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Data Movement Tools for Distributed Petascale Science

Raj Kettimuthu
Argonne National Laboratory and
The University of Chicago

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Outline

- Introduction
- Motivation
- Data Transfer Problem
- Requirements
- Reliable Data Movement Framework
- Future Directions

Today's Science Environments

- Large-scale collaborative science is becoming increasingly common

- Distributed community of users to access and analyze large amounts of data

Simulation Science

- In simulation science, the data sources are supercomputer simulations
  - For eg, DOE-funded climate modeling groups generate large reference simulations at supercomputer centers
- Combustion, fusion, computational chemistry, and astrophysics communities have similar requirements for remote and distributed data analysis

Experimental Science

- Data sources are facilities such as high energy and nuclear physics experiments and light sources.
  - For eg, LHC at CERN will produce petabytes of raw data per year for 15 years
- DOE light sources can also produce large quantities of data that must be distributed, analyzed, and visualized
- The international fusion experiment, ITER

Science Environments

- Raw simulation or observational data is just a starting point for most investigations
- Understanding comes from further analysis, reduction, visualization, and exploration

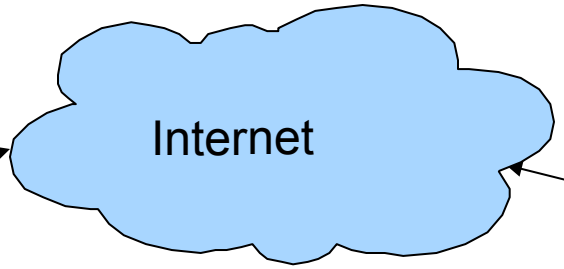
Petascale resource

Compute Cluster

Scientist's Desktop

- Furthermore the data is a community asset that must be accessible to any member of a distributed collaboration

Network Capabilities

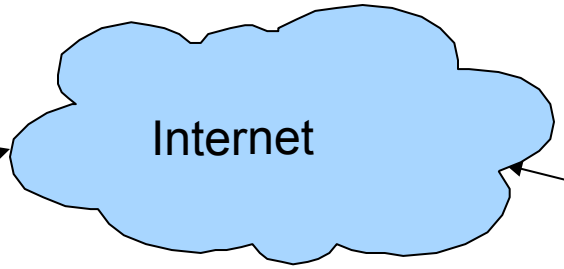


Scientist A in California

Scientist B in New York

- Scientist A wants to transfer 1 Terabyte of data to Scientist B
- What is the fastest way to transfer the data?

Network Capabilities



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FedEx

Network Capabilities

- Until a few years ago, Tri-labs (Los Alamos, Lawrence Livermore and Sandia) transferred data via tapes sent thru fedex
- To transfer 100 TB in 24 hours, need a sustained data rate > 9.5 Gbit/s
- 10 Gbit/s networks are becoming increasingly common in scientific environments
  - DOE's ESNet, UltraScience Net, Science Data Networks and Internet2 have 10Gb/s or higher links
  - Thanks to the advancement in networking technologies

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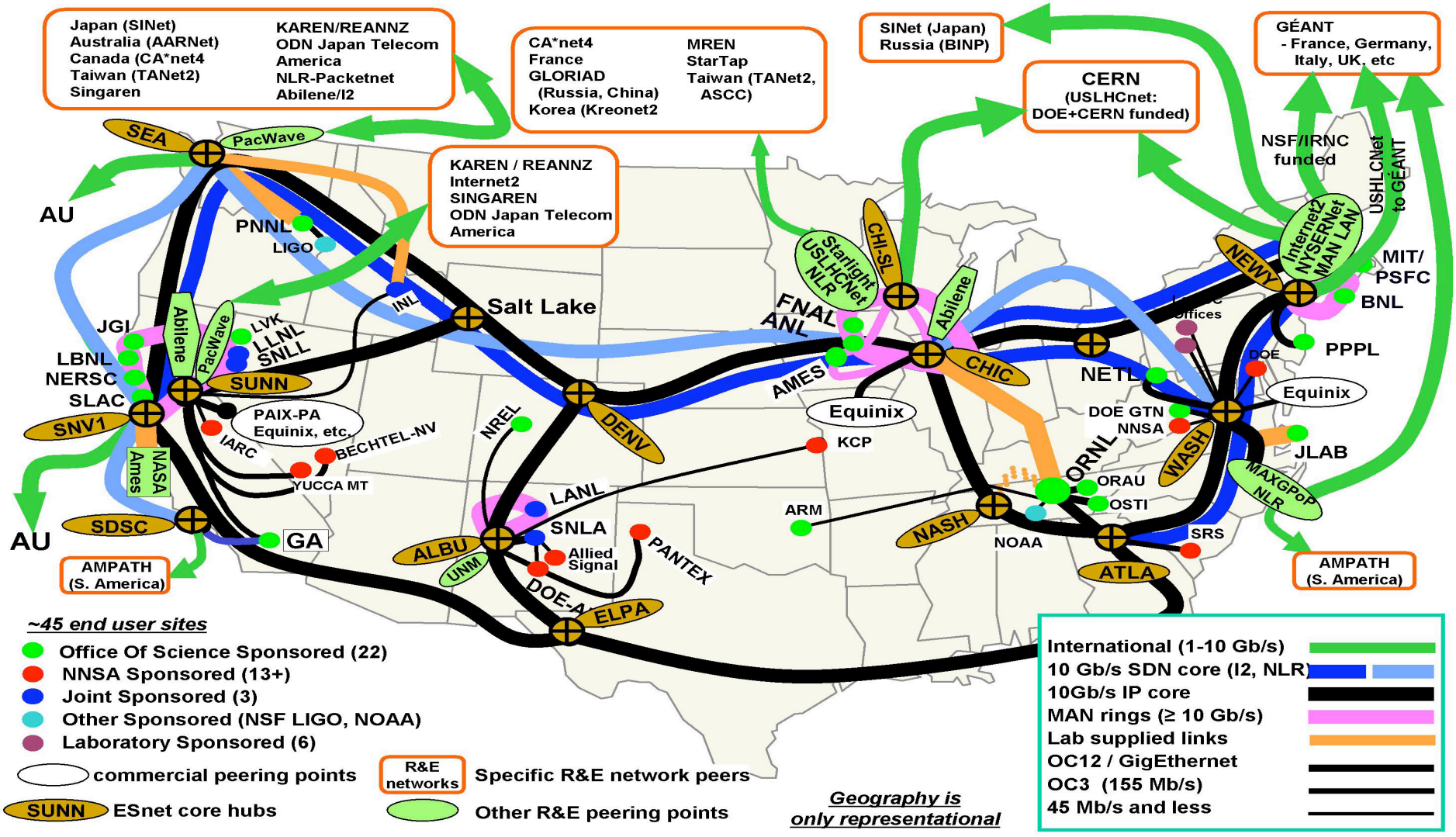
ESNET

ESnet Provides Global High-Speed Internet Connectivity for DOE Facilities and Collaborators (12/2007)



End-to-end problem

- Now that high-speed networks are available, can we move data at network speeds on the network?
- What if the speed of airplanes had increased by the same factor as computers over the last 50 years, namely five orders of magnitude?

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We would be able to cross US in less than a second

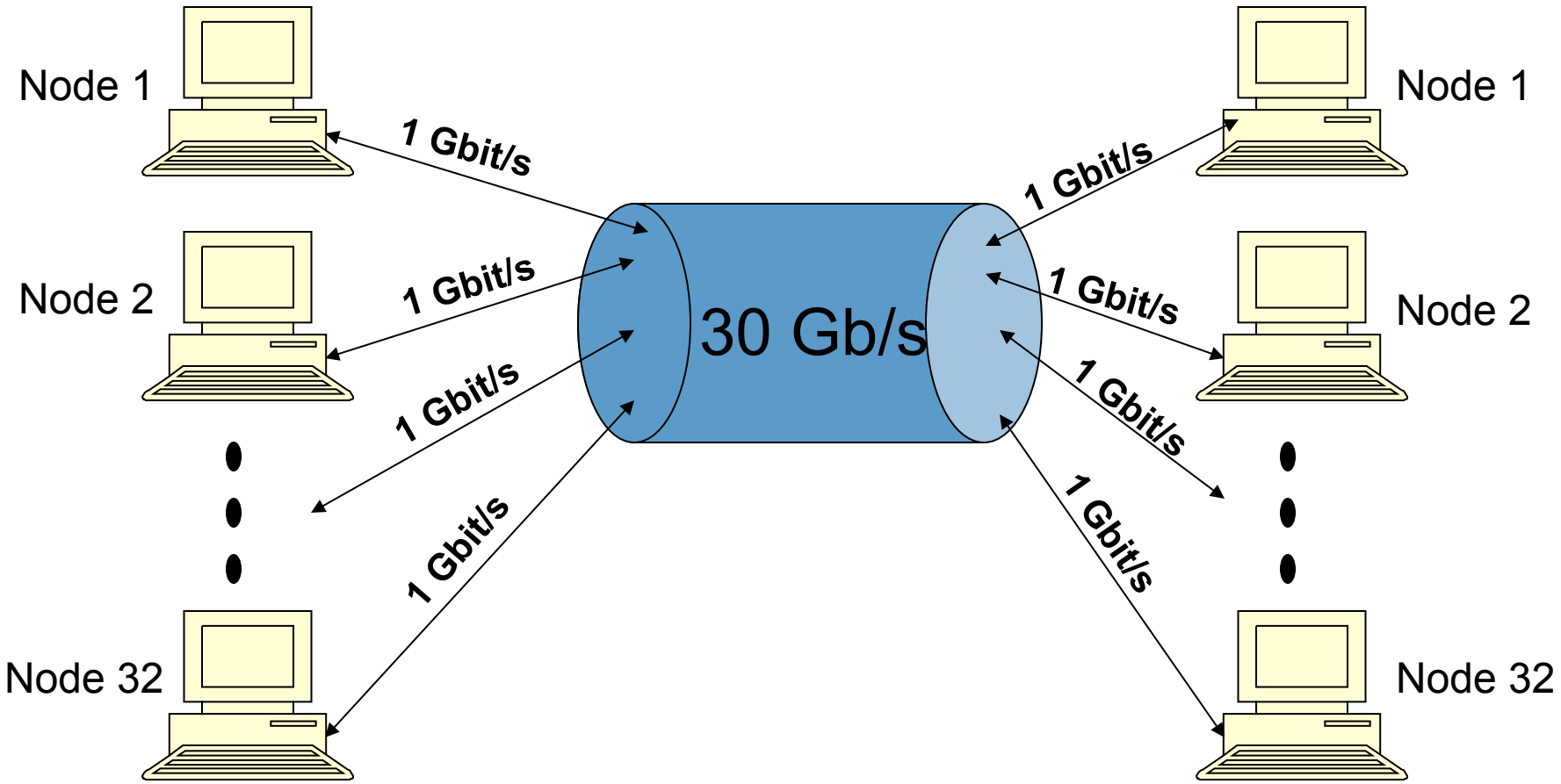
Yes. But it would still take two hours to get to downtown

End-to-end problem

- Data movement in distributed science environments is an end-to-end problem
- A 10 Gbit/s network link between the source and destination does not guarantee an end-to-end data rate of 10 Gbit/s
- Other factors such as storage system, disk, data rate supported by the end node
- Deal with failures of various sorts
  - Firewalls can cause difficulties

End-to-end data transfer

Efficient and robust wide area data transport requires the management of complex systems at multiple levels.



