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A Tutorial on Configuring and Deploying GridFTP for Managing Data Movement in Grid/HPC Environments

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Obtain Installer Now

GridFTP Tutorial

- Installing to a remote machine
  - http://www.gridftp.org/tutorials
- Installing to laptop (linux and mac users)
  - 1 of 3 ways
    - CD
    - USB Drive
    - http://www.gridftp.org/tutorials

Outline

- Introduction
- Security Options
- GSI Configuration
- Optimizations
- Advanced Configurations
- New Features

What is Globus GridFTP

- GridFTP - Protocol based on FTP. Includes extensions defined in RFCs and additional features
- Globus provides a reference implementation
- Widely used, open source, robust, ***production quality,*** data mover
  - Parallel streams
  - Striped transfers (cluster-to-cluster)
  - Partial file transfer
  - Multiple security options (GSI, SSH)
  - Third party transfers
  - Extensible for both file system & protocols

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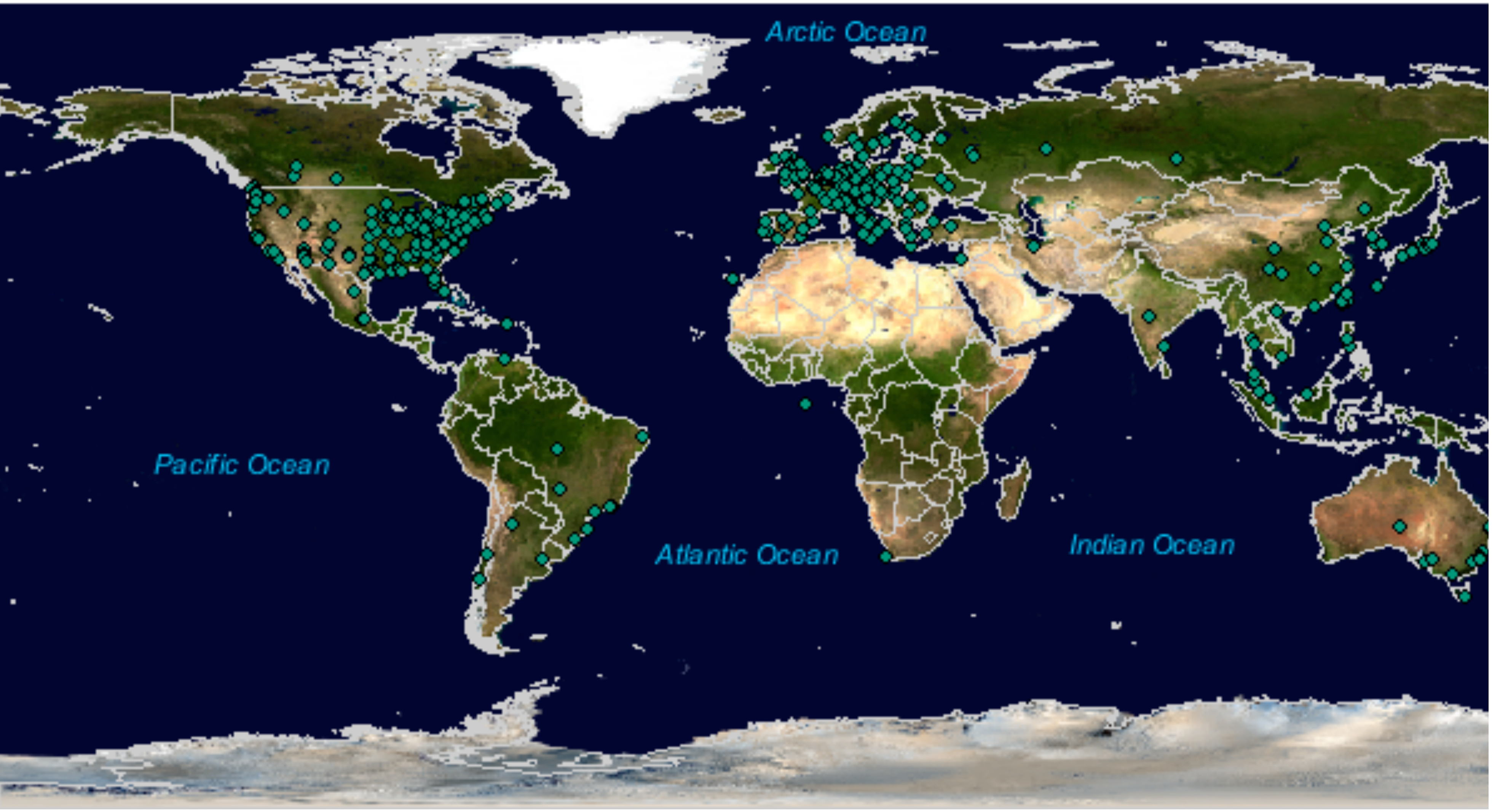
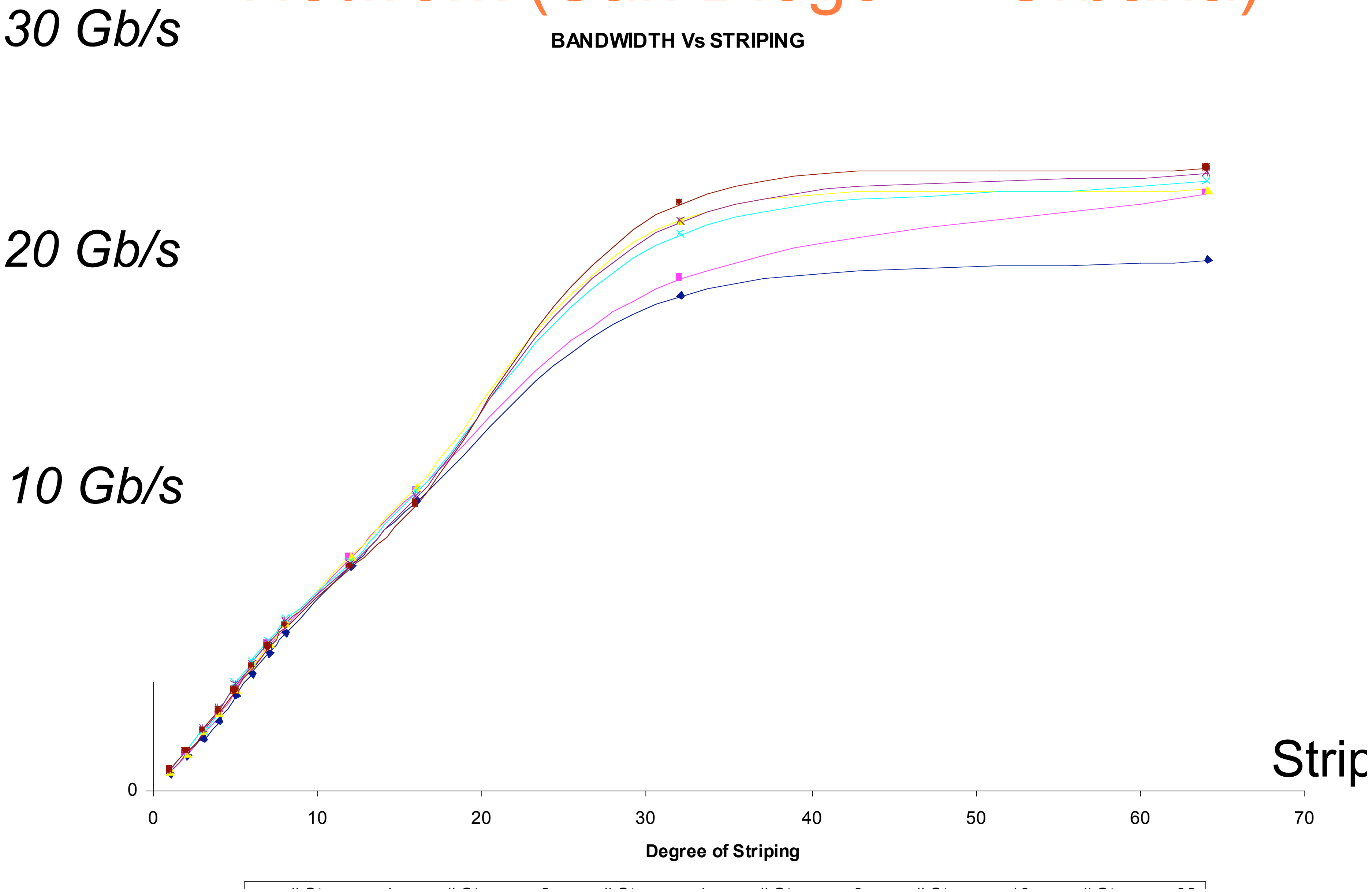
GridFTP Servers Around the Wo



Created by Lydia Prieto ; G. Zarrate; Anda Imanitchi (Florida State University) usi

Memory to Memory over 30 Gigabit/s Network (San Diego — Urbana)



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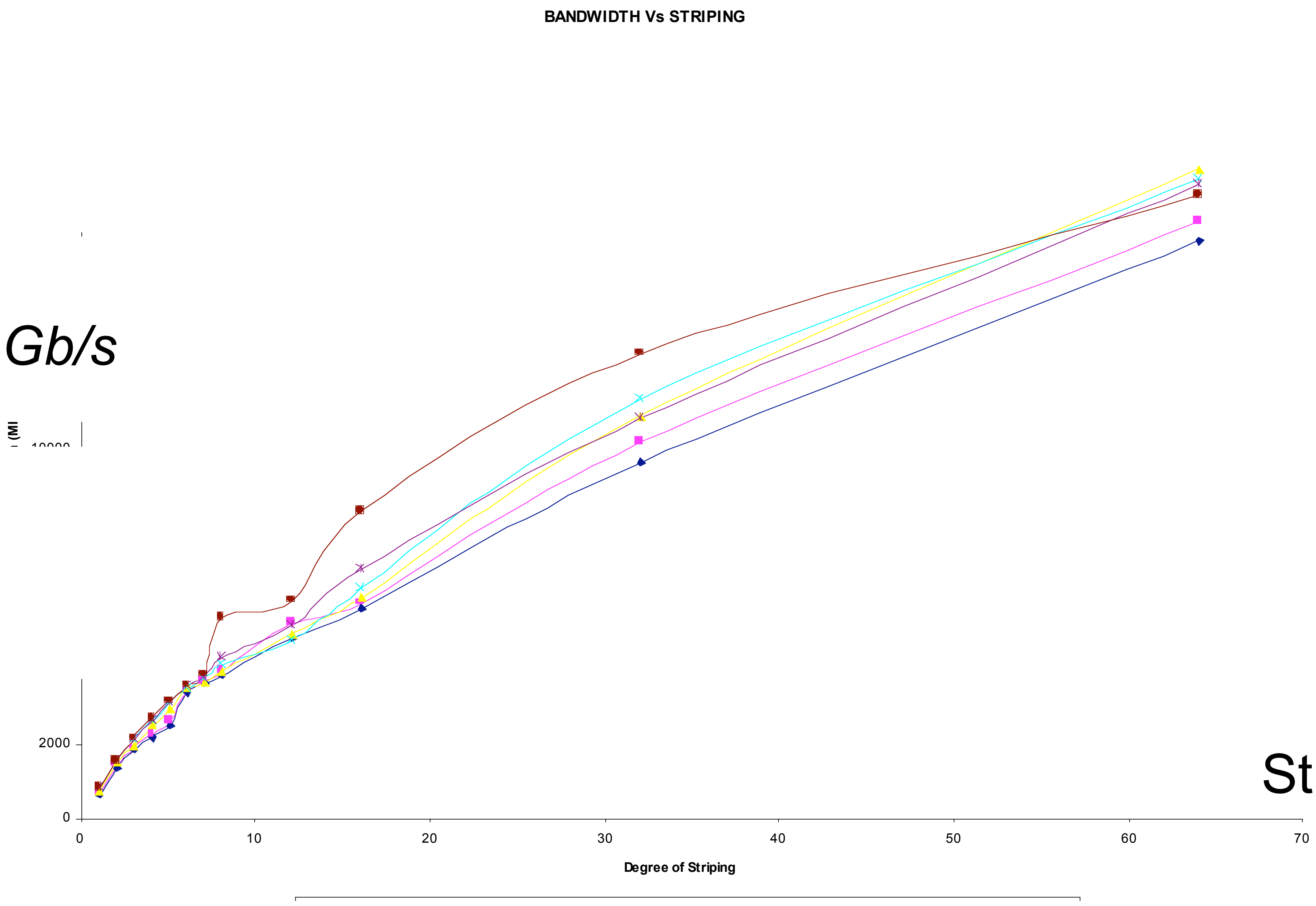
Disk to Disk over 30 Gigabit/s Network (San Diego — Urbana)

