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The Globus GridFTP Framework and Server

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Outline

- Motivation
- GridFTP Protocol
- Globus GridFTP design and architecture
- Performance
- New features
- Summary

Motivation

Motivation

- Science is increasingly data-driven
- Geographically distributed communities of scientists need to access and analyze large amounts of data
  - Simulation science applications such as climate modeling
  - Experimental science applications such as high-energy physics
- Rapid increase in raw capacity of wide area network - feasible to move large amounts of data across WAN

Motivation

- NSF TeraGrid links large clusters and storage systems at nine sites
  - With a network providing up to 30 Gbit/s
- In principle, move data across this network at > 3 Gbyte/s or 10 Tbyte/hr
- In practice orchestration of such transfers is technically challenging
  - Exploit parallelism in multiple dimension
  - Deal with failures of various sorts

Motivation

- Effective end-to-end data transfers thus demand a systems approach
  - File systems, computers, network interfaces, network protocols - managed in an integrated fashion to meet performance & robustness goals.
- These considerations motivate the work that I describe here
  - Design, implementation & evaluation of a modular & extensible data transfer system suitable for wide area and high-performance environments.

The GridFTP Protocol

What is GridFTP?

- A secure, robust, fast, efficient, standards based, widely accepted data transfer protocol
- A Protocol
  - Multiple Independent implementation can interoperate
    - This works. Fermi Lab has an implementation with their DCache system and U. Virginia has a .Net implementation that work with ours.
    - Lots of people have developed clients independent of the Globus Project.
- The Globus Toolkit supplies a reference implementation:
  - Server
  - Client tools (globus-url-copy)
  - Development Libraries

GridFTP: The Protocol

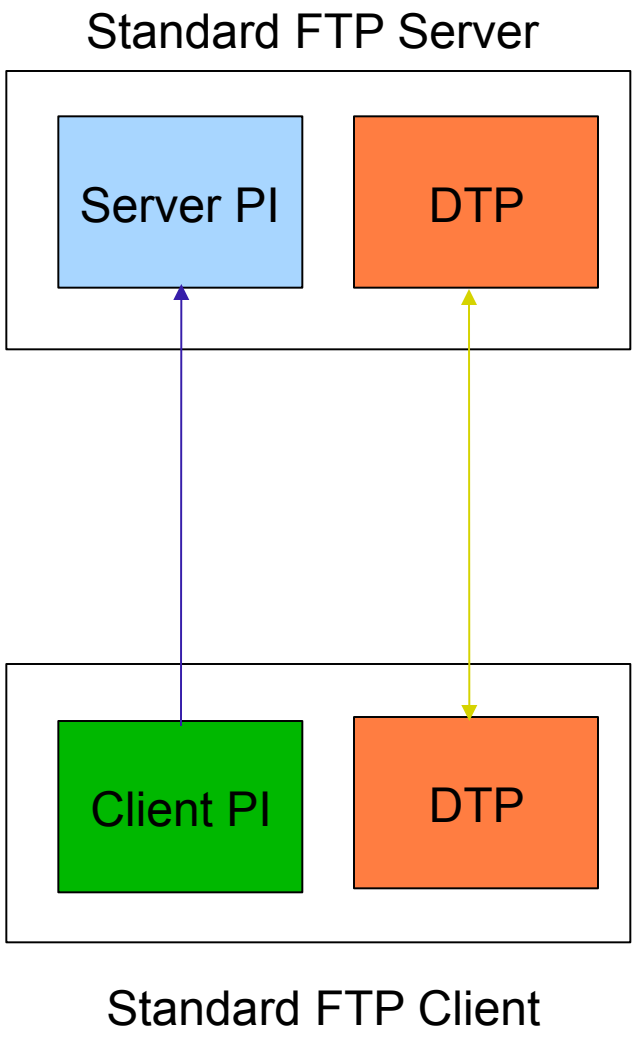
- Existing standards
  - RFC 959: File Transfer Protocol
  - RFC 2228: FTP Security Extensions
  - RFC 2389: Feature Negotiation for the File Transfer Protocol
  - Draft: FTP Extensions
  - GridFTP: Protocol Extensions to FTP for the Grid
    - Grid Forum Recommendation
    - GFD.20
    - http://www.ggf.org/documents/GWD-R/GFD-R.020.pdf

Understanding GridFTP

- GridFTP (and normal FTP) use (at least) two separate socket connections
- Control Channel
  - Command/Response
  - Basic file system operations eg. mkdir, delete etc
  - Used to establish data channels
- Data channel
  - Pathway over which *file* is transferred
  - Many different underlying protocols can be used
    - MODE command determines the protocol

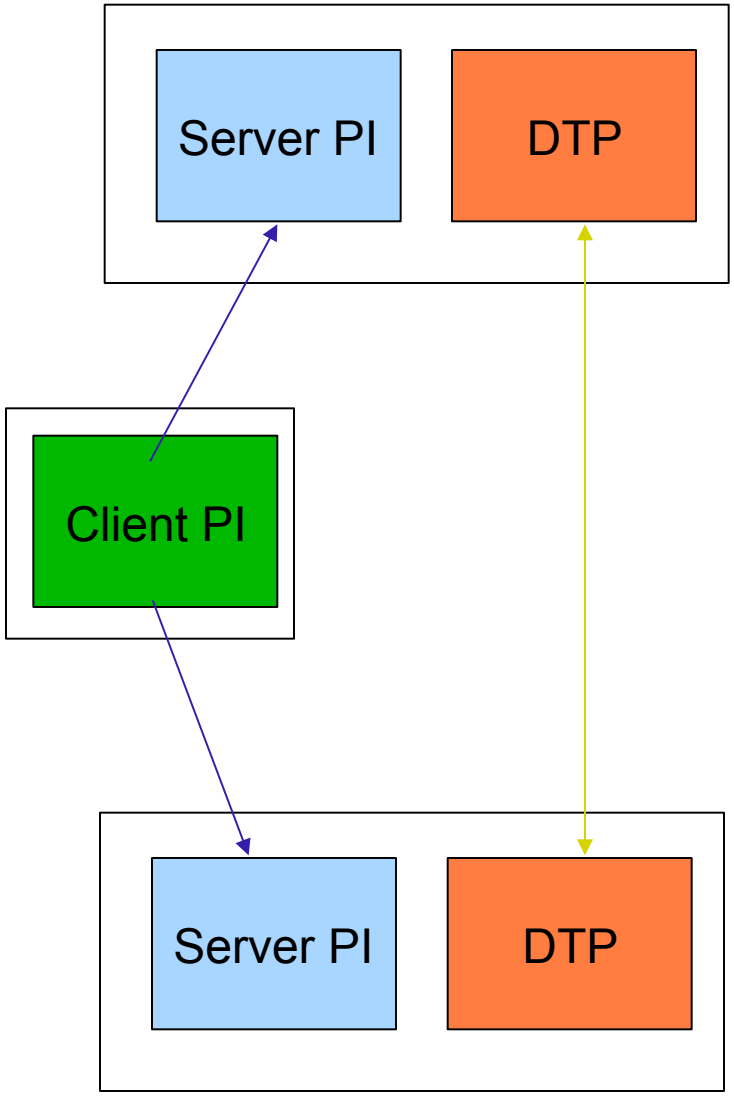
Simple Two Party Transfer

- GridFTP (and normal FTP) has 3 distinct components:
  - Client and server protocol interpreters which handle control channel protocol
  - Data Transfer Process which handles the accessing of actual data and its movement via the data channel



