Diskless Linux Clusters

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Outline:

- Why diskless operation?
- Issues with diskless nodes
- Our choices
- Configuring the Linux kernel
- The boot sequence
- Pros and cons

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- giving users and applications a unified cluster image
- requires integration at multiple levels: kernel, filesystem, namespace, . . .
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Manageability

Flexibility

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Sometimes, even when you do have disks,
you don't want to touch them!

Issues with diskless nodes

- How do I boot?
  - *Floppy*
  - *Network (PXE, etherboot)*
- Where is my root filesystem?
  - *Network file system (NFS)*
- Where do I swap to?
  - *Just don't.*
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Moreover, if we want a single root filesystem for all nodes:

- Where is my identity?
  - *Created on the fly*
  - *Stored remotely*

Requirements and Choices

Our requirements for system organization:

- Dedicated system (no PBS, . . .)
- Easily reconfigurable at the system level:
  - ▷ *System libraries*
  - ▷ *Kernel*
  - ▷ *Running set of daemons*
  - ▷ *Cluster-wide user environment*

Our choices:

- Root filesystem over NFS, read-only mounted
  - ▷ *root filesystem based on the Debian distribution*
  - ▷ *the root filesystem exported to nodes is maintained using standard Debian tools (dpkg, apt-get)*
- GRUB bootloader
  - ▷ *integrates a BOOTP/DHCP client*
  - ▷ *can fetch and execute scripts specifying a boot sequence*
  - ▷ *we boot from floppies or PXE*
- Small local ramdisk, for volatile write access
  - ▷ `/tmp` *has to be writable! (think of lock files . . .)*
- Devfs virtual filesystem
  - ▷ *No device inode lookups over the network*
  - ▷ *No* `/dev` *files on the exported root filesystem*
- NFS-shared `/beowulf` filesystem
  - ▷ *holds the application libraries (MPICH, LAM, FFTW, . . .)*
  - ▷ *holds home directories*

Compute nodes

A closer look at one node . . .

```
cattuto@node10:~$ df -aTm
Filesystem        Type   1M-blocks   Used Available Use% Mounted on
/dev/root          nfs        5613   1341      3987  26% /
none               devfs         0      0         0    -  /dev
proc               proc          0      0         0    -  /proc
/dev/ram0          ext2          8      1         7   1% /ramdisk
node00:/beowulf    nfs       10199   8524      1676  84% /beowulf
```

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cattuto@node10:~$ ls -l /tmp
lrwxrwxrwx  1 root  root    12 Jan 30 13:48 /tmp -> /ramdisk/tmp/
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```

```
cattuto@node10:~$ ls -l /ramdisk
drwxr-xr-x  3 root  root  1024 Feb  8 15:02 etc/
drwxrwxrwt  5 root  root  1024 Feb 14 00:17 tmp/
drwxr-xr-x  9 root  root  1024 Feb  6 18:08 var/
cattuto@node10:~$
```

