the globus toolkit®
www.globustoolkit.org

Introduction to Globus Toolkit 4

Gergely Sipos
MTA SZTAKI
sipos@sztaki.hu

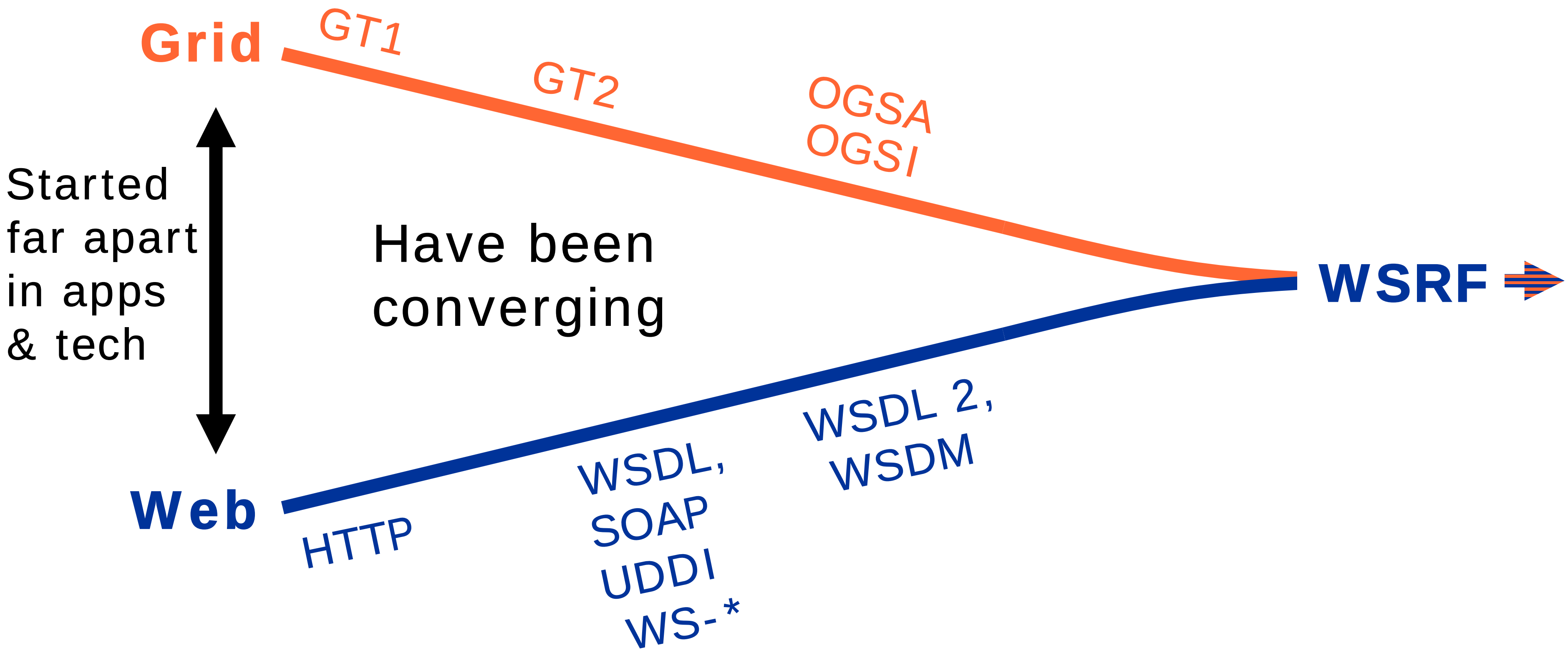
Credits

- Globus Toolkit v4 is the work of many talented Globus Alliance members, at
  - Argonne Natl. Lab & U.Chicago
  - USC Information Sciences Corporation
  - National Center for Supercomputing Applns
  - U. Edinburgh
  - Swedish PDC
  - Univa Corporation
  - Other contributors at other institutions
- Supported by DOE, NSF, UK EPSRC, and other sources

Overview

- Web services
- Grids meets Web services: WSRF
- WSRF based services in Globus Toolkit 4

Grid and Web Services: Convergence



The definition of WSRF means that Grid and Web communities can move forward on a common base

Web services technology

- Web designed for application to human interactions
- Served very well its purpose:
  - Information sharing: a distributed content library.
  - Enabled B2C e-commerce.
  - Non-automated B2B interactions.
- How did it happen?
  - Built on very few standards: http + html
  - Shallow interaction model: very few assumptions made about computing platforms.
- The Web is everywhere. There is a lot more we can do!
  - Open, automated B2B e-commerce: Business process integration on the Web.
- Current approach is *ad-hoc* on top of existing standards.
  - e.g., application-to-application interactions with HTML forms.

- Goal: **enabling systematic application-to-application interaction on the Web.**

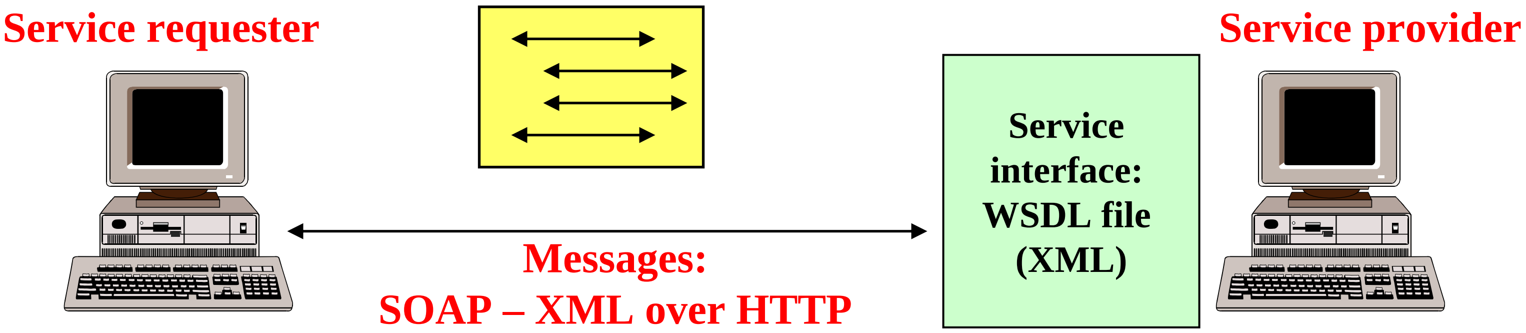
What is the WS technology?

- Web services define a technique
  - For describing software components to be accessed
  - Methods for accessing these components
  - Discovery methods that enable the identification of relevant service providers

- A web service is a piece of software that is made available on the Internet and utilizes a standardized XML messaging system. In other words a web service is a remote procedure call over the Internet using XML messages.

- Web services standards are being defined within the W3C (World Wide Web Consortium) and other standard bodies and form the basis for major new industry initiatives such as
  - Microsoft .Net
  - IBM Dynamic e-Business
  - Sun One, ...

WS standards 1: SOAP and WSDL



Service requester

Service provider

Service interface: WSDL file (XML)

Messages:
SOAP – XML over HTTP

- SOAP provides a means of messaging between a service provider and a service requester.
- SOAP is a simple enveloping mechanism for XML payloads that defines an RPC convention.
- SOAP is independent of the underlying transport protocol
- SOAP client reads a WSDL file to get
  - the address and message information of a web service.
- Once the WSDL file is read, the client can start sending SOAP messages to the web service.
- Benefit: loosely coupling components by document oriented communication

A WSDL example

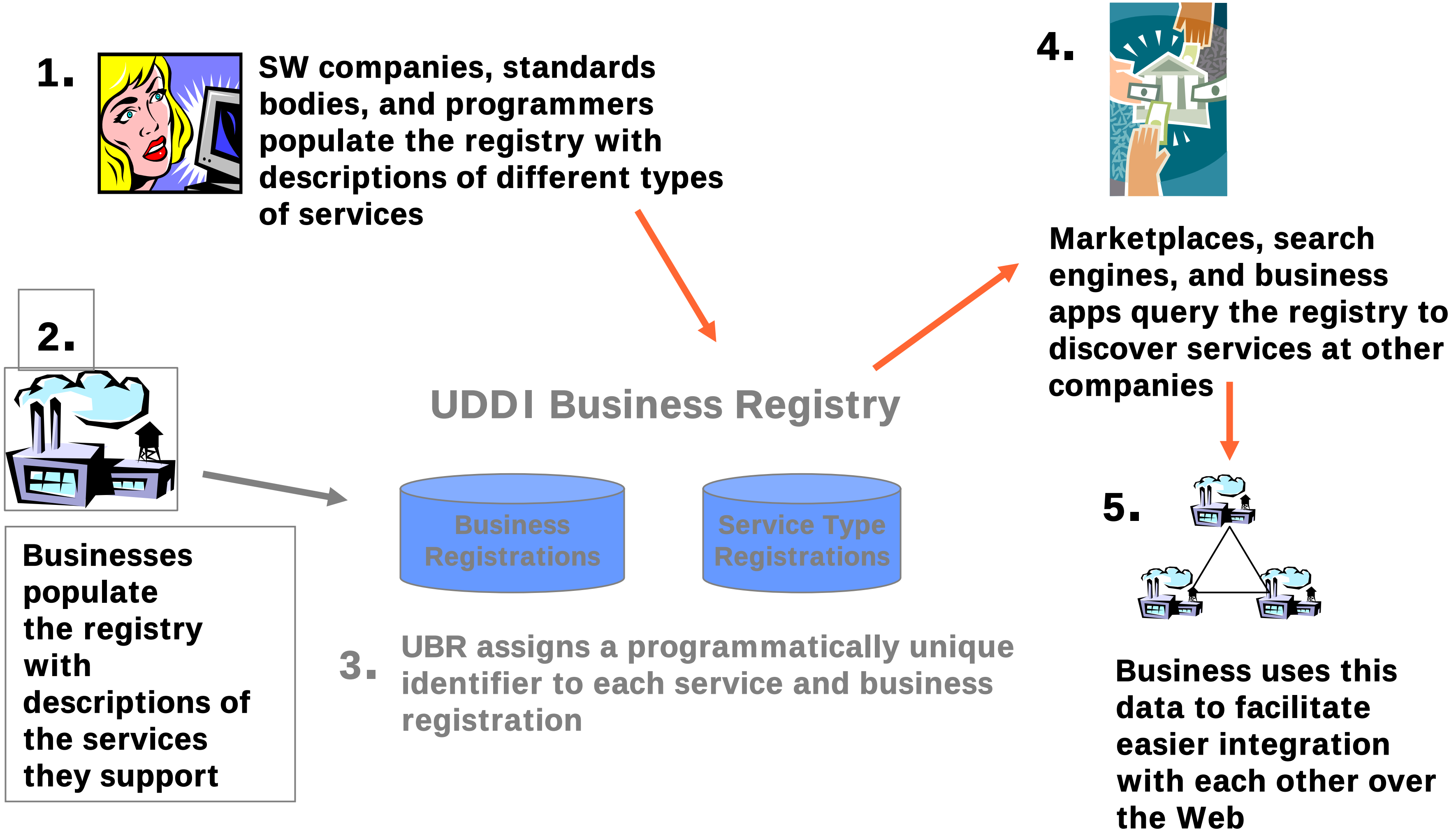
```
<wsdl:definitions targetNamespace="…">
  <wsdl:types>
    <schema>
      <xsd:element name="fooInput" …/>
      <xsd:element name="fooOutput" …/>
    </schema>
  </wsdl:types>
  <wsdl:message name="fooInputMessage">
    <part name="parameters" element="fooInput"/>
  </wsdl:message>
  <wsdl:message name="fooOutputMessage">
    <part name="parameters" element="fooOutput"/>
  </wsdl:message>
  <wsdl:portType name="fooInterface">
    <wsdl:operation name="foo">
      <input message="fooInput"/>
      <output message = "fooOutput"/>
    </wsdl:operation>
  </wsdl:portType>
</wsdl:definitions>
```

WS standards 2: UDDI

- How can I discover business partners with compatible web service solutions?
- How do let other business know about my exposed web services?
- *Web services are great, after you find out about them, but the discovery process is difficult*

- *Information system for Web services:*
  UDDI - Universal Description, Discovery and Integration

The WS vision



1. SW companies, standards bodies, and programmers populate the registry with descriptions of different types of services

2. Businesses populate the registry with descriptions of the services they support

UDDI Business Registry

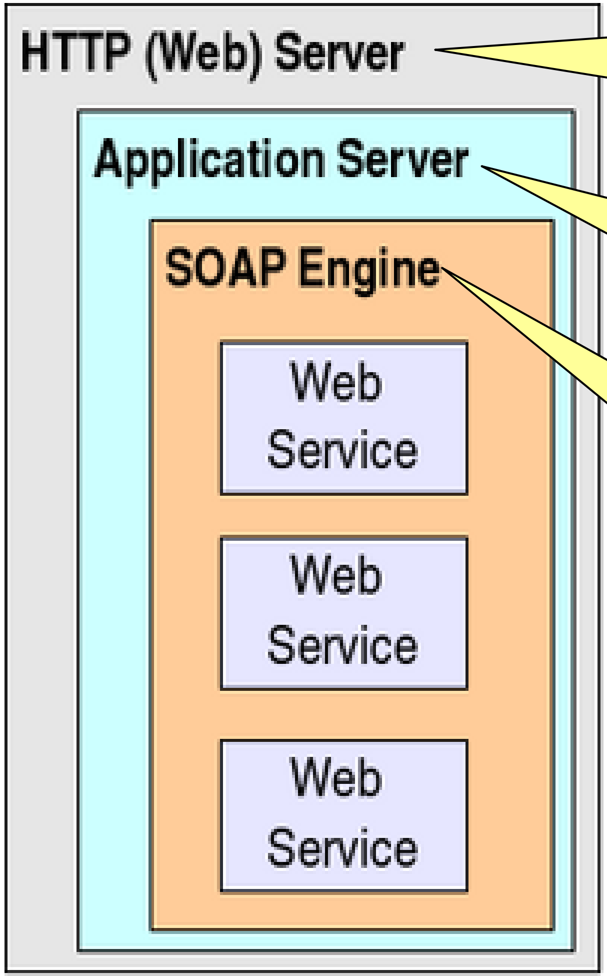
3. UBR assigns a programmatically unique identifier to each service and business registration

