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The Open Grid Services Architecture

Kate Keahey

keahey@mcs.anl.gov

Ian Foster

foster@mcs.anl.gov

Overview

- Introducing the main players
  - Grid Computing
  - Globus Toolkit
  - Web Service (example)
- The Shape of an OGSA Grid
- The Open Grid Services Architecture
  - Grid Services: what are they? (example)
  - WSDL conventions and extentions
  - OGSA interfaces and behaviors (examples)
  - OGSA Security
- OGSA: status and future

Grid Computing

RED HERRING
TOP TEN TRENDS 2001

DISTRIBUTE THE WEALTH

Distributed computing initiatives.

GLOBUS PROJECT

Globus is a research and development project focused on enabling the application of grid computing concepts to scientific and engineering computing. The grid is an emerging infrastructure protocol that enables the integrated use of remote high-end computers, databases, scientific instruments, networks, and other resources.

I.B.M. Making a Commitment to Next Phase of the Internet

The New York Times

By STEVE LOHR

I.B.M. is announcing today a new initiative to support and exploit a technology known as grid computing, which the company and much of the computer research community say is the next evolutionary step in the development of the Internet.

Computing power on tap

Jun 21st 2001
From The Economist print edition

Economist.com

In the first of two articles, we look at the most ambitious attempt yet to combine millions of computers seamlessly around the world—to make processing power available on demand anywhere, rather like electrical power.

Merrill Lynch

Globus Grid Computing—the Next Internet
by John Roy/Steve Milunovich

The Internet was first a network and is now a communications platform. The next evolutionary step could be to a platform for distributed computing. This ability to manage applications and share data over the network is called "grid computing."

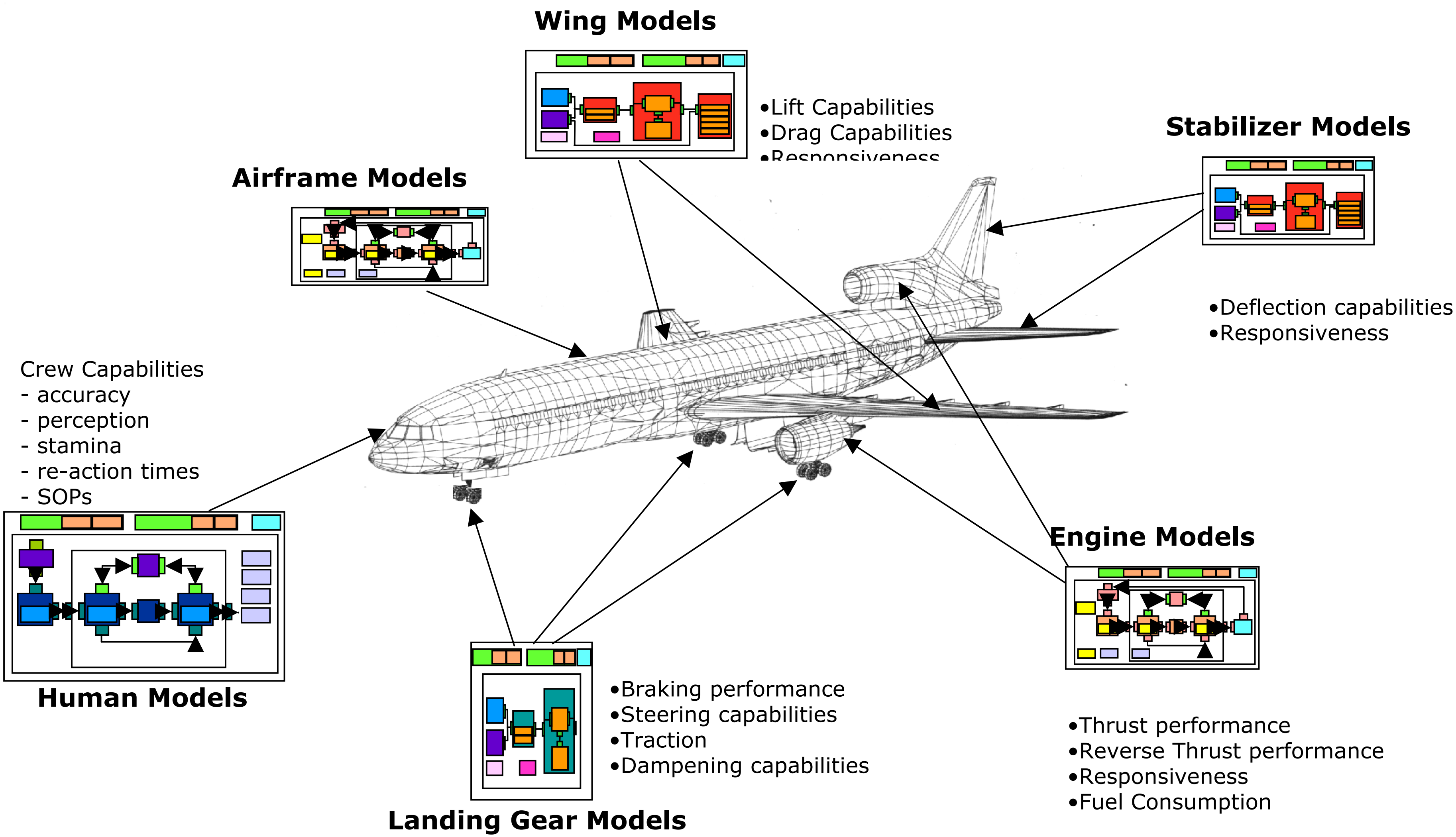
Grid Scenarios (*eScience*)

- A biochemist exploits 10,000 computers to screen 100,000 compounds in an hour
- 1,000 physicists worldwide pool resources for peta-op analyses of petabytes of data
- Civil engineers collaborate to design, execute, & analyze shake table experiments
- Climate scientists visualize, annotate, & analyze terabyte simulation datasets
- An emergency response team couples real time data, weather model, population data

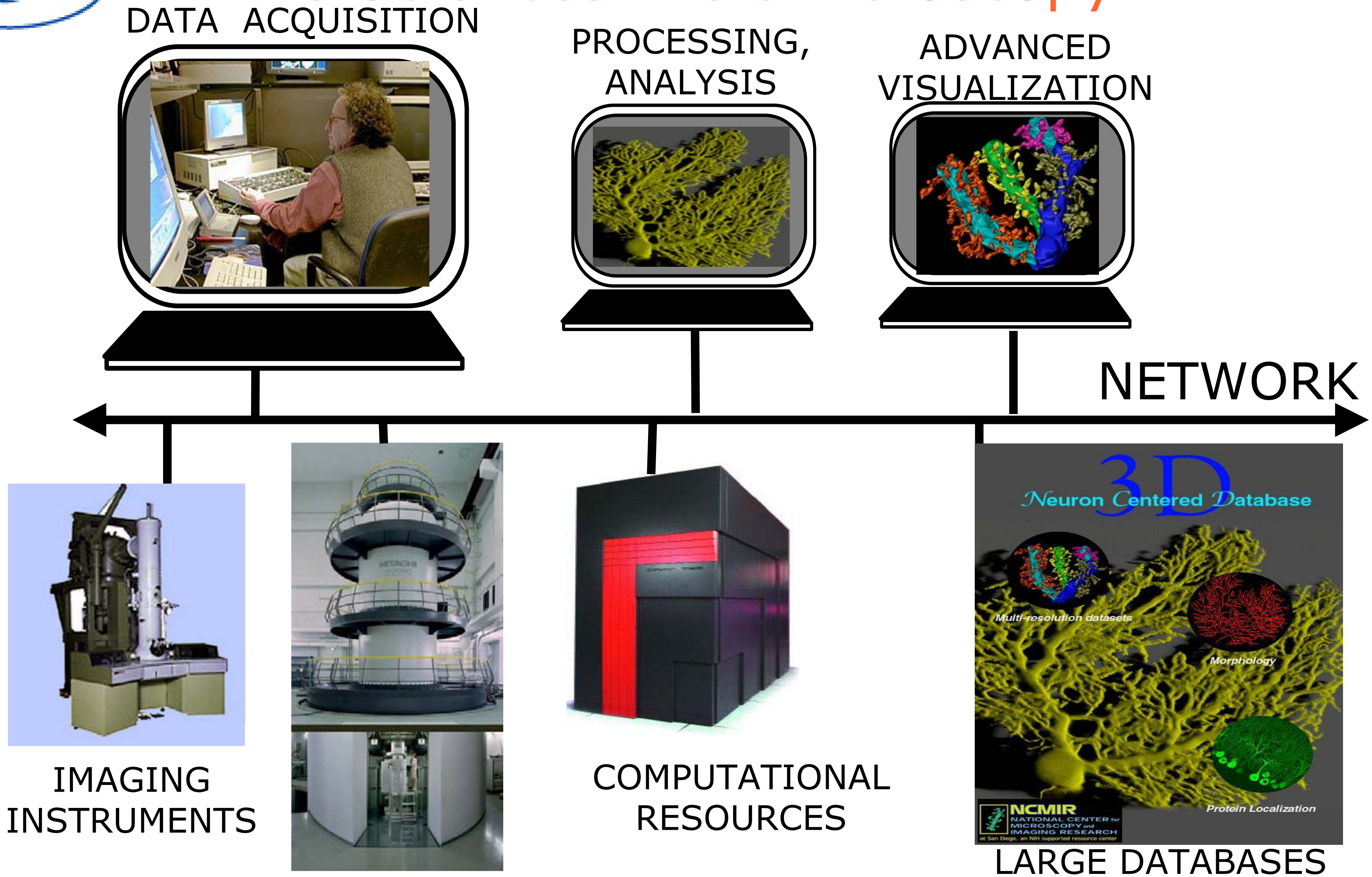
Grid Scenarios (*eBusiness*)

- Engineers at a multinational company collaborate on the design of a new product
- A multidisciplinary analysis in aerospace couples code and data in four companies
- An insurance company mines data from partner hospitals for fraud detection
- An application service provider offloads excess load to a compute cycle provider
- An enterprise configures internal & external resources to support eBusiness workload

Grids at NASA: Aviation Safety

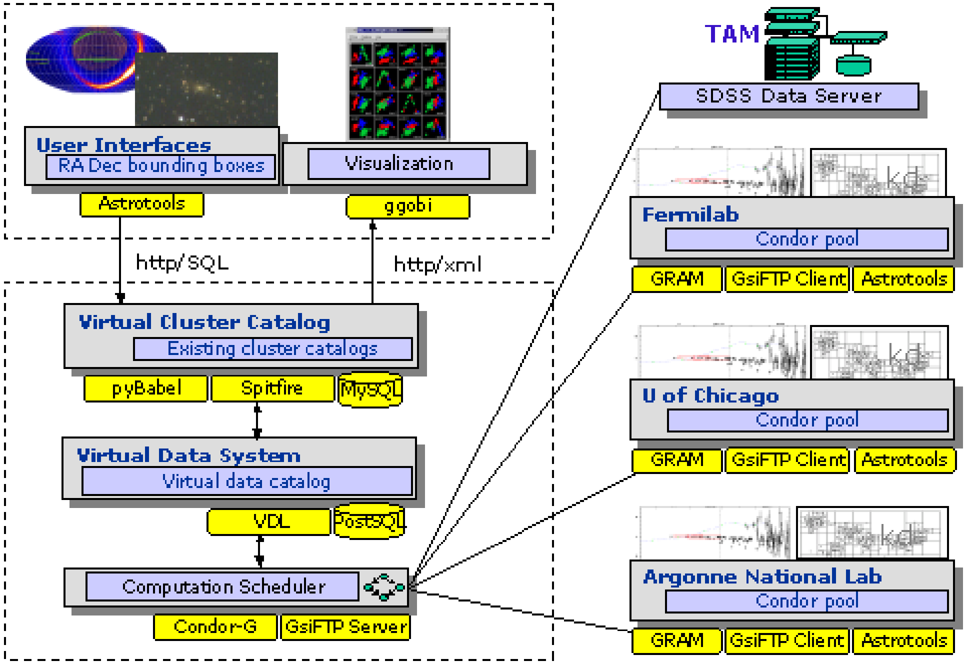


Life Sciences: Telemicroscopy



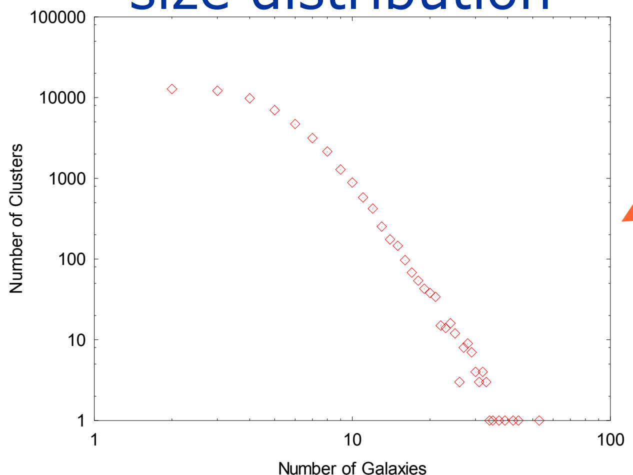
Sloan Digital Sky Survey Analysis

Size distribution of galaxy clusters?



Chimera Virtual Data System
+ GriPhyN Virtual Data Toolkit
+ iVDGL Data Grid (many CPUs)

Galaxy cluster size distribution



www.griphyn.org/chimera

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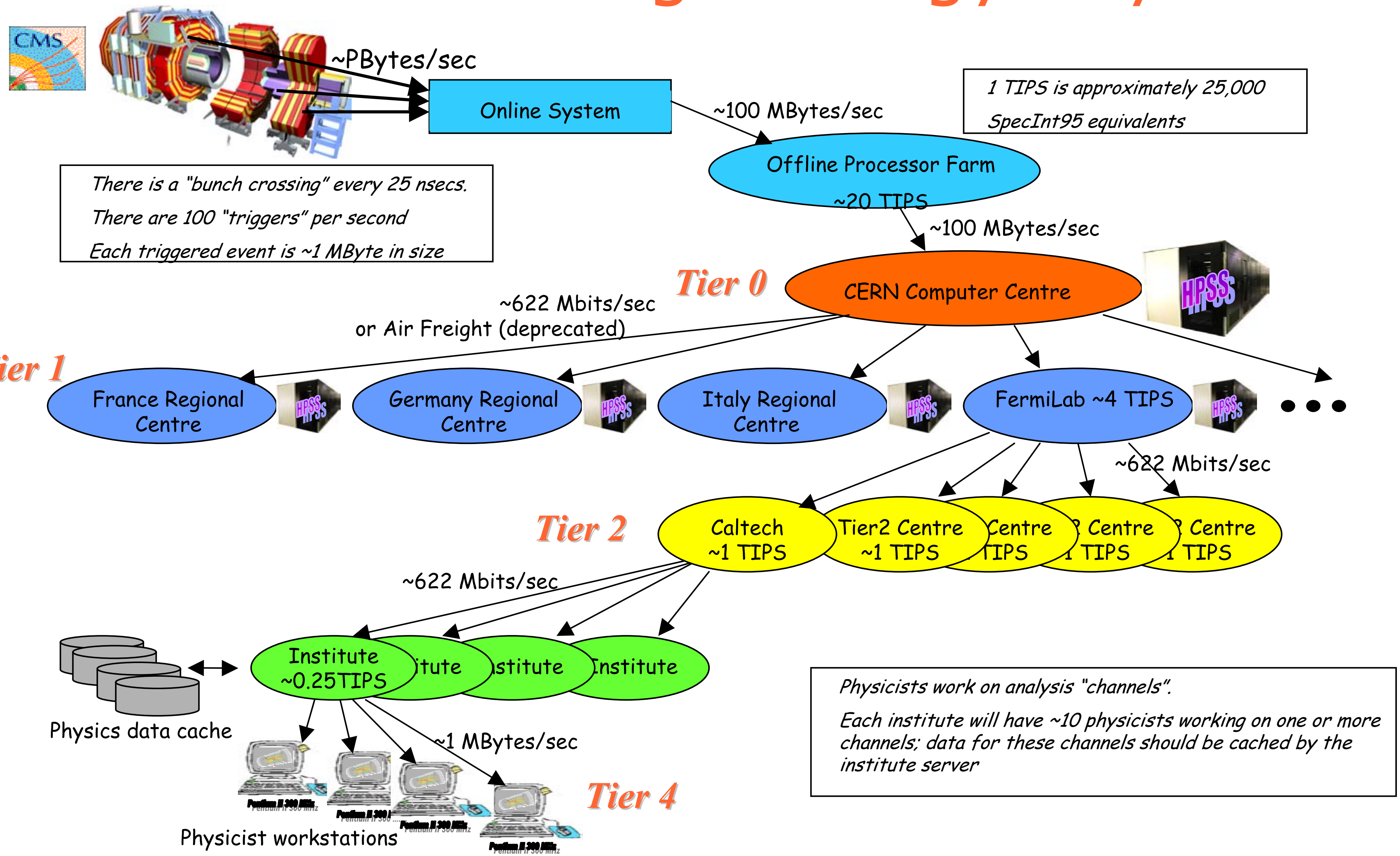
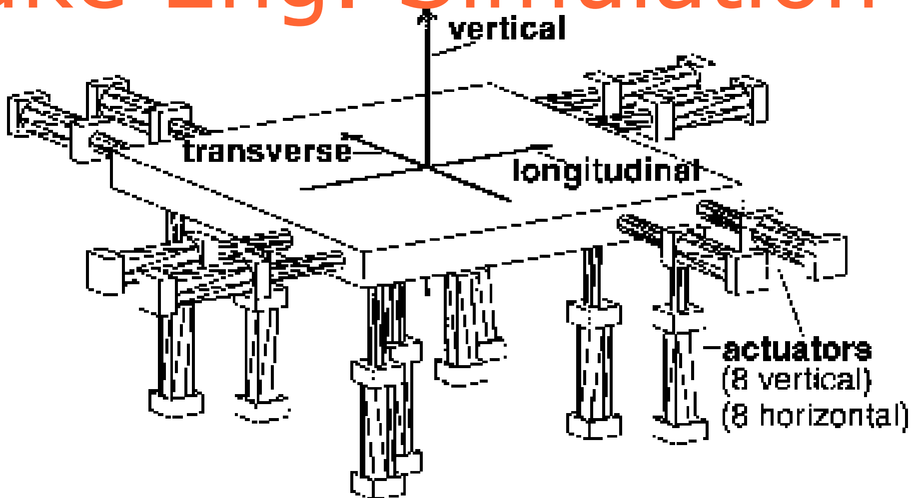
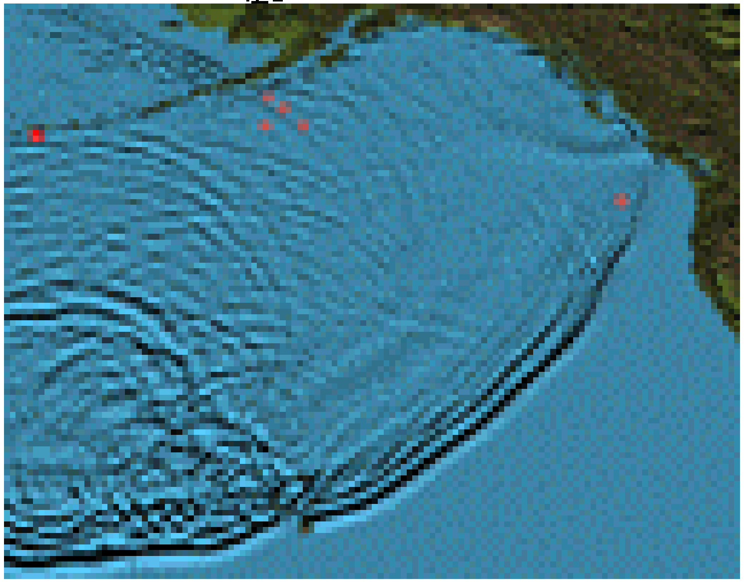
Grid Communities & Applications: Data Grids for High Energy Physics



