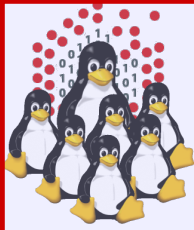


Installation Procedures for Clusters

PART 3 – Cluster Management
Tools and Security

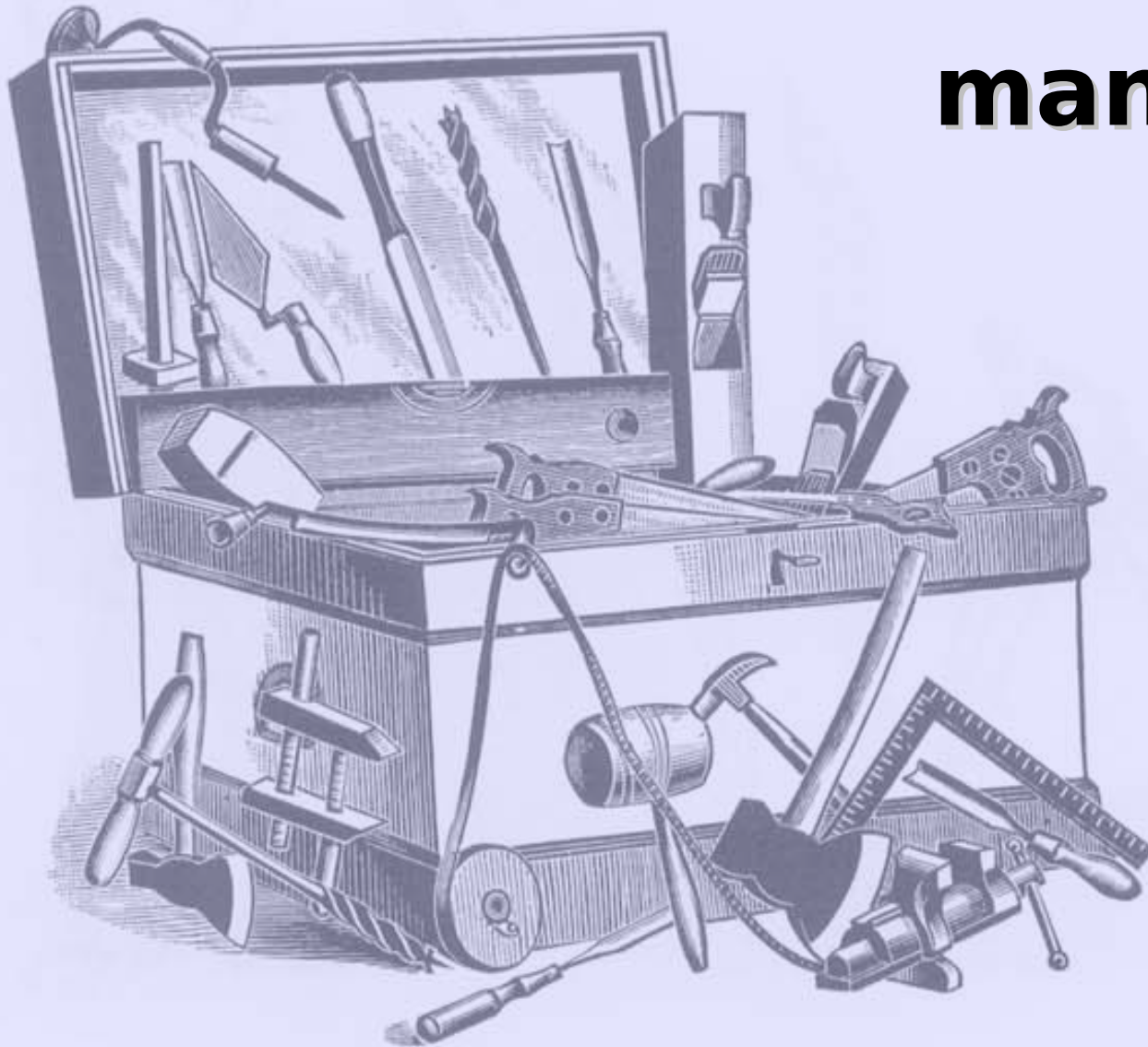




Agenda

- Cluster Services
- Overview on Installation Procedures
- Configuration and Setup of a NETBOOT Environment
- Troubleshooting
- **Cluster Management Tools**
- **Notes on Security**
- Hands-on Laboratory Session

Cluster management tools





CLUSTER MANAGEMENT Administration Tools

Requirements:

- ✓ cluster-wide command execution
- ✓ cluster-wide file distribution and gathering
- ✓ password-less environment
- ✓ must be simple, efficient, easy to use for CLI addicted

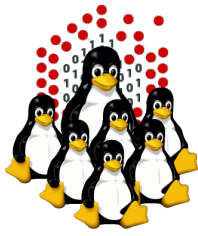




CLUSTER MANAGEMENT Administration Tools

- C3 tools – The Cluster Command and Control tool suite
 - ◆ allows configurable clusters and subsets of machines
 - ◆ concurrently execution of commands
 - ◆ supplies many utilities
 - ➔ cexec (parallel execution of standard commands on all cluster nodes)
 - ➔ cexecs (as the above but serial execution, useful for troubleshooting and debugging)
 - ➔ cpush (distribute files or directories to all cluster nodes)
 - ➔ cget (retrieves files or directory from all cluster nodes)
 - ➔ crm (cluster-wide remove)
 - ➔ ... and many more
- PDSH – Parallel Distributed SHell
 - ◆ same features as C3 tools, few utilities
 - ➔ pdsh, pdcp, rpdcp, dshbak
- Cluster-Fork – NPACI Rocks
 - ◆ serial execution only
- ClusterSSH
 - ◆ multiple xterm windows handled through one input grabber
 - ◆ Spawn an xterm for each node! DO NOT EVEN TRY IT ON A LARGE CLUSTER!





