Grid Computing

ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

Definitions (I)

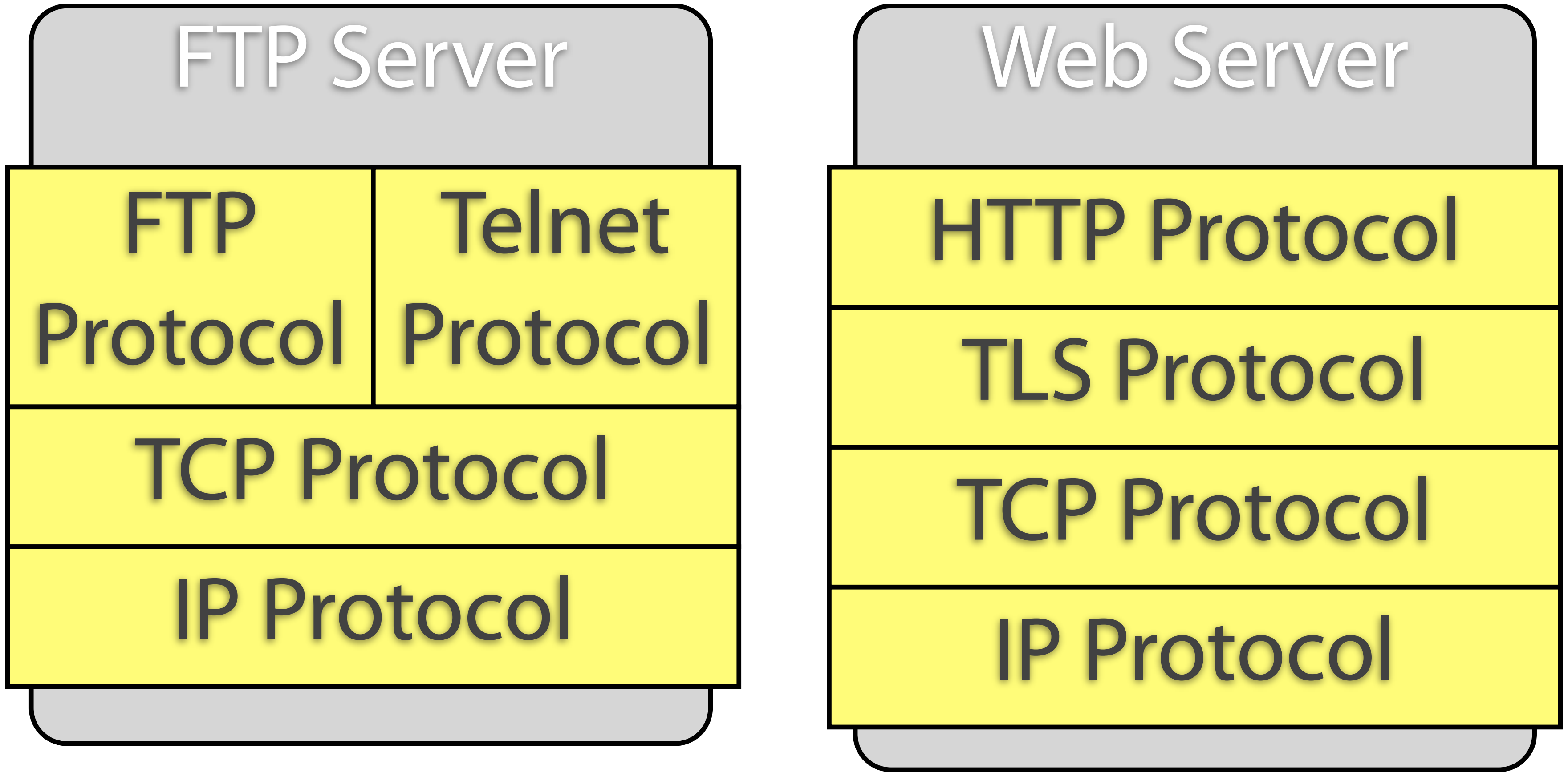
- Resource
  - An entity that may be shared
    - CPU, storage, data, software,…
  - Not necessarily a physical entity
    - Filesystem, bandwidth, thread pool…
  - Defined in terms of interfaces and capabilities
    - Open/close/read/write define the access methods to a filesystem
    - Copy/delete/move/create/cat define the methods to manipulate data

Definitions (II)

- Protocol
  - A formal description of messages format and a set of rules to exchange messages
    - Messages allow two or more resources to communicate
    - Rules may define a sequence of message exchanges
    - Message may change resources status and/or behavior
  - A good protocol does a single job
    - Filesystem, bandwidth, thread pool…
  - Defined in terms of interfaces and capabilities (APIs)
    - Open/close/read/write define the access methods to a filesystem
    - Copy/delete/move/create/cat define the methods to manipulate data

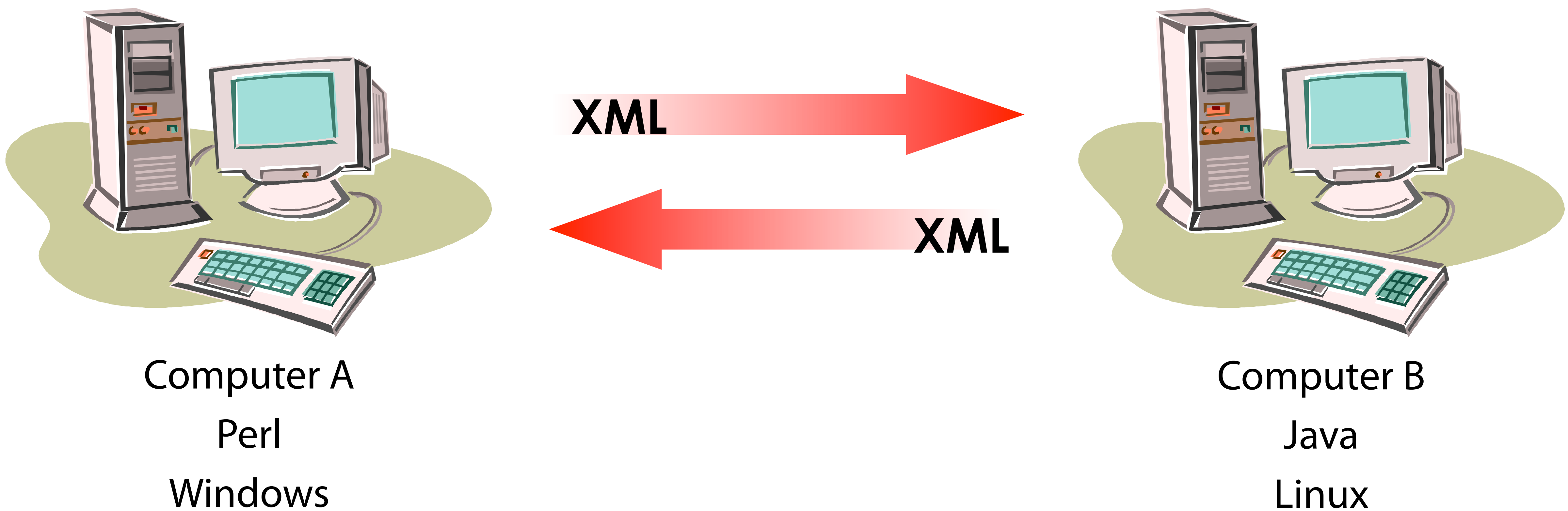
Definitions (III)

- Service
  - A server-side protocol implementation providing a set of capabilities
    - The protocol defines the interactions between a client and a server
    - A server implementing a protocol is the service
  - Every service needs a protocol to implement
  - A service can implement more than one protocol, but good services expose just one
    - Examples
    - FTP servers (ftp://)
    - Web servers (http://)
    - Mail servers (pop or imap)



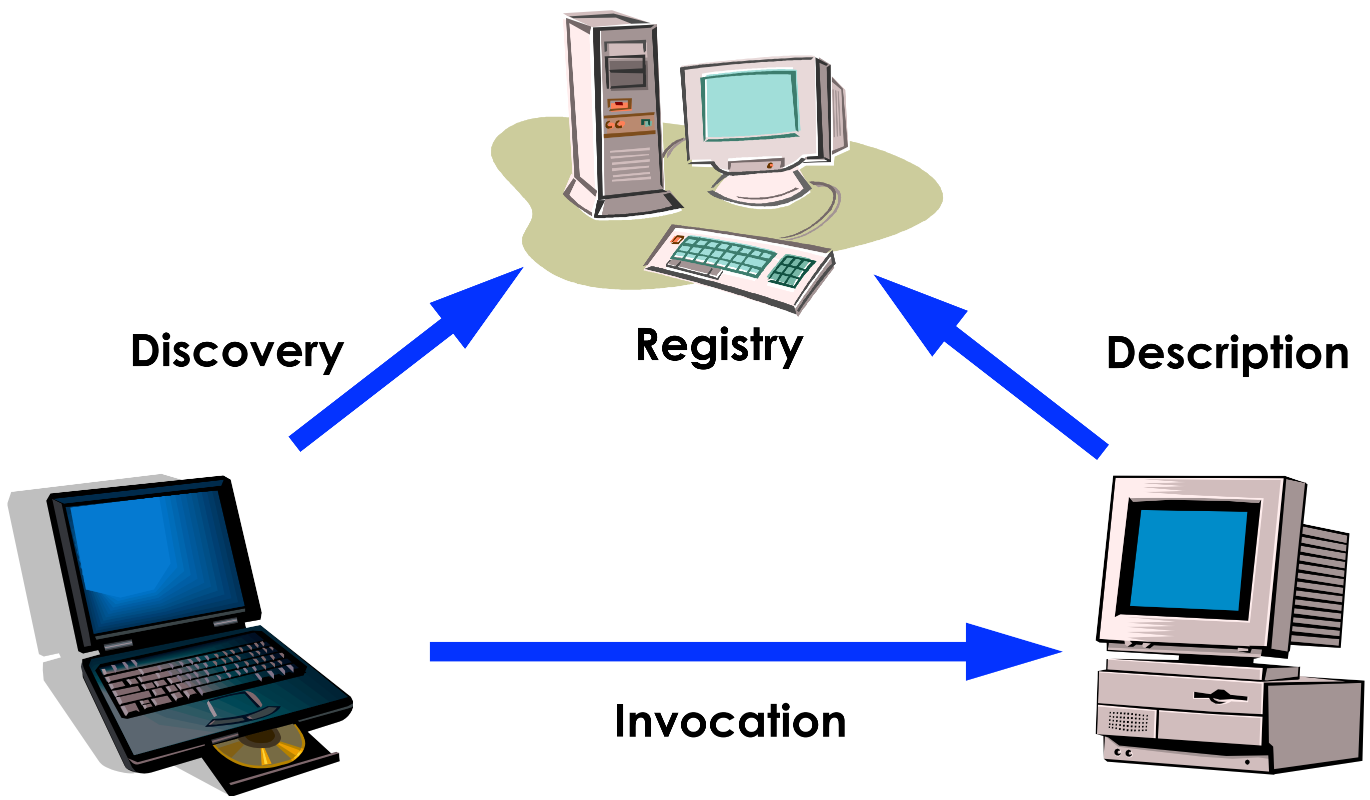
Example

- A web service is a service available on the Internet
- It allows creation of client/server applications.
- Platform and language independent protocol based on XML.
- Most use HTTP for transporting messages
- Lend themselves naturally to build loosely coupled distributed systems.