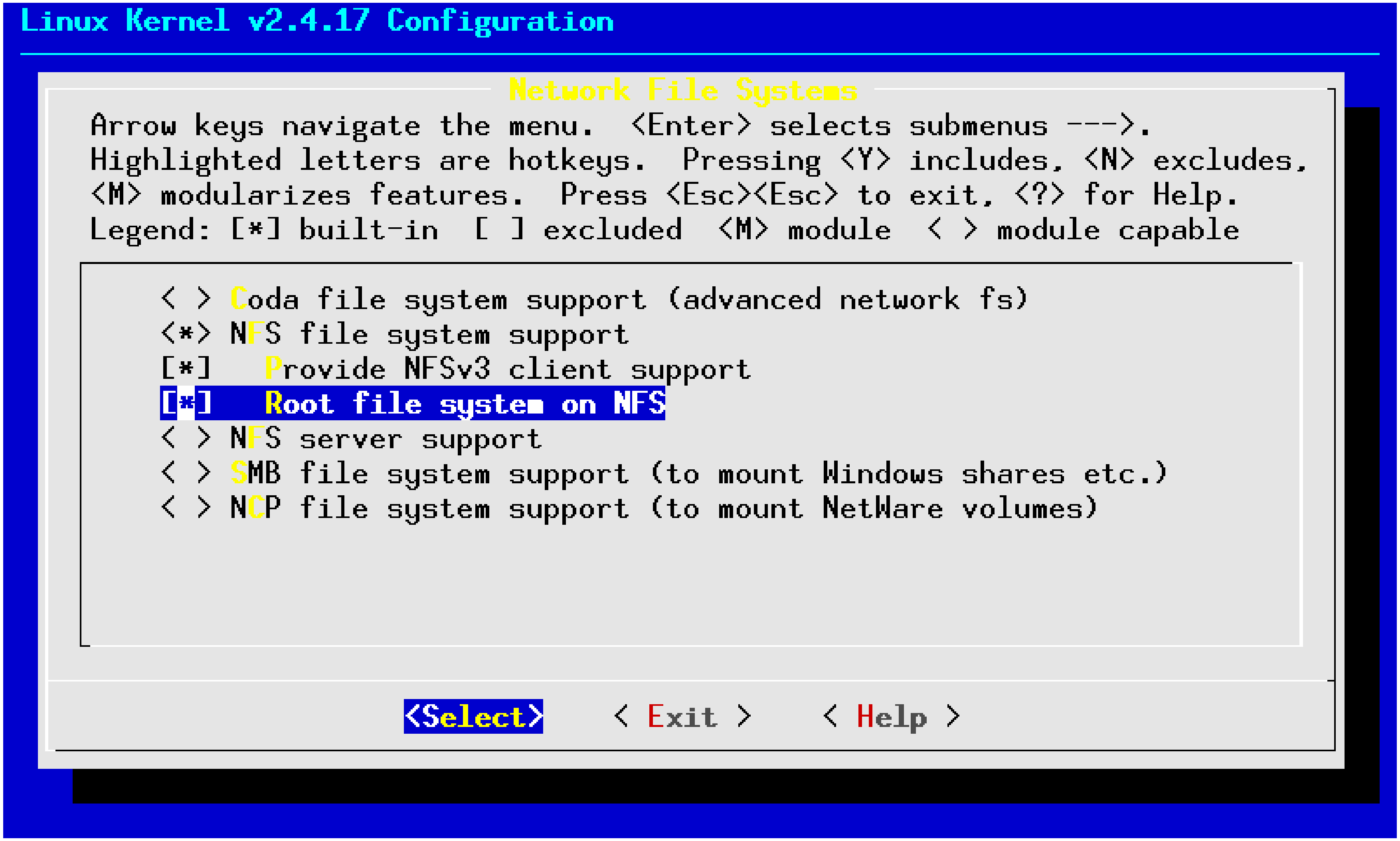
Kernel configuration (1)

```
Linux Kernel v2.4.17 Configuration
                         Networking options
  Arrow keys navigate the menu.  <Enter> selects submenus --->.
  Highlighted letters are hotkeys.  Pressing <Y> includes, <N> excludes,
  <M> modularizes features.  Press <Esc><Esc> to exit, <?> for Help.
  Legend: [*] built-in  [ ] excluded  <M> module  < > module capable
        ^(-)
        <*> Unix domain sockets
        [*] TCP/IP networking
        [ ]   IP: multicasting
        [ ]   IP: advanced router
        [*]   IP: kernel level autoconfiguration
        [*]     IP: DHCP support (NEW)
        [*]     IP: BOOTP support (NEW)
        [ ]     IP: RARP support (NEW)
        < >   IP: tunneling
        < >   IP: GRE tunnels over IP
        v(+)

              <Select>    < Exit >    < Help >
```

