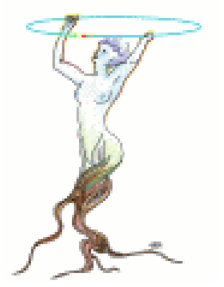


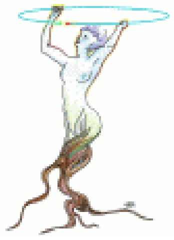
PROOF - Parallel ROOT Facility

Fons Rademakers

http://root.cern.ch

Bring the KB to the PB not the PB to the KB

PROOF



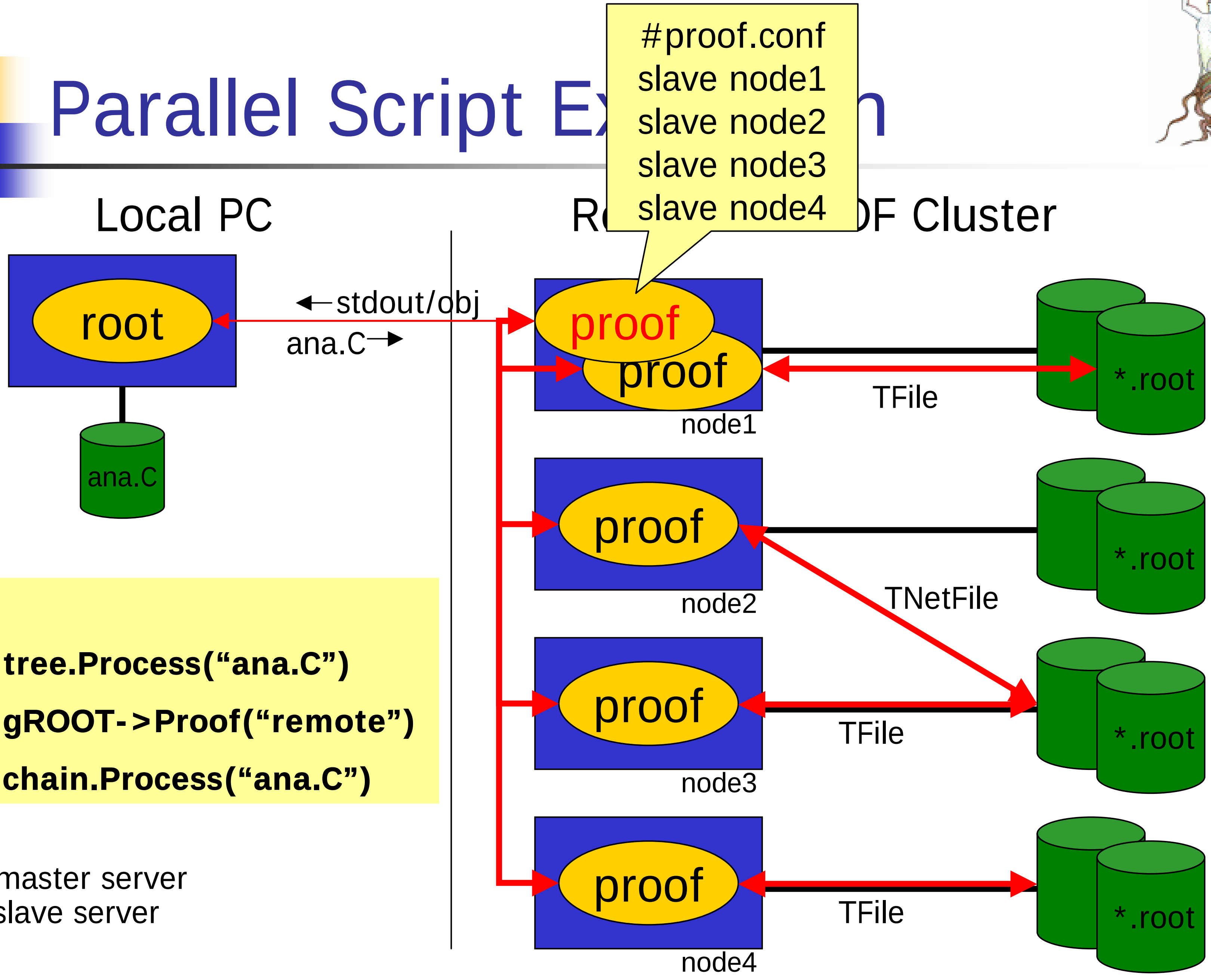
- Collaboration between core ROOT group at CERN and MIT Heavy Ion Group
  - Fons Rademakers
  - Maarten Ballintijn
- Part of and based on ROOT framework
  - uses heavily ROOT networking and other infrastructure classes
- Currently no external technologies