20 Gb/s

10 Gb/s



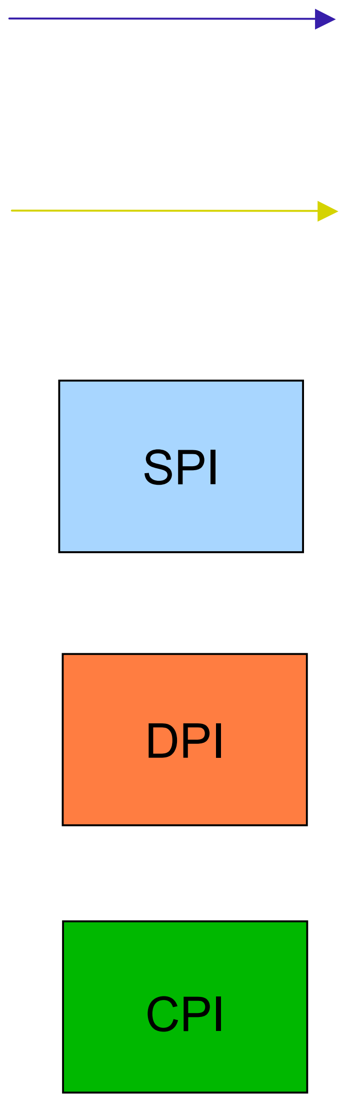
Stripi

Understanding GridFTP

- 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

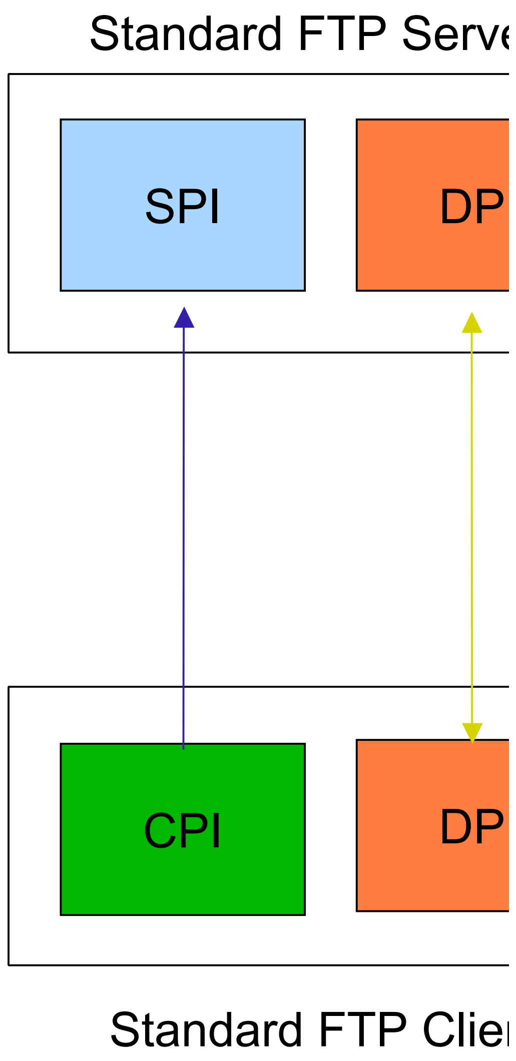
Architecture Components

- Control Channel (CC)
  - Path between client and server used to exchange all information needed to coordinate transfers
- Data Channel (DC)
  - The network pathway over which the 'files' flow
- Server Protocol Interpreter (SPI)
  - AKA: Frontend
  - Server side implementation of the control channel functionality
- Data Protocol Interpreter (DPI)
  - AKA: Backend
  - Handles the actual transferring of files
- Client Protocol Interpreter (CPI)
  - Client side implementation of the control channel functionality



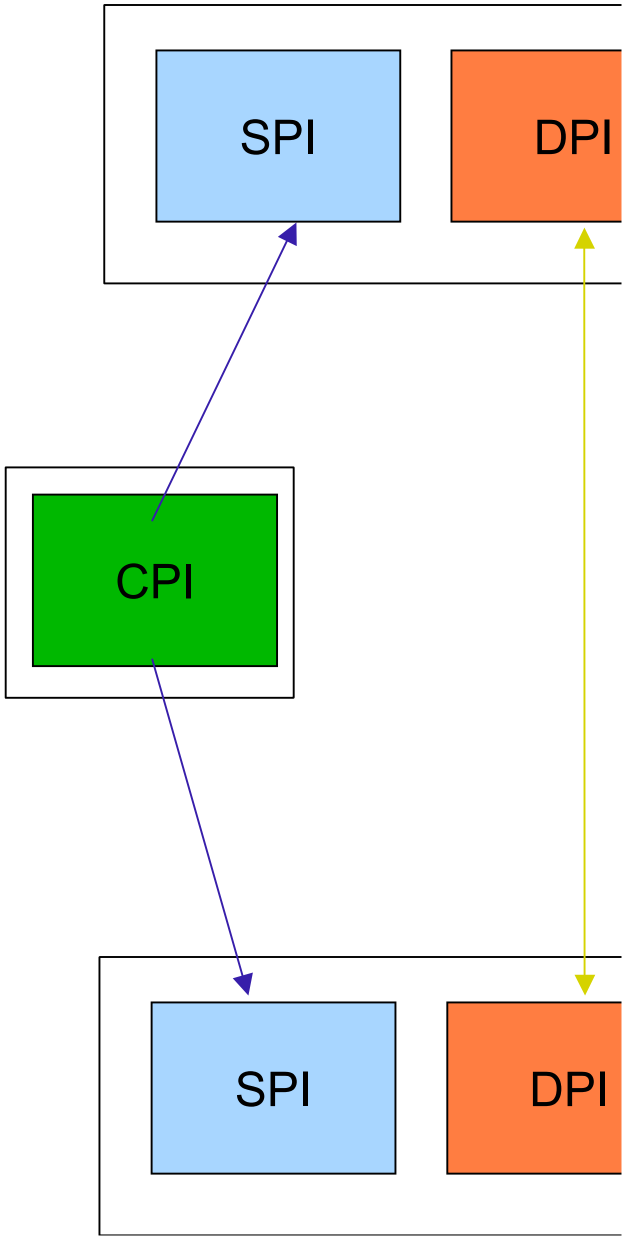
Simple Two Party Transfer

- Clear boxes represent process spaces
- The Server Side
  - SPI and DPI are co-located in the same process space
- The Client Side
  - CPI and DPI are co-located in the same process
- Interaction
  - The client connects and forms a CC with the server
  - Information is exchanged to establish the DC
  - A file is transferred over the DC



Simple Third Party Transfer

- Client initiates data transfer between 2 servers
- Servers have co-located SPI and DPI
- 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 form 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

- PASV command
  - Sent to the *passive* side of the transfer
  - Listen for a connection and reply with the contact information (IP address and port)
- PORT IP,PORT
  - Actively establish a connection to a given passive listener
- Firewall
  - Port side must be able to connect to PASV side
  - Configure port range for the PASV side

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Data Channel Protocols

- MODE Command
  - Allows the client to select the data channel protoco
- 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)

