
# GAT Tutorial


## *Getting started with the Grid Application Toolkit*

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# Overview

- What is GAT and why do we need it?

- JavaGAT structure and overview
- Security
- Grid I/O
- Resource Management
- Application Information Management
- Monitoring

- Hands-on session


# The GridLab Project


- EU Project Funded by 5th Framework
- 3 years, 5 million euros
- Partners
  - PSNC, AEI, ZIB, MASARYK, SZTAKI, ISUFI, Cardiff, NTUA, Chicago, ISI, Wisconsin, Sun, Compaq,...
  - Vrije Universiteit Amsterdam
- 12 Work Packages covering
  - Grid Portals, Mobile Users, Data Management, Applications, Testbed, ...
  - GAT: The Grid Application Toolkit

# Grid Application

# Writing Grid Applications

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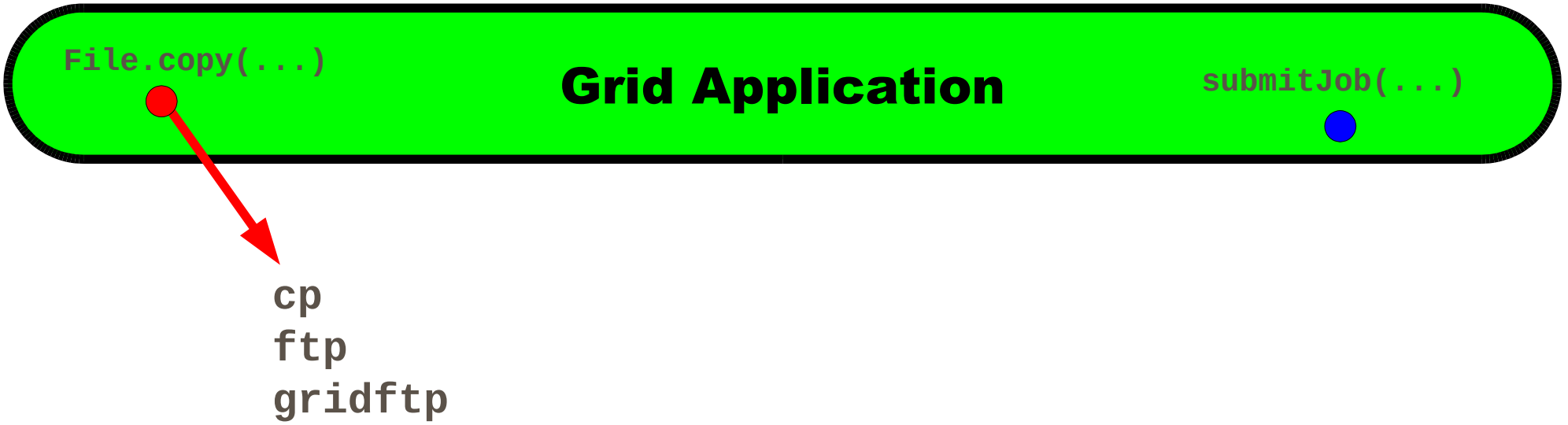

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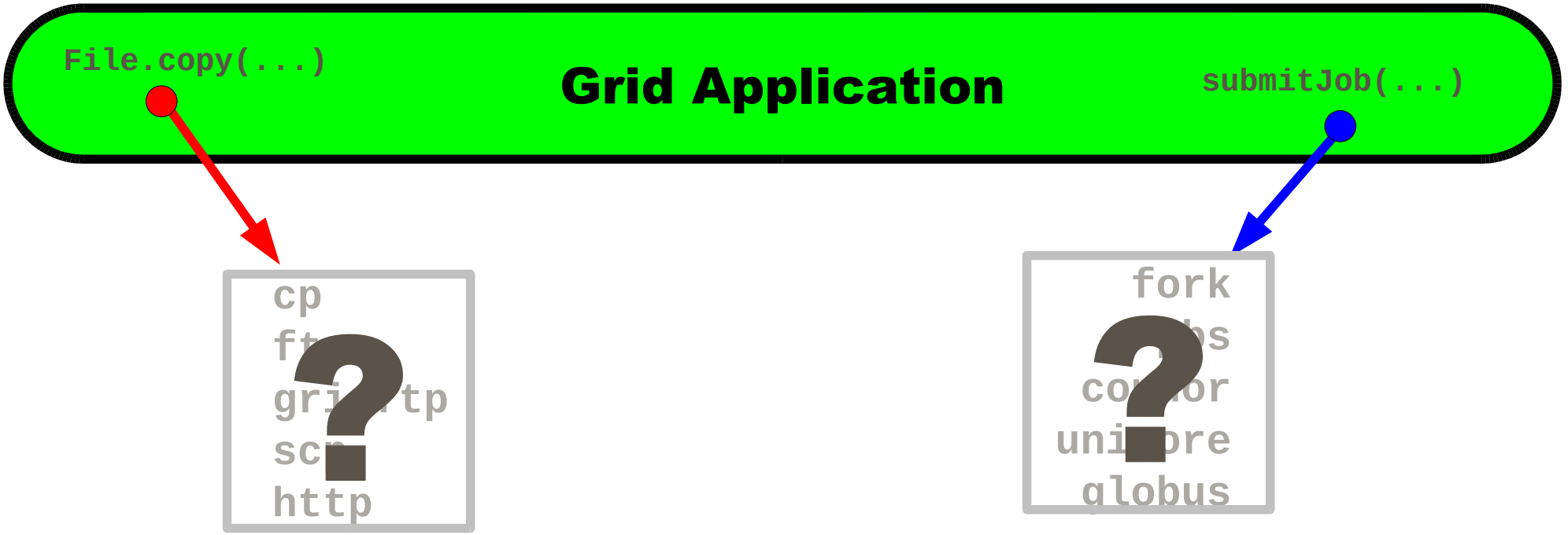


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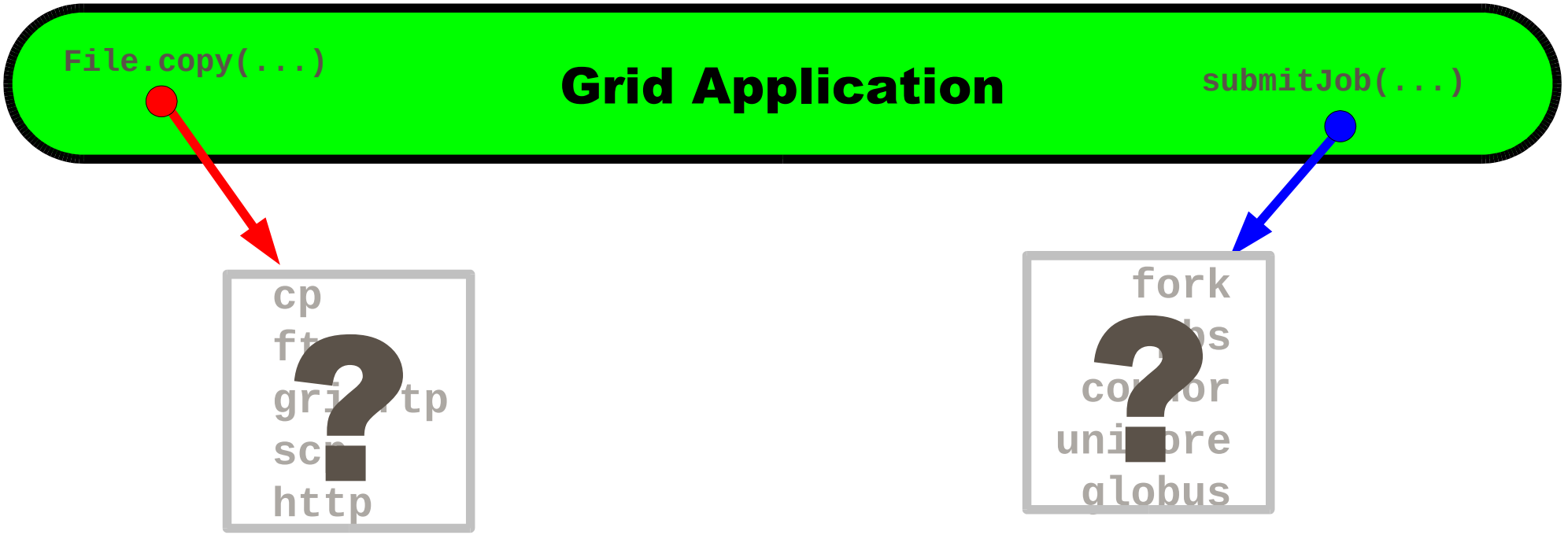


- Which should you use?
- Some might not be available on all sites

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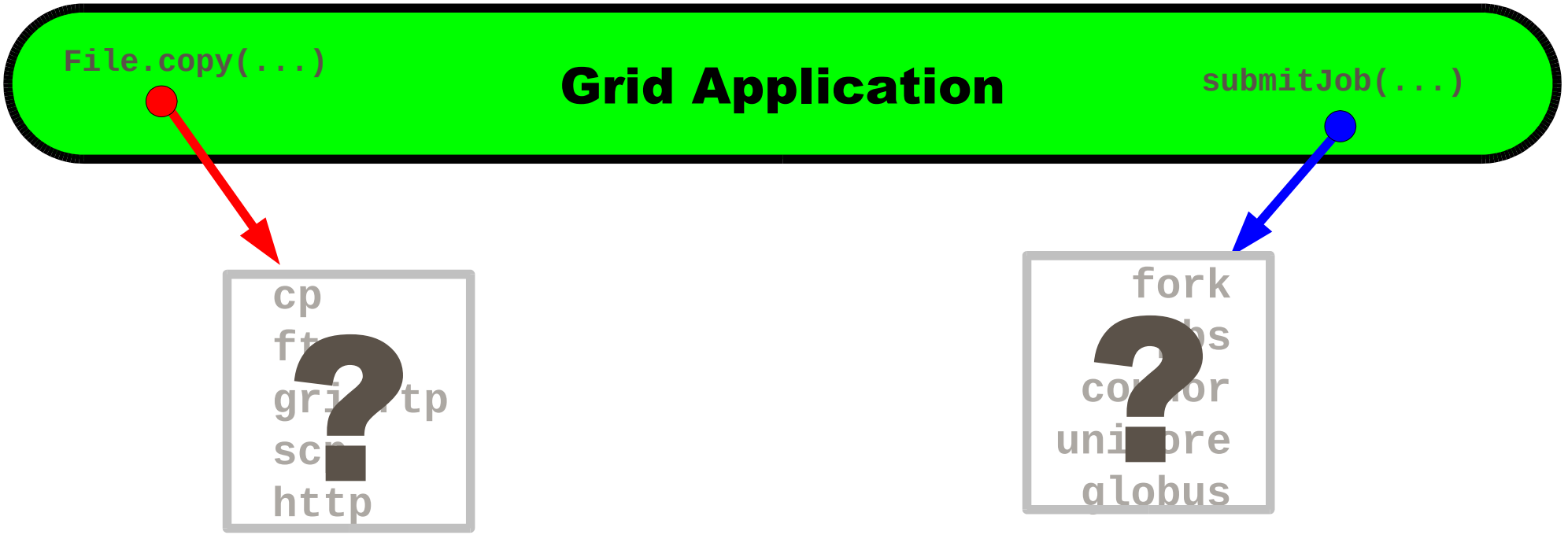


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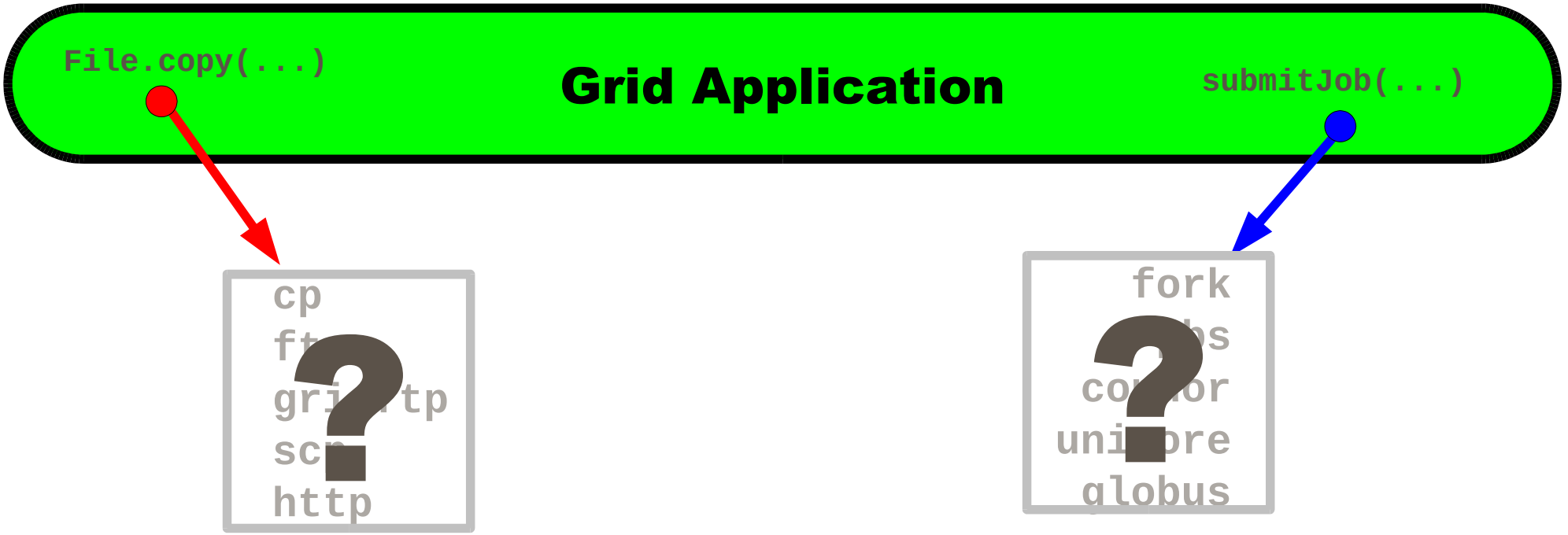


