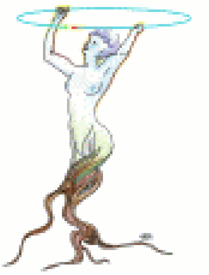
PROOF and ROOT Grid Features

Fons Rademakers



PROOF - Parallel ROOT Facility

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

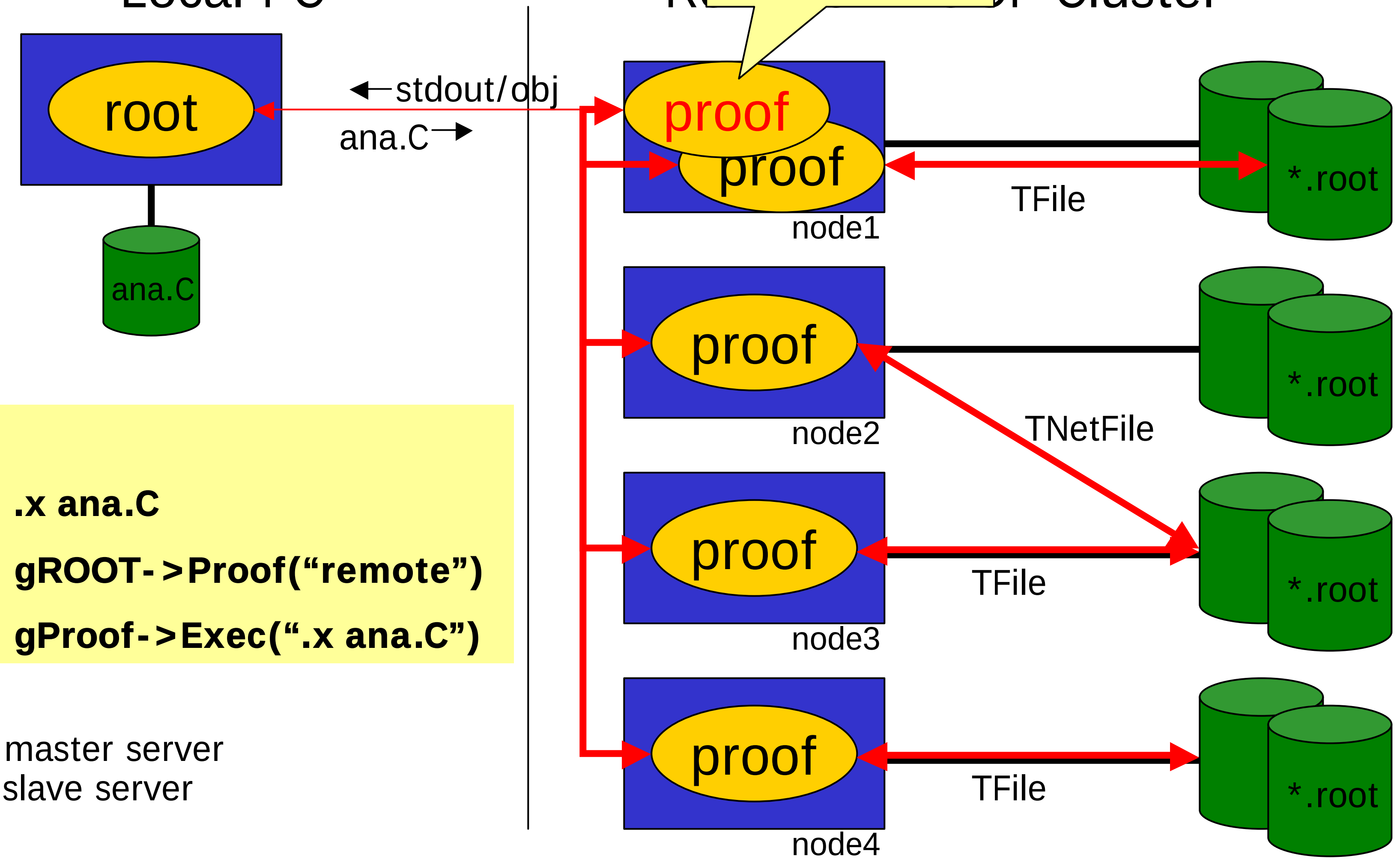
Parallel ROOT Facility

- The PROOF system allows:
  - parallel execution of scripts
  - parallel analysis of chains of trees

  on clusters of heterogeneous machines
- Its design goals are:
  - transparency, scalability, adaptivity
- Prototype developed in 1997 as proof of concept (only for simple queries resulting in 1D histograms)