4. Marketplaces, search engines, and business apps query the registry to discover services at other companies

5. Business uses this data to facilitate easier integration with each other over the Web

Business processes realized by on-demand workflows of Web services

The server side in a Web Services application



HTTP (Web) Server

Application Server

SOAP Engine

Web Service

Web Service

Web Service

A piece of software that knows how to handle HTTP messages **(Apache HTTP server)**

A piece of software that provides a 'living space' for applications that must be accessed by different clients **(Jakarta Tomcat)**

A piece of software that knows how to handle SOAP requests and responses **(Apache Axis)**

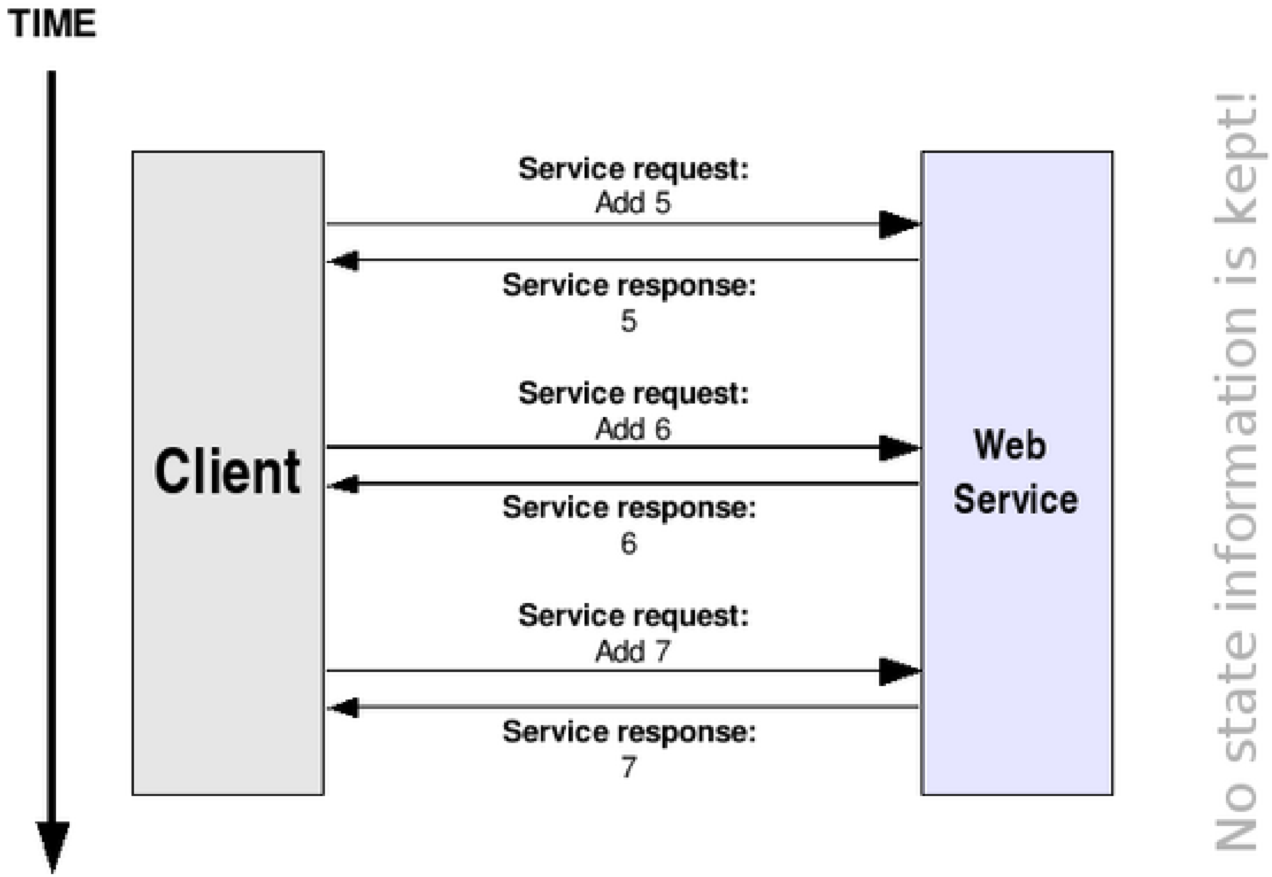
Grid community meets Web services: Open Grid Services Architecture (OGSA)

The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration. I. Foster, C. Kesselman, J. Nick, S. Tuecke, Open Grid Service

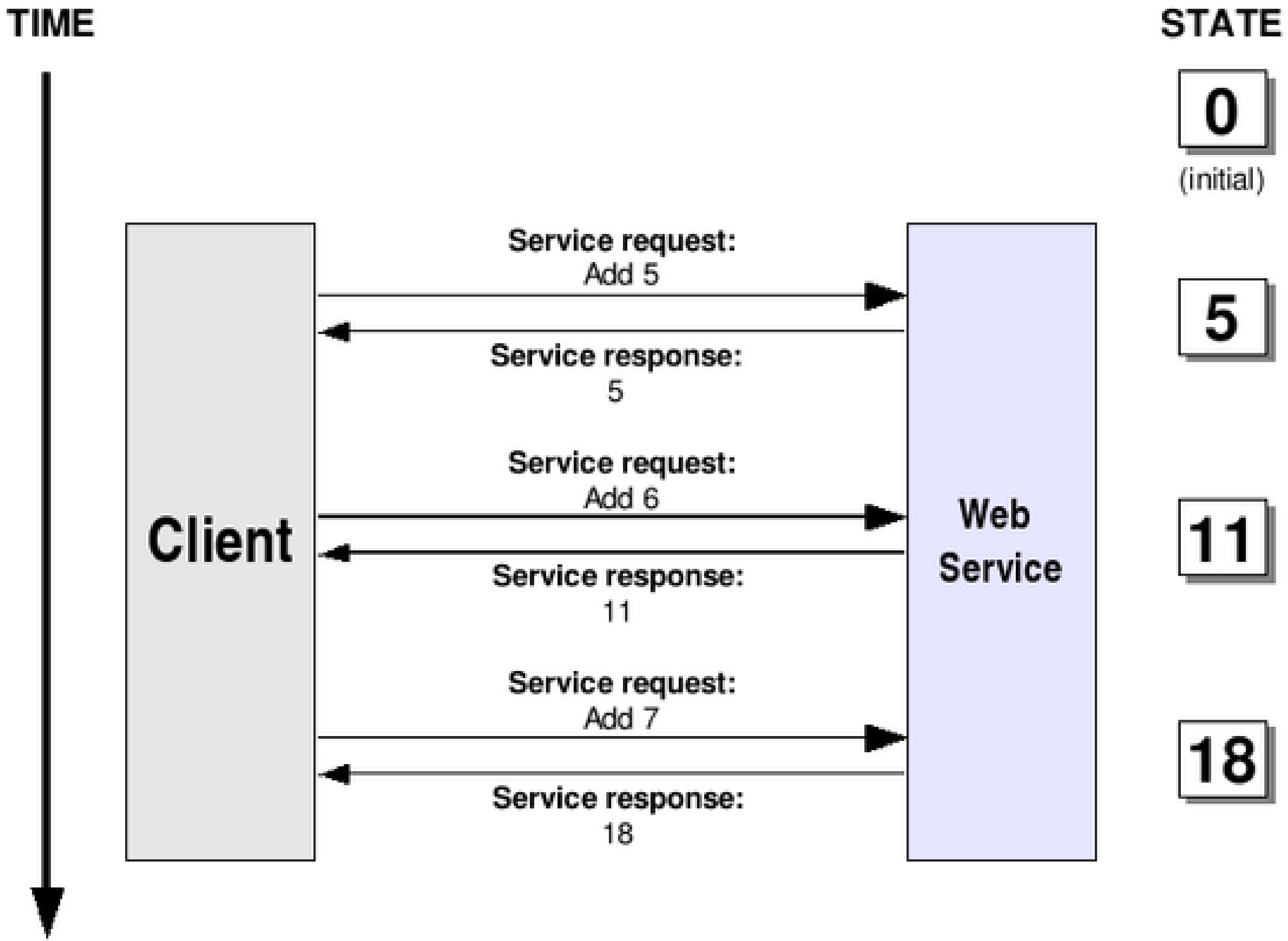
- Service orientation to virtualize resources
  - **Everything is a service!**
- From Web services
  - Standard interface definition mechanisms
  - Evolving set of other standards: security, etc.
- From Grids (Globus Toolkit)
  - Service semantics, reliability & security models
  - Lifecycle management, discovery, other services
- OGSA implementation: WSRF – A framework for the definition & management of composable, interoperable services

WSRF: The Web Services Resource Framework

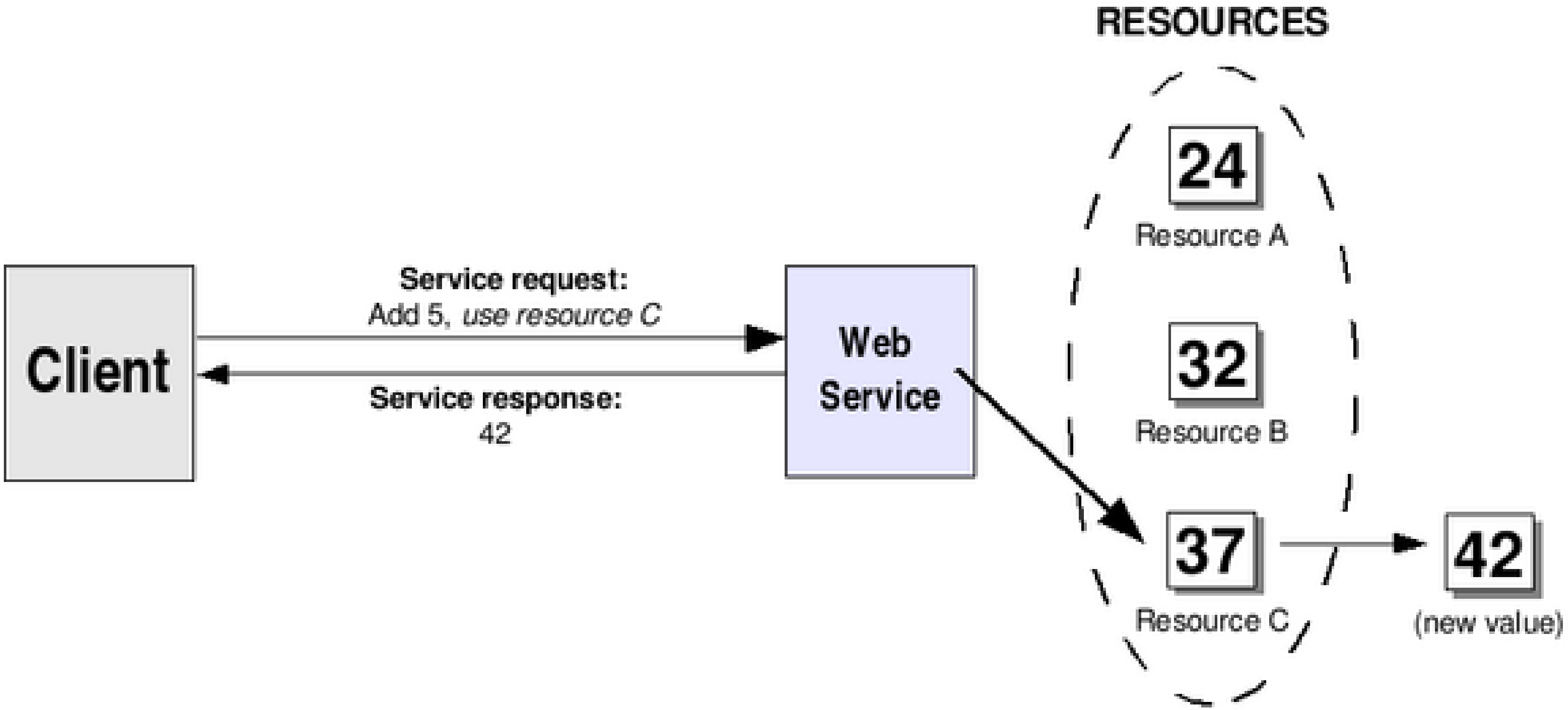
- Web services technology does not give support for state management
- WSRF: It's all about state



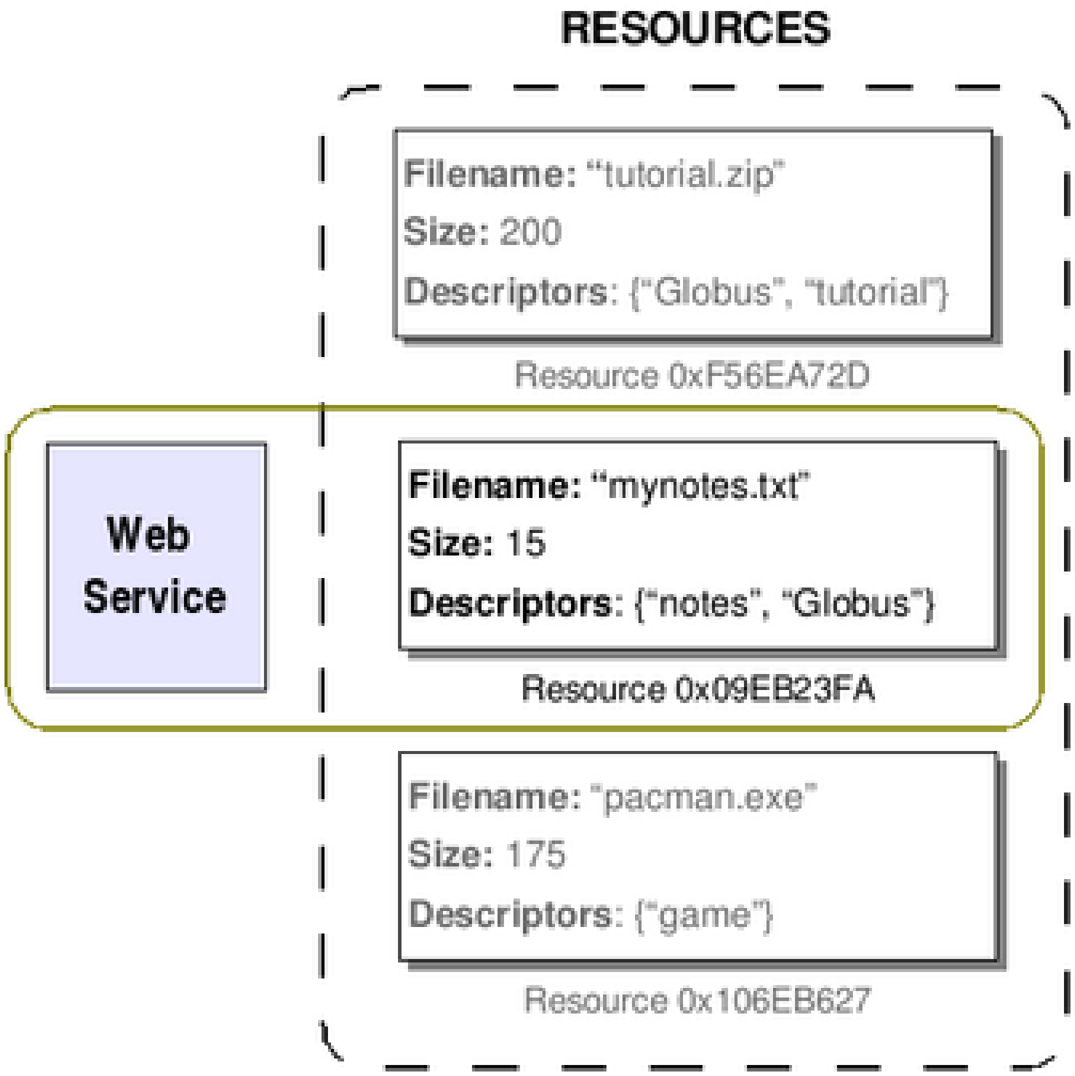
WSFR as a stateful Web Service invocation



