Setting up and using a Globus Toolkit 5 based Grid

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Outline

- Introduction
  - Grid and Globus Toolkit
- Grid Security Infrastructure
- GT5 Installation and Configuration
- GridFTP
- GRAM
Distributed Computing Use Case

Supercomputer A

Internet

Supercomputer B

User

Data Store A

Data Store B

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The Grid

- Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations
  - “On-demand” access to ubiquitous distributed computing
  - Transparent access to distributed data
  - Easy to plug resources into
  - Complexity of the infrastructure is hidden
Virtual Organization

Site A

Virtual Organization (VO)

Site B

Site C

Site D
“Coordinating multiple resources”: ubiquitous infrastructure services, app-specific distributed services

“Sharing single resources”: negotiating access, controlling use

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

“Controlling things locally”: Access to, & control of, resources
The Globus Toolkit centers around

- **Connectivity layer:**
  - *Security:* Grid Security Infrastructure (GSI) - allows collaborators to share resources without blind trust

- **Resource layer:**
  - *Resource Management:* Grid Resource Allocation Management (GRAM)
  - *Data Transfer:* Grid File Transfer Protocol (GridFTP)

- Also collective layer protocol
  - *Replica Management* (RLS)

- Focuses on simplifying heterogeneity for application developers
Grid Security Infrastructure (GSI)

- Open source libraries, tools and standards which provide security functionality of the Globus Toolkit
- Goal is to support VO
- Provides for cross-organizational:
  - Authentication
  - Authorization
  - Single sign-on
Terminology

Authentication: Proving who you are.

Authorization: What are you allowed to do?

Delegation: Granting a right to another entity.

John Doe @ NCSA
GSI

- Based on asymmetric cryptography
  - Private and Public Key - allows for two entities to authenticate with minimal cross-organizational support

- Certificates - Central concept in GSI
  - Information vital to identifying and authenticating user/service
  - Distinguished Name – unique Grid id for user/service
  - "/DC=org/DC=doegrids/OU=People/CN=Raj Kettimuthu 227852"

- Certificate Authority (CA)
  - Trusted 3rd party that confirms identity

- Host credential
  - Long term credential

- User credential
  - Passphrase protected
Digital Signatures

- Used to determine if the data has been tampered
- Also, identify who signed the data
- Digital signatures are generated by
  - Creating secure hash of the data
  - Encrypting the hash with private key
- The resulting encrypted data is the signature
- This hash can then be decrypted only by the corresponding public key
Certificates

- Allow for binding of an Identity (John Doe) to a key or person
Proxy Certificates

- X.509 Proxy Certificates are our extension
- Standardized in IETF
- Allow for dynamic delegation
- Proxy credentials are short-lived credentials created by user
  - Proxy signed by user certificate private key
- Stored unencrypted for easy repeated access
Delegation

- Enabling another entity to run on behalf of you
- E.g. Service that runs a job needs to transfer files.

- Ensure
  - Limited lifetime
  - Limited capability

- GSI uses proxy certificates for delegation
Authorization

- **Establishing rights of an identity**
  - Can user do some action on some resource

- **Identity based authorization**
  - Establish identity using authentication
  - Check policy to see what identity can do
  - Eg: Gridmap authorization a list of mappings from allowed DNs to user name
    - "/DC=org/DC=doegrids/OU=People/CN=Raj Kettimuthu 227852" kettimut
  - Identity based authorization may not scale

- **Attribute based authorization**
  - Attributes are information about an entity
    - Employee of Argonne National Lab
    - Member of virtual organization ABC
GSI Stack

- GSI uses a standard PKI for identity certificates.
- Each entity (user, service) has an X.509 certificate from a CA that uniquely names it.
GSI Stack

- SSL, using the certificates, is used as the network protocol
- Performs authentication, like in the web, but client as well as server
- Also provides message protection as needed (integrity, encryption)
GSI Stack

- X.509 Proxy Certificates
- SSL
- PKI (Certs, CAs)