Roles

- Service Provider
  - Implements the service and make it available on the Internet
- Service Requestor
  - Service consumers use existing services opening a network connection, sending XML requests and receiving XML responses
- Service Registry
  - The service registry provides a central point where service providers can publish their services and service requestors can look for existing services



Protocols

Discovery	UDDI
Description	WSDL
Invocation	SOAP,XML-RPC
Transpost	HTTP,FTP

Elements of Grid Computing

- Resource sharing
  - Computers, data, storage, sensors, networks, …
  - Sharing always conditional: issues of trust, policy, negotiation, payment, …
- Coordinated problem solving
  - Beyond client-server: distributed data analysis, computation, collaboration, …
- Dynamic, multi-institutional virtual organizations
  - Community overlays on classic org structures
  - Large or small, static or dynamic

Virtual Organizations

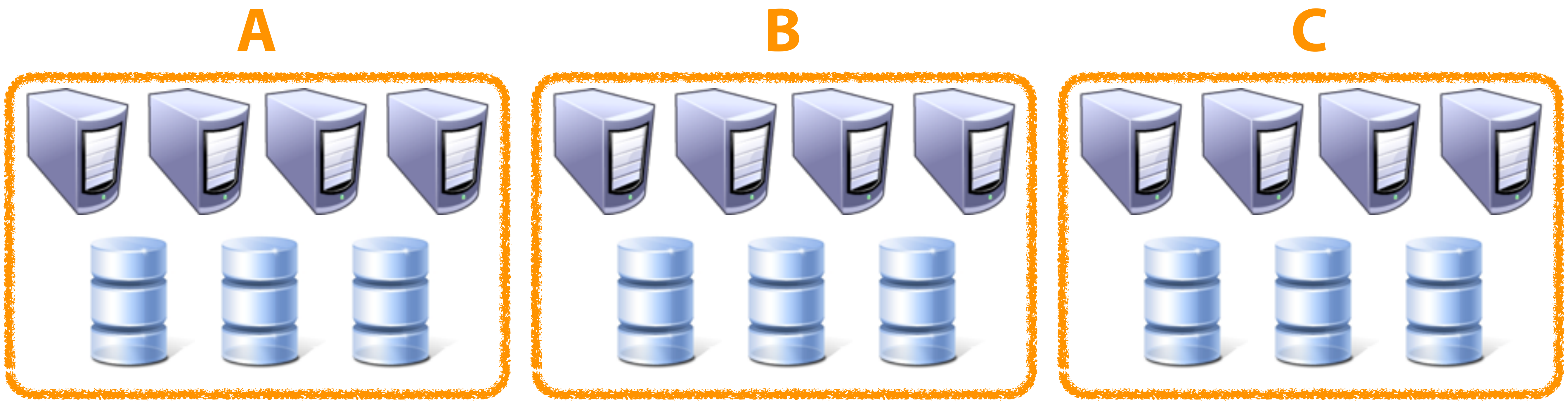
- Components
  - set of individual/institutions
  - set of resources
  - set of sharing rules
- Dynamic set of individuals and/or institutions defined by a shared goal and a set of sharing rules
- May vary in size, scope, duration and structure
  - Example: class students for cooperative lecture writing
  - Example: industrial consortium building a new aircraft
- The sharing is highly controlled, with resource providers and consumers defining clearly and carefully just what is shared

Example of VOs

- Three physical organizations (A, B, C)
- Two virtual organizations (X, Y)

Example of VOs

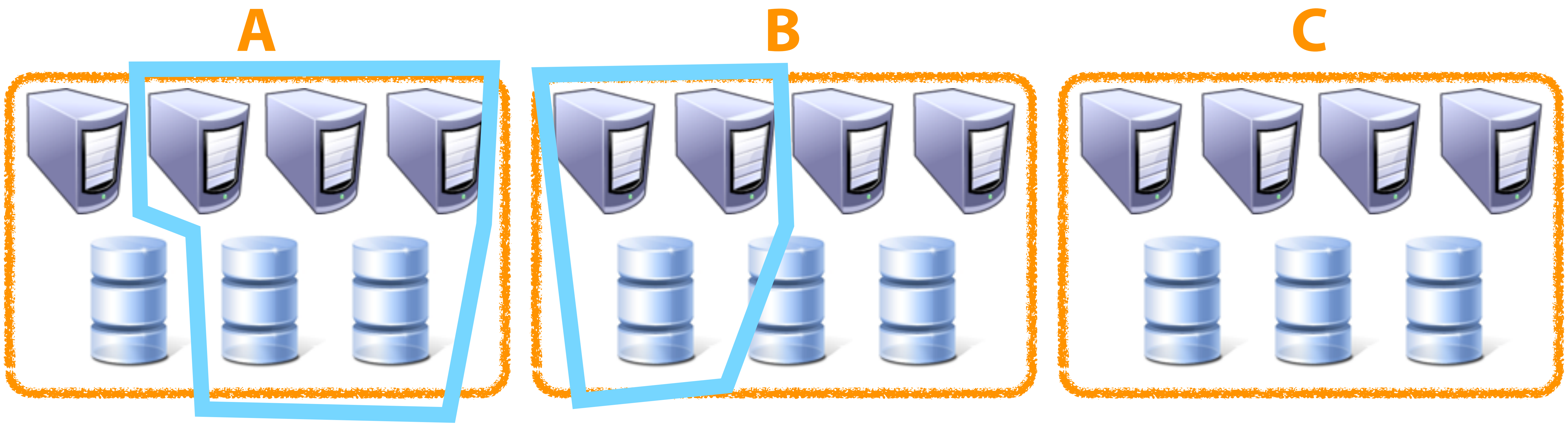
- Three physical organizations (A, B, C)
- Two virtual organizations (X, Y)



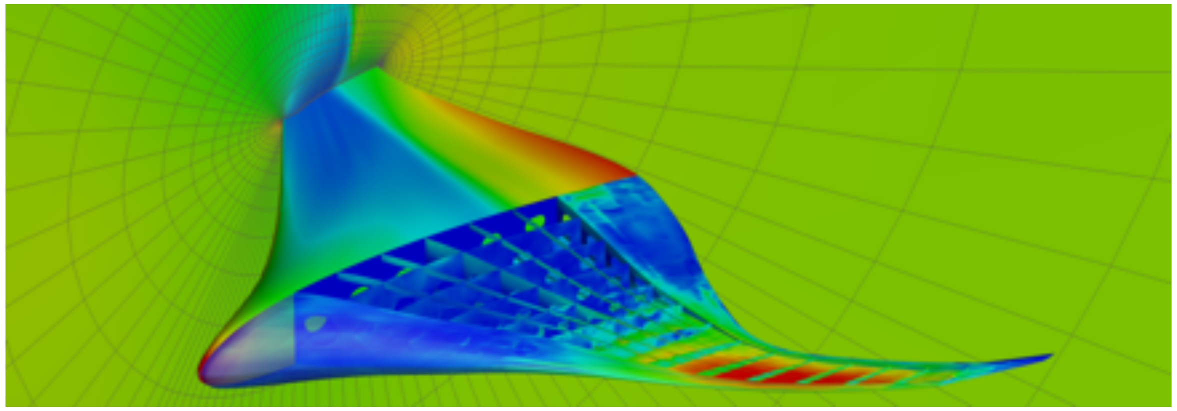
lunedì 24 settembre 12

Example of VOs

- Three physical organizations (A, B, C)
- Two virtual organizations (X, Y)