CLUSTER MANAGEMENT Monitoring Tools

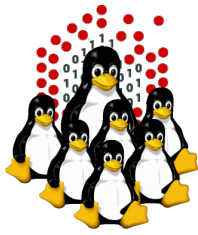
- Ad-hoc scripts (BASH, PERL, ...) + cron

- **Ganglia**

- excellent graphic tool
- XML data representation
- web-based interface for visualization
- <http://ganglia.sourceforge.net/>

- **Nagios[®]**

- complex but can interact with other software
- configurable alarms, SNMP, E-mail, SMS, ...
- optional web interface
- <http://www.nagios.org/>

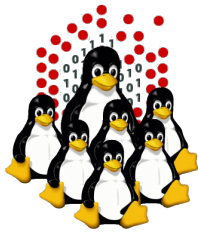


CLUSTER MONITORING

About Ganglia

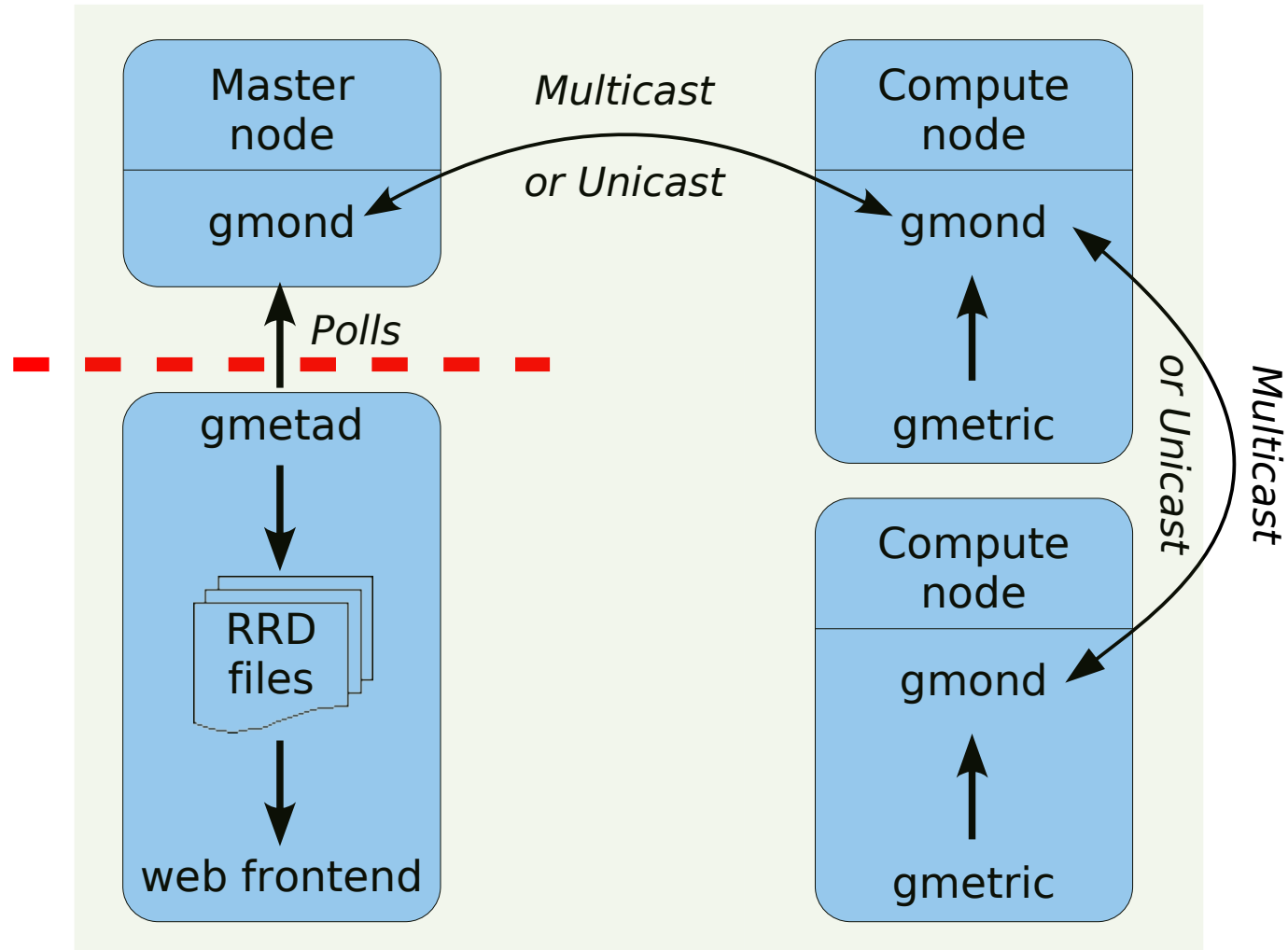


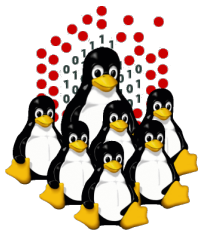
- is a cluster-monitoring program
- a web-based front-end displays real-time data (aggregate cluster and each single system)
- collects and communicates the host state in real time (a multithreaded daemon process runs on each cluster node)
- monitors a collection of metrics (CPU load, memory usage, network traffic, ...)
- *gmetric* allows to extend the set of metrics to monitor



CLUSTER MONITORING

About Ganglia - Components





CLUSTER MONITORING Ganglia at work /1



DEMOCRITOS/SISSA Grid >

Name / Info

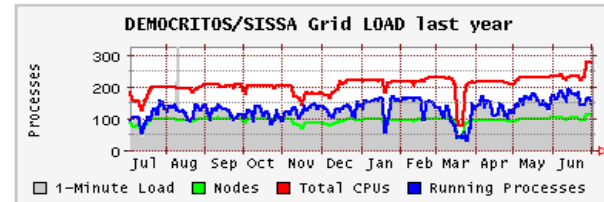
[DEMOCRITOS/SISSA Grid \(4 sources\)](#) (tree view)

Hosts up: 113
(276 CPUs Total)

Hosts down: 1

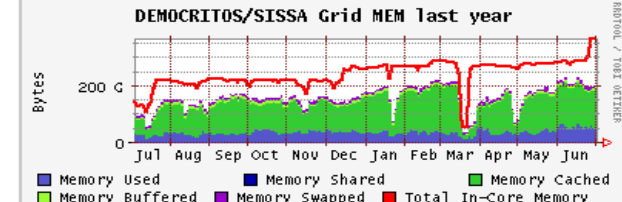
Load Averages

124.76 124.33 124.26



%CPU User, Nice, System, Idle

45.5 1.3 1.0 52.6



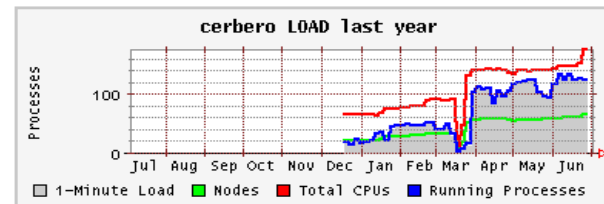
[cerbero](#) (physical view)

Cluster Localtime:
July 2, 2006, 9:19 pm

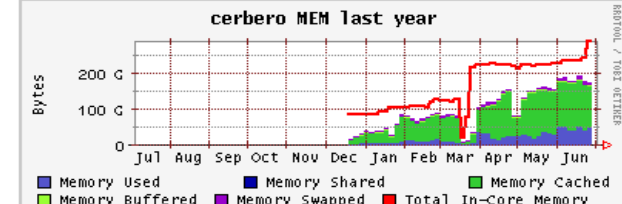
Hosts up: 70
(188 CPUs Total)