- X.509 Proxy Certificates are our extension
- Standardized in IETF (pkix)
- Allow for dynamic delegation
GSI Stack

- Grid-Mapfile
- X.509 Proxy Certificates
- SSL
- PKI (Certs, CAs)

- Grid-Mapfile maps Grid users (identified by certificates) to local users (e.g., Unix account)
- Allows authorization using normal local methods (e.g., filesystem perms, quotas)
GSI-Enabled Coordination

Site A

Allows for standard authentication method

Proxy Certificate

Site B

Allows for delegation to allow for coordinated resource usage

Site C

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GSI in Action: “Create Processes at A and B that Communicate & Access Files at C”

Single sign-on via “grid-id” & generation of proxy cred.
Or: retrieval of proxy cred. from online repository

User Proxy
Proxy credential

Remote process creation requests*

GSI-enabled GRAM server
Authorize
Map to local id
Create process
Generate credentials

Ditto
GSI-enabled GRAM server

Process
Local id
Delegated Proxy cred

Communication*

Remote file access request*

GSI-enabled GridFTP server
Authorize
Map to local id
Access file

* With mutual authentication

User

Site A
GSI-enabled GRAM server
Process
Local id
Delegated Proxy cred

Site B
GSI-enabled GRAM server
Process
Local id
Delegated Proxy cred

Site C
GSI-enabled GridFTP server
MyProxy – credential repository

- Allows users to acquire Grid credentials from Username/Password
- Enables mobility

MyProxy server

Web Server

The Grid

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Globus Toolkit 5
Installation Demo
## Installation Steps

### Installing Globus

- `wget http://www.globus.org/ftppub/gt5/5.0/5.0.0/installers/src/gt5.0.0-all-source-installer.tar.bz2`
- `tar xvfz gt5.0.0-all-source-installer.tar.bz2`
- `cd gt5.0.0-all-source-installer`
- `./configure -prefix /path/to/install`
- `make`
- `make install`
Fetching User and Host Certs

- **https://pki1.doegrids.org/ca/**
- download the DOE support CA files tarball from [http://pki1.doegrids.org/Other/doegrids.tar](http://pki1.doegrids.org/Other/doegrids.tar)
- untar it into /etc/grid-security/certificates
- cp /etc/grid-security/doegrids/globus-host-ssl.conf.1c3f2ca8 /etc/grid-security/globus-host-ssl.conf
  
  cp /etc/grid-security/doegrids/globus-user-ssl.conf.1c3f2ca8 /etc/grid-security/globus-user-ssl.conf
  
  cp /etc/grid-security/doegrids/grid-security.conf.1c3f2ca8/etc/grid-security/grid-security.conf
- run 'grid-cert-request -host <hostname>'' from your Globus install
- Go to [http://pki1.doegrids.org/ca/](http://pki1.doegrids.org/ca/)
  
  Select "Grid or SSL Server". Paste the Certificate Signing Request into the "PKCS#10 Request" text box. Fill out the rest of the form and "Submit".
GridFTP
What is GridFTP?

- High-performance, reliable data transfer protocol optimized for high-bandwidth wide-area networks
- Based on FTP protocol - defines extensions for high-performance operation and security
- Standardized through Open Grid Forum (OGF)
- GridFTP is the OGF recommended data movement protocol
GridFTP

- We (Globus Alliance) provide a reference implementation:
  - Server
  - Client tools (globus-url-copy)
  - Development Libraries

- Multiple independent implementations can interoperate
  - Fermi Lab and U. Virginia have home grown servers that work with ours
Globus GridFTP

- **Performance**
  - Parallel TCP streams, optimal TCP buffer
  - Non TCP protocol such as UDT

- **Cluster-to-cluster data movement**

- **Multiple security options**
  - Anonymous, password, SSH, GSI

- **Support for reliable and restartable transfers**
GridFTP Servers Around the World

Understanding GridFTP

- Two channel protocol like FTP
- Control Channel
  - Command/Response
  - Used to establish data channels
  - Basic file system operations eg. mkdir, delete etc
- Data channel
  - Pathway over which *file* is transferred
  - Many different underlying protocols can be used
    - MODE command determines the protocol
Client/Server and 3rd Party Transfers