Parallel ROOT Facility

- The PROOF system allows:
  - parallel analysis of trees in a set of files
  - parallel analysis of objects in a set of files
  - parallel execution of scripts

  on clusters of heterogeneous machines
- Its design goals are:
  - transparency, scalability, adaptability
- Prototype developed in 1997 as proof of concept, full version nearing completion now

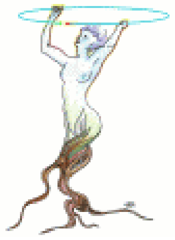
Parallel Script Ex n



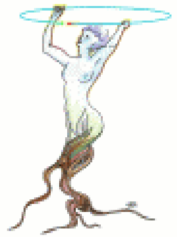
```
$ root
root [0] tree.Process(“ana.C”)
root [1] gROOT->Proof(“remote”)
root [2] chain.Process(“ana.C”)
```

proof = master server
proof = slave server

Data Access Strategies



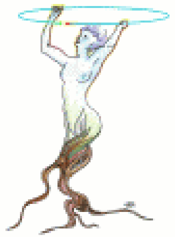
- Each slave get assigned, as much as possible, packets representing data in local files
- If no (more) local data, get remote data via rootd and rfio (needs good LAN, like GB eth)
- In case of SAN/NAS just use round robin strategy



PROOF Transparency

- On demand, make available to the PROOF servers any objects created in the client
- Return to the client all objects created on the PROOF slaves
  - the master server will try to add “partial” objects coming from the different slaves before sending them to the client

PROOF Scalability



- Scalability in parallel systems is determined by the amount of communication overhead (Amdahl's law)
- Varying the packet size allows one to tune the system. The larger the packets the less communications is needed, the better the scalability
  - Disadvantage: less adaptive to varying conditions on slaves

PROOF Adaptability

- Adaptability means to be able to adapt to varying conditions (load, disk activity) on slaves
- By using a “pull” architecture the slaves determine their own processing rate and allows the master to control the amount of work to hand out
    - disadvantage: too fine grain packet size tuning hurts scalability

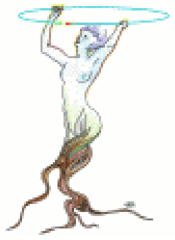
PROOF Error Handling

- Handling death of PROOF servers
  - death of master
    - fatal, need to reconnect
  - death of slave
    - master can resubmit packets of death slave to other slaves
- Handling of ctrl-c
  - OOB message is send to master, and forwarded to slaves, causing soft/hard interrupt

PROOF Authentication

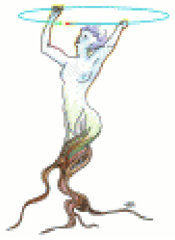
- PROOF supports secure and un-secure authentication mechanisms
  - Un-secure
    - mangled password send over network
  - Secure
    - SRP, Secure Remote Password protocol (Stanford Univ.), public key technology
    - Kerberos5
    - Soon: Globus authentication

PROOF Grid Interface



- PROOF can use a Grid Resource Broker to detect which nodes in a cluster can be used in the parallel session
- PROOF can use Grid File Catalogue and Replication Manager to map LFN's to chain of PFN's
- PROOF can use Grid Monitoring Services
- Access will be via abstract Grid interface

Running a PROOF Job



```
// Analyze TChains in parallel

gROOT->Proof();
TChain *chain = new TChain(“AOD");
chain->Add("lfn://alien.cern.ch/alice/prod2002/file1");
. . .
chain->Process(“myselector.C”);
```

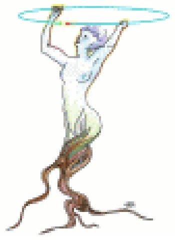
```
// Analyze generic data sets in parallel

gROOT->Proof();
TDSet *objset = new TDSet("MyEvent", "*", "/events");
objset->Add("lfn://alien.cern.ch/alice/prod2002/file1");
. . .
objset->Add(set2003);
objset->Process(“myselector.C++”);
```

Different PROOF Scenarios – Static, stand-alone

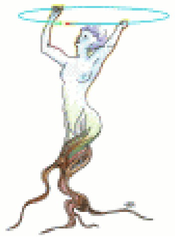
- This scheme assumes:
  - no third party grid tools
  - remote cluster containing data files of interest
  - PROOF binaries and libs installed on cluster
  - PROOF daemon startup via (x)inetd
  - per user or group authentication setup by cluster owner
  - static basic PROOF config file
- In this scheme the user knows his data sets are on the specified cluster. From his client he initiates a PROOF session on the cluster. The master server reads the config file and fires as many slaves as described in the config file. User issues queries to analyse data in parallel and enjoy near real-time response on large queries.
- Pros: easy to setup
- Cons: not flexible under changing cluster configurations, resource availability, authentication, etc.