Requirements

- Fast
- Easy-to-use
- Secure
- Reliable
- Extensible
- Standard
- Robust

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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

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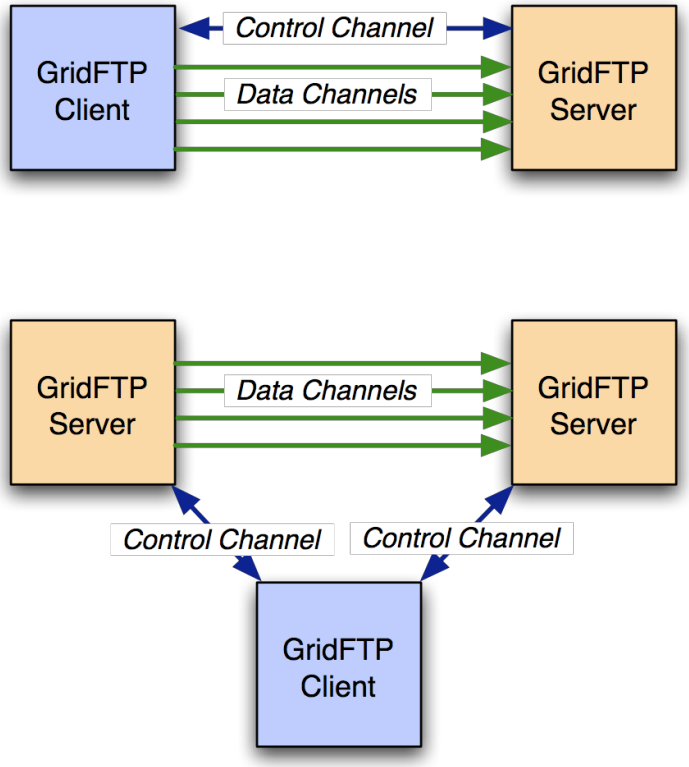
GridFTP

- We (Globus Alliance) supply a reference implementation:
  - Server
  - Client tools
  - Development Libraries
- Multiple independent implementations can interoperate
  - Fermi Lab and U. Virginia have home grown servers that work with ours

GridFTP

- Two channel protocol like FTP
- Control Channel
  - Communication link (TCP) over which commands and responses flow
  - Low bandwidth; encrypted and integrity protected by default
- Data Channel
  - Communication link(s) over which the actual data of interest flows
  - High Bandwidth; authenticated by default; encryption and integrity protection optional

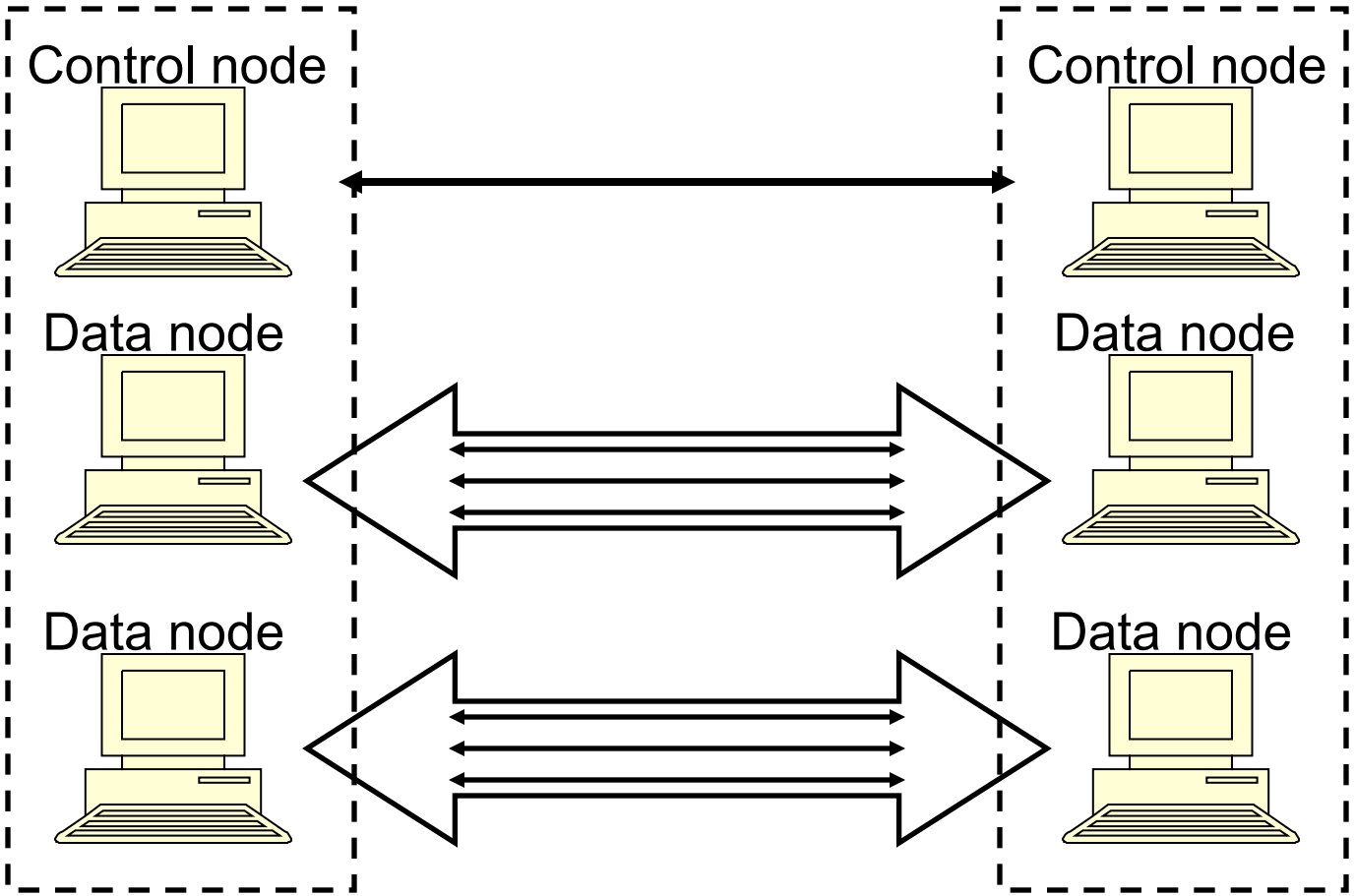


Globus GridFTP Features

- GridFTP is Fast
  - Parallel TCP streams
  - Non TCP protocol such as UDT
  - Set optimal TCP buffer sizes
  - Order of magnitude greater
- Cluster-to-cluster data movement
  - Co-ordinated data movement using multiple computers at each end
  - Another order of magnitude