The resource approach to statefulness



WS-Resource



RESOURCES

Filename: "tutorial.zip"
Size: 200
Descriptors: {"Globus", "tutorial"}

Resource 0xF56EA72D

Web Service

Filename: "mynotes.txt"
Size: 15
Descriptors: {"notes", "Globus"}

Resource 0x09EB23FA

Filename: "pacman.exe"
Size: 175
Descriptors: {"game"}

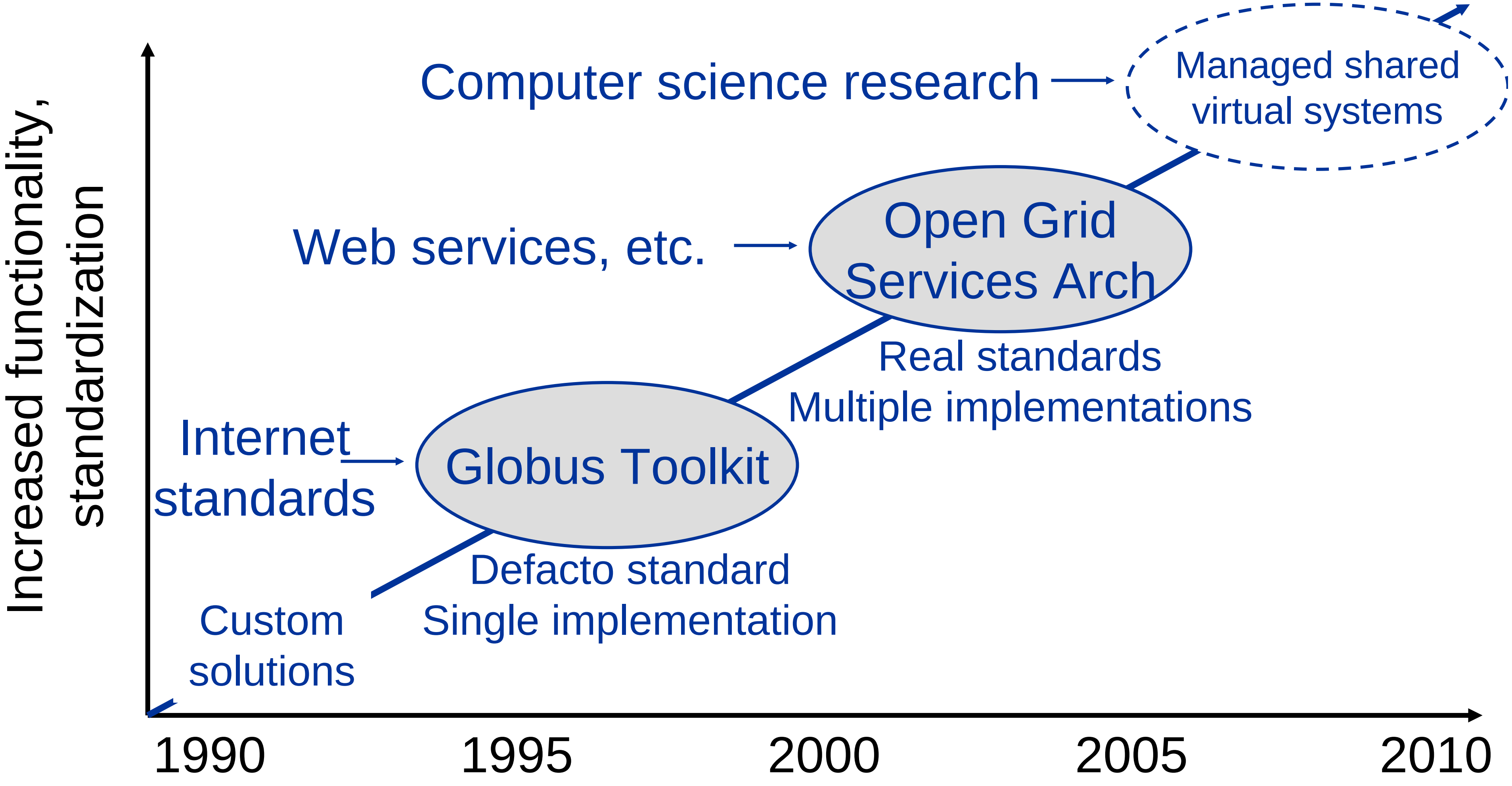
Resource 0x106EB627

Web Service
+
Resource
=
WS-Resource

The WSRF specification

- The Web Services Resources Framework is a collection of 4 different specifications:
  - WS-ResourceProperties
  - WS-ResourceLifetime
  - WS-ServiceGroup
  - WS-BaseFaults
- Related specifications
  - WS-Notification
  - WS-Addressing

The Emergence of Open Grid Standards



Computer science research

Managed shared virtual systems

Web services, etc.

Open Grid Services Arch

Real standards
Multiple implementations

Internet standards

Globus Toolkit

Defacto standard
Single implementation

Custom solutions

WSRF structure

- A standard substrate: **the Grid service**
  - A Grid service is a special type of Web service
  - Standard interfaces and behaviors that address key distributed system issues: naming, service state, lifetime, notification
- ... supports standard service specifications
  - Agreement, data access & integration, workflow, security, policy, diagnostics, etc.
  - Target of current & planned OGF efforts
- ... and arbitrary application-specific services based on these & other definitions

Why Open Standards Matter

- Ubiquitous adoption demands open, standard protocols
  - Standard protocols enable *interoperability*
  - Avoid product/vendor lock-in
  - Enables innovation/competition on end points
- Further aided by open, standard interfaces and APIs
  - Standard APIs enable *portability*
  - Allow implementations to port to different vendor platforms

Web services vs. Grid services

- "Web services" address discovery & invocation of persistent services
  - Interface to persistent state of entire enterprise
- In Grids we also need transient services, created/destroyed dynamically
  - Interfaces to the states of distributed activities
  - E.g. workflow, video conf., dist. data analysis
- Significant implications for how services are managed, named, discovered, and used
  - In fact, much of our work is concerned with the management of services

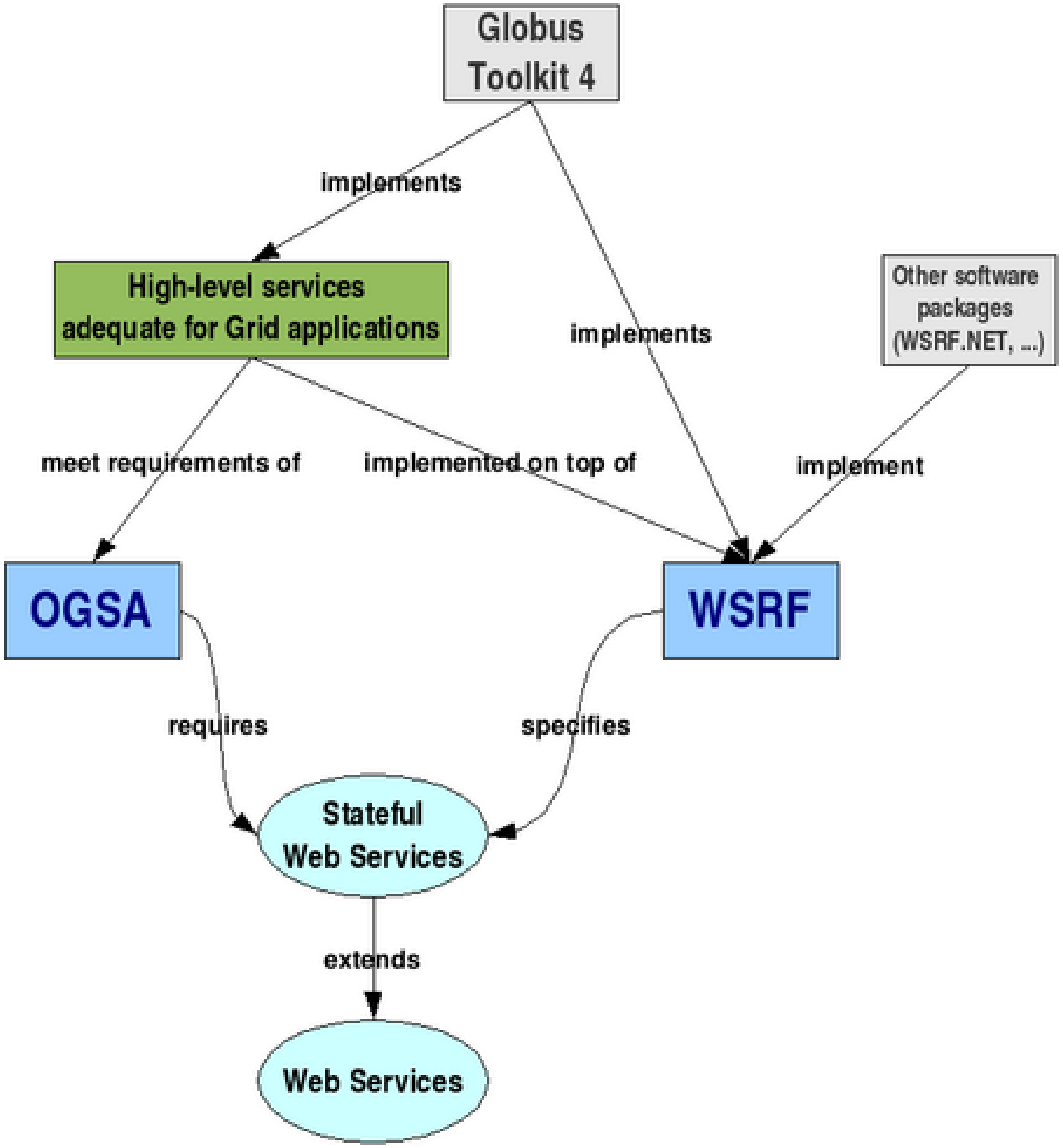
Open Grid Services Infrastructure (OGSI) Specification

- Defines fundamental interfaces (using extended WSDL) and behaviors that define a Grid Service
    - A unifying framework for interoperability & establishment of total system properties
- Defines WSDL conventions and extensions
    - For describing and naming services
- Defines basic patterns of interaction, which can be combined with each other and with custom patterns in a myriad of ways

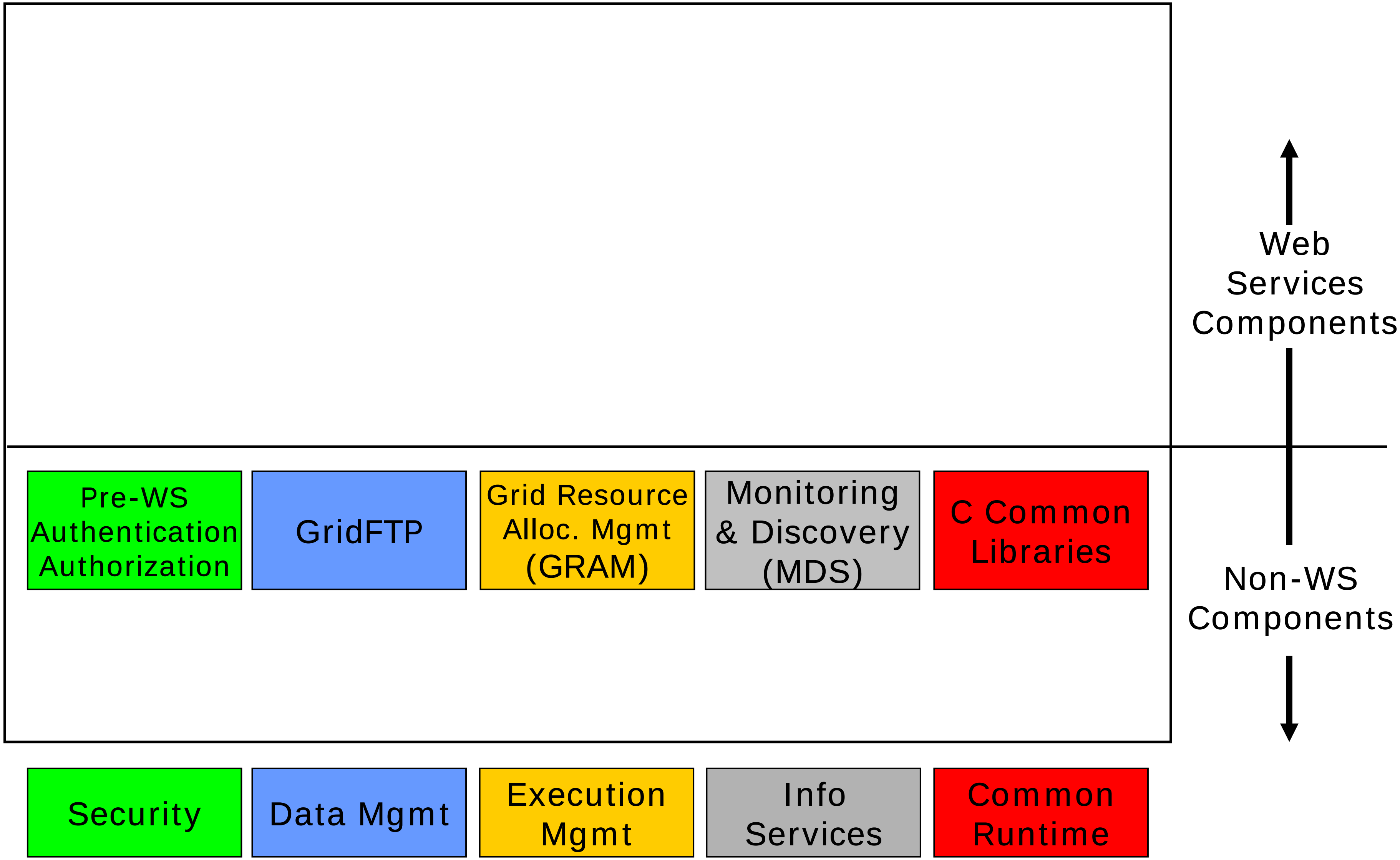
OGSI: Standard Web Services Interfaces & Behaviors