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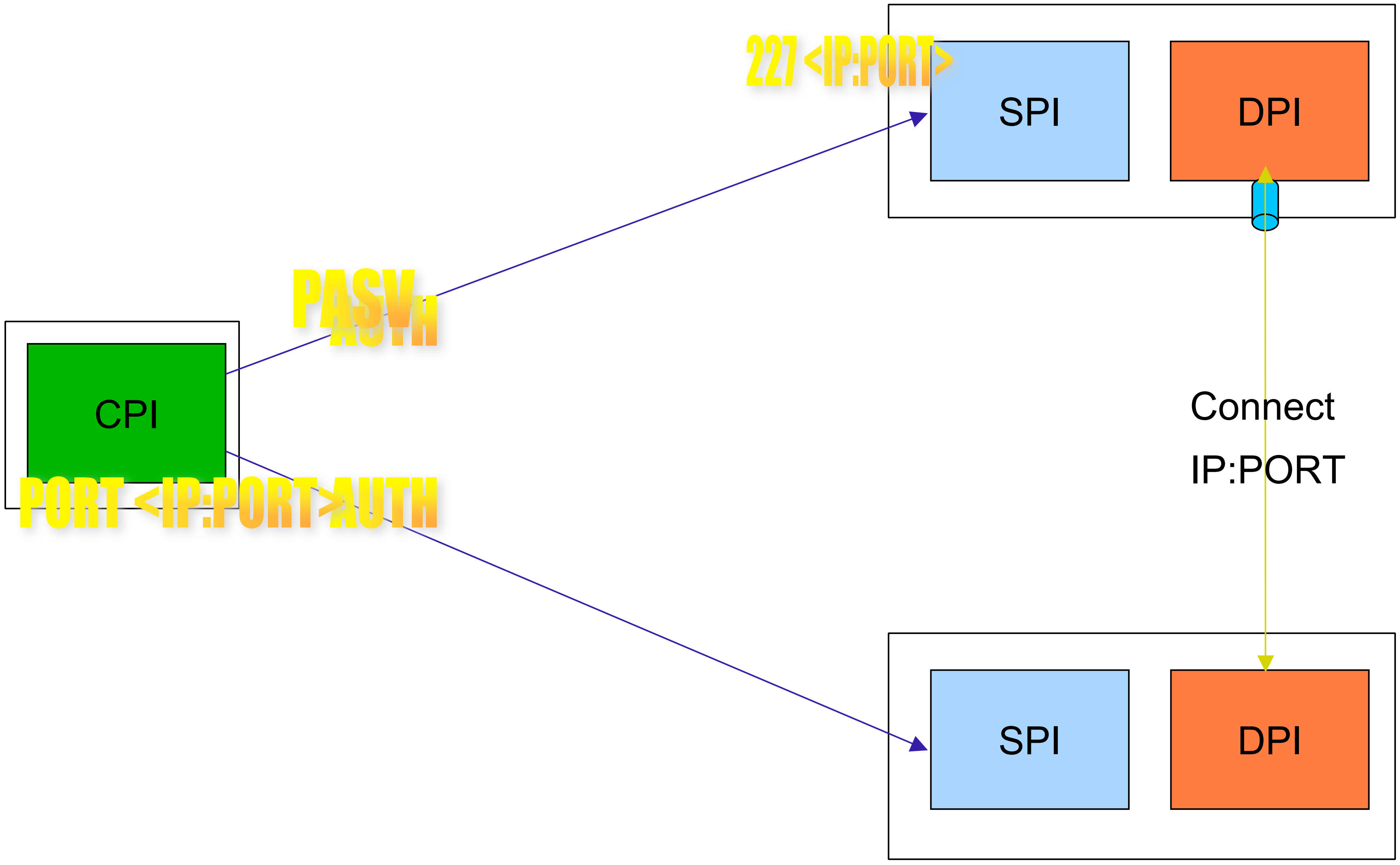
Data Channel Establishment



Exercise 1
Anonymous Transfer

- Install the GridFTP Server
  - http://www.gridftp.org/tutorials/
  - tar xvfz gt-gridftp*.tar.gz
  - cd gt-gridftp-installer
  - ./configure -prefix /path/to/install
    - *ignore any java/ant warnings*
  - make gridftp install
- Setup the environment (repeat for all globus sessions)
  - export GLOBUS_LOCATION=/path/to/install
  - source $GLOBUS_LOCATION/etc/globus-user-env.sh

Exercise 1

- 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
  - globus-url-copy -v ftp://localhost:<port>/etc/group ftp://localhost:<port>/tmp/group2
- 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

Exercise 1

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

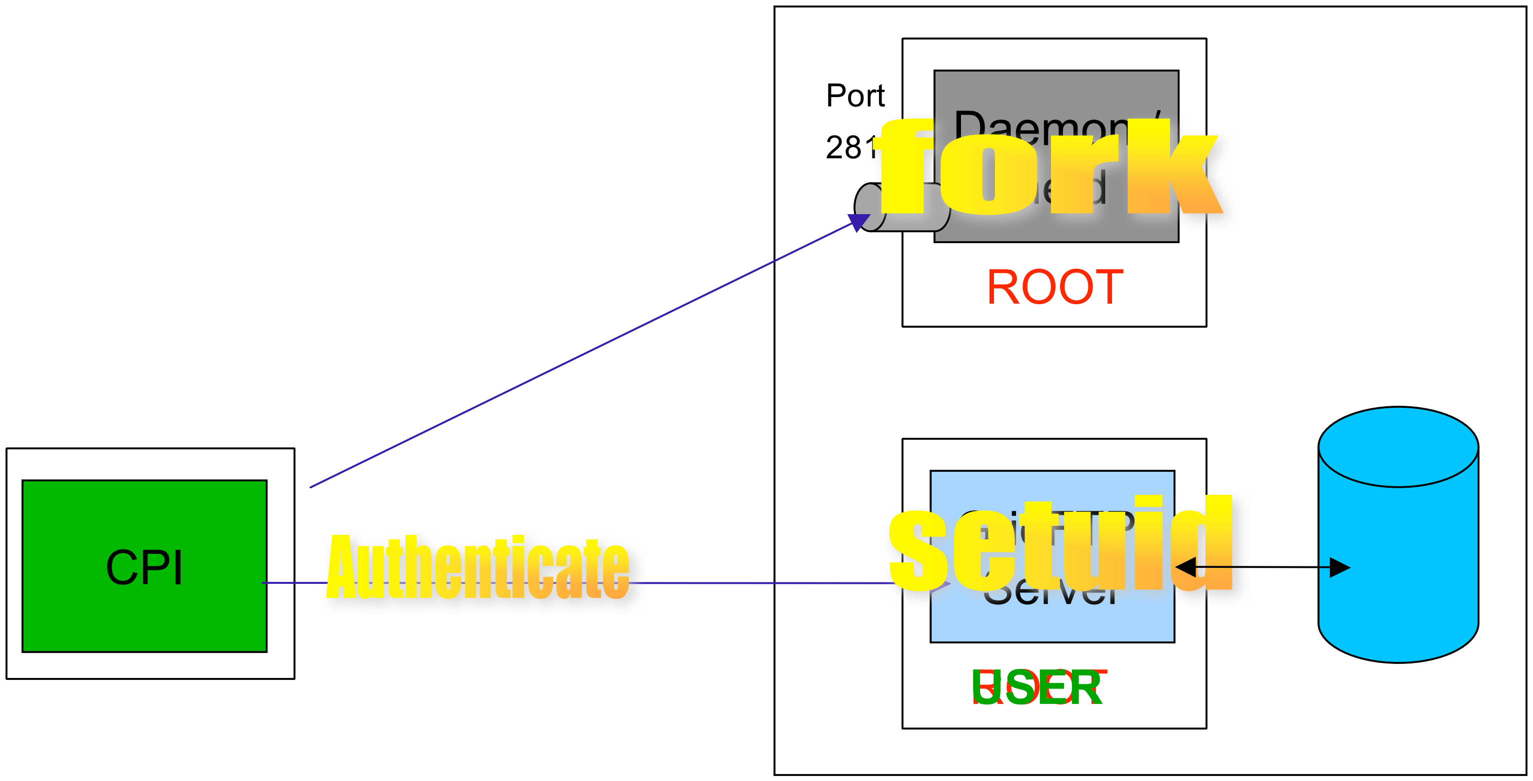
Security Options

- 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

- File permissions are handled by the OS
- inetd or daemon mode
  - Fork on TCP accept
- User is mapped to a local account
  - Client connects and the server forks
  - The child process authenticates the connection
  - The child process setuid() to a local user

inetd/daemon Interactions



(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.

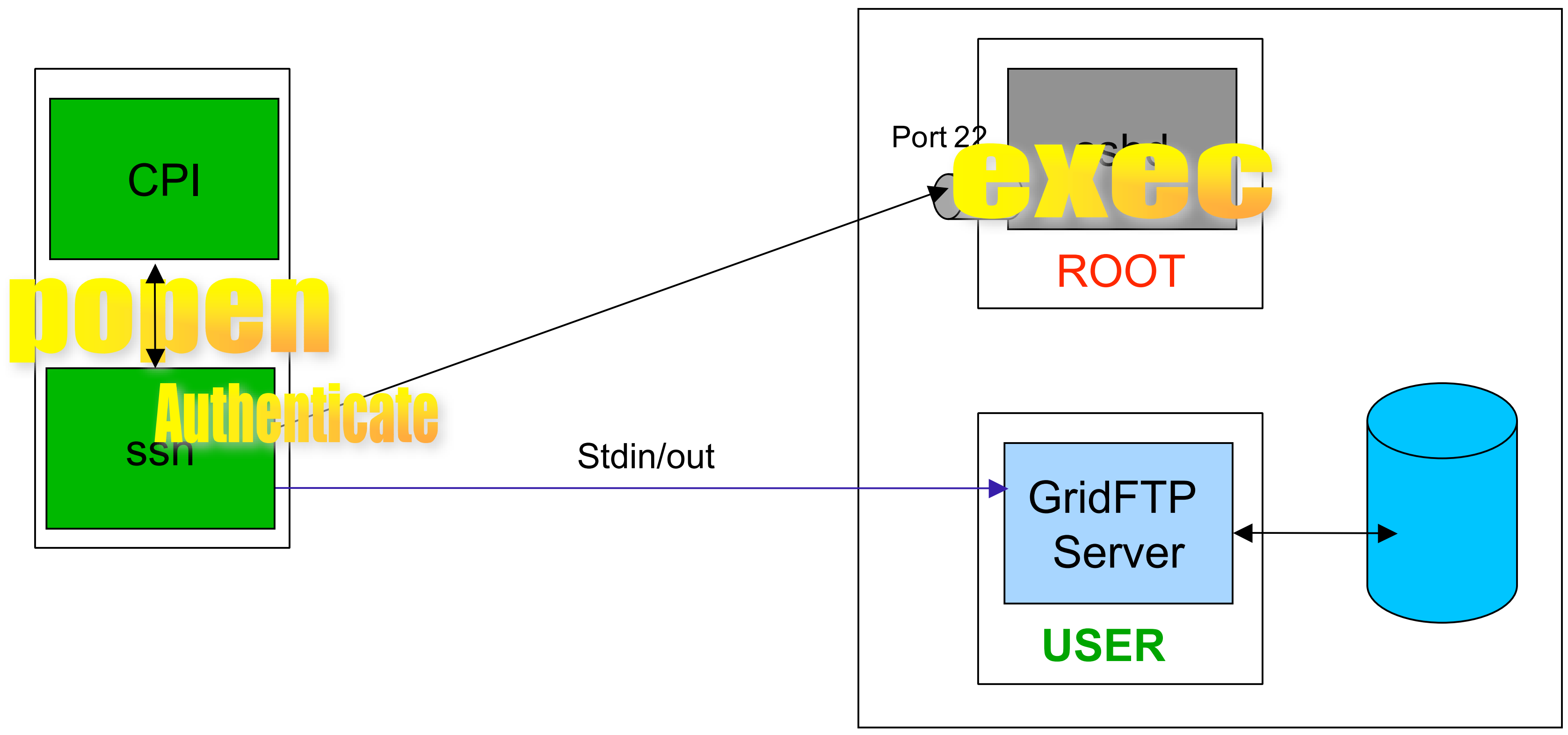
Exercise 2
Password file

- Create a password file
  - gridftp-password.pl > pwfile
- Run the server in password mode
  - globus-gridftp-server –p 5000 -password-file /full/path/of/pwfile
- Connect with standard ftp program
  - ftp localhost 5000
  - ls, pwd, cd, etc...
- Transfer with globus-url-copy
  - globus-url-copy file:///etc/group ftp://username:pw@localhost:5000/tmp/group
  - globus-url-copy -list ftp://username:pw@localhost:5000/