Grid Communities and Applications: Network for Earthquake Eng. Simulation

- NEESgrid: US national infrastructure to couple earthquake engineers with experimental facilities, databases, computers, & each other
- On-demand access to experiments, data streams, computing, archives, collaboration





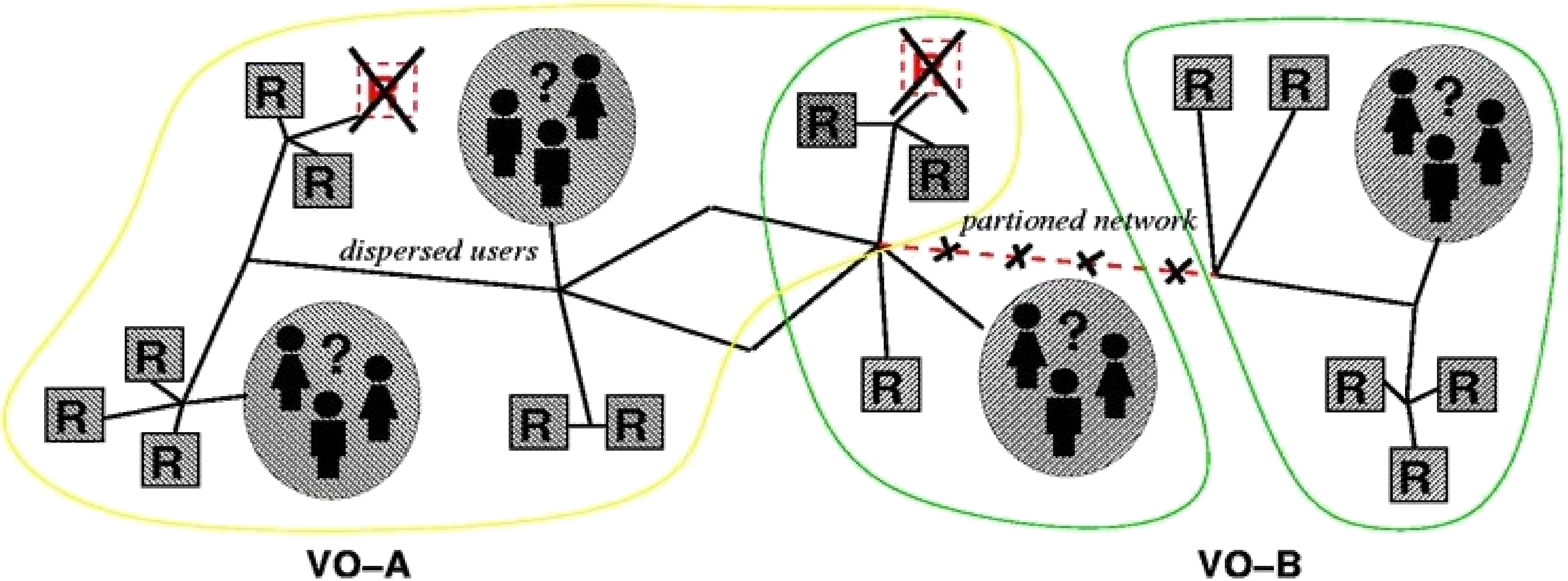
NEESgrid: Argonne, Michigan, NCSA, UIUC, USC www.neesgrid.org

Requirements Include …

- Online negotiation of access to services and resources: who, what, why, when, how
- Establishment of applications and systems able to deliver multiple qualities of service
- Other:
  - Dynamic formation and management of Virtual Organizations (VOs)
  - Autonomic management of infrastructure elements
- In short: open, extensible, evolvable infrastructure

The Grid Problem

Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations



The Grid World: Current Status

- Dozens of major Grid projects in scientific & technical computing/research & education
- Considerable consensus on key concepts and technologies
  - Open source Globus Toolkit™ a de facto standard for major protocols & services
  - Far from complete or perfect, but out there, evolving rapidly, and large tool/user base
- Industrial interest emerging rapidly
- Opportunity: convergence of eScience and eBusiness requirements & technologies

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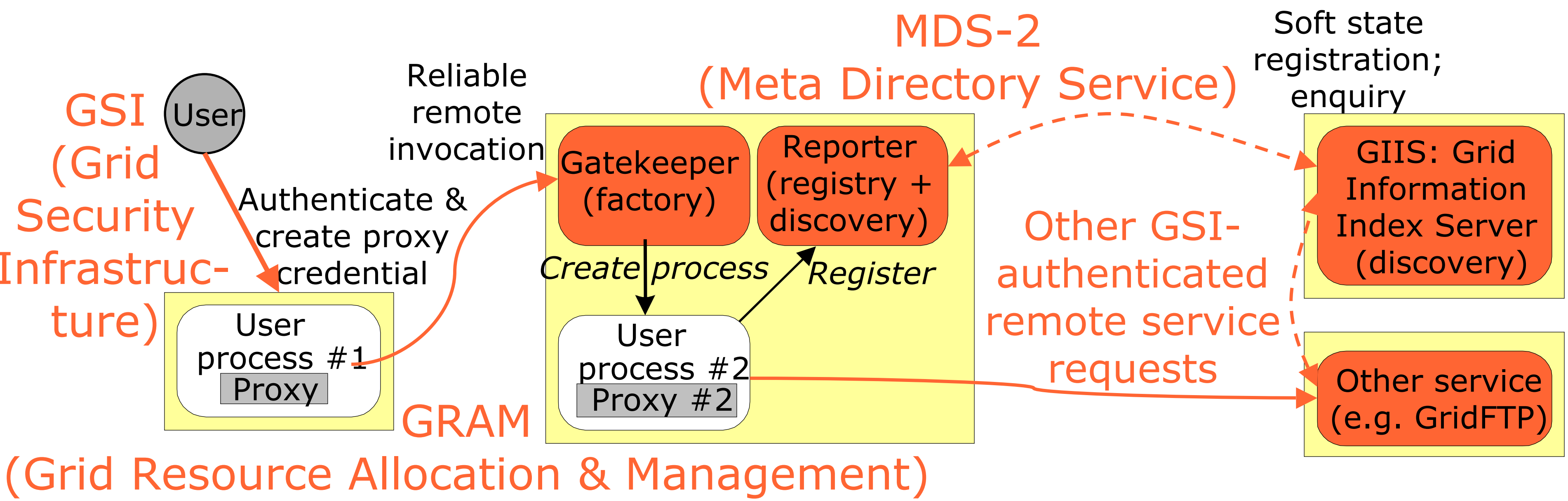
The Globus Toolkit

- Tools enabling resource sharing within VOs
  - GRAM (Grid Resource Allocation and Management)
    - Tool for remote job and resource management
  - GSI (Grid Security Infrastructure)
    - Authentication based on Grid-wide credential
    - Single sign-on, delegation
    - Authorization
  - MDS (Monitoring and Discovery Service)
    - Grid-wide information on the state of resources
  - Data Grid Technologies
    - GridFTP
    - Replica Management
    - Virtual data
- Protocols and APIs

The Globus Toolkit in One Slide

- Grid protocols (GSI, GRAM, …) enable resource sharing within virtual orgs; toolkit provides reference implementation (= Globus Toolkit services)



- Protocols (and APIs) enable other tools and services for membership, discovery, data mgmt, workflow, …

Globus Toolkit: Evaluation (+)

- Good technical solutions for key problems, e.g.
  - Authentication and authorization
  - Resource discovery and monitoring
  - Reliable remote service invocation
  - High-performance remote data access
- This & good engineering is enabling progress
  - Good quality reference implementation, multi-language support, interfaces to many systems, large user base, industrial support
  - Growing community code base built on tools

Globus Toolkit: Evaluation (-)

- Protocol deficiencies, e.g.
  - Heterogeneous basis: HTTP, LDAP, FTP
  - No standard means of invocation, notification, error propagation, authorization, termination, …
- Significant missing functionality, e.g.
  - Databases, sensors, instruments, workflow, …
  - Virtualization of end systems (hosting envs.)
- Little work on total system properties, e.g.
  - Dependability, end-to-end QoS, …
  - Reasoning about system properties

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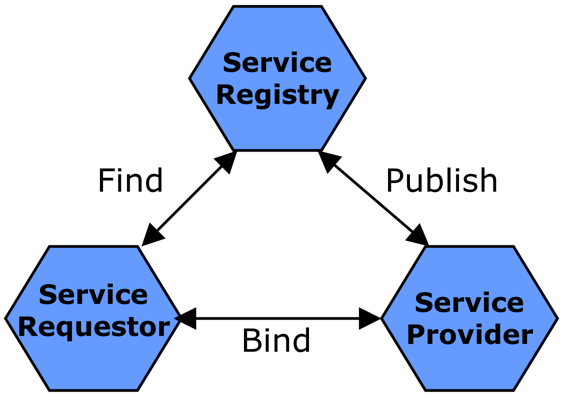
What is a Web service?

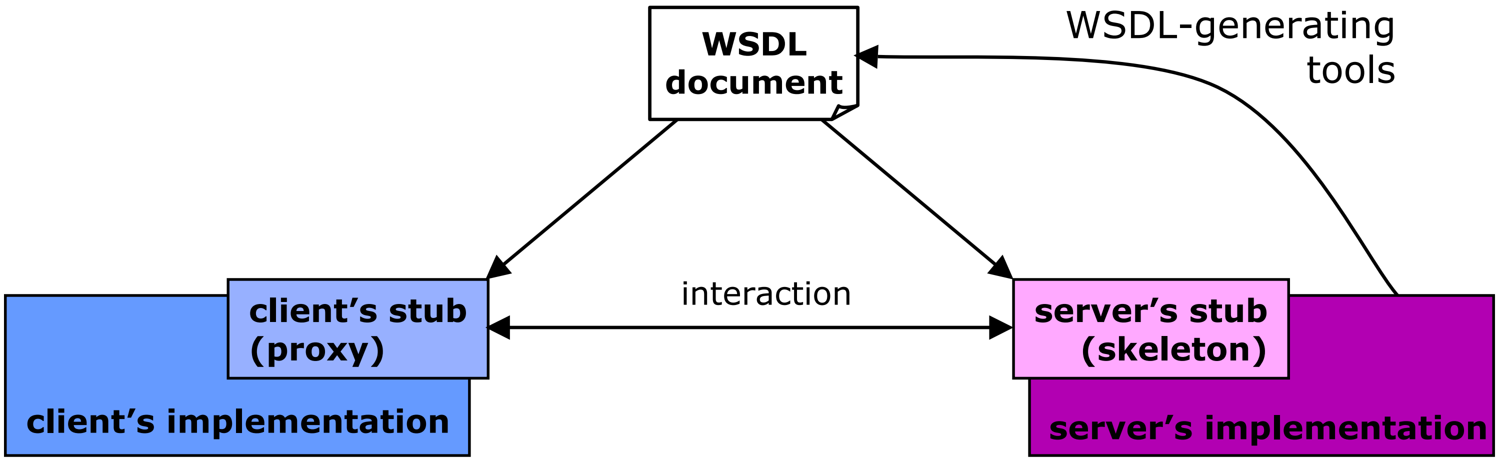
- Web service is an entity that can be:
  - Described (using WSDL)
  - Published
  - Discovered
  - Invoked by a client
- W3C technology standardization process
- Often associated with specific technologies and implementations
  - Standards: XML, WSDL, SOAP, UDDI
  - Implementations: WebSphere, .NET, others…

Service-Oriented Architecture



- Publish
  - WSDL: Web Services Description Language
  - UDDI: Universal Description, Discovery & Integration
- Find
  - WS-Inspection
- Bind
  - SOAP: Simple Object Access Protocol

WS: Mode of Operation



- Stubs:
  - Serialize/deserialize (encoding)
  - Implement interaction
- WSDL-generating tools
  - Significantly facilitate working with Web services
  - Strive to make the process transparent

WSDL Document Structure

- WSDL: Web Services Definition Language
- Document structure:
  - Service Description
  - Implemenation Details
- Service Description
  - Elements
    - PortType (~ class)
    - Operations (~ method)
    - Messages, message parts (~ parameters)
    - Types (type definitions)
  - Used for
    - Generating stubs and skeletons
    - Service discovery

WSDL Document Structure (cntd)

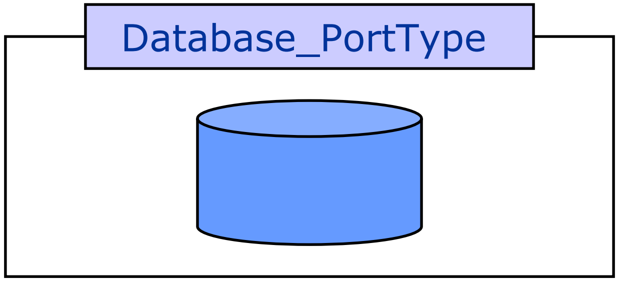
- Implementation Details
  - Binding
    - Messaging protocol (eg. SOAP)
    - Message Interpretation (eg. RPC or literal)
    - Data-encoding model (eg. SOAP or literal encoding)
    - Transport protocol (eg. HTTP or FTP)
  - Port: describes service endpoint
  - Service Element: groups Port elements together
- Others:
  - Definition: root element of a SOAP document

Web Service Technologies

- Simple Object Access Protocol (SOAP)
  - XML-based messaging protocol
  - Independent of the underlying transport protocol
    - HTTP, FTP, etc.
- WS-Inspection
  - XML language and conventions for locating service descriptions
  - WSIL: WS Inspection Language
  - Service description
    - Link to WSDL document
    - UDDI entry
- Other
  - WSFL: Web Services Flow Language

WS Example: Database Service

- WSDL definition for “Database_PortType” defines operations and bindings, e.g.:
  - QueryOperation(Query, Response)
  - Accessible over SOAP



Database: Service Description

```
<types>
 <schema targetNamespace="http://samples.ogsa.globus.org/database/database.xsd"
            xmlns="http://www.w3.org/2001/XMLSchema">

   <complexType name="query">
          <sequence>
                   <element name="send_query" type="string"/>
          </sequence>
   </complexType>
 </schema>
</types>

<message name="myDatabaseQuery">
       <part name="query_parameter" type="query"/>
</message>

<message name="myDatabaseResponse">
       <part name="response_parameter" type="“string"/>
</message>

<portType name="Database_PortType">
       <operation name="databaseQueryOperation">
              <input message="tns:myDatabaseQuery"/>
              <output message="tns:myDatabaseResponse"/>
       </operation>
</portType>
```

“parameter” type

“parameter”

“class”

“method”

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Database: Implementation

use SOAP

interpret as RPC call

use http for transport

```
<binding name="Database_Binding" type="tns:Database_PortType">
    <soap:binding style="rpc" transport="http://schemas.xmlsoap.org/soap/http"/>
    <operation name="databaseQueryOperation">
        <soap:operation soapAction="do_databaseQueryOperation"/>
        <input>
            <soap:body encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
                use="encoded" namespace="http://samples.ogsa.globus.org/database"/>
        </input>

        <output>
            <soap:body encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
                use="encoded" namespace="http://samples.ogsa.globus.org/database"/>
        </output>
    </operation>
</binding>

<service name="Database_Service">
    <port name="Database_Port" binding="tns:Database_Binding">
        <soap:address location="http://ept.mcs.anl.edu:8080/axis/services/Database_Port"/>
    </port>
</service>
```

use SOAP encoding

the service is located here

Web Services Evaluation (+)

- Key to success:
  - Emphasize protocols rather than APIs
  - Build on established technologies and protocols
  - Web-wide rather than enterprise-wide scope
  - A set of independent technologies
  - Industry support

Web Services Evaluation (-)

- Developing technology:
  - Lack of standard language bindings
  - Others
- Web Services applied to Grids:
  - WS describe <u>persistent</u> services
    - For Grids we must also support transient instances
    - Lifecycle management issues
  - Need to provide information about a service
    - Need ways to access that information
  - Implications on how services are managed

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WS+Grids: Benefits of the Union

- Service orientation
  - virtualize resources
  - unify resources/services/information
- Capitalize on useful WS properties
  - Standards for service description and discovery
  - Leverage commercial efforts
- Refactor Globus protocol suite to enable common base and expose key capabilities
- Provide a unifying architecture for computational Grids

