Introduction to CFEngine 3

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What is CFEngine?

"Cfengine, or the configuration engine is an agent / software robot and a high level policy language [...] to administrate and configure large computer networks." — CFEngine v2, https://www.gnu.org/software/cfengine/

"For many users, CFEngine is simply a configuration tool – i.e. software for deploying and patching systems according to a policy." — CFEngine v3, https://docs.cfengine.com/latest/guide-introduction.html

Disclaimers

1. CFEngine works on GNU/Linux, *BSD, Solaris, and Windows. *My experience is limited to GNU/Linux only.*
2. CFEngine comes in a free/open-source version ("CFEngine community") and a commercial version ("CFEngine Enterprise"), with more features and professional support. *My experience is limited to the "CFEngine community" only.*

Alternatives?

Puppet — a better CFEngine 2 ;-), written and extensible in Ruby.

Chef — a Ruby framework for managing systems.

SaltStack — A configuration management and remote execution framework. Conceptually very similar to Puppet, but written and extensible in Python.

Ansible — not quite an alternative: it's more geared to software deployment than configuration management. . .

(Theory)

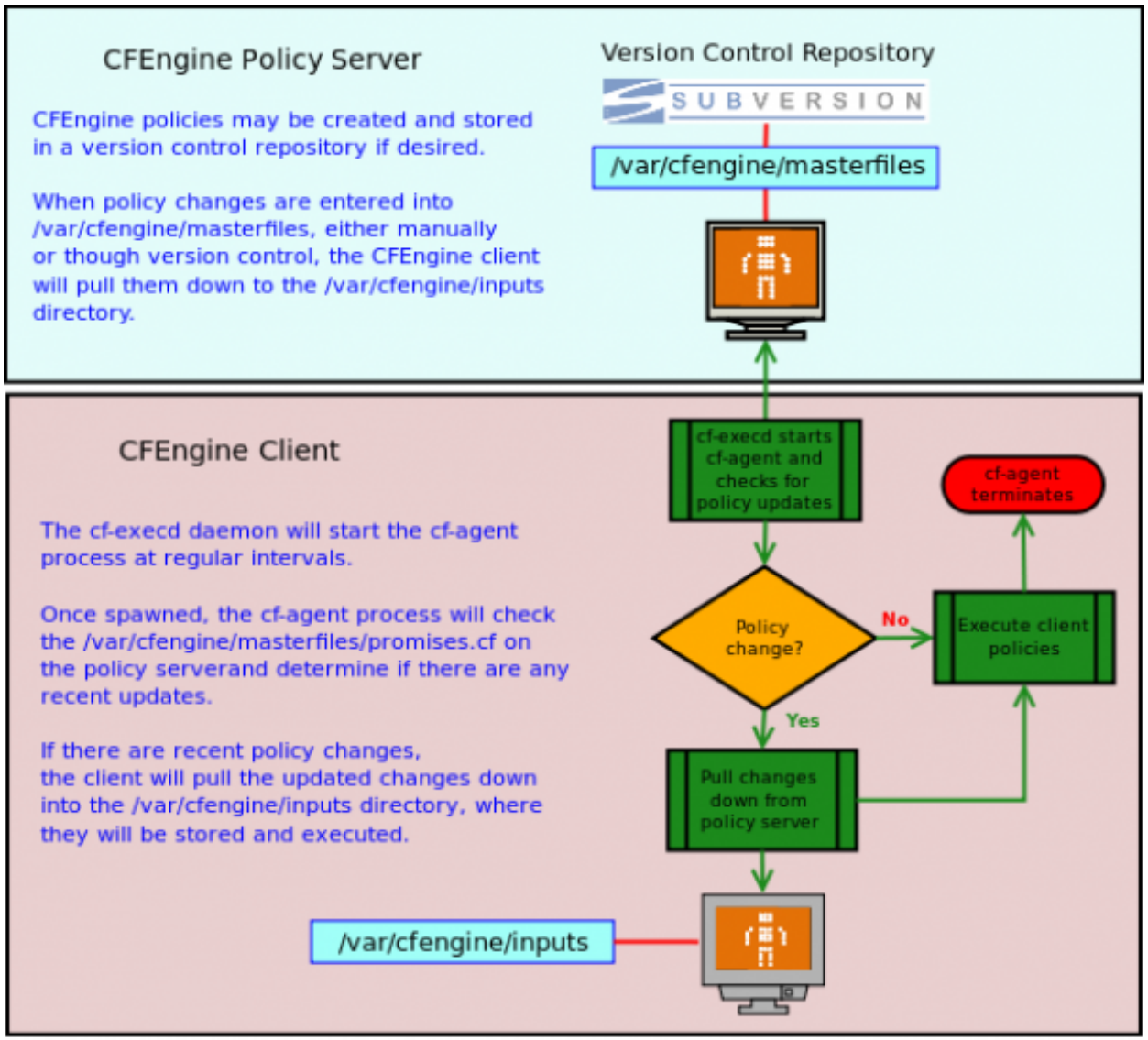
So, how does it work?