GridFTP Over SSH

- sshd acts similar to inetd
- control channel is routed over ssh
  - globus-url-copy *popens* ssh
  - ssh authenicates with sshd
  - ssh/sshd remotely starts the GridFTP server as use
  - stdin/out becomes the control channel

sshftp:// Interactions



Exercise 3
sshftp

- Configure SSHFTP
  - $GLOBUS_LOCATION/setup/globus/setup-globus-gridftp-sshftp
    - Enables **client** support for sshftp:// urls for this $GLOBUS_LOCATION
  - $GLOBUS_LOCATION/setup/globus/setup-globus-gridftp-sshftp -server -nonroot
    - Enables **server** support for sshftp:// connections **for this user only**.
    - To enable for all users run as root and remove -nonroot.
- globus-url-copy transfers
  - globus-url-copy -v file:///etc/group sshftp://localhost/tmp/group
  - globus-url-copy -list sshftp://localhost/tmp/

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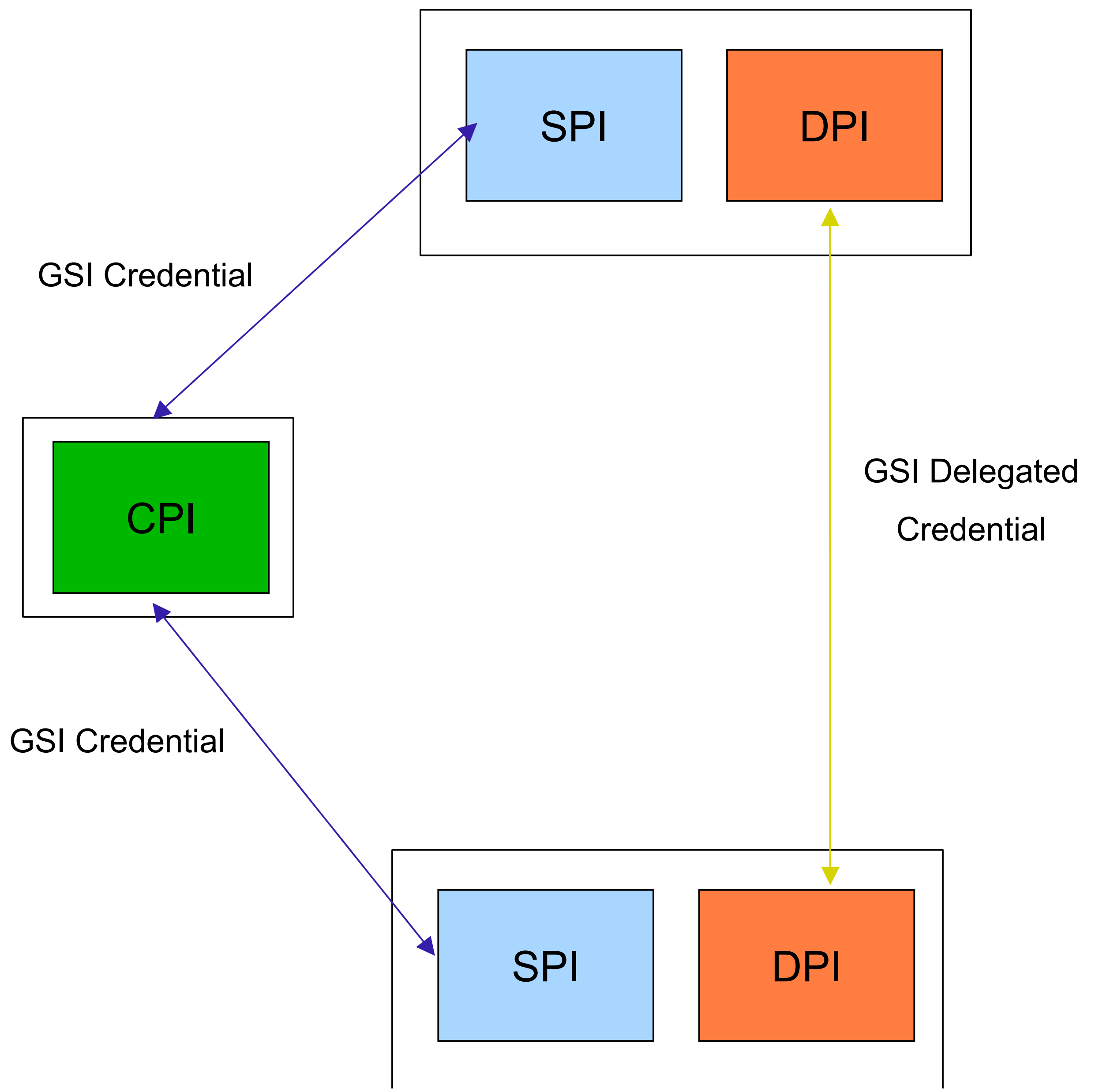
Exercise 3
What happened?

- globus-url-copy popen'ed ssh
- ssh authenticates with sshd
- ssh remotely starts globus-gridftp-server
- guc reads/writes control channel messages from/to ssh
- ssh reads/writes control channel messages from/to stdin/out
- server reads/writes control channel messages from/to stdin/ou
- control channel messaging is routed through ssh via stdin/stdout

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



Certificates

- Certificate Authority (CA)
  - Trusted 3rd party that confirms identity
- Host credential
  - Long term credential
  - Allows a client to verify the host is what they expect
- User credential
  - Passphrase protected
  - Used to activate a short term proxy

Exercise 4
GSI Security

- Setup simpleCA
- Create a user credential
- Create proxy
  - grid-proxy-init
- Create gridmap file
- Run GridFTP server
- Perform a GSI authenticated transfer
- Evaluate results

Optimizations

- TCP buffer size
- Disk block size
- Parallel streams
- Cached connections
- Partial file transfers

TCP Buffer Size

- Most important tuning parameter for TCP
  - Memory the kernel *allocates* for retransmits/reorderi
  - Affects the maximum window size
- Bandwidth Delay Product (BWDP)
  - BWDP = latency * bandwidth
  - The optimal number of bytes that can be sent befor waiting on an acknowledgement (ACK)
    - The optimal number of *in-flight* bytes

BWDP

- Send |window| of bytes
- When receiver gets first byte it sends ACK
- ACK takes 1 trip to get back to sender
- Ideally sender is never stalled out waiting for an ACK
  - thus the window size must be large enough so that we are sending for one entire RTT

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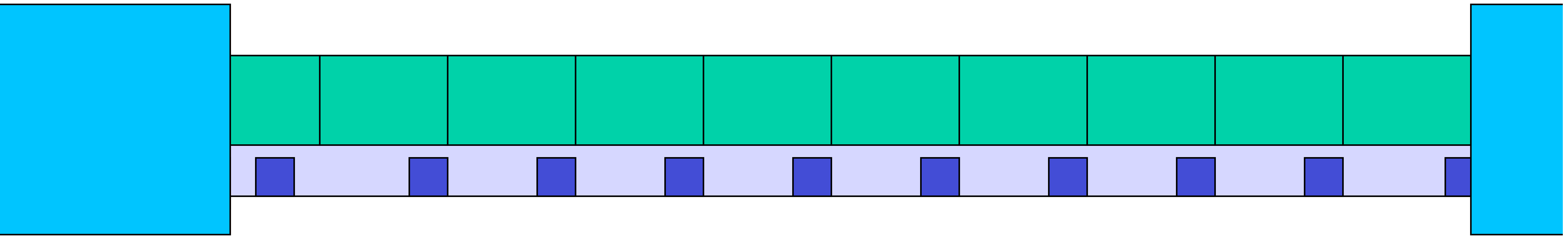
Window and ACKs

Small TCP Buffer Size

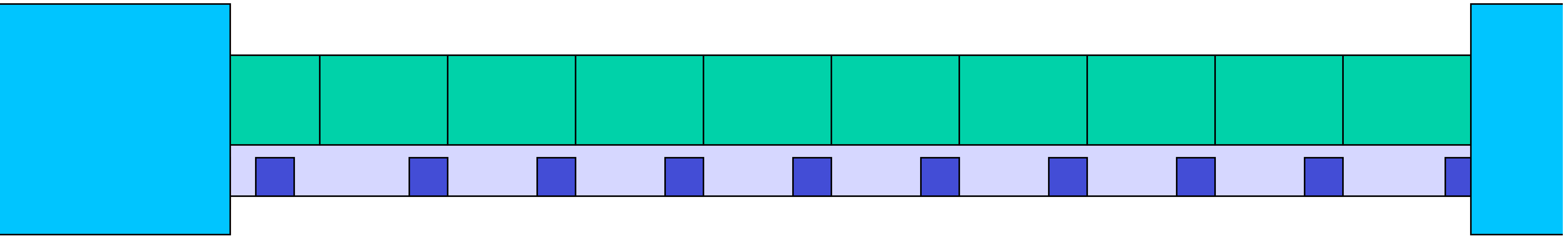


🟩 Data Packet

🟦 Acknowledgement

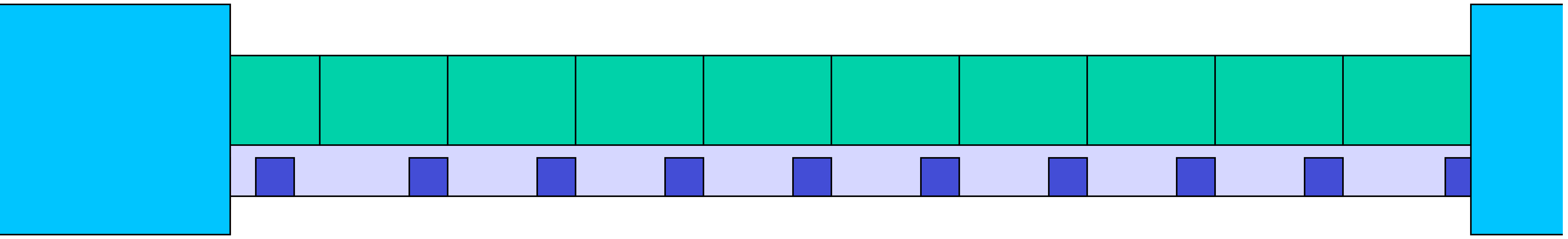
Window and ACKs

Half Full (1 trip)