- **Two party transfer**
  - The client connects and forms a CC with the server
  - Information is exchanged to establish the DC
  - A file is transferred over the DC

- **Third party transfer**
  - Client initiates data transfer between 2 servers
  - Client forms CC with 2 servers.
  - Information is routed through the client to establish DC between the two servers.
  - Data flows directly between servers
  - Client is notified by each server SPI when the transfer is complete
Control Channel Establishment

- Server listens on a well-known port (2811)
- Client forms a TCP Connection to server
- 220 banner message
- Authentication
  - Anonymous
  - Clear text USER <username>/PASS <pw>
  - Base 64 encoded GSI handshake
- 230 Accepted/530 Rejected
Data Channel Establishment

GridFTP Server

Connect
IP:PORT

GridFTP Server

GridFTP Client
Data Channel Protocols

- **MODE Command**
  - Allows the client to select the data channel protocol

- **MODE S**
  - Stream mode, no framing
  - Legacy RFC959

- **MODE E**
  - GridFTP extension
  - Parallel TCP streams
  - Data channel caching

| Descriptor (8 bits) | Size (64 bits) | Offset (64 bits) |
Globus-url-copy

- Command line scriptable client
- Globus does not provide an interactive client
- Commonly used client for GridFTP

Syntax overview

- `globus-url-copy [options] srcURL dstURL`
- `guc gsiftp://localhost/foo file:///bar`
  - Client/server, using FTP stream mode
  - 3rd party transfer, MODE E

URL rules

- `protocol://[user:pass@[host]]/path`
- host can be anything resolvable - IP address, localhost, DNS name
Demonstration

- **globus-gridftp-server options**
  - globus-gridftp-server --help

- **Start the server in anonymous mode**
  - globus-gridftp-server --control-interface 127.0.0.1 -aa -p 5000

- **Run a two party transfer**
  - globus-url-copy -v file:///etc/group ftp://localhost:5000/tmp/group

- **Run 3rd party transfer**

- **Experiment with -dbg, -vb -fast options**
  - globus-url-copy -dbg file:///etc/group ftp://localhost:5000/tmp/group
  - globus-url-copy -vb file:///dev/zero ftp://localhost:5000/dev/null

- **Kill the server**
Demonstration
Examine debug output

- TCP connection formed from client to server
- Control connection authenticated
- Several session establishment options sent
- Data channel established
  - PASV sent to server
    - Server begins listening and replies to client with contact info
  - Client connected to the listener
  - File is sent across data connection
Security Options

- **Clear text (RFC 959)**
  - Username/password
  - Anonymous mode (anonymous/<email addr>)
  - Password file

- **SSHFTP**
  - Use ssh/sshd to form the control connection

- **GSIFTP**
  - Authenticate control and data channels with GSI
User Permissions

- User is mapped to a local account and file permissions are handled by the OS
- inetd or daemon mode
  - Daemon mode - GridFTP server is started by hand and listens for connections on port 2811
  - Inetd/xinetd - super server daemon that manages internet services
  - Inetd can be configured to start up a GridFTP server upon receiving a connection on port 2811
inetd/daemon Interactions

CPI

Authenticate

Daemon/Server

GridFTP Server

USER

Port 2811

ROOT

fork

setuid
(x)inetd Entry Examples

- **xinetd**
  ```
  service gsiftp
  {
    socket_type = stream
    protocol = tcp
    wait = no
    user = root
    env += GLOBUS_LOCATION=<GLOBUS_LOCATION>
    env += LD_LIBRARY_PATH=<GLOBUS_LOCATION>/lib
    server = <GLOBUS_LOCATION>/sbin/globus-gridftp-server
    server_args = -i
    disable = no
  }
  ```

- **inetd**
  ```
  gsiftp stream tcp nowait root /usr/bin/env env
  GLOBUS_LOCATION=<GLOBUS_LOCATION>
  LD_LIBRARY_PATH=<GLOBUS_LOCATION>/lib
  <GLOBUS_LOCATION>/sbin/globus-gridftp-server -i
  ```