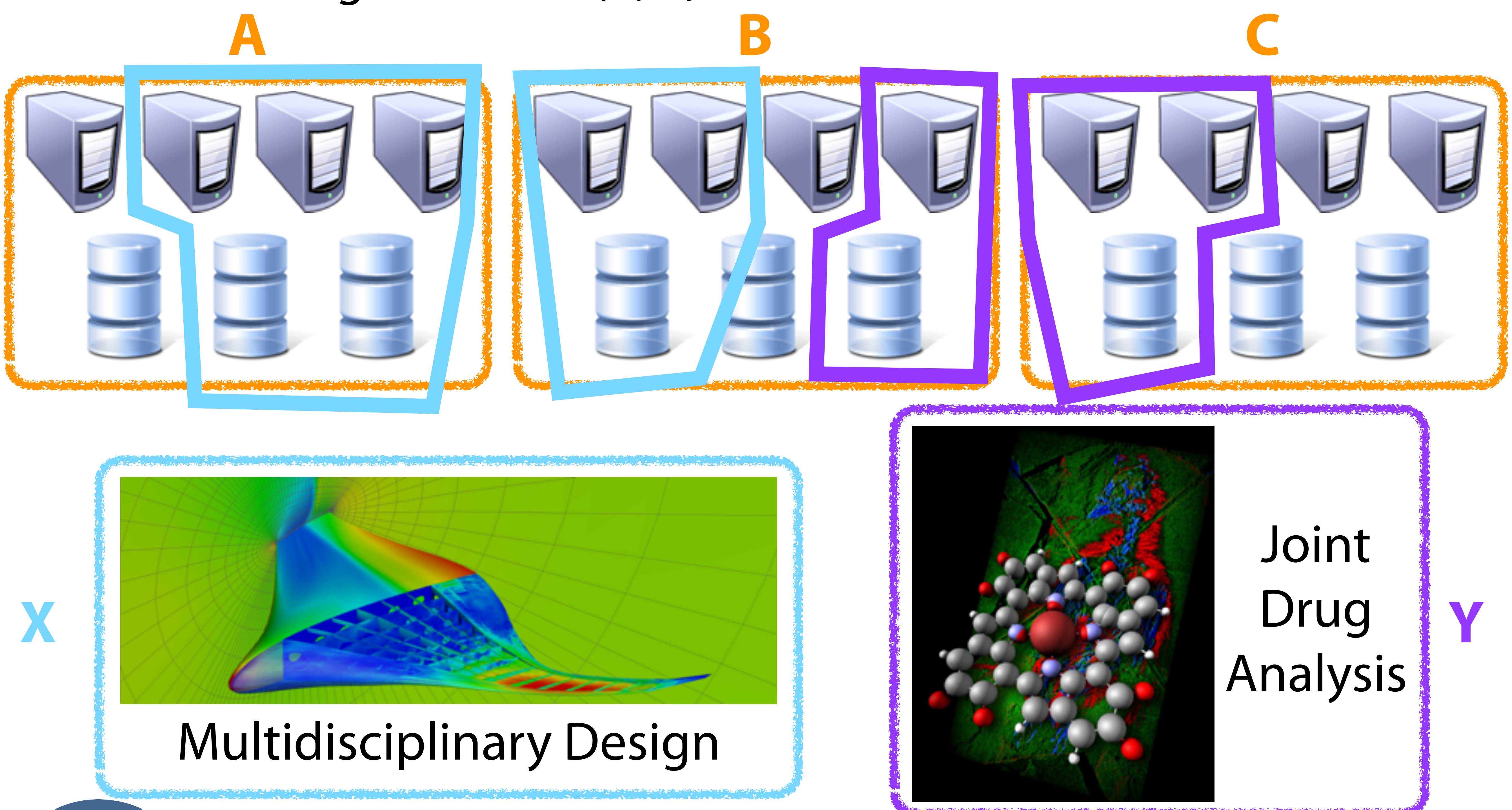
X



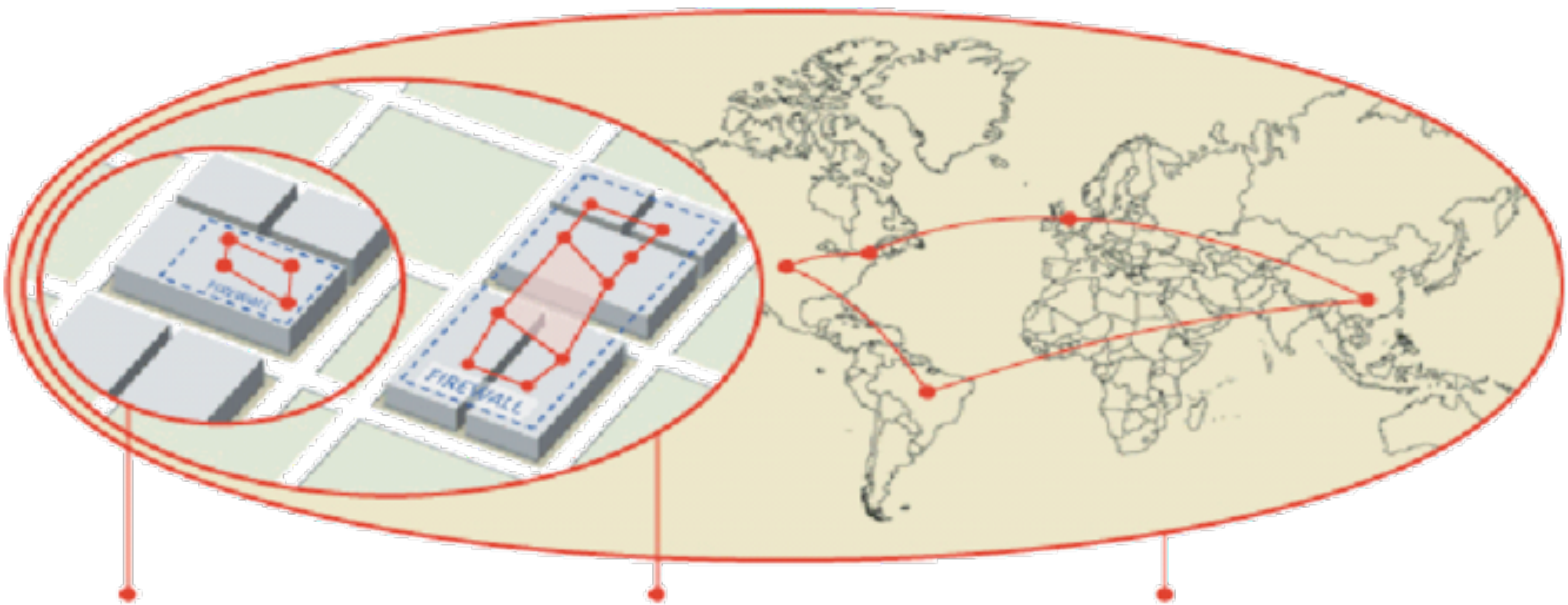
Multidisciplinary Design

Example of VOs

- Three physical organizations (A, B, C)
- Two virtual organizations (X, Y)



Scope of Grids



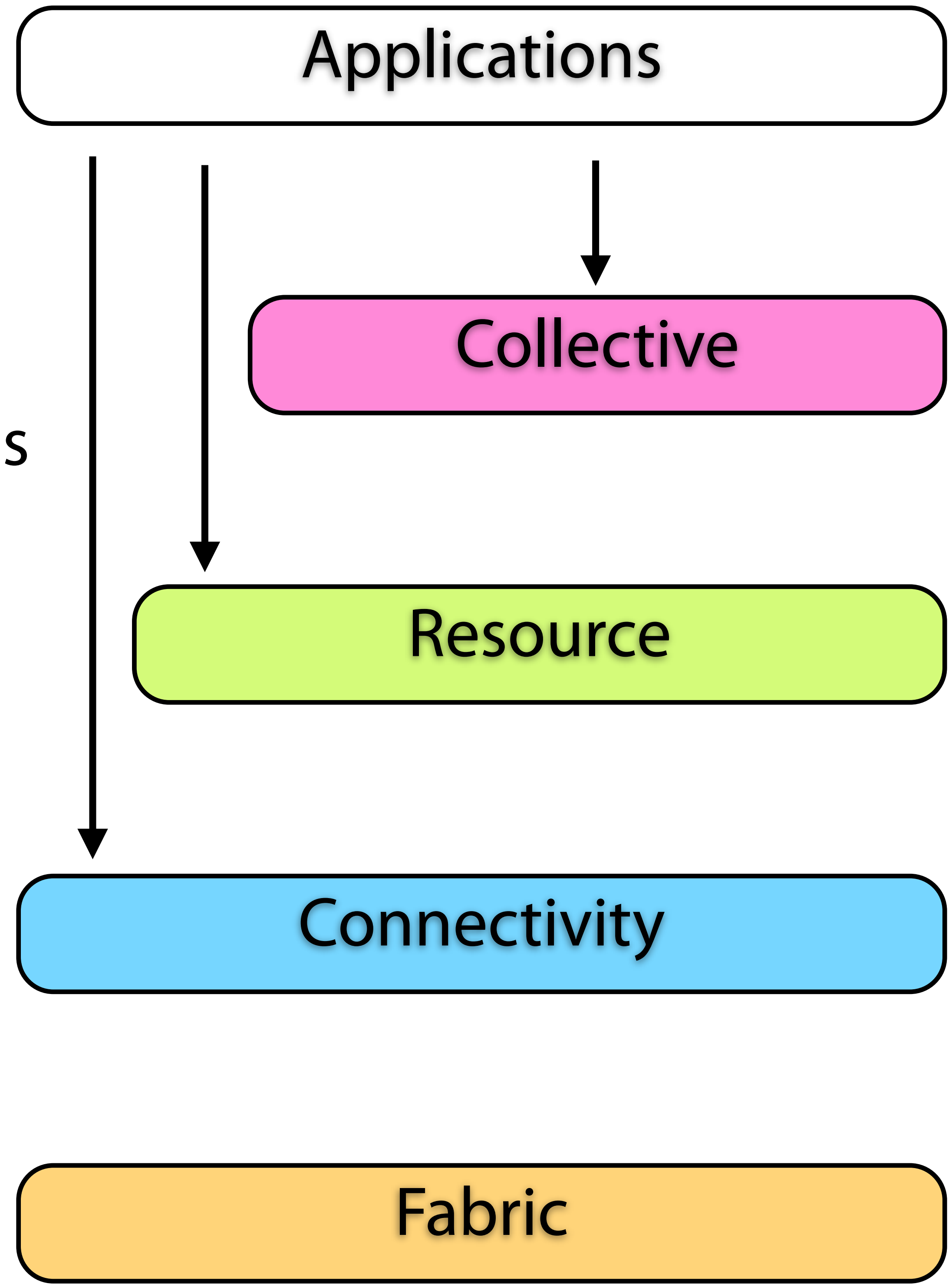
Grid Architecture

“Coordinating multiple resources”:
Ubiquitous infrastructure services, application-specific distributed services