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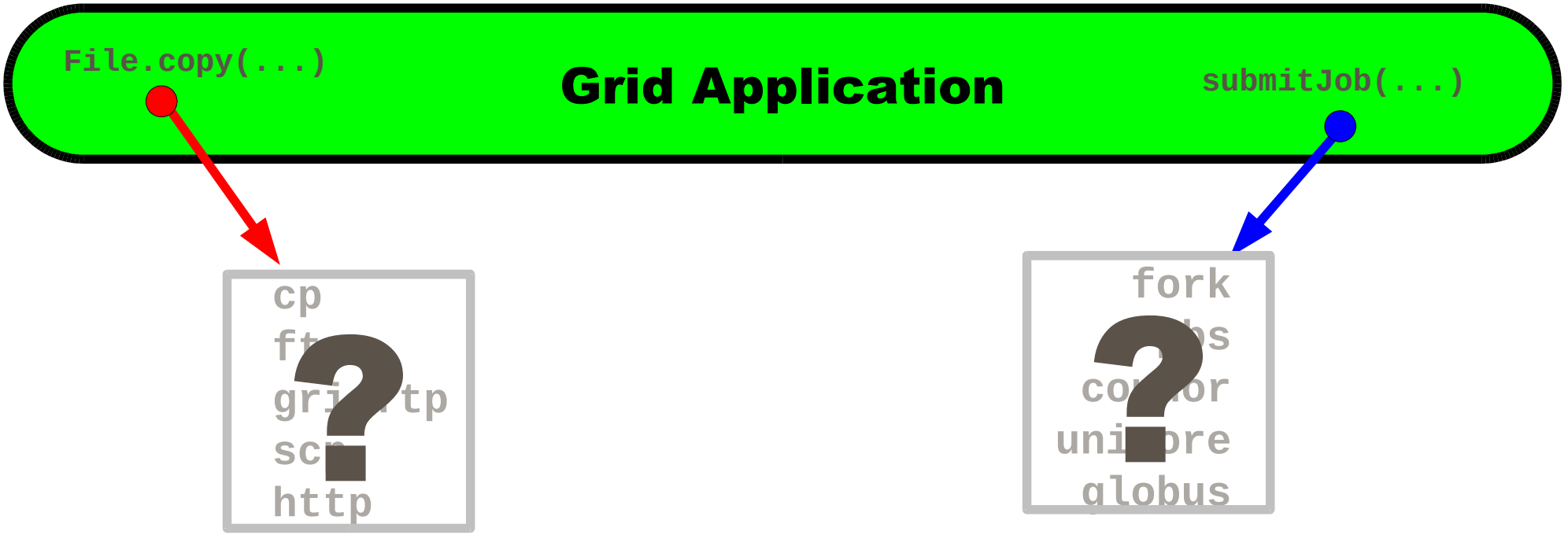


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- Exponential number of combinations!

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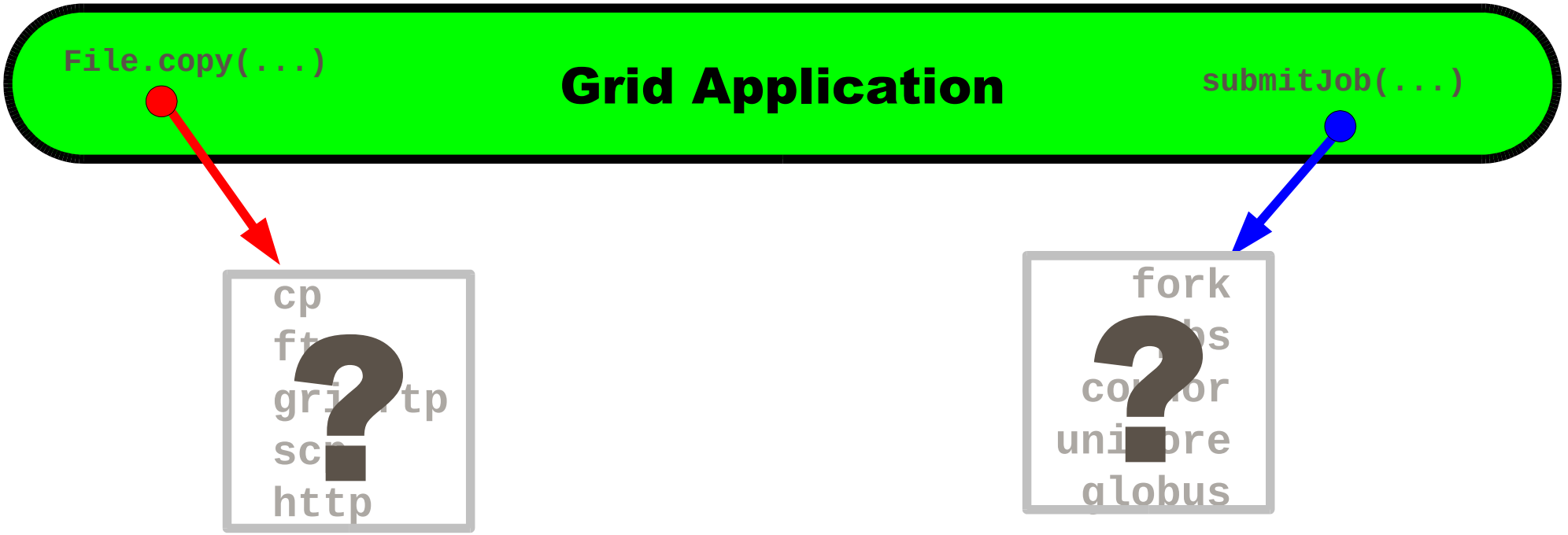



- Which should you use?
- Some might not be available on all sites
- Some may not work for [illegible]
- Versions differences (Globus changes every 2 months)
- Exponential number of combinations!

**Not portable!**

# Globus File copy (C++)

```
int RemoteFile::GetFile (char const* source,   char const* target) {
globus_url_t                        source_url;
globus_io_handle_t                  dest_io_handle;
globus_ftp_client_operationattr_t   source_ftp_attr;
globus_result_t                     result;
globus_gass_transfer_requestattr_t  source_gass_attr;
globus_gass_copy_attr_t             source_gass_copy_attr;
globus_gass_copy_handle_t           gass_copy_handle;
globus_gass_copy_handleattr_t       gass_copy_handleattr;
globus_ftp_client_handleattr_t      ftp_handleattr;
globus_io_attr_t                    io_attr;
int                                 output_file = -1;

if ( globus_url_parse (source_URL, &source_url) != GLOBUS_SUCCESS ) {
  printf ("can not parse source_URL \"%s\"\n", source_URL);
  return (-1);
}

if ( source_url.scheme_type != GLOBUS_URL_SCHEME_GSIFTP &&
     source_url.scheme_type != GLOBUS_URL_SCHEME_FTP    &&
     source_url.scheme_type != GLOBUS_URL_SCHEME_HTTP   &&
     source_url.scheme_type != GLOBUS_URL_SCHEME_HTTPS  ) {
  printf ("can not copy from %s - wrong prot\n", source_URL);
  return (-1);
}
globus_gass_copy_handleattr_init  (&gass_copy_handleattr);
globus_gass_copy_attr_init        (&source_gass_copy_attr);

globus_ftp_client_handleattr_init (&ftp_handleattr);
globus_io_fileattr_init           (&io_attr);

globus_gass_copy_attr_set_io      (&source_gass_copy_attr, &io_attr);
                                    &io_attr);
globus_gass_copy_handleattr_set_ftp_attr
                                  (&gass_copy_handleattr,
                                    &ftp_handleattr);
globus_gass_copy_handle_init      (&gass_copy_handle,
                                    &gass_copy_handleattr);
```

```
if (source_url.scheme_type == GLOBUS_URL_SCHEME_GSIFTP ||
    source_url.scheme_type == GLOBUS_URL_SCHEME_FTP    ) {
  globus_ftp_client_operationattr_init (&source_ftp_attr);
  globus_gass_copy_attr_set_ftp (&source_gass_copy_attr,
                                 &source_ftp_attr);
}
else {
  globus_gass_transfer_requestattr_init (&source_gass_attr,
                                  source_url.scheme);
  globus_gass_copy_attr_set_gass(&source_gass_copy_attr,
              &source_gass_attr);
}

output_file = globus_libc_open ((char*) target,
              O_WRONLY | O_TRUNC | O_CREAT,
              S_IRUSR  | S_IWUSR | S_IRGRP |
              S_IWGRP);
if ( output_file == -1 ) {
  printf ("could not open the file \"%s\"\n", target);
  return (-1);
}
/* convert stdout to be a globus_io_handle */
if ( globus_io_file_posix_convert (output_file, 0,
                                   &dest_io_handle)
     != GLOBUS_SUCCESS) {
  printf ("Error converting the file handle\n");
  return (-1);
}

result = globus_gass_copy_register_url_to_handle (
         &gass_copy_handle, (char*)source_URL,
         &source_gass_copy_attr, &dest_io_handle,
         my_callback, NULL);
if ( result != GLOBUS_SUCCESS ) {
  printf ("error: %s\n", globus_object_printable_to_string
          (globus_error_get (result)));
  return (-1);
}
globus_url_destroy  (&source_url);
return (0);
}
```

# CoG/RFT File copy (C++)

```
package org.globus.ogsa.gui;

import java.io.BufferedReader;
import java.io.File;
import java.io.FileReader;
import java.net.URL;
import java.util.Date;
import java.util.Vector;
import javax.xml.rpc.Stub;
import org.apache.axis.message.MessageElement;
import org.apache.axis.utils.XMLUtils;
import org.globus.*
import org.gridforum.ogsi.*
import org.gridforum.ogsi.holders.TerminationTimeTypeHolder;
import org.w3c.dom.Document;
import org.w3c.dom.Element;

public class RFTClient {
 public static void copy (String source_url, String target_url) {
  try {
   File requestFile      = new File (source_url);
   BufferedReader reader = null;
   try {
     reader = new BufferedReader (new FileReader (requestFile));
   } catch (java.io.FileNotFoundException fnfe) { }
   Vector requestData = new Vector ();
   requestData.add (target_url);
   TransferType[] transfers1      = new TransferType[transferCount];
   RFTOptionsType multirftOptions = new RFTOptionsType ();

   multirftOptions.setBinary           (Boolean.valueOf  (
         (String)requestData.elementAt (0)).booleanValue ());
   multirftOptions.setBlockSize        (Integer.valueOf  (
         (String)requestData.elementAt (1)).intValue     ());
   multirftOptions.setTcpBufferSize    (Integer.valueOf  (
         (String)requestData.elementAt (2)).intValue     ());
   multirftOptions.setNotpt            (Boolean.valueOf  (
         (String)requestData.elementAt (3)).booleanValue ());
   multirftOptions.setParallelStreams  (Integer.valueOf  (
         (String)requestData.elementAt (4)).intValue     ());
   multirftOptions.setDcau(Boolean.valueOf(
          (String)requestData.elementAt (5)).booleanValue ());

 int i = 7;
 for (int j = 0; j < transfers1.length; j++)
 {
   transfers1[j] = new TransferType ();

   transfers1[j].setTransferId     (j);
   transfers1[j].setSourceUrl      ((String)requestData.elementAt (i++));
   transfers1[j].setDestinationUrl ((String)requestData.elementAt (i++));
   transfers1[j].setRftOptions     (multirftOptions);
 }

TransferRequestType transferRequest = new TransferRequestType ();
transferRequest.setTransferArray (transfers1);

int concurrency = Integer.valueOf
                ((String)requestData.elementAt(6)).intValue();

if (concurrency > transfers1.length)
{
  System.out.println ("Concurrency should be less than the number"
                      "of transfers in the request");
  System.exit (0);
}
transferRequest.setConcurrency (concurrency);

TransferRequestElement requestElement = new TransferRequestElement ();
requestElement.setTransferRequest (transferRequest);

ExtensibilityType extension = new ExtensibilityType ();
extension = AnyHelper.getExtensibility (requestElement);

OGSIServiceGridLocator factoryService = new OGSIServiceGridLocator ();
Factory factory = factoryService.getFactoryPort (new URL (source_url));
GridServiceFactory gridFactory = new GridServiceFactory (factory);

LocatorType locator = gridFactory.createService (extension);
System.out.println ("Created an instance of Multi-RFT");

MultiFileRFTDefinitionServiceGridLocator loc
                  = new MultiFileRFTDefinitionServiceGridLocator();
RFTPortType rftPort = loc.getMultiFileRFTDefinitionPort (locator);
  ((Stub)rftPort)._setProperty (Constants.AUTHORIZATION,
                                NoAuthorization.getInstance());
  ((Stub)rftPort)._setProperty (GSIConstants.GSI_MODE,
                                GSIConstants.GSI_MODE_FULL_DELEG);
  ((Stub)rftPort)._setProperty (Constants.GSI_SEC_CONV,
                                Constants.SIGNATURE);
  ((Stub)rftPort)._setProperty (Constants.GRIM_POLICY_HANDLER,
                                new IgnoreProxyPolicyHandler ());

  int requestid = rftPort.start ();
  System.out.println ("Request id: " + requestid);

 }
 catch (Exception e)
 {
  System.err.println (MessageUtils.toString (e));
 }
}
```

# Why GAT?

- The situation today:
  - Grids: everywhere
  - Grid applications: nowhere
- Why is this?
  - Application programmers accept the Grid as a computing paradigm only very slowly.
- Problems:
  - Interfaces are NOT simple
  - Portability / interoperability
    - Different and evolving interfaces to the 'Grid'
    - Environment changes in many ways
    - WSDL and web services do not solve all these problems