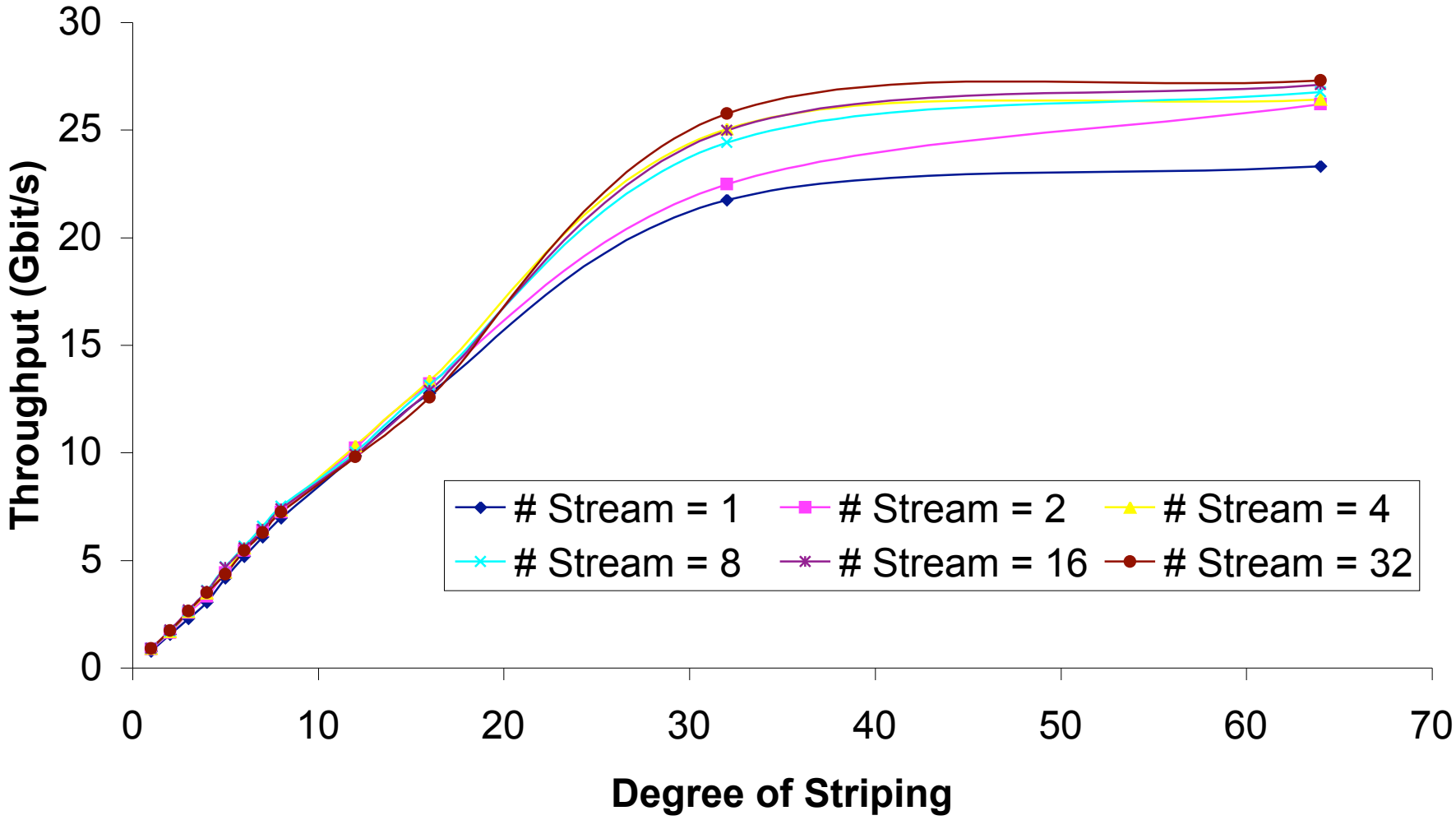
"Grid-enabled Particle Physics Event Analysis: Experiences Using a 10 Gb, High-latency Network for a High-Energy Physics Application", FGCS Journal, August 2003

Cluster-to-Cluster transfers



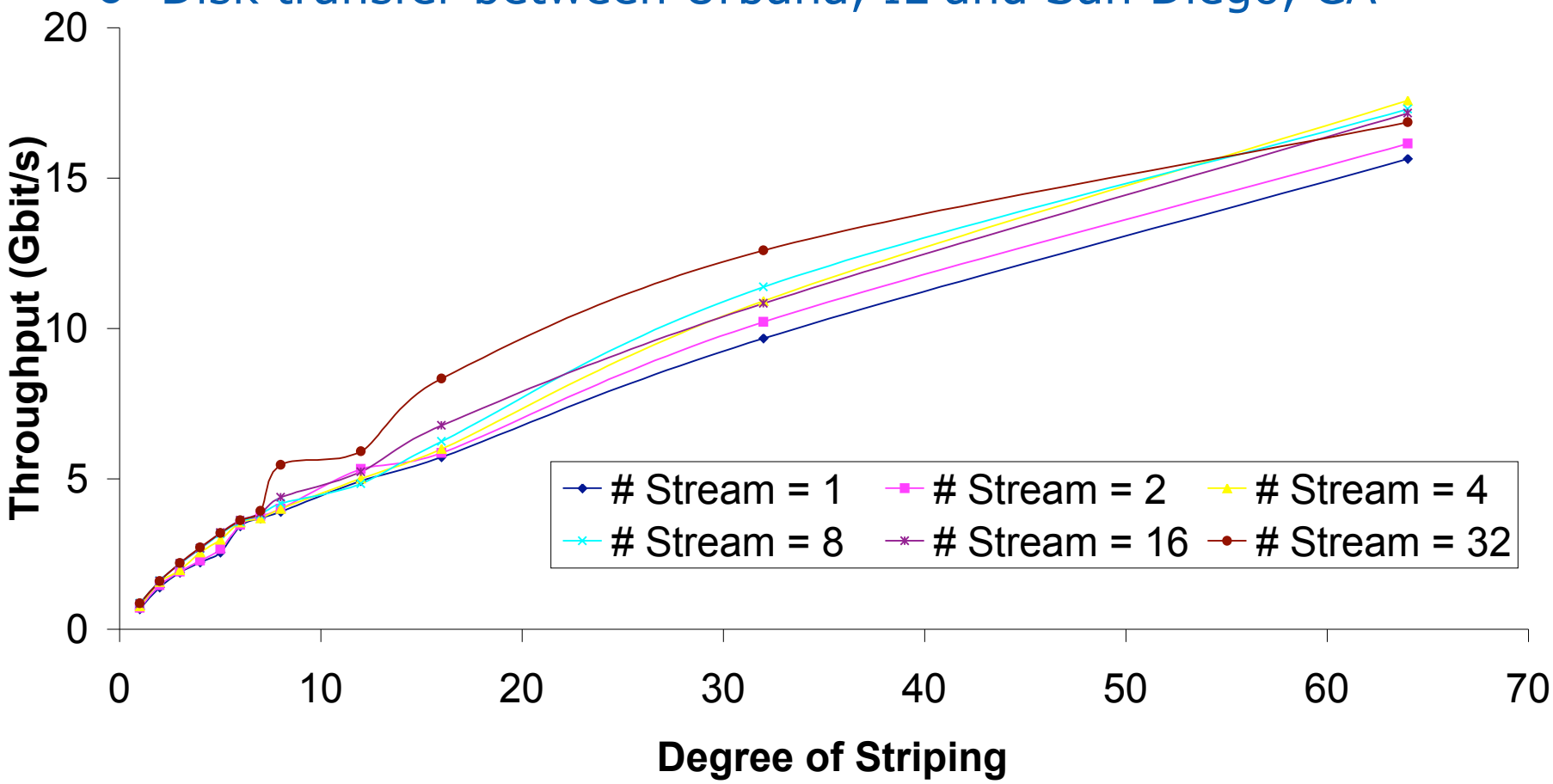
Performance

- Mem. transfer between Urbana, IL and San Diego, CA



Performance

- Disk transfer between Urbana, IL and San Diego, CA



"The Globus Striped GridFTP Framework and Server", ACM/IEEE conference on Supercomputing (SC'05)

Security

- Often there is need to authenticate clients and control access to the data
- Globus GridFTP supports multiple security mechanisms to authenticate and authorize clients
  - Anonymous access
  - Username/password
  - SSH security
  - Grid Security Infrastructure (GSI)

Easy-to-use

- Simple to install
  - Configure; make gridftp install;
  - Installs only gridftp and its dependencies
  - Binaries available for many platforms
- Various clients
  - Command-line client - globus-url-copy
  - Client libraries - well-defined API
  - Graphical User Interface

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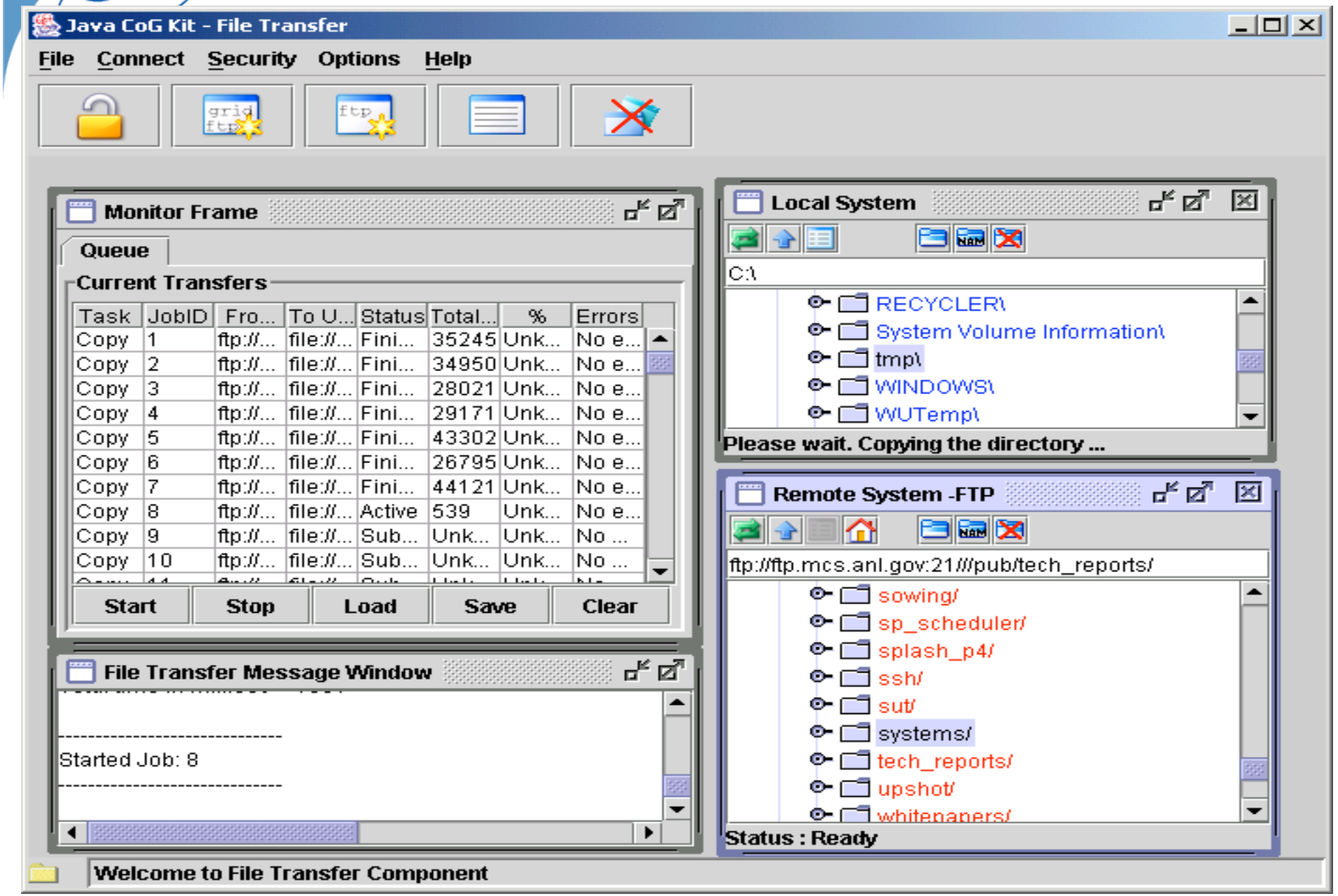
GUI Client