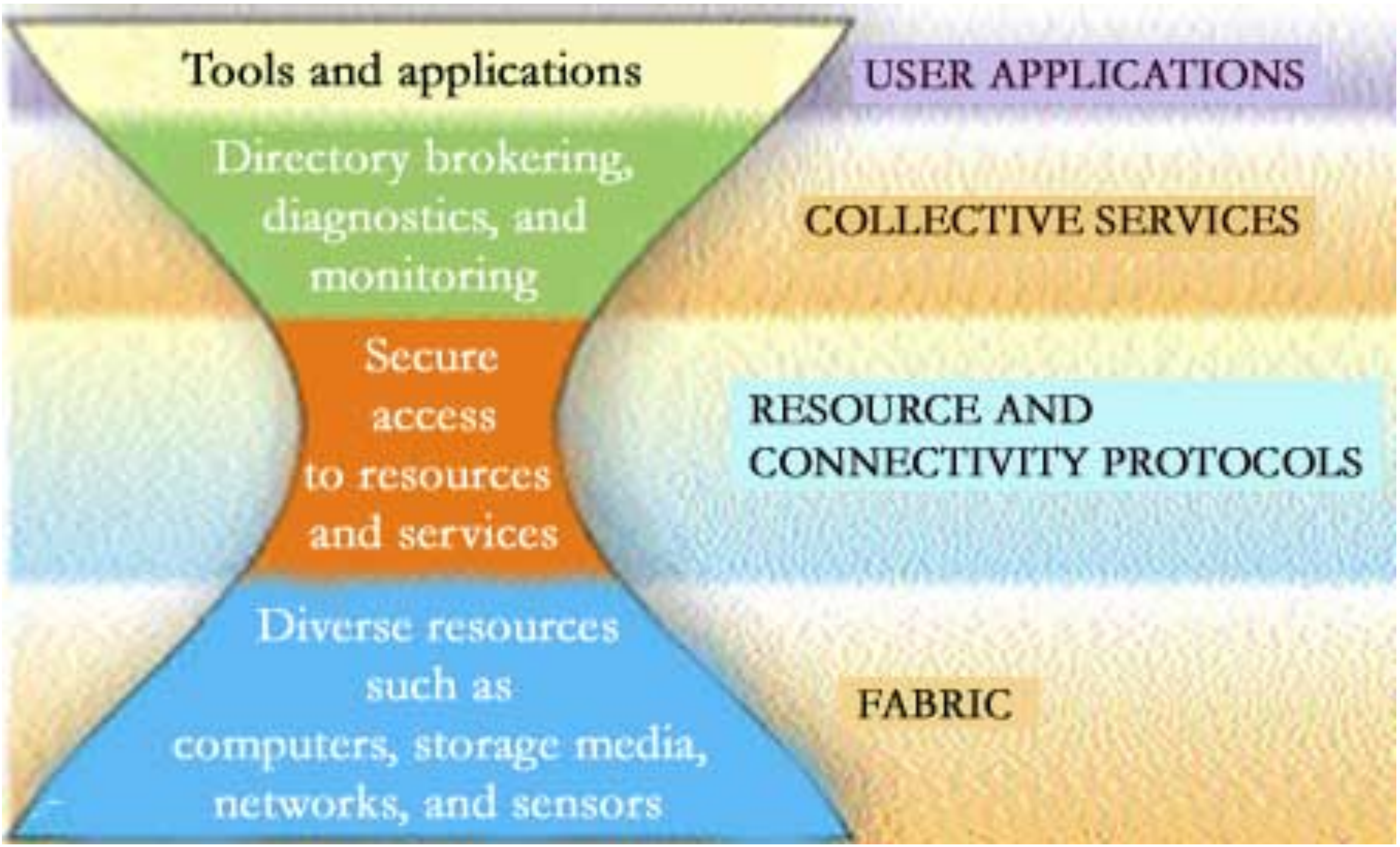
“Sharing single resources”:
Negotiating access, controlling use

“Talking to things”:
Communication (Internet protocols) & security

“Controlling things locally”:
Access to & control of resources



The Hourglass Model



I. Foster, "The Grid: A New Infrastructure for 21st Century Science," Physics Today, vol. 55, no. 2, pp. 42–47, 2002.

Fabric Layer

- Just what you would expect: the diverse mix of resources that may be shared
  - Individual computers, Condor pools, file systems, archives, metadata catalogs, networks, sensors, etc.
- Few constraints on low-level technology: connectivity and resource level protocols form the "neck in the hourglass"
- Defined by interfaces not physical characteristics

Connectivity Layer

- Communication
  - Internet protocols: IP, DNS, routing, etc.
- Security: Grid Security Infrastructure (GSI)
  - Uniform authentication, authorization, and message protection mechanisms in multi-institutional setting
  - Single sign-on, delegation, identity mapping
  - Public key technology, SSL, X.509, GSS-API
  - Supporting infrastructure: Certificate Authorities, certificate & key management, …

Resource Layer

- Grid Resource Allocation Management (GRAM)
  - Remote allocation, reservation, monitoring, control of compute resources
- GridFTP protocol (FTP extensions)
  - High-performance data access & transport
- Grid Resource Information Service (GRIS)
  - Access to structure & state information
- Others emerging: Catalog access, code repository access, accounting, etc.
- All built on connectivity layer: GSI & IP

Collective Layer

- Index servers a.k.a. meta-directory services
  - Custom views on dynamic resource collections assembled by a community
- Resource brokers
  - Resource discovery and allocation
- Replica catalogs
- Replication services
- Co-reservation and co-allocation services
- Workflow management services
- etc…

ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

Grid Services

App

Applications

Science | Engineering | Biology | Collaboration | Medicine

User

Application Development and Deployment

Languages/Compilers | Libraries | Debuggers | Monitors | Web Tools

Resource Management and Scheduling

Core

Distributed Resources Managers

Information | Data | Execution | Accounting | Monitoring | QoS

Security

Fabric

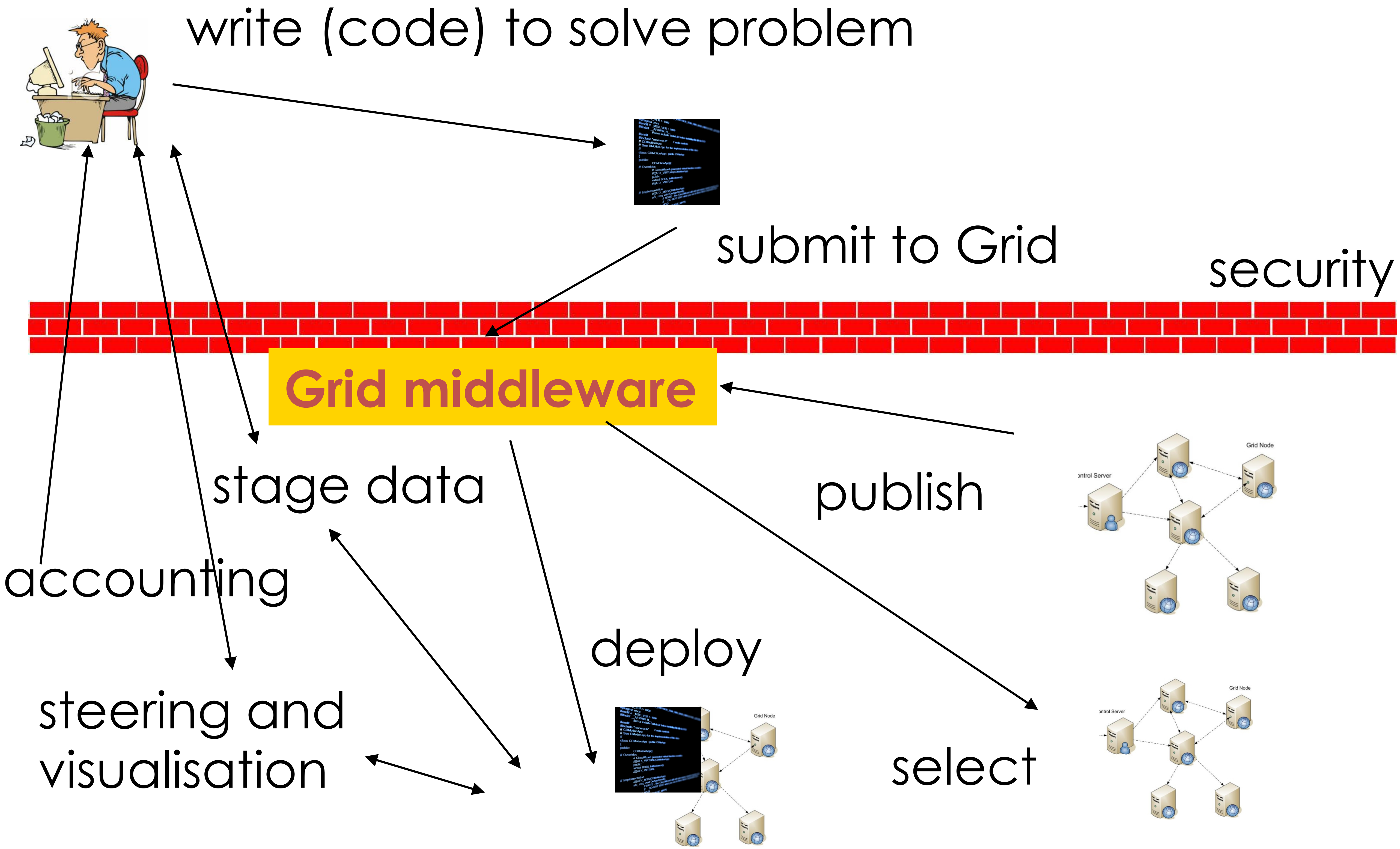
Local Resources Managers

Operating Systems | Queueing Systems | Libraries | Kernels | Internet Protocols

Networked Resources across VOs

Computers | Networks | Storage | Data Sources | Scientific Instruments

Using the Grid



Grid Scenarions

- **Collaboration Grids**
  - Multiple institutions, secure, widely distributed, VOs
  - Collaborative agreements & commercial partnerships
  - Financial Model: Increase overall revenue
- **Data Center Grids** (evolving to Clouds)
  - Centralized management of multiple platforms
  - Aggregation of enterprise resources and applications
  - Financial Model: Reduce Total Cost Ownership (TCO)
- **Cluster Grids**
  - Networks of Workstations, Blades, etc.
  - Cycle scavenging, Homogeneous workload
  - Financial Model: Lower marginal costs