# What is GAT?

- GAT: Grid Application Toolkit
  - API and Toolkit for developing and running portable grid applications independently of the underlying grid infrastructure and available services
- GAT is used by applications to access grid services
- Simple API
- GAT Adaptors (“plugins”)
  - Connect GAT to grid services
  - Allow for multiple providers (Globus, Unicore, ProActive, …)
- GAT Engine
  - Provides runtime delegation of GAT-API calls to adaptors

# GAT Philosophy (1)

- GAT does not aim to replace existing “grid infrastructure.”
- GAT aims to provide a simple, clear interface to many different infrastructures
  - GRAM
  - Condor
  - Unicore
  - GridFTP
  - …
- Open source, BSD-like licence

# GAT Philosophy (2)

- Applications make GAT-API calls for grid operations
  - Applications link against GAT
- Applications run irrespective of available infrastructure
  - GAT Engine loads all available adaptors at runtime
  - Upon a call to the GAT-API the GAT Engine determines which adaptor(s) provide the “grid operation”
  - Upon “grid operation” failure another adaptor may be called
- There exist a set of default adaptors which provide default local capabilities
  - Grid applications can thus be compiled, linked, and tested without any available grid services
  - The same application executable can run in a “full grid environment.” No recompilation / linking

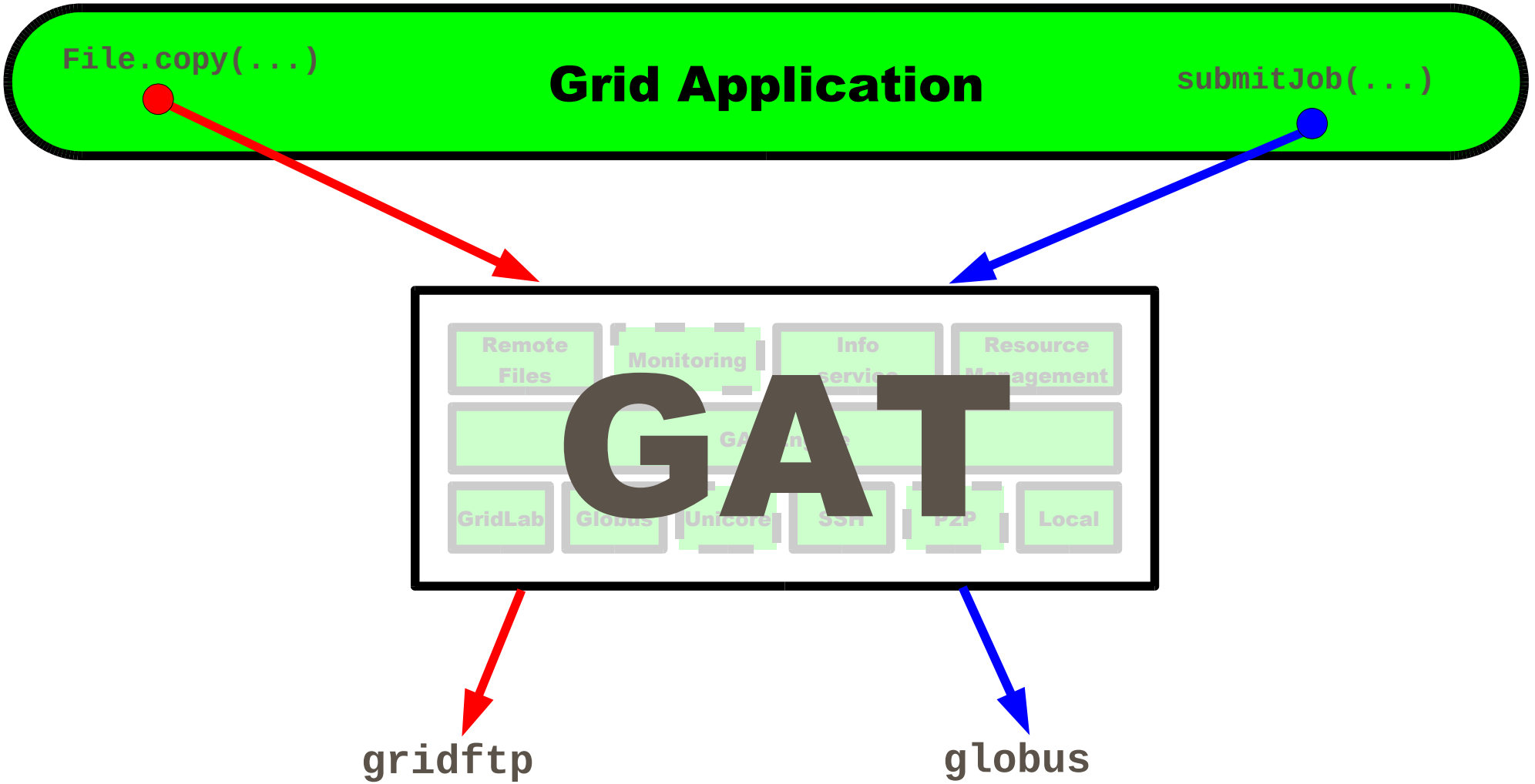
# The GAT API

- A language independent, object oriented specification
- Language bindings
  - C, C++, Java, python, ...
- Work in progress
  - Perl, .net, fortran
- Adopt the “look-and-feel” of the target language
- focus on well-known programming paradigms
  - Provide a File API for file access
  - Not (web)services to services to files. . .
  - Programmers expect open, close, read, write, seek. Do not introduce fancy things like the need to ask a service discovery service to tell me the location of an service which is able to tell me the location of my file...

# GAT API features

- Security (deal with passwords, credentials, etc)
- Grid I/O
  - File operations, remote file access, file replication
  - Inter-process communication
- Resource Management
  - Resource brokering
  - Forking grid applications, job management
- Application Information Management
  - Global repository for application specific information
  - Query this information repository
- Monitoring
  - Grid monitoring
  - Application monitoring and steering

# Grid Applications with GAT



# File Copy with GAT (C++)

```
#include <GAT++.hpp>

void RemoteFile::GetFile (
    GAT::Context context, std::string source_url,
    std::string target_url) throws GAT::Exception {
    GAT::File file (context, source_url);
    file.Copy      (target_url);
}
```

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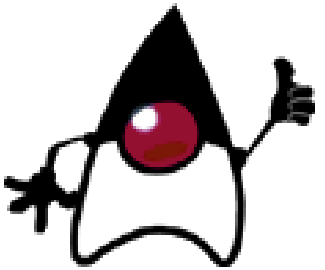
# Overview

- What is GAT and why do we need it?

- JavaGAT overview and structure
- Security
- Grid I/O
- Resource Management
- Application Information Management
- Monitoring

- Hands-on session

# Why Java?

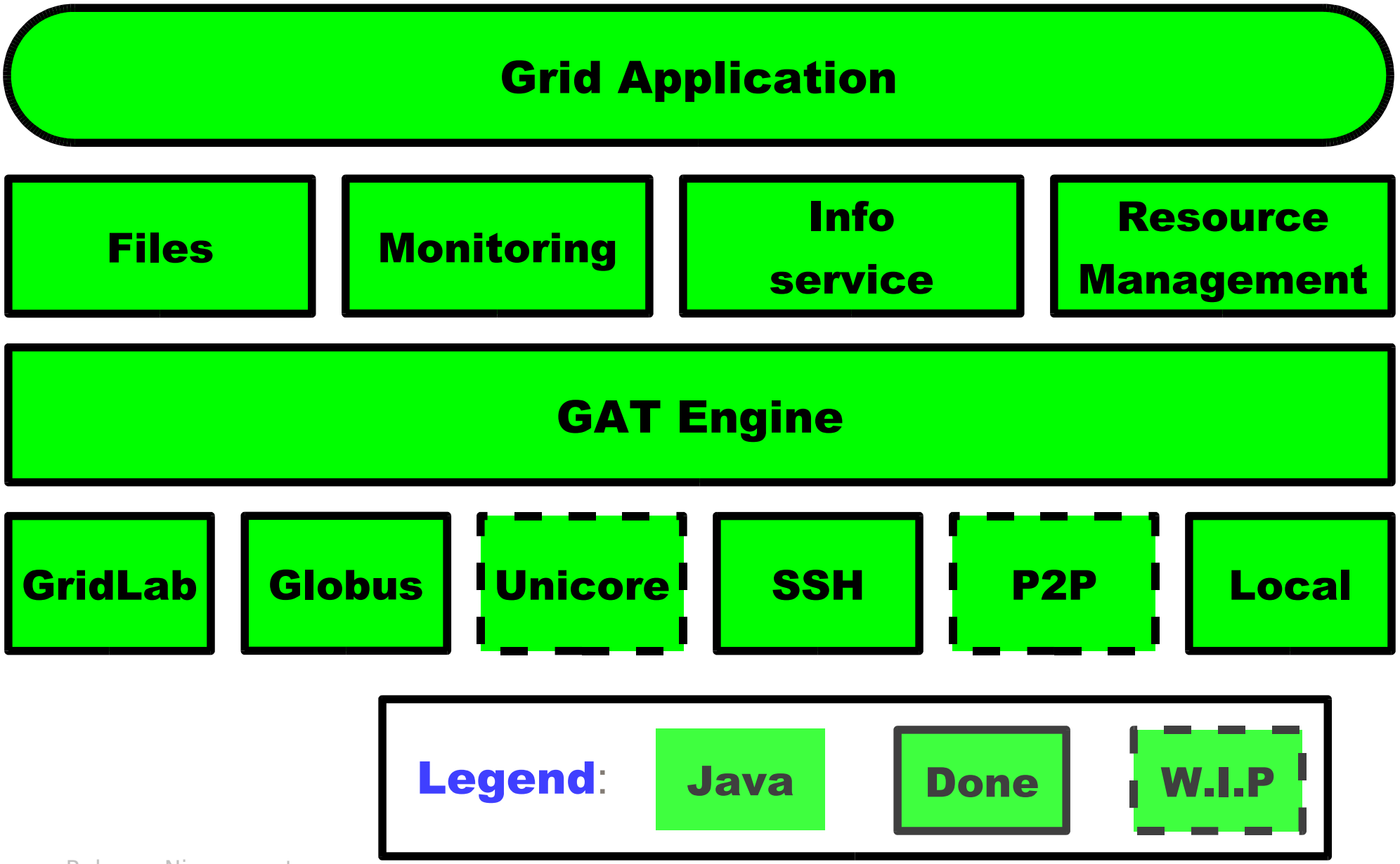


- Java is widely used, object oriented.
- Secure (language, sandbox)
- Java is “write once, run everywhere”.
  - Compile application on your desktop machine.
  - This creates machine independent bytecode.
  - Copy application files and the GAT to any grid site (portal typically does this for you).
  - Just run it. No recompilation / configuration.
- Performance of current JITs is good.
  - Compiled (just-in-time)
  - Runtime, profile-driven optimizations
  - Applications are typically 10% slower than C.
- Ideal for grid computing?

# GAT API

- GAT API is an object oriented specification, but language independent.
- Tension between existing language features and the GAT specification.
  - Programmers do not want to learn new APIs for features already in the language.
  - GAT should “feel” the same across platforms.
- Find the tight trade-off

# Java GAT Structure



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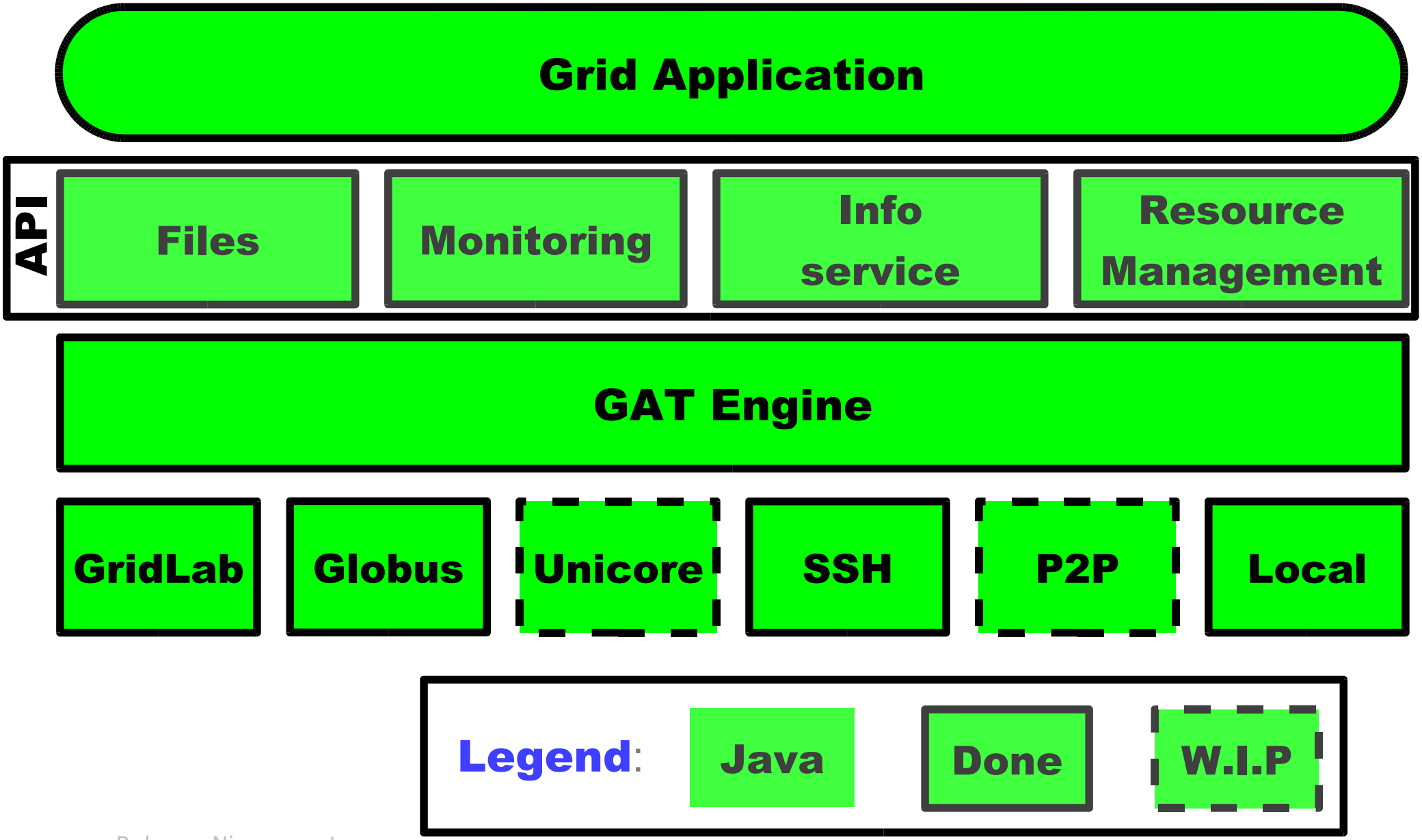