Window and ACKs

Optimized TCP Buffer Size



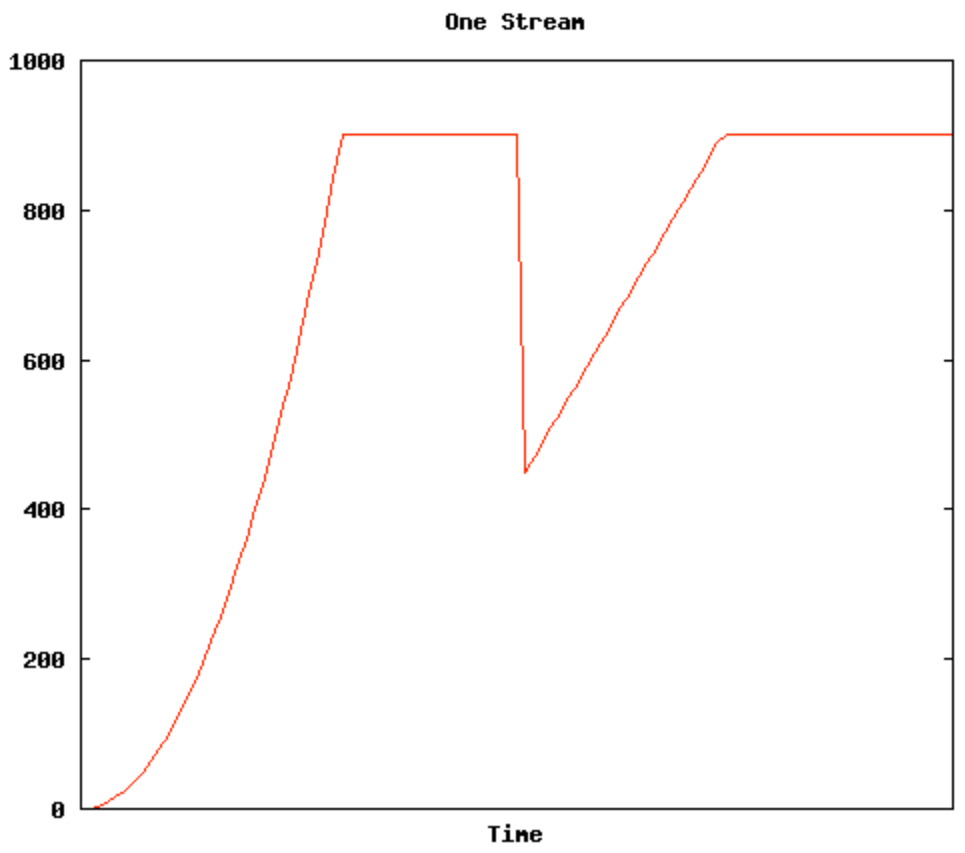
AIMD

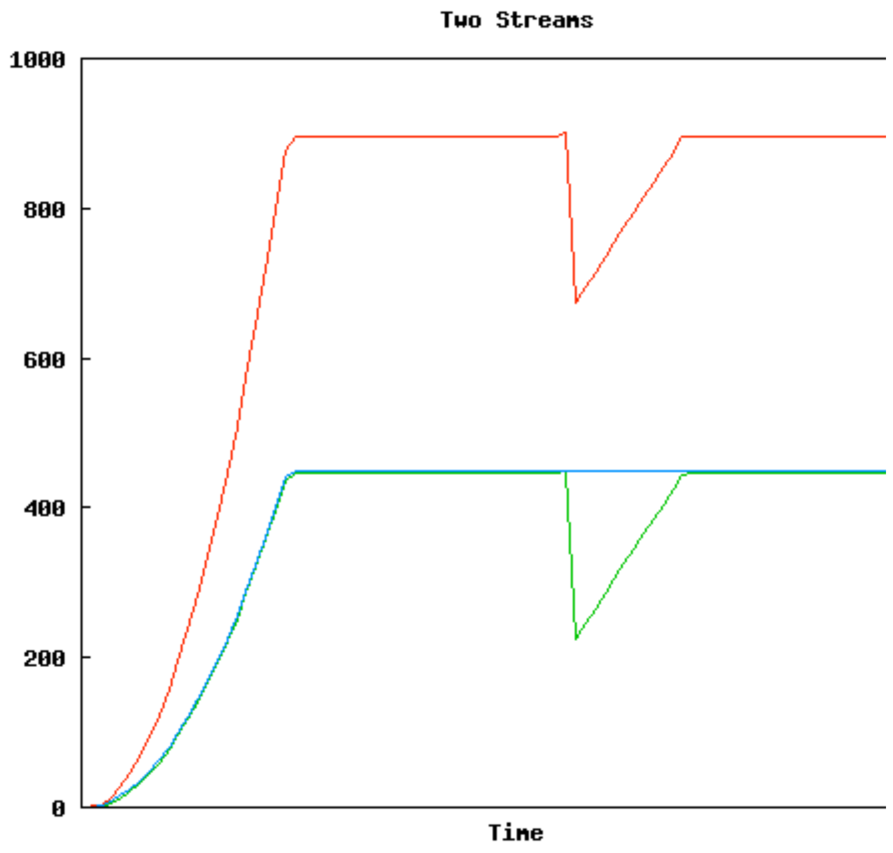
- Additive Increase Multiplicative Decrease
  1. Window size increases exponentially
  2. A congestion event occurs
  3. Window size is cut in half
  4. Window linearly increases
- Conclusion
  – Dropped packets are costly

Why Parallel TCP?

- Taking advantage of loopholes in the system
  - *Cheat* TCP out of intended fair backoff
- Reduces the severity of a congestion event
  - Only effects 1/p of the overall transfer
- Faster recovery
  - Smaller size to recover
- Work around for low TCP buffer limits
- *Almost a side effect of striping*

Lost Packets





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

Demonstration 1

Performance

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

Partial File Transfer

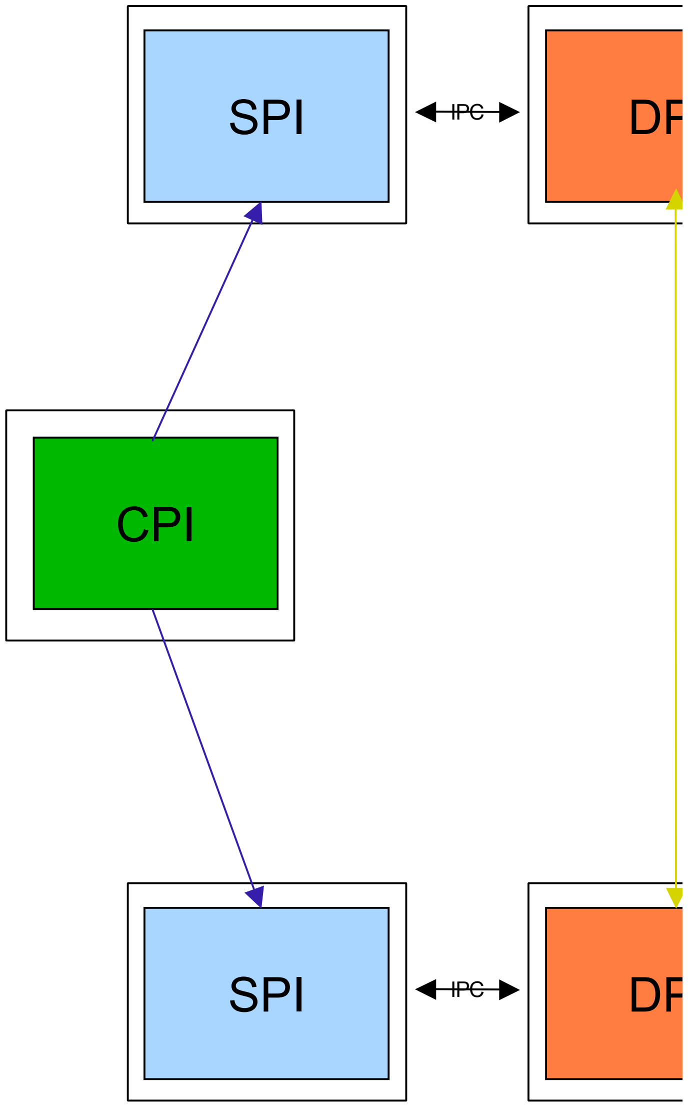
- Large file transfer fails
  - We don't want to start completely over
  - Ideally we start where we left off
- Restart markers sent periodically
  - Contain blocks written to disk
  - Sent every 5s by default
  - In worst case recovery sends 5s of redundant data
- Reliable File Transfer Service

Advanced Configurations

- Separation of processes
- Proxy server
- Striping
- Data Storage Interface (DSI)
- Alternative data channel stack

Separated Third Party Transfer

- DPI and SPI do not need to be in the same process.
  - nor on the same host
- Separation is transparent to client
- Opaque communication mechanisms between SPI and DPI

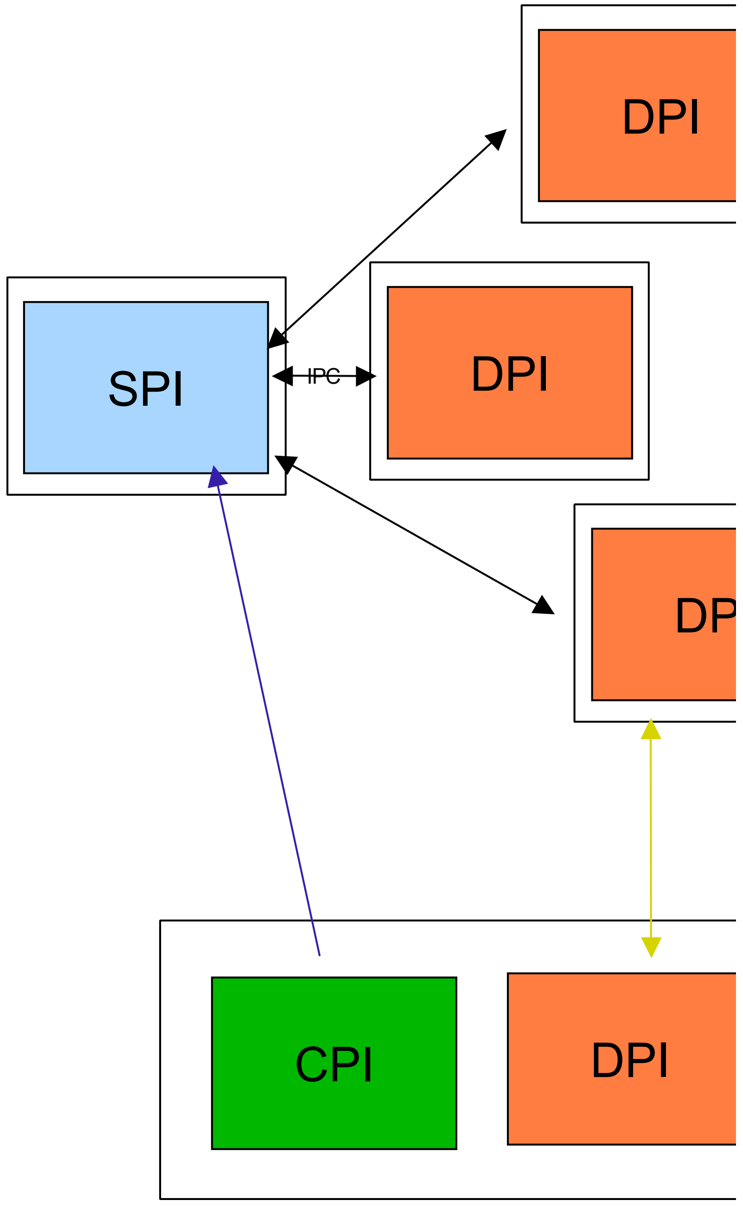


Separation of Process Advantage

- More secure
  - *Frontend* (SPI) no longer must be run as root
  - Client never communicates with a root process
- Load balancing proxy server
  - Select the least busy backend
  - Backends can come and go dynamically
- Striping
  - Many backends can be used for a single transfer