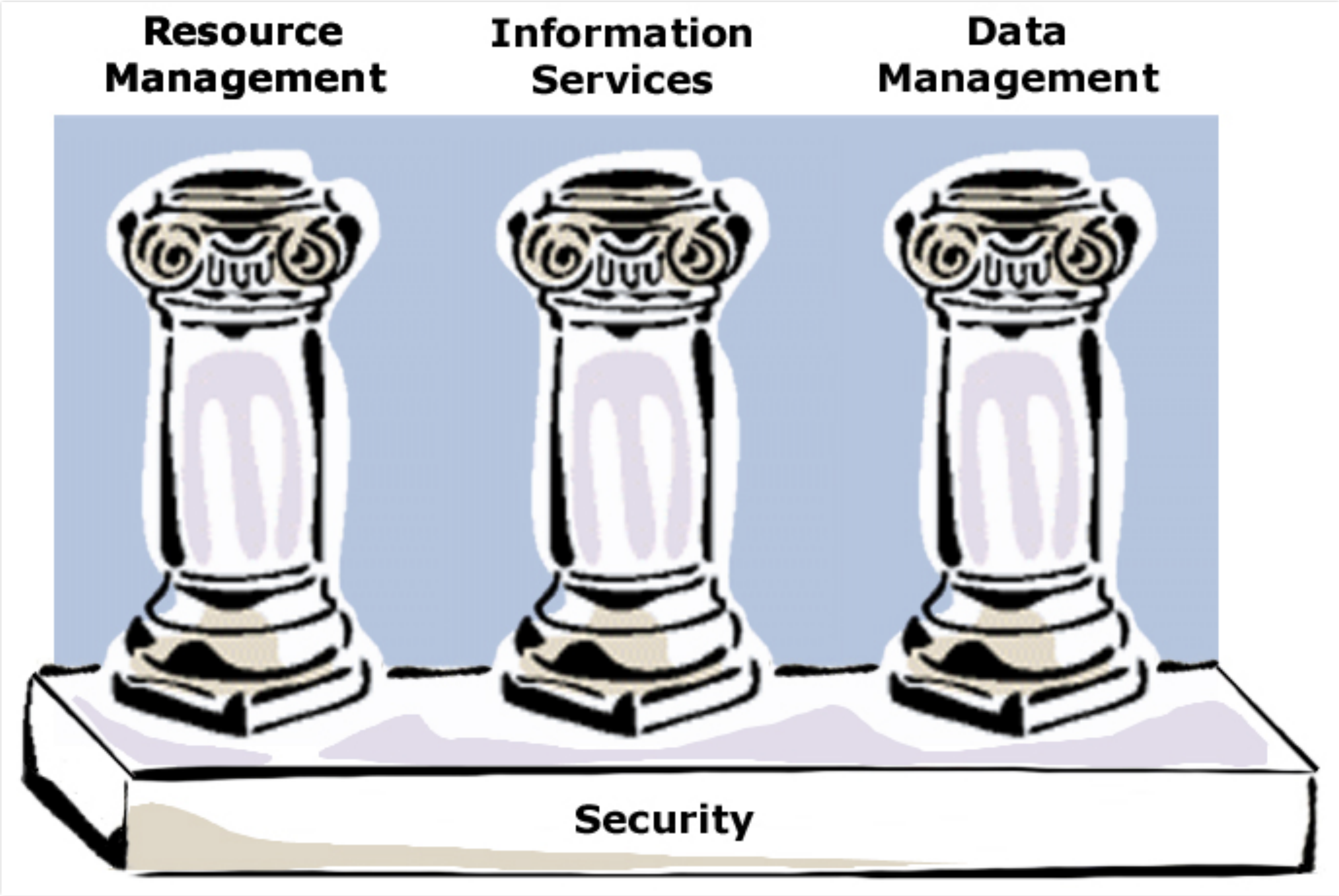
Globus Toolkit

- An example Grid middleware

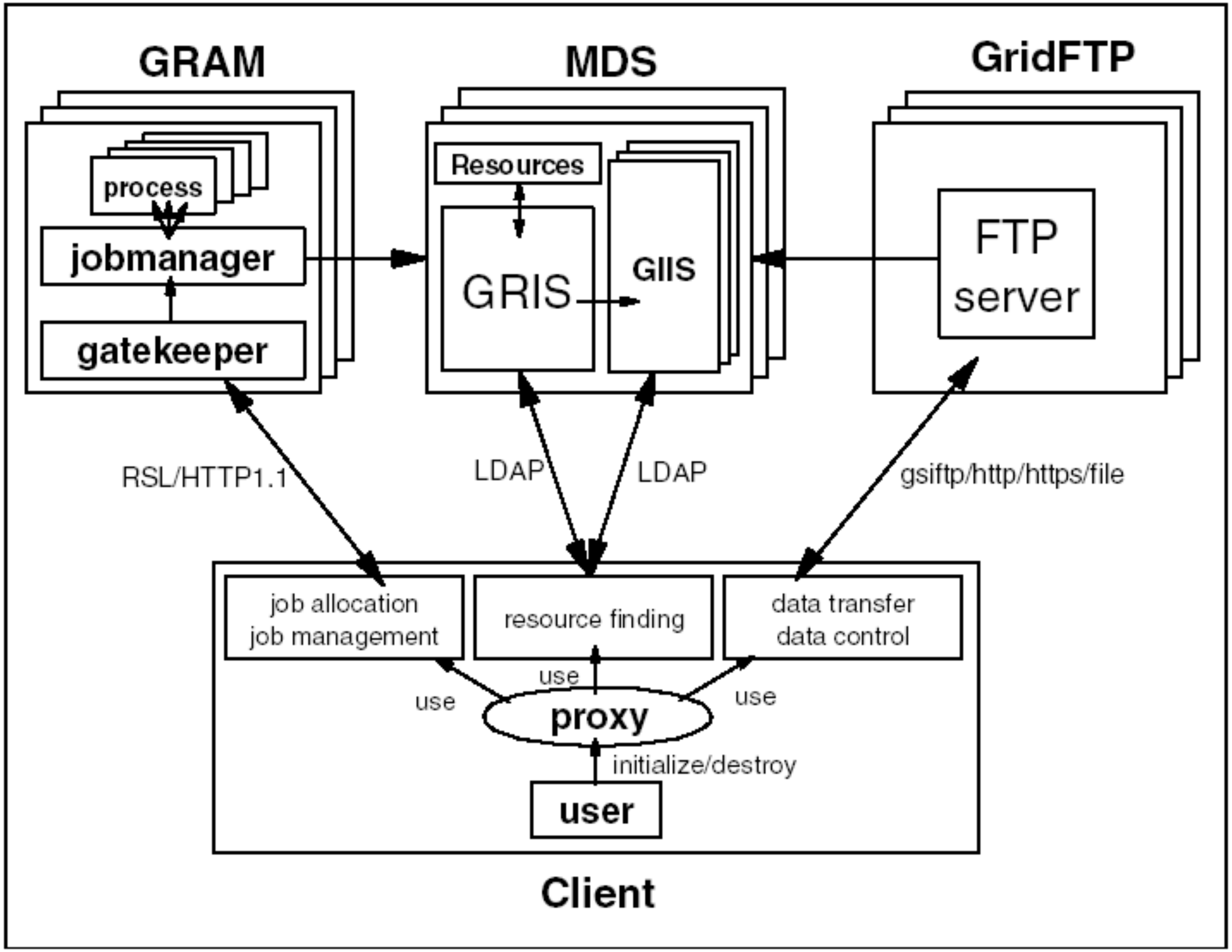
http://www.globus.org/toolkit/

- A software toolkit addressing key technical problems in the development of Grid enabled tools, services, and applications
  - Offer a modular "bag of technologies"
  - Enable incremental development of Grid-enabled tools and applications
  - Implement standard Grid protocols and APIs (the "core" of the hourglass)
  - Is available under liberal open source license
- Now is evolving to Cloud middleware