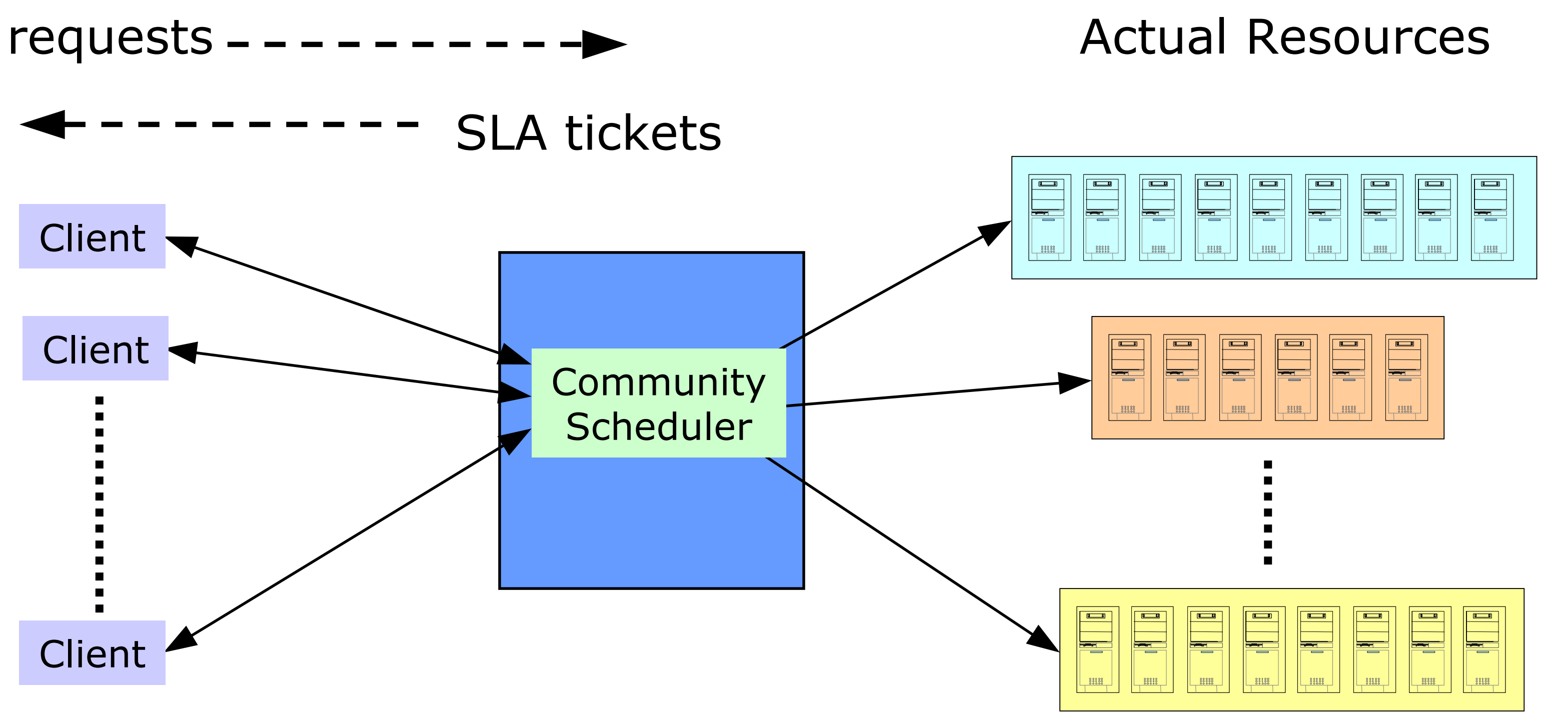
Globus Toolkit Refactoring

- Grid Security Infrastructure (GSI)
  - Used in Grid service network protocol bindings
  - Also: Security Services
- Meta Directory Service 2 (MDS-2)
  - Native part of each Grid service:
    - Discovery, Notification, Registry, RegistryManagement
- Grid Resource Allocation & Mngt (GRAM)
  - Job Manager Service
  - Gatekeeper -> Factory for job mgr instances
- GridFTP
  - Refactor control channel protocol
- Other services refactored to used Grid Services

Moving Forward with Grid Services

- Benefits of service orientation
  - Focus on interface
    - Minimal shared understanding between interacting entities
  - Local/remote transparency
  - Modularity, Reusability, etc.
- Virtualization
  - Encapsulation of diverse implementation behind a common interface
  - Defining interactions with services in terms of QoS constraints and Service Level Agreements (SLA)
  - Living up to SLAs: Adaptive behaviors

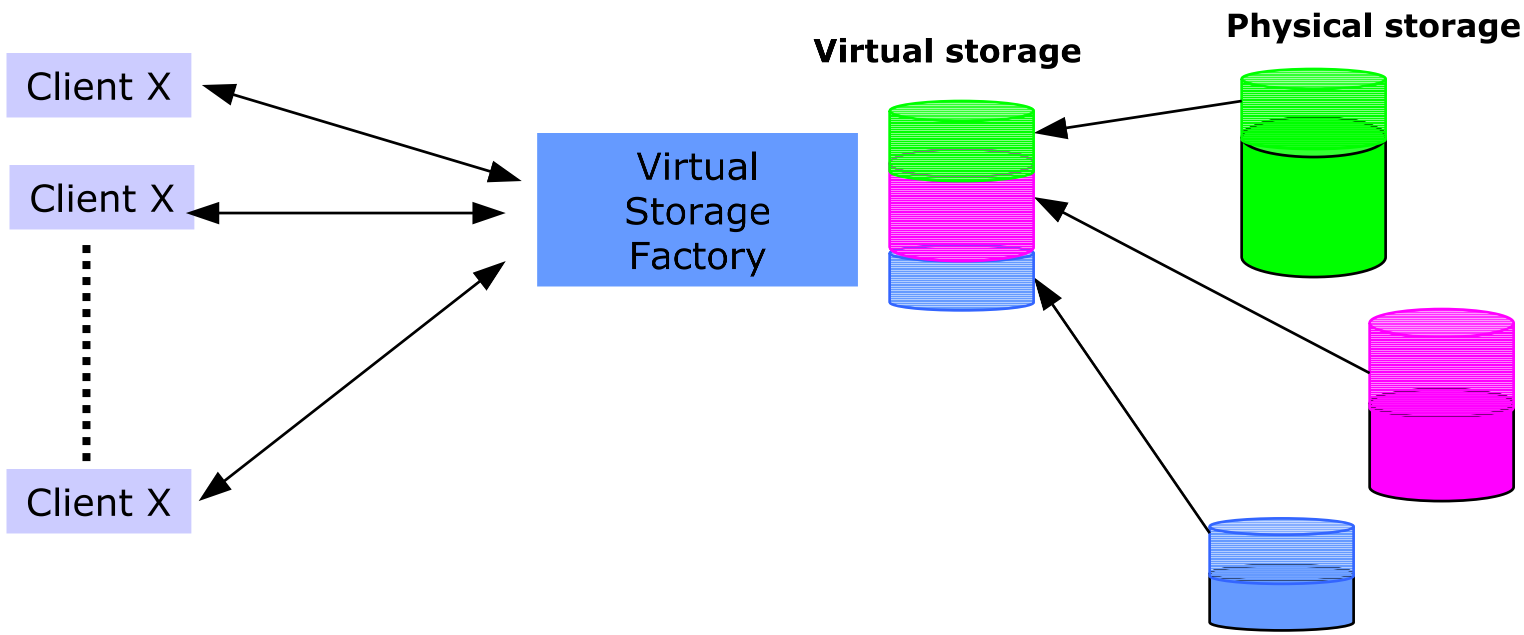
Towards Virtualizing Resources



- SNAP: Service Negotiation and Acquisition Protocol

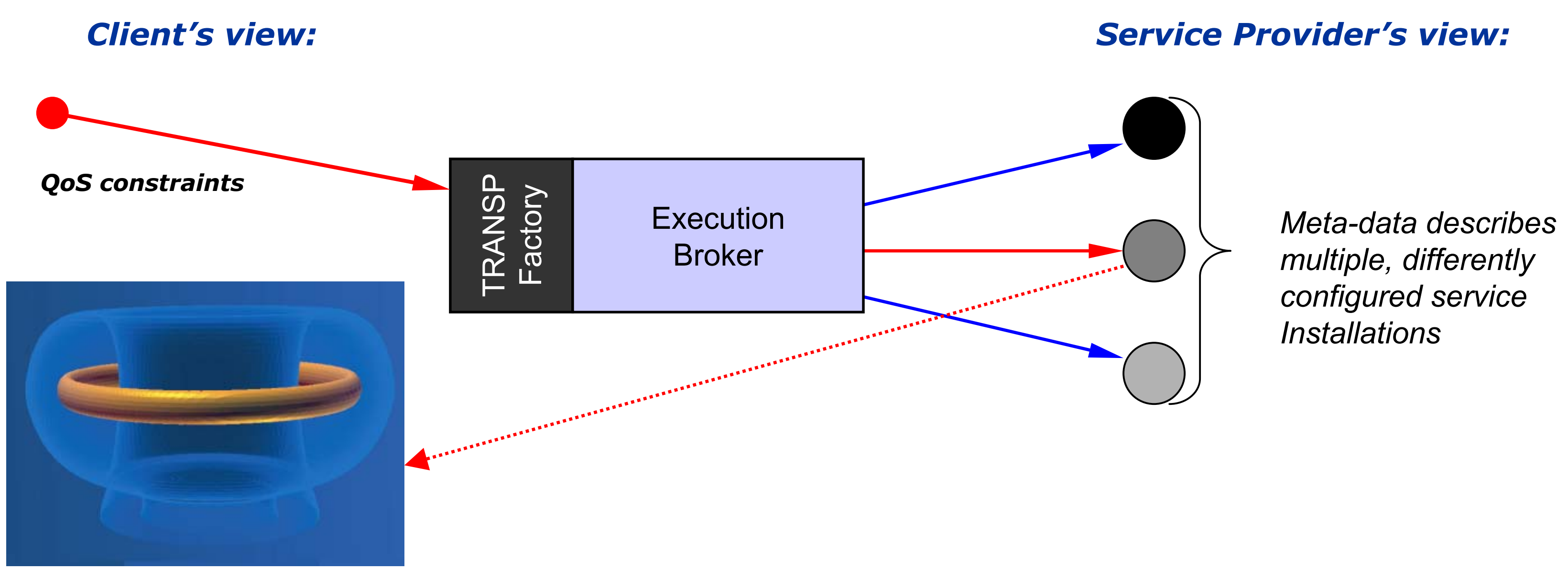
Virtualizing Resources: Example

- Application: Virtual Storage
  - Garbage collecting unused space in an organization
  - Providing it to users as "virtual storage"

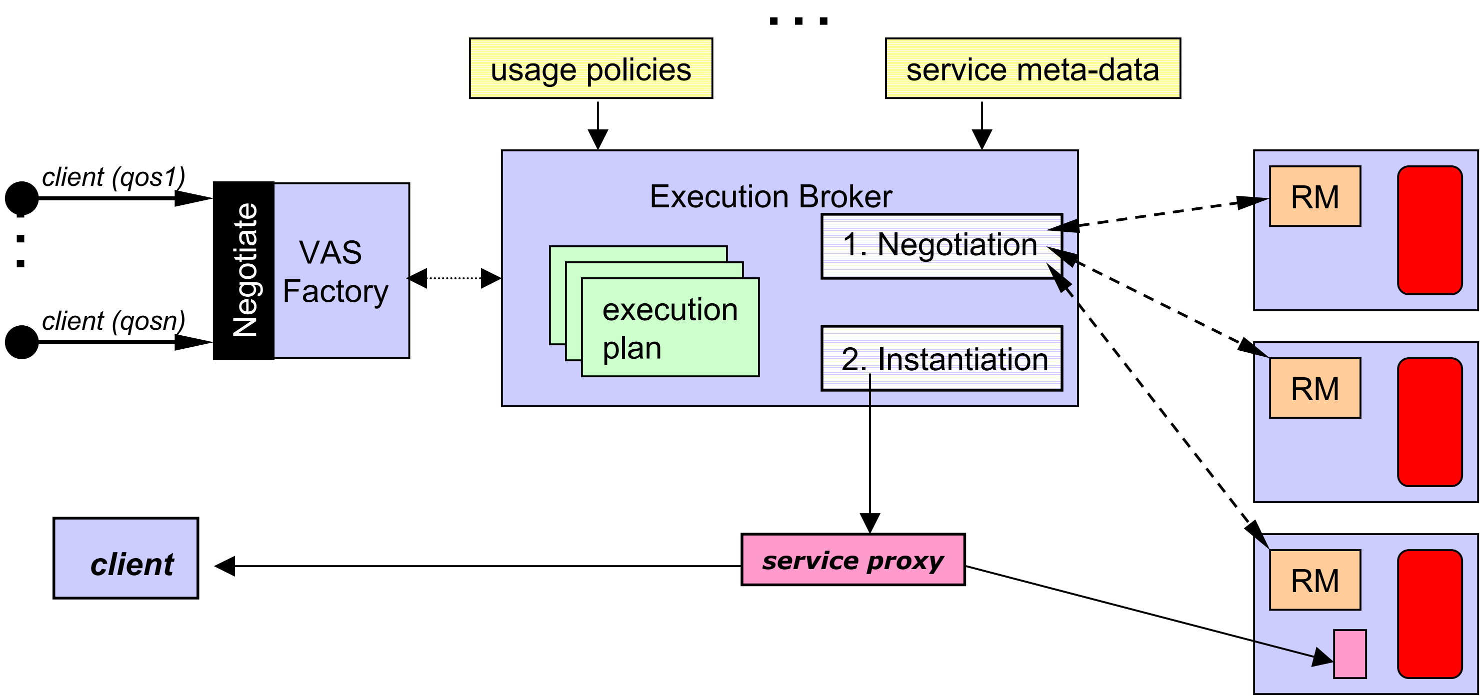


Virtual Application Services (VAS)

- Example: the National Fusion Collaboratory
- Requirements
  - Codes as "network services" (portability reasons)
  - Different interaction modes
    - Real-time constraints (betw. Experimental pulses: ~15mins)
    - Batch jobs where accuracy is important



VAS: Behind the scenes

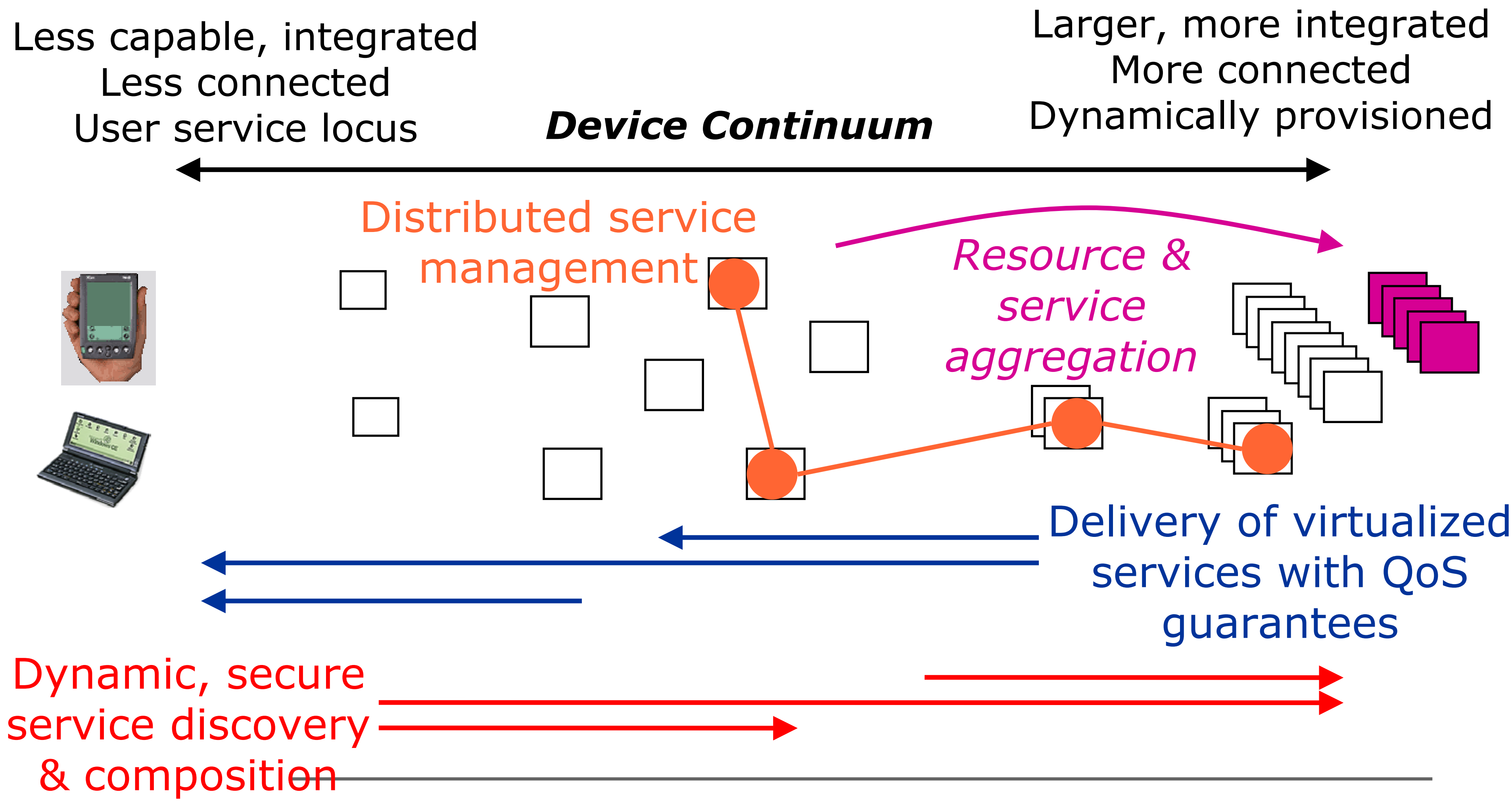


- Adaptive capabilities
- Capable of adjusting to different models

Composing Services

- Resource composition
  - Complex resource configuration
  - CPUs, networking, storage…
  - Redundant configuration to provide for failure
- Application Service Composition
  - Workflow and orchestration
  - Constraint-based service discovery
  - Reliable and Adaptive Workflow execution
  - Reproducibility
    - Data provenance

Virtualization and Distributed Service Management



Grid Evolution

- Paradigm change:
  - Spend less time telling the infrastructure *how* to do things
  - Spend more time telling the infrastructure *what* to do
- Service abstraction
  - Presents a more intuitive interface to the user
  - Allows the infrastructure developer to focus on key areas of the infrastructure

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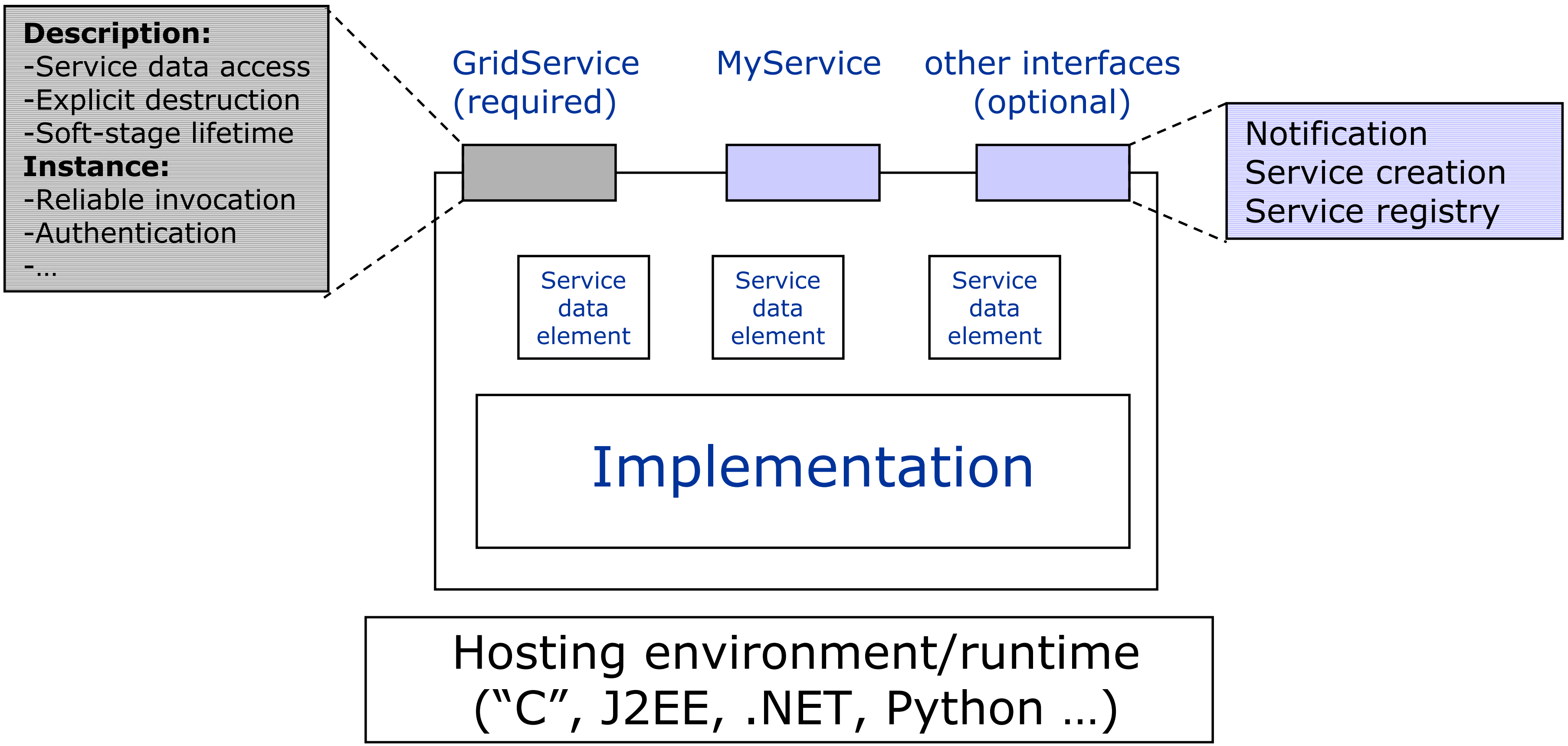
Open Grid Services Architecture

- From Web services
  - Standard interface definition mechanisms
    - Interface and implementation (multiple protocol bindings)
    - local/remote transparency
    - Language interoperability
  - A homogenous architecture basis
- From Grids
  - Service semantics
  - Lifecycle management
  - Reliability and security models
  - Discovery
  - Other services: resource management, authorization, etc.