Requirements

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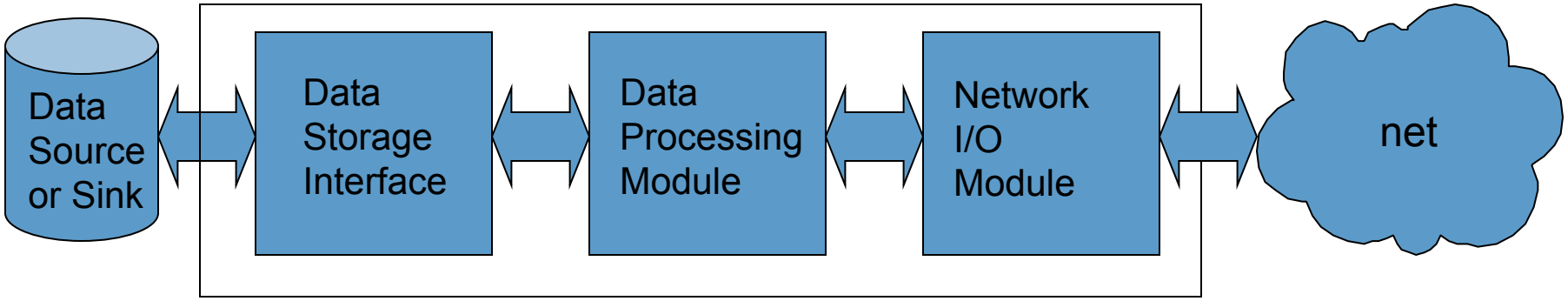
- Robust
- Easy-to-use ✓

Modular



Well defined interfaces

Data Storage Interface (DSI)

- POSIX file system
- High Performance Storage System (HPSS)
- Storage Resource Broker (SRB)

"Globus Data Storage Interface (DSI) - Enabling Easy Access to Grid Datasets", Data Grids Workshop 2006

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Modular

- Network I/O module
  - Simple Open/Close/Read/Write interface
  - Well-defined abstraction called drivers
  - Easy to plug-in external libraries
  - TCP, UDT, Phoebus
- Data processing module
  - Compression (under development)
  - Checksum

"The Globus eXtensible Input/Output System (XIO): A protocol independent IO system for the Grid", IEEE IPDPS 2005

GridFTP in production

- Many Scientific communities rely on GridFTP
  - High Energy Physics - LHC computing Grid
  - Southern California Earthquake Center (SCEC), Earth Systems Grid (ESG), Relativistic Heavy Ion Collider (RHIC), European Space Agency, BBC use GridFTP for data movement
- GridFTP facilitates an average of more than 3 million data transfers every day

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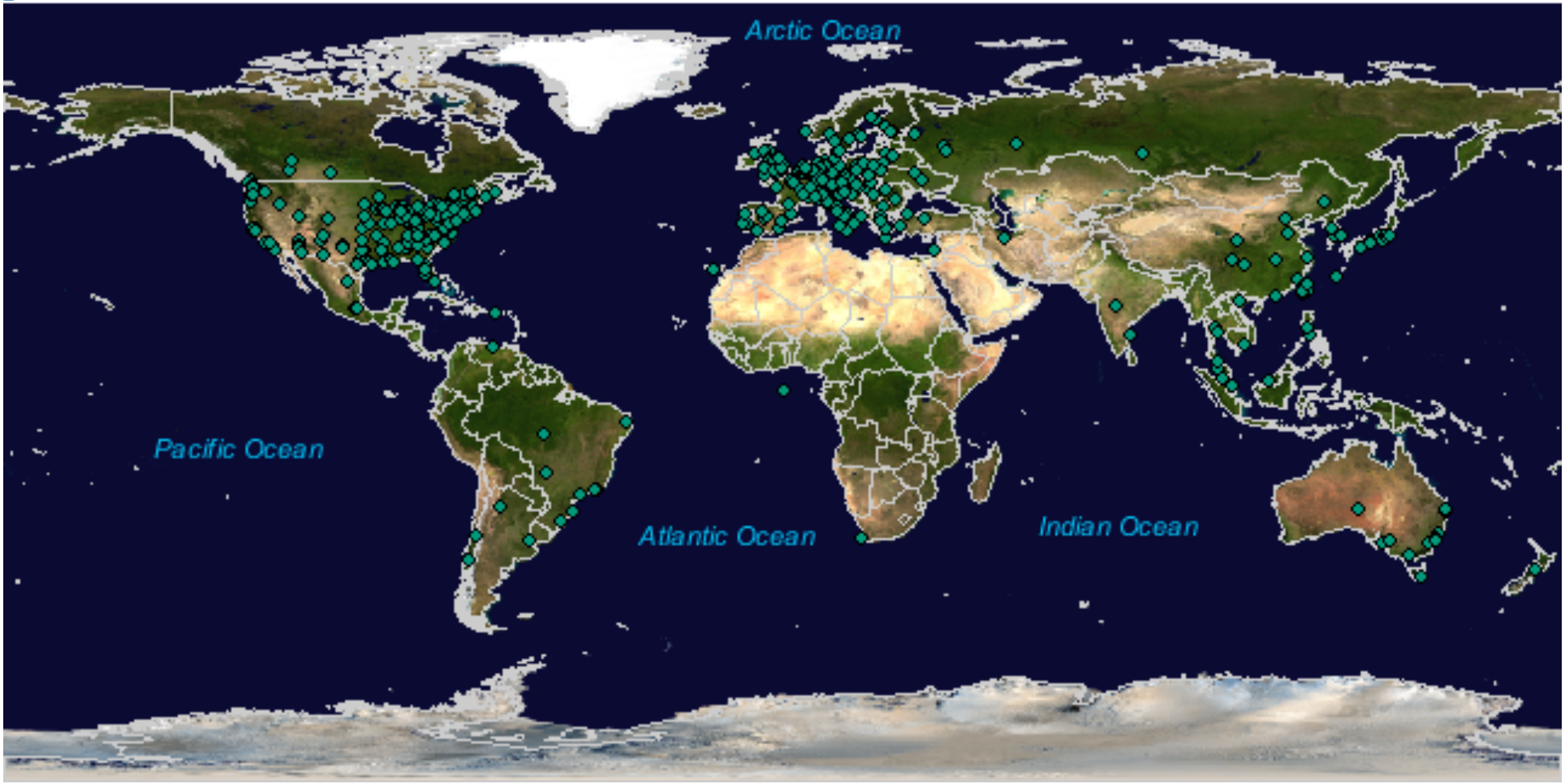
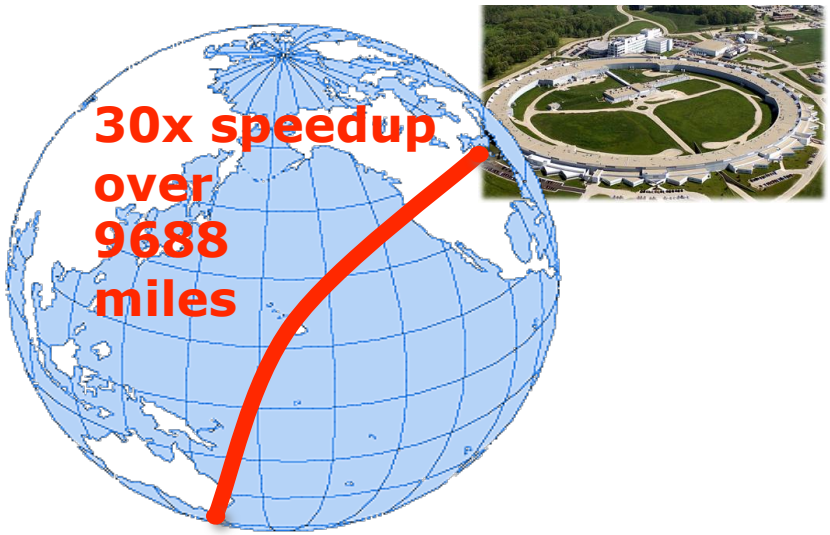
GridFTP Servers Around the World

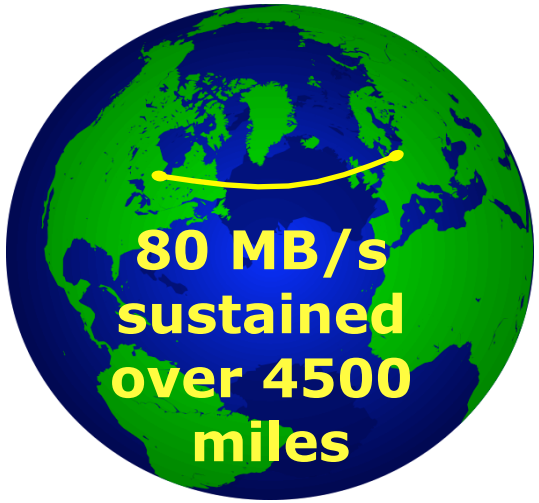


Created by Lydia Prieto ; G. Zarrate; Anda Imanitchi (Florida State University) using MaxMind's GeoIP technology (http://www.maxmind.com/app/ip-locate).

GridFTP in production



One terabyte moved from an Advanced Photon Source tomography beamline to Australia, at a rate 30x faster than standard FTP



1.5 terabyte moved from University of Wisconsin, Milwaukee to Hannover, Germany at a sustained rate of 80 megabyte/sec

Handling failures

- GridFTP server sends restart and performance markers periodically
  - Default every 5s - configurable
- Helpful if there is any failure
  - No need to transfer the entire file again
  - Use restart markers and transfer only the missing pieces
- GridFTP supports partial file transfers

Server failure

- Command-line client - globus-url-copy - support transfer retries
  - Use restart markers
- Recover from server and connection failures
- What if the client fails in the middle of a transfer?