Key Protocols



GT2 Protocols and Services



ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

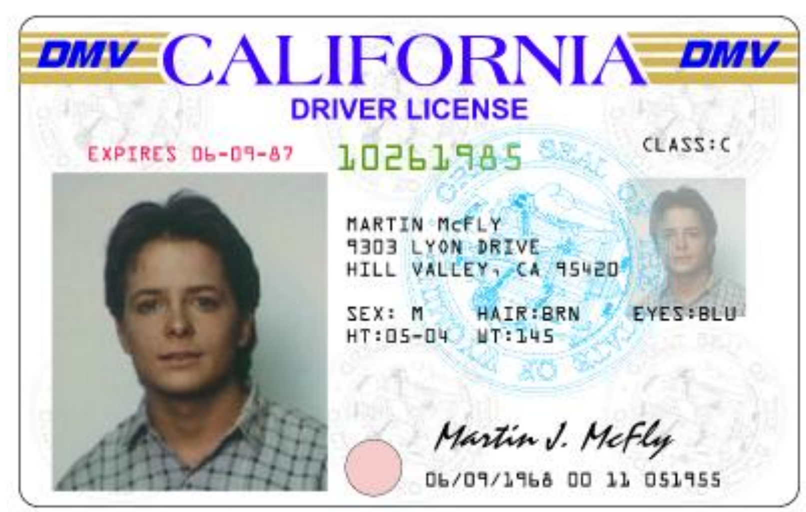
lunedì 24 settembre 12

Grid Security

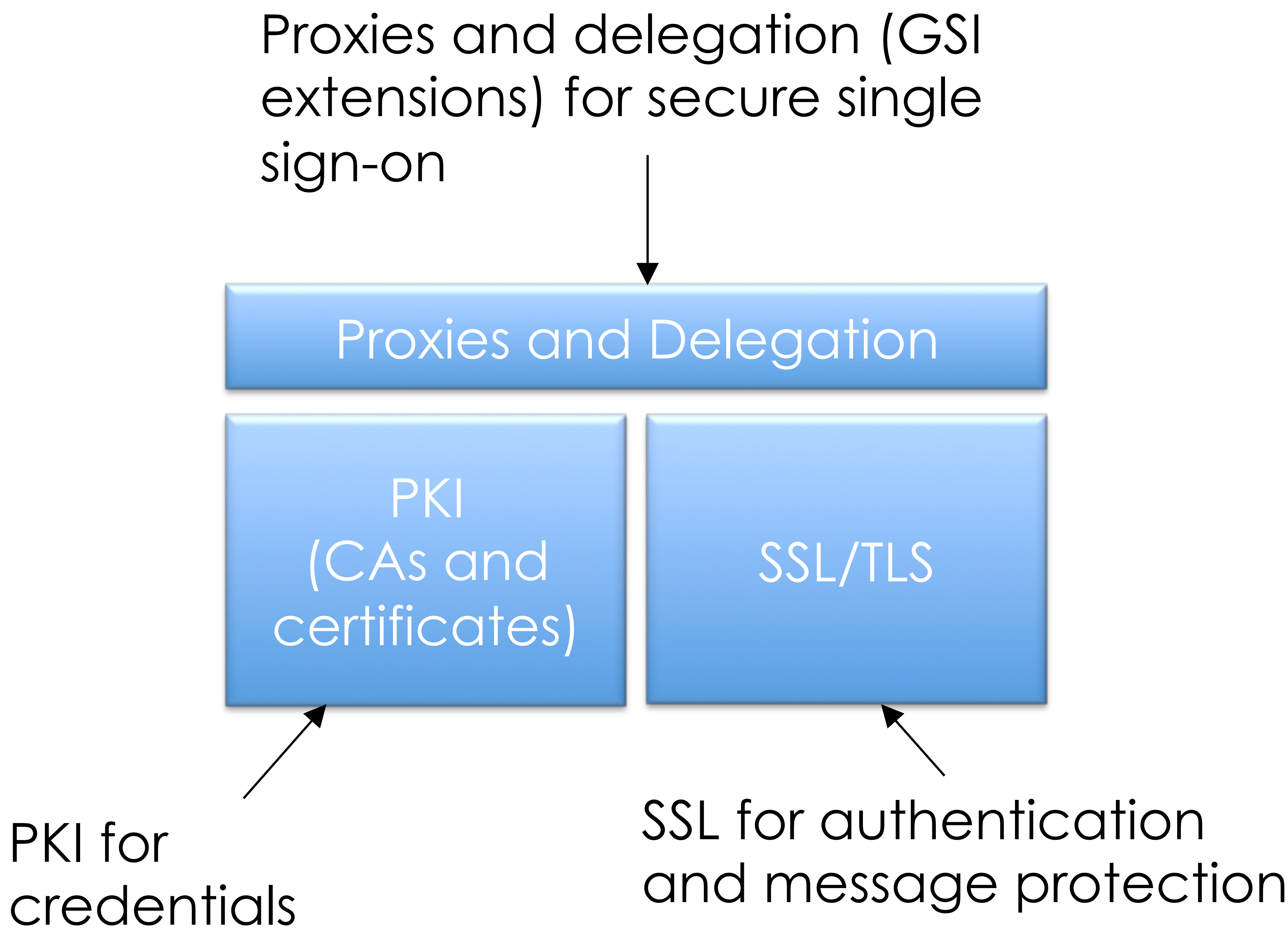
- Resources being used may be valuable & the problems being solved sensitive
- Resources are often located in distinct administrative domains
  - Each resource has own policies & procedures
- Set of resources used by a single computation may be large, dynamic, and unpredictable
  - Not just client/server, requires delegation
- It must be broadly available & applicable
- Standard, well-tested, well-understood protocols; integrated with wide variety of tools

Public Key Infrastructure

- PKI allows you to know that a given public key belongs to a given user
- PKI builds upon asymmetric encryption:
  - Each entity has two keys: public and private
  - Data encrypted with one key can only be decrypted with the other
  - The private key is known only to the owner
- The public key is given to the world encapsulated in a X.509

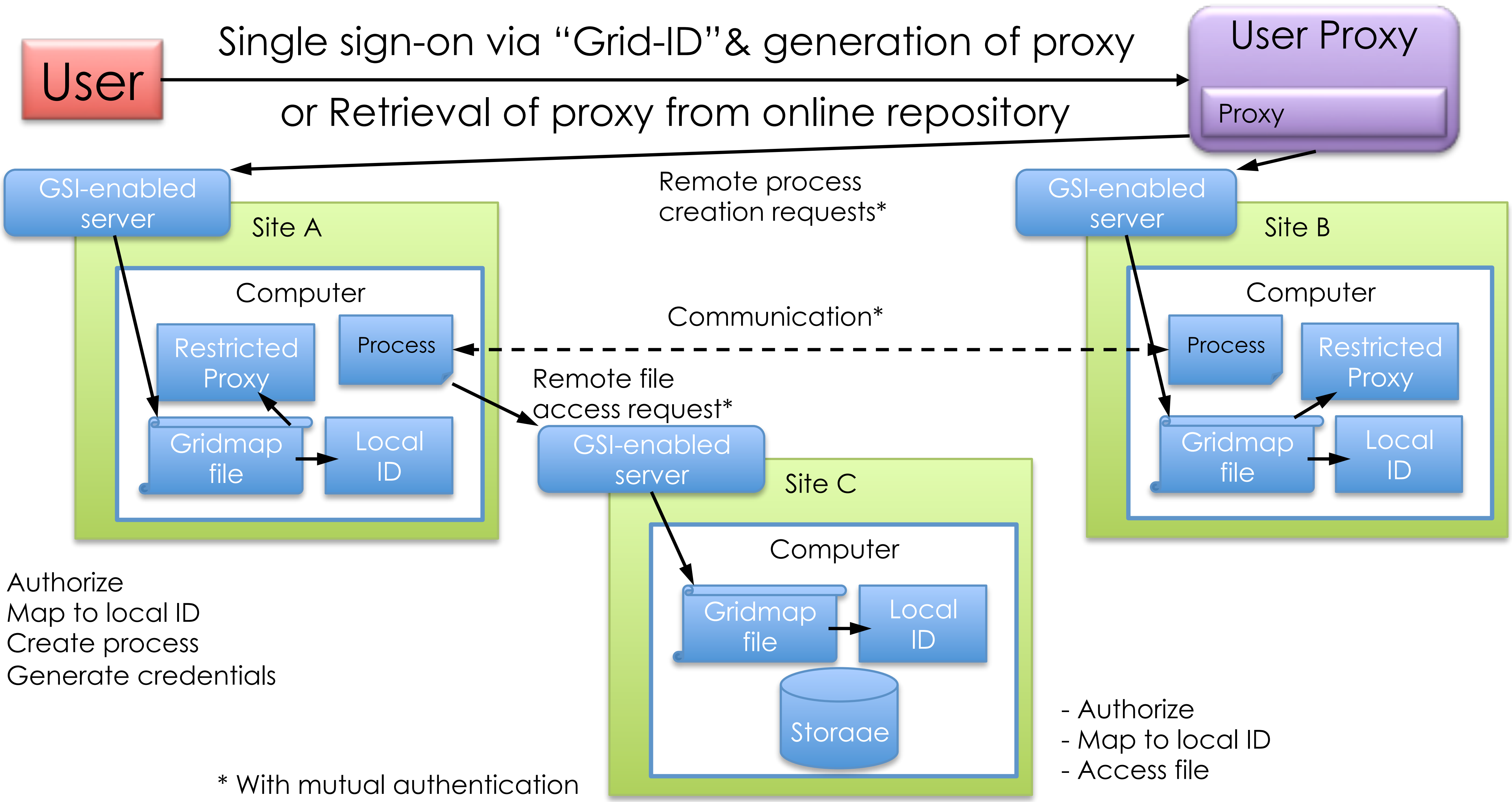


Grid Security Infrastructure



GSI in Action

"Create Processes at A and B that Communicate & Access Files at C"



