access.
(d) *Data Containers*…transparently aggregate multiple Data Objects into one large file that can be stored and transferred more efficiently than multiple smaller files.
(e) *Input/Output Containers*…allow for a remote execution of multiple commands in large batches.
(f) *Replication*…keeps multiple synchronized copies of Data Objects at different sites.
(g) *Packing*…aggregates multiple Data Objects into a single buffer before sending the files over the network reducing latencies associated with multiple requests.
Furthermore, SRB can pre-spawn processes on the server. The administrator can determine the size of the 'SRB Server pool'. Performance is improved by reducing latency during the initial connect to SRB.

Scalability

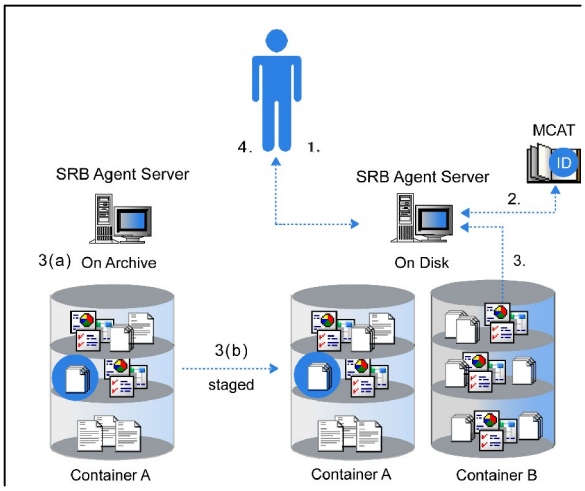
SRB's architecture – comprised of Clients, Agents, and the MCAT database – allows for nearly infinite scalability by adding more Agents as more capacity is needed and scaling the MCAT database for higher transaction rates using the database vendor's mechanisms (like Oracle Real Application Clusters).

Containers

Three major problems typically occur with distributed archival storage systems. The first is a high latency rate when retrieving data from tape. The second is file storage limitations. Archives are designed to store small numbers of very large files and data Collections are more likely to contain large numbers of small files. Finally, if the data is distributed over a Wide Area Network (WAN), serious latencies can result when transferring a large number of files. Through its patented Container technology, SRB can overcome all of these obstacles.

SRB manages Containers so that archives can be transparently integrated with all other enterprise-wide data. SRB incorporates Containers so it can manage distributed Data Collections across multiple storage systems.

Figure 9: SRB Container Design



Additionally, SRB manages Containers transparent to end-users or applications by presenting in-Container Objects just like any other SRB Data Object in the Global Namespace.

Data Objects are physically packed into a Container before being stored into an archive. This assures that associated Data Objects will reside on the same tape while decreasing the number of Data Objects managed by the archive. When retrieving these Data Objects at a later time, the correct Container is automatically staged to disk and all the read access happens against the staged copy. Since related Data Objects are

retrieved together, access time can improve dramatically.

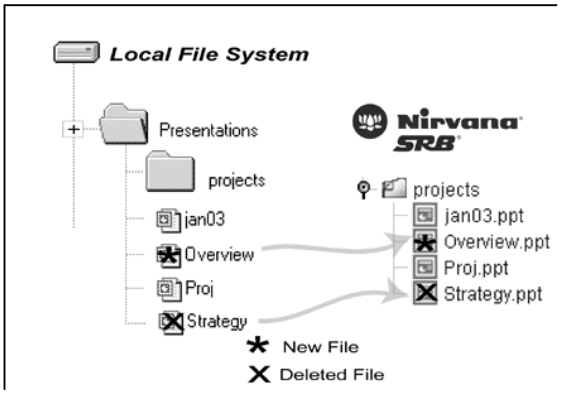
Automation

SRB has the ability to automatically launch helper processes or daemons upon start-up. Two of those daemons are particularly useful when it comes to easing the data transfer into the SRB Federation or automating data management.

Directory Synchronization Daemon

As files are added to, or deleted from, local directories, the *Directory Synchronization* Daemon (DS) running in the background detects these activities. When changes are noted to the local directory structure, the new information is registered and updated in the MCAT.