Parallel Script Ex n

```
#proof.conf
slave node1
slave node2
slave node3
slave node4
```



```
$ root
root [0] .x ana.C
root [1] gROOT->Proof("remote")
root [2] gProof->Exec(".x ana.C")
```

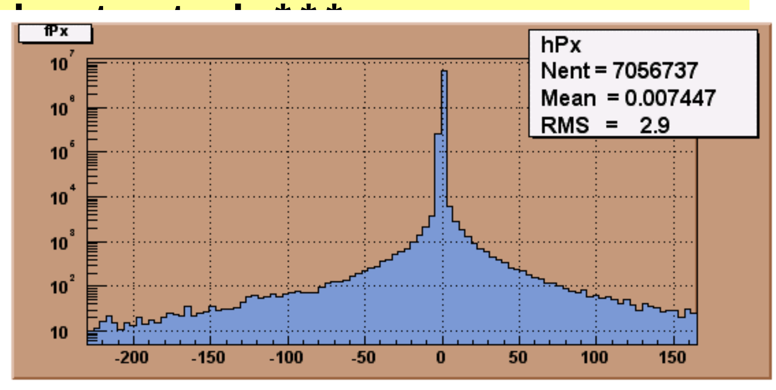
proof = master server
proof = slave server

PROOF Aware ROOT Script

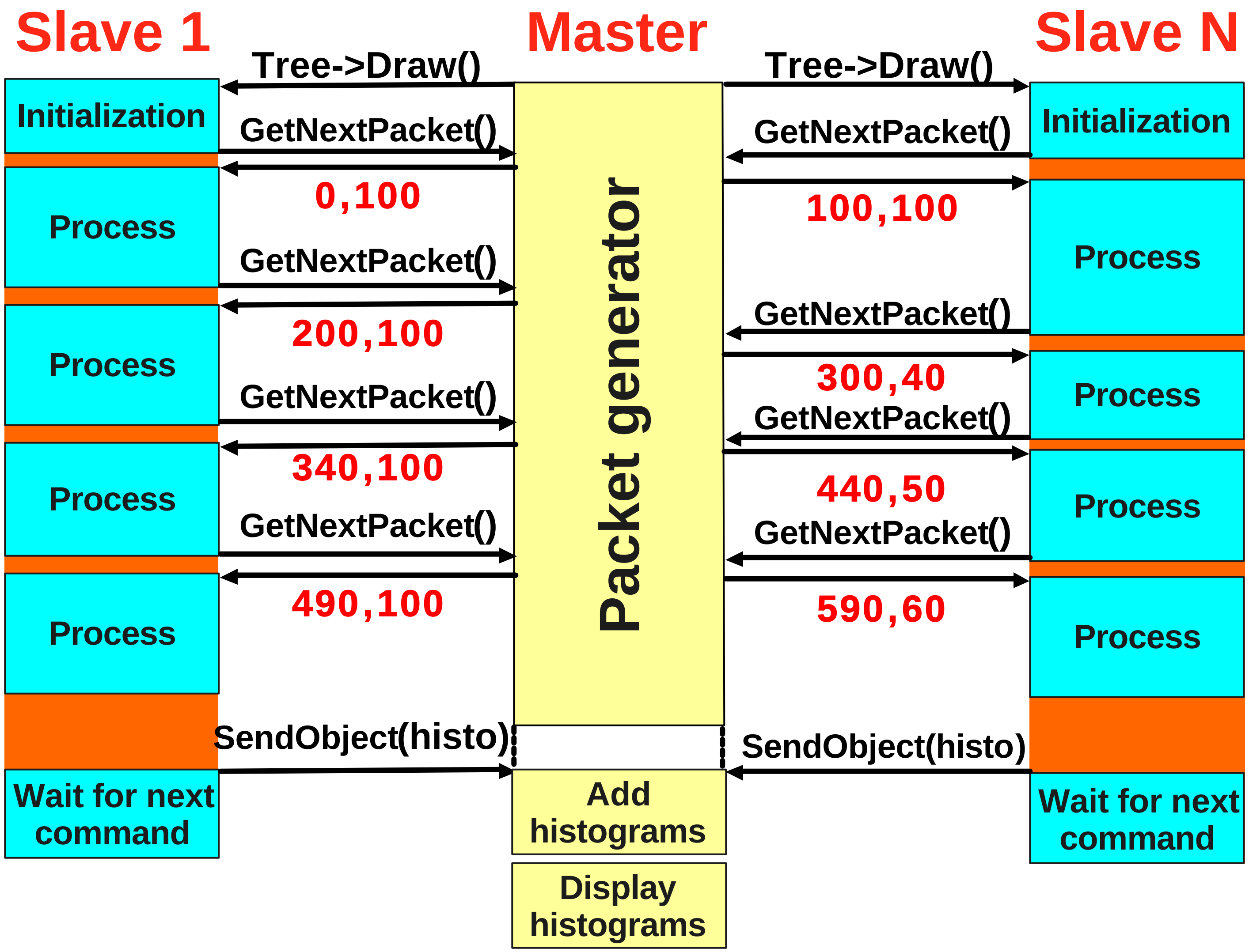
```
void ana {
   if (gROOT->IsProofServ()) {
      if (gProofServ->IsMaster()) {
         printf("Macro running on master server\n");
         // single remote init
      } else {
         printf("Macro running on %d of %d\n", gProofServ->GetGroupId(),
                gProofServ->GetGroupSize());
         // parallel remote init
      }
   } else {
      printf("Macro running in local ROOT session\n");
      // local init
   }
   ...
}
```