- Authorize
- Map to local ID
- Create process
- Generate credentials

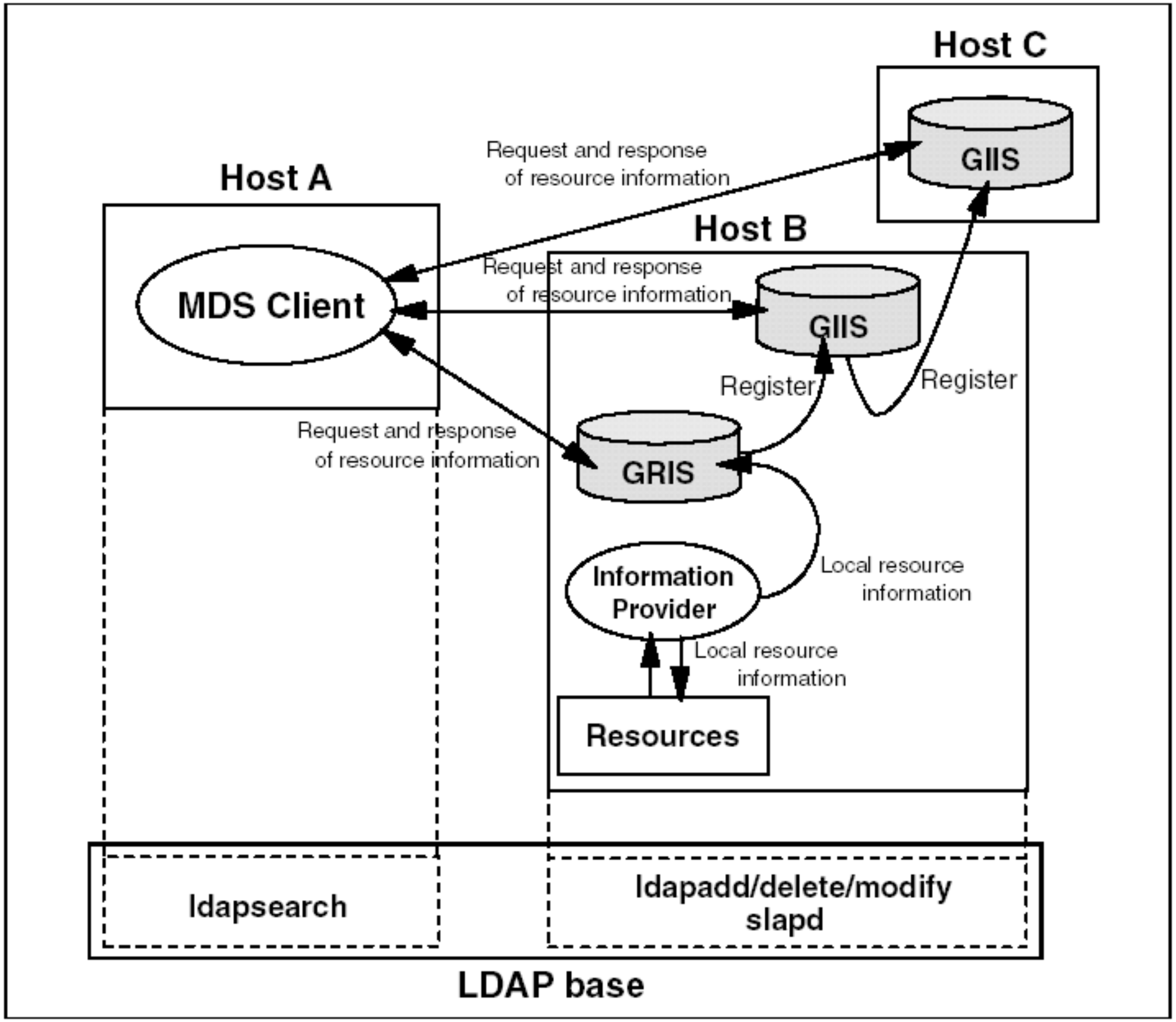
- Authorize
- Map to local ID
- Access file

* With mutual authentication

Grid Information Service

- Provide access to static and dynamic information regarding system components
- A basis for configuration and adaptation in heterogeneous, dynamic environments
- Resource Description Services
  - Supplies information about a specific resource
- Aggregate Directory Services
  - Supplies collection of information which was gathered from multiple resource description services
  - Customized naming and indexing

MDS Protocols and Services



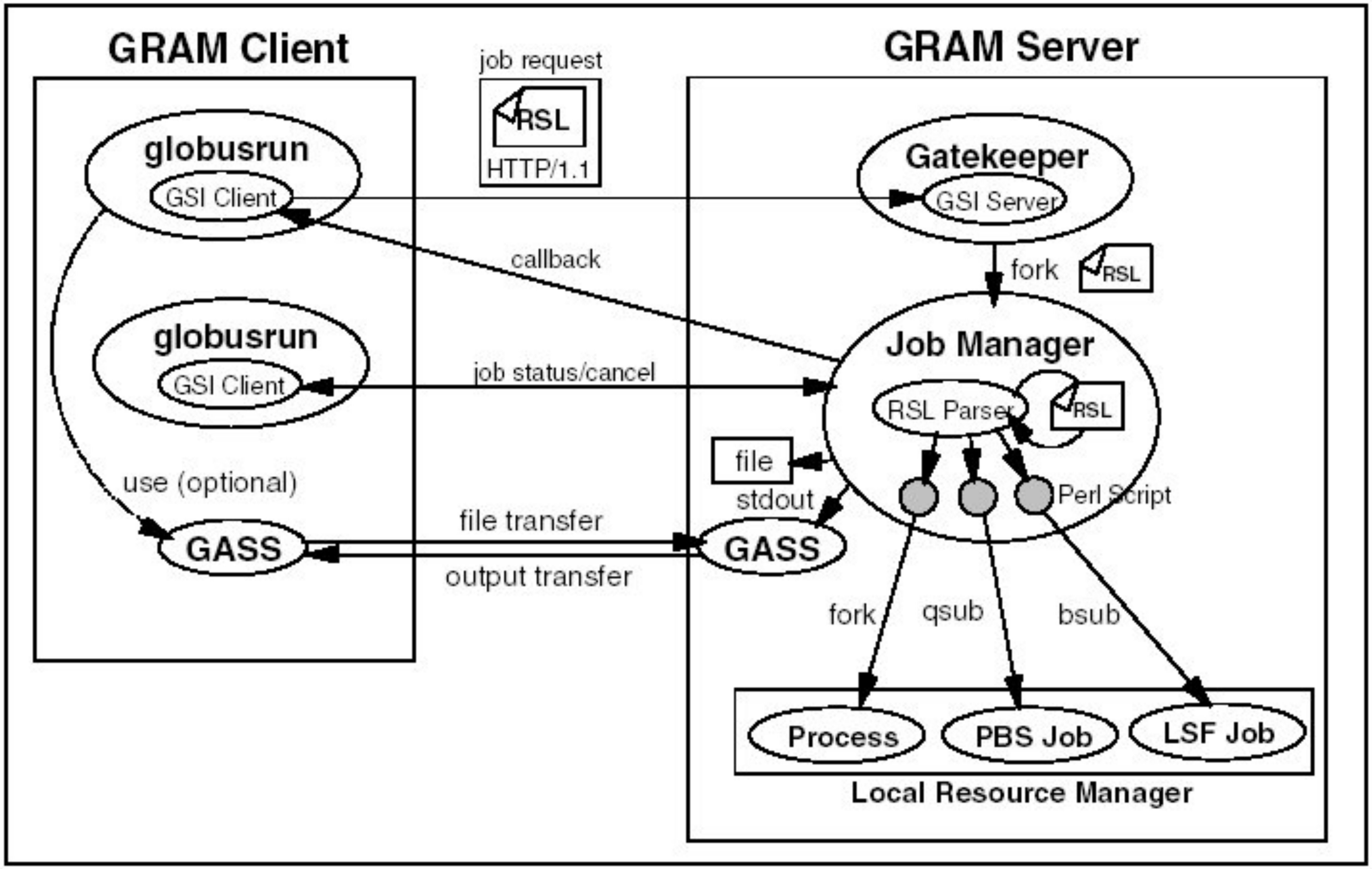
Grid Resource Management

- Grid Resource Management System consists of :
  - Local resource management system (Resource Layer)
    - Basic resource management unit
    - Provide a standard interface for using remote resources
    - Grid Resource Allocation Manager (GRAM)
  - Global resource management system (Collective Layer)
    - Coordinate all Local resource management system within multiple or distributed Virtual Organizations (VOs)
    - Provide high-level functionalities to efficiently use all of resources
      - Job Submission
      - Resource Discovery and Selection
      - Scheduling
      - Co-allocation
      - Job Monitoring, etc.
    - e.g. Meta-scheduler, Resource Broker, etc.

Definitions

- **Resource**: entity able to execute one or more jobs on the behalf of the user
- **Client**: process using GRAM protocol to submit a job request
- **Job**: one or more processes being part of a job request
- **Job request**: a message containing the request and the specification for a job execution on a remote resource. A typical job request specifies:
  - When and where processes should be created
  - How and what processes to create
  - How to execute and terminate processes
- **Gatekeeper**: remote resources service managing incoming job requests (GT2)
- **Job Manager**: service instantiated by the gatekeeper to manage the execution and monitor the job's processes (GT2)