- **Remember to add 'gsiftp' to /etc/services with port 2811.**
GridFTP Over SSH

- sshd acts similar to inetd

- control channel is routed over ssh
  - globus-url-copy *popens* ssh
  - ssh authenticates with sshd
  - ssh/sshd remotely starts the GridFTP server as user
  - stdin/out becomes the control channel
sshtftp:// Interactions

- CPI
- SSH
- Authenticate

GridFTP Server

Port 22

ROOT

USE

R

Stdin/out

popen

exec
GSI Authentication

- **Strong security on both channels**
  - SSH does not give us data channel security
- **Delegation**
  - Authenticates DC on clients behalf
  - Flexibility for grid services such as RFT
    - Agents can authenticate to GridFTP servers on users behalf
  - Enables encryption, integrity on data channel
GSI Authentication

- GridFTP Server
- GridFTP Client
- GSI Credential
- GSI Delegated Credential
Troubleshooting

- **Can I get connected?**
  - `telnet` to the port: `telnet hostname port`
  - 2811 is the default port

- **You should get something like this:**
  - `<add GridFTP banner>`

- **If not, you have firewall problems, or server config problems.**
Troubleshooting

- no proxy
  - grid-proxy-destroy
  - guc gsiftp://localhost/dev/zero file:///dev/null
  - add –dbg
  - grid-proxy-init
  - guc gsiftp://localhost/dev/zero file:///dev/null
  - add –dbg
Setting TCP buffer sizes

- It is critical to use the optimal TCP send and receive socket buffer sizes for the link you are using.
  - Recommended size to fill the pipe
    - 2 x Bandwidth Delay Product (BDP)
  - Recommended size to leave some bandwidth for others
    - around 20% of (2 x BDP) = .4 * BDP
Setting TCP buffer sizes

- Default TCP buffer sizes are way too small for today’s high speed networks
  - Until recently, default TCP send/receive buffers were typically 64 KB
  - Tuned buffer to fill Argonne to LBL link: 8 MB
    - 125X bigger than the default buffer size
  - With default TCP buffers, you can only get a small % of the available bandwidth!
TCP tuning

- Many OS’s now include TCP autotuning
  - TCP send buffer starts at 64 KB
  - As the data transfer takes place, the buffer size is continuously re-adjusted up to max autotuning size
- Default autotuning maximum buffers on Linux 2.6: 256K to 1MB, depending on version
  
  ```
  net.core.rmem_max = 16777216
  net.core.wmem_max = 16777216
  # autotuning min, default, and max number of bytes to use
  net.ipv4.tcp_rmem = 4096 87380 16777216
  net.ipv4.tcp_wmem = 4096 65536 16777216
  ```
- [http://fasterdata.es.net/TCP-tuning/](http://fasterdata.es.net/TCP-tuning/)
Parallel Streams
Parallel TCP Streams

- Potentially unfair
- Reduces the severity of a congestion event
  - Only effects $1/p$ of the overall transfer
- Faster recovery
  - Smaller size to recover
- But they are necessary when you don’t have root access, and can’t convince the sysadmin to increase the max TCP buffers

Graph from Tom Dunigan, ORNL
Data channel caching

- Establishing a data channel can be expensive
  - Round trips over high latency links
  - Security handshake can be expensive

- Mode E introduces data channel caching
  - Mode S closes the connection to indicate end of data
  - Mode E uses meta data to indicate file barriers
    - Doesn’t need to close

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<thead>
<tr>
<th>Descriptor</th>
<th>Size</th>
<th>Offset</th>
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<tbody>
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<td>(8 bits)</td>
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Demonstration Performance

- Transfer on a real network
  - Show performance markers
  - Show transfer rate
- Calculate the BWDP
- Vary -tcp-bs
- Vary -p
Data Channel Protocols