Parallel Tree Analysis

```
root [0] .! ls -l run846_tree.root
-rw-r-r--  1  rdm    cr   598223259  Feb 1  16:20  run846_tree.root

root [1] TFile f("run846_tree.root")

root [2] gROOT->Time()

root [3] T49->Draw("fPx")
Real time 0:0:11, CP time 10.860

root [4] gROOT->Proof()
*** Proof slave server : pcna49a.cern.ch started ***
*** Proof slave server : pcna49b.cern.c
*** Proof slave server : pcna49c.cern.c
*** Proof slave server : pcna49d.cern.c
*** Proof slave server : pcna49e.cern.c
Real time 0:0:4, CP time 0.140

root [5] T49->Draw("fPx")
Real time 0:0:3, CP time 0.240
```



Workflow For Tree Analysis



Slave 1

Master

Slave N

Tree->Draw()

Tree->Draw()

Initialization

GetNextPacket()

0,100

Process

GetNextPacket()

200,100

Process

GetNextPacket()

340,100

Process

GetNextPacket()

490,100

Process

SendObject(histo)

Wait for next command

Packet generator

Add histograms

Display histograms

Initialization

GetNextPacket()

100,100

Process

GetNextPacket()

300,40

Process

GetNextPacket()

440,50

Process

GetNextPacket()

590,60

Process

SendObject(histo)

Wait for next command

PROOF Session Statistics

```
root [6] T49->Print("p")
Total events processed:                     10585
Total number of packets:                    147
Default packet size:                        100
Smallest packet size:                       20
Average packet size:                        72.01
Total time (s):                             2.78
Average time between packets (ms):          10.93
Shortest time for packet (ms):              99
Number of active slaves:                    5
   Number of events processed by slave 0: 1890
   Number of events processed by slave 1: 2168
   Number of events processed by slave 2: 2184
   Number of events processed by slave 3: 2667
   Number of events processed by slave 4: 1676
```

PROOF Error Handling

- Handling death of PROOF servers
  - death of master
    - fatal, need to reconnect
  - death of slave
    - master will 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
    - Soon: Globus authentication