Hosts down: 0

111.72 111.80 112.15



65.4 2.1 1.5 29.7



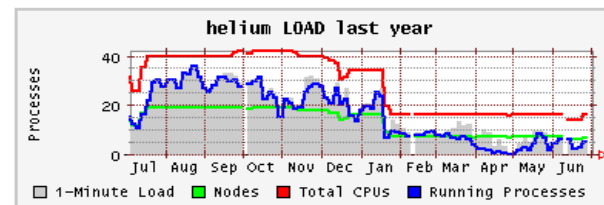
[helium](#) (physical view)

Cluster Localtime:
July 2, 2006, 9:19 pm

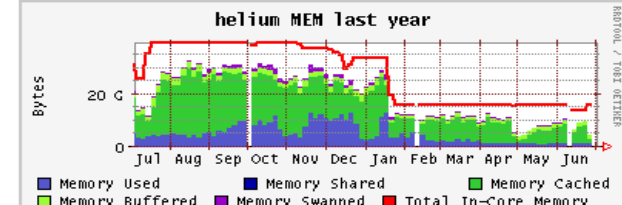
Hosts up: 7
(16 CPUs Total)

Hosts down: 0

4.00 4.00 3.75



28.6 0.0 0.0 71.4



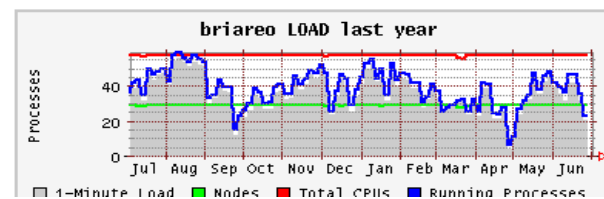
[briareo](#) (physical view)

Cluster Localtime:
July 2, 2006, 9:19 pm

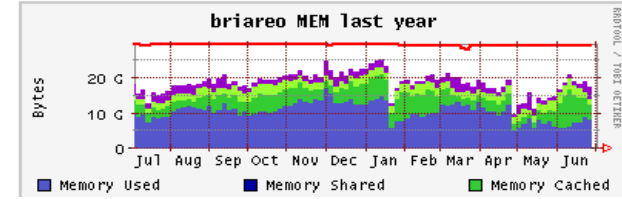
Hosts up: 29
(58 CPUs Total)

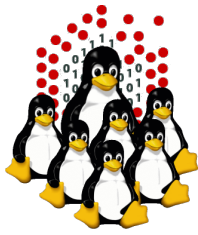
Hosts down: 0

8.73 8.49 8.35



12.4 0.0 0.4 92.1





CLUSTER MONITORING Ganglia at work /2



DEMOCRITOS/SISSA Grid > cerbero > a103.hpc

a103.hpc Overview

This node is up and running

Time and String Metrics	
Name	Value
boottime	Thu, 27 Apr 2006 08:50:03 +0200
gexec	OFF
machine_type	x86_64
os_name	Linux
os_release	2.6.13.3
sys_clock	Thu, 27 Apr 2006 08:51:14 +0200
uptime	66 days, 12:33

Constant Metrics	
Name	Value
cpu_idle	17.5 %
cpu_num	4
cpu_speed	2192 MHz
mem_total	4059676 KB
mtu	1500 B
swap_total	4192956 KB

Graphs of Volatile Metrics. Range

DEMOCRITOS/SISSA Grid > cerbero > a103.hpc

a103.hpc Info

a103.hpc
10.1.2.3
Location: Unknown

Load: 3.84 4.00 3.99
1m 5m 15m

Last heartbeat received 4 seconds ago. Uptime 66 days, 12:33

CPU Utilization: 94.2 4.0 1.6
user sys idle

Hardware	Software
CPUs: 4 x 2192 Mhz	OS: Linux 2.6.13.3 (x86_64)
Memory (RAM): 3964 MB	Booted: April 27, 2006, 8:50 am
Local Disk: Using 17.074 of 68.024 GB	Uptime: 66 days, 12:33
Most Full Disk Partition: 25.2% used.	Swap: Using 8.7 of 4094.7 MB swap.

Physical View | Reload

DEMOCRITOS/SISSA Grid > cerbero > --Choose a Node

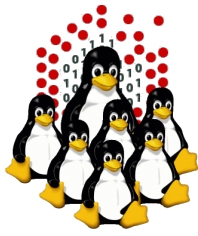
Overview of cerbero

There are **70 nodes (188 CPUs)** up and running.
There are no nodes down.

Current Cluster Load: 112.42, 111.8, 112.08

Snapshot of cerbero | Legend

cerbero load_one



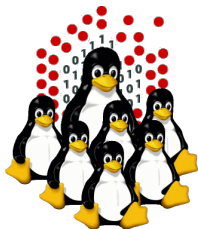
CLUSTER MONITORING

What does Nagios provide?

Nagios[®]