Simple Third Party Transfer

- Client initiates data transfer between 2 servers
- Client forms CC with 2 servers.
- Commands routed through the client to establish DC between the two servers.
- Data flows directly between servers
  - Client is notified by each server PI when the transfer is complete



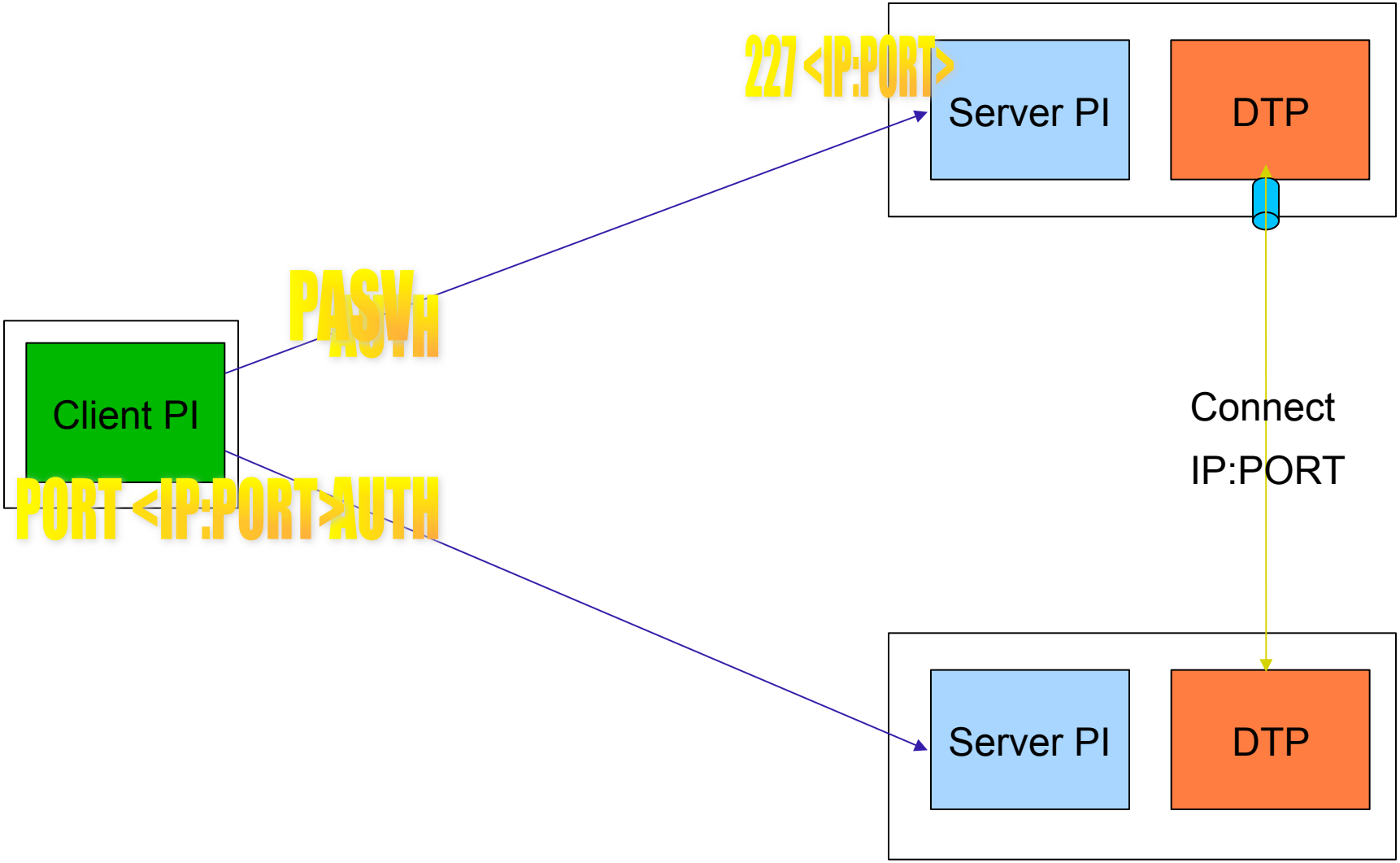
Control Channel Establishment

- Server listens on a well-known port (2811)
- Client form a TCP Connection to server
- Banner message
- Authentication
  - Anonymous
  - Clear text USER <username>/PASS <pw>
  - Base 64 encoded GSI handshake - Grid Security Infrastructure based on PKI
- Accepted / 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

Data Channel Establishment



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)

What issues are we addressing?

- Striping
  - Storage systems are often clusters, and we need to be able to utilize all of that parallelism
- Collective Operations
  - Essentially, the striping should be invisible to the outside world
- Uniform interface
  - Ideally, any data source can be treated the same way

What issues are we addressing?

- Network Protocol Independence
  - TCP has well known issues with high Bandwidth-Delay Product networks
  - Need to be able to take advantage of aggressive protocols on circuits.
- Diverse Failure Modes
  - Much happening under the covers, so must be resilient to failures
- End-to-End Performance
  - We need to be able to manage performance for a wide range of resources

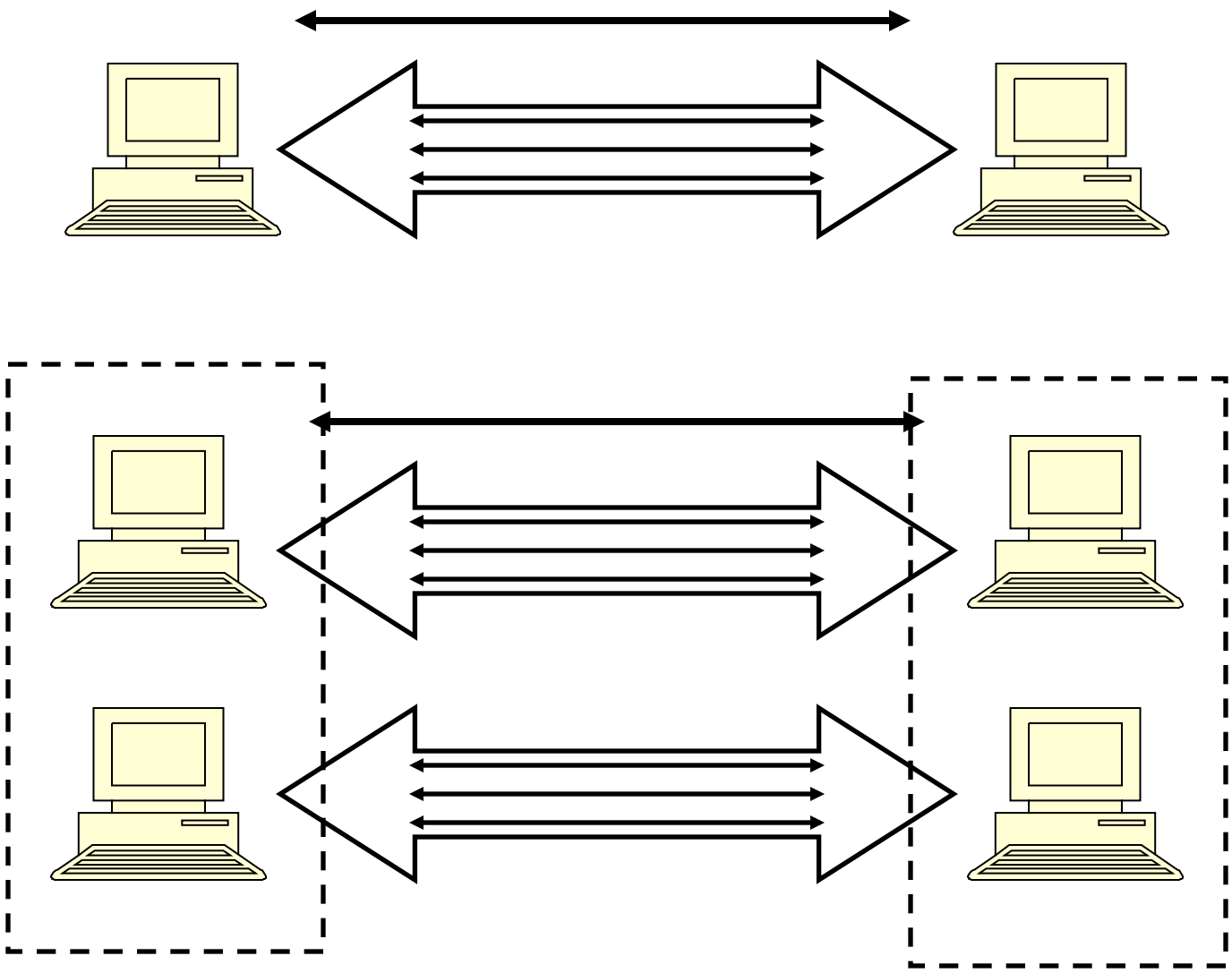
What did the GridFTP protocol add?