Proxy Server

- The separation of processes buys the ability to proxy
  - *Allows for load balancing*
  - *SPI can choose from a pool of DPIs to service a client request*



Striping

- A coordinated multi-host transfer
  - 1 SPI per server
  - Many DPIs per SPI
  - Each DPI transfers a portion of the file
  - Allows for fast transfers
  - Many NICs per transfer

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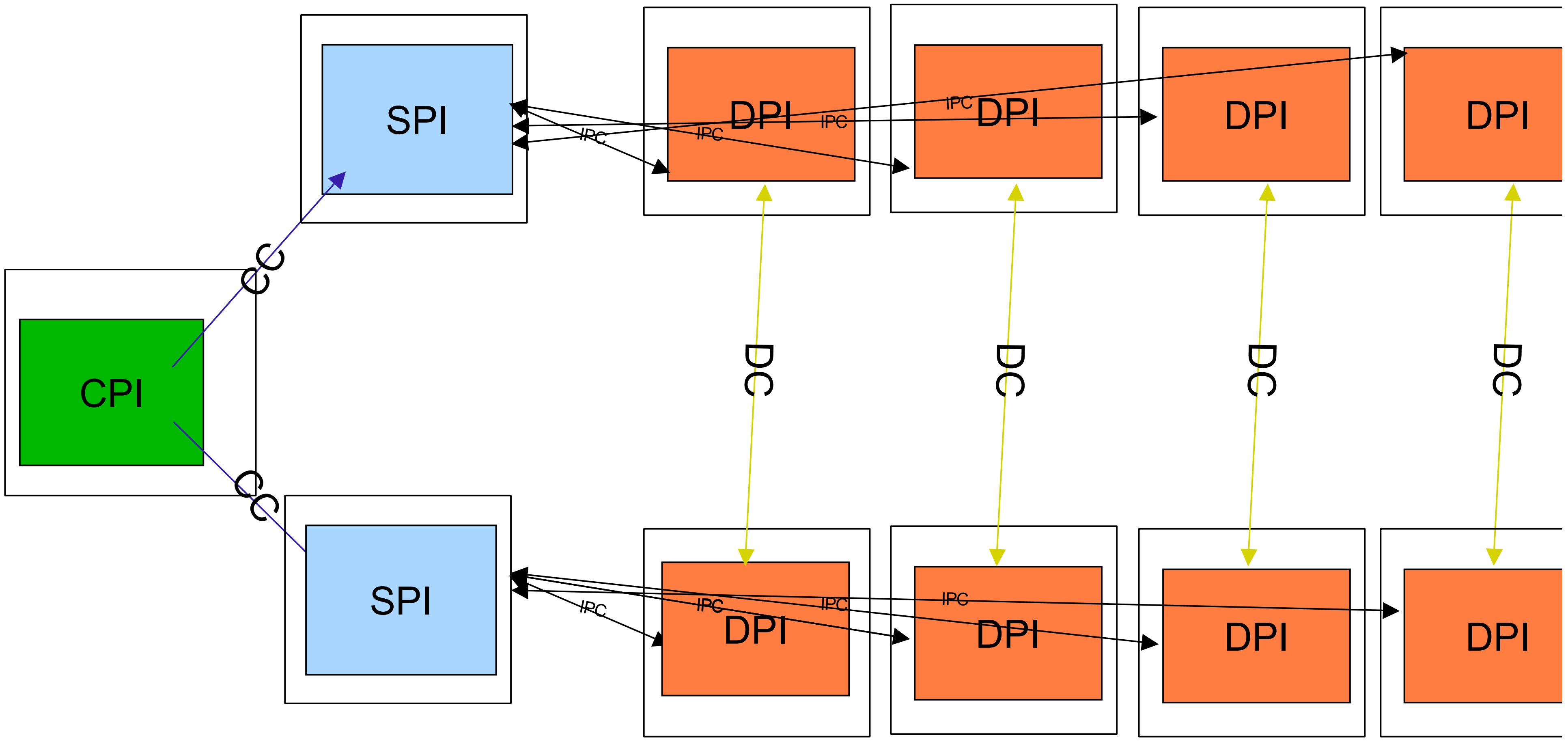
Striping



Demonstration 3
Striping

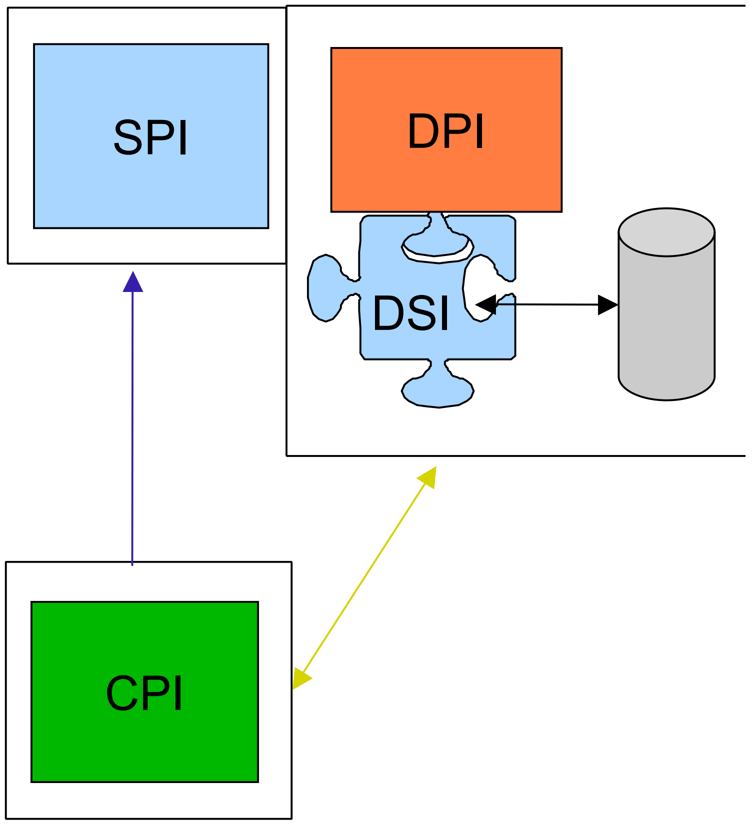
- Show a striped transfer
  - 3rd party transfers
  - show performance increases
    - globus-url-copy -vb

Data Storage Interface (DSI)

- Modular abstraction to storage systems
  - GridFTP is a network interface to storage
  - customize to specific storage systems
    - software, optimization, etc
- Existing DSIs
  - SRB, HPSS, posix FS, remote

DSI

- DSI plugs into DPI
  - works with stripes as well
- All interaction with storage goes through DSI
- DSI is transparent to client or remote party



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

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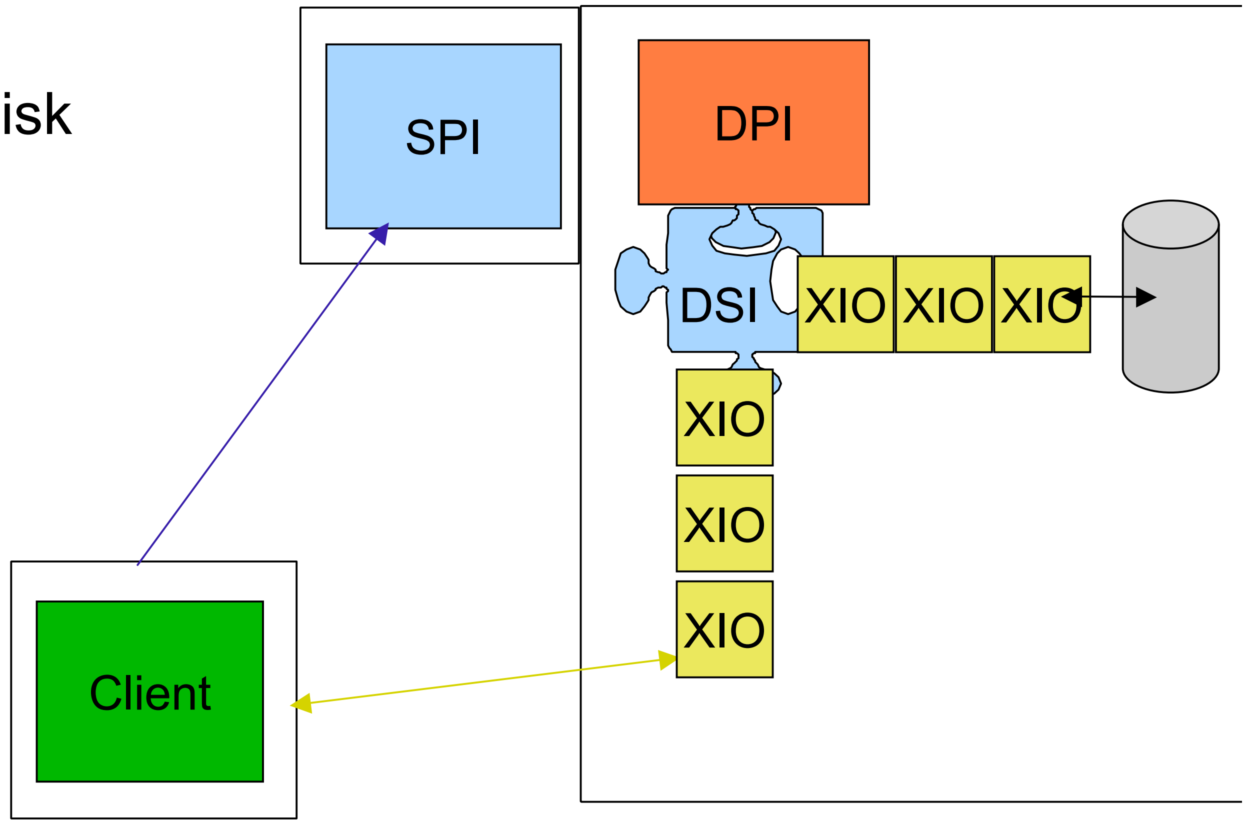
XIO Driver Stacks