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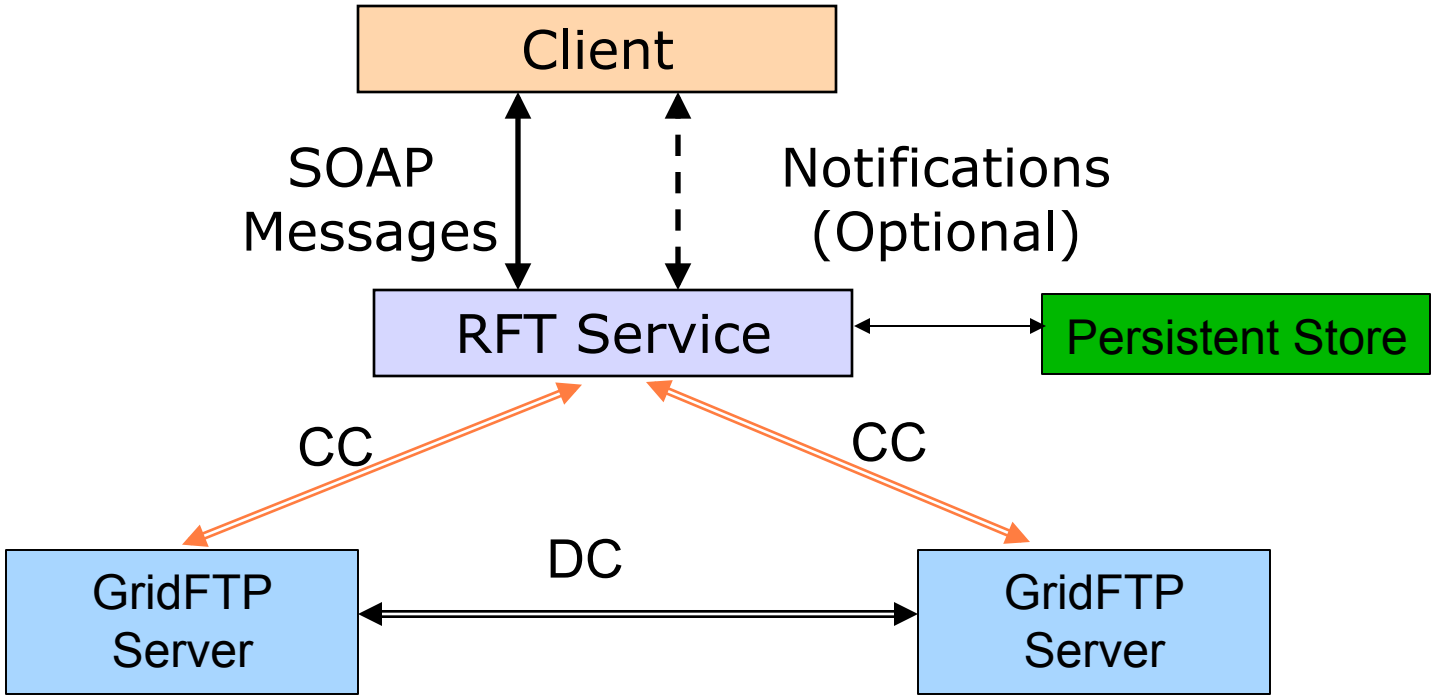
Globus Reliable File Transfer Service (RFT)

- GridFTP client that provides more reliability
- GridFTP - on demand transfer service
  - Not a queuing service
- RFT
  - Queues requests
  - Orchestrates transfers on client's behalf
  - Writes to persistent store
  - Recovers from GridFTP and RFT service failures

RFT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Notifications
(Optional)
RFT Service
Persistent Store
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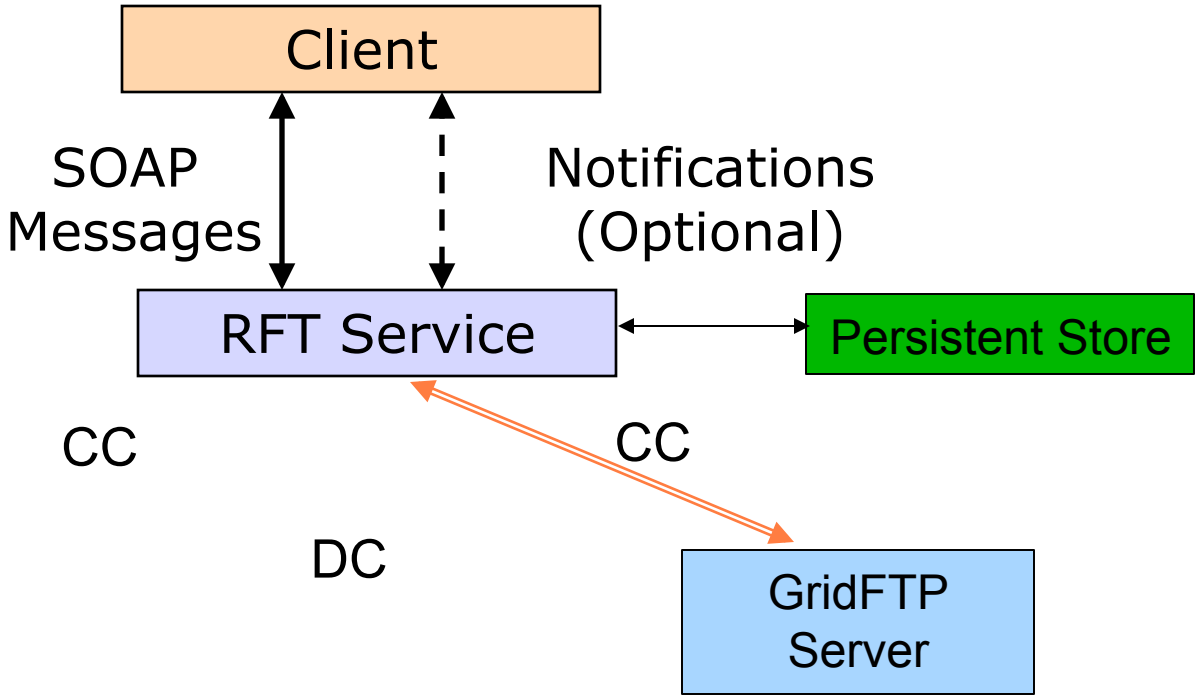
GridFTP
Server
GridFTP
Server

