Data Replication in LIGO

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Outline

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- Basic Data Challenge
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LIGO, LIGO science

Facility dedicated to detection and use of cosmic gravitational waves

Two sites: Livingston, LA and Hanford, WA

Three interferometers: Two in Hanford, one in Livingston

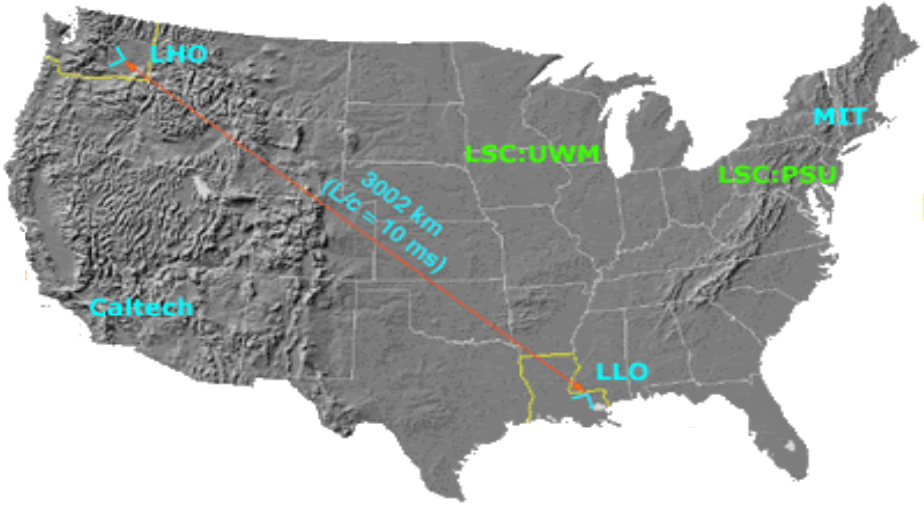
Partnership with Virgo (Italy and France) and GEO (Germany and the United Kingdom)

LIGO is supported by the NSF

4 km LIGO interferometer in Livingston, LA

LIGO Scientific Collaboration

The LIGO Scientific Collaboration (LSC) currently includes 428 people at 52 different institutions; data replication mainly occurs at Caltech, MIT, interferometer sites Livingston and Hanford, UWM, Penn State, Albert Einstein Institute (Germany), Cardiff (UK), Birmingham (UK)



Basic Data Challenge

- Basic issue is to distribute approx. one TB raw data / day to all sites
  - » Data is continually generated at both interferometer sites (LLO and LHO) during “science runs” - long periods of uninterrupted data collection ; current is S5 and has lasted over a year and a half
  - » Caltech (CIT) retrieves the data from the LHO and LLO sites and provides access to it for “Tier-2” sites (all sites besides CIT, LLO and LHO)
  - » Tier-2 sites replicate from CIT or other sites that have already transferred desired data
  - » Processed data sets (e.g., filtered or calibrated) are occasionally created at various sites. They are initially replicated from the site of origin.

Specific Problems & Challenges

Metadata Service

- Require all data to be described in some fashion by a specific metadata schema
- Metadata must be generated continually during a science run
- Must be able to distribute metadata constantly and consistently to each site that needs it
- Example of some metadata fields
  - gpsStart: 815497955 (seconds since beginning of GPS epoch)
  - gpsEnd: 815498048
  - runTag: S5
  - frameType: H1_RDS_C03_L2
  - md5: 28329c0eee60dbbde352a1ba94bca61f

Specific Problems & Challenges

- Storage of data
  - » Each site has their own in-house storage solution
    - – most have some configuration of commodity hard disk drives, CIT uses SAM-QFS (disk and tape)
    - – local filesystems and layout may differ as well, for example:
      - UWM uses 24 NFS-mounted storage servers
      - Cardiff stores on 100 compute nodes
      - CIT has one large filesystem with SAM-QFS
  - » Must provide a way for administrators to store incoming data on their systems in a customizable way