- Naming and bindings (basis for virtualization)
  - Every service instance has a unique name, from which can discover supported bindings
- Lifecycle (basis for fault resilient state management)
  - Service instances created by factories
  - Destroyed explicitly or via soft state
- Information model (basis for monitoring & discovery)
  - Service data (attributes) associated with GS instances
  - Operations for querying and setting this info
  - Asynchronous notification of changes to service date
- Service Groups (basis for registries & collective svcs)
  - Group membership rules & membership management
- Base Fault type

Relationship between OGSA, GT4, WSRF, and Web Services



Globus Toolkit version 2 (based on custom protocols)



Pre-WS Authentication Authorization

GridFTP

Grid Resource Alloc. Mgmt (GRAM)

Monitoring & Discovery (MDS)

C Common Libraries

Web Services Components

Non-WS Components

Security

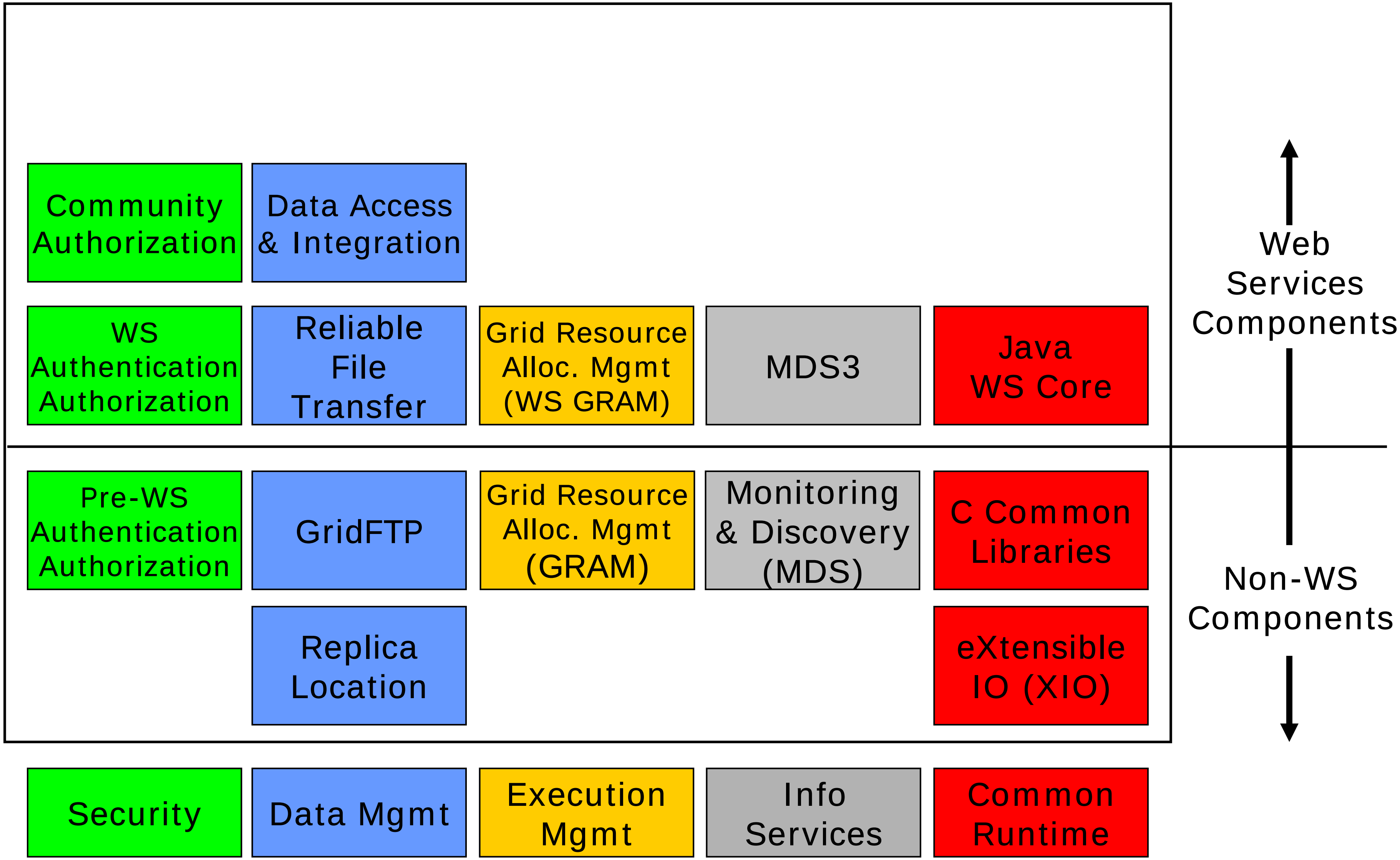
Data Mgmt

Execution Mgmt

Info Services

Common Runtime

Globus Toolkit version 3
OGSI based (~pre WSRF)



Community Authorization

Data Access & Integration

WS Authentication Authorization

Reliable File Transfer

Grid Resource Alloc. Mgmt (WS GRAM)

MDS3

Java WS Core

Pre-WS Authentication Authorization

GridFTP

Grid Resource Alloc. Mgmt (GRAM)

Monitoring & Discovery (MDS)

C Common Libraries

Replica Location

eXtensible IO (XIO)

Web Services Components

Non-WS Components

Security

Data Mgmt

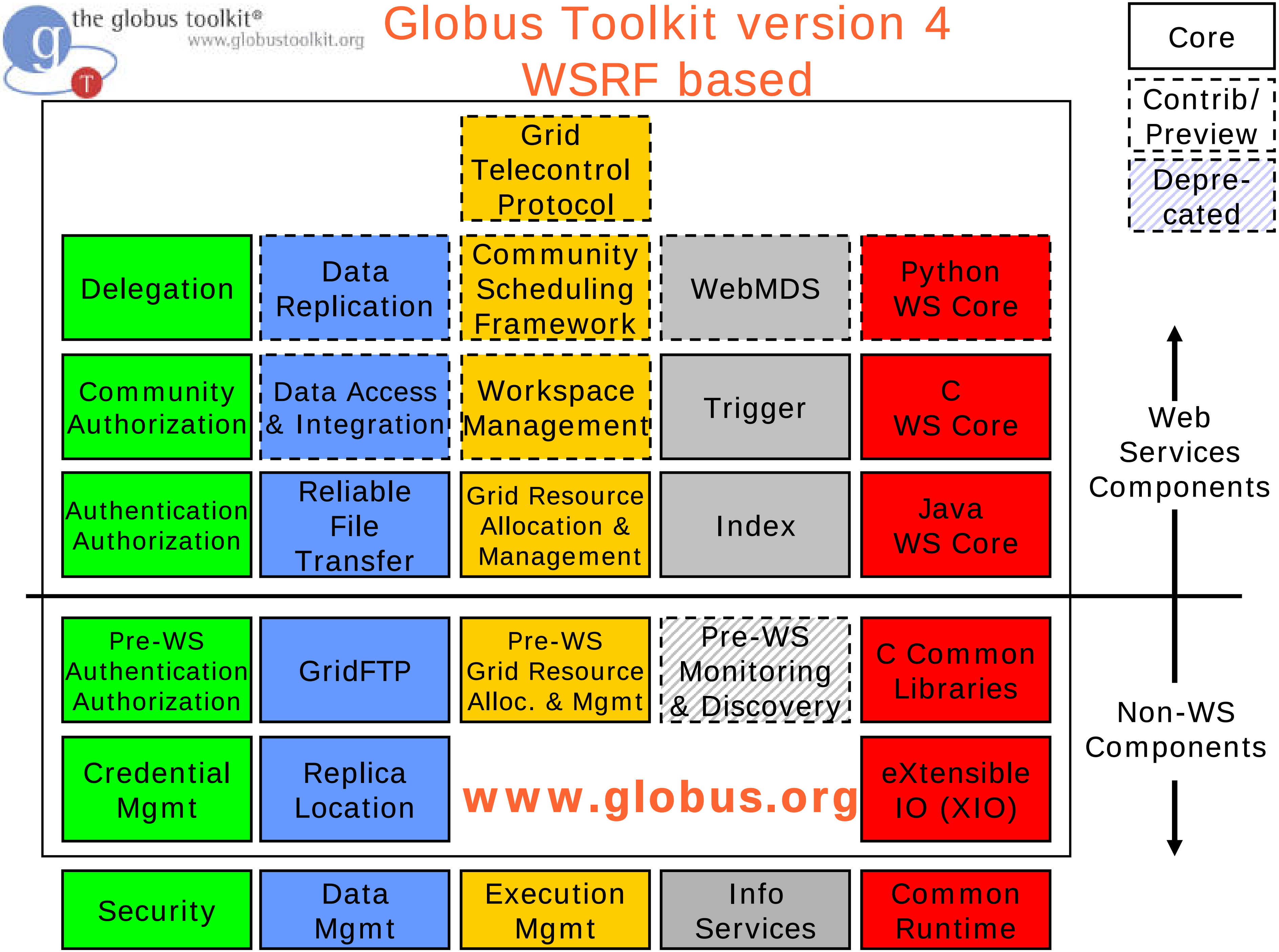
Execution Mgmt

Info Services

Common Runtime

the globus toolkit®
www.globustoolkit.org

Globus Toolkit version 4 WSRF based



Core

Contrib/ Preview

Depre- cated

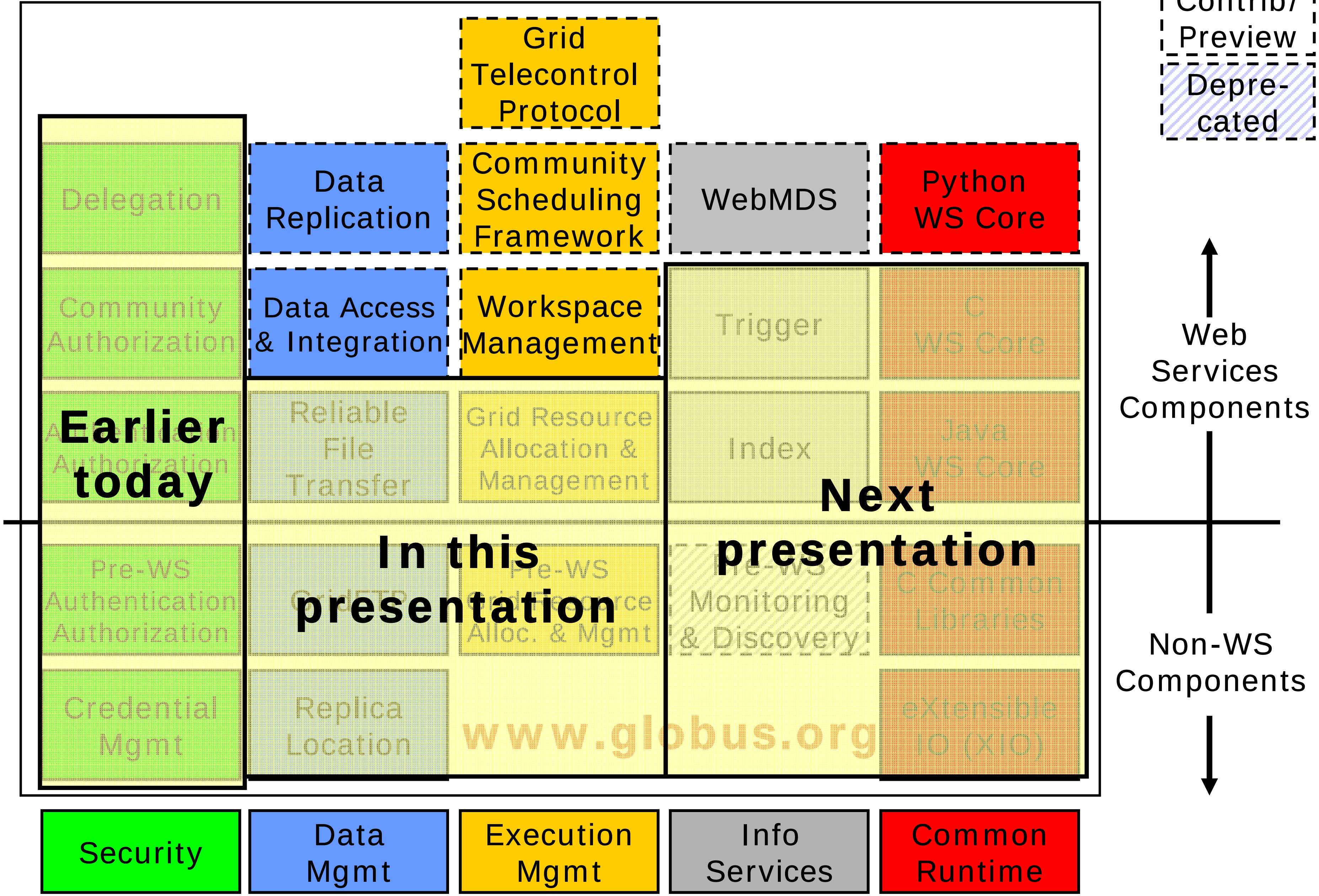
		Grid Telecontrol Protocol		
Delegation	Data Replication	Community Scheduling Framework	WebMDS	Python WS Core
Community Authorization	Data Access & Integration	Workspace Management	Trigger	C WS Core
Authentication Authorization	Reliable File Transfer	Grid Resource Allocation & Management	Index	Java WS Core
Pre-WS Authentication Authorization	GridFTP	Pre-WS Grid Resource Alloc. & Mgmt	Pre-WS Monitoring & Discovery	C Common Libraries
Credential Mgmt	Replica Location	www.globus.org		eXtensible IO (XIO)
Security	Data Mgmt	Execution Mgmt	Info Services	Common Runtime