The Grid Service

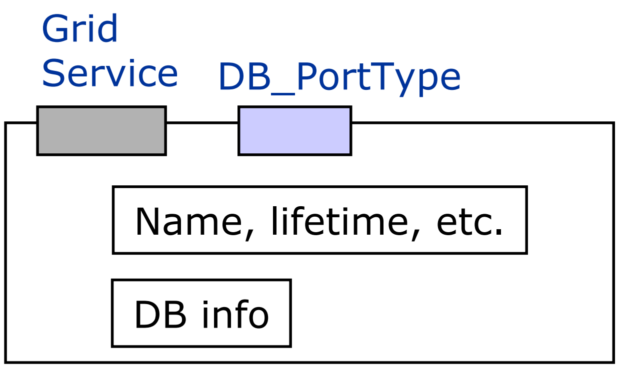


The Grid Service

- A WSDL-defined service that conforms to a set of conventions relating to its interface and behaviors
- Description composed of two parts:
  - Grid service description
    - Describes how a client can interact with service instances: syntax and semantics (portTypes)
    - Can be used by any number of GS instances
  - Grid service instance
    - Embodies state
    - Has one or more unique Grid Service Handles
    - Has one or more Grid Service References

Grid Service Example: Database Service

- A DBaccess Grid service will support at least two portTypes
  - GridService
  - Database_PortType
- Each has service data
  - GridService: basic introspection information, lifetime, …
  - DB info: database type, query languages supported, current load, …, …



The Database Grid Service

```
<portType name="GridServicePortType">
  <operation name="findServiceData">
    <input message="tns:FindServiceDataInputMessage"/>
    <output message="tns:FindServiceDataOutputMessage"/>
    <fault name="QueryNotSupportedFault" message="ogsa-faults:QueryNotSupportedFault"/>
    <fault name="InvalidQueryFault" message="ogsa-faults:InvalidQueryFault"/>
  </operation>
  <operation name="setTerminationTime">
    …
  </operation>
  <operation name="getTerminationTime">
    …
  </operation>
  <operation name="destroy">
    …
  </operation>
</portType>
```

Grid Service Functionality

Database_PortType
Inherits from GridService

```
<portType name="Database_PortType" extends "gsdl:GridService">
        <operation name="databaseQueryOperation">
                <input message="tns:myDatabaseQuery"/>
                <output message="tns:myDatabaseResponse"/>
        </operation>
</portType>
```

Open Grid Services Architecture: Fundamental Structure

1) WSDL conventions and extensions for describing and structuring services
   - Useful independent of "Grid" computing
2) Standard WSDL interfaces & behaviors for core service activities
   - Necessary for Grid computing
3) Higher-level services

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WSDL Extensions and Conventions

- Defined using WSDL extensibility elements
- WSDL conventions and extensions
  - serviceData: properties of a service that may be queried
  - serviceDataDescription:formal description of serviceData elements
  - portType inheritance: recently added to WSDL
    - Extending portTypes
  - Naming:naming conventions on portType and serviceType
  - Grid Service Reference (can be a WSDL document)
  - Grid Service Handle

Service Data

- Describes
  - Meta-data (info about the service instance)
  - State data (runtime properties)
- Represented by a Service Data Element (SDE)
  - Structural
    - Extensibility element in portType
    - Any GS that of this description must implement them
  - Non-structural
    - Described by serviceDataSet

Service Data Element

- Information:
  - Name
  - Type (XML type)
  - Extensibility attributes
    - Lifetime declarations
      - goodFrom, goodUntil, availableUntil
    - Application-specific
  - Extensibility elements
    - Service data value
    - Application-specific

Service Data Descriptions

- Specifies properties (type) of SDEs
- Extends the definitions element
- Interface
  - Name,
  - XML type of service data element values conforming to this description
  - minOccurs, maxOccurs
  - mutability

Service Data Set

- A set of SDEs
- Each Grid Service must have exactly one service Data Set
- Accessible in two ways:
  - FindServiceData
  - Notification
- It must include all structural SDEs
- It may in addition also include some non-structural SDEs

Naming and Change Management

- The change management problem
  - GS semantics may evolve
    - On the interface level: adding new operations
    - On the implementation level: bug fixes, etc.
  - Users rely on this behavior
- OGSA requirement: all elements of a GS description must be immutable
  - Qualified name (namespace and locally unique name) must refer to only one WSDL specification
  - If a change is needed a new service with a new qualified name must be defined

Naming: Handles and References

- Grid Service Handle (GSH)
  - Uniquely identifies a service
  - Has the form of URI
- Grid Service Reference (GSR)
  - Contains all the information a client needs in order to communicate with a service
  - Its form depends on the binding
- GSH must be resolved to GSR in order to use a service
  - Information on how to resolve encoded in the URI
- Separation of name from implementation details facilitates manipulation of a service

Grid Service Handle

- Name in the form of URI
  - The URI scheme defines the protocol for resolving it
- Properties
  - GSH is valid for the lifetime of a GS instance
  - Must not refer to more than one service instance
  - A GS has at least one GSH
  - GSH may resolve to different GSRs pointing to the same service
- Resolver protocols
  - Untrusted (http)
  - Trusted (https)

Grid Service Reference

- Network-wide pointer to a specific GS instance
  - Web service binding mechanism
  - Binding-specific information about the endpoint
  - May include expiration time (treat is as a hint)
- Binding-specific
  - SOAP: WSDL document
  - RMI/IIOP: CORBA-compliant IOR
- May become invalid during the lifetime of an instance (independent lifecycle)
- Many GSRs to a service may exist at the same time
- Use of invalid GSR should result in an exception

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Standard Interfaces and Behaviors

- Grid Service: basic behavior
- HandleResolver: mapping from GSH to GSR
- Lifecycle
  - Support transient services
  - Service instances created by <u>factories</u>
  - Destroyed <u>explicitly</u> or via <u>soft state</u>
- Notifications
  - Registering interest and delivering notifications
- Registration
  - Allows clients to register and unregister registry contents

Grid Service Interface (Recap)

- Must be implemented by all Grid services
- Interface:
  - FindServiceData
    - Input
      - QueryExpressionType: query mechanism used
      - QueryExpression: actual query
    - Output
      - Result of Query
  - SetTerminationTime
    - Request that termination time of this service be changed
    - Input: client timestamp and new termination time
    - Output: service timestamp and current termination time
  - Destroy
    - Explicit destruction request, returns an ack

Handle Resolver

- Resolves GSH into GSR
  - Optionally, the client can do it by itself
- Interface
  - FindByHandle
    - Input: GSH & unsatisfactory GSRs
    - Output: GSR
    - Faults: invalidHandle, no valid references, etc.

Lifecycle

- GS instances created by factory or manually
- Destroyed explicitly or via soft state
  - Negotiation of initial lifetime with a factory (=service supporting Factory interface)
  - Lifetime can subsequently be extended by sending "keepalive" messages
- Soft state lifetime management avoids
  - Explicit client teardown of complex state
  - Prevents resource "leaks" in hosting environments

GS Creation: Factory

- Creates a new service instance
  - Reliable once and only once creation
- Interface
  - CreateService
    - Input:
      - TerminationTime
      - ServiceParameters (specific to a service)
    - Output: ServiceTimestamp information & Service Locator
- ServiceLocator can be used to obtain GSH

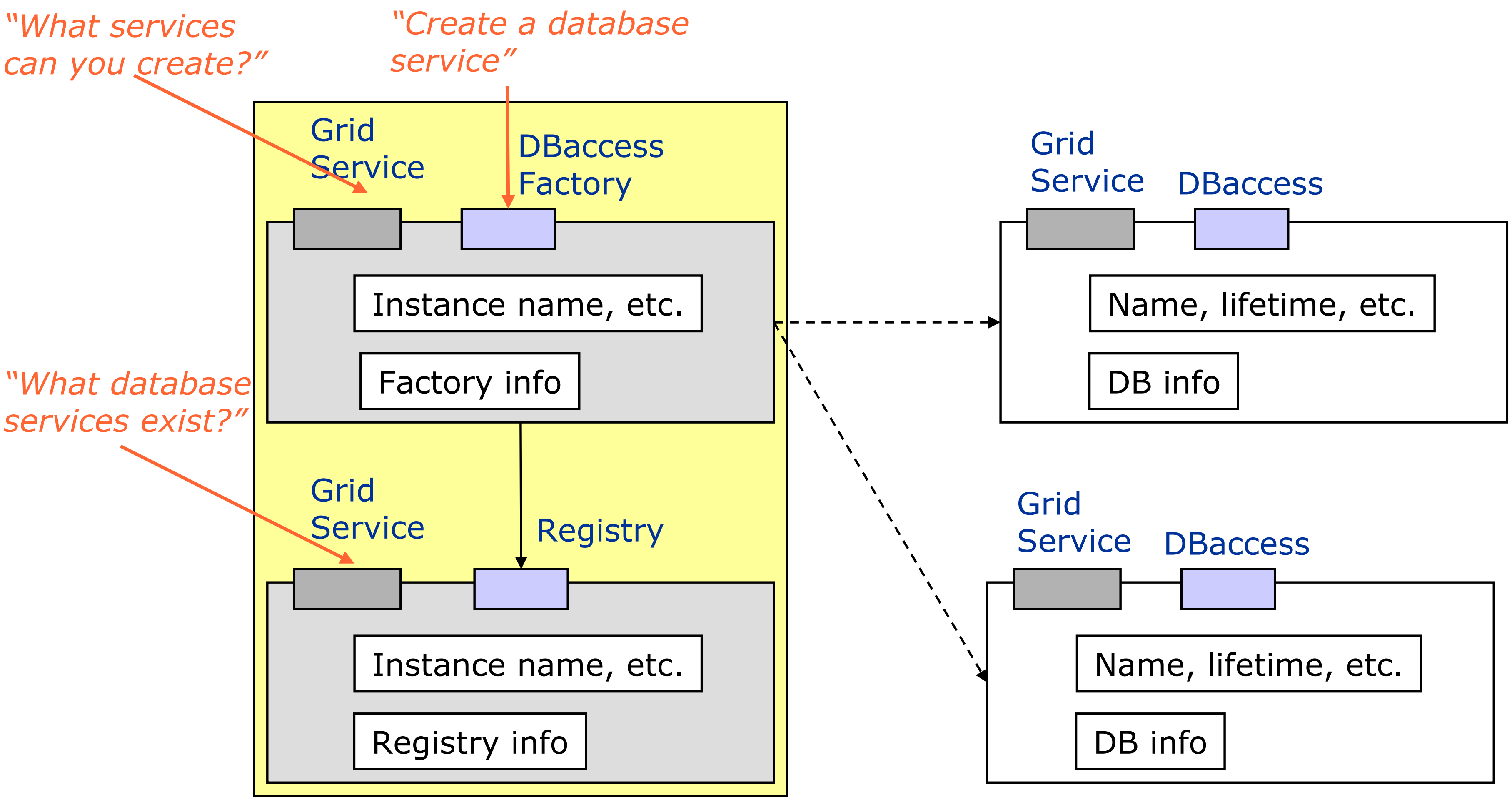
Grid Service Termination

- Explicit destruction
  - Destroy operation in the Grid Service
- Soft-state destruction
  - Allowing the termination time to expire
  - SetTerminationTime operation resets the value of the TerminationTime SDE
  - Reaffirmation of interest does not guarantee that the service will stay alive

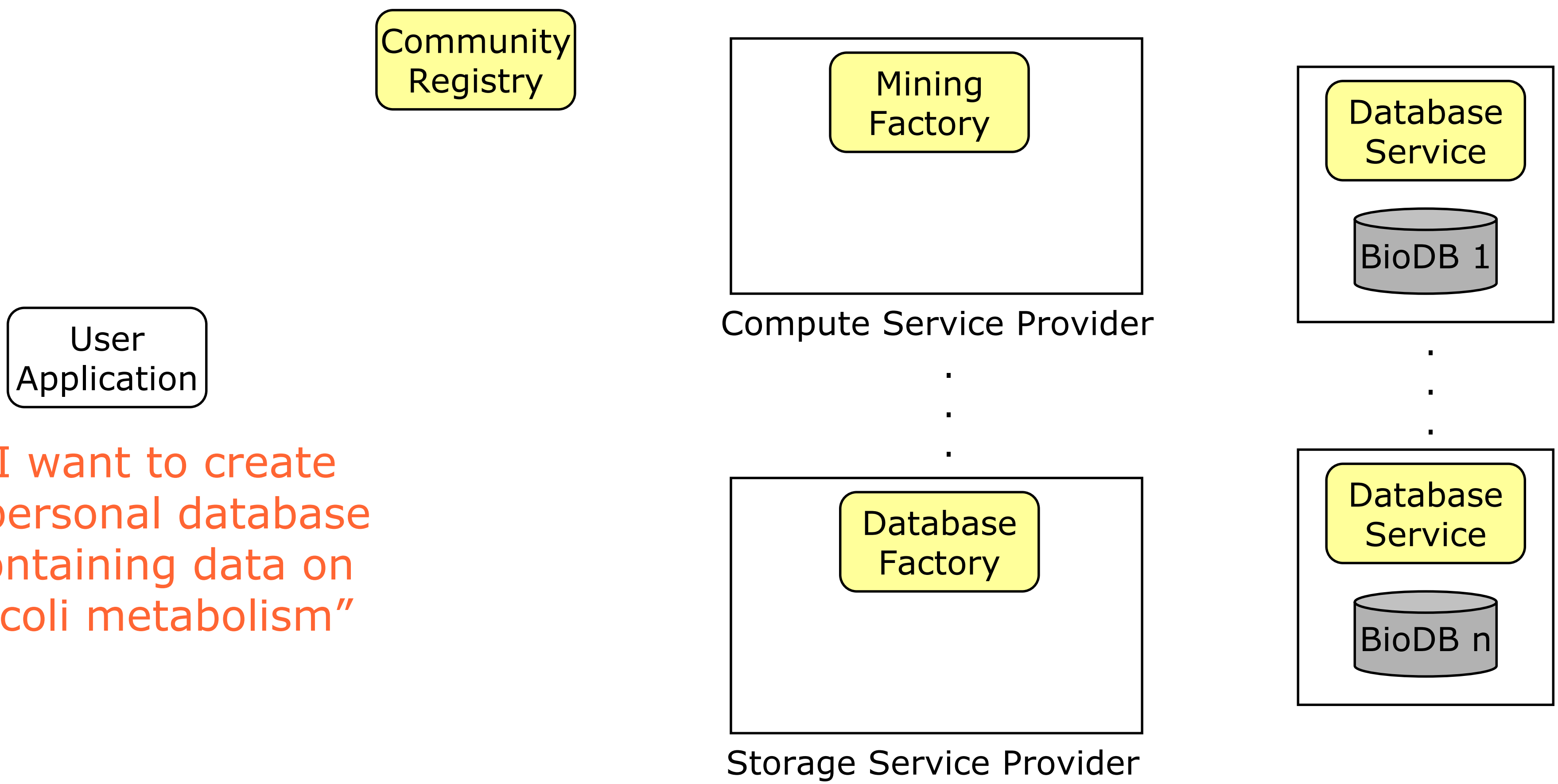
Registry

- The Registry interface may be used to register Grid service instances with a registry
  - A set of Grid services can periodically register their GSHs into a registry service, to allow for discovery of services in that set
- Registrations maintained in a service data element associated with Registry interface
  - Standard discovery mechanisms can then be used to discover registered services
  - Returns a WS-Inspection document containing the GSHs of a set of Grid services

