# BootManager Technical Documentation

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# 1. Overview

This document describes the implementation of the package called the BootManager at a technical level. The BootManager is used in conjunction with the PlanetLab BootCD to securely boot nodes, including remote installation, debugging, and validation. It is the primary method used by the PlanetLab Central Management Authority (MA) to manage nodes.

# 2. Components

The entire BootManager system consists of several primary components. These are:

- The existing, stardard MA provided calls to allow principals to add and manage node records, and a new call to generate node-specific configuration files
- New MA API calls with a new authentication mechanism for node-based MA calls
- A code package to be run in the boot cd environment on nodes containing core install/validate/boot logic

The intention with the BootManager system is to send the same script to all nodes (consisting of the core BootManager code), each time the node starts. Then, the BootManager will run and detiremine which

operations to perform on the node, based on its state of installation. All state based logic for the node boot, install, debug, and reconfigure operations are contained in one place; there is no boot state specific logic located on the MA servers.

# 3. Soure Code

All BootManager source code is located in the repository 'bootmanager' on the PlanetLab CVS system. For information on how to access CVS, consult the PlanetLab website. Unless otherwise noted, all file references refer to this repository.

# 4. Management Authority Node Fields

The following MA database fields are directly applicable to the BootManager operation, and to the node-related API calls (detailed below).

## 4.1. node_id

An integer unique identifier for a specific node.

## 4.2. node_key

This is a per-node, unique value that forms the basis of the node authentication mechanism detailed below. When a new node record is added to the MA by a principal, it is automatically assigned a new, random key, and distributed out of band to the nodes. This shared secret is then used for node authentication. The contents of node_key are generated using this command:

```
openssl rand -base64 32
```

Any = (equals) characters are removed from the string.

## 4.3. boot_state

Each node always has one of four possible boot states, stored as a string, refered to as boot_state. These are:

1. 'inst'

   Install. The boot state cooresponds to a new node that has not yet been installed, but record of it does exist. When the BootManager starts, and the node is in this state, the user is prompted to continue with the installation. The intention here is to prevent a non-PlanetLab machine (like a user's desktop machine) from becoming inadvertantly wiped and installed with the PlanetLab node software. This is the default state for new nodes.

2. 'rins'

   Reinstall. In this state, a node will reinstall the node software, erasing anything that might have been on the disk before.

3. 'boot'

   Boot to bring a node online. This state cooresponds with nodes that have sucessfully installed, and can be chain booted to the runtime node kernel.

4. 'dbg'

   Debug. Regardless of whether or not a machine has been installed, this state sets up a node to be debugged by administrators. In debug mode, no node software is running, and the node can be accessed remotely by administrators.

# 5. Existing Management Authority API Calls

These calls, take from the PlanetLab Core Specification and extended with additional parameters, are used by principals to maintain the set of nodes managed by a MA. See the Core Specification for more information. The MA may provide an easy to use interface, such as a web interface, that calls these directly.

- AddNode( authentication, node_values )

  Add a new node record. node_values contains hostname, ip address and other network settings, and the new fields: boot_state. The resultant node_id is returned.

- UpdateNode( authentication, node_id, update_values )

  Update an existing node record. update_values can include hostname, ipaddress, and the new fields: boot_state.

- DeleteNode( authentication, node_id )

  Delete a node record.

# 6. New Management Authority API Calls

The API calls available as part of the MA API that are intended to be run by principals leverage existing authentication mechanisms. However, the API calls described below that will be run by the nodes themselves need a new authentication mechanism.

## 6.1. Node Authentication

As is done with other MA API calls, the first parameter to all BootManager related calls will be an authentication structure, consisting of these named fields:

- AuthMethod

  The authentication method, only 'hmac' is currently supported

- node_id

  The node id, contained in the configuration file on the node.

- node_ip

  The node's primary IP address. This will be checked with the node_id against MA records.

- value

  The authentication string, depending on method. For the 'hmac' method, a hash for the call using the HMAC algorithm, made from the parameters of the call and the key contained on the configuration file. For specifics on how this is created, see below.

Authentication is succesful if the MA is able to create the same hash from the values usings its own copy of the NODE_KEY. If the hash values to not match, then either the keys do not match or the values of the call were modified in transmision and the node cannot be authenticated.

Both the BootManager and the authentication functions at the MA must agree on a method for creating the hash values for each call. This hash is essentially a finger print of the method call, and is created by this algorithm:

1. Take the value of every part of each parameter, except the authentication structure, and convert them to strings. For arrays, each element is used. For dictionaries, not only is the value of all the items used, but the keys themselves. Embedded types (arrays or dictionaries inside arrays or dictionaries, etc), also have all values extracted.