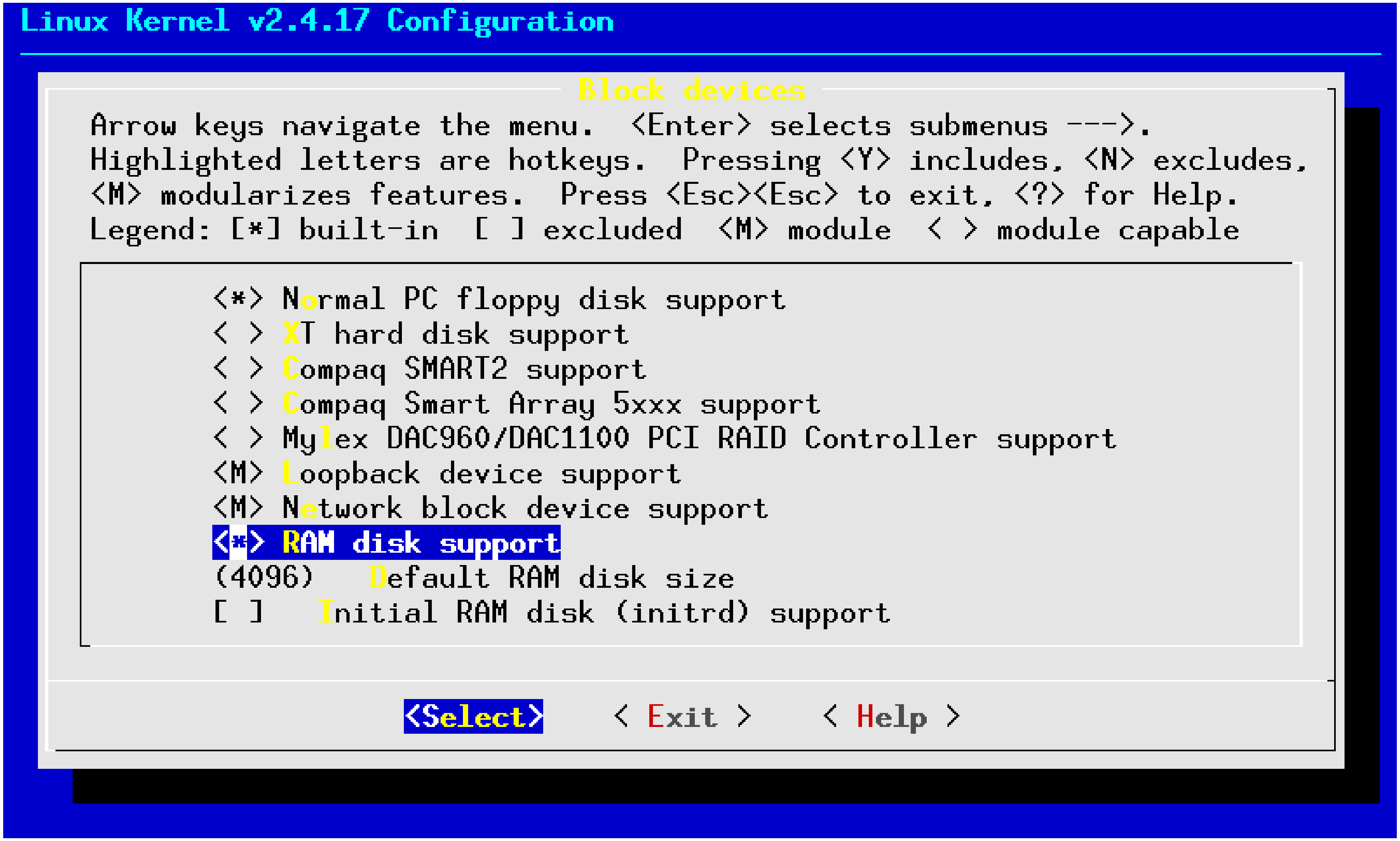
→ *enable boot-time automatic IP configuration*

Kernel configuration (2)



→ *enable NFS support and NFSroot functionality*

Kernel configuration (3)



→ *enable ramdisk support*

The boot sequence

1. Power on. GRUB is loaded from the PXE ROM or boot floppy

2. GRUB probes the NIC and sends out
   a DHCP query to configure the network

3. GRUB downloads (via TFTP) a boot script from the DHCP server

4. The boot script fetches a kernel image
   and fires it up, passing it proper parameters

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   a DHCP query to configure the network
3. GRUB downloads (via TFTP) a boot script from the DHCP server
4. The boot script fetches a kernel image
   and fires it up, passing it proper parameters
5. The Linux kernel boots and the IP autoconfiguration code
   sends out a DHCP query to configure the NIC
6. The root filesystem is mounted over NFS (read-only)
   from the DHCP server
7. System initialization begins.