- Extended Block Mode
  - Data is sent in “packets” with a header containing a 64 bit offset and length
  - Allows out-of-order reception of packets
- Restart and Performance Markers
  - Allows for robust restart and perf monitoring
- SPAS/SPOR
  - Striped PASV and striped PORT
  - Allows a list of IP/ports to be returned

What did the GridFTP Protocol add?

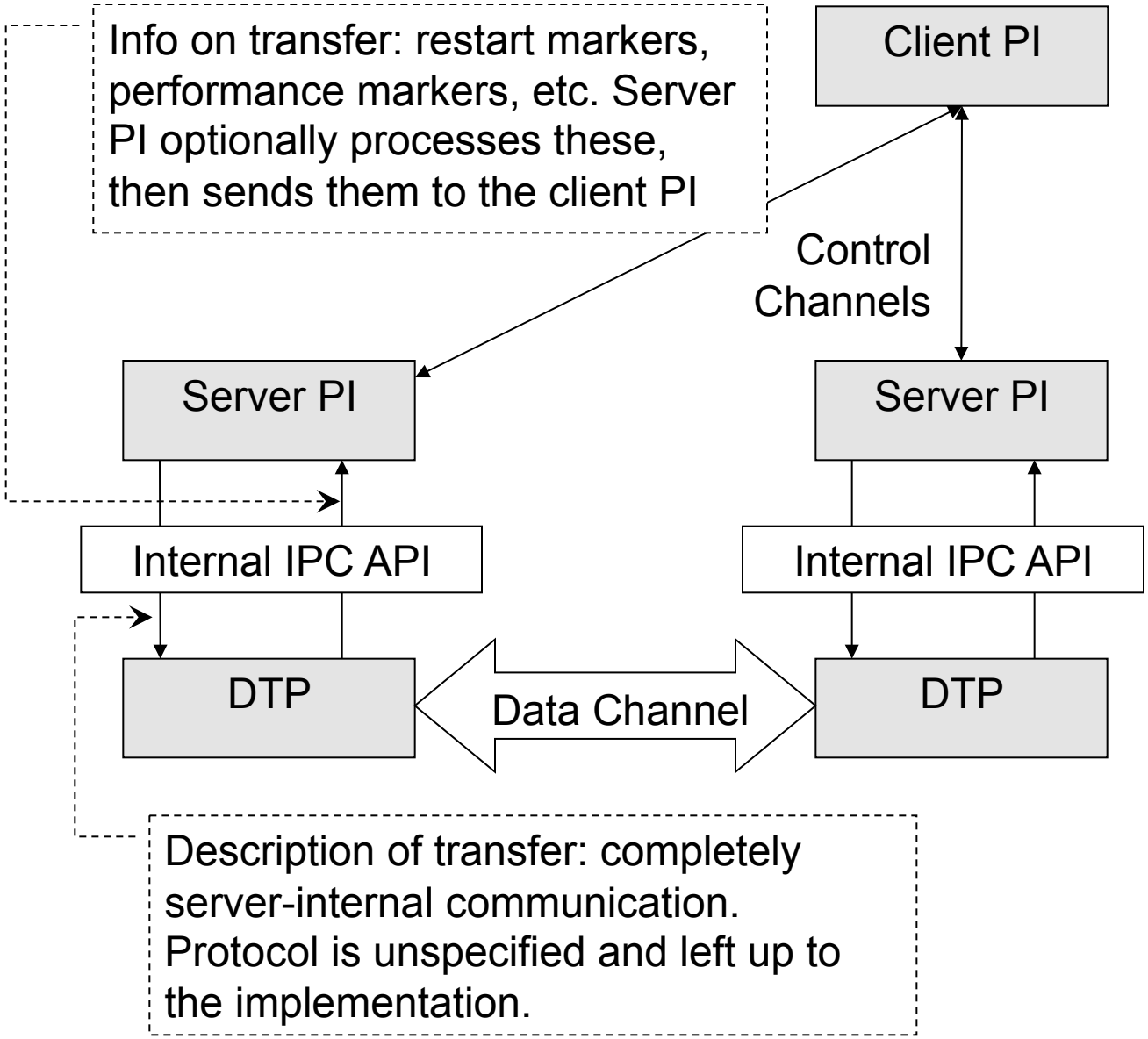
- Data Channel Authentication
  - Needed since in third party transfer, you don't know who will connect to the listener.
- ESTO/ERET
  - Allows for additional processing on the data prior to storage/transmission
  - We use this for partial file transfers
- SBUF/ABUF
  - Manual and automatic TCP buffer tuning
- Options to set parallelism/striping parameters