Web Services Components

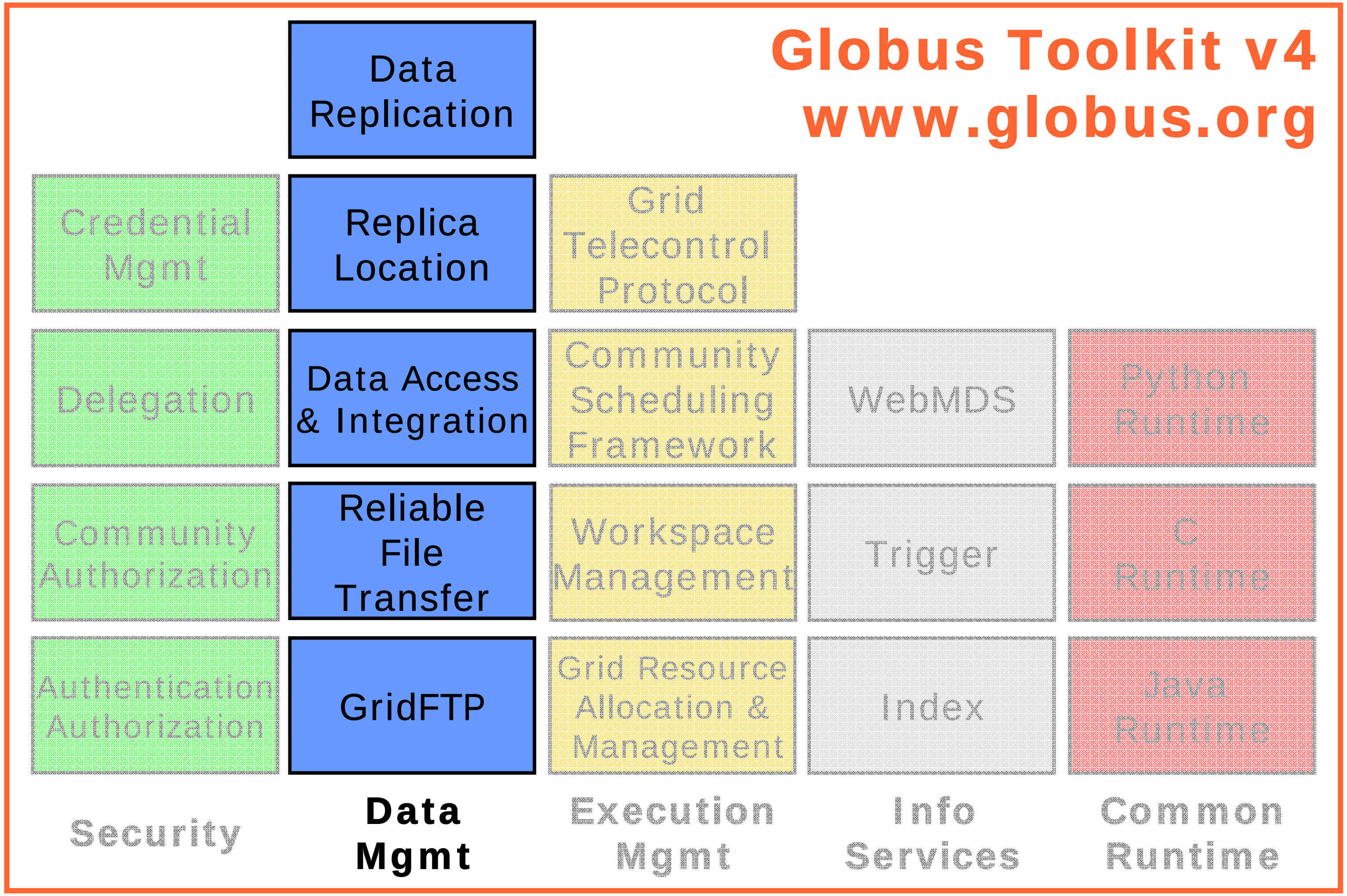
Non-WS Components

the globus toolkit® www.globustoolkit.org

Globus Toolkit version 4 WSRF based



Globus Toolkit: Open Source Grid Infrastructure



Globus Toolkit v4
www.globus.org

Security	Data Mgmt	Execution Mgmt	Info Services	Common Runtime
	Data Replication			
Credential Mgmt	Replica Location	Grid Telecontrol Protocol		
Delegation	Data Access & Integration	Community Scheduling Framework	WebMDS	Python Runtime
Community Authorization	Reliable File Transfer	Workspace Management	Trigger	C Runtime
Authentication Authorization	GridFTP	Grid Resource Allocation & Management	Index	Java Runtime

GT4 Data Management

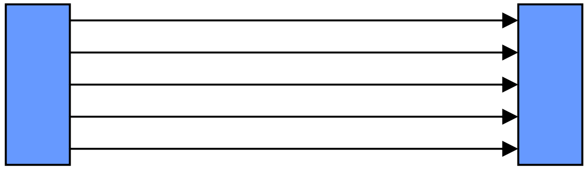
- **Stage / move** large data to/from nodes
  - GridFTP, Reliable File Transfer (RFT)
  - Alone, and integrated with GRAM
- **Locate** data of interest
  - Replica Location Service (RLS)
- **Replicate** data for performance/reliability
  - Distributed Replication Service (DRS)
- Provide **access** to diverse data sources
  - File systems, parallel file systems, hierarchical storage: GridFTP
  - Databases: OGSA DAI

GridFTP

- A high-performance, secure, reliable data transfer protocol optimized for high-bandwidth wide-area networks
- GridFTP server ~ high performance FTP server with GSI
- Multiple nodes work together and act as a single GridFTP server
- Each node moves (reads or writes) only the pieces of the file that it is responsible for.
- Pluggable
    - Front-end: e.g., future WS control channel
    - Back-end: e.g., HPSS, cluster file systems
    - Transfer: e.g., UDP, NetBLT transport

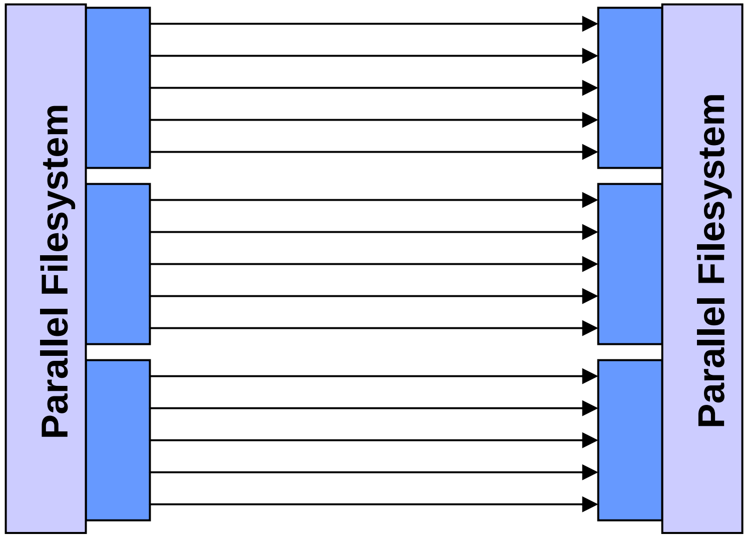
Striped GridFTP Service

- A distributed GridFTP service that runs on a storage cluster
  - Every node of the cluster is used to transfer data into/out of the cluster
  - Head node coordinates transfers
- Multiple NICs/internal busses lead to very high performance
  - Maximizes use of Gbit+ WANs



Parallel Transfer

Fully utilizes bandwidth of network interface on single nodes.

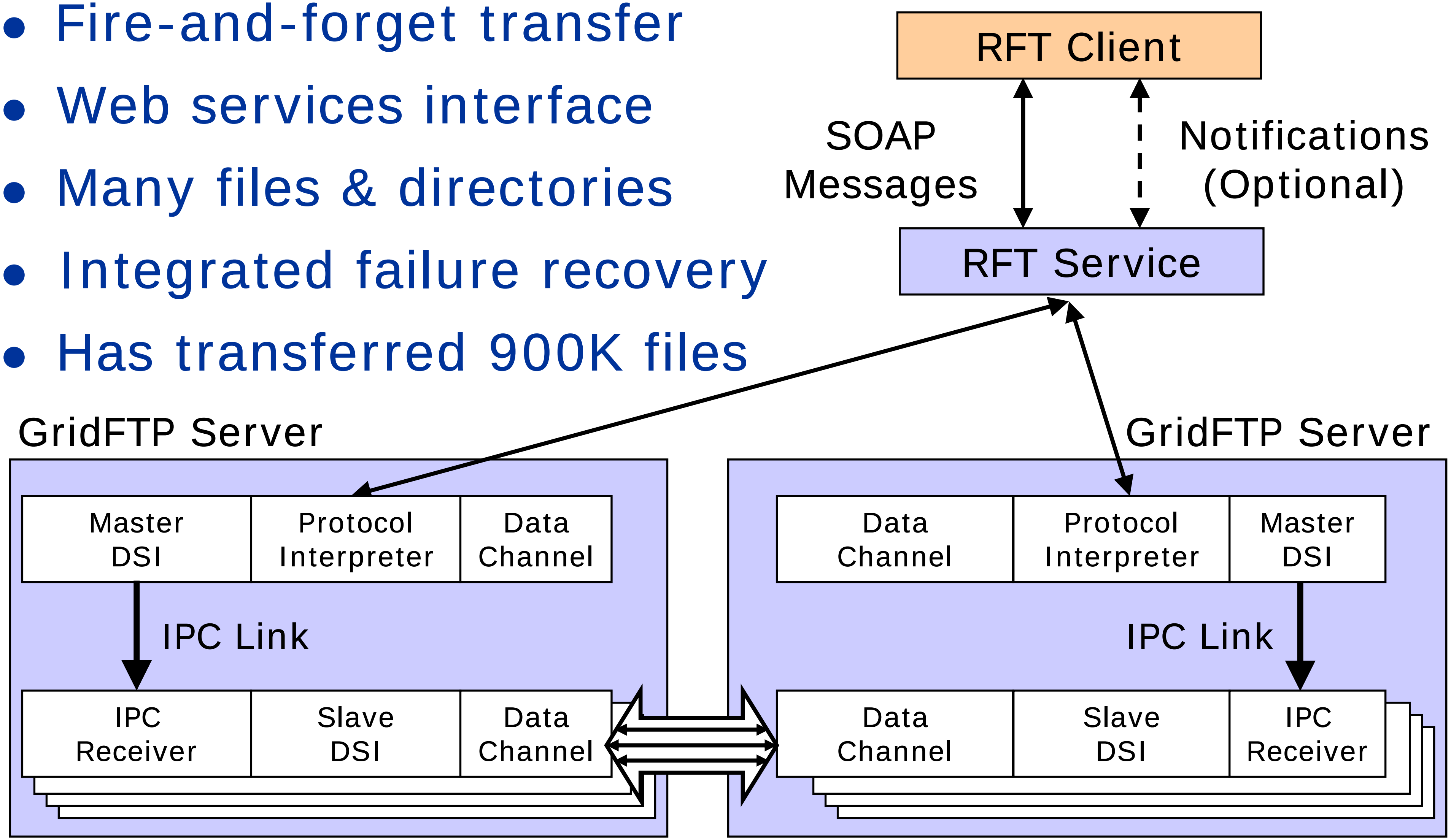


Striped Transfer

Fully utilizes bandwidth of Gb+ WAN using multiple nodes.