8. Devfs is mounted

9. The ramdisk is created, populated and mounted

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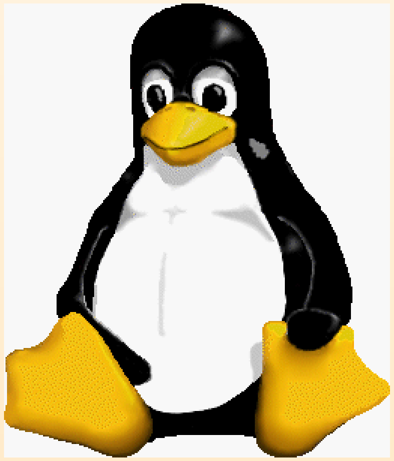
10. Boot scripts complete local configuration (on ramdisk)
11. Remote `/beowulf` filesystem gets mounted
12. Per-node configuration is performed (if any)
13. System is ready!



A glance at the server side . . .

```
virgo-bwulf:/beowulf/boot# ls -l
  1 root  root 827361 Nov 23 16:18 bzImage-2.4.17
  1 root  root 921385 Nov 18 16:13 bzImage-2.4.17-mosix
  1 root  root    151 Jan 29 21:34 install.lst
  1 root  root    232 Jan 29 21:34 local.lst
  1 root  root    139 Jan 29 21:34 node-rw.lst
  1 root  root    102 Jan 29 21:34 node.lst
  1 root  root     11 Feb 14 00:49 node10.lst -> install.lst
```

- At boot time, GRUB configures the network via DHCP
- Then, each node attempts to download and execute a GRUB boot script:
  - ▷ *if there is a node-specific script, go for it*
  - ▷ *otherwise, use the generic* `node.lst`
- The boot script downloads the right kernel and starts it
  - ▷ *the kernel command line can be manipulated by GRUB*
- Kernel and boot sequence of all the nodes can be controlled by changing files and symlinks in `/beowulf/boot` - and only that.

Pros and Cons

Pros:

- Manageability
  - ▷ *Single point of control for kernel image and boot sequence of all nodes*
  - ▷ *Single point of control for system libraries*
  - ▷ *Single point of control for application libraries (`/beowulf`)*
  - ▷ *Single point of control for user environment (`/beowulf/env`)*
  - ▷ *Chrooted operation on node root filesystem, using Debian tools*
  - ▷ *Compute nodes share an identical namespace*
- Flexibility
  - ▷ *Nodes need not have the same running set of daemons*
  - ▷ *Local disks, if present, can be automatically partitioned and populated (useful for local swapping, PVFS, . . .)*
- No loss of performance wrt nodes with local installation (OSCAR style)

Cons:

- Scalability
  - ▷ *During boot, all nodes access the same NFS filesystem (then VFS caching takes over)*
  - ▷ *In practice: no noticeable slowdown of boot sequence was observed*

Other directions:

- Scyld: second generation Beowulf clusters
  - *User friendly cluster installation procedure*
  - *Diskless operation*
  - *Kernel modifications to support distributed process space (BProc)*
  - *Kernel lightweight facilities to start remote processes*
  - *Cluster control tools*

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- Single System Image efforts

  "I really want to see the Compaq clustering code, the IBM DLM and OpenGFS in the 2.5 tree creating a real clustered Linux with true failover facilities. That will really open the door to the enterprise market." -Alan Cox (Nov 8th, 2001)

References

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