RFT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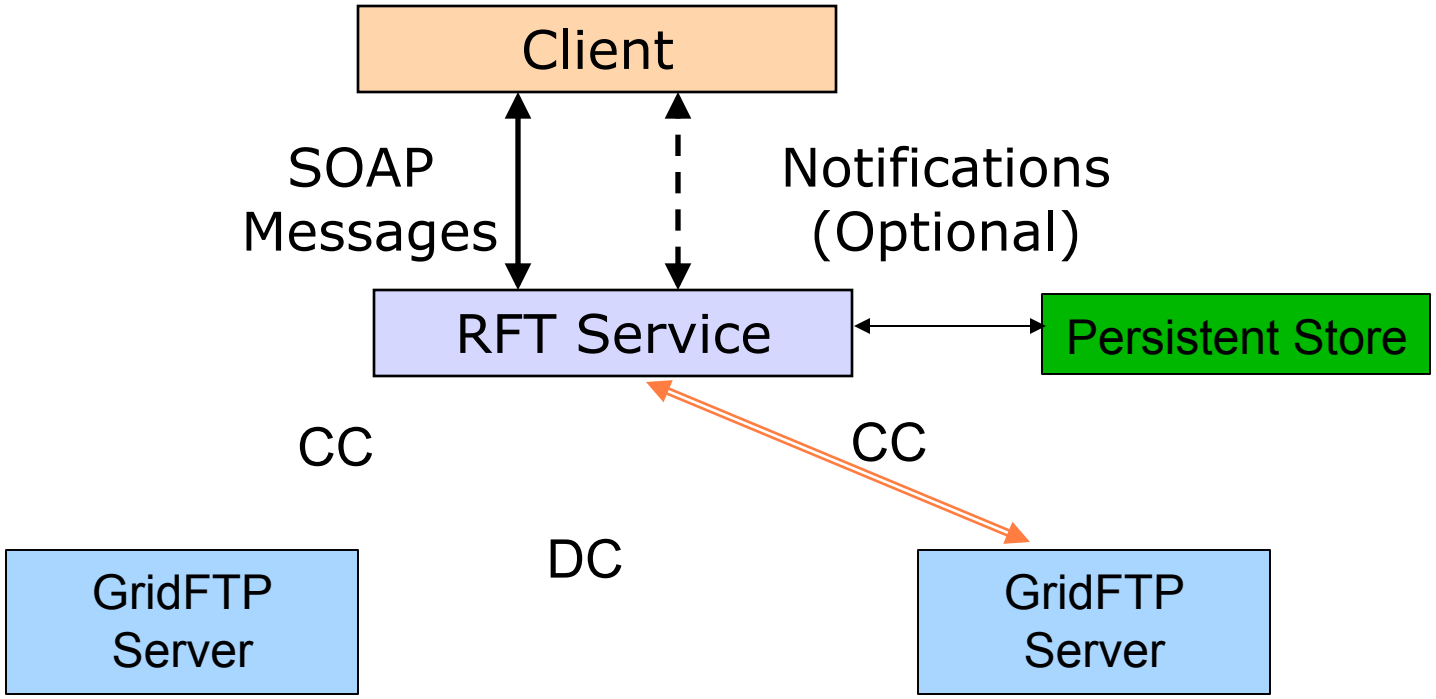
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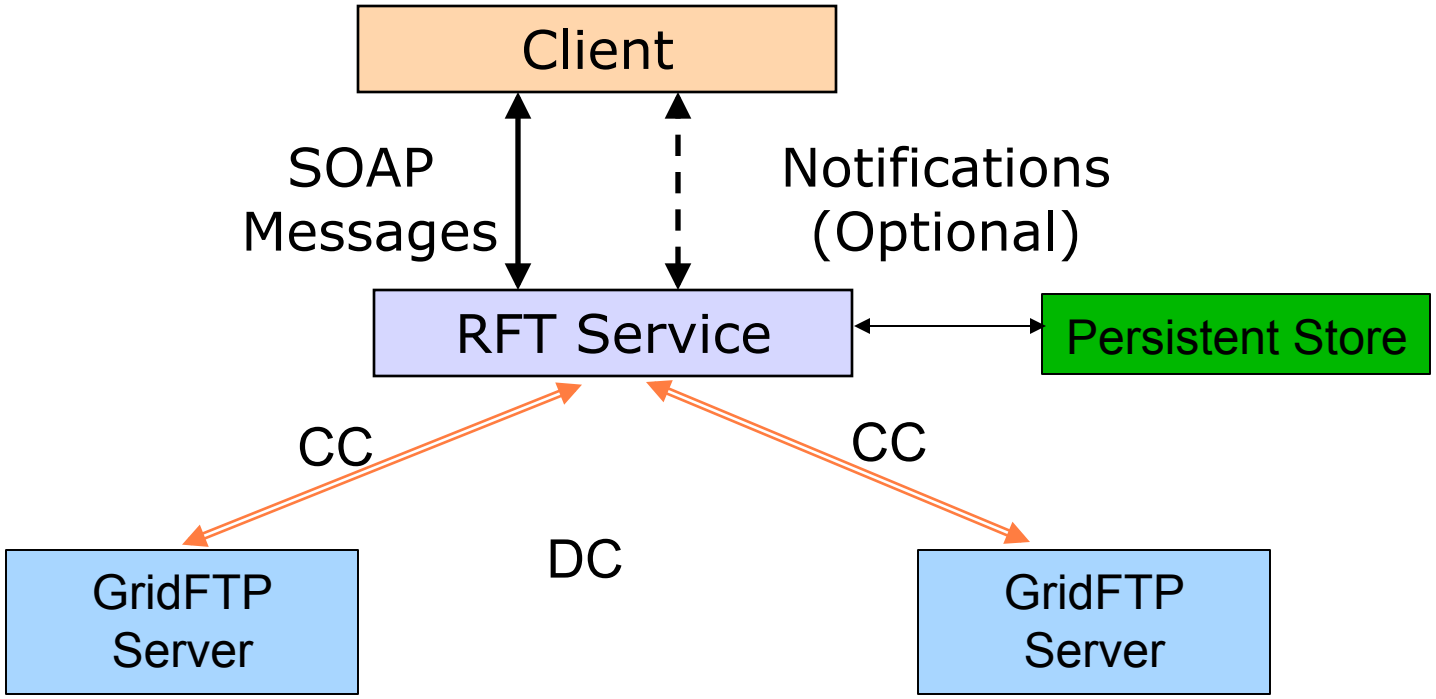
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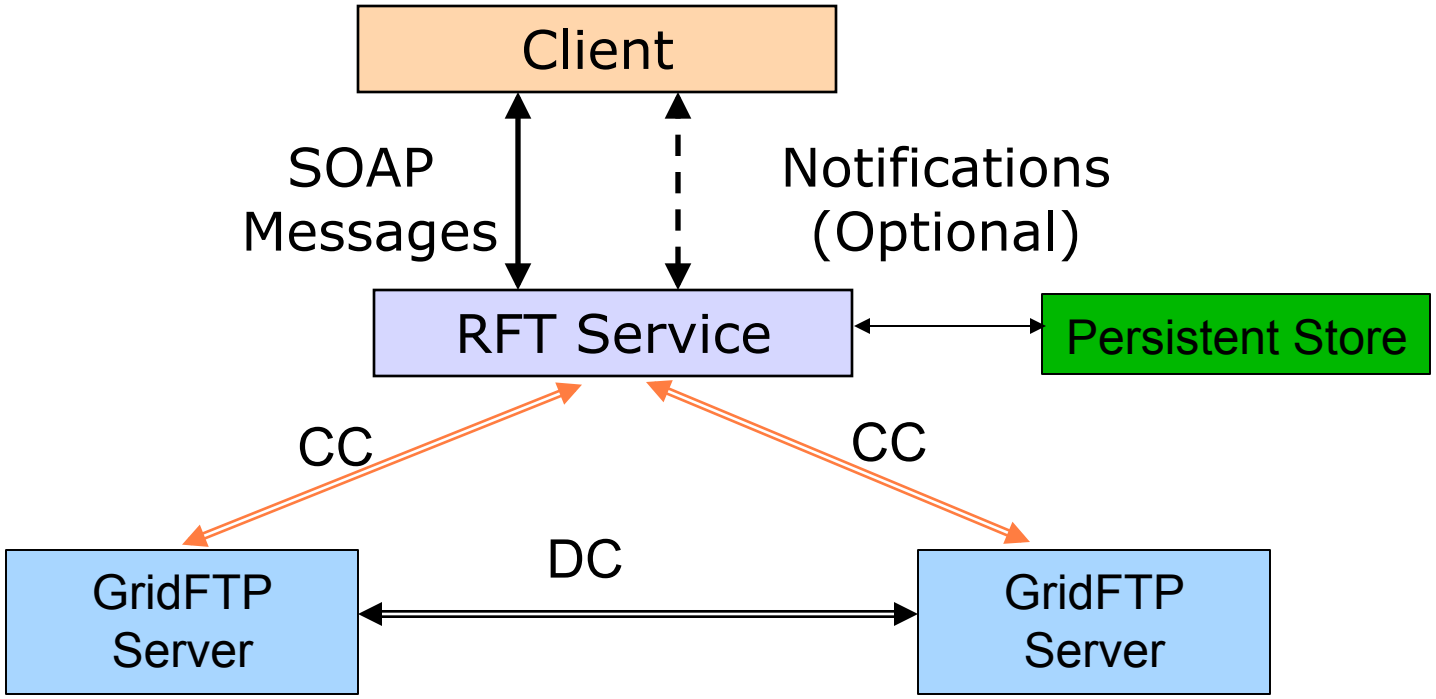
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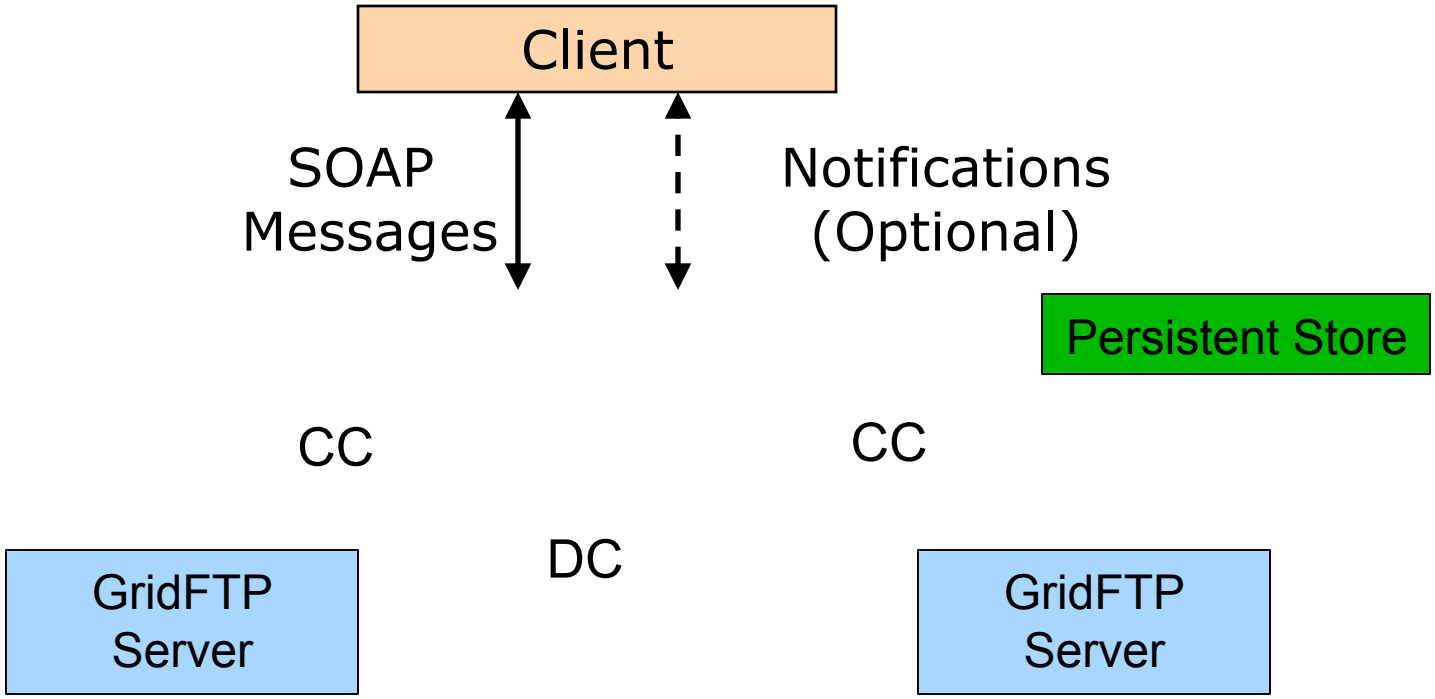