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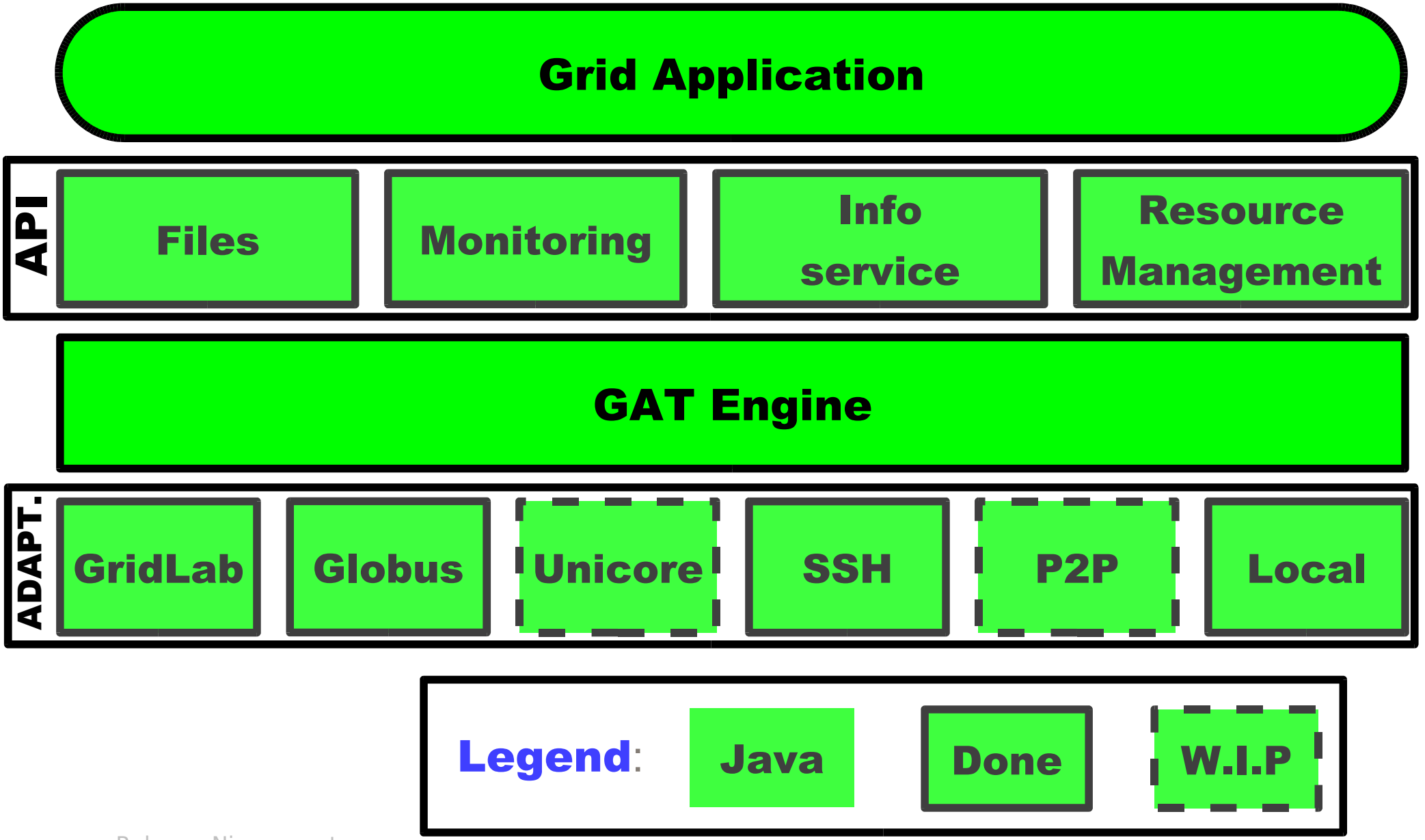

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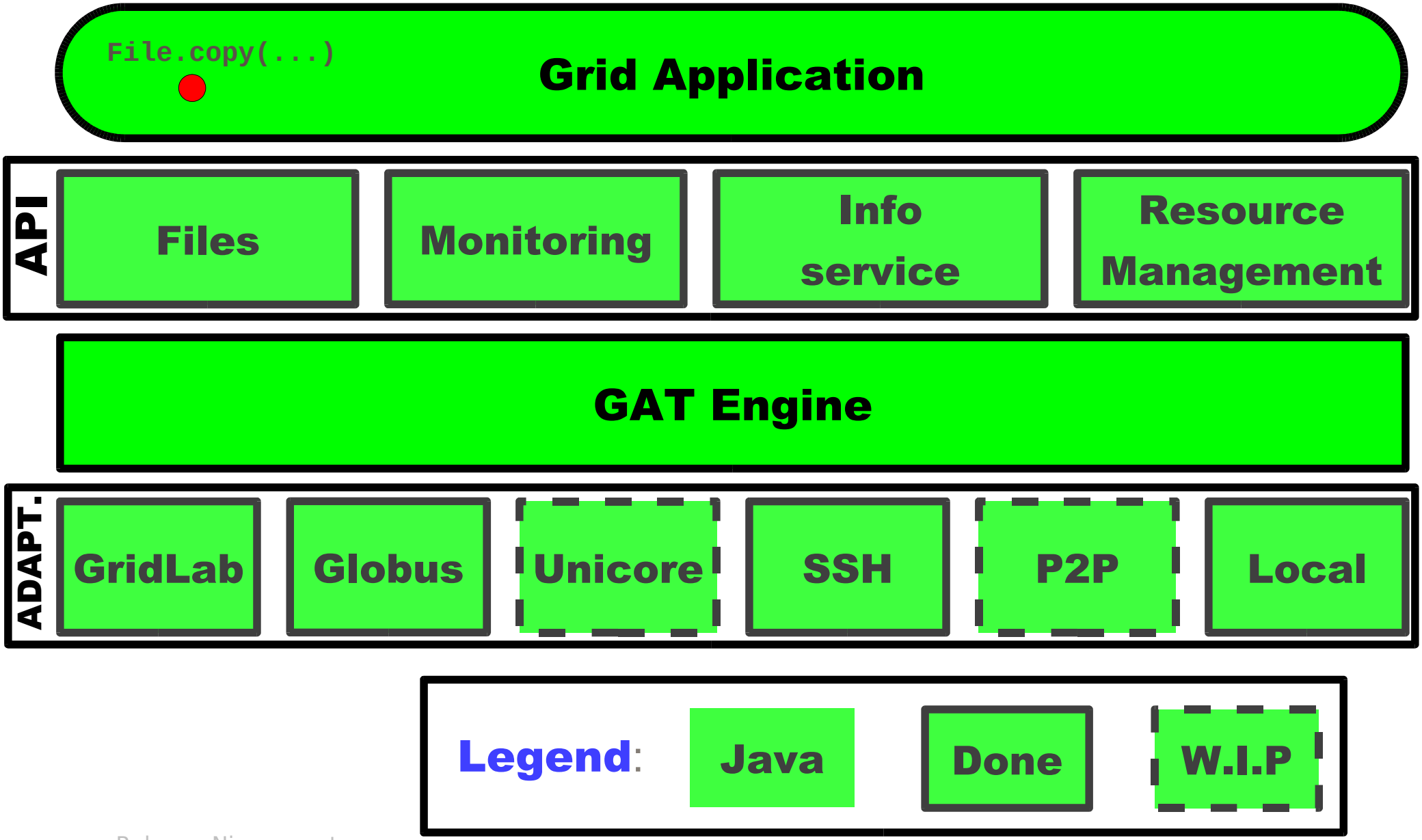

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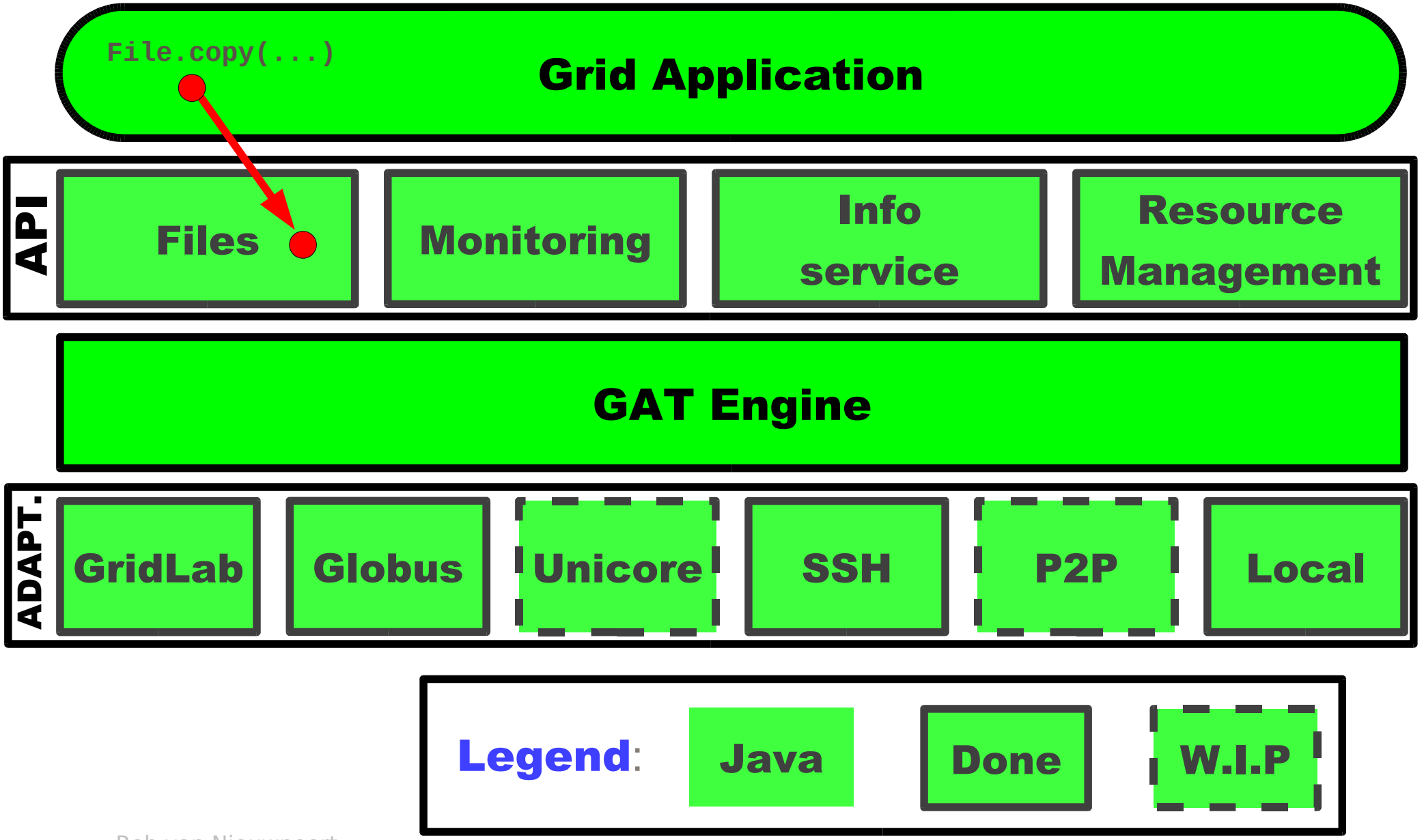