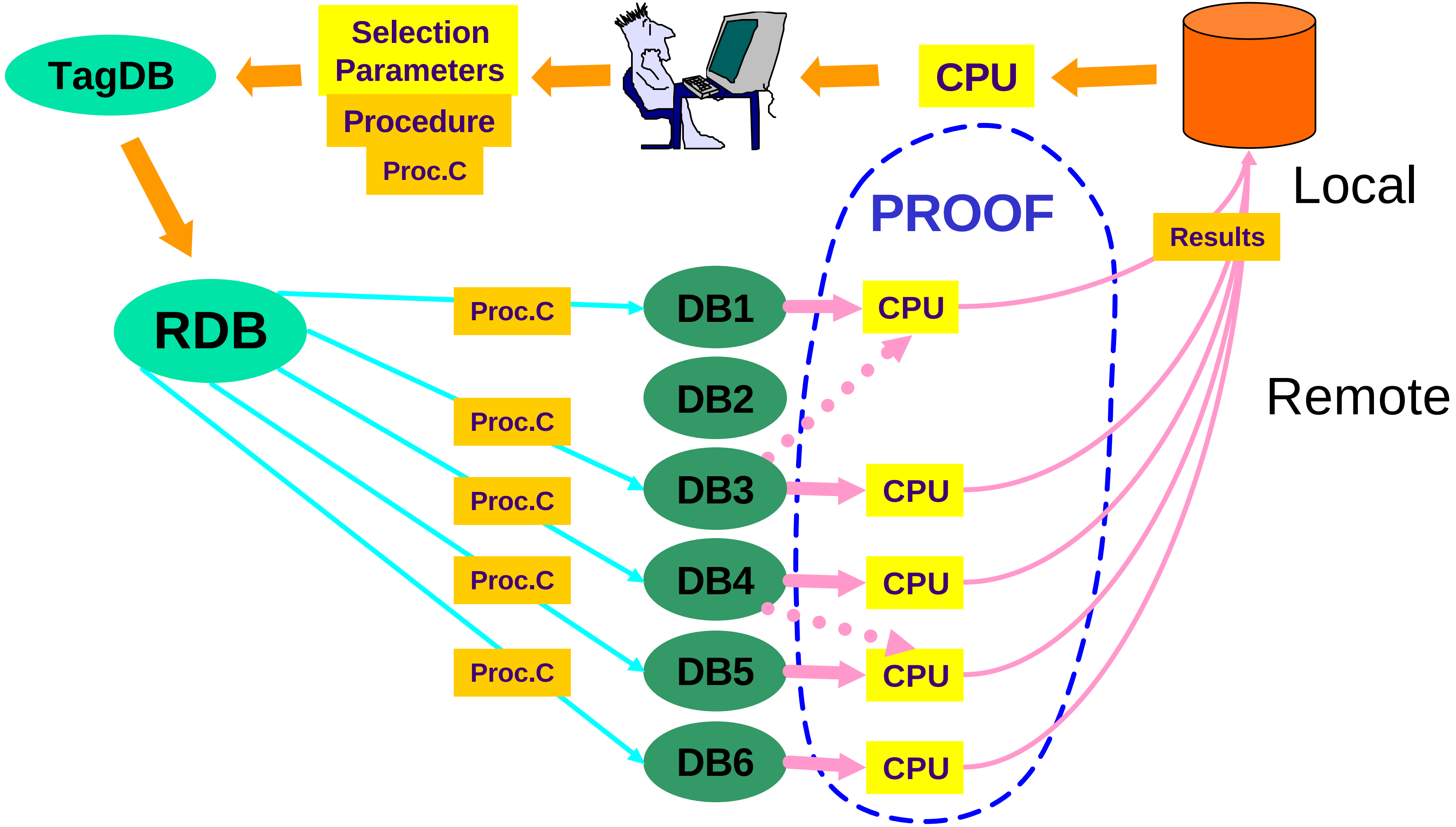
PROOF Grid Interface

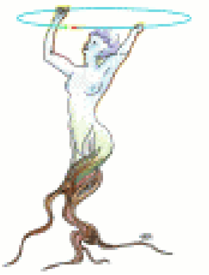
- PROOF can use Grid Resource Broker to detect which nodes in a cluster can be used in the parallel session
- PROOF can use Grid File Catalogue and Replication Manager to map LFN's to chain of PFN's
- PROOF can use Grid Monitoring Services