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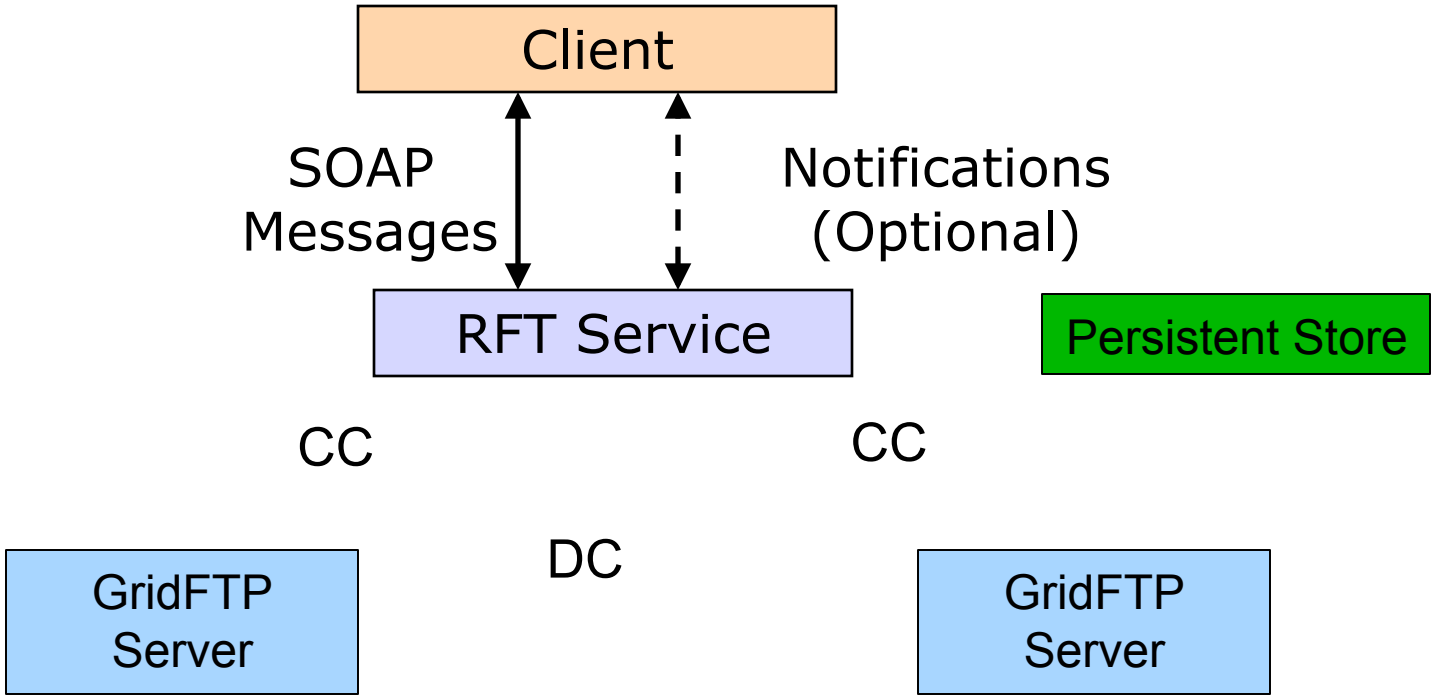
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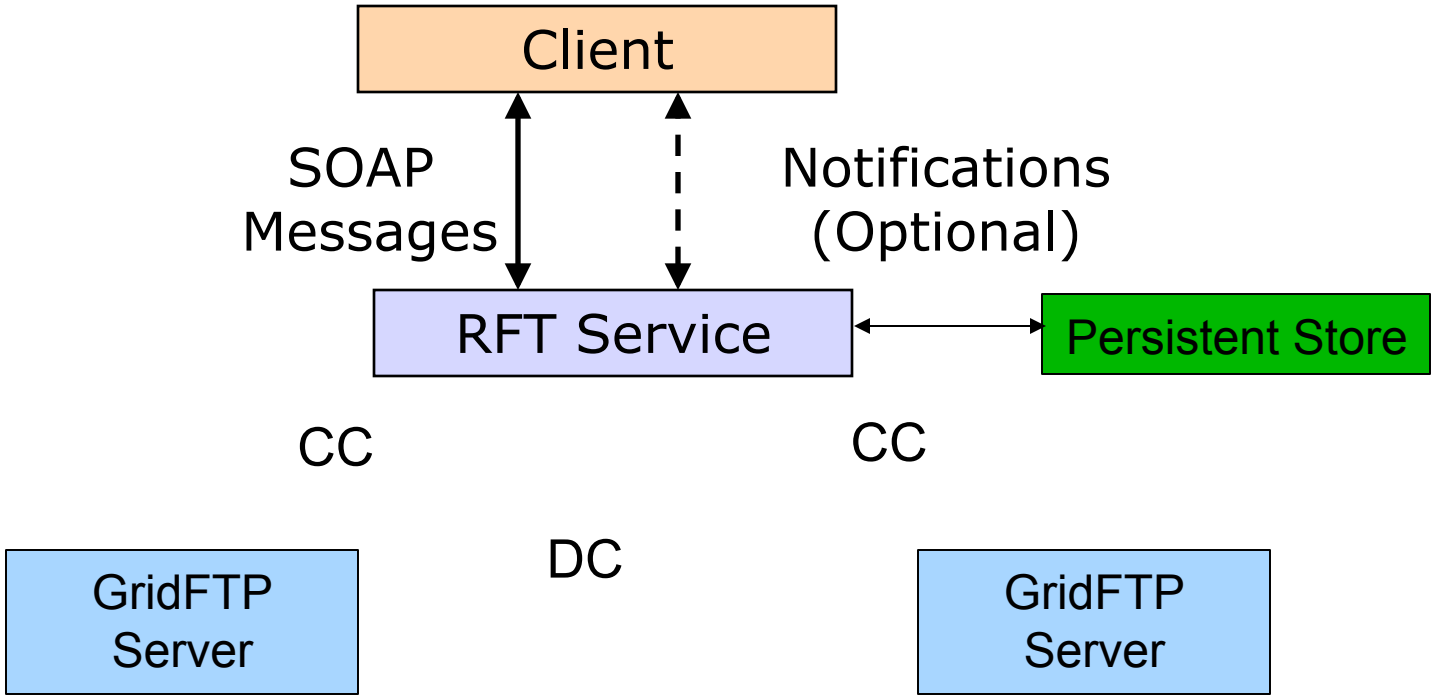
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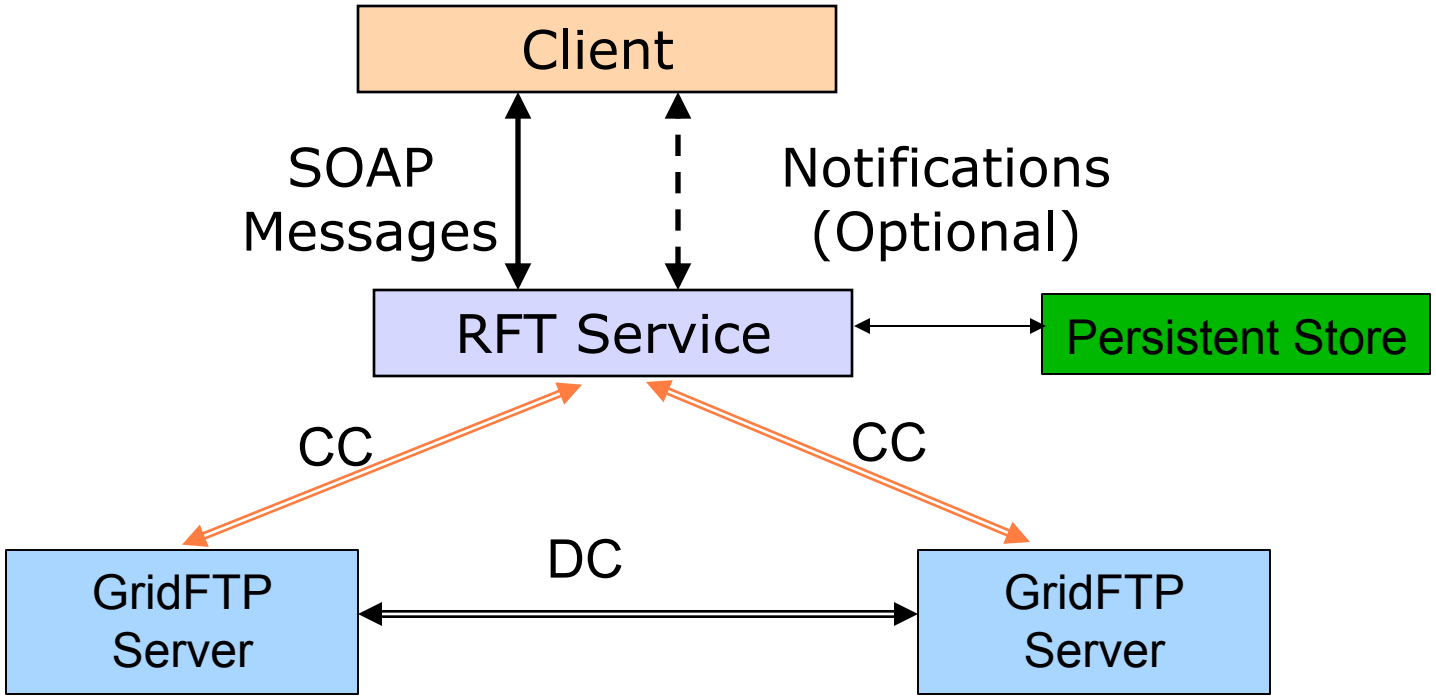
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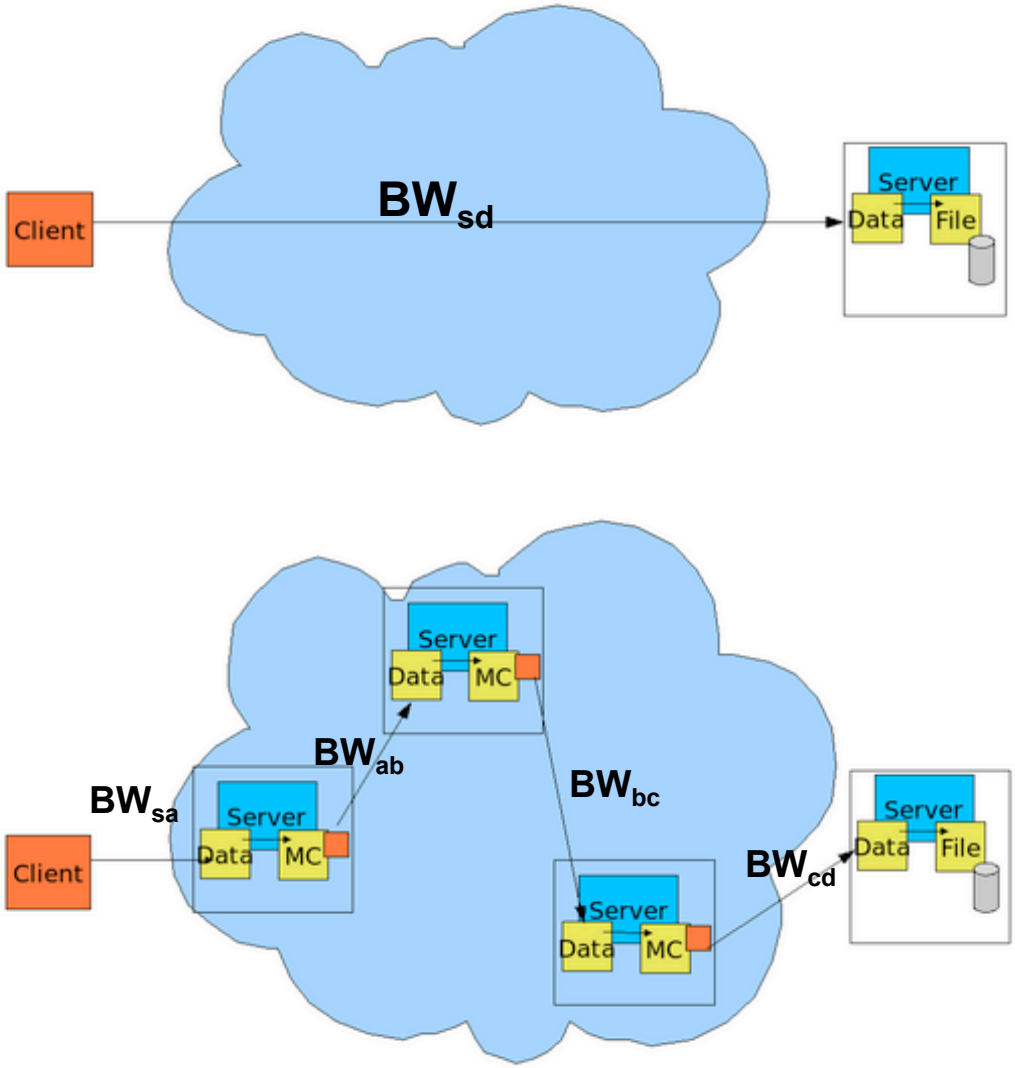
- Standard ✓
- Robust ✓
- Easy-to-use ✓