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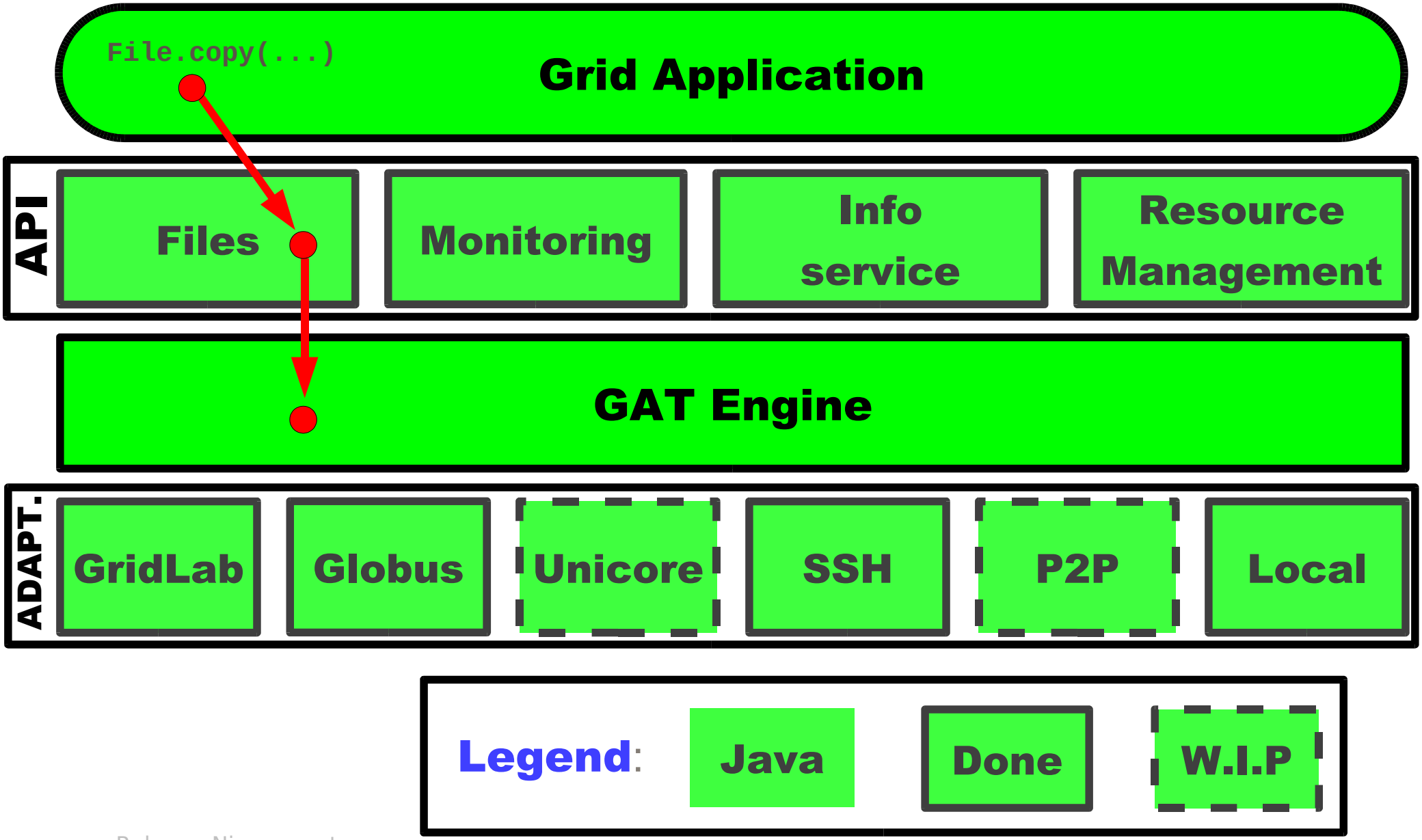

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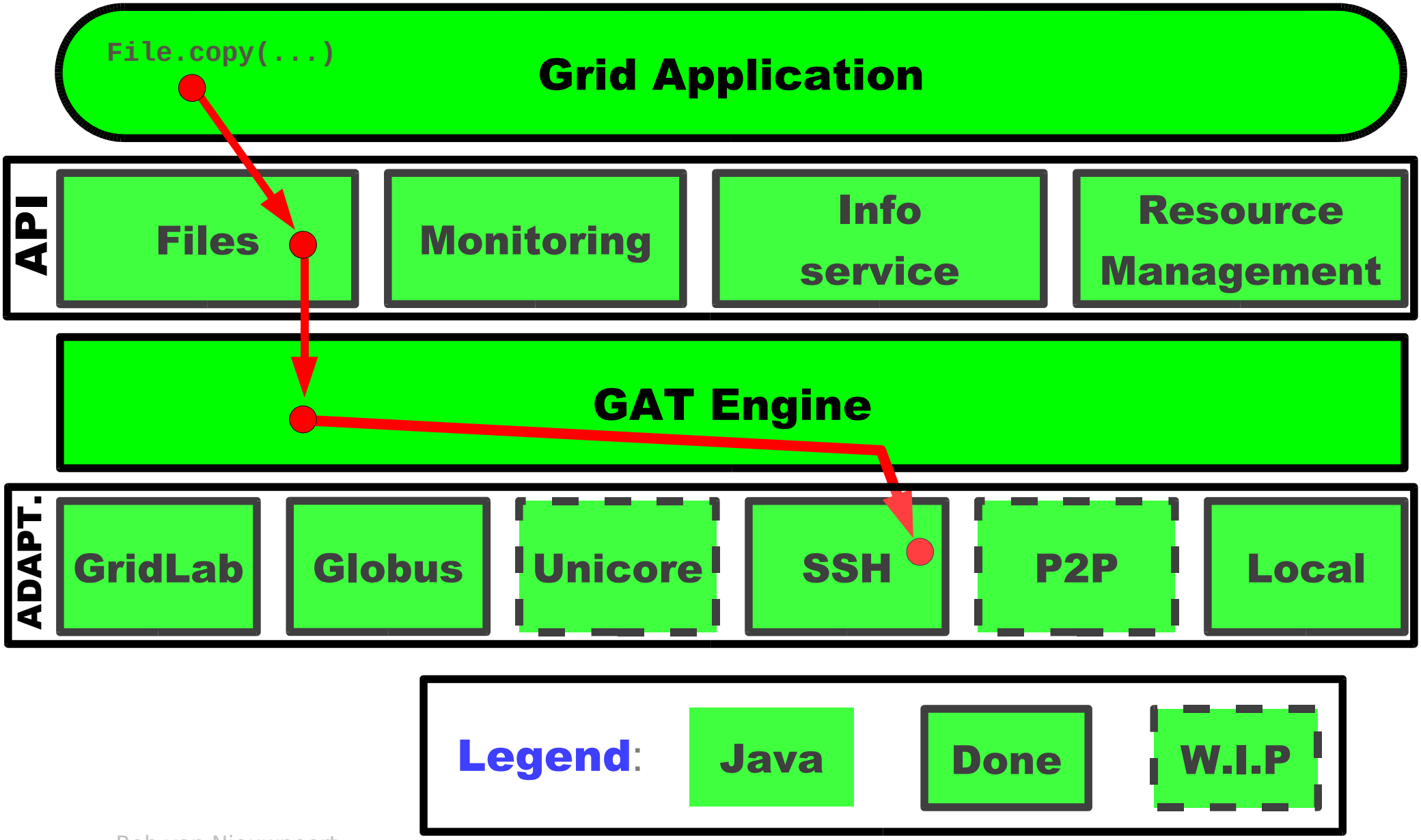

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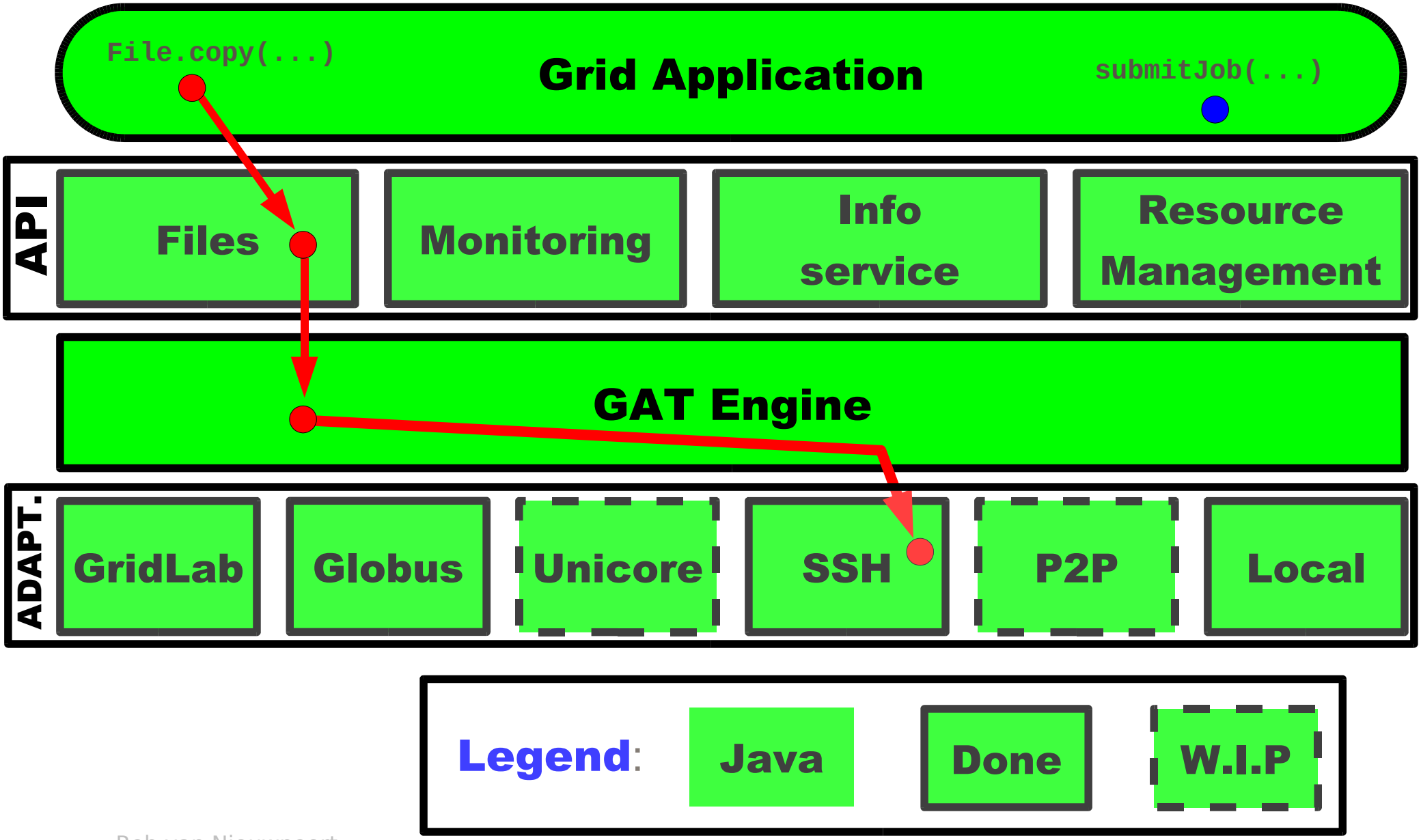

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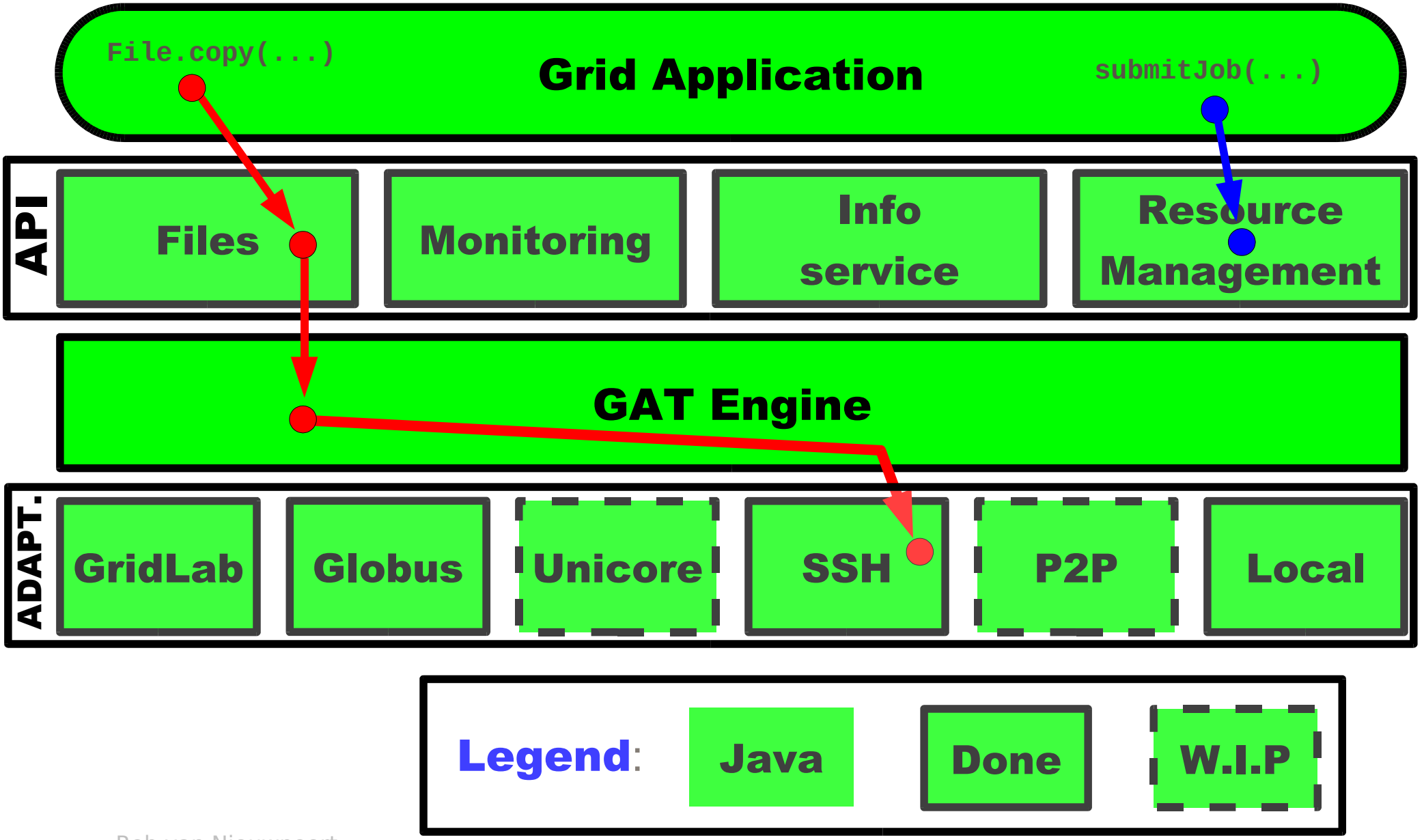