- **MODE Command**
  - Allows the client to select the data channel protocol

- **MODE S**
  - Stream mode, no framing
  - Legacy RFC959

- **MODE E**
  - GridFTP extension
  - Parallel TCP streams
  - Data channel caching

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Firewall

- Control channel port is statically assigned
- Data channel ports dynamically assigned
- Mode E requires that the data sender make an active connection
Firewall

- Outgoing allowed at sender, incoming blocked at receiver
Firewall

- Outgoing allowed at sender, incoming blocked at receiver

Mode S

GridFTP Source Server

DATA Channel

TCP 2811

GridFTP Dest Server

DATA Channel

TCP 2811

Client
Firewall

- Outgoing allowed at sender, incoming blocked at receiver

Mode E

![Diagram showing Firewall configuration with GridFTP Source Server, GridFTP Dest Server, and Client. The diagram illustrates the DATA Channel and ATA Channel, with TCP 2811 connection points. The firewall blocks incoming traffic at the receiver.]
Firewall

- Open a port range on the receiver’s ends firewall and set GLOBUS_TCP_PORT_RANGE to that open range
- 50000-51000 is the recommended port range for data channel connections
- export GLOBUS_TCP_PORT_RANGE = 50000,51000
Firewall

- Outgoing blocked at sender
  - Can open a range of ports for outgoing connections to specific set of remote hosts (any remote port)
  - Use GLOBUS_TCP_SOURCE_RANGE to make the local end bound to a specified range
  - If outgoing connections can be opened up only for specific remote port range at specific remote hosts
    - firewall rule needs to modified on a case-by-case basis
Partial File Transfer

- **Large file transfer fails**
  - We don't want to start completely over
  - Ideally we start where we left off
- **Restart markers sent periodically**
  - Contain blocks written to disk
  - Sent every 5s by default
  - In worst case recovery sends 5s of redundant data
Striping or Cluster-to-cluster transfer

- A coordinated transfer between multiple nodes at end of the transfer
  - 1 SPI at each end
  - Many DPIs per SPI
  - Each DPI transfers a portion of the file
  - Allows for fast transfers
  - Many NICs per transfer
Cluster-to-cluster transfer

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Modular

- Globus GridFTP is based on XIO and is modular
- Well-defined interfaces
Data Storage Interface (DSI)

- Number of storage systems in use by the scientific and engineering community
  - High Performance Storage System (HPSS)
  - Distributed File System (DFS)
  - Storage Resource Broker (SRB)

- Use incompatible protocols for accessing data and require the use of their own clients
- Modular abstraction to storage systems
Globus XIO

- Framework to compose different protocols
- Provides a unified interface for open/close/read/write
- Driver interface to hook 3rd party protocol libraries
Alternative stacks

- All I/O in GridFTP is done with Globus XIO
  - data channel and disk

- XIO allows you to set an I/O software stack
  - transport and transform drivers
  - ex: compression, gsi, tcp

- Substitute UDT for TCP

- Add BW limiting, or netlogger
All data passes through XIO driver stacks

- to network and disk
- observe data
- change data
- change protocol
Lots of Small Files (LOSF) Problem
Concurrency

- Use concurrency optimization for transferring lots of small files

- What is a small file?
  - Depends on the network bandwidth and latency
  - Files of size $\leq 100$ MB

- Transfer multiple files concurrently
  - `globus-url-copy -cc`
GRAM
What is GRAM?

- GRAM is a Globus Toolkit component
  - For Grid *job management*
- GRAM is a unifying remote interface to Resource Managers
  - Yet preserves local site security/control
- GRAM provides stateful job control
  - Reliable create operation
  - Asynchronous monitoring and control
  - Remote credential management
  - Remote file staging and file cleanup
Grid Job Management Goals

Provide a service to securely:

- Create an environment for a job
- Stage files to/from environment
- Cause execution of job process(es)
  - Via various local resource managers
- Monitor execution
- Signal important state changes to client
Traditional Interaction

- Satisfies many use cases
- TACC’s Ranger (62976 cores!) is the Costco of HTC ;-), one stop shopping, why do we need more?
GRAM Benefit