- All data passes through XIO driver stacks
  - to network and disk
  - observe data
  - change data
  - change protocol



Demonstration 4

GridFTP over UDT

- Show a transfer with UDT as the transport protocol
  - Show dynamic data channel protocol stack selection
  - Show the performance increases
- Requirements
  - Threaded build of the Globus GridFTP server
  - Threaded build of globus-url-copy (for client-server transfers)
- Transferring a file
  - globus-url-copy -udt file:///etc/group ftp://localhost:5000/tmp/group

Lots of Small Files (LOSF) problem

- GridFTP is traditionally only fast with large file partitions
  - Overhead added on a per file basis
  - Bad for a large data set partitioned into many small files
- Transfer request latency
  - 1 control channel RTT between transfers
    - 1) Transfer request, 2) completion acknowledgment
  - Data transfer is idle between requests
    - Less overall time spent transferring data

Solution - Pipelining

- Allow many outstanding transfer requests
- Send next request before previous completes
  - Latency is overlapped with the data transfer
  - When one finishes the next has already traversed the network
- Backward compatible
  - Wire protocol doesn’t change
  - Client side sends commands sooner, but server reads them at the same time
- ‘-pp’ option in globus-url-copy enables pipelining

Demonstration 5

Pipelining

- Show lots of small files transfers with and without pipelining
  - Show performance increases with pipelining

New Features

- gwtftp
- GFork
  - Resource management
  - Dynamic backends

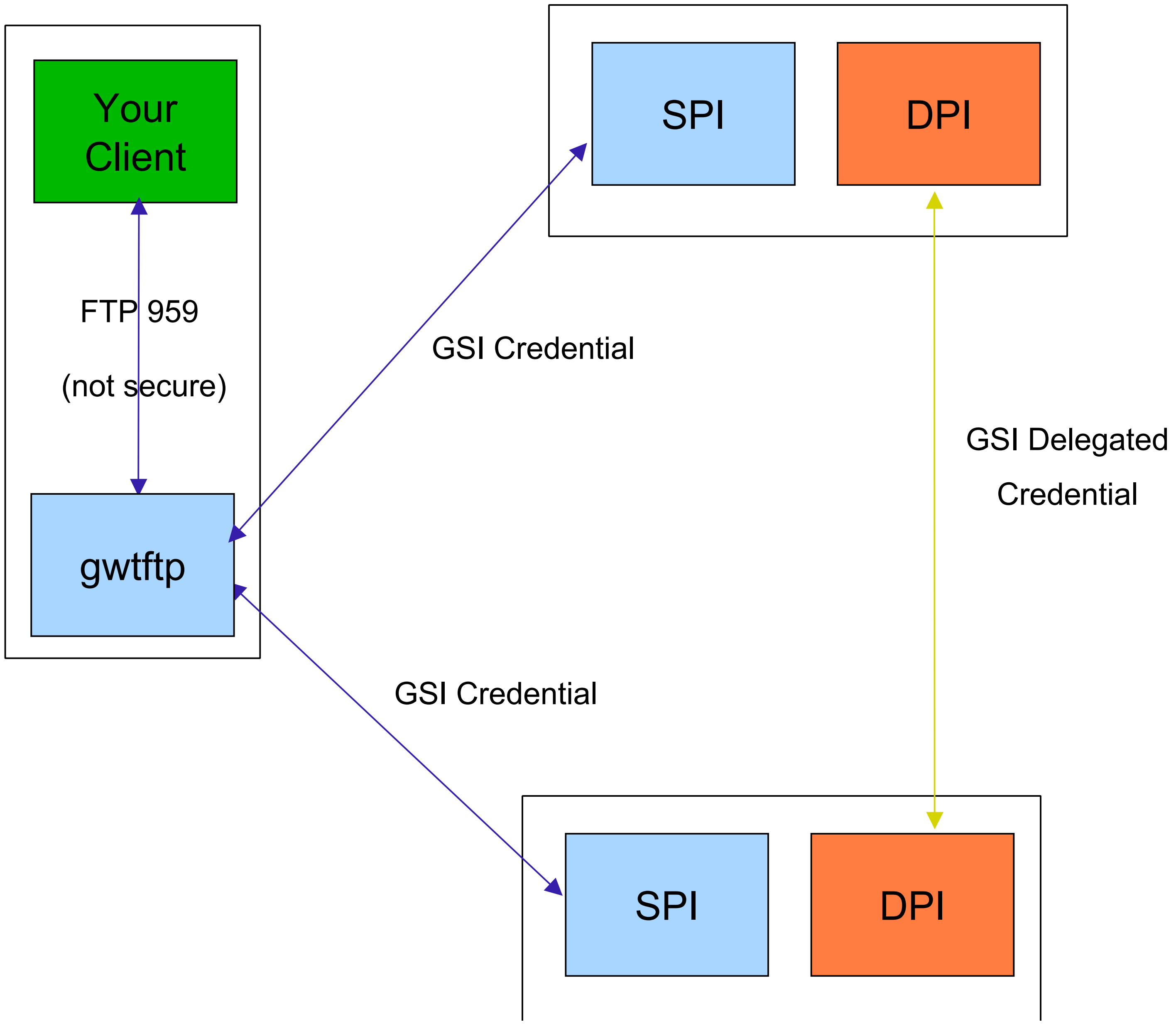
Clients

- globus-url-copy
  - CLI. good for scripting
  - all you should ever need :-)
- GUI Clients?
- Windows Clients?
- GridFTP Where There's FTP (gwtftp)

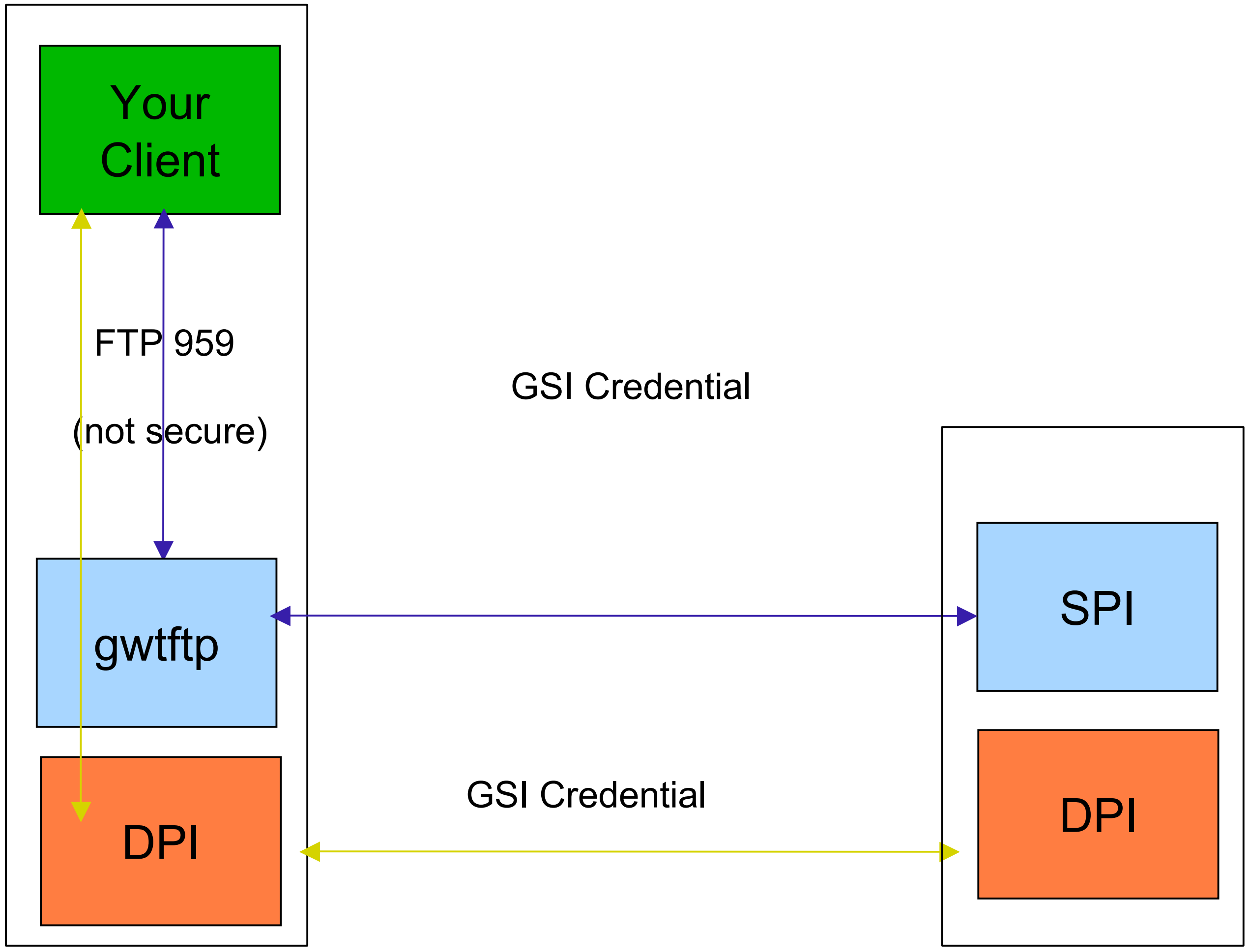
gwtftp

- Everyone has a favorite FTP client
  - So use it!
- A proxy server/protocol translator
  - Not secure from client to proxy
    - Run on a trusted net (127.0.0.1)
  - Data channel routed or direct
    - If 3pt it is direct and secure
    - If 2 party must route through proxy, or be insecure