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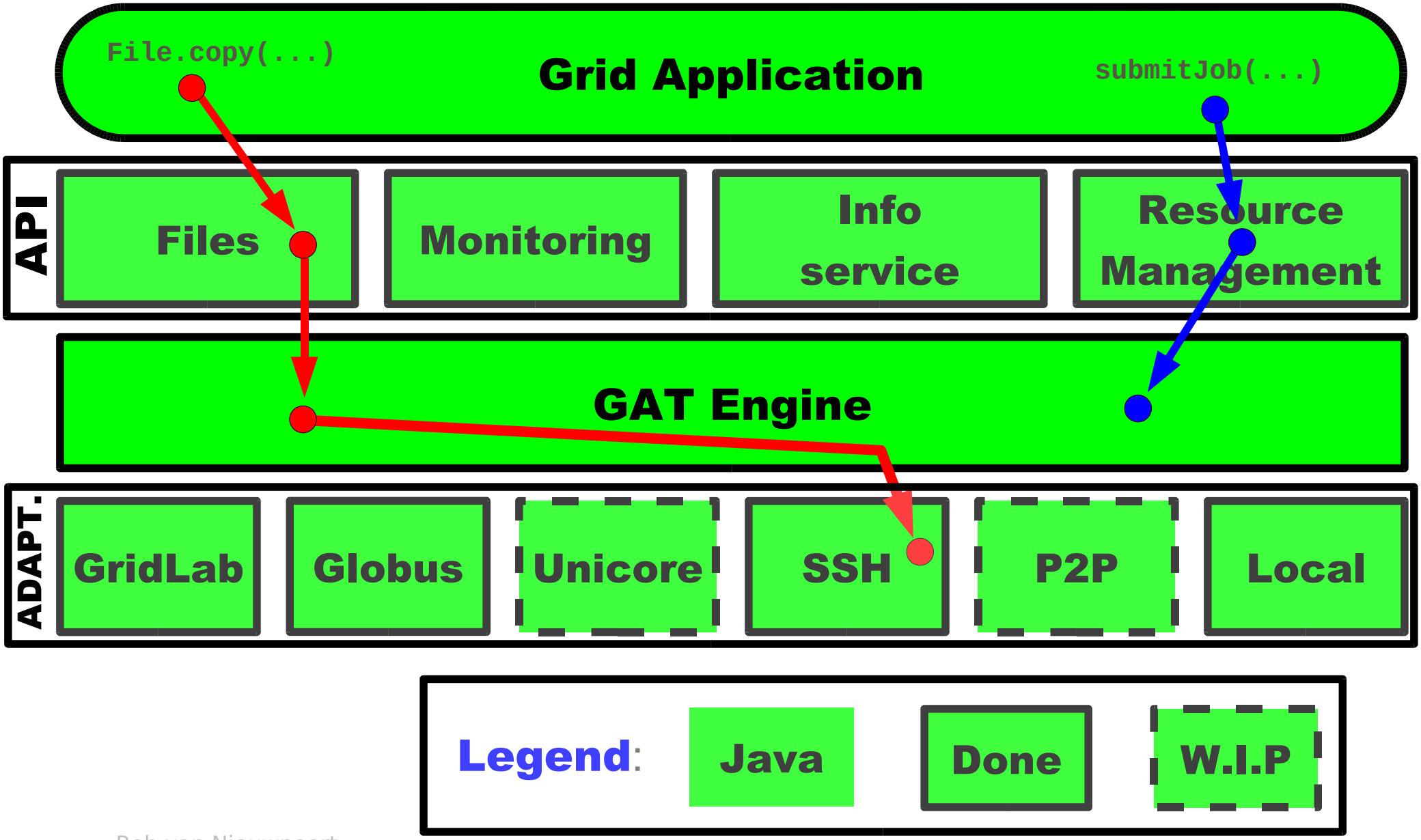

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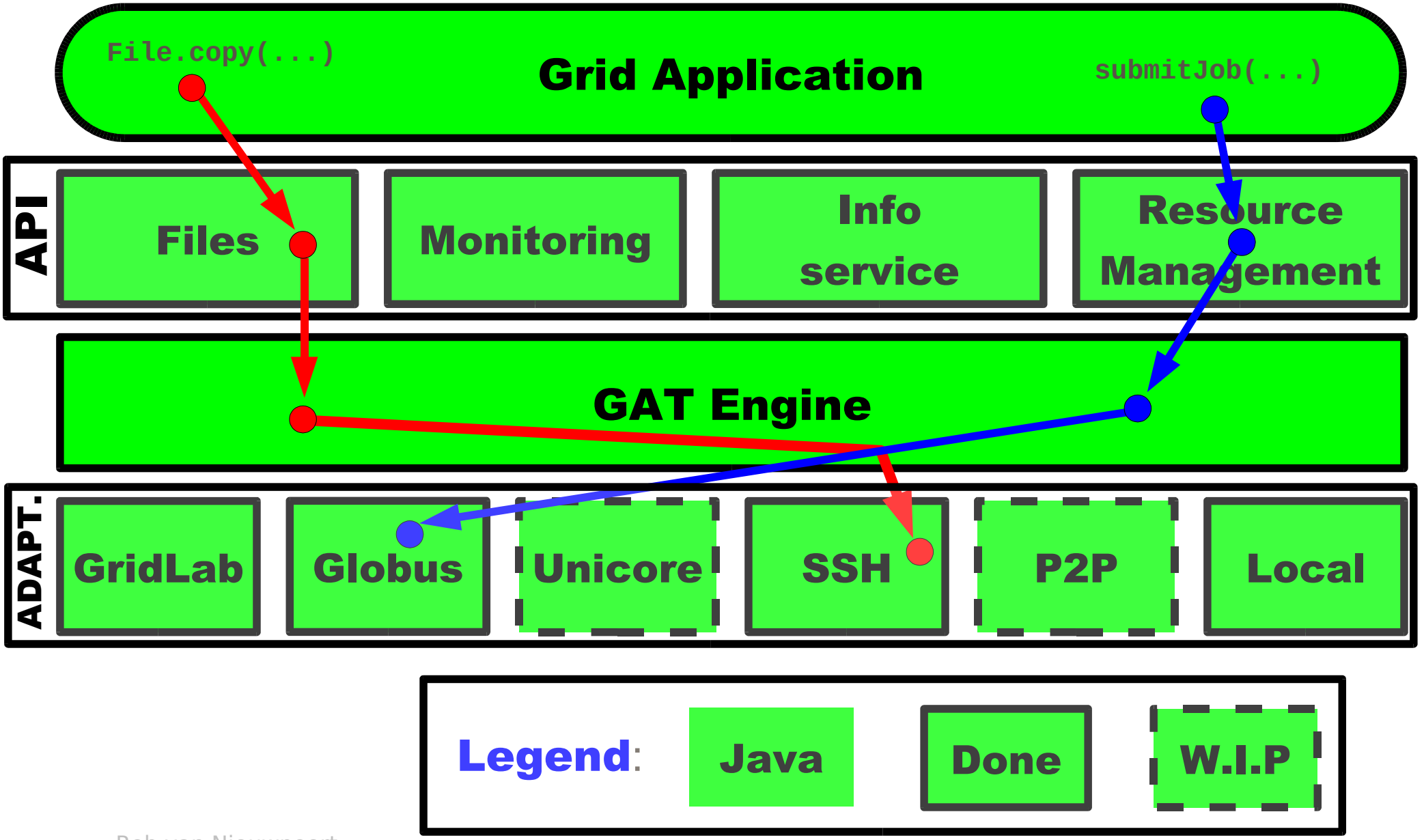

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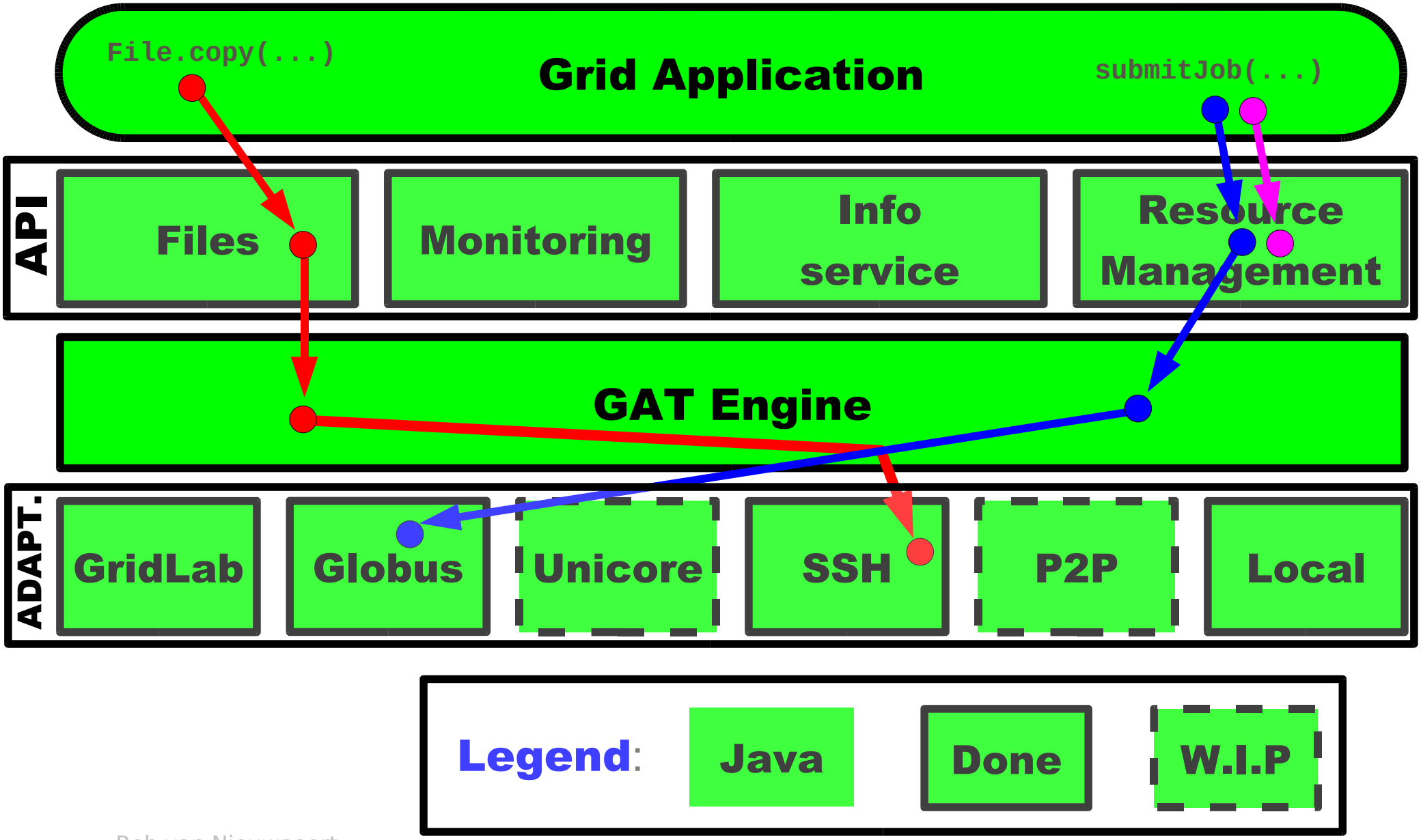

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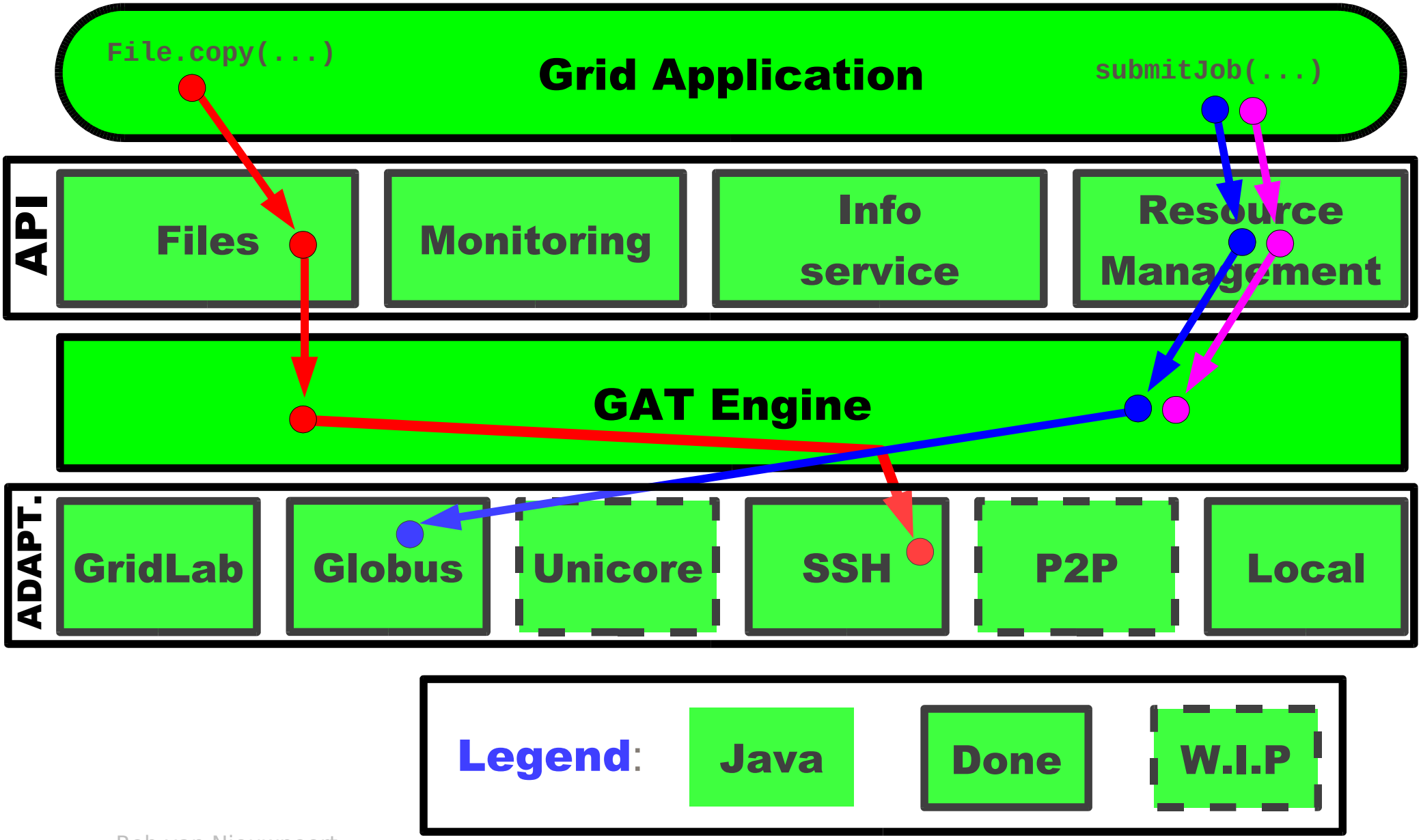