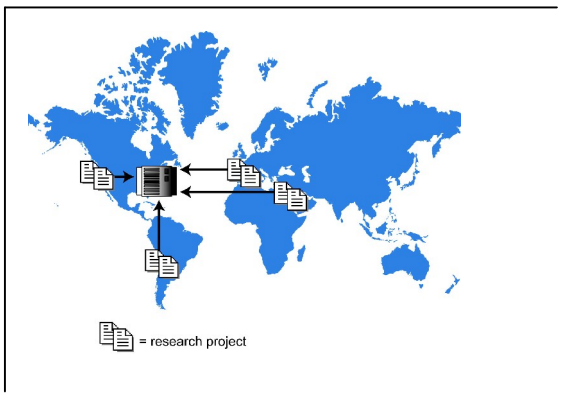
Figure 10: DS Daemon



Hierarchical Storage Management Daemon

A *Hierarchical Storage Management* (HSM) Daemon is a policy engine that routinely queries the MCAT. For example, an administrator sets a policy to migrate data from distributed Locations to one particular archival storage system with the criterion that all data over 10MB be included. In another example, data associated with a specific project and that has been accessed fewer than five times on average per day would be migrated. Besides migration, other actions can be performed on the data including replication, deletion, backup, or simply reporting.
The policies are extremely flexible and can contain standard metadata, customized metadata or expressions. All this happens behind the scenes, transparent to the end-user or applications, so that the Global Namespace does not change.

Figure 11: HSM Daemon



Additional Interfaces

The following client interfaces exist and can be added to SRB MapServer as an option: Web Client, Scommands (command-line client), Acommands (command-line administration), and Software Development Kit (SDK).

The SRB Web Client runs on any system that supports Internet Explorer or Netscape Navigator browsers. The SRB Web Client is therefore accessible from anywhere on the internet and does not require any client-side software installation.

In order to enable automation of certain tasks and to write scripts, a command line-based interface (Scommands) is also available. The Scommands essentially extend the functionality of local UNIX commands ('ls', 'cd', 'pwd', etc.) into the Global Namespace and are especially useful for terminal sessions or scripting.

Command line-based administration is optionally available through the Acommands. They are used for administrative tasks that require bulk operations or scripting.

The SDK allows application developers to integrate the SRB Global Namespace and all of SRB's services and functionality into their own applications. The SDK is available in both C and Java and comes with detailed documentation and examples.

Additional Drivers

A parallel disk driver is available that extends the standard SRB disk driver with extra performance using parallel threads and various caching mechanisms optimized for both random and sequential data access.

SRB includes relational database resources to permit DBMS-style row-based access to data stored in databases. SRB includes an HTML, XML or customized template interface to databases so that queries can be returned in any format and records within one format can easily be transferred into another format.

Most relational databases can also be used to store binary large objects (LOBJs). SRB supports drivers for such large object databases in order to store Data Objects directly into database tables.

A driver to SCSI tape drives and tape libraries is also natively supported by SRB. Since tape storage is still relatively more cost effective compared to disk, SRB makes tape management also very straightforward and therefore reduces Total Cost of Ownership (TCO) for tape archives significantly.

Internet data sources can be seamlessly integrated with drivers for FTP and HTTP servers.

Tickets

SRB employs an additional authentication mechanism whereby data-sharing Tickets can be sent out to internal or external SRB Users. The ticket then grants controlled access to Data Objects or entire Collections. Additional restrictions such as time limits and limits on the number of accesses can be built into every Ticket.

Reports

In combination with relational database drivers, the MCAT can be used to report on various SRB Objects. Examples are:

- Resource Usage (how are resources utilized over time)
- Data Object Access Pattern
- Data Ownership report (which users uses how much storage)
- Valid Tickets
- Audit Trails (for certain Data Objects or entire Collections)

Conclusion

As part of an integrated Image Storage Architecture, SRB MapServer enables a more powerful use of geospatial data. It supports productive collaboration and is the basis of an ideal enterprise data management tool for ArcGIS implementations ranging from 20TB and a single storage resource to highly complex cross-enterprise federations of unlimited size. SRB's simple and intuitive interfaces permit the easy management of different systems throughout a department, organization, community, state, or federal agency, reducing complexity to simplicity in both ease-of-use as well as administration.

Nirvana Storage developed SRB in cooperation with the San Diego Supercomputer Center, and the product is currently operational in over 100 governmental, scientific, and research data federations, where it is used to support collaborative projects (over 120TB and 30 Million files) among networked institutions. Some of this SRB experience is described in papers entitled "The SDSC Storage Resource Broker," and "SRB Case Studies", both of which are available on request. SRB and SRB MapServer are ideally suited to complex computing environments where knowledge workers would benefit from simplified, easy access to shared, high-value data in heterogeneous working environments.

About Nirvana Storage

Nirvana Storage is a division of General Atomics, the founder of the San Diego Supercomputer Center (SDSC). Nirvana Storage specializes in advanced information management systems for complex storage environments.

About General Atomics

General Atomics (GA) and its affiliated companies comprise one of the world's leading resources for high-technology systems development and nuclear technology. General Atomics is a leader in high-tech systems development, from nuclear fission and fusion to the Predator Unmanned Aerial Vehicle. Founded in 1955, GA is based in San Diego, CA, and has a total employment, including subsidiaries and affiliated companies, of approximately 3,000.

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