Parallelism vs Striping



Architecture / Design of our Implementation

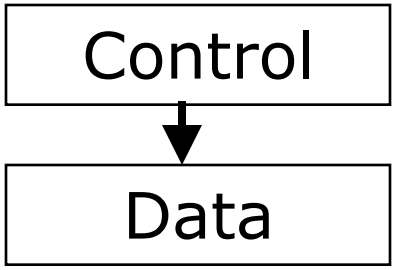
Overall Architecture



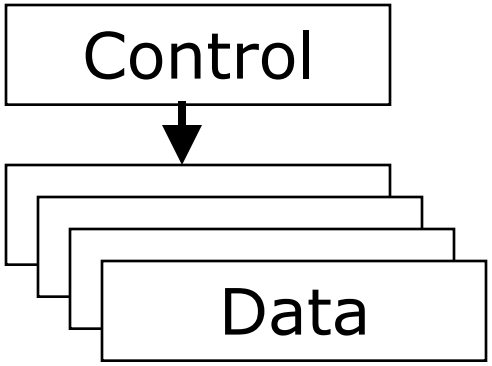
Possible Configurations

Typical Installation

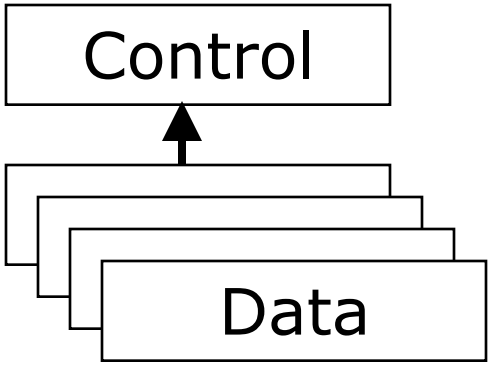
Separate Processes



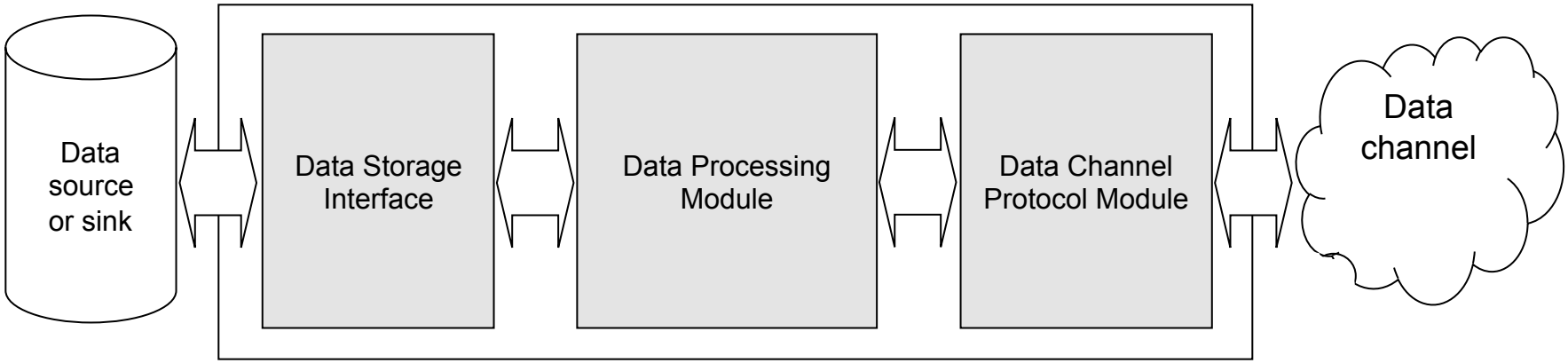
Striped Server



Striped Server (future)



Data Transfer Processor



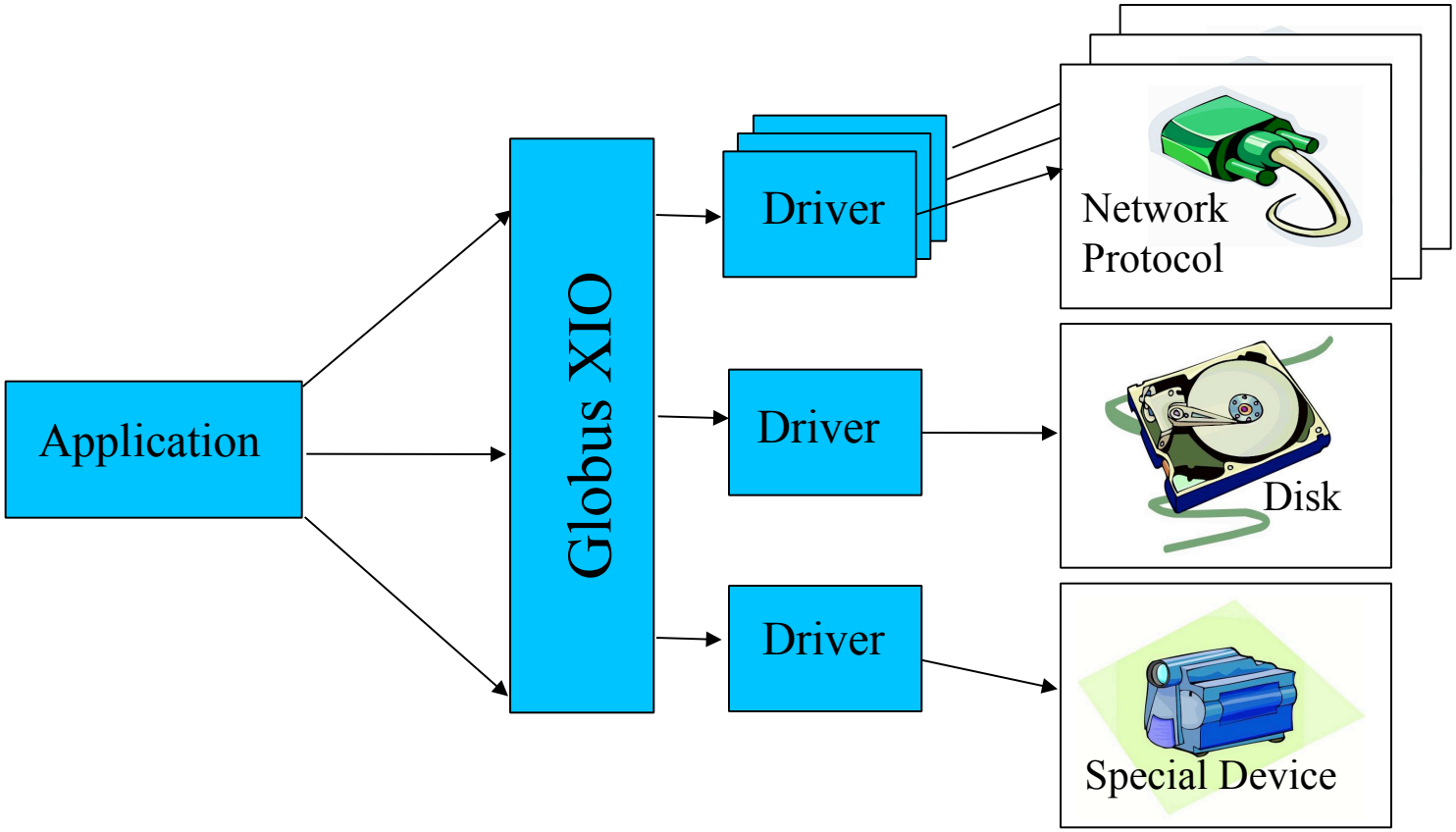
Data Storage Interface

- This is a very powerful abstraction
- Several can be available and loaded dynamically via the ERET/ESTO commands
- Anything that can implement the interface can be accessed via the GridFTP protocol
- We have implemented
  - POSIX file (used for performance testing)
  - HPSS (tape system; IBM)
  - Storage Resource Broker (SRB; SDSC)
  - NeST (disk space reservation; UWis/Condor)

Globus Extensible IO (XIO) System

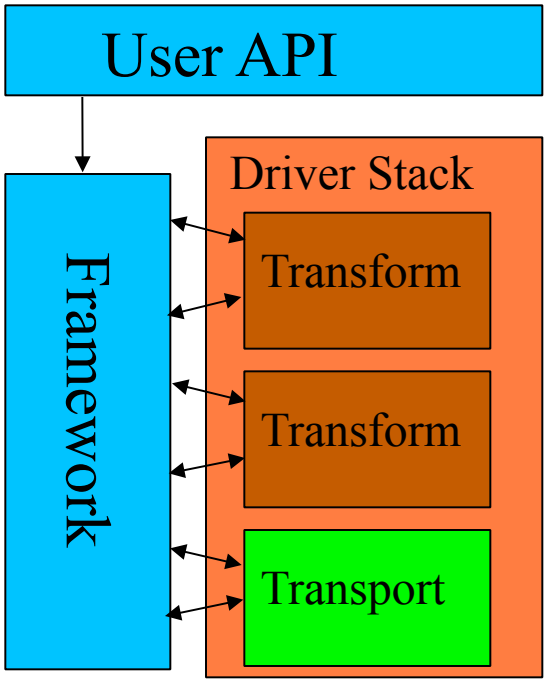
- XIO framework presents a standard open/close/read/write interface to many different protocol implementations
  - including TCP, UDP, HTTP -- and now UDT
- The protocol implementations are called drivers.
  - A driver can be dynamically loaded and stacked by any Globus XIO application.