2. Alphabetically sort all the parameters.

3. Concatenate them into a single string.

4. Prepend the string with the method name and [, and append ].

The implementation of this algorithm is in the function serialize_params in the file source/BootAPI.py. The same algorithm is located in the 'plc_api' repository, in the function serialize_params in the file PLC/Auth.py.

The resultant string is fed into the HMAC algorithm with the node key, and the resultant hash value is used in the authentication structure.

This authentication method makes a number of assumptions, detailed below.

1. All calls made to the MA are done over SSL, so the details of the authentication structure cannot be viewed by 3rd parties. If, in the future, non-SSL based calls are desired, a sequence number or some other value making each call unique will would be required to prevent replay attacks. In fact, the current use of SSL negates the need to create and send hashes across - technically, the key itself could be sent directly to the MA, assuming the connection is made to an HTTPS server with a third party signed SSL certificate being verified.

2. Athough calls are done over SSL, they use the Python class libary xmlrpclib, which does not do SSL certificate verification.

## 6.2. New API Calls

The calls available to the BootManager, that accept the above authentication, are:

- BootUpdateNode( authentication, update_values )

  Update a node record, including its boot state, primary network, or ssh host key.

- BootCheckAuthentication( authentication )

  Simply check to see if the node is recognized by the system and is authorized.

- BootGetNodeDetails( authentication )

  Return details about a node, including its state, what networks the MA database has configured for the node, and what the model of the node is.

- BootNotifyOwners( authentication, message, include_pi, include_tech, include_support )

  Notify someone about an event that happened on the machine, and optionally include the site Principal Investigators, technical contacts, and PlanetLab Support.

The new calls used by principals, using existing authentication methods, are:

- GenerateNodeConfigurationFile( authentication, node_id )

  Generate a configuration file to be used by the BootManager and the BootCD to configure the network for the node during boot. This resultant file also contains the node_id and node_key values. A new node_key is generated each time, invalidating old files. The full contents and format of this file is detailed below.

# 7. Core Software Package

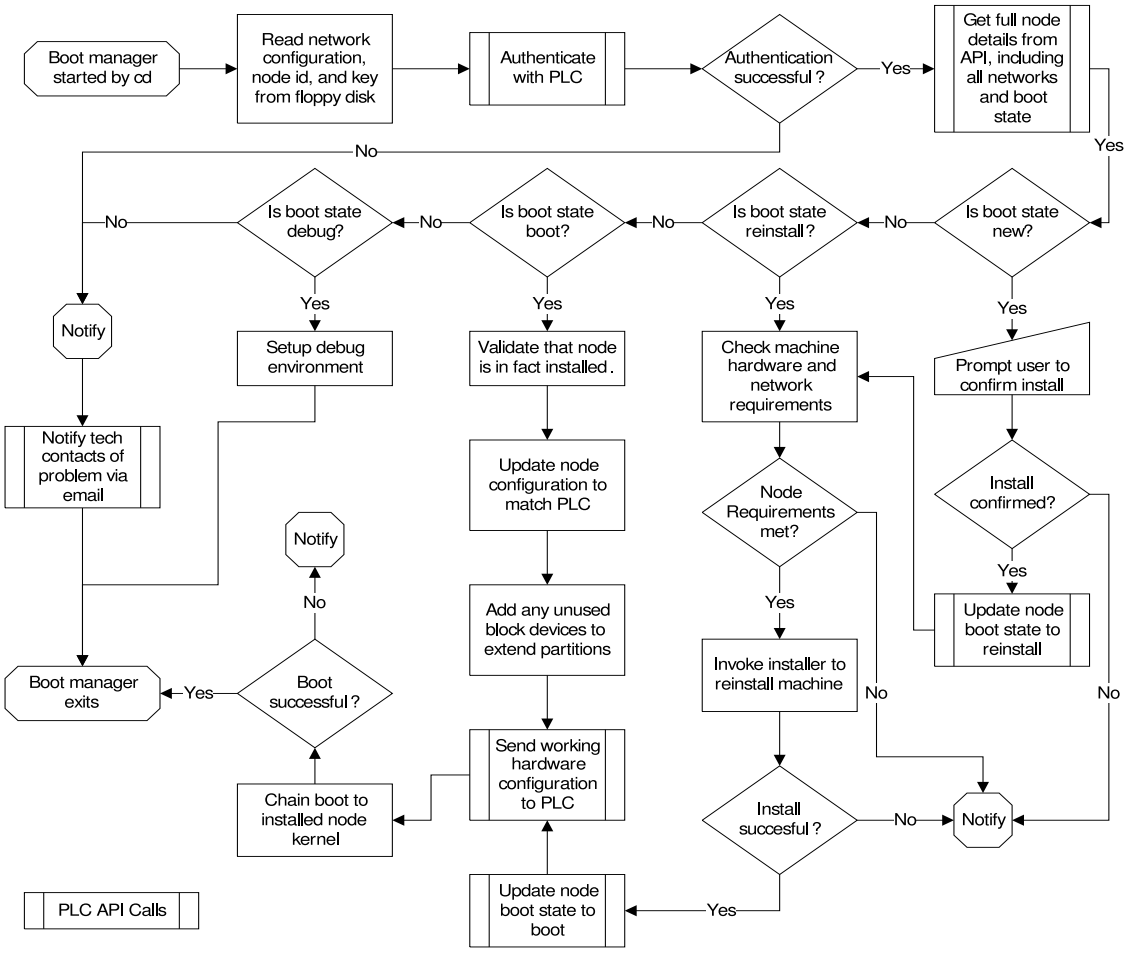
The BootManager core package, which is run on the nodes and contacts the MA API as necessary, is responsible for the following major functional units:

- Configuring node hardware and installing the PlanetLab operating system
- Putting a node into a debug state so administrators can track down problems
- Reconfiguring an already installed node to reflect new hardware, or changed network settings
- Booting an already installed node into the PlanetLab operating system

## 7.1. BootManager Flow Chart

Below is a high level flow chart of the BootManager, from the time it is executed to when it exits. This core state machine is located in source/BootManager.py.

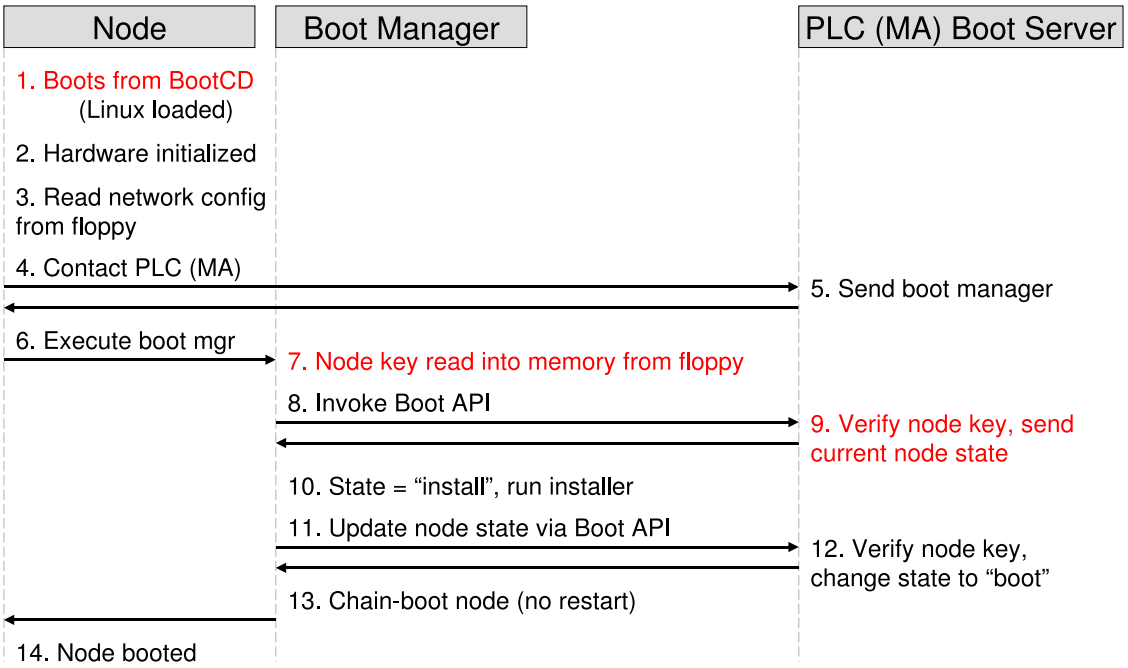
**Figure 1. BootManager Flow Chart**




# 7.2. Example Execution Session

Below is one example session of the BootManager, for a new node being installed then booted.

**Figure 2. Example Execution Session**




# 7.3. Boot CD Environment

The BootManager needs to be able to operate under all currently supported boot cds. The new 3.0 cd contains software the current 2.x cds do not contain, including the Logical Volume Manager (LVM) client tools, RPM, and YUM, among other packages. Given this requirement, the boot cd will need to download as necessary the extra support files it needs to run. Depending on the size of these files, they may only be downloaded by specific steps in the flow chart in figure 1, and thus are not mentioned.