Transient Database Services

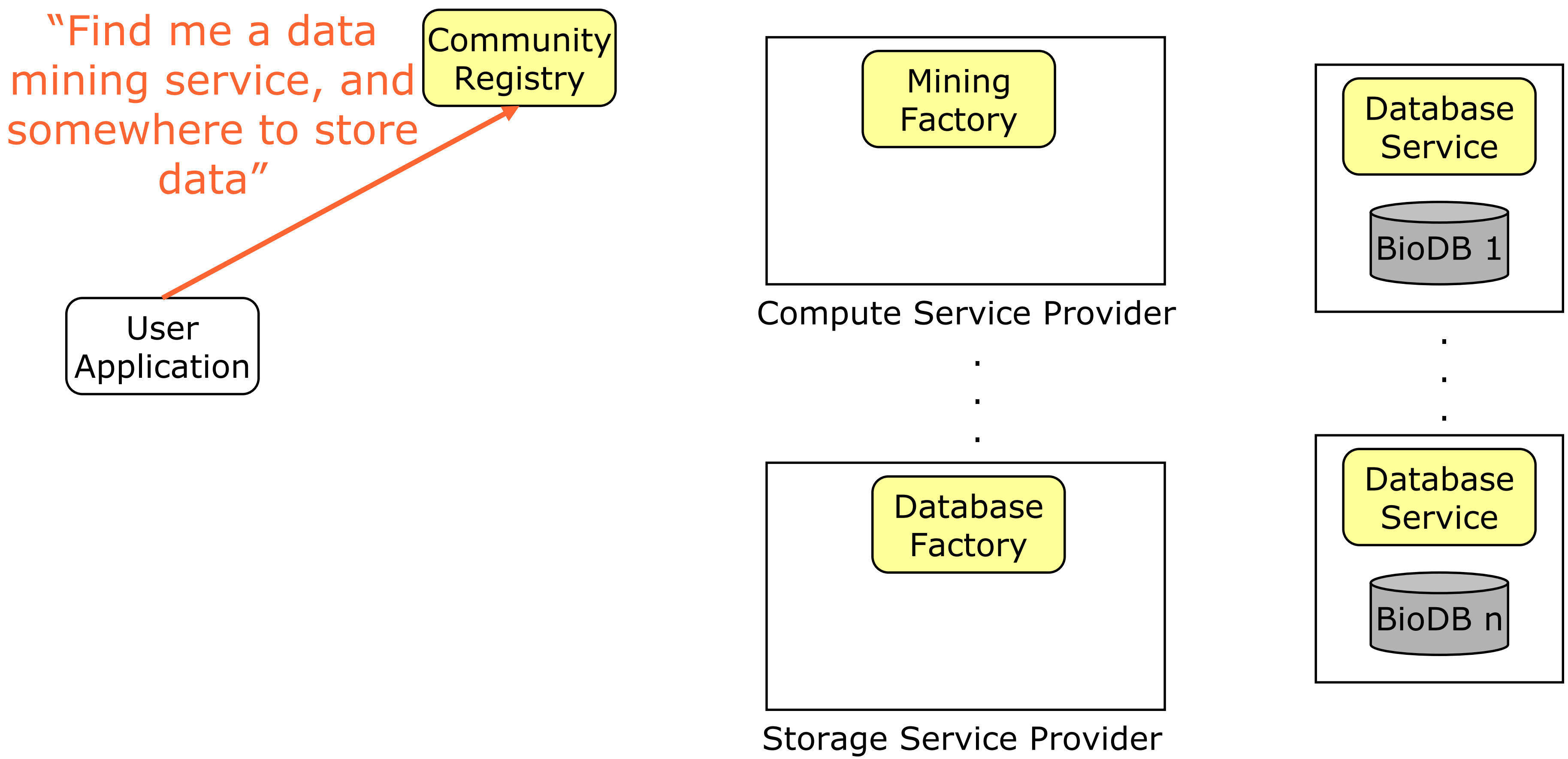


Example: Data Mining for Bioinformatics



"I want to create a personal database containing data on e.coli metabolism"

Example: Data Mining for Bioinformatics



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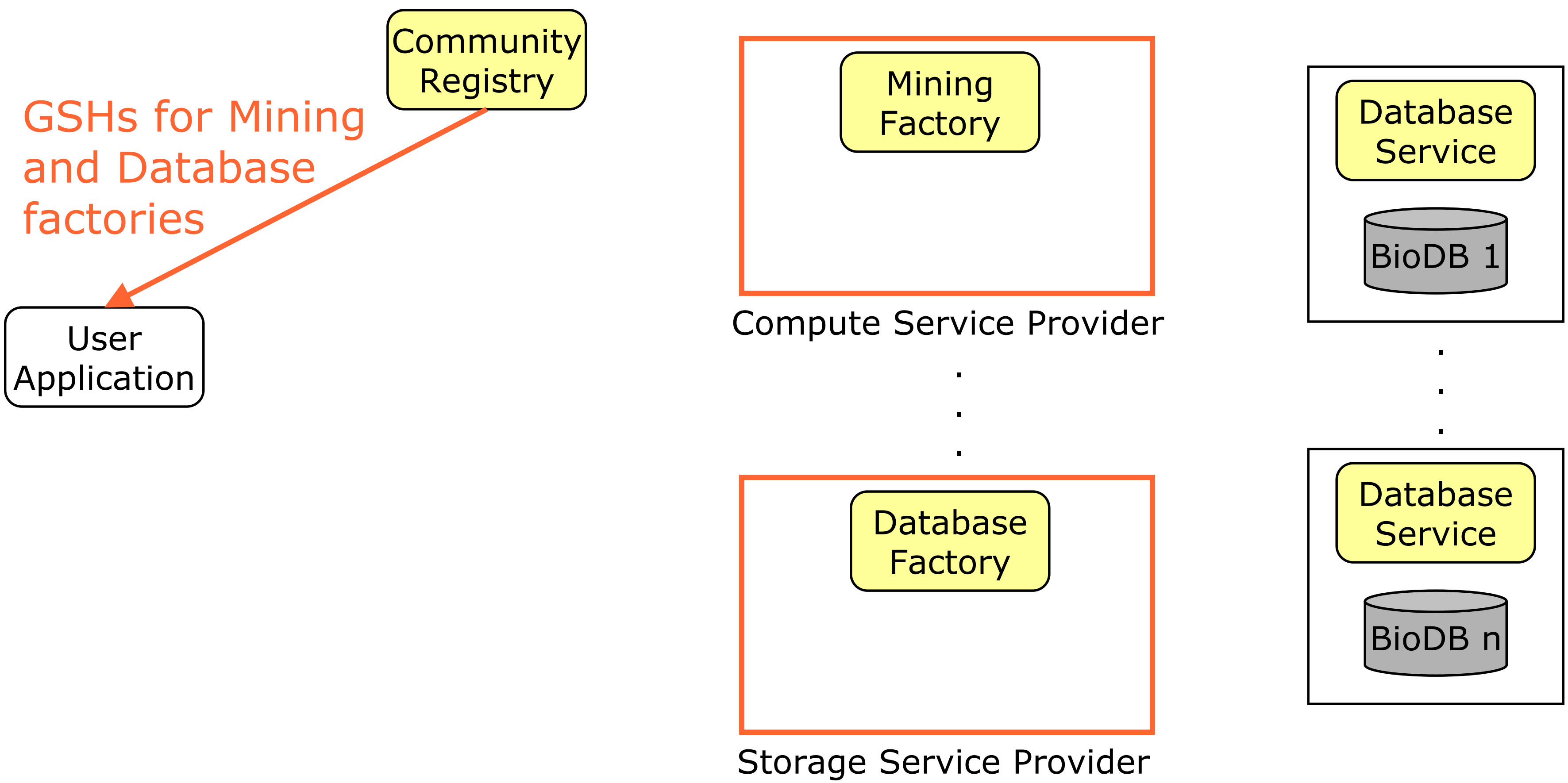

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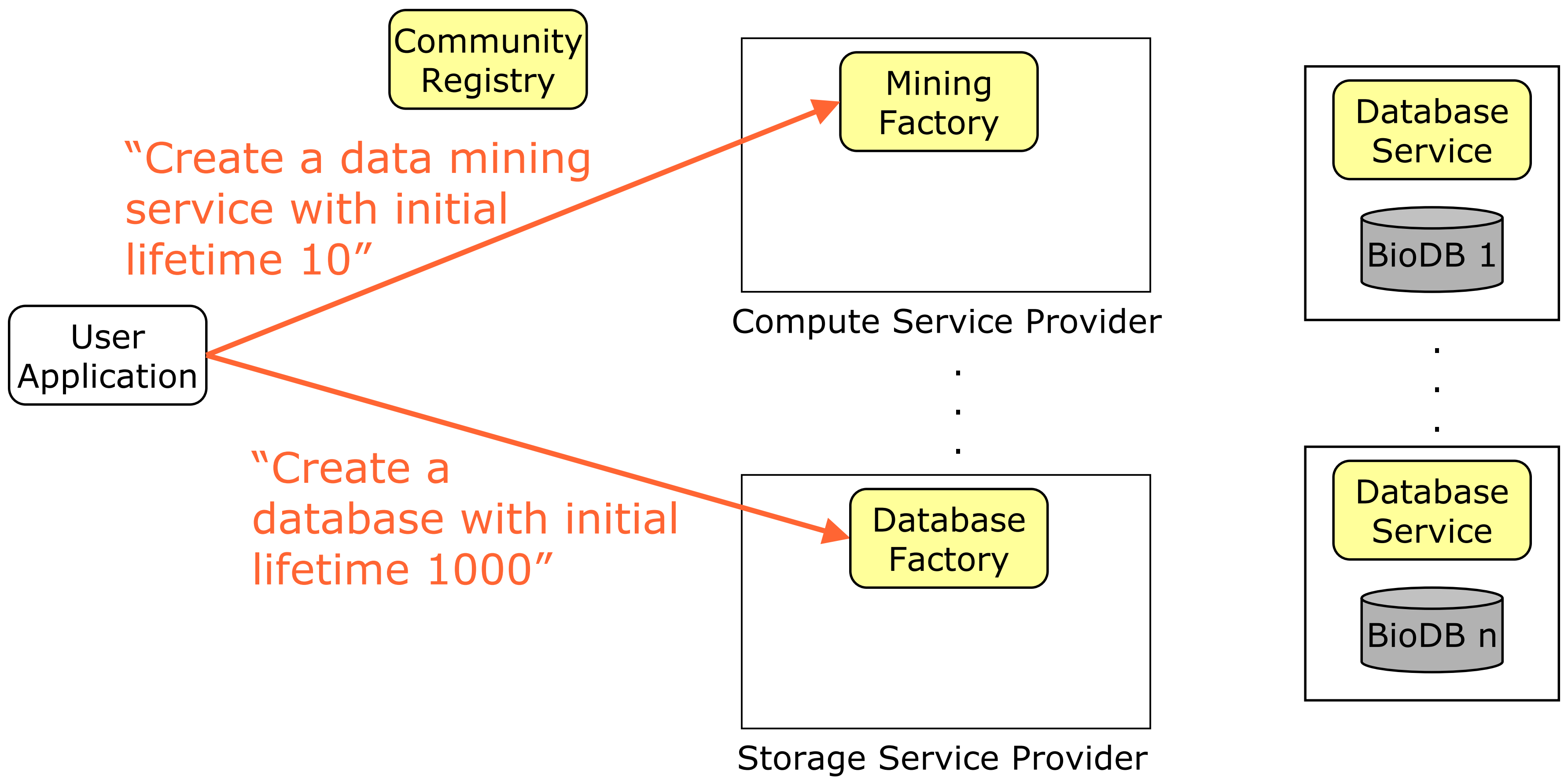

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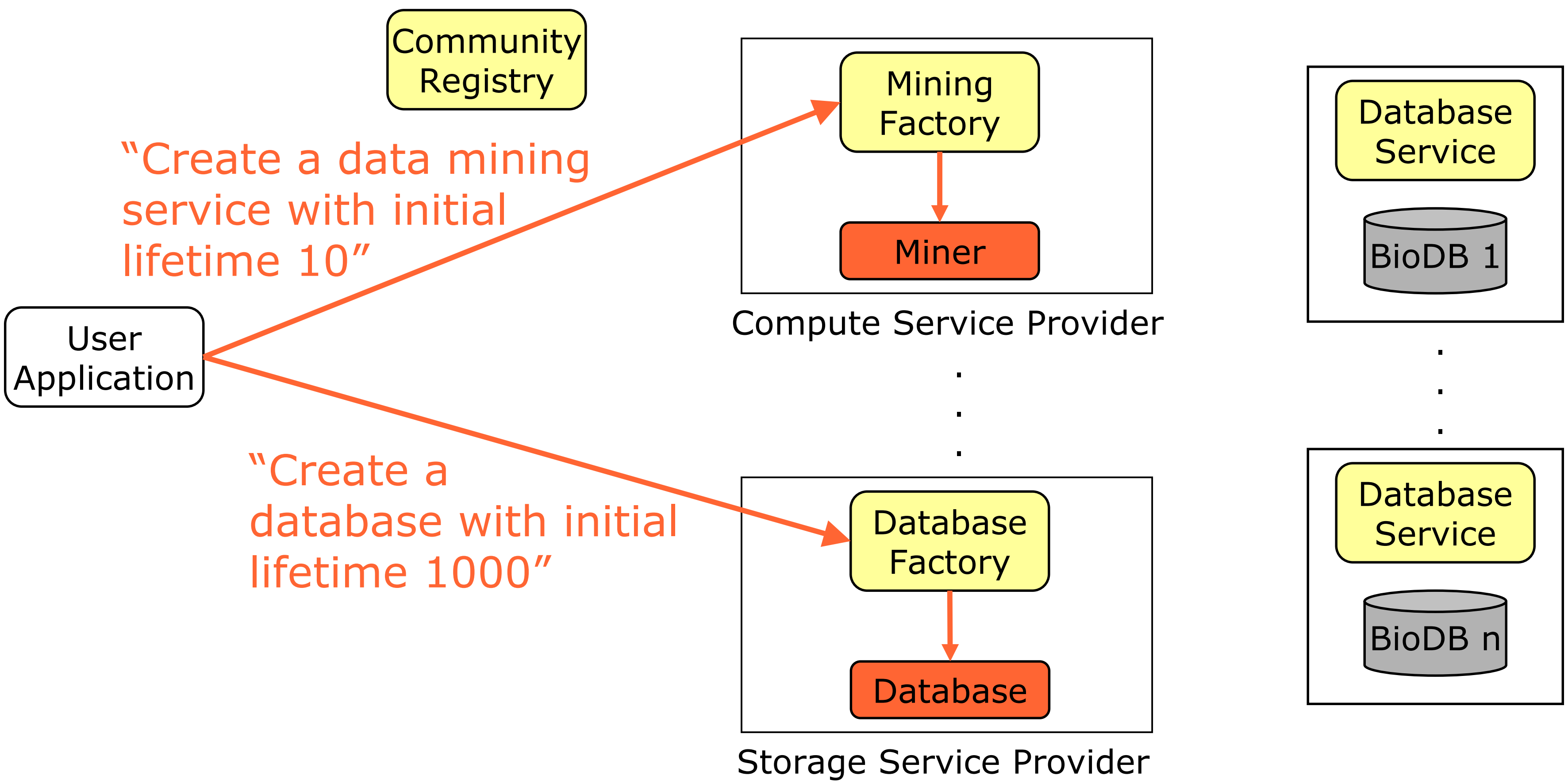

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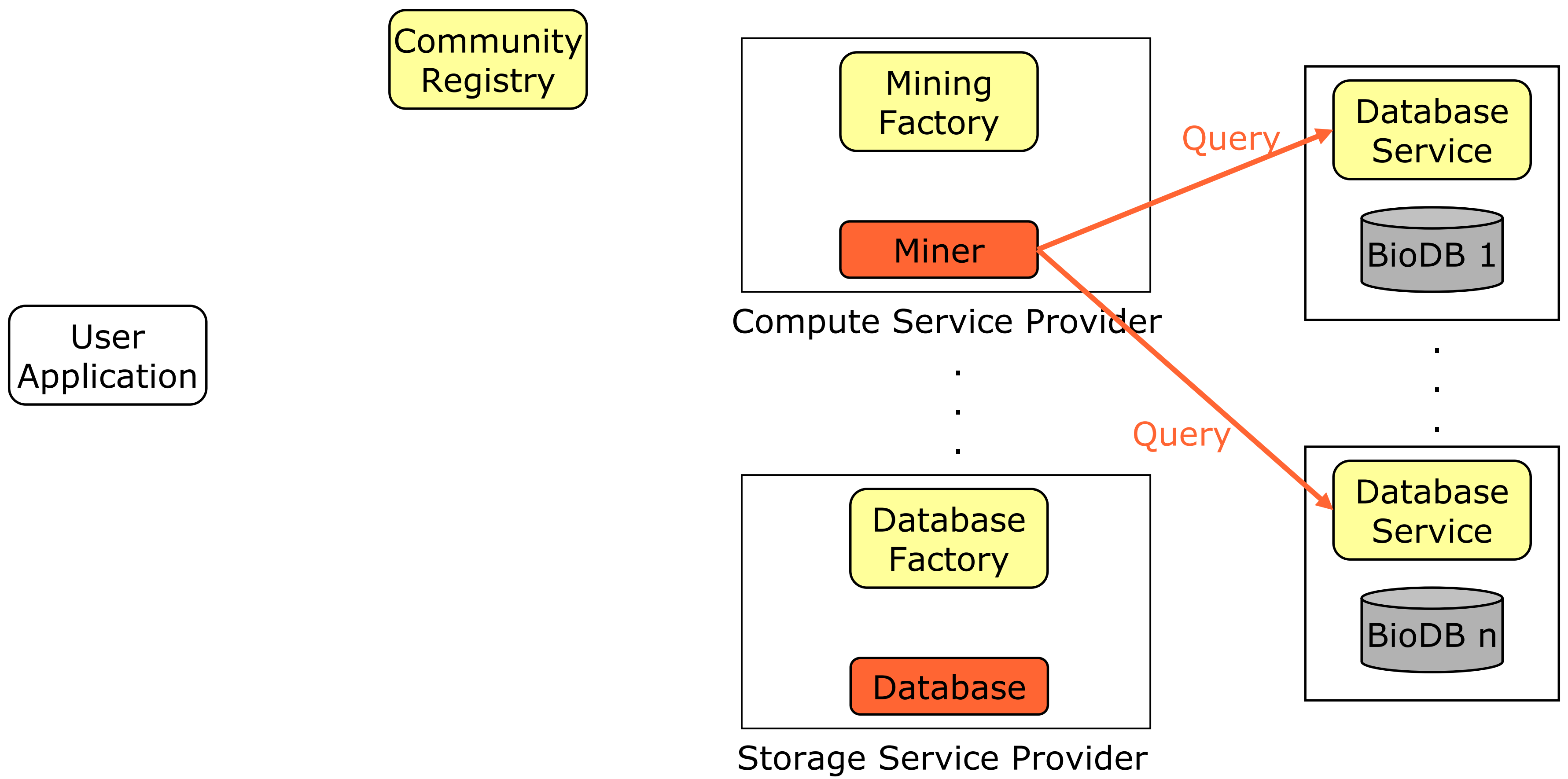