Reliable File Transfer: Third Party Transfer

- Fire-and-forget transfer
- Web services interface
- Many files & directories
- Integrated failure recovery
- Has transferred 900K files



Data services on a Grid: role of OGSA-DAI

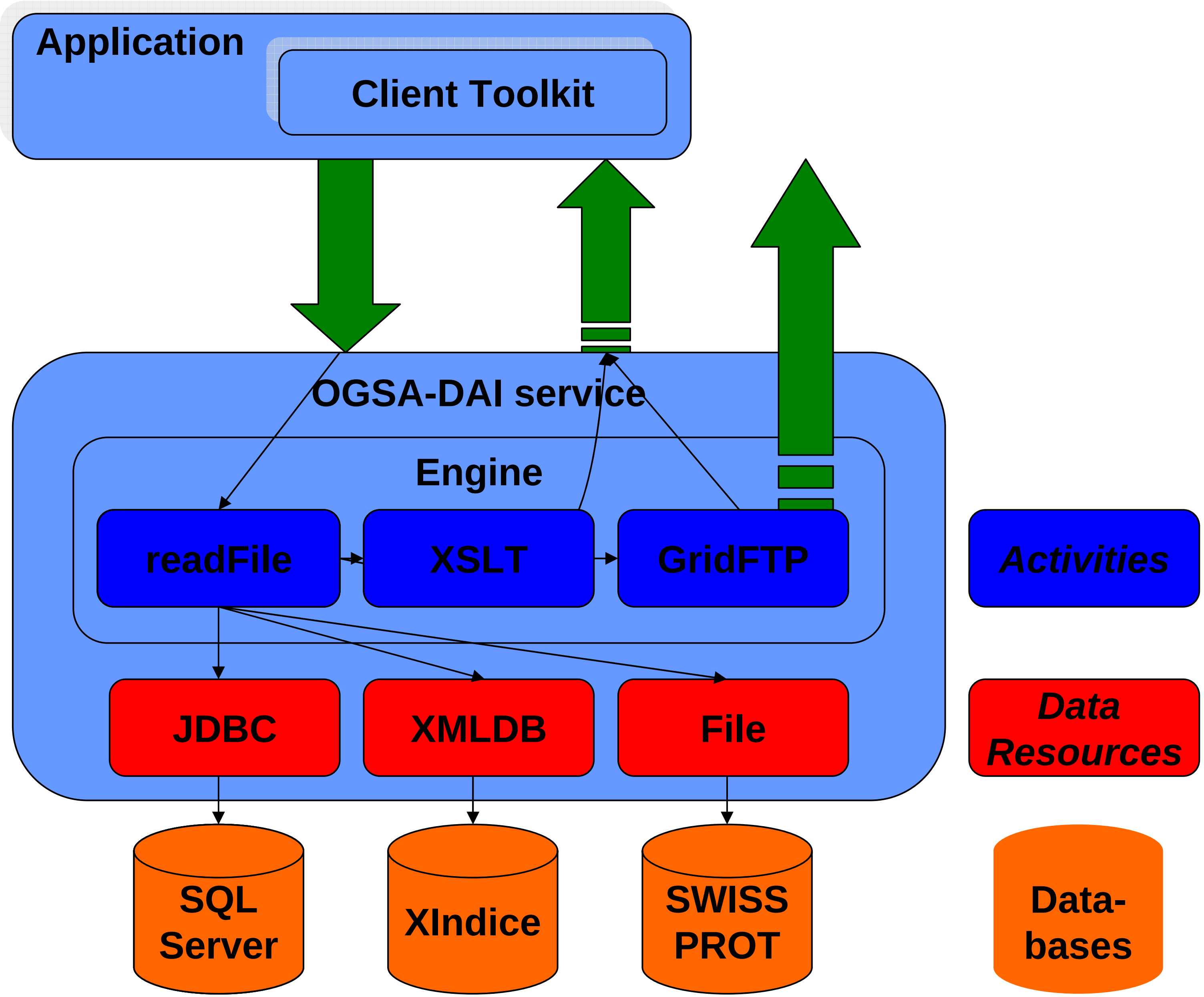
Simple data files

- Middleware supporting
  - **Replica files**
  - **Logical filenames**
  - **Catalogue**: maps logical name to physical storage device/file
  - **Virtual filesystems**, POSIX-like I/O

Structured data

  - RDBMS, XML datab es
- Requ *da*
  ols rt
  o t o
  co y
  on and federation

The OGSA-DAI Framework



Application

Client Toolkit

OGSA-DAI service

Engine

readFile

XSLT

GridFTP

Activities

JDBC

XMLDB

File

Data Resources

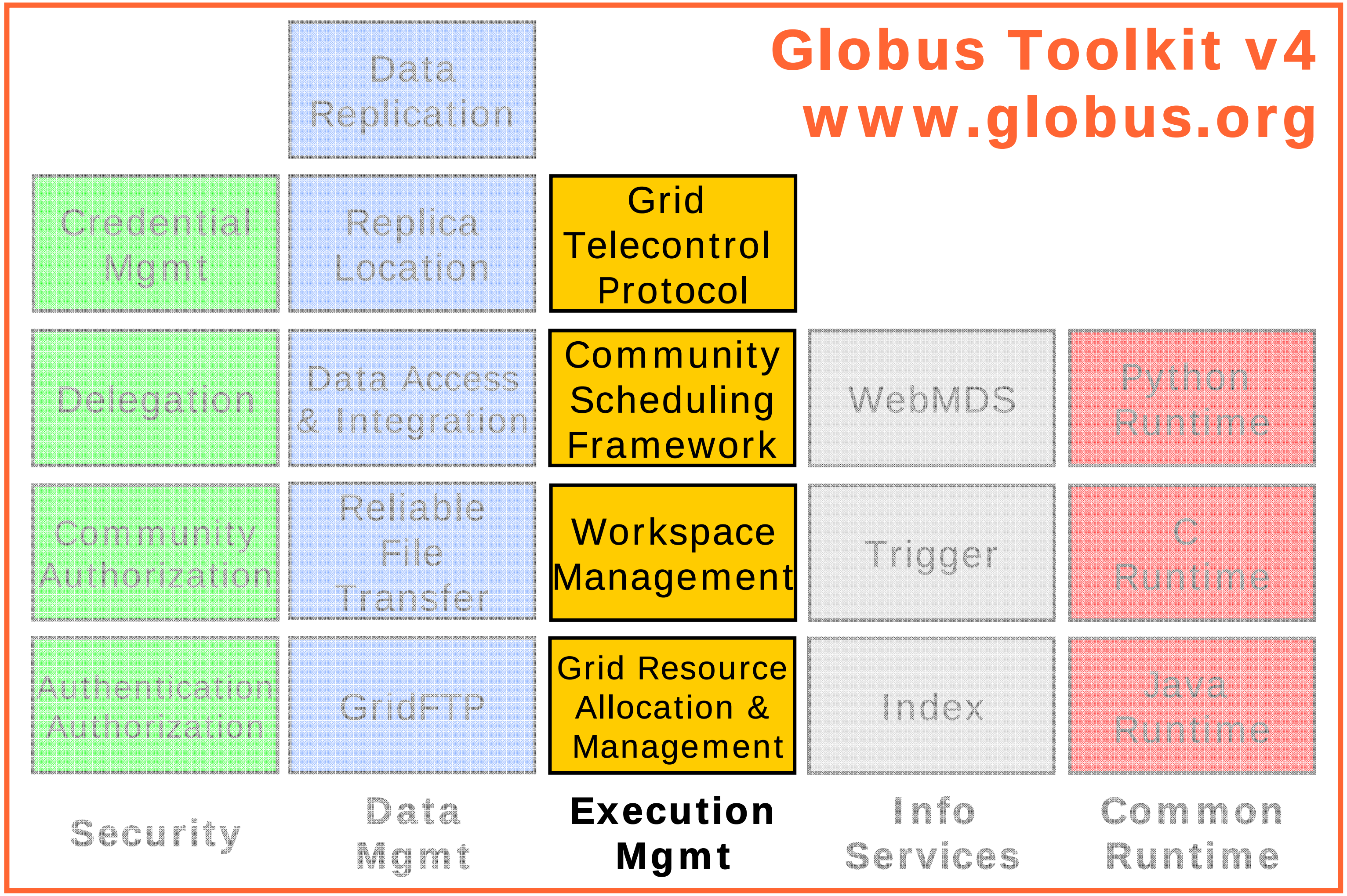
SQL Server

XIndice

SWISS PROT

Data-bases

Globus Toolkit: Open Source Grid Infrastructure



Globus Toolkit v4
www.globus.org

Security	Data Mgmt	Execution Mgmt	Info Services	Common Runtime
	Data Replication			
Credential Mgmt	Replica Location	Grid Telecontrol Protocol		
Delegation	Data Access & Integration	Community Scheduling Framework	WebMDS	Python Runtime
Community Authorization	Reliable File Transfer	Workspace Management	Trigger	C Runtime
Authentication Authorization	GridFTP	Grid Resource Allocation & Management	Index	Java Runtime

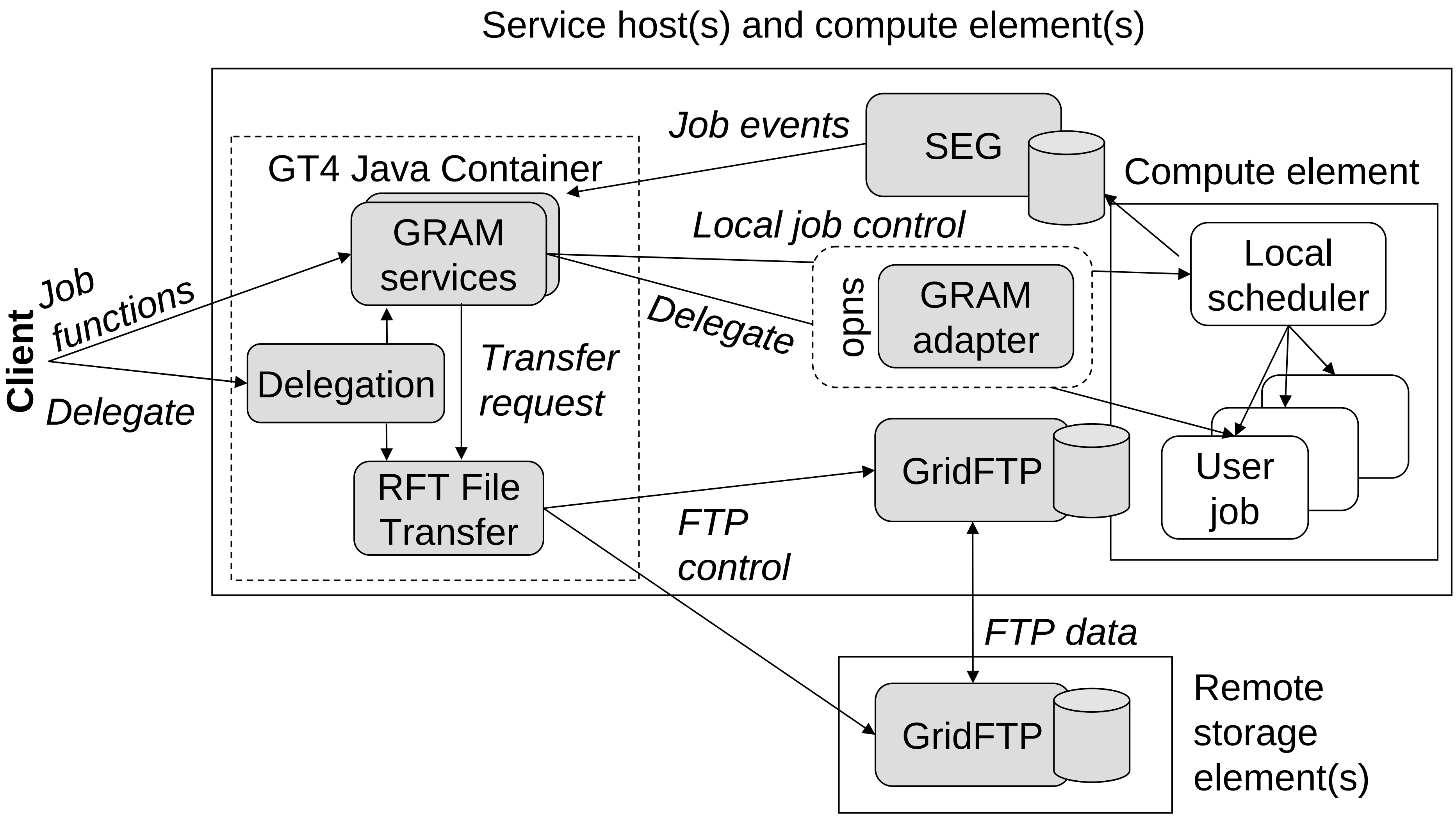
Execution Management (GRAM)

- Common WS interface to schedulers
  - Unix, Condor, LSF, PBS, SGE, ...
- More generally: interface for process execution management
  - Lay down execution environment
  - Stage data
  - Monitor & manage lifecycle
  - Kill it, clean up
- A basis for application-driven provisioning

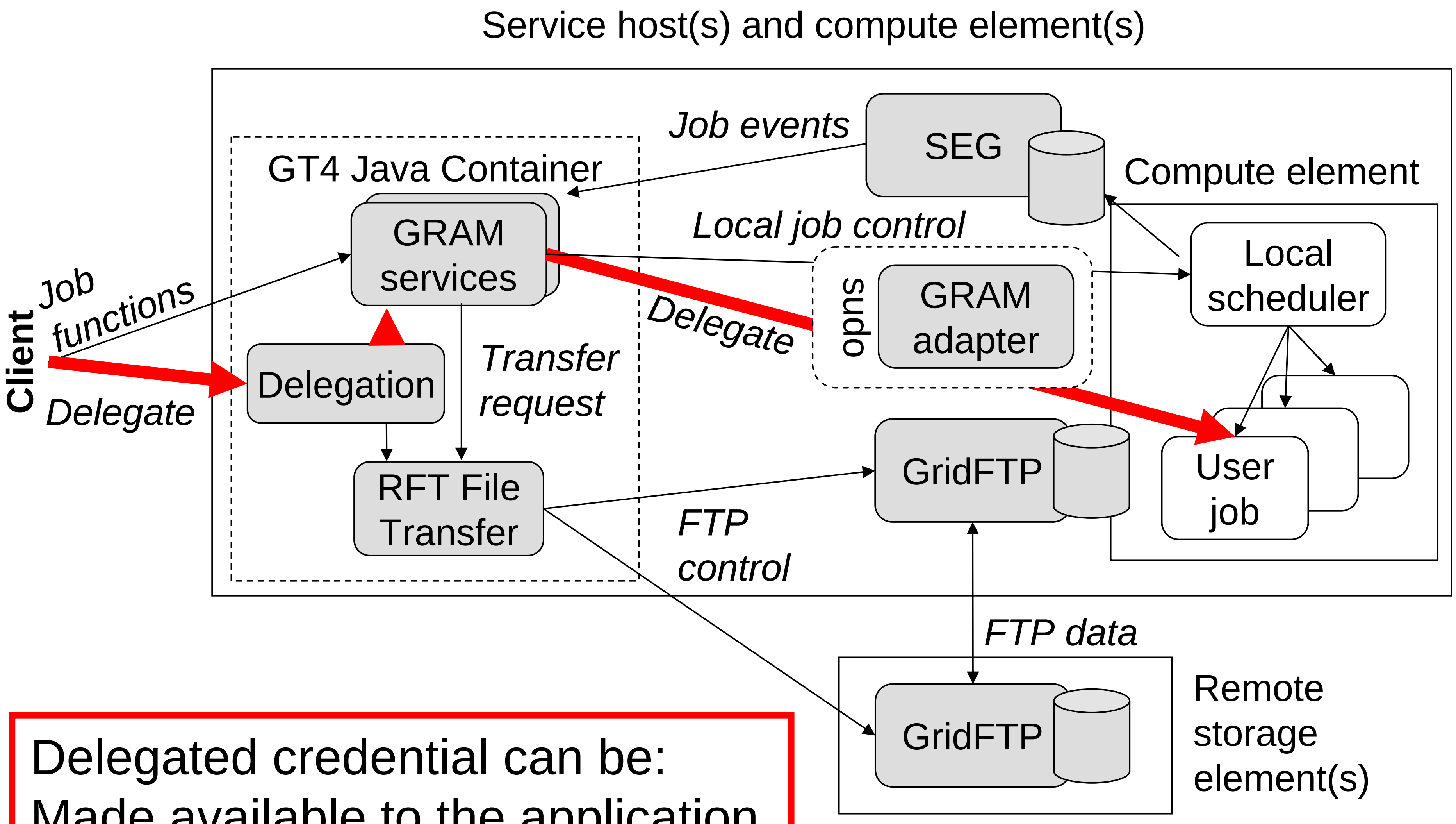
GT4 WS GRAM

- 2nd-generation WS implementation optimized for performance, flexibility, stability, scalability
- Streamlined critical path
  - Use only what you need
- Flexible credential management
  - Credential cache & delegation service
- GridFTP & RFT used for data operations
  - Data staging & streaming output
  - Eliminates redundant GASS code