Different PROOF Scenarios – Dynamic, PROOF in Control



- This scheme assumes:
  - grid resource broker, file catalog, meta data catalog, possible replication manager
  - PROOF binaries and libraries installed on cluster
  - PROOF daemon startup via (x)inetd
  - grid authentication
- In this scheme the user queries a metadata catalog to obtain the set of required files (LFN's), then the system will ask the resource broker where best to run depending on the set of LFN's, then the system initiates a PROOF session on the designated cluster. On the cluster the slaves are created by querying the (local) resource broker and the LFN's are converted to PFN's. Query is performed.
- Pros: use grid tools for resource and data discovery. Grid authentication.
- Cons: require preinstalled PROOF daemons. User must be authorized to access resources.

Different PROOF Scenarios – Dynamic, AliEn in Control

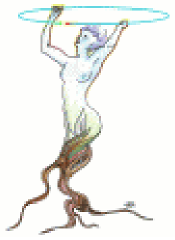


- This scheme assumes:
  - AliEn as resource broker and grid environment (taking care of authentication, possible via Globus)
  - AliEn file catalog, meta data catalog, and replication manager
- In this scheme the user queries a metadata catalog to obtain the set of required files (LFN's), then hands over the PROOF master/slave creation to AliEn via an AliEn job. AliEn will find the best resources, copy the PROOF executables and start the PROOF master, the master will then connect back to the ROOT client on a specified port (callback port was passed as argument to AliEn job). In turn the slave servers are started again via the same mechanism. Once connections have been setup the system proceeds like in example 2.
- Pros: use AliEn for resource and data discovery. No pre-installation of PROOF binaries. Can run on any AliEn supported cluster. Fully dynamic.
- Cons: no guaranteed direct response due to the absence of dedicated "interactive" queues.

Different PROOF Scenarios – Dynamic, Condor in Control

- This scheme assumes:
  - Condor as resource broker and grid environment (taking care of authentication, possible via Globus)
  - Grid file catalog, meta data catalog, and replication manager
- This scheme is basically same as previous AliEn based scheme. Except for the fact that in the Condor environment Condor manages free resources and as soon as a slave node is reclaimed by its owner, it will kill or suspend the slave job. Before any of those events Condor will send a signal to the master so that it can restart the slave somewhere else and/or re-schedule the work of that slave on the other slaves.
- Pros: use grid tools for resource and data discovery. No pre-installation of PROOF binaries. Can run on any Condor pool. No specific authentication. Fully dynamic.
- Cons: no guaranteed direct response due to the absence of dedicated "interactive" queues. Slaves can come and go.

TGrid Class – Abstract Interface to AliEn



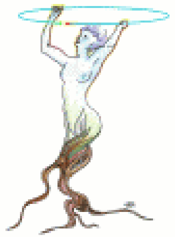
```
class TGrid : public TObject {
public:
   virtual Int_t        AddFile(const char *lfn, const char *pfn) = 0;
   virtual Int_t        DeleteFile(const char *lfn) = 0;
   virtual TGridResult *GetPhysicalFileNames(const char *lfn) = 0;
   virtual Int_t        AddAttribute(const char *lfn,
                                     const char *attrname,
                                     const char *attrval) = 0;
   virtual Int_t        DeleteAttribute(const char *lfn,
                                        const char *attrname) = 0;
   virtual TGridResult *GetAttributes(const char *lfn) = 0;
   virtual void         Close(Option_t *option="") = 0;

   virtual TGridResult *Query(const char *query) = 0;

   static TGrid *Connect(const char *grid, const char *uid = 0,
                         const char *pw = 0);

   ClassDef(TGrid,0)  // ABC defining interface to GRID services
};
```

Running PROOF Using AliEn



```
TGrid *alien = TGrid::Connect(“alien”);

TGridResult *res;
res = alien->Query(“lfn:///alice/simulation/2001-04/V0.6*.root“);

TDSet *treeset = new TDSet("TTree", "AOD");
treeset->Add(res);

gROOT->Proof(res);   // use files in result set to find remote nodes
treeset->Process(“myselector.C”);

// plot/save objects produced in myselector.C
. . .
```