Specific Problems & Challenges

- Data is not distributed equally
  - » Sites must be able to pick and choose what particular data they want to replicate
    - – Driven by users requests
  - » Sites must be able to tell what specific data another site has in order to replicate what it itself needs

- Users need to locate and access data
  - » Computing clusters at all sites; users may be at any one of them
  - » Users must find which sites have the data they want
  - » They must be able to locate and have their computing jobs able to locate the physical location of data at a certain site

LDR

- LDR – Lightweight/LIGO Data Replicator - was created to solve these problems
  - » Lightweight: minimal code base wrapped around other services
  - » LIGO: code is based around LIGO's needs
  - » What data we have
    - – custom metadata service
  - » Where data is located
    - – Globus RLS
  - » Authenticated, fast data transfer
    - – custom GridFTP client, standard server
  - » Ease of data transfer
    - – easy for administrators to pick and choose data to replicate and data to make available

LDR

- LDR runs at each site as a few separate daemons
  - » LDRMaster : monitors other daemons
  - » LDRSchedule: finds and schedules files for transfer
  - » LDRTransfer: supervises transfer and storage of files
  - » LDRMetadataServer: serves local metadata to other sites
  - » LDRMetadataUpdate: updates local metadata database

- Relies on a few other important pieces: MySQL, Globus RLS (Replica Location Service), Globus GridFTP Server, pyGlobus (python port of Globus Toolkit)

LDR

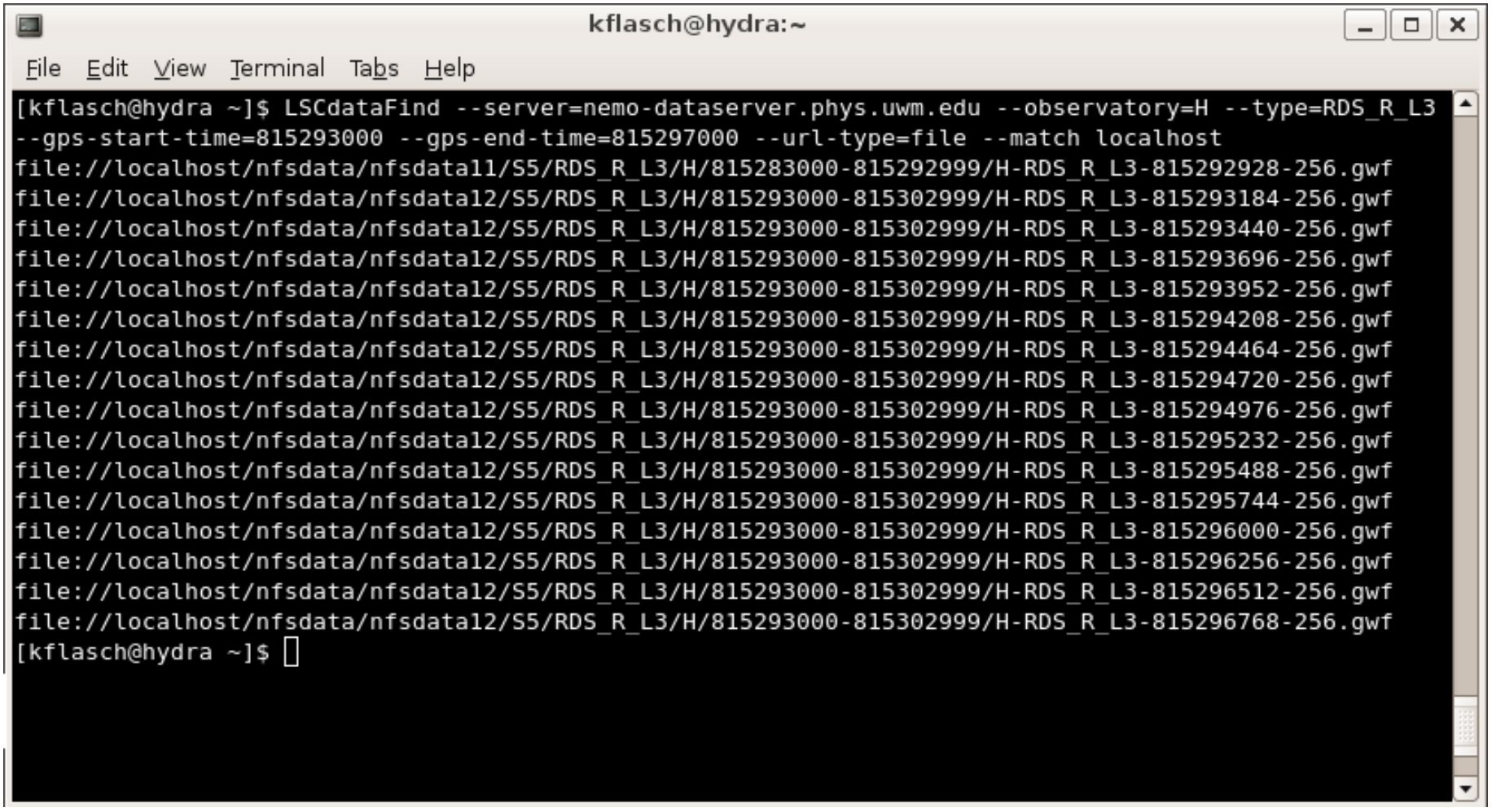
- Each site fulfills certain roles
  - » some publish new data, some provide data, some replicate data (or any combination)
  - » new data is published into metadata catalog and RLS for other sites to replicate