Globus XIO Approach



Globus XIO Framework

- Moves the data from user to driver stack.
- Manages the interactions between drivers.
- Assist in the creation of drivers.
  - Asynchronous support.
  - Close and EOF Barriers.
  - Error checking
  - Internal API for passing operations down the stack.

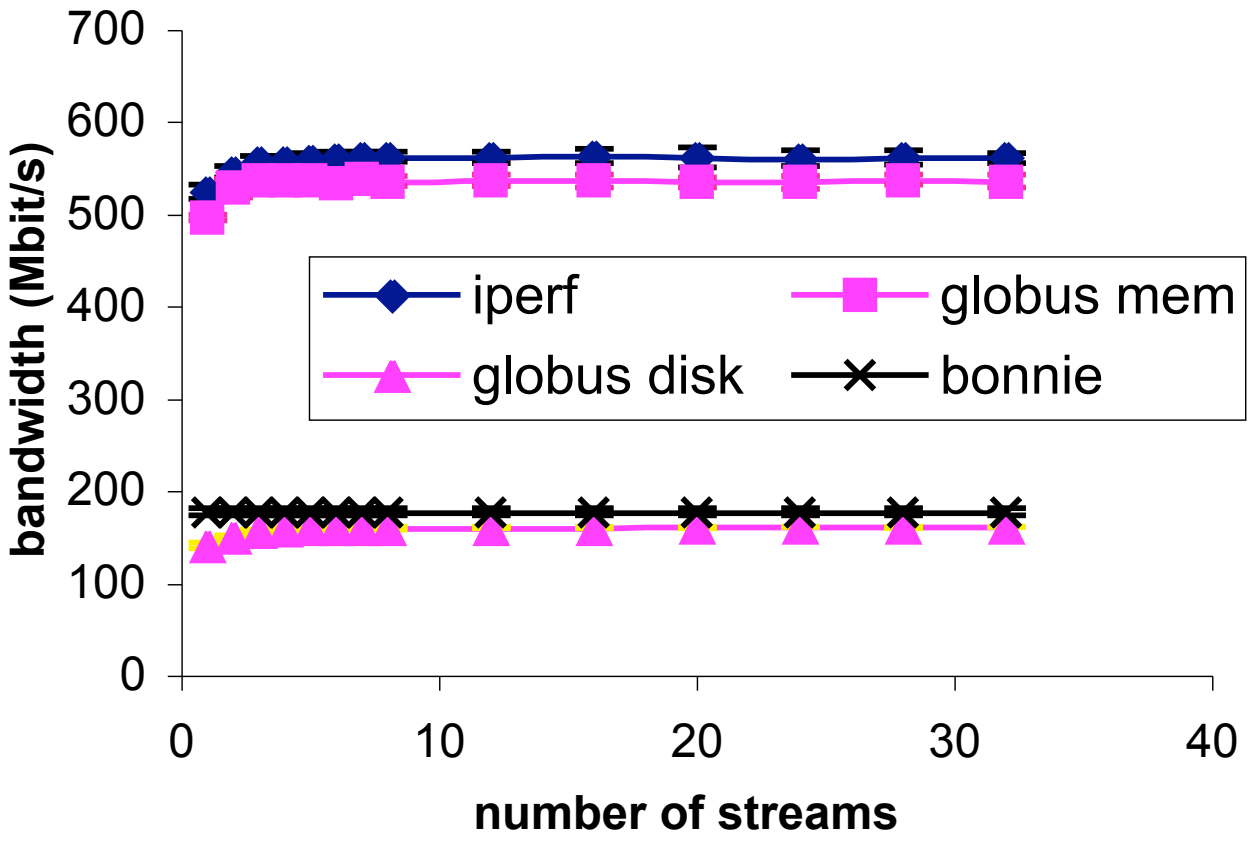


Performance Results

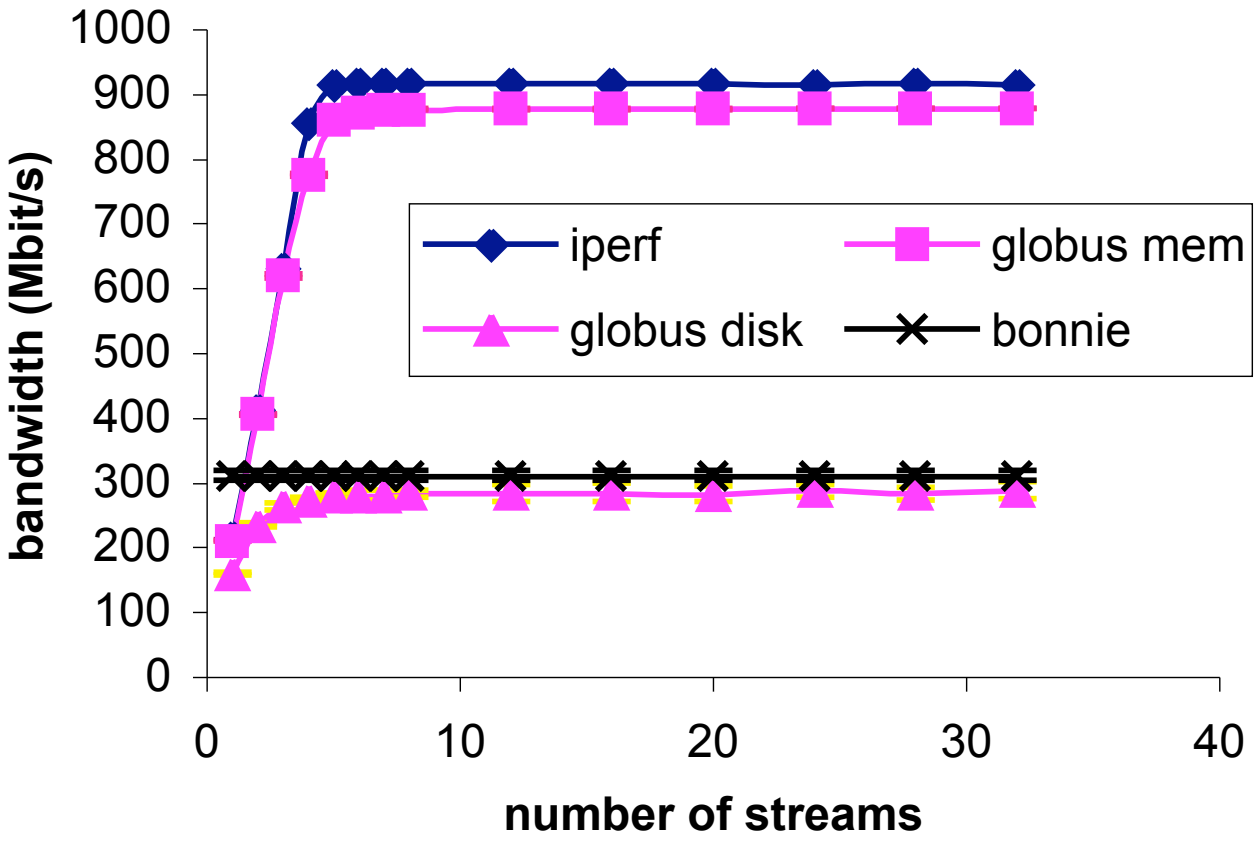
Experimental results

- Three settings
  - LAN - 0.2 msec RTT and 622 Mbit/s
  - MAN - 2.2 msec RTT and 1 Gbit/s
  - WAN - 60 msec RTT and 30 Gbit/s
  - MAN - Distributed Optical Testbed in the Chicago area
  - WAN - TeraGrid link between NCSA in Illinois and SDSC in California - each individual has a 1Gbit/s bottleneck link