GridFTP

GridFTP Overlay Network



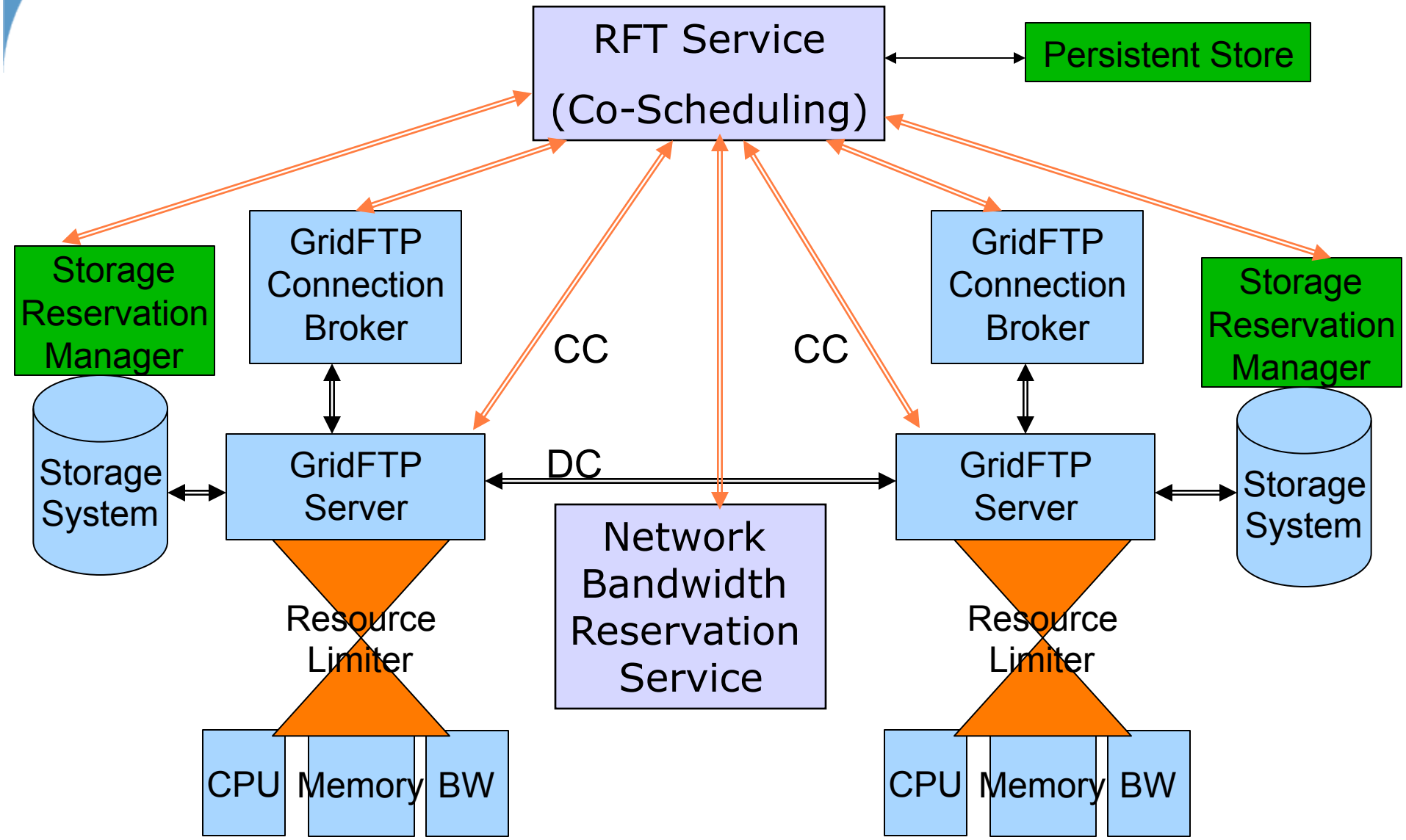
If Min(BW_{sa} , BW_{ab} , BW_{bc} , BW_{cd}) > BW_{sd},

Overlay route yields better performance

Best effort service

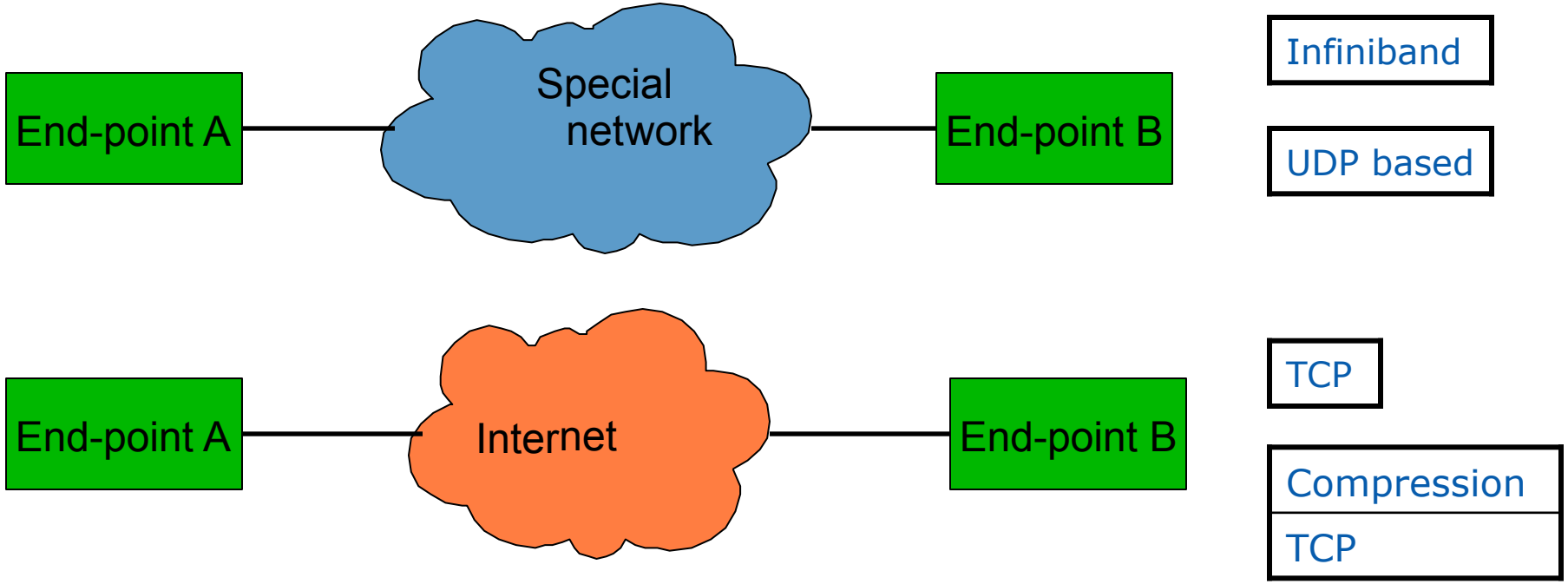
- Data movement in distributed environments is on best effort basis
- No Quality of Service (QoS) guarantees
- Network is shared
- Limited disk space
  - Destination might run out of space in the middle of a transfer
- End node, network, disk can fail any time

Managed Data Movement



Dynamic Selection of Protocols

- Compose protocol stack based on user needs and underlying network capabilities



Acknowledgments

- John Bresnahan
- Mike Link
- Ravi Madduri
- Martin Feller
- Gaurav Khanna
- Liu Wantao

Questions