- Local storage
  - » each site has its own storage solution
  - » administrator modifies a “local storage module” to govern how incoming data will be stored and recorded
    - – functions like newHoldingFile(), enterFile(), newFileCallback(), failedTransferCallback()

LDR and LSCdataFind

- Needed a way for users to easily find available data
- Work already done for LDR itself to find data to replicate to other sites, so a user tool was based on the LDR backend: LSCdataFind
- Uses a local RLS and Metadata service to allow users to specify characteristics about data they want (metadata fields like gpsStart, for example) and receive usable physical locations

LSCdataFind Example

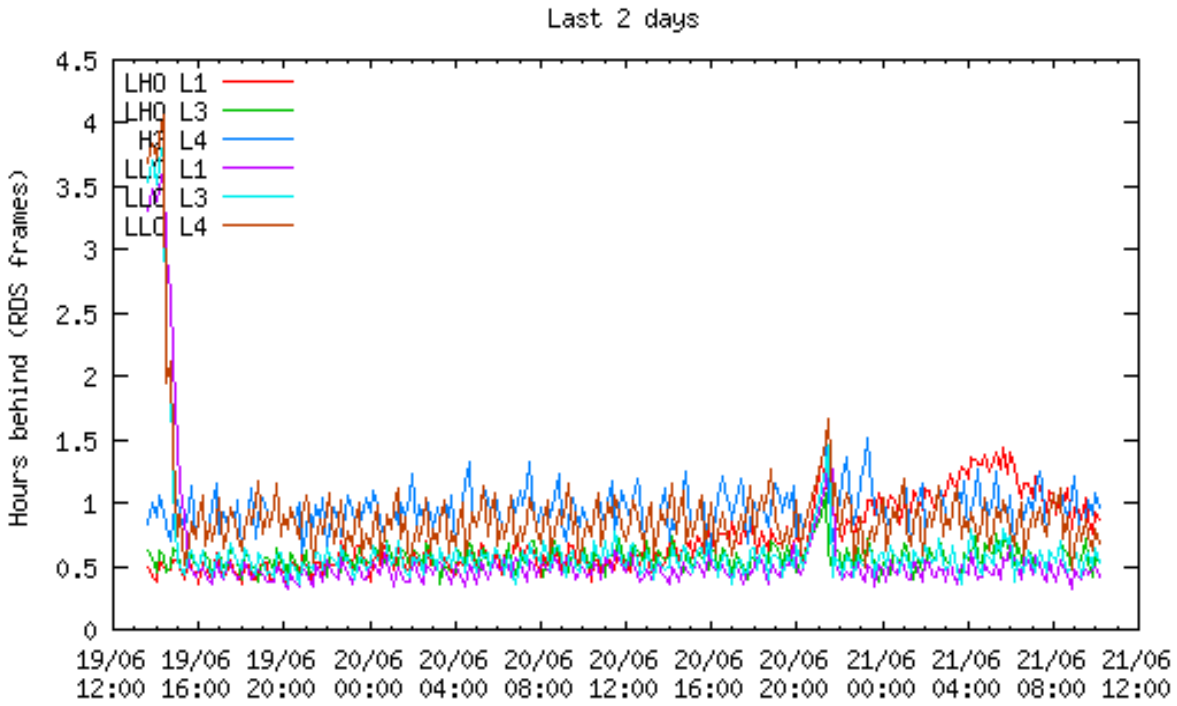


Successes

- Replicated over 770 TB of raw and processed S5 data so far
- Reliable (good enough) transfer rates (10-15 MB/s CIT -> UWM)
- Usable tool (LSCdataFind) for users to locate data at sites
- Small core development team
- Involved community
- Dependable, in production software!

Lag Plot for Data Transfer

Plot of time delay of transfer of data from interferometer sites to CIT for further Tier-2 replication



Warts

- No 24/7 reliability
  - » Issues coping with sites going down
  - » Unintelligent backend doesn't determine best/other places to go
- Had issues with RLS reliability (problems addressed thanks to the RLS team!)
- Not very user/administrator friendly
  - » Relies on learning much new terminology and software and support from the LSC community
  - » Interface is clumsy and obfuscated

Future of LIGO

- Next data run S6 is slated to begin in June of 2009
  - » LDR must be able to scale to amount of data it will need to track and replicate

- Enhanced and Advanced LIGO