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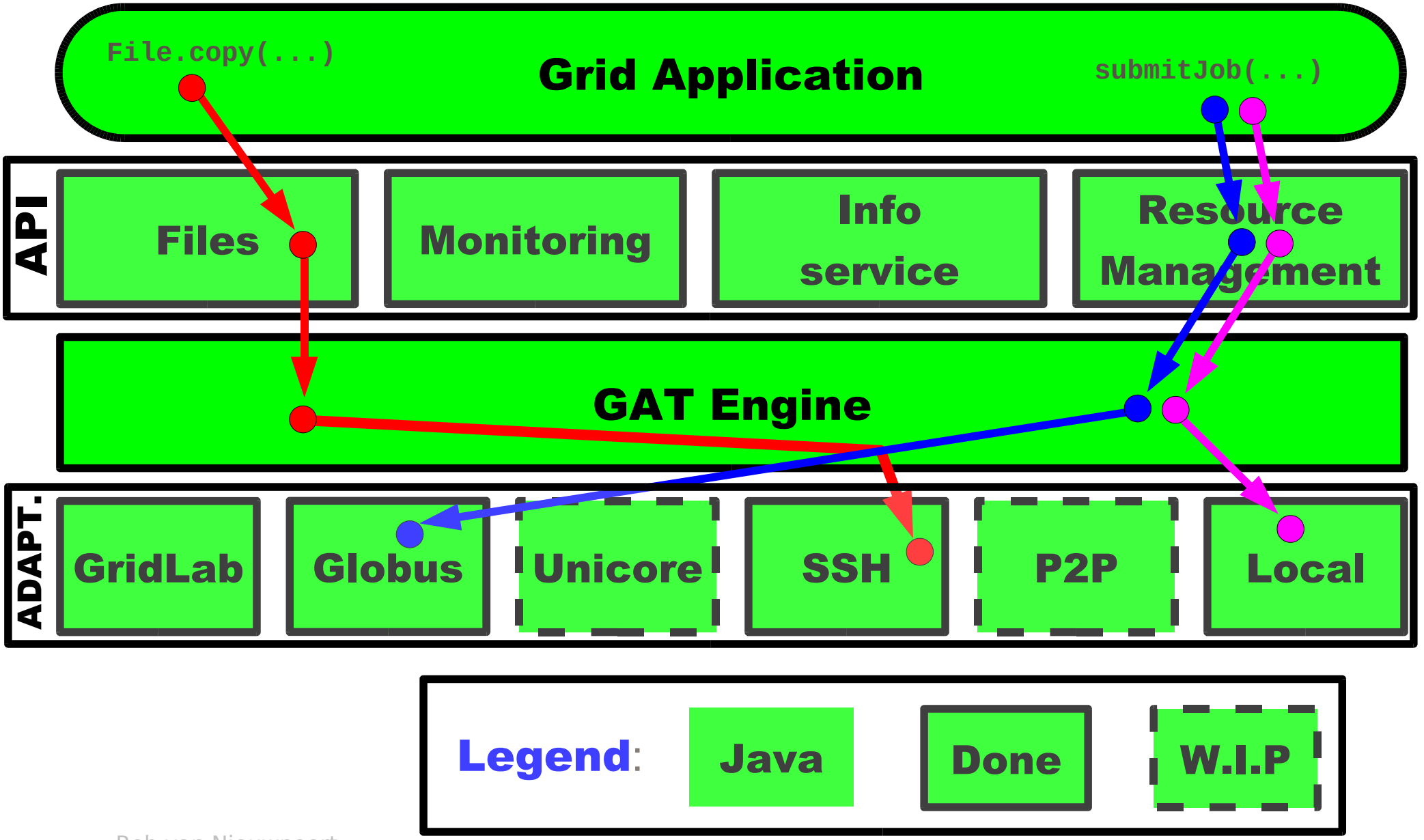

# Implementation

- Adaptors are Java JAR files, dynamically loaded into the application.
- Late binding (specification allows this):
  - The GAT engine selects the best adaptor for each method.
  - Example: Create file object.
  - Engine selects and instantiates all adaptors than can implement this file object.
  - File.copy from site A to site B and C.
  - A -> B copy with GridFTP.
  - A -> C copy with GridLab Data movement.
  - Provides flexibility and fault tolerance.
- Other implementations (C, C++, ...) use static binding

# Spec vs JavaGAT (1)

- Memory management is done for you (GC).
- GAT utility objects are not needed (list, table).
- No status objects, but exceptions
  - Can be nested.

# Spec vs JavaGAT (2)

- File and Streaming API:
  - JavaGAT subclasses existing “java.io” classes.
  - Streams and random access are separate
    - The GAT specification defines seeks on streams.
  - Directories are “first class citizens” and can be moved, copied, etc.
  - Directories can be used with any adopter
    - Stage in and out with resource broker.
  - Any Java code that uses files can now transparently use remote files.
    - File operations (getSize, isReadable).
    - Random File access.
    - Streaming.

# Available Adaptors

- Complete set of local adaptors.
- Generic:
  - Service locater (Igrid); used by GridLab adaptors
  - Stage in / out on top of GAT file; used by broker adaptors
  - Support for dealing with security contexts
  - Make writing new adaptors as easy as possible
- Many adaptors for grid middleware
  - Will be mentioned later

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# Some Basic GAT Objects

- Preferences
  - Key value pairs
  - Adaptor-specific instructions
  - Global or local, local overrides global
  - Example: `( "File.adaptor.name", "globus" )`
- GATContext
  - Contains security information
  - Contains global preferences
  - There can be more than one context
  - Needed to create GAT objects
- GAT
  - Factory for all GAT objects
- GAT Exceptions
  - Nested, helps debugging (Needed because of late binding)

# Some Basic GAT Objects

- URI
  - Slightly different semantics compared to java.net.URI
  - Use the right number of /'s in the URI's
  - Full URI is easy....
    - `protocol://machine/<path>file`
  - ....but some fields may be blank
    - `file:///output` (local file in current directory)
    - `file:////output` (local file in root (/) directory)
    - `file:////tmp/output` (local file in /tmp directory)
    - `ftp://10.0.0.1/output` (remote file in default ftp dir)
- Use the right scheme (protocol) in the URI:
  - JavaGAT can choose (late binding):
    - `any://`
  - Force a specific adaptor (early binding):
    - `ftp://, gsiftp://, http://, file://, ....`

# Example

```
GATContext context = new GATContext();
Preferences prefs = new Preferences();
prefs.put("File.adaptor.name", "globus");
context.addPreferences(prefs);

src = new URI("hello");
file = GAT.createFile(context, src);

OR use local preferences to override globals:

file = GAT.createFile(context, morePrefs, src);
```

# GAT Security

- SecurityContext
  - A container for security Information.
- Abstract, use subclasses
  - PasswordSecurityContext
  - CertificateSecurityContext
  - MyProxyServerCredentialSecurityContext
- Notes restrict the access to the context
  - Avoid broadcasting of passwords / credentials
  - Restrict access to a set of hosts or adaptors
  - One or more notes -> restricted to those adaptors/hosts
  - No notes -> any adaptor can use context for any host
- Typically not needed if default credentials / private keys are used

# GAT Security example

```
GATContext context = new GATContext();
SecurityContext pwd =
    new PasswordSecurityContext(username, password);

// restrict access
pwd.addNote("hosts", "hostname1:port1,hostname2:port2");
pwd.addNote("adaptors", "ftp,ssh");

SecurityContext cert =
    new CertificateSecurityContext(keyfile, username, passphrase);

// add them to the GAT context
context.addSecurityContext(pwd);
context.addSecurityContext(cert);
```

# Overview

- What is GAT and why do we need it?

- JavaGAT structure and overview
- Security
- Grid I/O
- Resource Management
- Application Information Management
- Monitoring

- Hands-on session


# Grid I/O Use Cases


- Copy, move, read, write files on the grid
- Random access to remote files
- Replicate files between different grid sites
- Inter-process communication

# Available Adaptors for Grid I/O

- File, streams and random file access:
  - Local files
  - GridLab data service
  - FTP, HTTP, HTTPS
  - GridFTP (Globus)
  - SSH, SFTP
- Logical file (replication):
  - Generic adaptor on top of GAT File
  - Logical file adaptor for GridLab replica service
- Pipe
  - Sockets

# Grid I/O Classes

- File
- FileInputStream / FileOutputStream
- RandomAccessFile

} Extend java.io classes

Grid-enable your code, just by replacing one "new" statement

- LogicalFile
  - Replicated file support

- Basic Inter-process communication
  - Endpoint
  - Pipe
  - PileListener

# GAT File

- Represents both files and directories (like java.io)
  - canRead, canWrite
  - delete
  - mkdir
  - list
  - copy
  - move
  - ...

# GAT File example

```
package tutorial;

import org.gridlab.gat.*;
import org.gridlab.gat.io.File;

public class RemoteCopy {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();

        URI src = new URI(args[0]);
        URI dest = new URI(args[1]);
        File file = GAT.createFile(context, src);              // create file object

        file.copy(dest);                                       // and copy it
        GAT.end();
    }
}
```

# GAT File Streaming Example

```
package tutorial;
import java.io.*;
import org.gridlab.gat.*;
import org.gridlab.gat.io.FileInputStream;

class RemoteCat {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();
        URI loc = new URI(args[0]);

        FileInputStream in = GAT.createFileInputStream(context, loc);
        InputStreamReader reader = new InputStreamReader(in);
        BufferedReader buf = new BufferedReader(reader);

        String result = buf.readLine();
        System.err.println("result = " + result);
        in.close();
    }
}
```

Standard java.io classes

# GAT Remote Random Access Files

- Random access to remote files
  - read
  - write
  - seek
  - length
  - ...

# GAT Logical File (replica management)

- LogicalFile class
  - An abstract representation of a set of identical physical files
  - addFile / addURI
  - removeFile / removeURI
  - replicate(URI destination)
- Replicate a logical file to a new location.
  - Copy one of the files in the set to the new location
  - Choose the “best” one
    - Closest in terms of bandwidth
    - Cheapest
    - …
    - Depends on adaptor
- Typically used for staging in files for jobs
  - Resource broker (or GAT) chooses one of the files in the set

# GAT Inter-Process Communication (1)

- Basic IPC primitives
  - Not intended for parallel programming
  - API looks like socket
  - Point to point only
  - Protocol independent
- Endpoint
  - Create them
  - listen (bind/accept in “socket speak”)
  - connect (setup connection to another Endpoint)
  - listen and connect both return a Pipe
- Pipe
  - A connection between to Endpoints (like a socket)
  - Provides InputStream and OutputStream

# GAT Inter-Process Communication (2)

- Endpoints are shared using the GAT application information service

- Asynchronous connection setup
- PipeListener
  - processPipe(Pipe pipe);
- Endpoint.listen(PipeListener p)
  - Asynchronous (returns immediately)
  - When a remote site connects, GAT calls processPipe on listener

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# Resource Management Use Cases

- Schedule, run jobs on the grid
- Stage in / stage out files that belong with jobs
- Cancel, checkpoint, migrate jobs
- Reserve resources

# Available Adaptors for Resource Management

- Local machine
- GridLab GRMS
- Globus
- ProActive

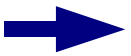
- Work-in-progress:
  - SSH
  - Resource broker adaptor for Unicore (Peggy Lindner)

# GAT Resource Management Classes (1)

- ResourceDescription
  - SoftwareResourceDescription
    - Describes a software component: library or Operating System, etc
    - Key/value pairs
    - “os.name”, “linux”
    - “os.release”, “2.6”
  - HardwareResourceDescription
    - Describes a hardware component: machine to run a job on
    - Key/value pairs
    - “memory.size”, “1GB”
    - “machine.type”, “i686”
  - Some keys and values defined in the spec, others may be adaptor specific
  - Both have a list of additional ResourceDescriptions
  - Build trees of ResourceDescriptions to express complex requirements

# Two requirements

SoftwareResourceDesciption
os.name=linux



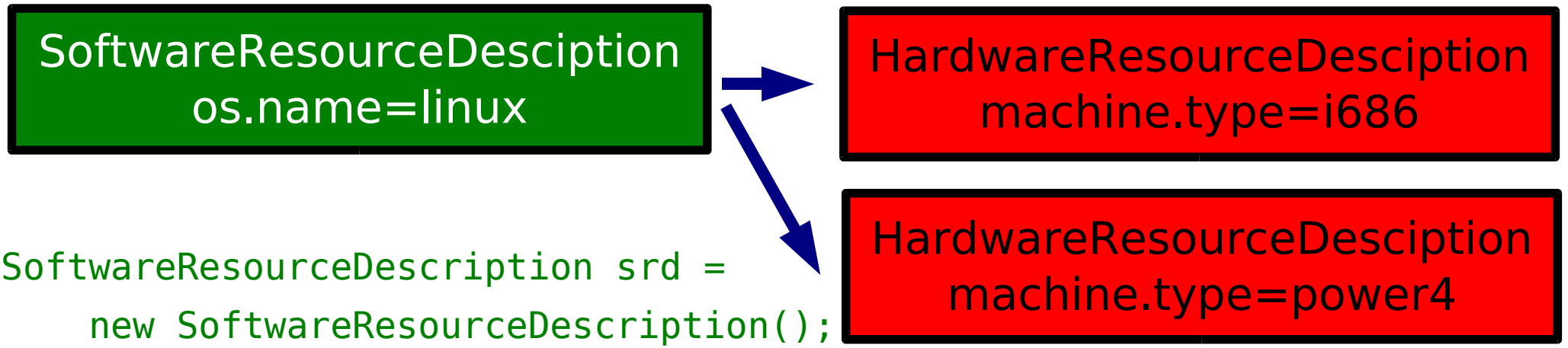
HardwareResourceDesciption
machine.type=i686

```
SoftwareResourceDescription srd =
    new SoftwareResourceDescription();
srd.addResourceAttribute("os.name", "linux);

HardwareResourceDescription hrd =
    new HardwareResourceDescription();
hrd.addResourceAttribute("machine.type", "i686");

srd.addResourceDesctiption(hrd); // require srd and hrd
```