GT4 WS GRAM Architecture

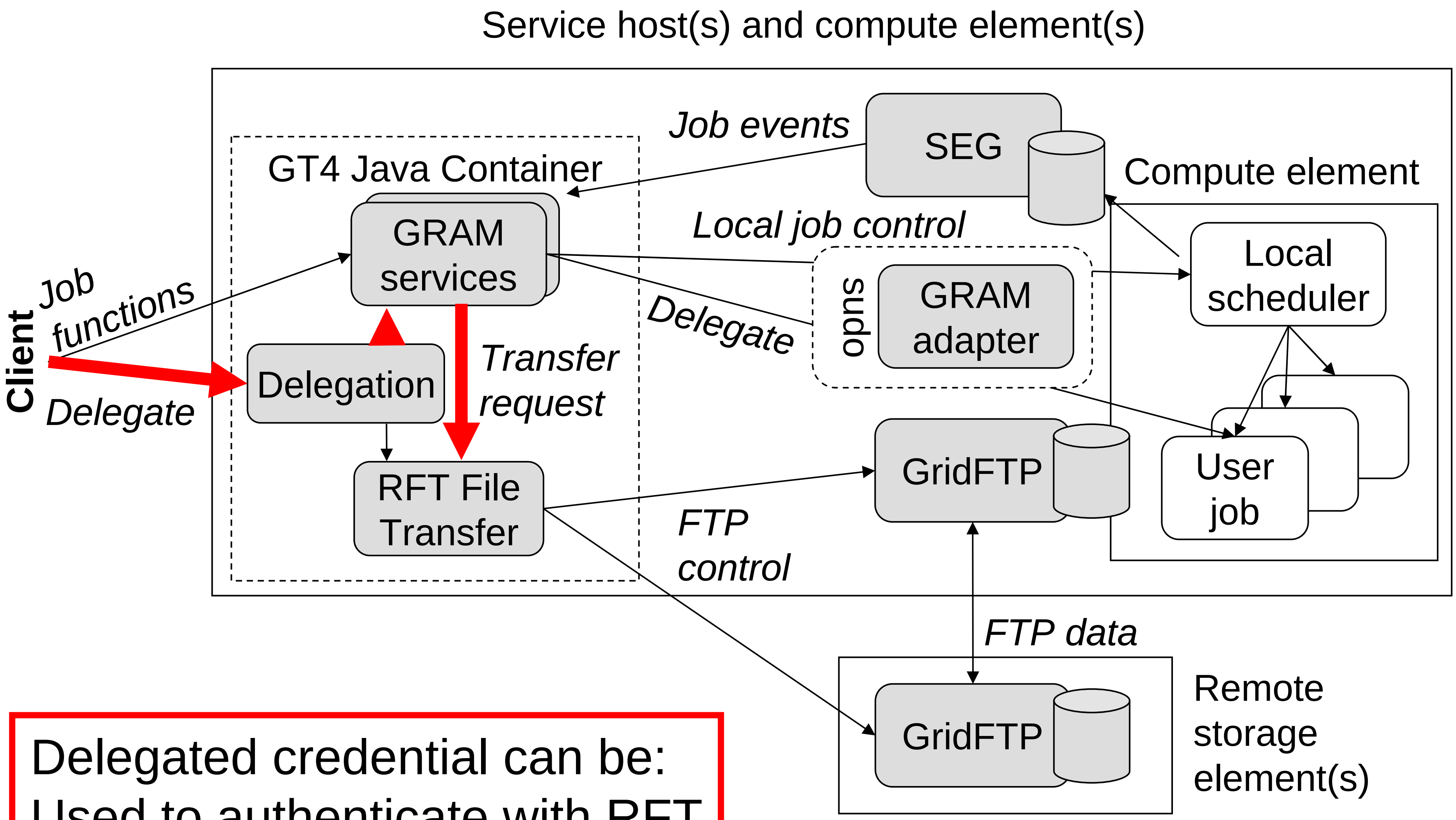


GT4 WS GRAM Architecture



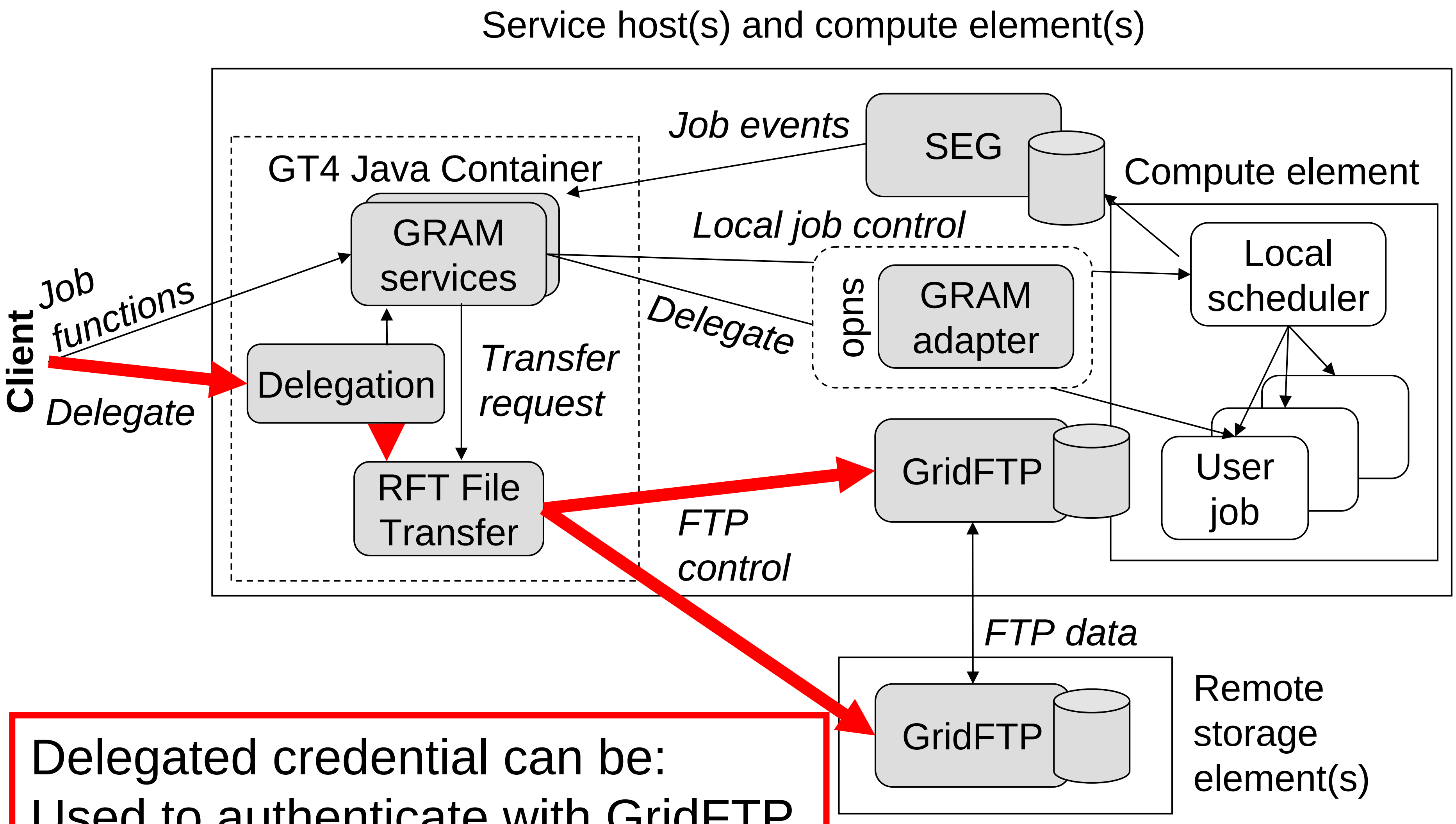
Delegated credential can be:
Made available to the application

GT4 WS GRAM Architecture



Delegated credential can be:
Used to authenticate with RFT

GT4 WS GRAM Architecture



Delegated credential can be:
Used to authenticate with GridFTP

Submitting a Sample Job

- Specify a remote host with –F
- -s is short for –streaming
- The output will be sent back to the terminal, control will not return until the job is done

```
globusrun-ws -submit -s
   –F remote.cluster.hu -c /bin/hostname
```

Descripbing complex jobs: RSL

```
globusrun-ws -submit
   -F remote.cluster.hu -f jobRSL.xml
```

```
<job>
<executable>/bin/echo</executable>
<argument>this is an example_string </argument>
<argument>Globus was here</argument>
<stdout>${GLOBUS_USER_HOME}/stdout</stdout>
 <stderr>${GLOBUS_USER_HOME}/stderr</stderr>
</job>
```

Resource Specification Language

```
<job>
<executable>/bin/echo</executable>
   <directory>/tmp</directory>
   <argument>12</argument>
<environment><name>PI</name>
   <value>3.141</value></environment>
<stdin>/dev/null</stdin>
<stdout>stdout</stdout>
<stderr>stderr</stderr>
</job>
```

Staging Data – Stage In

- GRAM’s RSL allows many fileStageIn/fileStageOut directives

```
<fileStageIn>
    <transfer>
        <sourceUrl>
                gsiftp://job.input.host:2811/bin/echo
        </sourceUrl>
        <destinationUrl>
                file:///${GLOBUS_USER_HOME}/my_echo
        </destinationUrl>
    </transfer>
</fileStageIn>
```

Staging Data – Stage Out

```
<fileStageOut>
  <transfer>
      <sourceUrl>
            file://${GLOBUS_USER_HOME}/stdout
      </sourceUrl>
      <destinationUrl>
  gsiftp://job.output.host:2811/tmp/stdout
      </destinationUrl>
  </transfer>
</fileStageOut>
```

Batch Submission

- Your client does not have to stay attached to the execution of the job
- -batch will disconnect from the job and output an End Point Reference (EPR)
  - You may redirect the EPR to a file with –o
  - Note: EPR → submitted job is a WS-resource
- Use the EPR file with –monitor or -status
- You may also kill the job using -kill

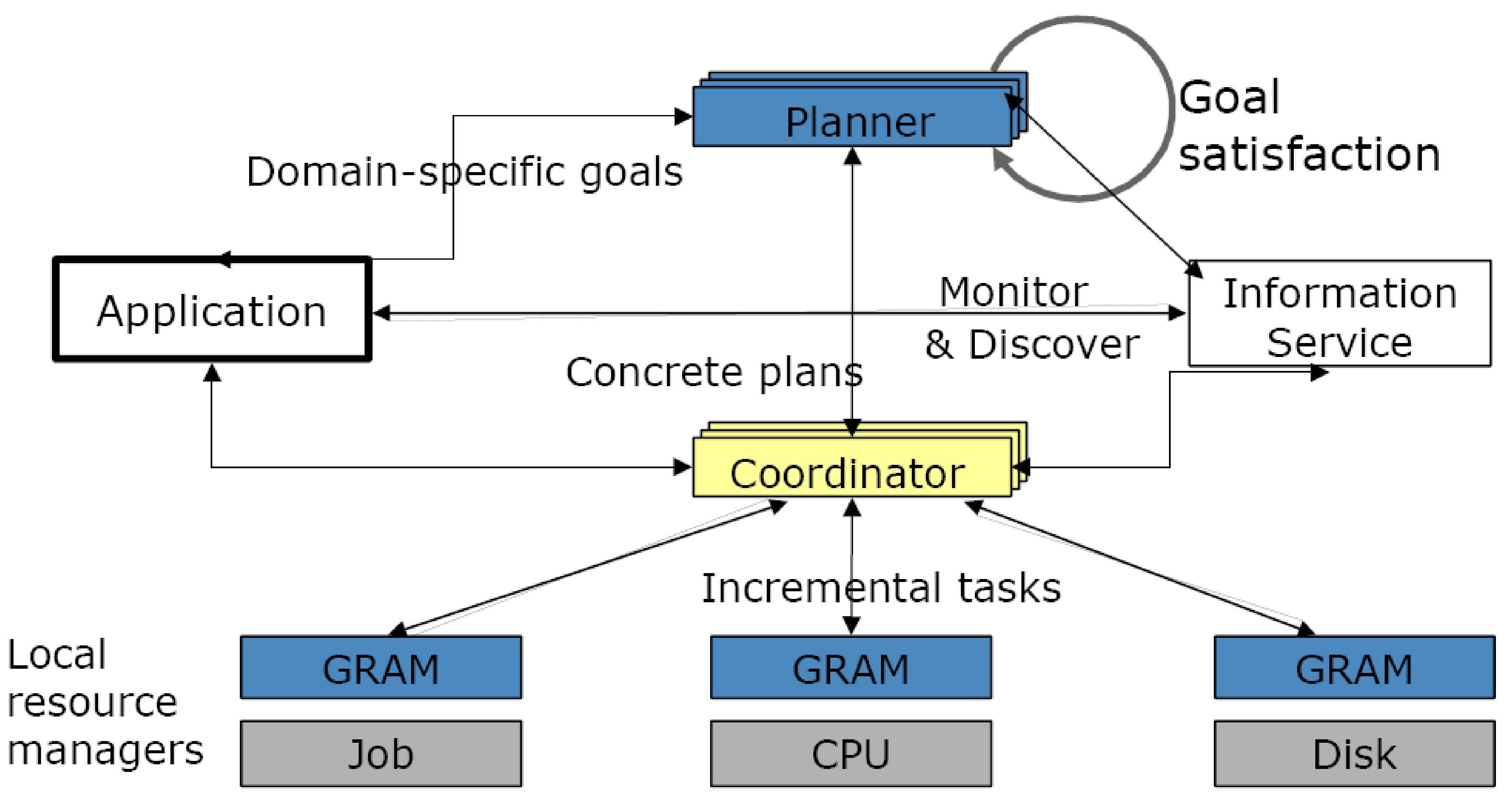
Specifying Scheduler Options

- RSL lets you specify various scheduler options
  - what queue to submit to
  - which project to select for accounting
  - max CPU and wallclock time to spend
  - min/max memory required
- All defined online under the schema document for GRAM