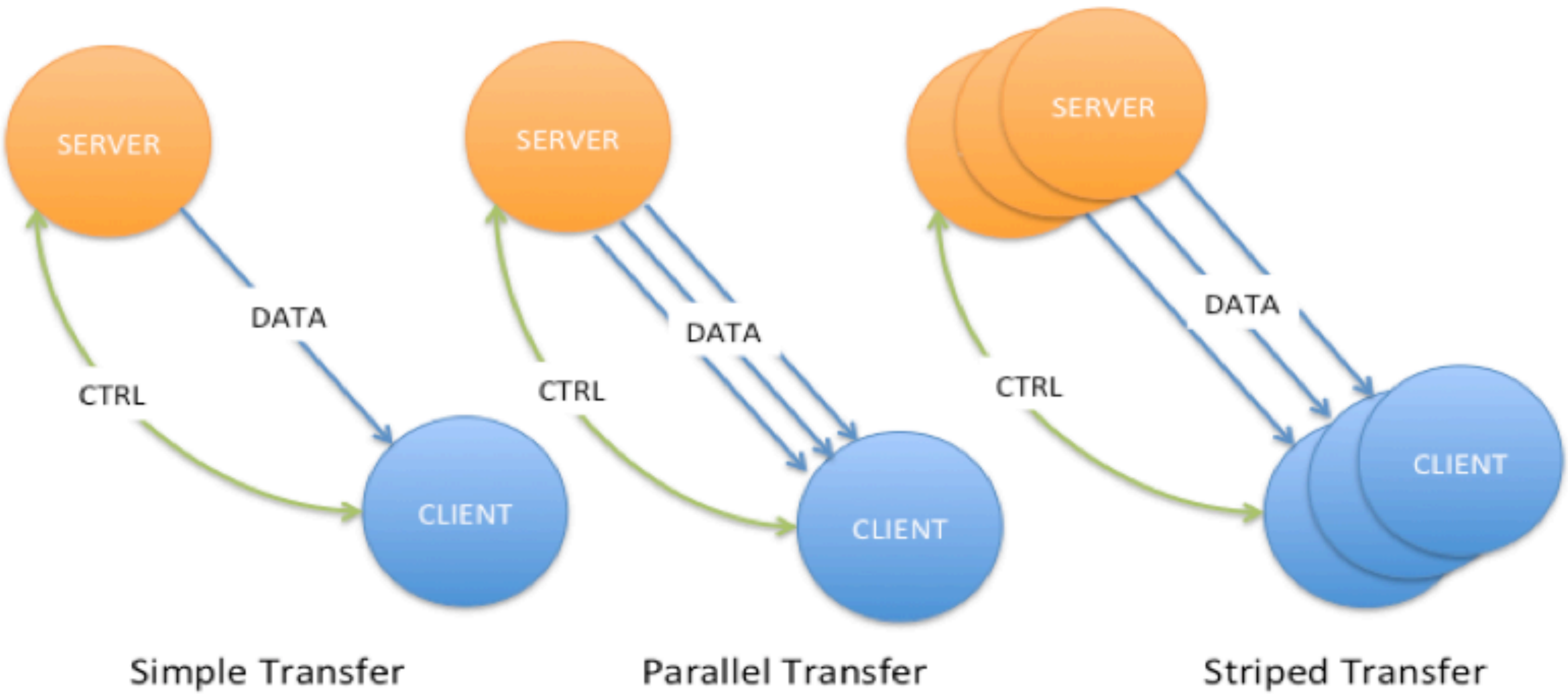
GRAM Protocols and Services



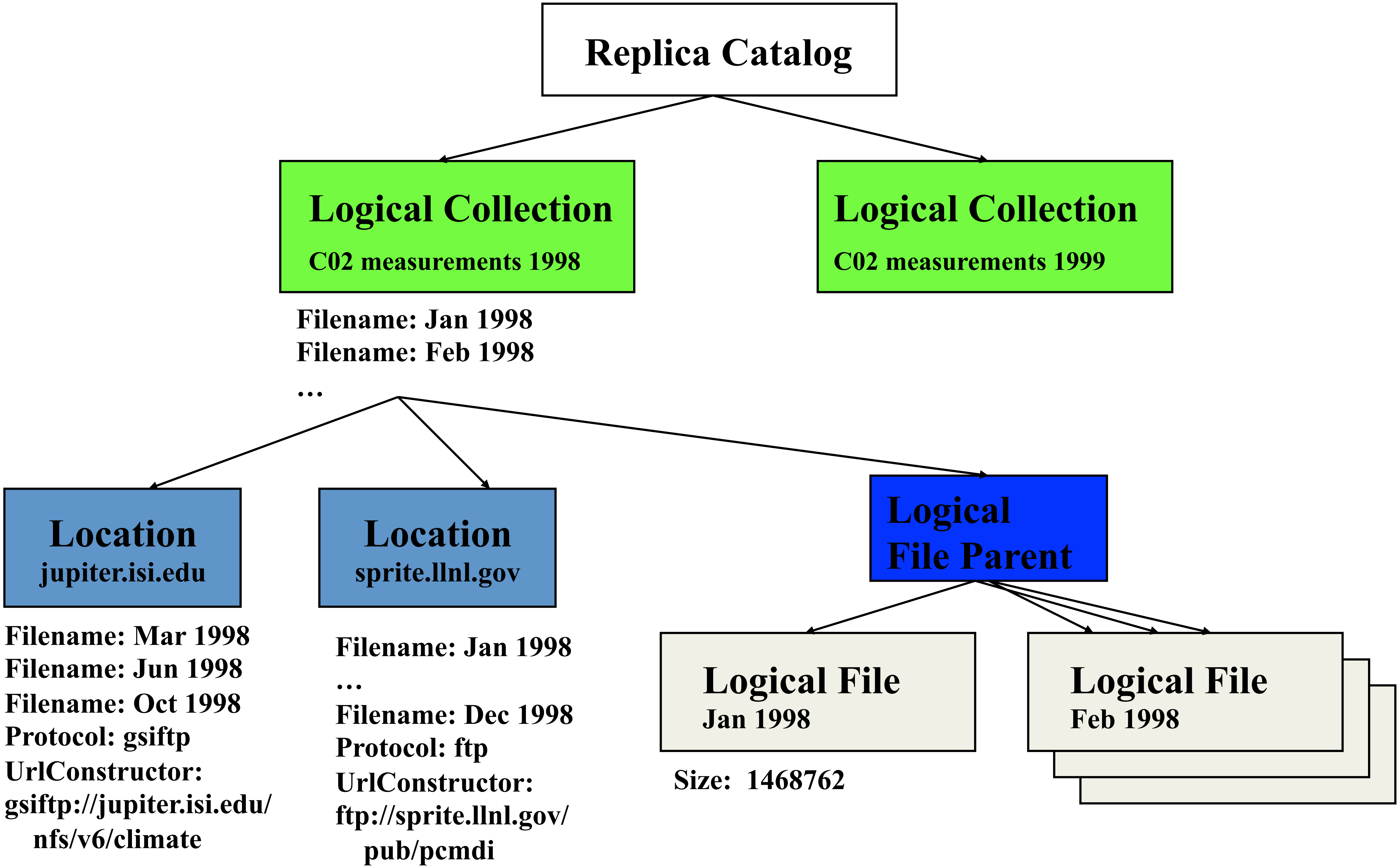
Grid Data Management

- Data access and transfer
  - **GASS**: Simple multi-protocol tool to transfer 'normal' files; integrated in GRAM
  - **GridFTP**: Reliable and high-performance file transfer protocol for 'big' files in computer networks
- Replica Management
  - **Replica Catalog**: Service to keep updated information on sets of replicated data
  - **Replica Management**: Service to create and manage sets of replicated data

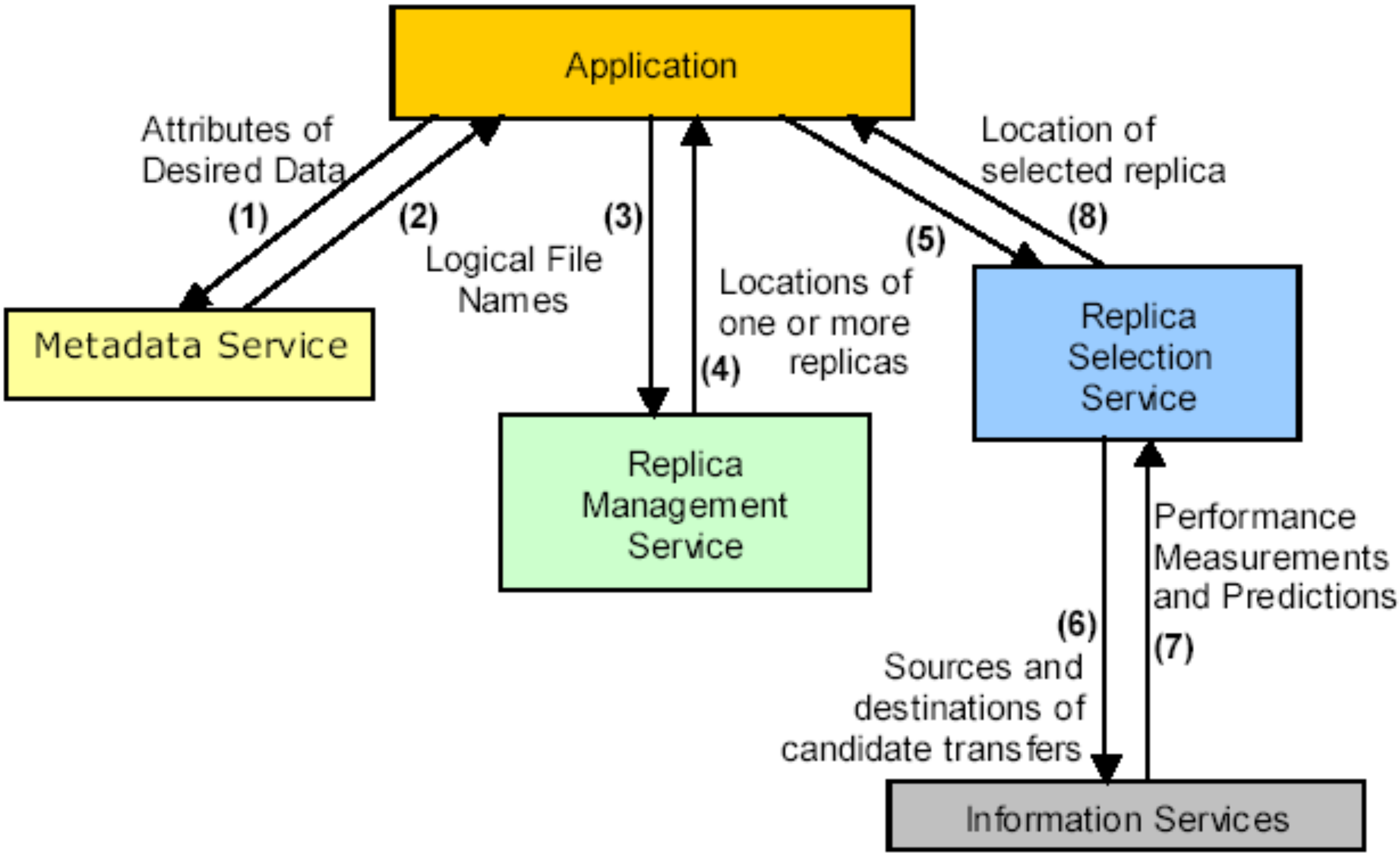
GridFTP


SERVER
DATA
CTRL
CLIENT
SERVER
DATA
CTRL
CLIENT
SERVER
DATA
CTRL
CLIENT
Simple Transfer
Parallel Transfer
Striped Transfer

Replica Catalog



Replica Management



Reading Assignments

- C. Kesselman, et al., *The Anatomy of the Grid: Enabling Scalable Virtual Organizations*, International Journal of Supercomputing Applications, pp. 1-25, 2001.

  http://www.globus.org/alliance/publications/papers/anatomy.pdf

- I. Foster, et al., *The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration*, Globus Research, Work-in-Progress 2002.

  http://www.globus.org/alliance/publications/papers/ogsa.pdf

- Links provided at:

  http://www.cli.di.unipi.it/doku/doku.php/magistraleinformaticanetworking/cpa/start