- Add remote execution capability
  - Enable clients/devices to manage jobs without logging into the cluster

GRAM API

Local Jobs

GRAM Service

LRM (e.g. PBS)

Compute Nodes

Resource A

remote GRAM Jobs
GRAM Benefit

- Provides LRM abstraction

GRAM API

Local Jobs

GRAM Jobs

Local Jobs

GRAM Service

LRM (e.g. PBS)

Compute Nodes

Resource A

GRAM Service

LRM (e.g. SGE)

Compute Nodes

Resource B
GRAM Benefit

- Scalable job management
- Interoperability
Users/Applications:
Science Gateways, Portals, CLI scripts, App Specific Web Service, etc.

Local Resource Managers:
PBS, Condor, LSF, SGE, Fork

GRAM
GRAM Client Interfaces

- **CLIs**
  - globusrun, globus-job-run, globus-job-submit, globus-job-clean, globus-job-get-output

- **C APIs**
  - www.globus.org/api/c-globus-5.0.0
  - Blocking and async functions for
    - submission, RSL manipulation, callbacks, cancelling, status

- **Java CoG JGlobus APIs**
  - www.cogkit.org/release/4_1_4/api/jglobus/
  - Classes: Gram, GramJob, GramAttributes
GRAM Authentication Test

- `globusrun -a -r never-1`

- **Resource Names**
  - `HOST:PORT/SERVICE:SUBJECT`

- `globusrun -a -r never-1.ci.uchicago.edu:2119/jobmanager:/DC=org/DC=doegrids/OU=Services/CN=host/never-1.ci.uchicago.edu`
globus-job-*

- bourne shell scripts that call globusrun
- Hide details of RSL
globus-job-run

- Blocking CLI to gram service
  - `globus-job-run never-1 /bin/hostname`
    - Basic job
  - `globus-job-run never-1 -np 5 /bin/sleep 10`
    - Multiple processes
  - `globus-job-run never-1 /bin/sleep 90`
    - Cancel execution by CTRL-C
  - `globus-job-run never-1 -env TEST=1 -env GRID=1 /usr/bin/env`
    - Augment job environment
globus-job-run cont..

- globus-job-run never-1 -env TEST=1 -env GRID=1 /usr/bin/env
  - Augment job environment

- globus-job-run -dump-rsl never-1 -env TEST=1 -env GRID=1 /usr/bin/env -u TEST
  - &(executable="/usr/bin/env")
  - (environment= ("TEST" "1") ("GRID" "1"))
  - (arguments= "-u" "TEST")
globus-job-submit, clean, get-output

- Non-blocking CLI to gram service
- `globus-job-submit never-1 /bin/hostname`
  - Returns job contact string
    - `https://never-1.ci.uchicago.edu:37980/16073836513828969566/7364555675185249161/`
  - Service will save the output, use `get-output`
- `globus-job-get-output <job contact>`
  - Returns – “never-1.ci.uchicago.edu”
- `globus-job-clean <job contact>`
  - Clean up after yourself!
globus-job-status

- globus-job-submit never-1 /bin/sleep 10
  - Get your remote job running
- globus-job-status <job contact>
  ACTIVE
- globus-job-status <job contact>
  DONE
  - Monitor status
- globus-job-clean <job contact>
  - Don’t forget to cleanup
globusrun

- C program
- Takes an Resource Specification Language (RSL) as an argument
- `globusrun -p "&(executable=/bin/ls)"
  - RSL Parsed Successfully...
- `globusrun -p "&(executable=/bin/ls) (howabout=this) (eventhough=(this doesnt) (make sense))"
  - RSL Parsed Successfully...
globusrun continued

- globusrun –j –r never-1 “&(executable=/bin/ls)”
  - Toolkit version: 4.3.0-HEAD Job Manager version: 10.5 (1256257907-0)
- globusrun -b -r never-1 "&(executable=/bin/sleep)(arguments=10)”
  - globus_gram_client_callback_allow successful
  - GRAM Job submission successful
  - https://never-1.ci.uchicago.edu:34159/16073843111170748796/736455675185248438/
  - GLOBUSGRAM_PROTOCOL_JOB_STATE_ACTIVE
globusrun continued