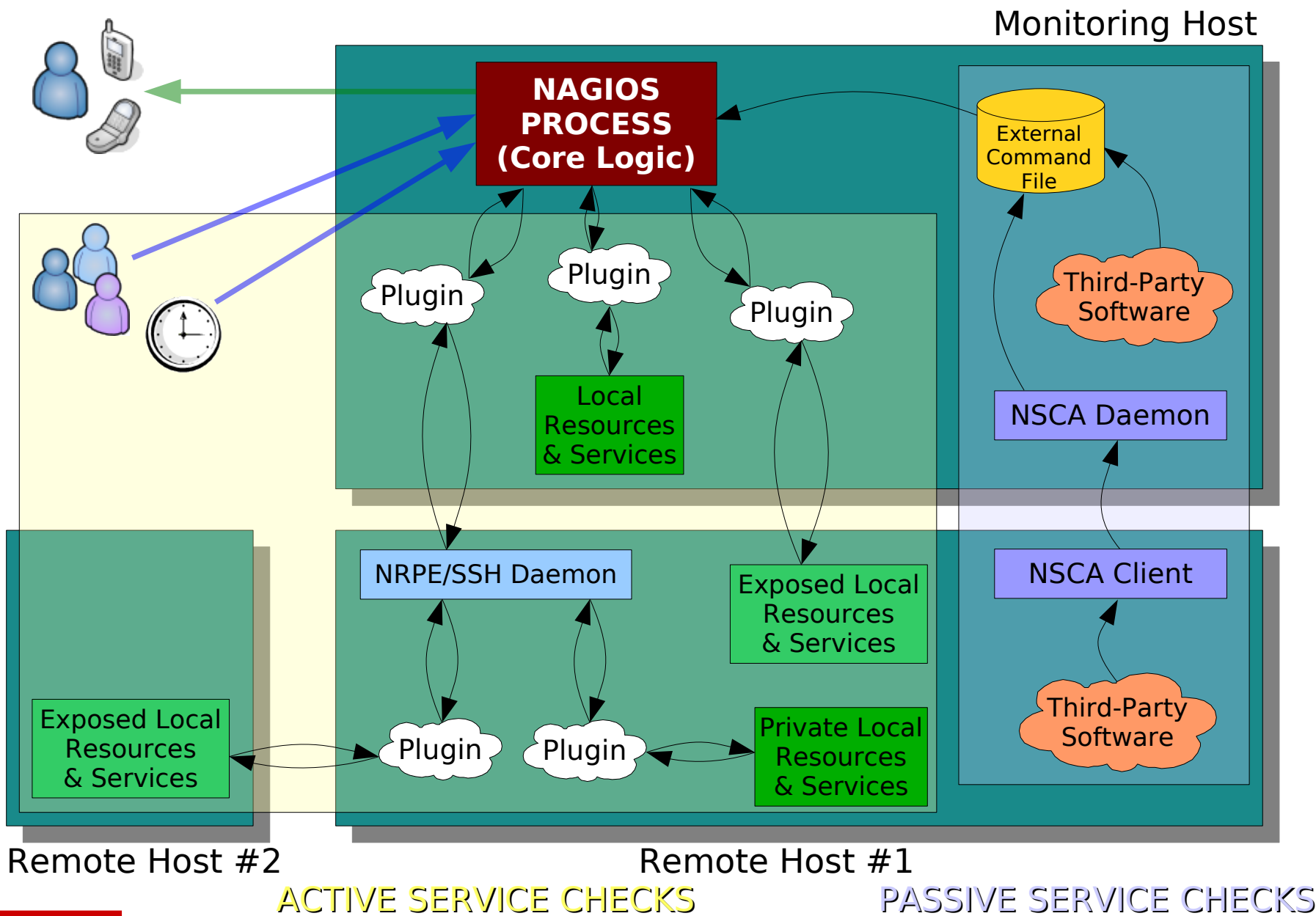
- ✓ Comprehensive Network Monitoring
- ✓ Problem Remediation
- ✓ Proactive Planning
- ✓ Immediate Awareness and Insight
- ✓ Reporting Options
- ✓ Multi-Tenant/Multi-User Capabilities
- ✓ Integration With Your Existing Applications
- ✓ Customizable Code
- ✓ Easily Extendable Architecture
- ✓ Stable, Reliable, and Respected Platform
- ✓ Huge Community

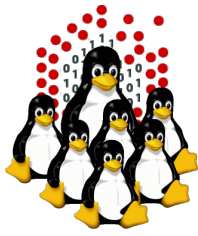




CLUSTER MONITORING

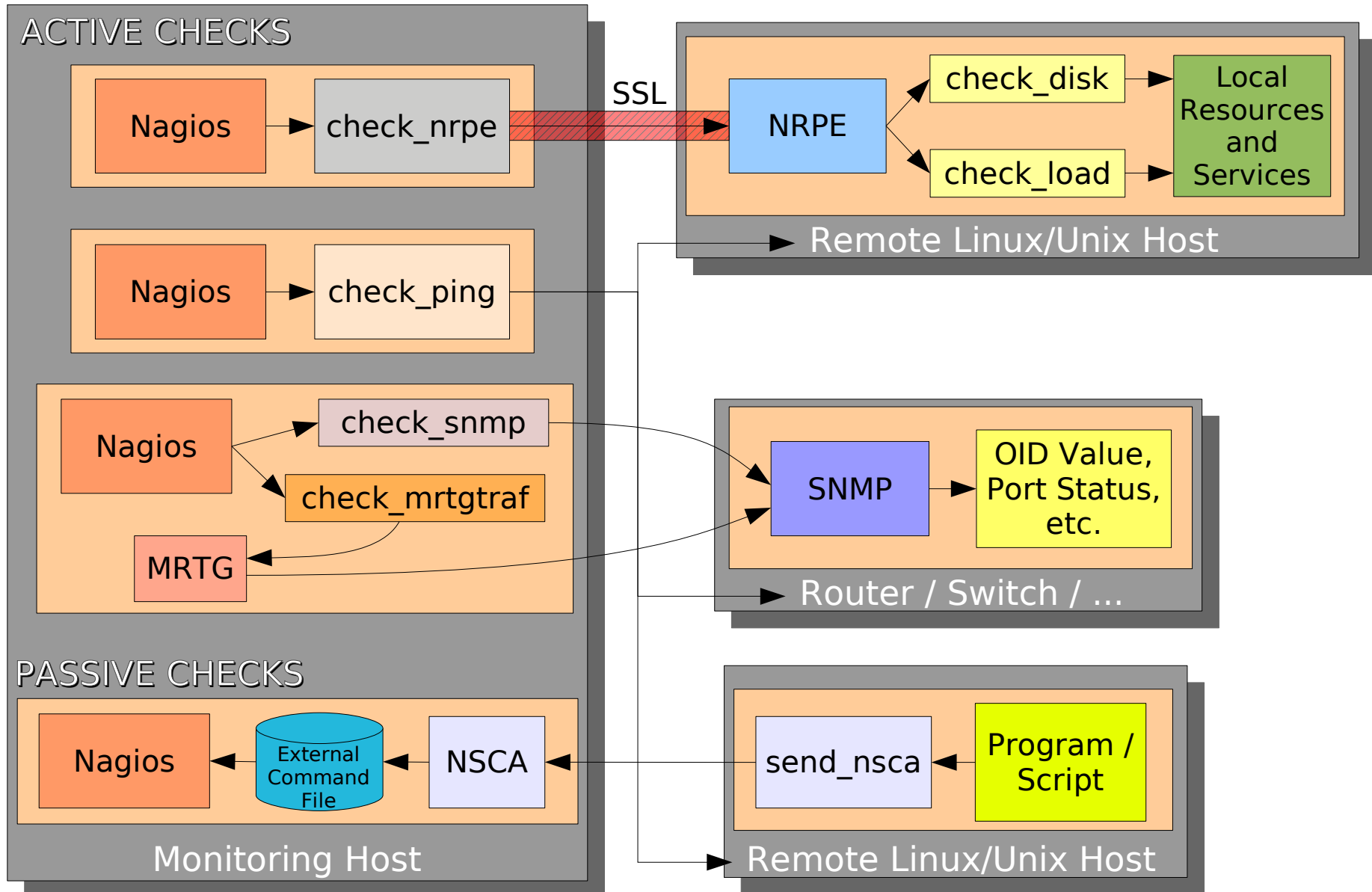
Nagios components





CLUSTER MONITORING

Nagios components – Plugins





CLUSTER MONITORING Nagios at work /0 - MAP

Nagios®

General

- Home
- Documentation

Current Status

- Tactical Overview
- Map
- Hosts
- Services
- Host Groups
 - Summary
 - Grid
- Service Groups
 - Summary
 - Grid
- Problems
 - Services (Unhandled)
 - Hosts (Unhandled)
 - Network Outages