  - » Enhanced LIGO (S6) will increase the sensitivity of the interferometers
  - » Advanced LIGO will greatly increase the sensitivity and therefore replication and storage requirements for all new data
  - » Advanced LIGO will also likely involve increased demand for greater turnaround in specific data replication

Future of LDR

- Move Metadata daemons to WSRF-compliant services, probably built on Globus Java WS core
- Integrate Lots Of Small Files / pipelined GridFTP
  - » We replicate many big files, but increasingly more small files such as user processed ones ; pipelining will help us maintain good transfer rates
- Improve monitoring by leveraging Globus MDS 4
- Investigate integrating Globus RFT and Globus DRS
- Focus on stability and scaling...

Scaling

- Metadata
  - about 17,800,000 files tracked at CIT currently; We have managed to continue scaling our metadata services to this point
  - Starting to feel strain and will need to cope with scaling much higher for S6
- Data transfer
  - Current data rates are acceptable and will continue to be
  - No worries about scaling with GridFTP; only limitation is network
- User demands
  - Currently, we are able to handle user requests for data location
  - Expect more users, more queries and faster expected response time

Credits

- Current Development Team
  - Stuart Anderson, Gerald Davies, Kevin Flasch, Filippo Grimaldi, Steffen Grunewald, Ben Johnson, Scott Koranda, Dan Kozak, Greg Mendel, Brian Moe, Murali Ramsunder, David Stops, Igor Yakushin
- Alumni
  - Bruce Allen, Paul Armor, Keith Bayer, Patrick Brady, Junwei Cao, Mike Foster, Tom Kobialka, Adam Mercer
- More information
  - LIGO: http://www.ligo.caltech.edu/
  - UWM LSC: http://www.lsc-group.phys.uwm.edu/
  - LDR: http://www.lsc-group.phys.uwm.edu/LDR/