Setting Up PROOF

- Install ROOT system
- For automatic execution of daemons add proofd and rootd to /etc/inetd.conf and /etc/services (not mandatory, servers can be started by users)
  - The rootd (1094) and proofd (1093) port numers have been officially assigned by IANA
- Setup proof.conf file describing cluster
- Setup authentication files (globally, users can override)

PROOF and the GRID





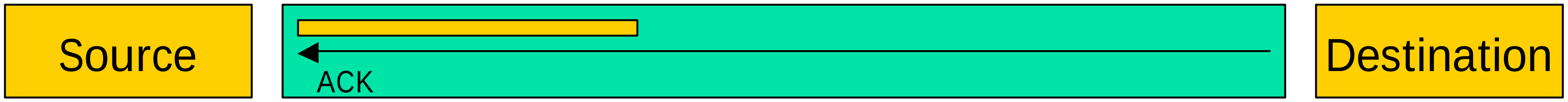
New Grid Features in ROOT

Main Grid Issues

- Distributed computing over wide area networks (WAN's). Requires:
  - efficient use of WAN pipes
  - user authentication
  - file catalogue and file replication
  - resource allocation and brokering
  - resource monitoring
  - etc.

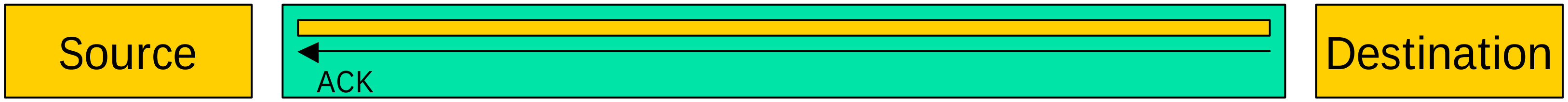
Long Fat Pipes

- Long fat pipes are WAN links with a large bandwidth*delay product
- For optimal performance keep pipe full
- By default this is not the case
  - maximum TCP buffer size is 64KB
  - for a pipe with a 192KB bandwidth*delay product the pipe is empty 60% of the time



TCP Window Scaling (RFC 1323)

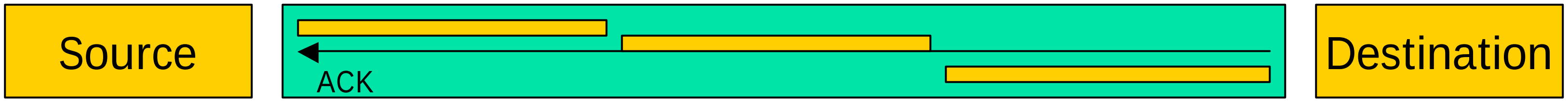
- A solution is to use a TCP buffer size equal to the bandwidth*delay product
- This support for large TCP buffers (window scaling) is described in RFC 1323



- Problem: system administrators are needed to change maximum TCP buffer sizes on source and destination machines, e.g. for Linux:
  - echo 200000 > /proc/sys/net/core/rmem_max

Parallel Sockets

- Buffer is striped over multiple sockets in equal parts
- Ideal number of parallel sockets depends on bandwidth*delay product (assuming default 64KB TCP buffer size). No system manager needed to tune network

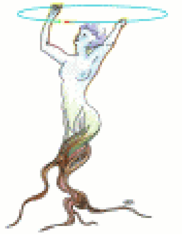


- Same performance as with large buffers

New Grid Features in ROOT

- Parallel socket classes, TPSocket and TPServerSocket, that derive from TSocket and TServerSocket
- TNetFile and rootd daemon modified to use parallel sockets
- New TFTP class using parallel sockets and rootd daemon

Parallel FTP



- Parallel FTP via the TFTP class and the rootd daemon
- Uses the TPSocket class
- Supports all standard ftp commands
- Anonymous ftp
- Performance, CERN - GSI:
  - wu-ftp: 1.4 MB/s
  - TFTP: 2.8 MB/s

Coming soon...

- Interface to Grid authentication service
- Interface to Grid file catalog
- Interface to Grid resource broker