Quick Search:

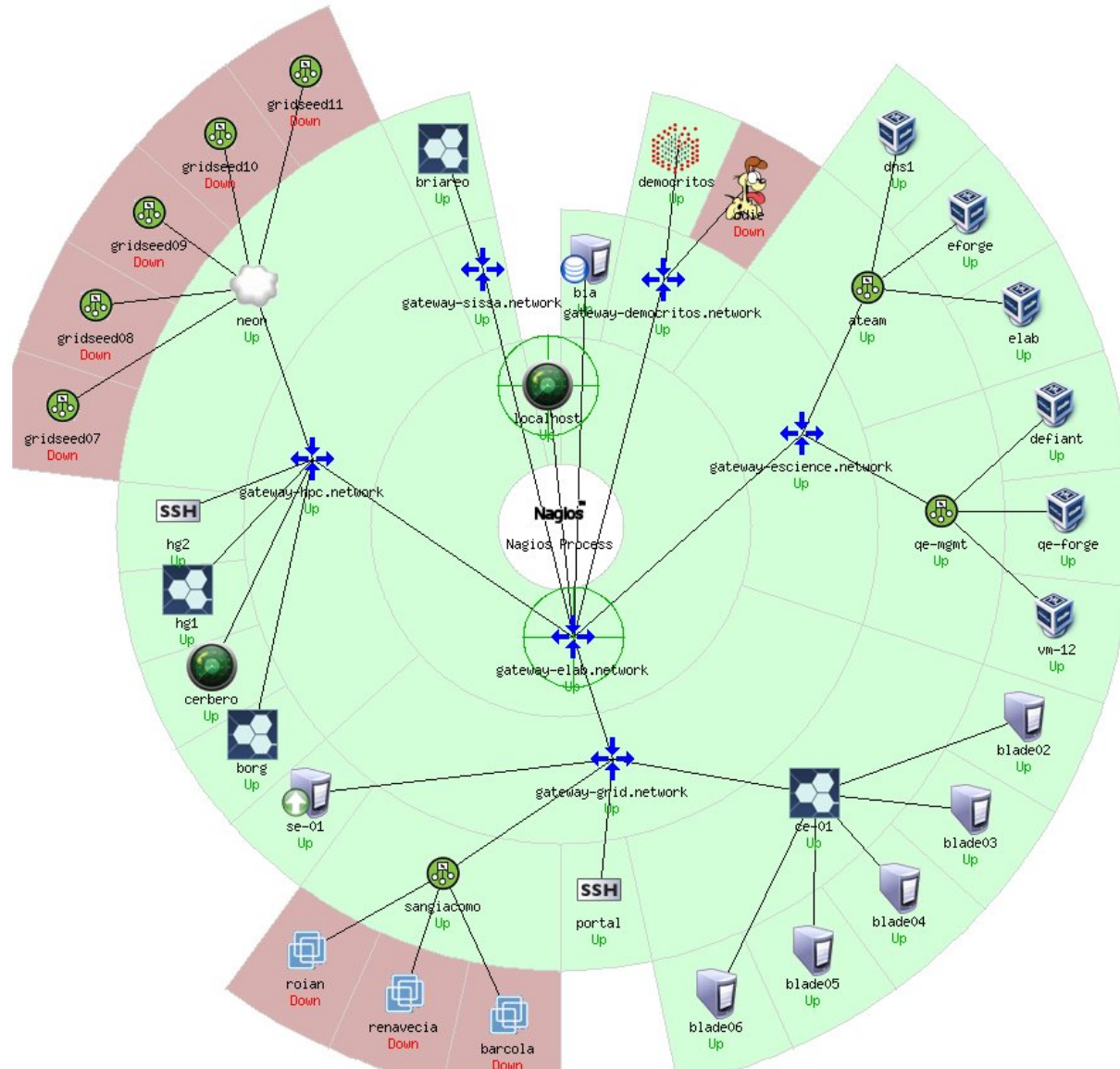
Reports

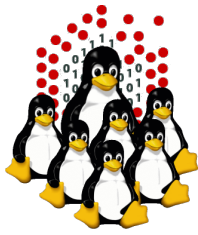
- Availability
- Trends
- Alerts
 - History
 - Summary
 - Histogram
- Notifications
- Event Log

System

- Comments
- Downtime
- Process Info
- Performance Info
- Scheduling Queue
- Configuration

Update





CLUSTER MONITORING

Nagios at work /1 – Tactical Overview

Hosts

4 Down	0 Unreachable	164 Up	0 Pending
--------	---------------	--------	-----------

1 Scheduled

4 Acknowledged

Services

37 Critical	3 Warning	0 Unknown	1392 Ok	91 Pending
-------------	-----------	-----------	---------	------------

2 Unhandled Problems

3 Unhandled Problems

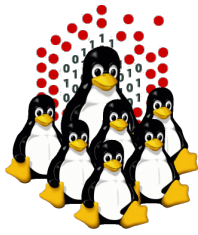
64 Disabled

91 Disabled

35 on Problem Hosts

Monitoring Features

Flap Detection	Notifications	Event Handlers	Active Checks	Passive Checks
Enabled All Services Enabled No Services Flapping All Hosts Enabled No Hosts Flapping	Enabled 472 Services Disabled 2 Hosts Disabled	Enabled All Services Enabled All Hosts Enabled	Enabled 155 Services Disabled All Hosts Enabled	Enabled All Services Enabled All Hosts Enabled



CLUSTER MONITORING

Nagios at work /2 – Host Status

Host Information

Last Updated: Fri Mar 20 12:51:53 CET 2009
Updated every 90 seconds
Nagios® 3.0.6 - www.nagios.org
Logged in as *nagiosadmin*

- [View Status Detail For This Host](#)
- [View Alert History For This Host](#)
- [View Trends For This Host](#)
- [View Alert Histogram For This Host](#)
- [View Availability Report For This Host](#)
- [View Notifications This Host](#)

Host
c007
(c007)

Member of
c-nodes

10.2.10.7

Host State Information

Host Status:	UP (for 1d 0h 48m 9s)
Status Information:	PING OK - Packet loss = 0%, RTA = 0.21 ms
Performance Data:	rta=0.207000ms;3000.000000;5000.000000;0.000000 pl=0%;80;100;0
Current Attempt:	1/15 (HARD state)
Last Check Time:	03-20-2009 12:51:34
Check Type:	ACTIVE
Check Latency / Duration:	0.590 / 4.276 seconds
Next Scheduled Active Check:	03-20-2009 12:56:44
Last State Change:	03-19-2009 12:03:44
Last Notification:	N/A (notification 0)
Is This Host Flapping?	NO (0.00% state change)
In Scheduled Downtime?	NO
Last Update:	03-20-2009 12:51:44 (0d 0h 0m 9s ago)