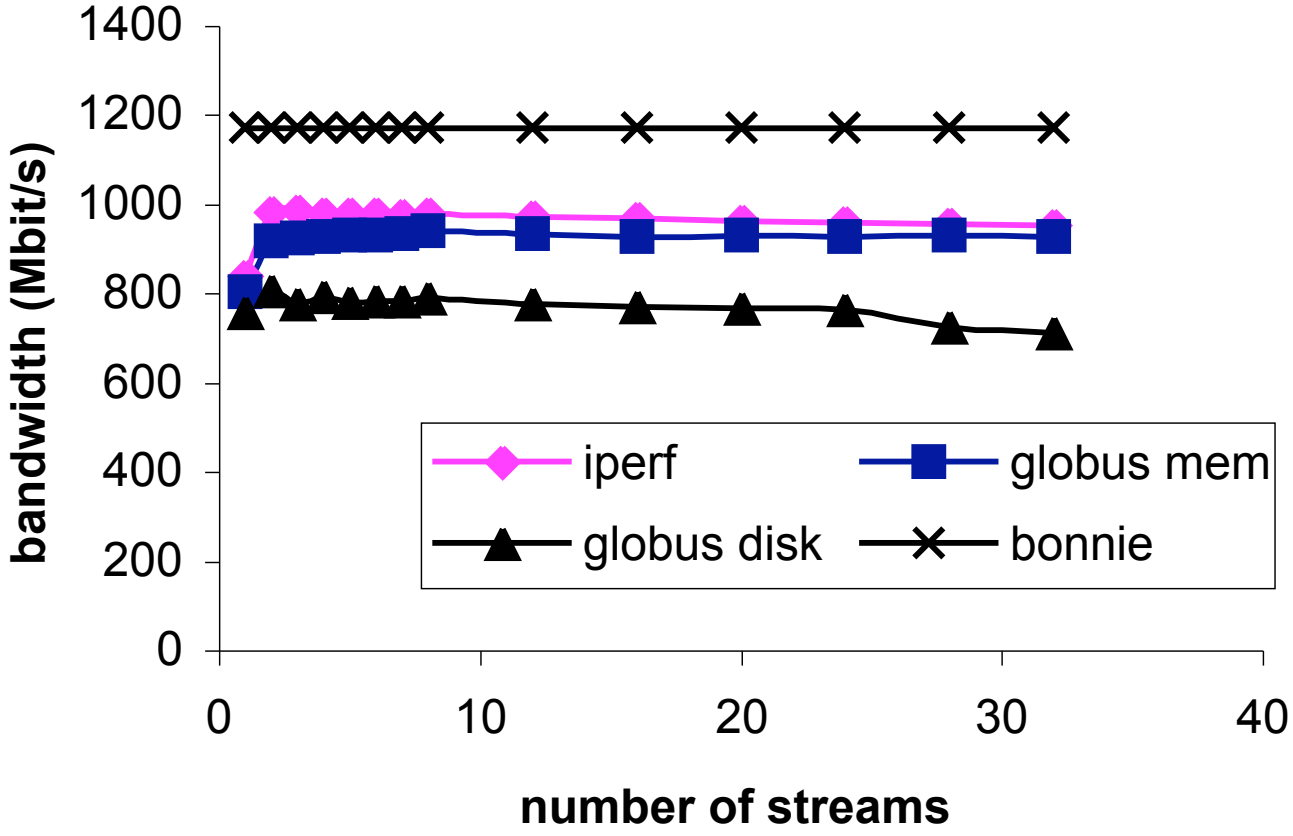
Experimental results - LAN



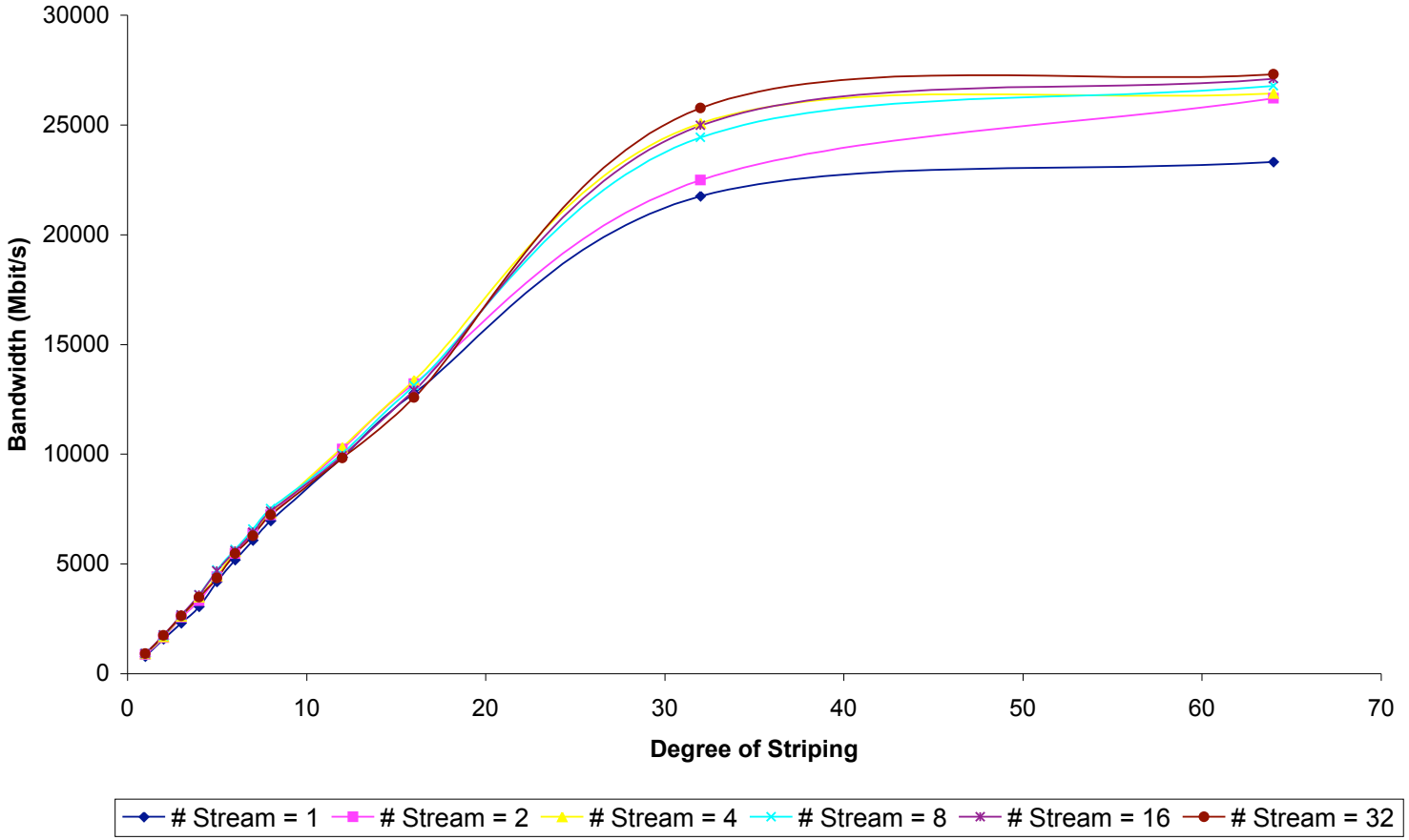
Experimental results - MAN



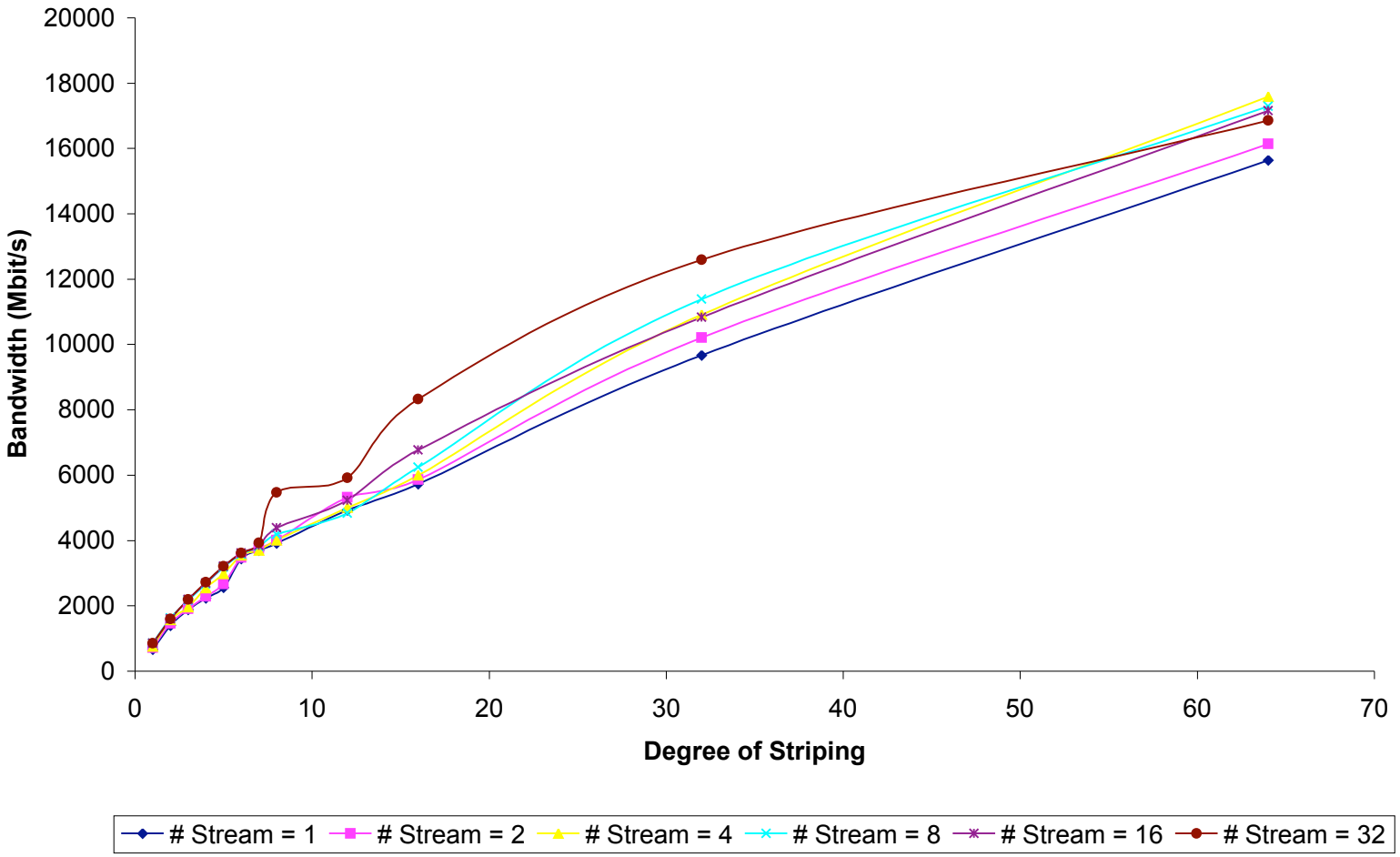
Experimental results - WAN



Memory to Memory Striping Performance



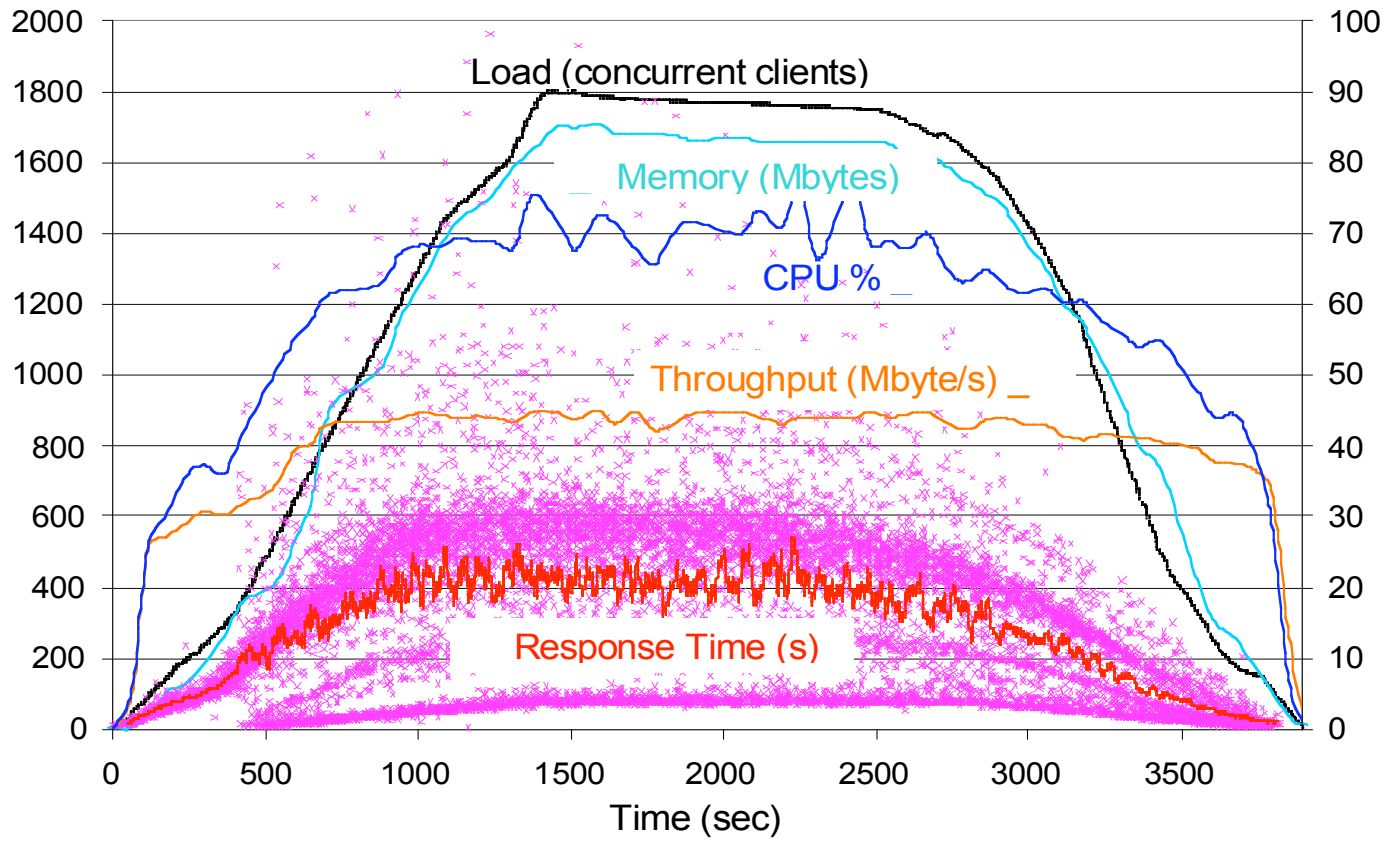
Disk to Disk Striping Performance



Scalability tests

- Evaluate performance as a function of the number of clients
- DiPerf test framework to deploy the clients
- Ran server on a 2-processor 1125 MHz x86 machine running Linux 2.6.8.1
  - 1.5 GB memory and 2 GB swap space
  - 1 Gbit/s Ethernet network connection and 1500 B MTU
- Clients created on hosts distributed over PlanetLab and at the University of Chicago (UofC)

Scalability Results



Left axis - load, response time, memory allocated

Right axis - Throughput and CPU %

Scalability results

- 1800 clients mapped in a round robin fashion on 100 PlanetLab hosts and 30 UofC hosts
- A new client created once a second and ran for 2400 seconds