See the PlanetLab BootCD Documentation for more information about the current, 3.x boot cds, how they are build, and what they provide to the BootManager.

# 7.4. Node Configuration Files

To remain compatible with 2.x boot cds, the format and existing contents of the configuration files for the nodes will not change. There will be, however, the addition of three fields:

1. NET_DEVICE

   If present, use the device with the specified mac address to contact the MA. The network on this device will be setup. If not present, the device represented by 'eth0' will be used.

2. NODE_KEY

   The unique, per-node key to be used during authentication and identity verification. This is a fixed length, random value that is only known to the node and the MA database.

3. NODE_ID

   The MA assigned node identifier.

An example of a configuration file for a dhcp networked machine:

```
IP_METHOD="dhcp"
HOST_NAME="planetlab-1"
DOMAIN_NAME="cs.princeton.edu"
NET_DEVICE="00:06:5B:EC:33:BB"
NODE_KEY="79efbe871722771675de604a227db8386bc6ef482a4b74"
NODE_ID="121"
```

An example of a configuration file for the same machine, only with a statically assigned network address:

```
IP_METHOD="static"
IP_ADDRESS="128.112.139.71"
IP_GATEWAY="128.112.139.65"
IP_NETMASK="255.255.255.192"
IP_NETADDR="128.112.139.127"
IP_BROADCASTADDR="128.112.139.127"
IP_DNS1="128.112.136.10"
IP_DNS2="128.112.136.12"
HOST_NAME="planetlab-1"
DOMAIN_NAME="cs.princeton.edu"
NET_DEVICE="00:06:5B:EC:33:BB"
NODE_KEY="79efbe871722771675de604a227db8386bc6ef482a4b74"
NODE_ID="121"
```

Existing 2.x boot cds will look for the configuration files only on a floppy disk, and the file must be named 'planet.cnf'. The new 3.x boot cds, however, will initially look for a file named 'plnode.txt' on either a floppy disk, or burned onto the cd itself. Alternatively, it will fall back to looking for the original file name, 'planet.cnf'. This initial file reading is performed by the boot cd itself to bring the nodes network online, so it can download and execute the BootManager.

However, the BootManager will also need to identify the location of and read in the file, so it can get the extra fields not initially used to bring the network online (primarily node_key and node_id). Below is the search order that the BootManager will use to locate a file.

Configuration file location search order:

| File name | Floppy drive | Flash devices | Root file system, in / | CDRom, in /usr/boot | CDRom, in /usr |
|---|---|---|---|---|---|
| plode.txt | 1 | 2 | 4 | 5 | 6 |
| planet.cnf | 3 | | | | |

# 7.5. BootManager Configuration

All run time configuration options for the BootManager exist in a single file located at source/configuration. These values are described below. These values cannot be changed on the fly - they must be changed and a new BootManager package built and signed.

- `VERSION`

  The current BootManager version. During install, written out to /etc/planetlab/install_version

- `BOOT_API_SERVER`

  The full URL of the API server to contact for authenticated operations.

- TEMP_PATH

  A writable path on the boot cd we can use for temporary storage of files.

- SYSIMG_PATH

  The path were we will mount the node logical volumes during any step that requires access to the disks.

- CACERT_PATH

  Variable not used anymore.

- NONCE_FILE

  Variable not used anymore.

- PLCONF_DIR

  The path that PlanetLab node configuration files will be created in during install. This should not be changed from /etc/planetlab, as this path is assumed in other PlanetLab components.

- SUPPORT_FILE_DIR

  A path on the boot server where per-step additional files may be located. For example, the packages that include the tools to allow older 2.x version boot cds to partition disks with LVM.

- ROOT_SIZE

  During install, this sets the size of the node root partition. It must be large enough to house all the node operational software. It does not store any user/slice files. Include 'G' suffix in this value, indicating gigabytes.

- SWAP_SIZE

  How much swap to configure the node with during install. Include 'G' suffix in this value, indicating gigabytes.

- SKIP_HARDWARE_REQUIREMENT_CHECK

  Whether or not to skip any of the hardware requirement checks, including total disk and memory size constraints.

- MINIMUM_MEMORY

  How much memory is required by a running PlanetLab node. If a machine contains less physical memory than this value, the install will not proceed.

- MINIMUM_DISK_SIZE

  The size of the small disk we are willing to attempt to use during the install, in gigabytes. Do not include any suffixes.

- TOTAL_MINIMUM_DISK_SIZE

  The size of all usable disks must be at least this sizse, in gigabytes. Do not include any suffixes.