CLUSTER MONITORING

Nagios at work /3 – Service Status Detail

Current Network Status
 Last Updated: Fri Mar 20 12:51:28 CET 2009
 Updated every 90 seconds
 Nagios® 3.0.6 - www.nagios.org
 Logged in as nagiosadmin

[View History For This Host](#)
[View Notifications For This Host](#)
[View Service Status Detail For All Hosts](#)

Host Status Totals

Up	Down	Unreachable	Pending
1	0	0	0

All Problems	All Types
0	1

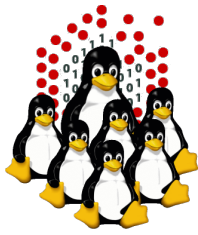
Service Status Totals

Ok	Warning	Unknown	Critical	Pending
9	1	0	0	0

All Problems	All Types
1	10

Service Status Details For Host 'c007'

Host ↑↓	Service ↑↓	Status ↑↓	Last Check ↑↓	Duration ↑↓	Attempt ↑↓	Status Information
c007	EDAC memory errors	WARNING	03-20-2009 12:42:12	0d 14h 9m 16s	3/3	WARNING - several correctable memory errors
	NFS mounts from local fstab	OK	03-20-2009 12:44:38	1d 0h 46m 53s	1/3	NFS mounts OK
	NTP server	OK	03-20-2009 12:48:58	1d 0h 22m 31s	1/3	NTP OK: Offset 0.001392602921 secs
	PING	OK	03-20-2009 12:48:31	1d 0h 42m 57s	1/3	PING OK - Packet loss = 0%, RTA = 0.24 ms
	SSH	OK	03-20-2009 12:42:48	1d 0h 28m 41s	1/3	SSH OK - OpenSSH_4.3 (protocol 2.0)
	job events	OK	03-19-2009 11:15:51	5d 19h 16m 0s	1/3	job 22372 by smogunov/tosatti
	load average	OK	03-20-2009 12:47:14	1d 0h 4m 14s	1/3	OK - load average: 0.00, 0.00, 0.00
	lustre client	OK	03-20-2009 12:47:08	1d 0h 4m 21s	1/3	lustre client OK
	pbs mom	OK	03-20-2009 12:47:21	1d 0h 44m 7s	1/4	TCP OK - 0.000 second response time on port 15002
	reverse ping IB	OK	03-20-2009 12:46:02	1d 0h 45m 26s	1/3	PING OK - Packet loss = 0%, RTA = 0.39 ms



CLUSTER MONITORING

Nagios at work /4 – Service Problems

Current Network Status
 Last Updated: Fri Mar 20 12:50:50 CET 2009
 Updated every 90 seconds
 Nagios® 3.0.6 - www.nagios.org
 Logged in as *nagiosadmin*

[View History For all hosts](#)
[View Notifications For All Hosts](#)
[View Host Status Detail For All Hosts](#)

Display Filters:

Host Status Pending | Up
 Types:
 Host Properties: Any
 Service Status All Problems
 Types:
 Service Not In Scheduled Downtime & Has Not Been
 Properties: Acknowledged & Active Checks Enabled

Host Status Totals

Up	Down	Unreachable	Pending
164	4	0	0

All Problems	All Types
4	168

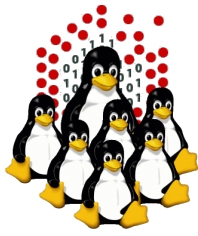
Service Status Totals

Ok	Warning	Unknown	Critical	Pending
1474	3	0	36	10

All Problems	All Types
39	1523

Service Status Details For All Hosts

Host ↑↓	Service ↑↓	Status ↑↓	Last Check ↑↓	Duration ↑↓	Attempt ↑↓	Status Information
a199	EDAC memory errors	CRITICAL	03-20-2009 12:42:09	10d 1h 28m 46s	3/3	CRITICAL - many correctable memory errors
c007	EDAC memory errors	WARNING	03-20-2009 12:42:12	0d 14h 8m 38s	3/3	WARNING - several correctable memory errors
m038	EDAC memory errors	WARNING	03-20-2009 12:44:44	10d 1h 26m 10s	3/3	WARNING - several correctable memory errors
m045	EDAC memory errors	WARNING	03-20-2009 12:43:54	10d 1h 27m 25s	3/3	WARNING - several correctable memory errors



CLUSTER MONITORING

Nagios at work /5 – Mail Report

Nagios[®]

```
Date: Fri, 6 Nov 2009 12:18:34 +0100
From: nagios@monitor.hpc.sissa.it
To: root@localhost
Subject: ** PROBLEM Host Alert: c001 is DOWN **
```

```
***** Nagios *****
```

```
Notification Type: PROBLEM
Host: c001
State: DOWN
Address: 10.2.10.1
Info: CRITICAL - Host Unreachable (10.2.10.1)
```

```
Date/Time: Fri Nov 6 12:18:34 CET 2009
```

```
Performance data:
```

```
Comment:
trying to reboot c001
```



LOCAL AND REMOTE ACCESS

LOCAL ACCESS

- ➔ LOCAL CONSOLE (max ~10m for PS2, ~5m USB; ~30m VGA) (*)
- ➔ KVM (max ~30m) (*)
- ➔ SERIAL CONSOLE (RS232, max ~15m@19200baud / ~150m@9600baud) (*)

* repeaters and transceivers increase the max length

REMOTE ACCESS (OS dependent, **in-band**)

- ➔ SSH
- ➔ VNC, remote desktop, ...

REMOTE ACCESS (OS in-dependent, **out-of-band**)

- ➔ KVM over IP (hardware)
- ➔ SERIAL over IP (hardware; serial hubs, IBM RSA and other LOM systems)
- ➔ SERIAL over LAN (hardware; IPMI)
- ➔ JAVA CONSOLE, web appliances (hardware+sw; SUN and other vendors)

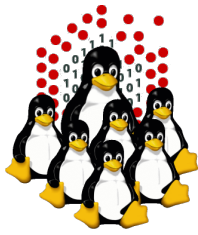


REMOTE MANAGEMENT

SysAdmins are lazy, IT-button-pusher-slaves cost too much, and Google already hired the only team of Highly Trained Monkeys available on the market.
We want remote management NOW!

What does the market offer?