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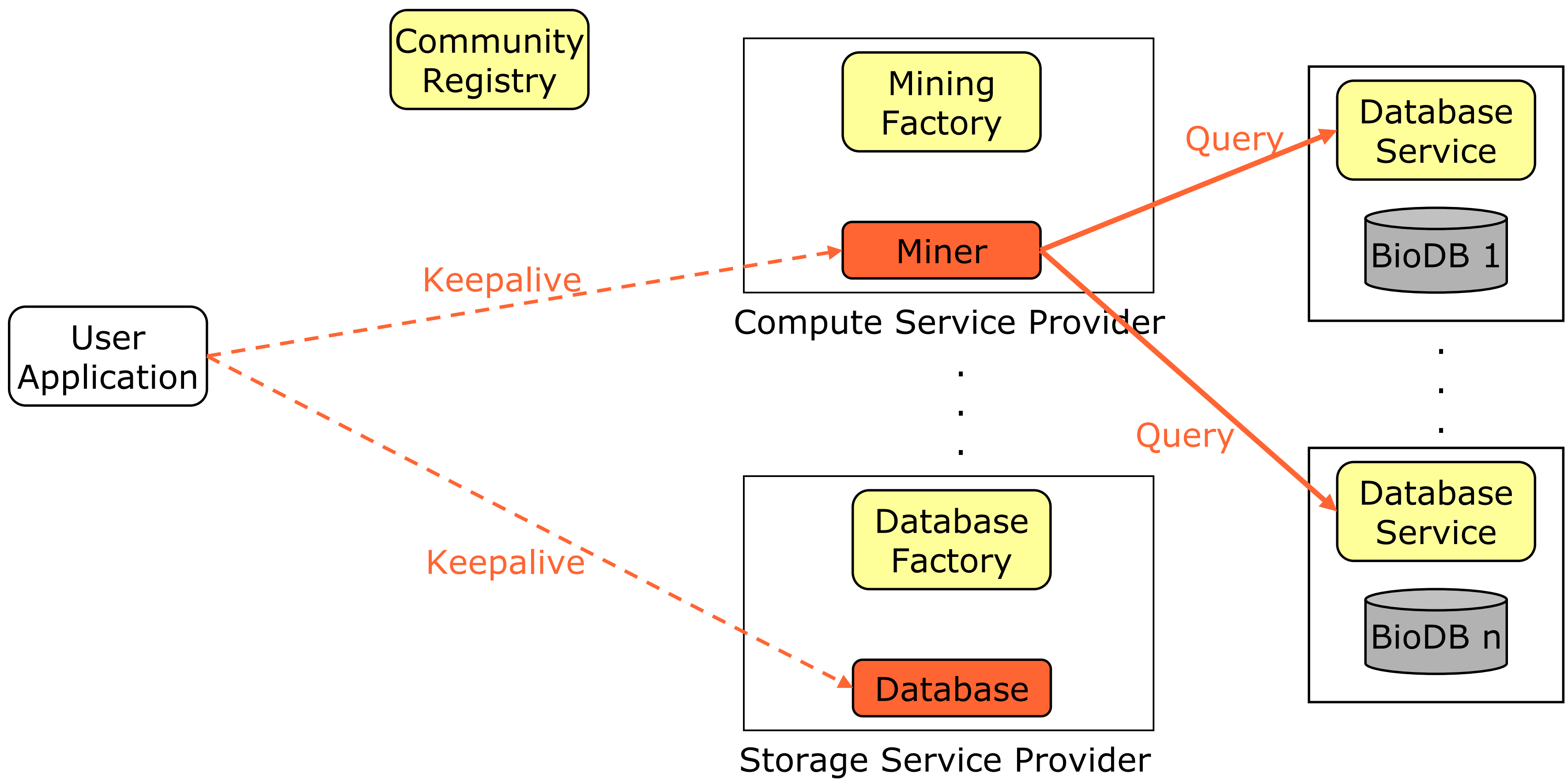

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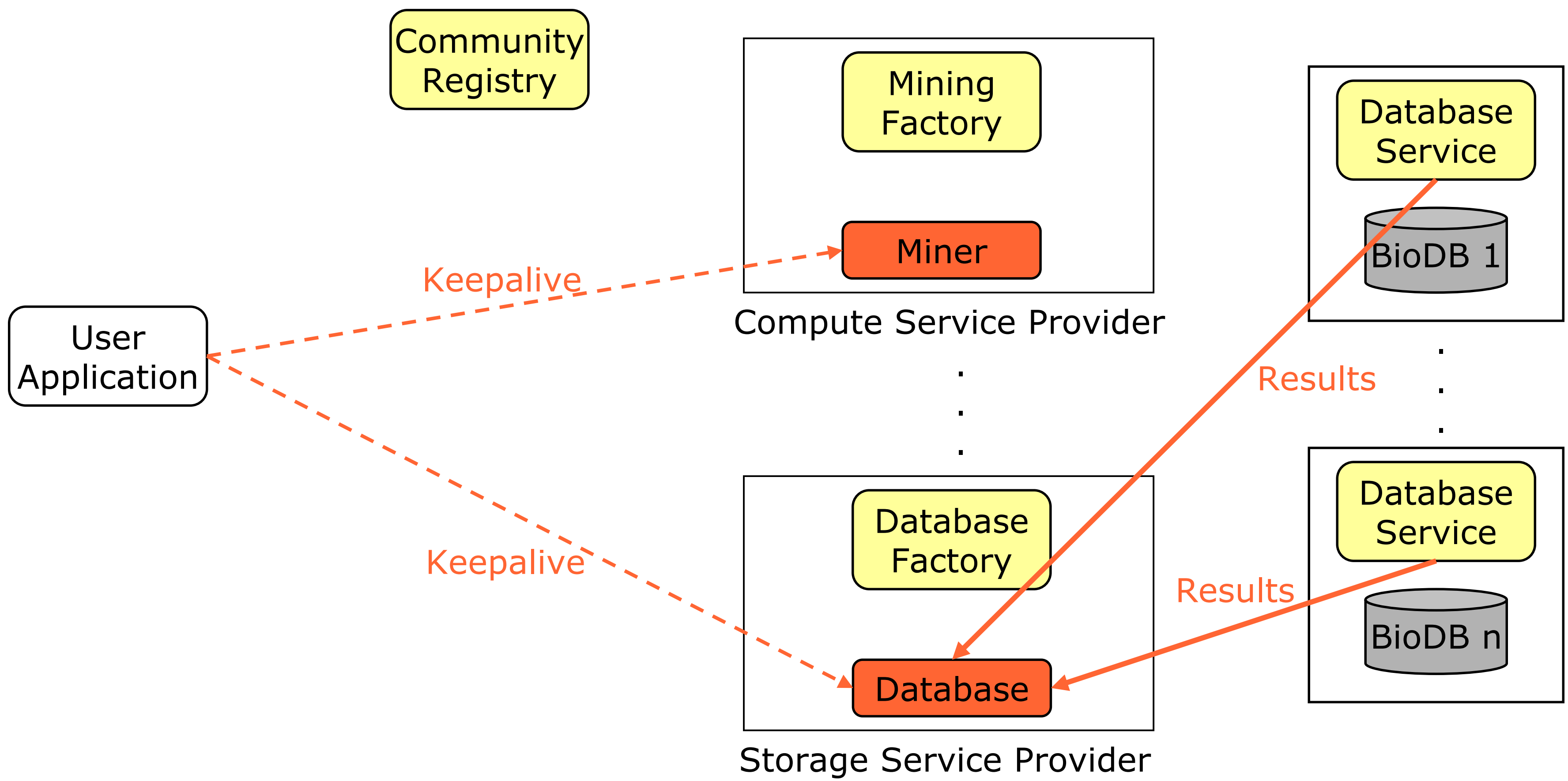

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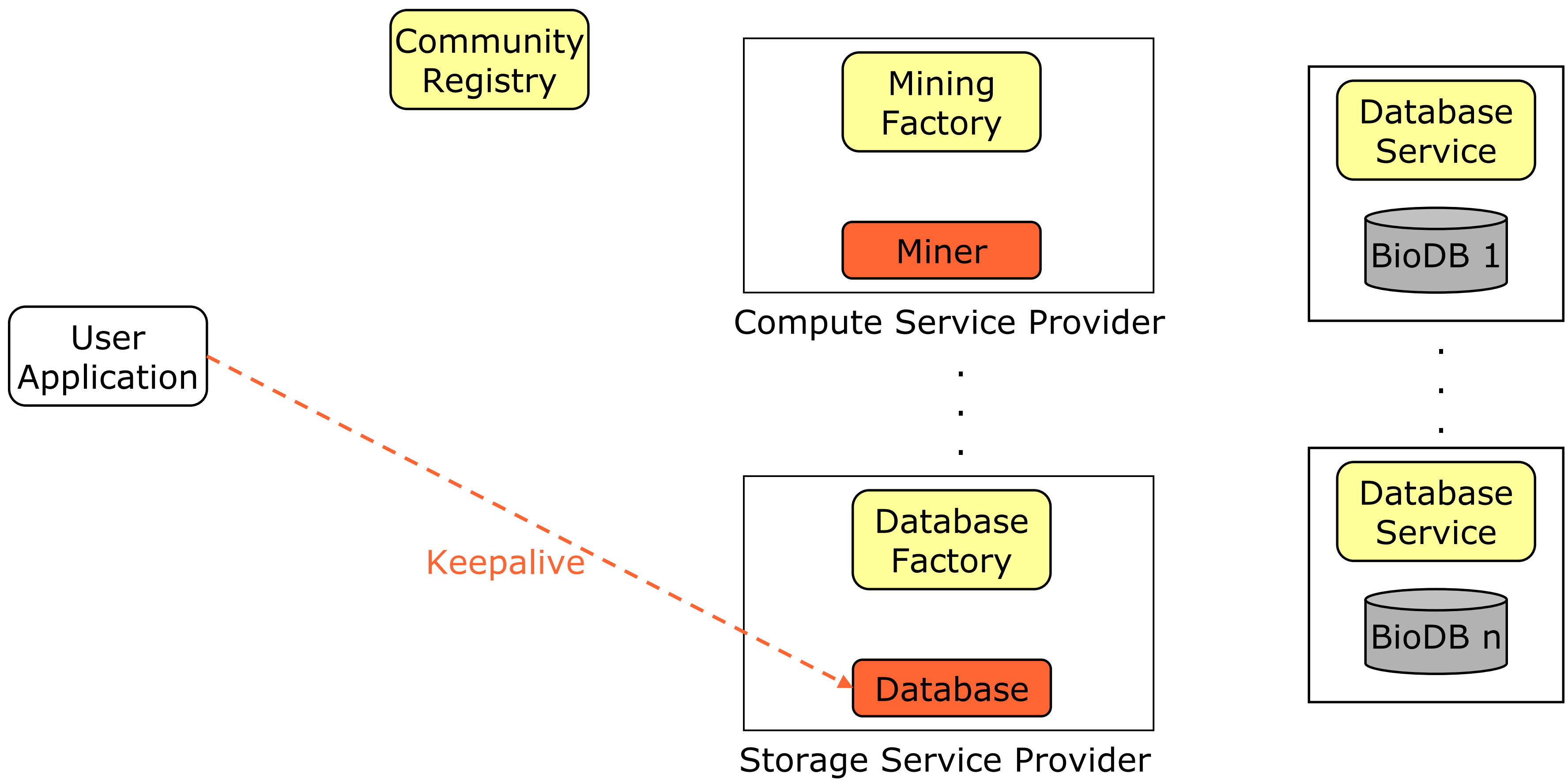

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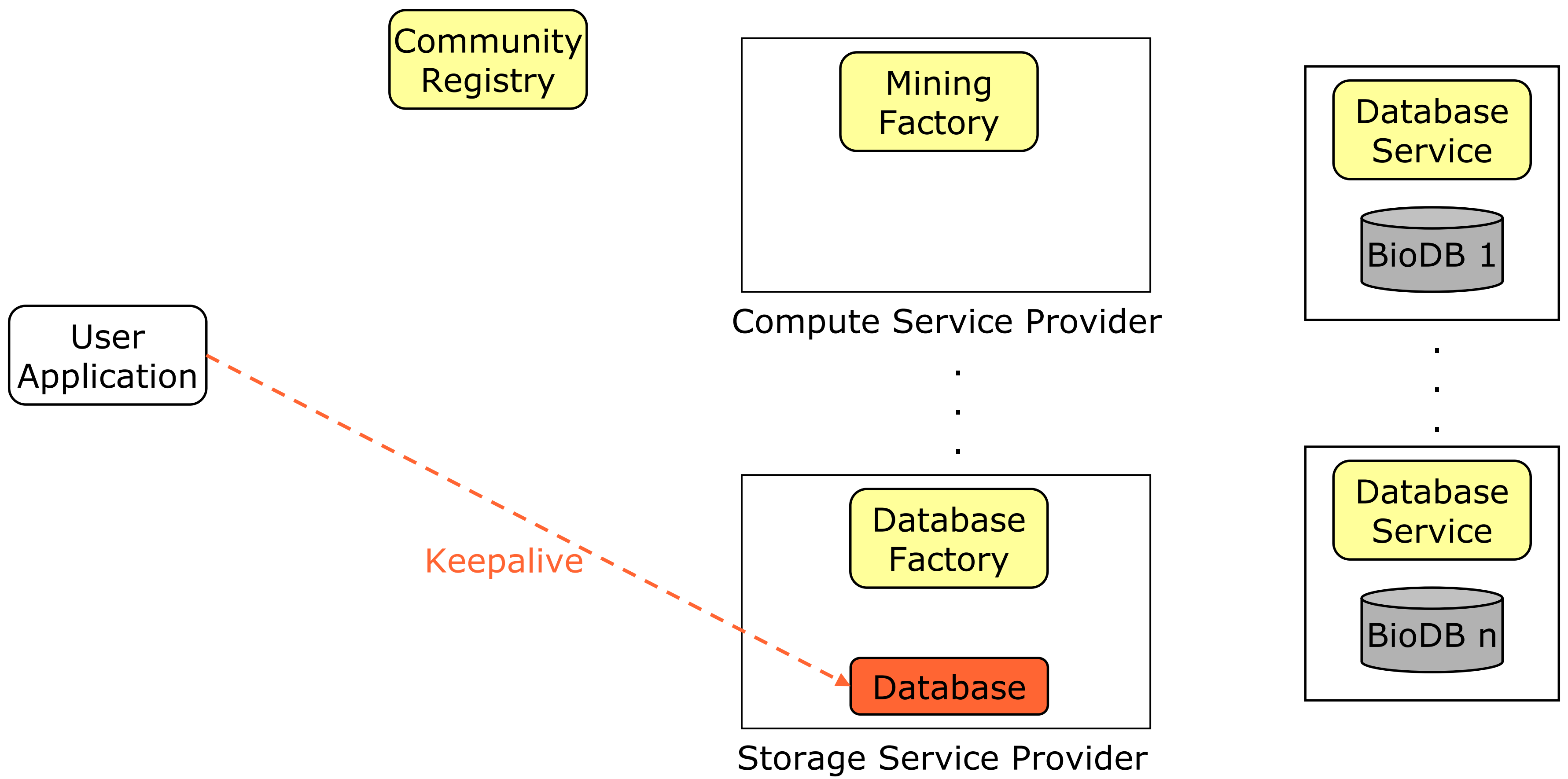
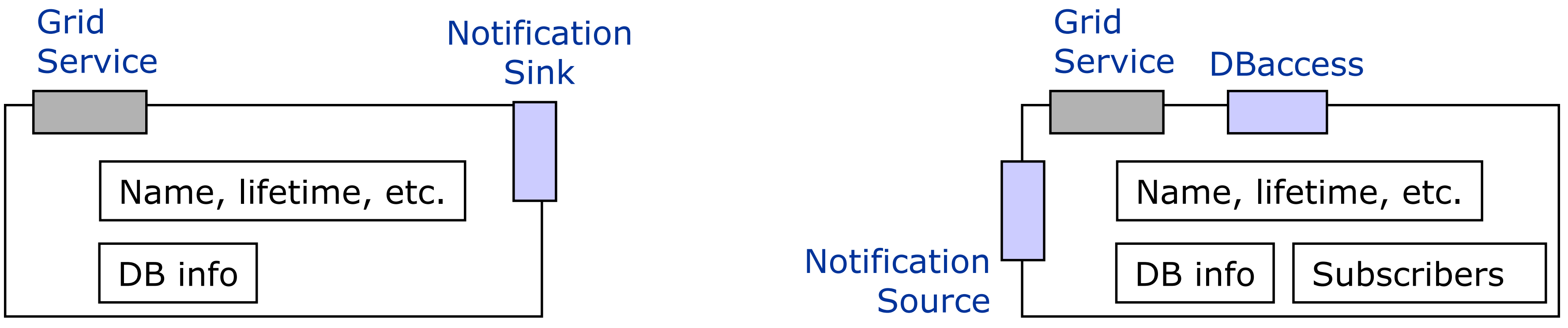


Notification Interfaces

- NotificationSource for client subscription
  - One or more *notification generators*
    - Generates notification message of a specific type
    - Typed *interest statements*: E.g., Filters, topics, …
    - Supports messaging services, 3rd party filter services, …
  - Soft state subscription to a generator
- NotificationSink for asynchronous delivery of notification messages
- A wide variety of uses are possible
  - E.g. Dynamic discovery/registry services, monitoring, application error notification, …

Notification Example

- Notifications can be associated with any (authorized) service data elements



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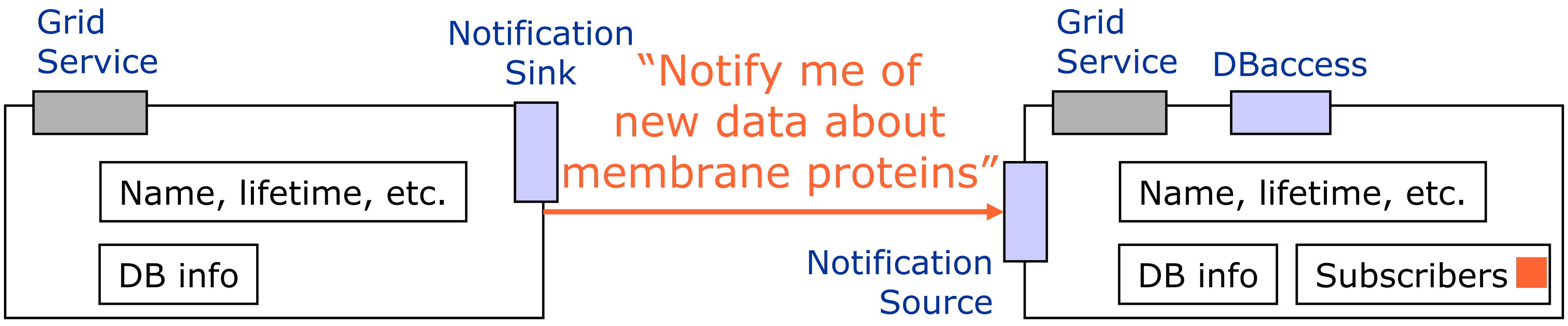