- INSTALL_LANGS

Which language support to install. This value is used by RPM, and is used in writting /etc/rpm/macros before any RPMs are installed.

- `NUM_AUTH_FAILURES_BEFORE_DEBUG`

  How many authentication failures the BootManager is willing to except for any set of calls, before stopping and putting the node into a debug mode.

# 7.6. Installer Hardware Detection

When a node is being installed, the BootManager must identify which hardware the machine has that is applicable to a running node, and configure the node properly so it can boot properly post-install. The general procedure for doing so is outline in this section. It is implemented in the `source/systeminfo.py` file.

The process for identifying which kernel module needs to be load is:

1. Create a lookup table of all modules, and which PCI ids coorespond to this module.
2. For each PCI device on the system, lookup its module in the first table.
3. If a module is found, put in into one of two categories of modules, either network module or scsi module, based on the PCI device class.
4. For each network module, write out an 'eth<index>' entry in the modprobe.conf configuration file.
5. For each scsi module, write out a 'scsi_hostadapter<index>' entry in the modprobe.conf configuration file.

This process is fairly straight forward, and is simplified by the fact that we currently do not need support for USB, sound, or video devices when the node is fully running. The boot cd itself uses a similar process, but includes USB devices. Consult the boot cd technical documentation for more information.

The creation of the PCI id to kernel module table lookup uses three different sources of information, and merges them together into a single table for easier lookups. With these three sources of information, a fairly comprehensive lookup table can be generated for the devices that PlanetLab nodes need to have configured. They include:

1. The installed `/usr/share/hwdata/pcitable` file

   Created at the time the hwdata rpm was built, this file contains mappings of PCI ids to devices for a large number of devices. It is not necessarily complete, and doesn't take into account the modules that are actually available by the built PlanetLab kernel, which is a subset of the full set available (again, PlanetLab nodes do not have a use for network or video drivers, and thus are not typically built).

2. From the built kernel, the `modules.pcimap` from the `/lib/modules/<kernelversion>/` directory.

   This file is generated at the time the kernel is installed, and pulls the PCI ids out of each module, for the modules list they devices they support. Not all modules list all devices they sort, and some contain wild cards (that match any device of a single manufacturer).

3. From the built kernel, the `modules.dep` from the `/lib/modules/<kernelversion>/` directory.

   This file is also generated at the time the kernel is installed, but lists the dependencies between various modules. It is used to generate a list of modules that are actually available.

It should be noted here that SATA (Serial ATA) devices have been known to exist with both a PCI SCSI device class, and with a PCI IDE device class. Under linux 2.6 kernels, all SATA modules need to be listed in modprobe.conf under 'scsi_hostadapter' lines. This case is handled in the hardware loading scripts by making the assumption that if an IDE device matches a loadable module, it should be put in the modprobe.conf file, as 'real' IDE drivers are all currently built into the kernel, and do not need to be loaded. SATA devices that have a PCI SCSI device class are easily identified.

It is enssential that the modprobe.conf configuration file contain the correct drivers for the disks on the system, if they are present, as during kernel installation the creation of the initrd (initial ramdisk) which is responsible for booting the system uses this file to identify which drivers to include in it. A failure to do this typically results in an kernel panic at boot with a 'no init found' message.

# 8. Backward Compatibility

This section only applies to those interested in sections of the BootManager that exist for backward compatibility with nodes not containing the NODE_KEY. This does not affect any nodes added to the system after deployment of the BootManager.

Given the large number of nodes in PlanetLab, and the lack of direct physical access to them, the process of updating all configuration files to include the new NODE_ID and NODE_KEY will take a fairly significant amount of time. Rather than delay deployment of the BootManager until all machines are updated, alternative methods for aquiring these values is used for these nodes.

First, the NODE_ID value. For any machine already part of PlanetLab, there exists a record of its IP address and MAC address in PlanetLab central. To get the NODE_ID value, if it is not located in the configuration file, the BootManager uses a standard HTTP POST request to a known php page on the boot server, sending the IP and MAC address of the node. This php page queries the MA database (by using a PHP page, not through the MA API), and returns a NODE_ID if the node is part of PlanetLab, -1 otherwise.

Second, the NODE_KEY value. All Boot CDs currently in use, at the time they request a script from the MA to run, send in the request a randomly generated value called a boot_nonce, usually 32 bytes or larger. During normal BootManager operation, this value is ignored. However, in the absense of a node key, we can use this value. Although it is not as secure as a typical node key (because it is not distributed through external mechanisms, but is generated by the node itself), it can be used if we validate that the IP address of the node making the request matches the MA record. This means that nodes behind firewalls can no longer be allowed in this situation.