- in-band and out-of-band controllers
- either built-in or pluggable
- proprietary controllers and protocols (SUN, IBM, HP, ...)
- well-known standards based SPs (IPMI/SNMP) (good)
- some provides ssh access (good)
- some allows only web-based management (bad)
- some requires java (bad)
- some requires weird tools, often closed-source (bad)
- some implements more of the above (VERY GOOD)
- some don't work... (REALLY BAD)



REMOTE MANAGEMENT

IPMI - Intelligent Platform Management Interface

IPMI (Intelligent Platform Management Interface)

- sensor monitoring
- system event monitoring
- power control
- serial-over-LAN (SOL)
- independent of the operating system, but works locally as well

- **OpenIPMI**

- <http://openipmi.sourceforge.net/>
- *ipmicmd, ipmilan, ipmish, ...*

- **GNU FreeIPMI**

- <http://www.gnu.org/software/freeipmi/>
- *bmc-config, ipmi-chassis, ipmi-fru, ipmiping, ipmipower, ...*

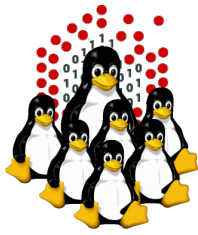
- **ipmitool**

- <http://ipmitool.sourceforge.net/>
- *ipmitool*

- **ipmiutil**

- <http://ipmiutil.sourceforge.net/>
- *ipmiutil*





REMOTE MANAGEMENT

IPMI - IPMITOOL

Local Interaction:

```
node01# modprobe ipmi_si
node01# modprobe ipmi_devintf
node01# modprobe ipmi_msghandler
```

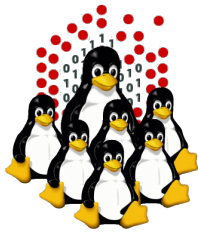
```
node01# ipmitool chassis status
node01# ipmitool sel [info|list|elist]
node01# ipmitool sdr [info|list|elist|type Temperature|...]
node01# ipmitool sensor [list|get 'CPU1 Dmn 0 Temp'|reading 'CPU1 Dmn 0 Temp']
node01# ipmitool fru [print 0]
```

```
node01# ipmitool lan set 1 ipsrc dhcp [ipsrc static / ipaddr x.x.x.x]
node01# ipmitool lan set 1 access on
```

Remote Interaction:

```
master# ipmitool -H sp-node01 -U adm -P xyz -I lan power status
master# ipmitool -H sp-node01 -U adm -P xyz -I lan power on
master# ipmitool -H sp-node01 -U adm -P xyz -I lan power off
master# ipmitool -H sp-node01 -U adm -P xyz -I lanplus sol activate
```





REMOTE MANAGEMENT

SNMP - Simple Network Management Protocol

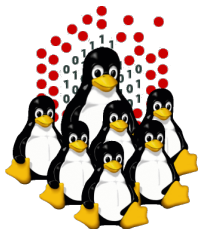
SNMP (Simple Network Management Protocol)

- monitor network-attached devices (switches, routers, UPSs, PDUs, hosts, ...)
- retrieve and manipulate configuration information (*get/set/trap* actions)
- v1: clear text, no auth (community string)
- v2: clear text, auth (but v2c uses comm. str.)
- v3: privacy, auth, access control
- depends on the NOS/FW, hosts need a local agent
- OID or mnemonic variables (using MIB files)

• Net-SNMP

- <http://www.net-snmp.org>
- *snmpset*
- *snmpget*
- *snmpwalk*
- many more...





REMOTE MANAGEMENT

SNMP - Net-SNMP



Single GET:

```
master# snmpget -v2c -c public ibm2.sp 1.3.6.1.4.1.2.3.51.2.22.1.5.1.1.4.6  
master# snmpget -v2c -c public -m /etc/ibm-blade.mib ibm2.sp bladePowerState.6
```

Multiple GET (walk):

```
master# snmpwalk -v2c -c public ibm2.sp 1.3.6.1.4.1.2.3.51.2.22.1.5.1.1.4  
master# snmpwalk -v2c -c public -m /etc/ibm-blade.mib ibm2.sp bladePowerState
```

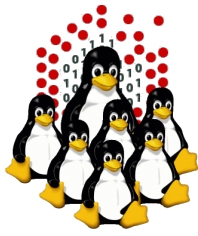
```
master# snmpget -v2c -0s -c public gesw01 system.sysName.0 (one transaction)  
master# snmpwalk -v2c -0s -c public gesw01 system (one transaction for each var.)  
master# snmpbulkwalk -v2c -0s -c public gesw01 system (single transaction)
```

Single SET:

```
master# snmpset -v3 -l authPriv -u ADMIN -a md5 -A AUTHPWD -x des -X PRIVPWD \  
  ibm2.sp 1.3.6.1.4.1.2.3.51.2.22.1.6.1.1.7.1 i 1  
master# snmpset -v3 -l authPriv -u ADMIN -a md5 -A AUTHPWD -x des -X PRIVPWD \  
  -m /etc/ibm-blade.mib ibm2.sp BLADE-MIB::powerOnOffBlade.1 i 1
```



SECURITY



SECURITY NOTES

What you should care of

- physical access / boot security
- active services
- software updates
- filesystem permissions
- user access
- intrusion detection
- system hardening
- virtualization





SECURITY NOTES

Hints /1

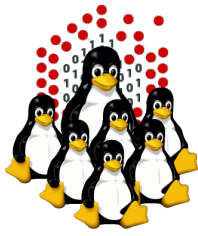
- ➔ PAM: `/etc/pam.d/*`, `/etc/security/*`
 - ➔ `limits.conf`: per-user resources limits (cputime, memory, number of processes, ...)
 - ➔ `access.conf`: which user from where
- ➔ SSH: `/etc/ssh/sshd_config`
- ➔ *TCPwrapper*: `/etc/hosts.{allow,deny}`, only for services handled by *(x)inetd* or compiled against *libwrap*
- ➔ firewall: OK on external network; overkill on the cluster network
- ➔ services: the least possible



SECURITY NOTES

Hints /2

- ➔ ownerships/permissions: local users+exported services, NFS *root_squash* for rw dirs
- ➔ *chroot* jails: for some (untrusted) services
- ➔ avoid automatic updates, manually patch as far as possible
- ➔ beware of test-accounts and passwordless environment outside the cluster
- ➔ *grsec*: if you are really paranoid... like we are and you should be ;)
- ➔ network devices: default passwords, SNMP, SP/IPMI, CDP and the like, ...