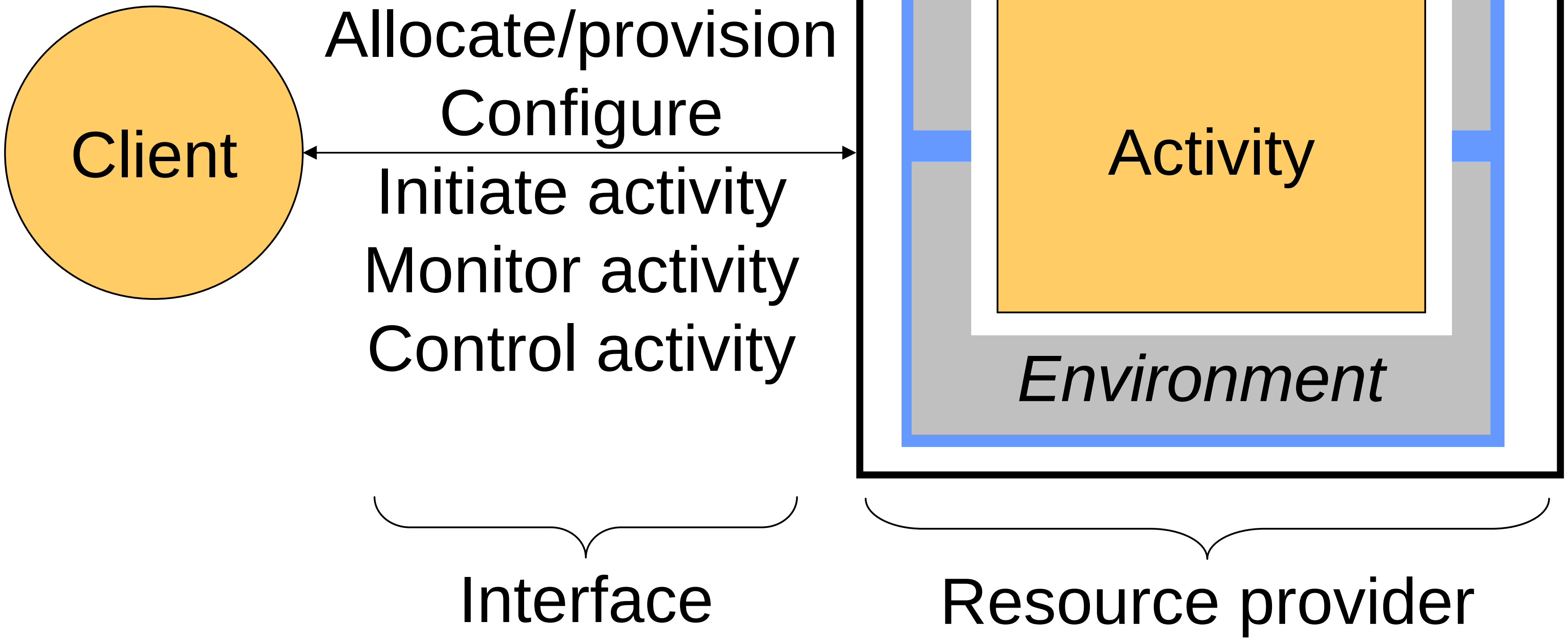
Choosing User Accounts

- You may be authorized to use more than one account at the remote site
- By default, the first listed in the grid-mapfile will be used
- You may request a specific user account using the <localUserId> element

Long term GRAM architecture



Workspace Service: The Hosted Activity



Client

Allocate/provision
Configure
Initiate activity
Monitor activity
Control activity

Policy

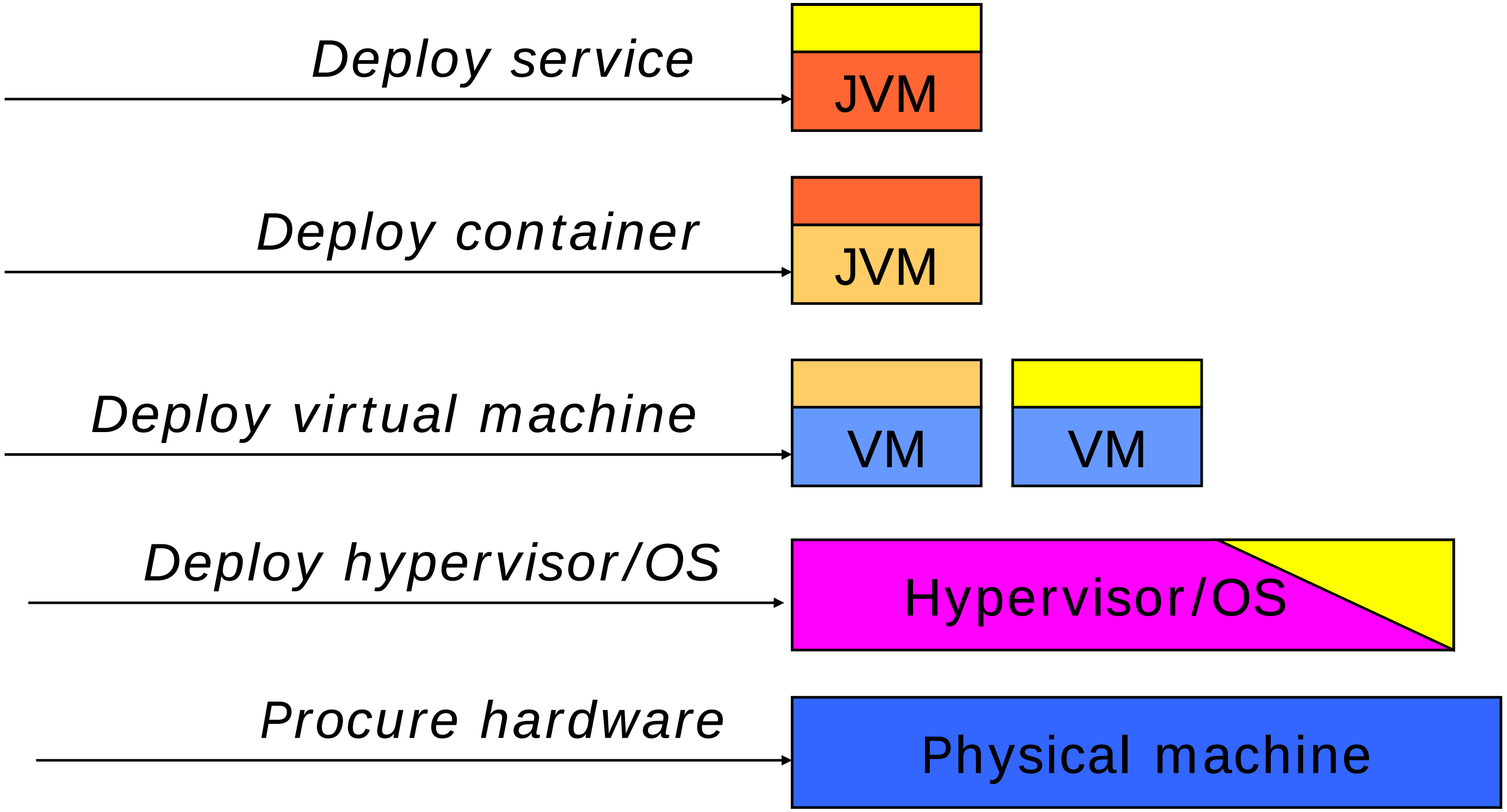
Activity

Environment

Interface

Resource provider

For Example …



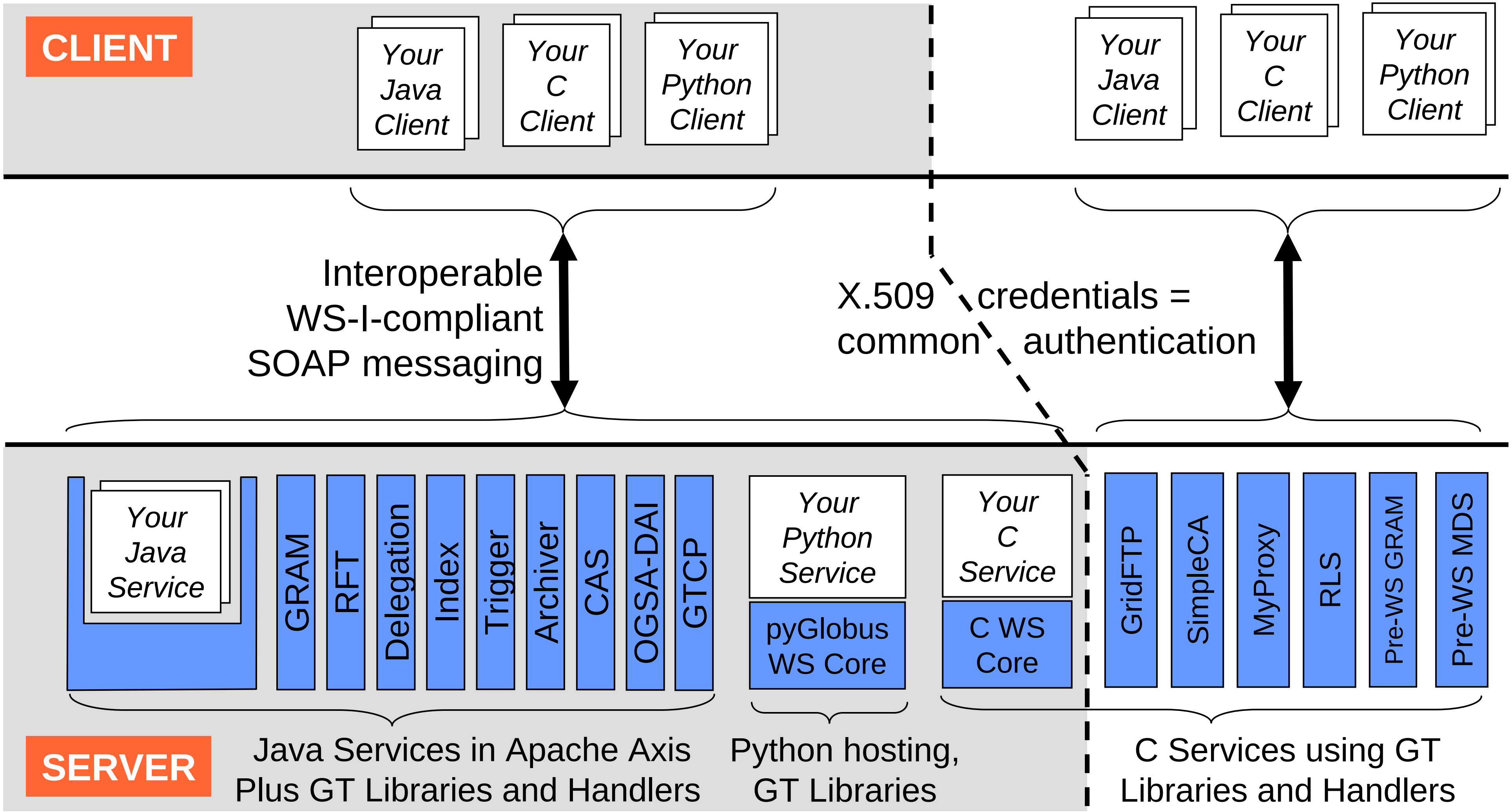
Provisioning, management, and monitoring at all levels

Summary

The Globus Toolkit is a Collection of Components

- A set of loosely-coupled components, with:
  - Services and clients
  - Libraries
  - Development tools
- GT components are used to build Grid-based applications and services
  - GT can be viewed as a Grid SDK
- GT4 use WS protocols for service interactions
- GT4 services work according to WSRF behavior paradigms

GT4 Summary


CLIENT
Your Java Client
Your C Client
Your Python Client
Your Java Client
Your C Client
Your Python Client
Interoperable WS-I-compliant SOAP messaging
X.509 credentials = common authentication
Your Java Service
GRAM
RFT
Delegation
Index
Trigger
Archiver
CAS
OGSA-DAI
GTCP
Your Python Service
pyGlobus WS Core
Your C Service
C WS Core
GridFTP
SimpleCA
MyProxy
RLS
Pre-WS GRAM
Pre-WS MDS
SERVER
Java Services in Apache Axis Plus GT Libraries and Handlers
Python hosting, GT Libraries
C Services using GT Libraries and Handlers

Further readings

- Service Oriented Architecture
  - “What is Service-Oriented Architecture?”. Hao He. http://webservices.xml.com/lpt/a/ws/2003/09/30/soa.html
  - “Service-Oriented Architecture: A Primer”. Michael S. Pallos. http://www.bijonline.com/PDF/SOAPallos.pdf
  - “The Benefits of a Service-Oriented Architecture”. Michael Stevens. http://www.developer.com/design/article.php/1041191
- Web services
  - Web Services Specifications - http://www.w3.org/2002/ws/
- OGSA, WSRF
  - “The Physiology of the Grid”. Ian Foster, Carl Kesselman, Jeffrey M. Nick, Steven Tuecke. http://www.globus.org/research/papers/ogsa.pdf
  - “The Anatomy of the Grid”. Ian Foster, Carl Kesselman, Steven Tuecke. http://www.globus.org/research/papers/anatomy.pdf
  - Web Services Resource Framework - http://www.globus.org/wsrf

Questions?