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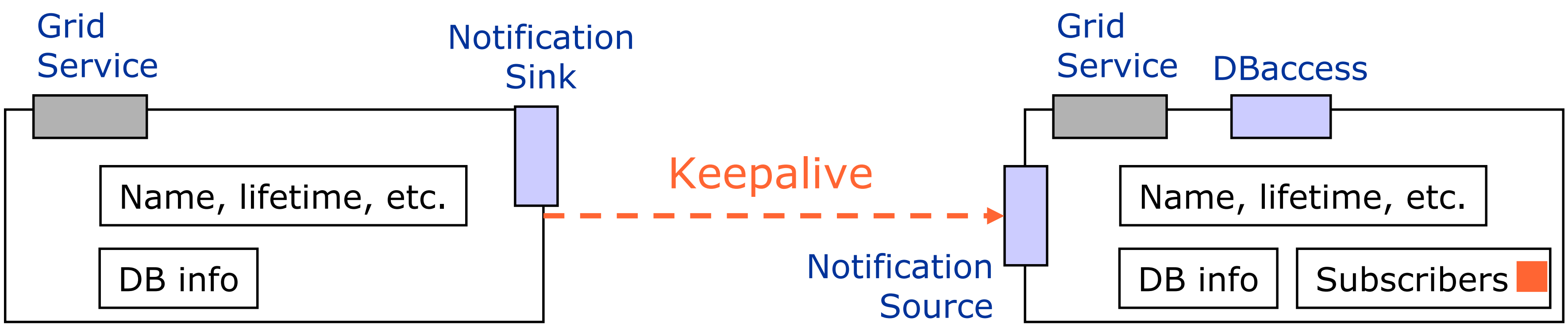

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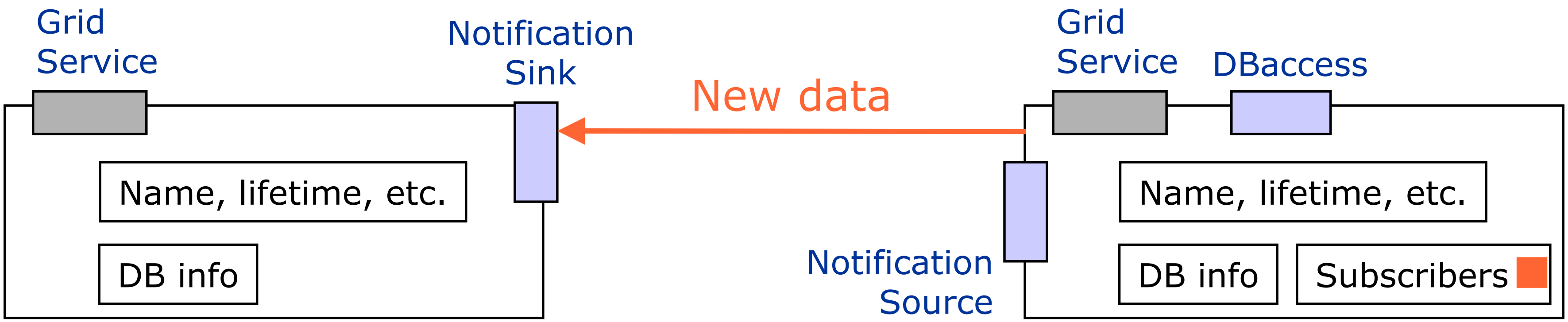


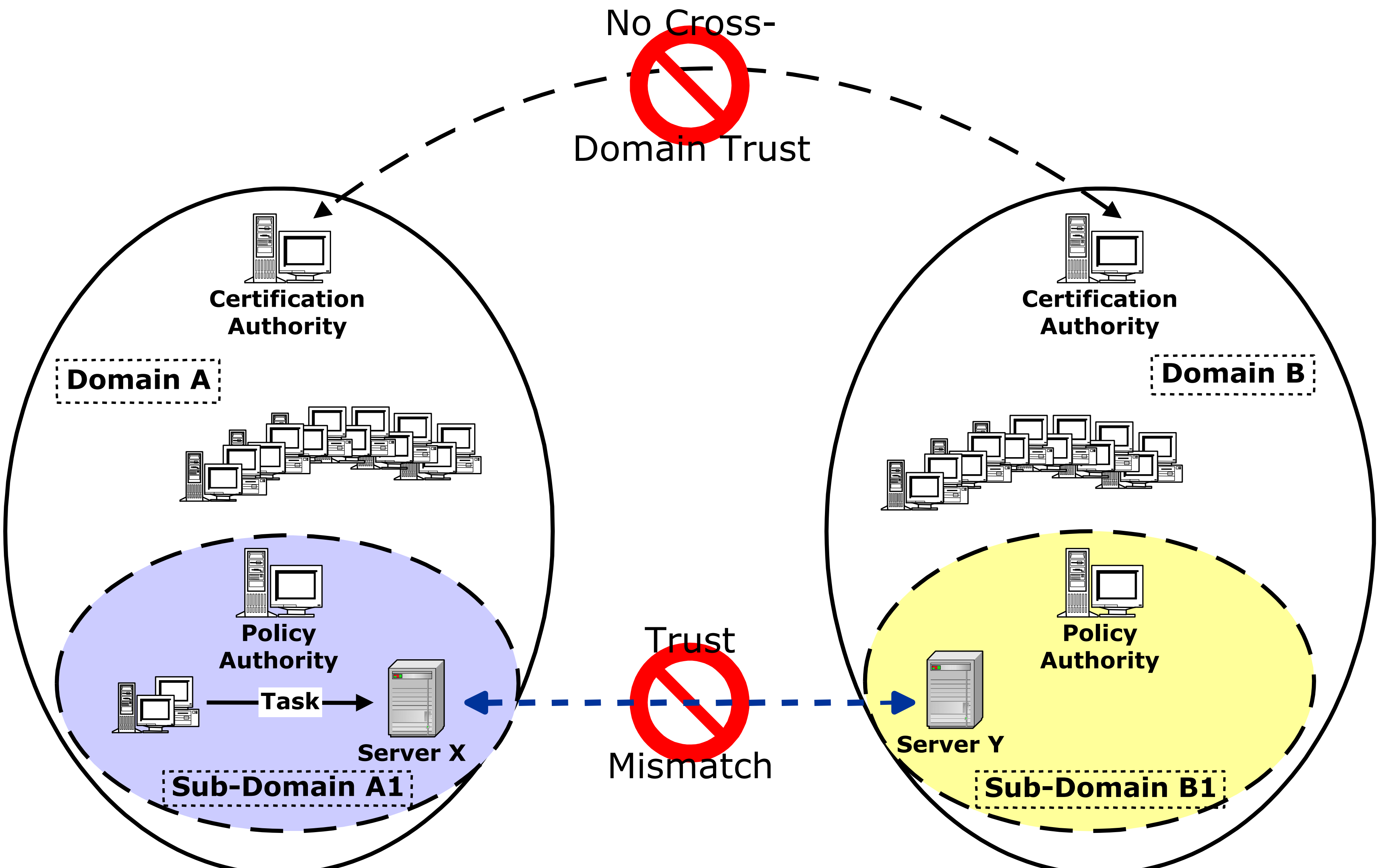
Implementing a Grid Service

- Write WSDL for a service
  - Association with Grid Service
- Generate stubs and skeletons based on WSDL
  - WSDL2Java
- Provide implementation of a service
- Implement a factory
  - Factory WSDL
  - Generate stubs and skeletons
  - Provide an implementation
  - Deploy in .wsdd file
- Provide implementation of a client
- Invoke services

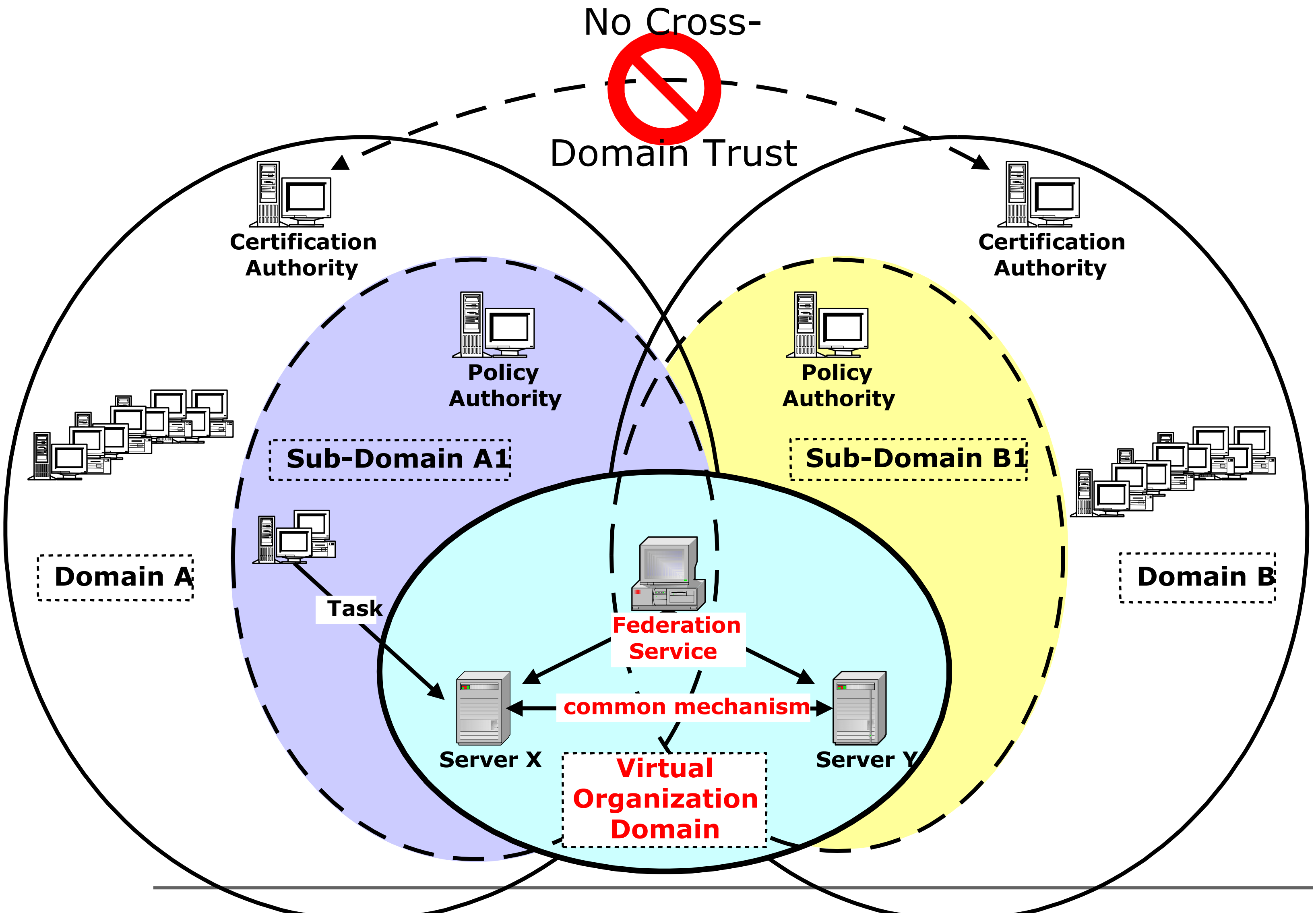
Overview

- Introducing the main players
  - Grid Computing
  - Globus Toolkit
  - Web Service (example)
- The Shape of an OGSA Grid
- The Open Grid Services Architecture
  - Grid Services: what are they? (example)
  - WSDL conventions and extensions
  - OGSA interfaces and behaviors (examples)
  - OGSA Security
- OGSA: status and future

Cross "Certification" Issue



Grid Solution: Use Virtual Organization as Bridge



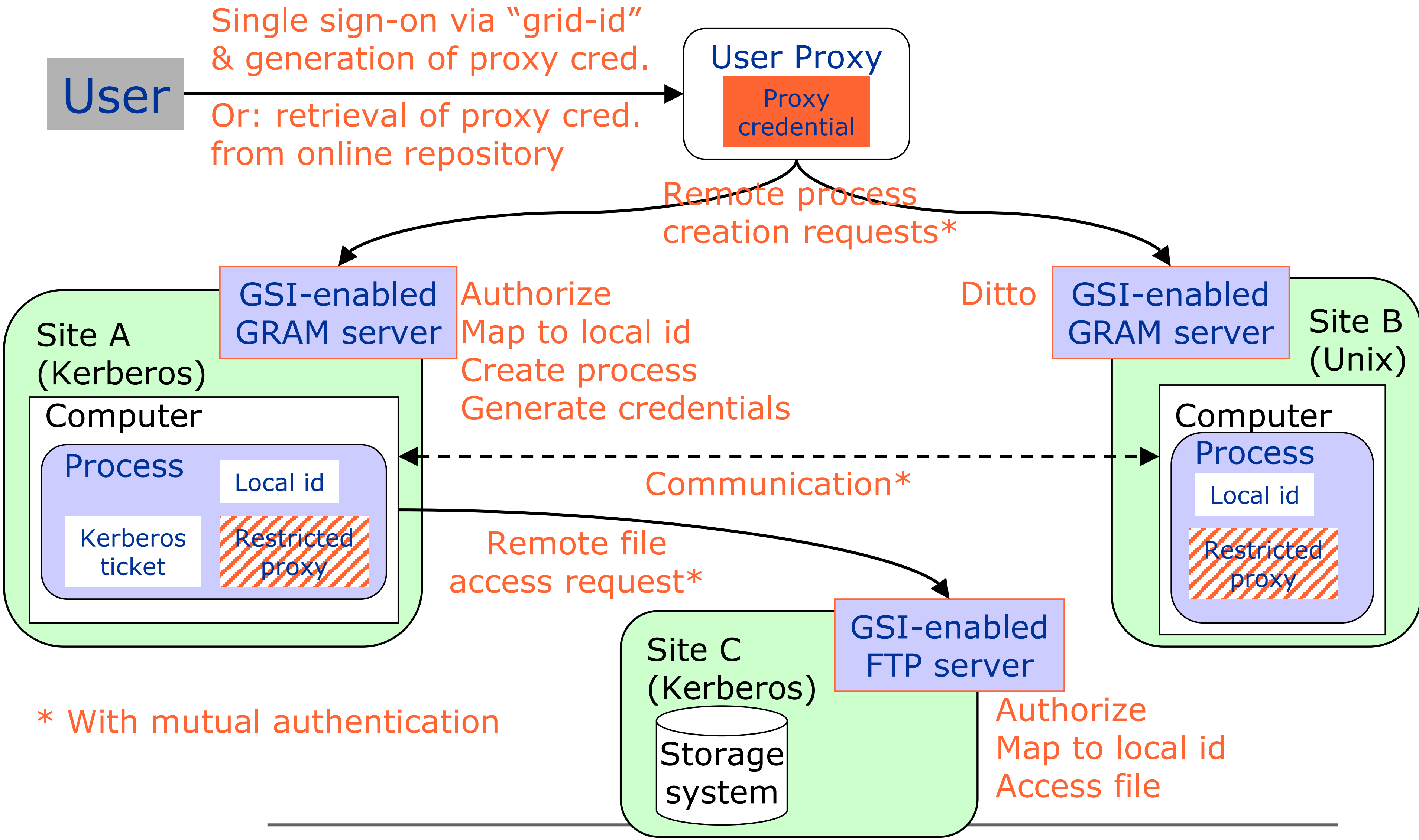
Grid Security Challenges

- Integration Issues
  - Existing services need to be used
  - Extensible architecture
- Interoperability Issues
  - Protocol, policy, and identity level
  - Quality of Protection (QoP)
- Trust Issues
  - Definition, management and enforcement of trust

Grid Security Requirements

- Authentication
- Delegation
- Single sign-on
- Credential Lifespan and renewal
- Authorization
- Privacy
- Confidentiality
- Integrity
- Policy exchange
- Secure logging
- Assurance
- Manageability
- Firewall traversal
- Securing the OGSA infrastructure…