- `globusrun -status <job contact>`
  - Getting status of a job
- `globusrun -k <job contact>`
  - Cancelling a job
globusrun expired proxy

- Create a new proxy via grid-proxy-init
- Restarting a job will cause the JM to use the new proxy for all jobs
  - globusrun -r never-1 "&(restart=<job contact>)"
File staging and RSL substitution

- Run `ls` on `never-1`, but first stage the file from `never-2`

  - `globusrun -s -r never-1 '(&(rsl_substitution = (GRIDFTP_SERVER gsiftp://never-2.ci.uchicago.edu)) (executable=/bin/ls) (arguments=/tmp/staged_file) (file_stage_in = ($(GRIDFTP_SERVER)/home/tutorial1/junk /tmp/staged_file)))'`
File Stage In Shared

- Run ls on never-1, but first stage the file from never-2

  ```bash
  globusrun -s -r never-1 '&(rsl_substitution = (GRIDFTP_SERVER gsiftp://never-2.ci.uchicago.edu)) (executable=/bin/ls) (arguments=/tmp/staged_file) (file_stage_in = ($(GRIDFTP_SERVER)/home/tutorial1/junk /tmp/staged_file))'
  ```
File stage in shared

- Run ls on never-1, but first stage the file from never-2 into the gass cache from globusrun’s built in GASS server
  - `globusrun -s -r never-1 `&(executable=/bin/ls) (arguments = -l /tmp/staged_file_link1) (file_stage_in_shared = (${GLOBUSRUN_GASS_URL}/home/tutorial1/junk /tmp/staged_file_link1))’
  - lrwxrwxrwx 1 tutorial1 tutorial1 122 Mar 2 01:22 /tmp/staged_file_link1 -> /home/tutorial1/.globus/.gass_cache/local/ md5/73/6a9ff8a069d11515f240090bf77327/md5/cb/ 20eadb906d8fd93d30cd6385f6703a/data
File stage out

- Run ls on never-1, then transfer the output using the gridftp server running on never-2
  - globusrun -r never-1 '&(executable=/bin/ls)
    (stdout=$(HOME)/results.txt)
    (file_stage_out =
     $(HOME)/results.txt
     gsiftp://never-2.ci.uchicago.edu/home/tutorial1/
     never-1-ls-results.txt))'
Same thing only remove the results.txt file on never-1 after the contents have been staged out.

```bash
globusrun -r never-1 '&(executable=/bin/ls) (stdout=$HOME/results.txt) (file_stage_out = ($HOME/results.txt
gsiftp://never-2.ci.uchicago.edu/home/tutorial1/never-1-ls-results.txt))(file_clean_up=$HOME/results.txt)'
```
GRAM5 Architecture

Job Submission

Client → Gatekeeper → Job Manager

Job Manager

1 process

throttled (default 5)

Resource Manager

User Job(s)

Job Monitoring

Job Manager

1 process

SEG

1 process

Resource Manager

User Job(s)

SEG log

RM log
Running the SEG

- By Default, jobs are monitored via polling
- But, SEG can be used and is more scalable and provides better performance

- For Fork, add “-seg-module fork” to $GLOBUS_LOCATION/etc/grid-services/jobmanager-fork

- Start the SEG
  - $GLOBUS_LOCATION/sbin/globus-job-manager-event-generator -scheduler fork -background -pidfile $GLOBUS_LOCATION/var/fork-pid
Examples of Production Scientific Grids

- APAC (Australia)
- China Grid
- DGrid (Germany)
- EGEE
- NAREGI (Japan)
- Open Science Grid
- Taiwan Grid
- TeraGrid
- ThaiGrid
- UK Nat’l Grid Service
Feedback

- Comments welcome
- If you need any specific functionality requirement, please let us know
Thank you

- More Information:
  - http://www.gridftp.org
  - http://www.globus.org/toolkit
  - gt-user@globus.org