SECURITY NOTES

Security Policy

- **HARDWARE**

- ➔ physical access
- ➔ redundancy

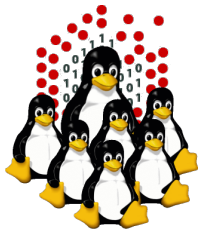
- **SOFTWARE**

- ➔ hardening
- ➔ configuration
- ➔ update
- ➔ backup

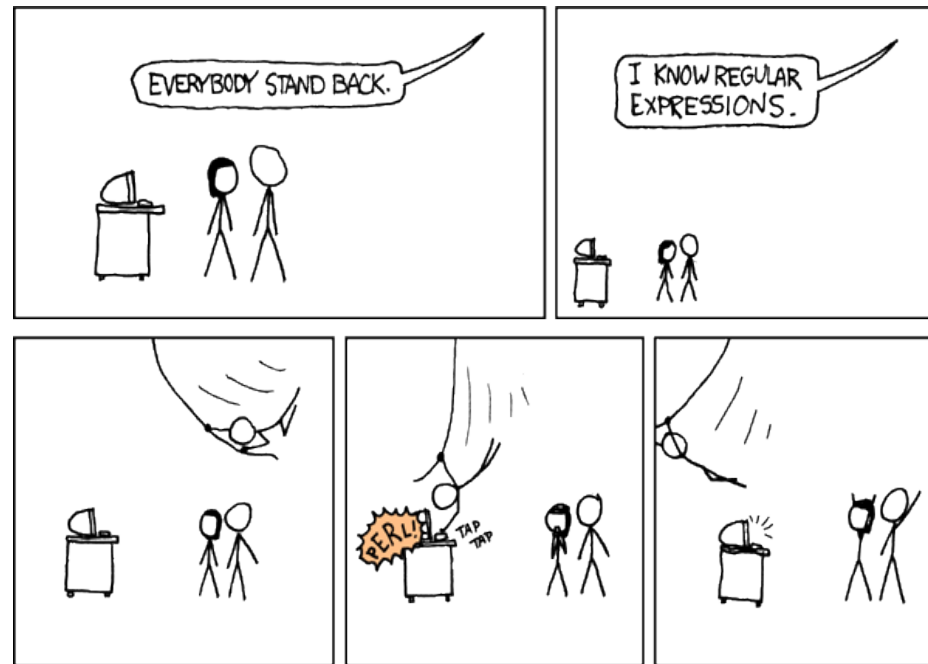
- **USERS' EDUCATION**

- ➔ “strong” passwords
- ➔ no account sharing
- ➔ prevent social engineering / phishing





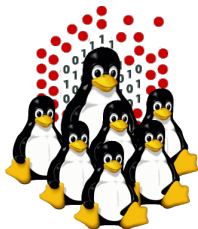
That's All Folks!



xkcd

(questions ; comments) | mail -s uheilaaa baro@democritos.it

(complaints ; insults) &>/dev/null



REFERENCES AND USEFUL LINKS

Cluster Toolkits:

- OSCAR – Open Source Cluster Application Resources
<http://oscar.openclustergroup.org/>
- NPACI Rocks
<http://www.rocksclusters.org/>
- Scyld Beowulf
<http://www.beowulf.org/>
- CSM – IBM Cluster Systems Management
<http://www.ibm.com/servers/eserver/clusters/software/>
- xCAT – eXtreme Cluster Administration Toolkit
<http://www.xcat.org/>
- Warewulf/PERCEUS
<http://www.warewulf-cluster.org/> <http://www.perceus.org/>

Installation Software:

- SystemImager <http://www.systemimager.org/>
- FAI <http://www.informatik.uni-koeln.de/fai/>
- Anaconda/Kickstart <http://fedoraproject.org/wiki/Anaconda/Kickstart>

Management Tools:

- openssh/openssl
<http://www.openssh.com>
<http://www.openssl.org>
- C3 tools – The Cluster Command and Control tool suite
<http://www.csm.ornl.gov/torc/C3/>
- PDSH – Parallel Distributed SHell
<https://computing.llnl.gov/linux/pdsh.html>
- DSH – Distributed SHell
<http://www.netfort.gr.jp/~dancer/software/dsh.html.en>
- ClusterSSH
<http://clusterssh.sourceforge.net/>
- C4 tools – Cluster Command & Control Console
<http://gforge.escience-lab.org/projects/c-4/>

Monitoring Tools:

- Ganglia <http://ganglia.sourceforge.net/>
- Nagios <http://www.nagios.org/>
- Zabbix <http://www.zabbix.org/>

Network traffic analyzer:

- tcpdump <http://www.tcpdump.org>
- Wireshark <http://www.wireshark.org>

UnionFS:

- Hopeless, a system for building disk-less clusters
<http://www.evolware.org/chri/hopeless.html>
- UnionFS – A Stackable Unification File System
<http://www.unionfs.org>
<http://www.fsl.cs.sunysb.edu/project-unionfs.html>

RFC: (<http://www.rfc.net>)

- RFC 1350 – The TFTP Protocol (Revision 2)
<http://www.rfc.net/rfc1350.html>
- RFC 2131 – Dynamic Host Configuration Protocol
<http://www.rfc.net/rfc2131.html>
- RFC 2132 – DHCP Options and BOOTP Vendor Extensions
<http://www.rfc.net/rfc2132.html>
- RFC 4578 – DHCP PXE Options
<http://www.rfc.net/rfc4578.html>
- RFC 4390 – DHCP over Infiniband
<http://www.rfc.net/rfc4390.html>
- PXE specification
<http://www.pix.net/software/pxeboot/archive/pxespec.pdf>
- SYSINUX <http://syslinux.zytor.com/>



Some acronyms...

HPC – High Performance Computing

OS – Operating System

LINUX – LINUX is not UNIX

GNU – GNU is not UNIX

RPM – RPM Package Manager

CLI – Command Line Interface

BASH – Bourne Again SHell

PERL – Practical Extraction and Report Language

PXE – Preboot Execution Environment

INITRD – INITIAL RamDisk

NFS – Network File System

SSH – Secure SHell

LDAP – Lightweight Directory Access Protocol

NIS – Network Information Service

DNS – Domain Name System

PAM – Pluggable Authentication Modules

LAN – Local Area Network

WAN – Wide Area Network

IP – Internet Protocol

TCP – Transmission Control Protocol

UDP – User Datagram Protocol

DHCP – Dynamic Host Configuration Protocol

TFTP – Trivial File Transfer Protocol

FTP – File Transfer Protocol

HTTP – Hyper Text Transfer Protocol

NTP – Network Time Protocol

NIC – Network Interface Card/Controller

MAC – Media Access Control

OUI – Organizationally Unique Identifier

API – Application Program Interface

UNDI – Universal Network Driver Interface

PROM – Programmable Read-Only Memory

BIOS – Basic Input/Output System

SNMP – Simple Network Management Protocol

MIB – Management Information Base

OID – Object Identifier

IPMI – Intelligent Platform Management Interface

LOM – Lights-Out Management

RSA – IBM Remote Supervisor Adapter

BMC – Baseboard Management Controller