GSI in One Slide

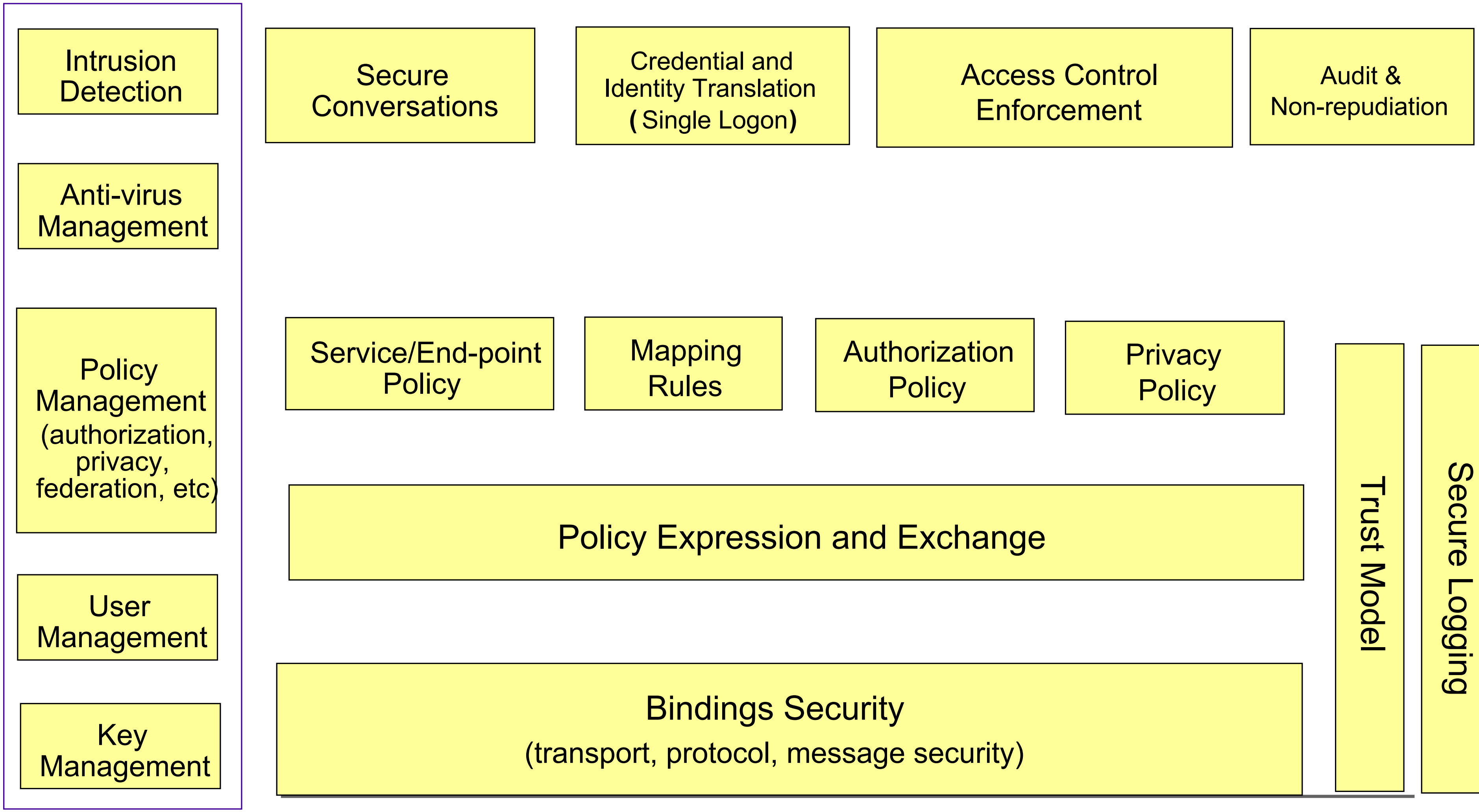


* With mutual authentication

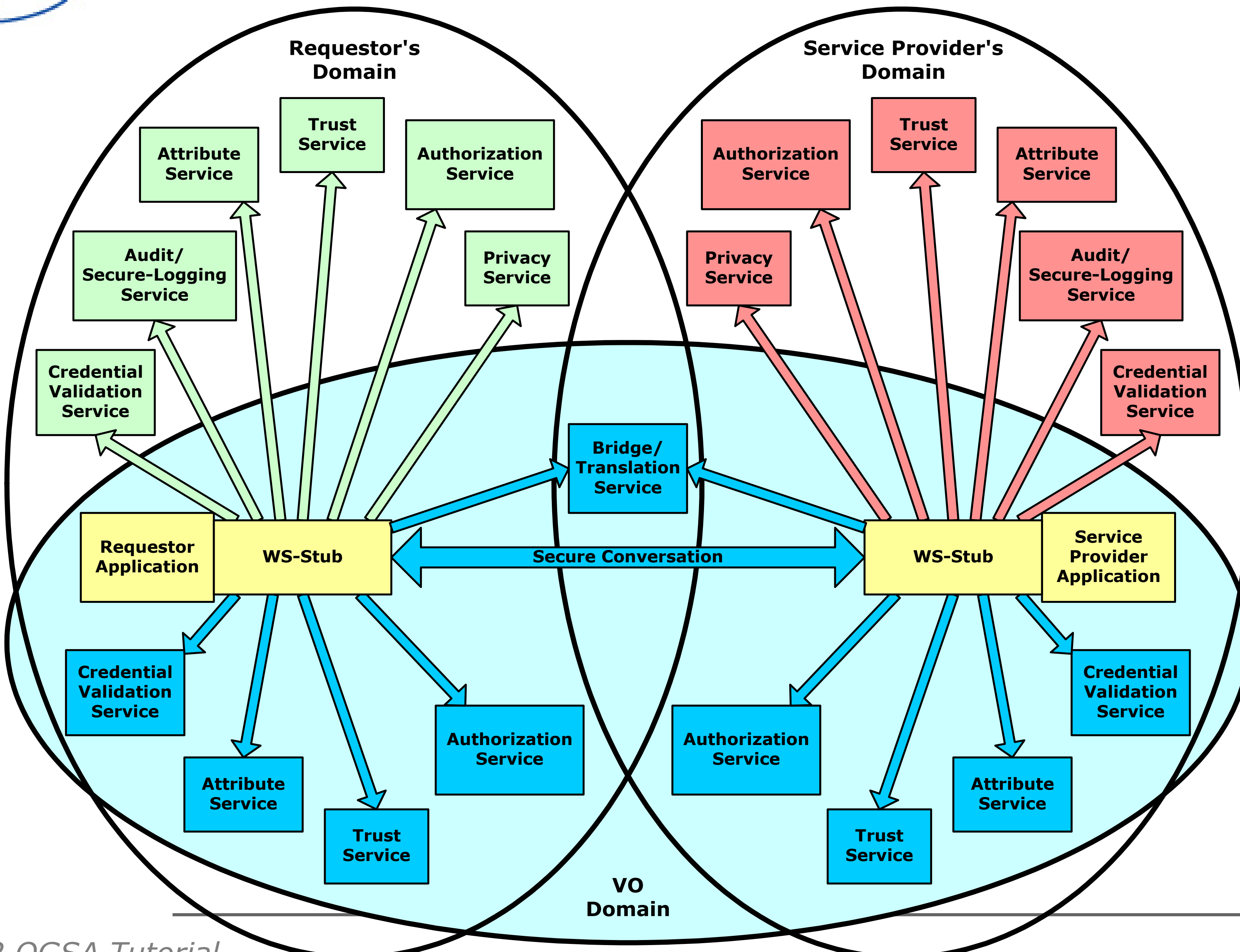
OGSA Security Architecture Goals

- Address the Grid Security Requirements
- Leverage existing/emerging Frameworks/Architecture/Standards
- OGSA Security Model
  - Secure Invocation of Grid Services
    - Securing Grid Services in general
  - Security services
    - Provide the necessary functionality

OGSA Security Architecture



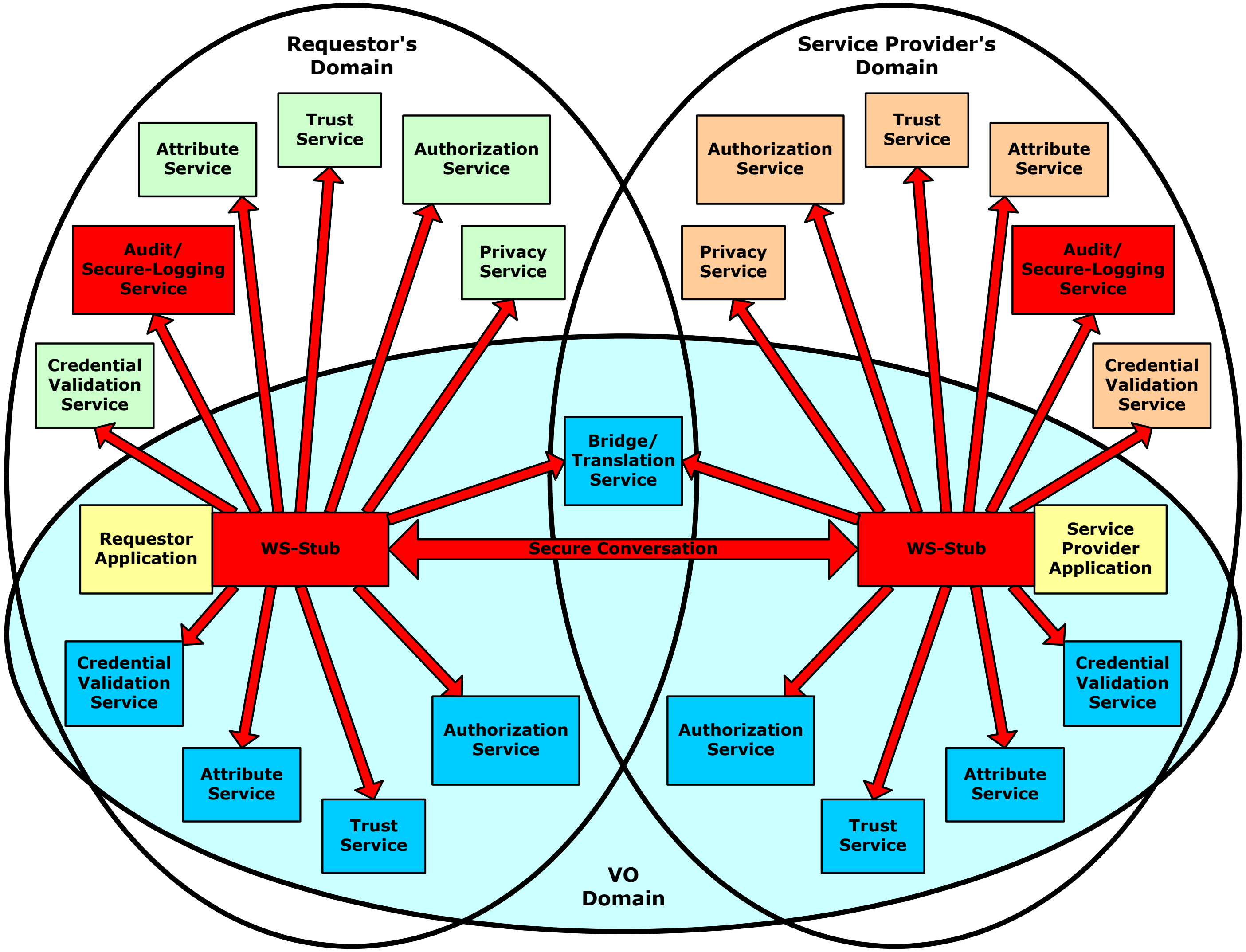
Security Services & VO



Example Service: Secure Logging and Audit

- Robust, secure audit infrastructure is essential for commercial Grid deployment
- Natural audit "code-points" in OGSA runtime
  - User's credentials, authorization decisions, invoked portTypes, parameter values, etc.
  - Allows for secure logging transparent and independent from applications
- Standard call-outs to external security services
  - More relevant audit code-points
- XML facilitates audit-entry filtering & mgmt

Transparent Audit Code-Points



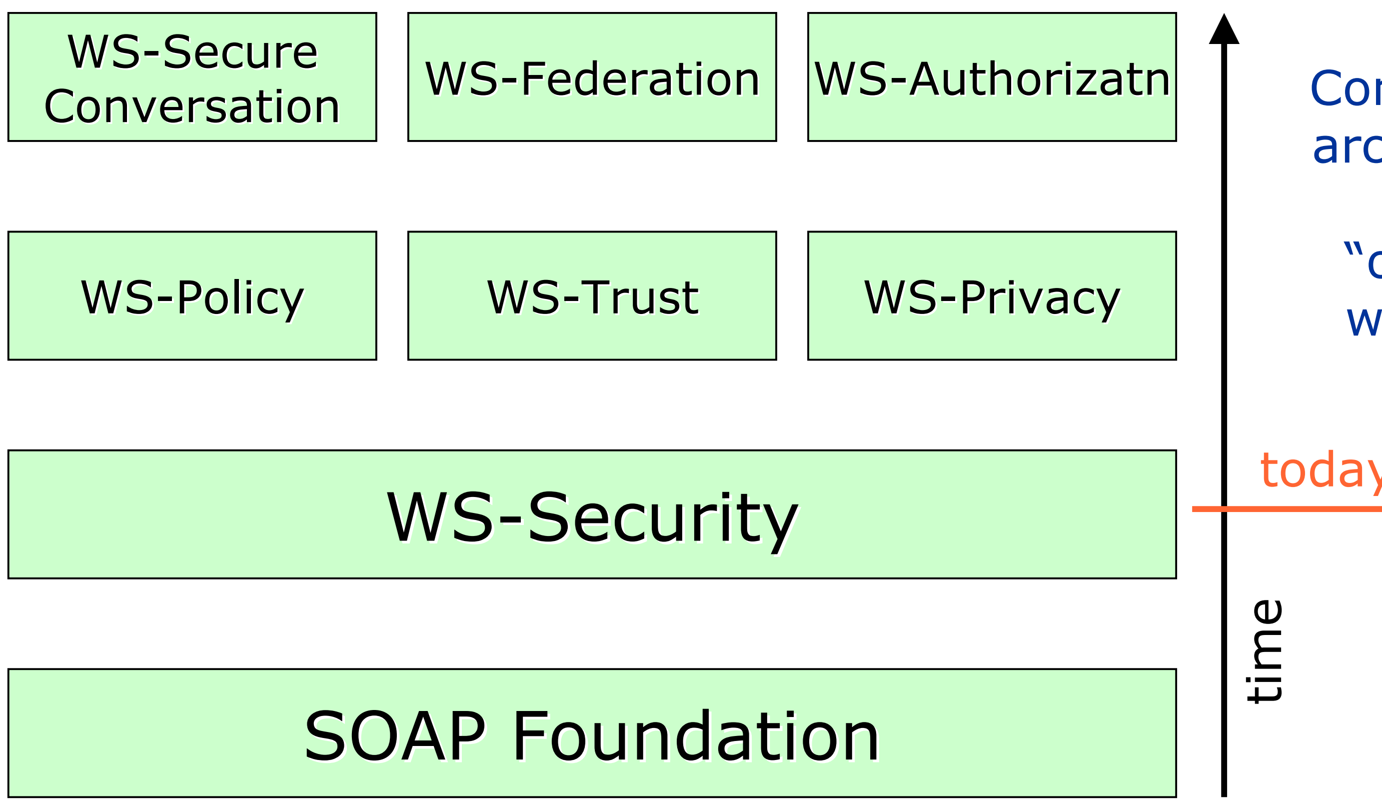
All service invocations and policy decisions within stubs are "natural" audit code-points

Leverage Existing/Emerging Security Standards

- WS-Security/Policy/Trust/Federation/ Authorization/SecureConversation/Privacy
- XKMS, XML-Signature/Encryption, SAML, XACML, XrML

- But…
    - Need to OGSA'fy
    - Need to define Profile/Mechanisms
    - Need to define Naming conventions
    - Need to address late/missing specs

WS Security Architecture Current/Proposed Specifications



Composable architecture

"only use what you need"

Grid Security in OGSA

- Two documents
  - OGSA Security Roadmap defines a set of required services and indicates for each if
    - Is provided by WS Security specs
    - May be provided by WS Security specs
    - Requires standardized profile/mechanisms and/or extensions for WS Security specs
  - The Security Architecture for Open Grid Services
  - Available at www.globus.org/ogsa/security
- GGF working group

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OGSA and the Globus Toolkit

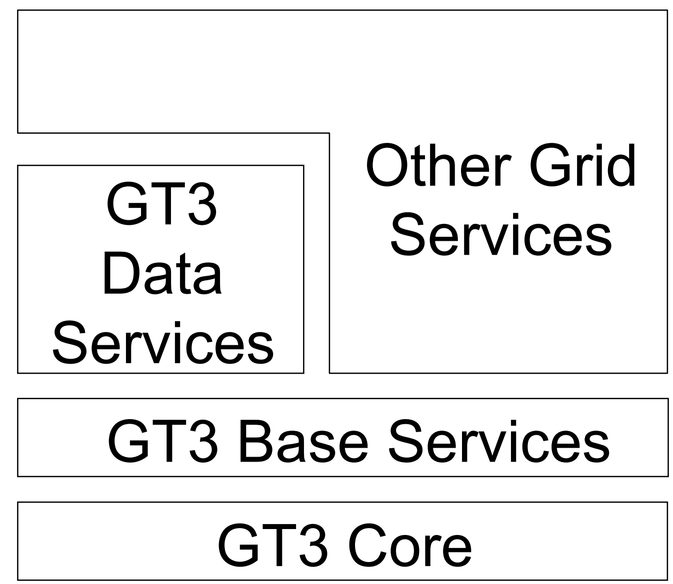
- Technically, OGSA enables
  - Refactoring of protocols (GRAM, MDS-2, etc.)—*while preserving all GT concepts/features*!
  - Integration with hosting environments: simplifying components, distribution, etc.
  - Greatly expanded standard service set
- Pragmatically, we are proceeding as follows
  - Develop open source OGSA implementation
    - Globus Toolkit 3.0; supports Globus Toolkit 2.0 APIs
  - Partnerships for service development
  - Also expect commercial value-adds

GT3: an OGSA-Compliant Globus Toolkit

- Open source implementation of OGSA from the Globus Project
- Globus Toolkit 3.0 (GT3)
  - first prototype Grid service implementation demonstrated on January 29, 2002
  - Several OGSI Technology Preview releases throughout the year
  - Alpha release expected end of 2002
  - For details see www.globus.org/ogsa
- Also, other implementations
  - Unicore, LBNL…

GT3 Structure

- GT3 Core
  - Implements Grid service interfaces & behaviors
  - Reference impln of evolving standard
  - Java, C, Python, C++…
- GT3 Base Services
  - Evolution of current Globus Toolkit capabilities
  - Backward compatible
- Many other Grid services



GT2 vs GT3 Strategy

- GT3 lets you do all the things you can do with GT2
  - Same familiar services: GRAM, GridFTP, etc.
  - Strong commitment to providing compatibility APIs
  - We do not enforce any particular programming model
- But GT3 also allows you to do many other things
  - Service orientation
  - Virtualization opportunities
  - New capabilities

Community Involvement: GGF

- GGF Working Groups:
  - OGSI-WG
    - refinement of the infrastructure-related portions of OGSA.
    - Formed February 2002
    - Led by S. Tuecke, D. Snelling
  - OGSA-WG
    - Architectural aspects
    - Formed July 2002, led by I. Foster, J. Nick, D. Gannon
  - OGSA Security WG
    - Formed July 2002, led by F. Siebenlist, N. Nagaratnam
  - Proposed: Java binding

Grids and OGSA: Research Challenges

- Grids pose profound problems, e.g.
  - Management of virtual organizations
  - Delivery of multiple qualities of service
  - Autonomic management of infrastructure
  - Software and system evolution
- OGSA provides foundation for tackling these problems in a rigorous fashion?
  - Structured establishment/maintenance of global properties
  - Reasoning about total system properties

Summary: Evolution of Grid Technologies

- Initial exploration (1996-1999; Globus 1.0)
  - Extensive appln experiments; core protocols
- Data Grids (1999-??; Globus 2.0+)
  - Large-scale data management and analysis
- Open Grid Services Architecture (2001-??, Globus 3.0)
  - Integration w/ Web services, hosting environments, resource virtualization
  - Databases, higher-level services
- Radically scalable systems (2003-??)
  - Sensors, wireless, ubiquitous computing

Summary

- The Grid problem: Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations
- Grid architecture: Protocol, service definition for interoperability & resource sharing
- Globus Toolkit a source of protocol and API definitions—and reference implementations
  - And many projects applying Grid concepts (& Globus technologies) to important problems
- Open Grid Services Architecture represents (we hope!) next step in evolution

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  - Talented team of scientists and engineers at ANL, USC/ISI, elsewhere (see www.globus.org)
- Open Grid Services Architecture (OGSA)
  - Karl Czajkowski @ USC/ISI, Jeff Nick, Steve Graham, Jeff Frey @ IBM, www.globus.org/ogsa
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