  - During this time, repeatedly requests the transfer of 10 Mbyte file from server's disk to client's /dev/null
- Total of 150.7 Gbytes transferred in 15,428 transfers

Scalability results

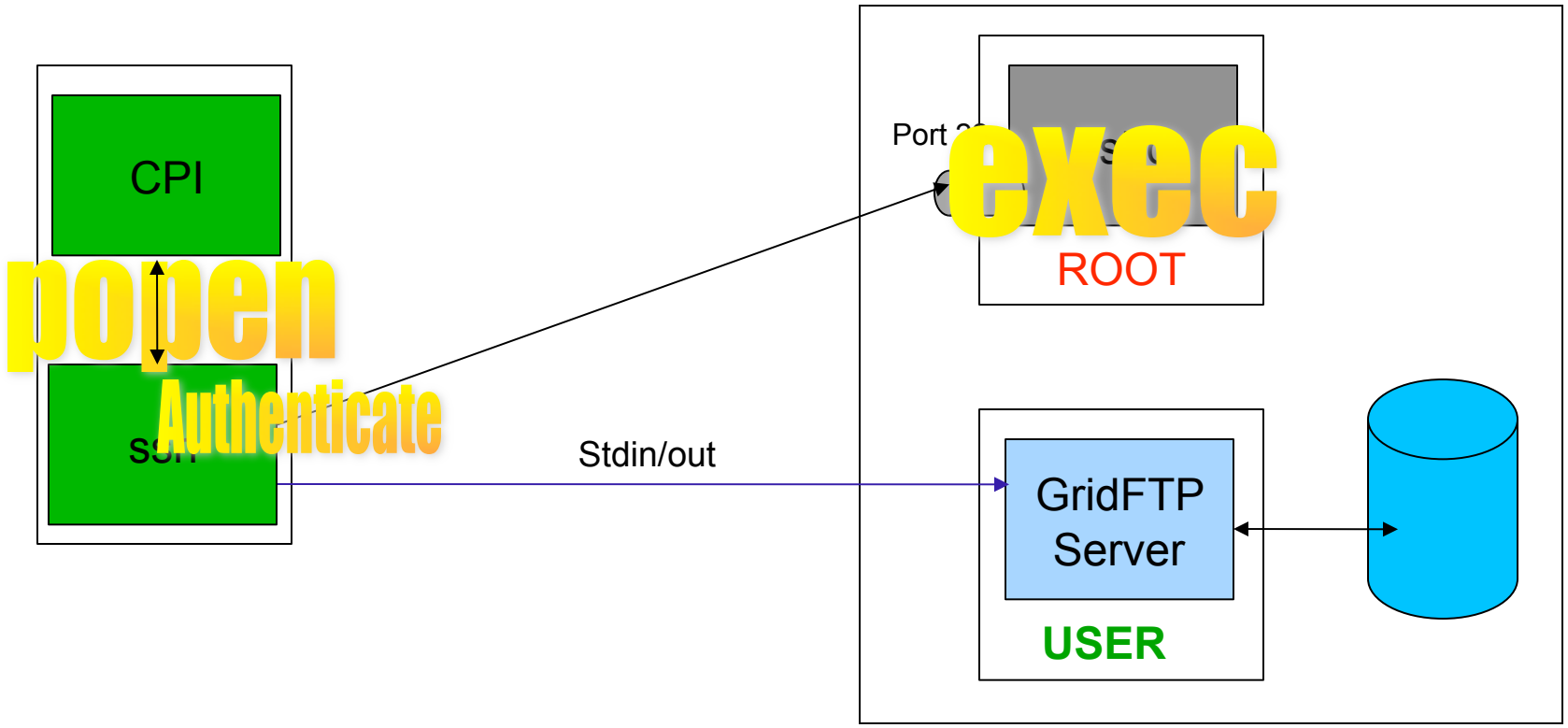
- Server sustained 1800 concurrent requests with 70% CPU and 0.94 Mbyte memory per request
- CPU usage, throughput, response time remain reasonable even when allocated memory exceeds physical memory
  - Meaning paging is occuring

New features

SSH security mechanism for GridFTP

- GridFTP traditionally uses GSI for establishing secure connections
- In some situations, preferable to use SSH security mechanism
- Leverages the fact that an SSH client can remotely execute programs by forming a secure connection with SSHD

SSHFTP Interactions



GridFTP over UDT

- UDT is an application-level data transport protocol that uses UDP to transfer data
- Implement its own reliability and congestion control mechanisms
- Achieves good performance on high-bandwidth, high-delay networks where TCP has significant limitations
- GridFTP uses Globus XIO interface to invoke network I/O operations
  - Created an XIO driver for UDT reference implementation
  - Enabled GridFTP to use it as an alternate transport protocol

GridFTP over UDT

	Argonne to NZ Throughput in Mbit/s	Argonne to LA Throughput in Mbit/s
Iperf – 1 stream	19.7	74.5
Iperf – 8 streams	40.3	117.0
GridFTP mem TCP – 1 stream	16.4	63.8
GridFTP mem TCP – 8 streams	40.2	112.6
GridFTP disk TCP – 1 stream	16.3	59.6
GridFTP disk TCP – 8 streams	37.4	102.4
GridFTP mem UDT	179.3	396.6
GridFTP disk UDT	178.6	428.3
UDT mem	201.6	432.5
UDT disk	162.5	230.0

Summary

- The GridFTP protocol provides a good set of features for data movement requirements in the Grid.
- The Globus implementation of this protocol provides a flexible design / architecture for integrating with different communities, storage systems, and protocols.
- Our implementation is robust and performant over a range of environments.

Questions?