# More Complex Descriptions




```
SoftwareResourceDescription srd =
    new SoftwareResourceDescription();
srd.addResourceAttribute("os.name", "linux);

HardwareResourceDescription hrd1 = new HardwareResourceDescription();
hrd1.addResourceAttribute("machine.type", "i686");

HardwareResourceDescription hrd2 = new HardwareResourceDescription();
hrd2.addResourceAttribute("machine.type", "power4");

srd.addResourceDesctiption(hrd1); // We must have Linux
srd.addResourceDesctiption(hrd2); // on either i686 or power4
```

# GAT Resource Management Classes (2)

- Resource
  - SoftwareResource
  - HardwareResource
- Reservation
- SoftwareDescription
  - Executable
  - Arguments
  - stdin, stdout, stderr
  - Pre-staged, post-staged files
- JobDescription
  - Must have SoftwareDescription
  - Has ResourceDescription or Resource

Describes the software you want to run on the grid

Describes your job:
Software and Requirements (for brokering)
or
Software and a specific resource to run on

# GAT Resource Management Classes (3)

- ResourceBroker
  - Submit job description
  - Find resources
  - Make reservations
- Job
  - Result of job submission
  - Query state
  - Cancel
  - Checkpoint
  - Migrate

# Resource Management Example (1)

```
public class SubmitLocalJob {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();

        SoftwareDescription sd = new SoftwareDescription();
        sd.setLocation("file:////bin/hostname");
        File stdout = GAT.createFile(context, "hostname.txt");
        sd.setStdout(stdout);

        JobDescription jd = new JobDescription(sd);
        ResourceBroker broker = GAT.createResourceBroker(context);
        Job job = broker.submitJob(jd);
        while (job.getState() != Job.STOPPED &&
               job.getState() != Job.SUBMISSION_ERROR) Thread.sleep(1000);
    }
}
```

# Resource Management Example (2)

```
public class SubmitRemoteJob {
    public static void main(String[] args) throws Exception {
     // ... above code is the same as before
        ResourceDescription rd = new HardwareResourceDescription();
        rd.addResourceAttribute("machine.node", args[0]);

        JobDescription jd = new JobDescription(sd, rd);
        ResourceBroker broker = GAT.createResourceBroker(context);
        Job job = broker.submitJob(jd);

        while (job.getState() != Job.STOPPED &&
                job.getState() != Job.SUBMISSION_ERROR) {
            System.err.println("job state = " + job.getInfo());
            Thread.sleep(1000);
        }
    }
}
```

# Overview

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# GAT Advert Service

- Advert service is a directory with an hierarchical name space
- The advert service can publish GAT objects
  - File
  - LogicalFile
  - Endpoint
  - Resource (software, hardware)
  - Job
- User attaches meta data to GAT objects
- Application can query, based on meta data
- Advert service is persistent
- Advert service is language independent

# Advert Service Use Cases

- Publish your (replicated) files, so other applications can open them
- Publish Endpoints to establish inter process communication
- Publish the (hardware) resources you found
- Spawn jobs, publish their Job object, let other applications (like a portal) monitor them

# Available Adaptors for the Advert Service

- Local system (file)
- GridLab Storagebox

# Advert Service Classes

- Advertisable
  - Marker interface (like java.io.Serializable)
  - GAT objects that implement this interface can be advertised
- MetaData
  - Table of (key,value) pairs (Strings)
  - Attached to Advertisable
- AdvertService
  - Publish adverts at some path in the hierarchical name space
  - Path uniquely identifies advert (one advert at any given path)
  - Supports current working directory (relative paths)
  - add(advert, metaData, path)
  - getAdvertisable(path)
  - find(metaData) metaData can contain regular expressions
  - ...

# Example: Publishing GAT Objects

```
public class AdvertServicePublish {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();
        AdvertService advert = GAT.createAdvertService(context);

        File file = GAT.createFile(context, "foo");
        MetaData meta = new MetaData();
        meta.put("name", "myTestFile");
        meta.put("purpose", "tutorial");
        advert.add(file, meta, "/home/rob/tutorialFile");

        Endpoint e = GAT.createEndpoint(context);
        meta = new MetaData();
        meta.put("name", "myTestEndpoint");
        meta.put("purpose", "tutorial");
        advert.add(e, meta, "/home/rob/tutorialEndpoint");
    }
}
```

# Example: retrieving GAT Objects

```
public class AdvertServicePrinter {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();

        AdvertService advert = GAT.createAdvertService(context);

        Advertisable result = advert.getAdvertisable(args[0]);
        if(result == null) {
            System.err.println("object not found");
            return;
        }

        System.err.println("got object back: " + result);
    }
}
```

# Querying the Advert Service

- Create MetaData query description
  - All fields in query must be matched
  - Results may have additional fields
  - MetaData value fields can be regular expressions

/home/rob/tutorialFile
"name", "myTestFile"
“purpose", "tutorial"

/home/rob/tutorialEndpoint
"name", "myTestEndpoint"
“purpose", "tutorial"

- {(“purpose”, “tutorial”)} matches both
- {(“purpose”, “tutorial”), (“location”, “any”)} matches none
- {(“name”, “.*File”)} matches blue
- {(“name”, “my.*”)} mathes both

# Example: Query the Advert Service

```
public class AdvertServiceQuery {
    public static void main(String[] args) throws Exception {
        GATContext context = new GATContext();
        AdvertService advert = GAT.createAdvertService(context);

        MetaData meta = new MetaData();
        meta.put(args[0], args[1]);

        String[] paths = advert.find(meta);
        if (paths == null) { System.err.println("no objects found");return; }

        System.err.println(paths.length + " adverts found");
        for (int i = 0; i < paths.length; i++) {
            Advertisable result = advert.getAdvertisable(paths[i]);
            System.err.println("advert " + i + " is " + result);
        }
    }
}
```

# Overview

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# GAT Monitoring and Steering System use cases

- Monitor and steer applications
  - Get application info (current iteration number)
  - Tell application to checkpoint
  - Change application variable to steer simulation
  - …
- Monitor grid resources
  - Host load
  - Free disc space
  - Current available network bandwidth
  - …
- Monitor and steer GAT objects
  - Monitor progress of GAT file copy
  - Monitor job status (is it in the queue or already scheduled)
  - …

# Available Adaptors for Monitoring

- External monitoring systems
  - Mercury
    - Monitors grid resources: hosts, queues, etc.
    - Monitors / steers applications
    - the GridLab project
    - the Datagrid project
    - the Hungarian Supergrid project
    - the P-GRADE Parallel Grid Runtime and Application Development Enviroment
  - Delphoi (work in progress)
    - Monitors network
    - The GridLab project
- Adaptor-specific (job management)

# Monitoring System Classes (1)

- Monitorable
  - A marker interface indicating which objects can be monitored
  - Interface to external monitoring system
- Monitorable GAT objects
  - File
  - LogicalFile
  - RandomAccessFile
  - FileInputStream
  - FileOutputStream
  - Endpoint
  - Pipe
  - AdvertService
  - Resource
  - Job

# Monitoring System Classes (2)

- MetricDefinition
  - A description of a measurable quantity within a monitoring system (free disk space)
  - Defines:
    - Measurement type: continuous / discrete
    - Data type and unit for parameters and return value
  - Create metrics by supplying parameters
    - Host name
    - Device name: /dev/hda
  - Monitoring system says:
    - I can measure free disk space.
      - I need two String parameters (device name, host name)
      - I will return a long value which is the free disk space in megabytes.
- Get list of MetricDefinitions from Monitorable

# Monitoring System Classes (3)

- Metric
  - Use a metric definition to define the metric you are interested in
  - MetricDefinition is: I can measure disk space
  - Metric is an instance of this: disk space on localhost, /dev/hda
  - Create by MetricDefinition.createMetric(“localhost”, “/dev/hda”);
- MetricValue
  - A value measured by the monitoring system
  - Poll monitoring system with Monitorable.getMeasurement(Metric)
  - Contains time stamp, value
- MetricListener
  - Asynchronous monitoring handler, produces new MetricValues
    - Can be called whenever something changes
    - Can be called with a specific frequency (for continuous metrics)

# Monitoring Example (1)

```
public class ListMetricDefinitions {
    public static void main(String[] args) throws Exception {
        GATContext c = new GATContext();
        c.addPreference("monitoring.adaptor.name", "mercury");

        Monitorable m = GAT.createMonitorable(c);

        List definitions = m.getMetricDefinitions();

        System.err.println("found " + definitions.size() + " definitions");

        for (int i = 0; i < definitions.size(); i++) {
            System.err.println(definitions.get(i));
        }
    }
}
```

# Monitoring Example (2)

```
public class GetMetric {
    public static void main(String[] args) throws Exception {
        GATContext c = new GATContext();
        c.addPreference("monitoring.adaptor.name", "mercury");

        Monitorable m = GAT.createMonitorable(c);
        MetricDefinition def = m.getMetricDefinitionByName("host.mem.free");

        HashMap params = new HashMap();
        params.put("host", args[0]);

        Metric metric = def.createMetric(params);
        MetricValue result = m.getMeasurement(metric);

        System.err.println("Free memory at " +
            new Date(result.getEventTime()) + " was: " + result.getValue());
    }
}
```

# The Power of GAT (1)

- Submit job to remote resource
- Stage in a directory
- Get output back
- Monitor the Job

- Resource broker independent
- Transfer protocol independent

- In 70 lines of code!

# The Power of GAT (2)

```
public class SubmitJobCallback implements MetricListener {
    boolean exit = false;

    public void start(String[] args) throws Exception {
        GATContext context = new GATContext();
        Job job = submitJob(context, args[0]);

        MetricDefinition md = job.getMetricDefinitionByName("job.status");
        Metric m = md.createMetric();   // no parameters needed for metric
        job.addMetricListener(this, m); // register callback for job.status

        // wait until job is done
        synchronized (this) {
            while (!exit) wait();
        }
    }
//  .... continued on next slide ....
```

My processMetricEvent method will be called when job.status changes

# The Power of GAT (3)

```
    public synchronized void processMetricEvent(MetricValue val) {
        String state = (String) val.getValue();

        System.err.println("SubmitJobCallback: Processing metric: "
            + val.getMetric() + ", state is " + state);

        if (state.equals("STOPPED") || state.equals("SUBMISSION_ERROR")) {
            exit = true;
            notifyAll();
        }
    }

//  .... continued on next slide ....
```

# The Power of GAT (4)

```
Job submitJob(GATContext context, String hostname) throws Exception {
    File outFile = GAT.createFile(context, "any:///hostname.txt");
    File stageInDir = GAT.createFile(context, "any:////home/rob/testDir");

    SoftwareDescription sd = new SoftwareDescription();
    sd.setLocation("file:////bin/hostname");
    sd.setStdout(outFile);
    sd.setPreStaged(stageInDir);

    Hashtable attributes = new Hashtable();
    attributes.put("machine.node", hostname);
    ResourceDescription rd = new HardwareResourceDescription(attributes);

    JobDescription jd = new JobDescription(sd, rd);
    ResourceBroker broker = GAT.createResourceBroker(context);
    return broker.submitJob(jd);
}
```

# The future of GAT

- GAT will be supported for at least the next two years
- GAT is being standardized within GGF
  - This will take time
  - GAT 2.0 will called SAGA (Simple API for Grid Applications)
  - SAGA is very close to GAT
    - Adds task model to GAT for asynchronous grid operations
- We will offer a migration path from GAT to SAGA

# Conclusion

- The GAT provides a simple and stable API to various Grid environments
- But powerful!
- Independent of grid middleware
- Portable
- Downloads:
  - www.gridlab.org
  - Distributions
  - Anonymous CVS access
  - C Platforms: Linux, Windows, Mac OS X, SGI Irix, True64 UNIX
  - Java Platforms: any (Java 1.4 or higher)
  - Support via mailing list gat@gridlab.org

# Hands-on Session

- Requirements:
  - Java 1.4 or newer
    - Download at java.sun.com
  - Ant 1.6 or newer
    - Java's equivalent of “make”
    - Download at ant.apache.org
- The Java GAT
  - www.gridlab.org
  - Click on Grid Application Toolkit
  - Click on GAT releases (on the left)
  - Download latest Java GAT version
  - Untar / unzip it in any place you like

# Building the JavaGAT

- Go to the JavaGATEngine directory
- Type **ant**
  - This takes about 10 seconds
  - The engine and all examples are now compiled
- Go to the JavaGATAdaptors directory
- Type **ant**
  - This takes about 10 seconds
  - The adaptors are now compiled
- Go back to the JavaGATEngine directory
  - Test it:

```
bin/run_gat_app tutorial.RemoteCat http://www.cs.vu.nl/~rob/hello.txt
```

Or (on windows)

```
bin\run_gat_app.bat tutorial.RemoteCat http://www.cs.vu.nl/~rob/hello.txt
```

# Capability Provider Interface (CPI)

- GAT objects are Java interfaces
- Below the API level, the GAT Engine provides CPI classes (Capability Provider Interface)
  - CPI classes implement the GAT object interfaces
  - All methods in the CPI classes throw exceptions
  - CPI classes provide additional generic code
- Adaptors extend a CPI class
  - Fill in some or all methods
  - Late binding: if a method is not implemented GAT selects another adaptor

# Adaptor Class Hierarchy