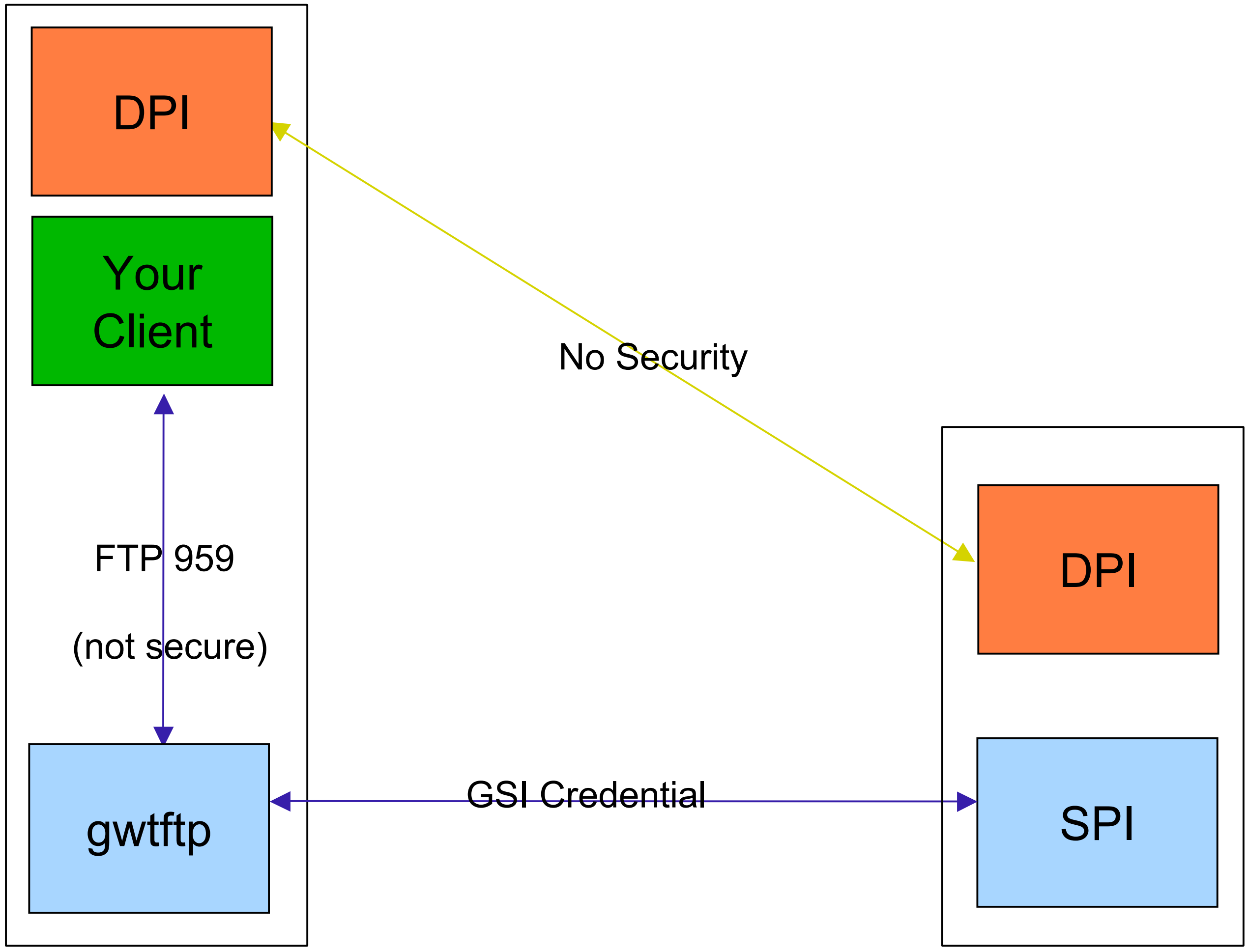
gwtftp (3pt)


Your Client
FTP 959
(not secure)
gwtftp
GSI Credential
SPI
DPI
GSI Delegated Credential
GSI Credential
SPI
DPI

gwtftp (2pt routed)



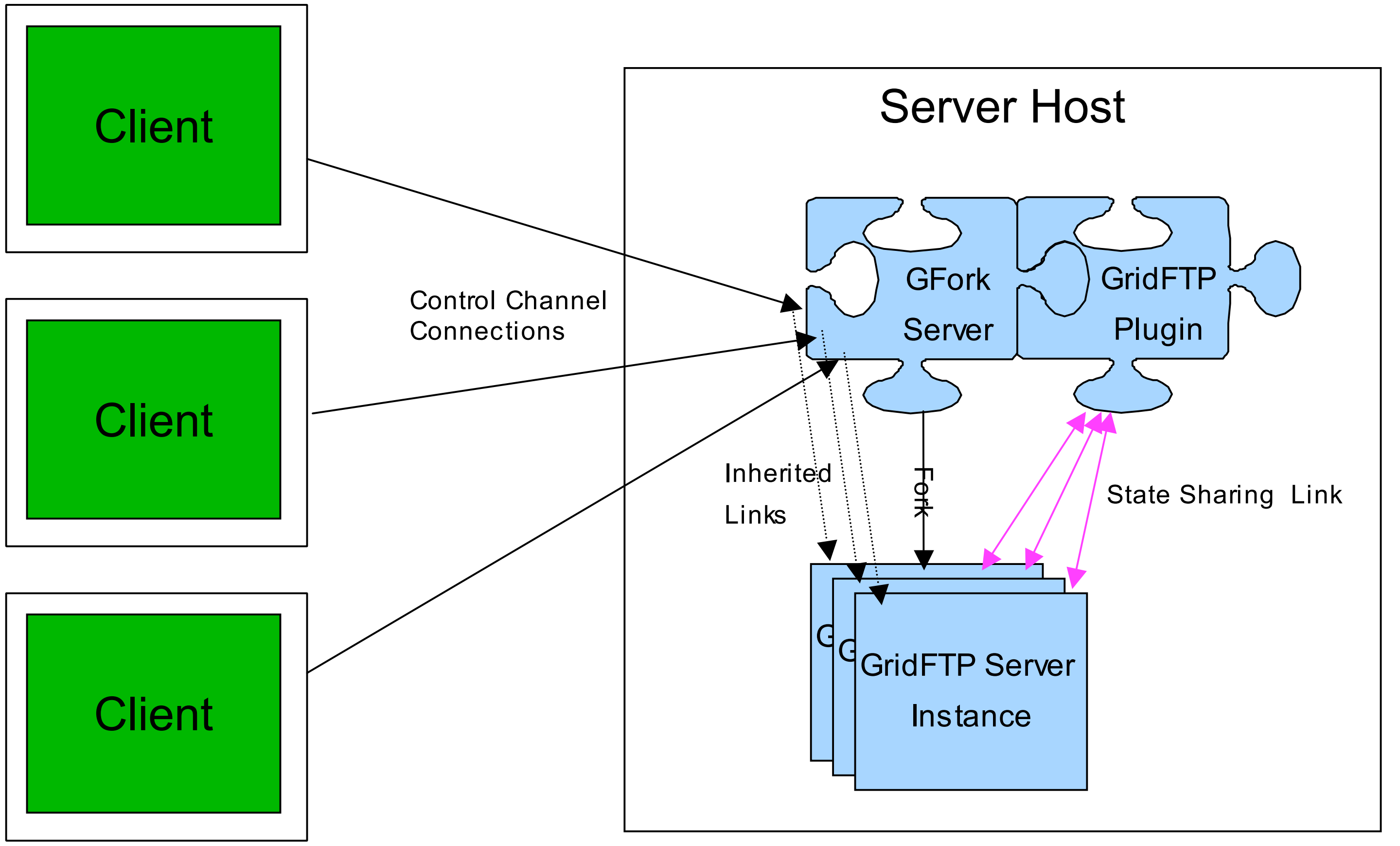
gwtftp (2pt direct)



GFork

- Fork/Exec is safer service model
  - sandboxes leaks/segfaults/security/etc
  - If 1 session dies service exists
- Transient state
  - We need permanent & shared state between sessions

GFork


Client
Client
Client
Control Channel Connections
Server Host
GFork Server
GridFTP Plugin
Inherited Links
Fork
State Sharing Link
GridFTP Server Instance

Dynamic Backends

- Dynamic list of available backends (DPIs)
- Frontend (SPI) listens for registration
  - Backends register (and timeout)
  - Select backend(s) to use for a transfer
- Backend failure is not system failure
- Resources can be provisioned to suit load

Dynamic Backends

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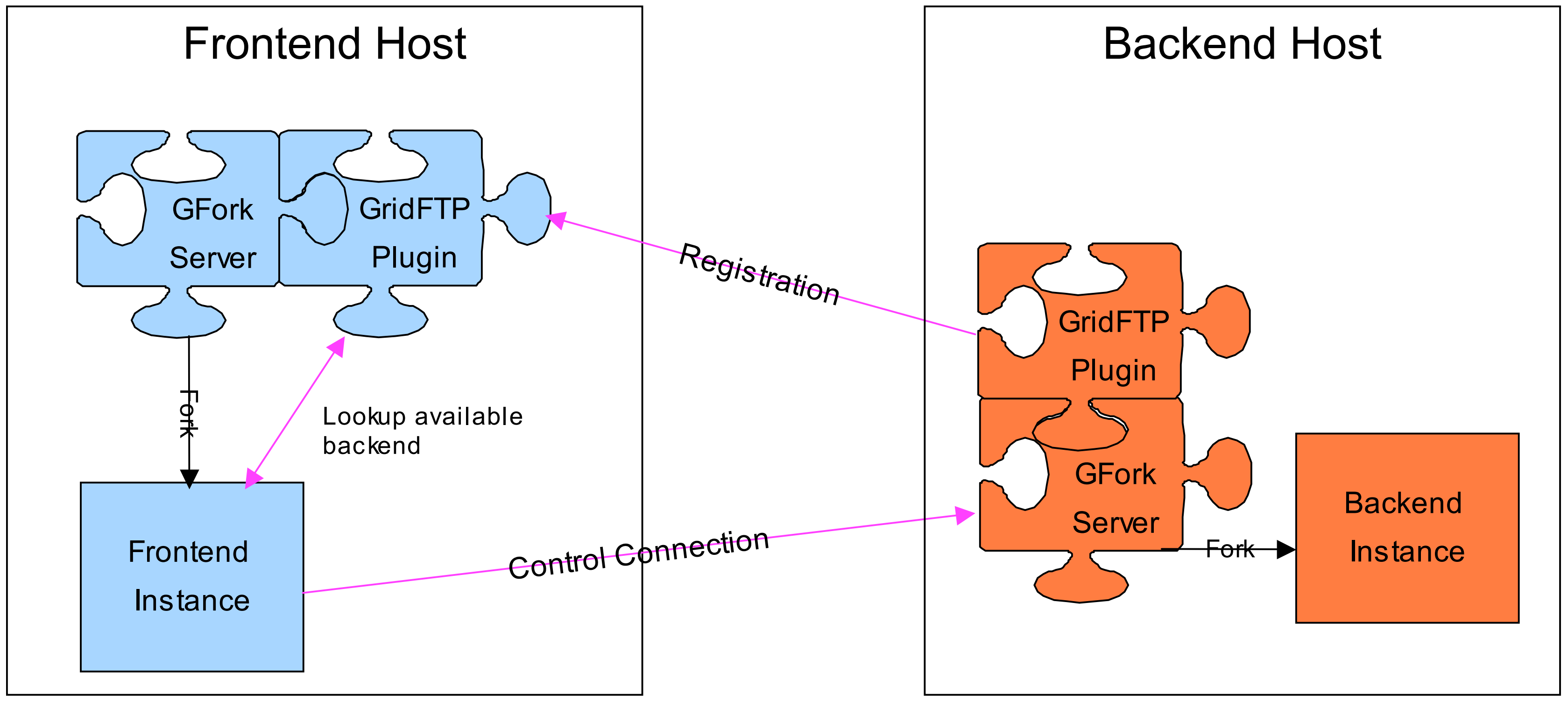
Dynamic Backends



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
  - gridftp-user@globus.org