> *"The idea of CFEngine is to create a single file or set of configuration files which will describe the setup of every host on your network. [...] the* ***configuration of the host is checked against this model and, if necessary, any deviations are fixed.***"[1]

The host configuration ("model") is built from atoms called **promises**.

[1] https://www.gnu.org/software/cfengine/cfdetails.html

The agent workflow



Promises

"A promise is the documentation or definition of an intention to act or behave in some manner. They are the rules which CFEngine clients are responsible for implementing."[2]

```
files:
  "/tmp/email.[a-z0-9]+"
  file_select   => days_old("10"),
  delete        => tidy,
  comment       => "Delete temporary email files";
```

[2] https://docs.cfengine.com/latest/guide-writing-and-serving-policy.html

Promises

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```
files:
  "/tmp/email.[a-z0-9]+"
  file_select    => days_old("10"),
  delete         => tidy,
  comment        => "Delete temporary email files";
```

Target of the promise. A set of files in this case.

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```
files:
   "/tmp/email.[a-z0-9]+"
   file_select    => days_old("10"),
   delete         => tidy,
   comment        => "Delete temporary email files";
```

Additional criteria for building the promise target.

[2] https://docs.cfengine.com/latest/guide-writing-and-serving-policy.html

Promises

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```
files:
   "/tmp/email.[a-z0-9]+"
   file_select    => days_old("10"),
   delete         => tidy,
   comment        => "Delete temporary email files";
```

Action to take. In this case, delete all ("tidy").

[2] https://docs.cfengine.com/latest/guide-writing-and-serving-policy.html

Promises

A promise has three possible outcomes:

state is. . . ▼	▼state was. . . ▼ as promised	not as such
as promised	**kept**	**repaired**
not as such		**not kept**

Bundles, I

Promises must be grouped into **bundles**.

```
bundle agent test {
  vars:
    "secrets" slist => { "/etc/shadow",
                         "/etc/sudoers" };
  files:
    "$(secrets)"
      create => "false",
      perms  => mog("0400", "root", "root");
}
```

(Practice)

Example: keep secret files only readable by root

```
bundle agent keep_secrets {
  vars:
    "secrets" slist => { "/etc/shadow",
                         "/etc/sudoers" };
  files:
    "$(secrets)"
      create => "false",
      perms  => mog("0400", "root", "root");
}
```

Define `secrets` as a *list of strings*. Also available: simple strings, and (fake) integers and floats.

Example: keep secret files only readable by root

```
bundle agent keep_secrets {
  vars:
    "secrets" slist => { "/etc/shadow",
                         "/etc/sudoers" };
  files:
    "$(secrets)"
      create => "false",
      perms  => mog("0400", "root", "root");
}
```

Since `secrets` is a *list*, this implcitly *loops* over all its values.

Example: edit a file

```
bundle agent nss_myhostname {
  files:
      "/etc/nsswitch.conf"
      edit_line => enable_nss_myhostname;
}

bundle edit_line enable_nss_myhostname {
  replace_patterns:
      "(?x) ^hosts:\s* (((?!myhostname)\w+\s+)+)$"
      replace_with => value(
        "hosts: $(match.1) myhostname");
}
```

Editing is a complex operation, that requires a sequence of action. Therefore, it has a special kind of bundle.

Example: edit a file

```
bundle agent nss_myhostname {
  files:
      "/etc/nsswitch.conf"
      edit_line => enable_nss_myhostname;
}

bundle edit_line enable_nss_myhostname {
  replace_patterns:
      "(?x) ^hosts:\s* (((?!myhostname)\w+\s+)+)$"
      replace_with => value(
        "hosts: $(match.1) myhostname");
}
```

Also available: `insert_lines`, `delete_lines`, `field_edits`. Which can all be combined together.

Example: edit a file

```
bundle agent nss_myhostname {
  files:
      "/etc/nsswitch.conf"
      edit_line => enable_nss_myhostname;
}

bundle edit_line enable_nss_myhostname {
  replace_patterns:
      "(?x) ^hosts:\s* (((?!myhostname)\w+\s+)+)$"
      replace_with => value(
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}
```

Full PCRE syntax is supported everywhere in CFEngine.

Example: edit a file

```
bundle agent nss_myhostname {
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      "/etc/nsswitch.conf"
      edit_line => enable_nss_myhostname;
}

bundle edit_line enable_nss_myhostname {
  replace_patterns:
      "(?x) ^hosts:\s* (((?!myhostname)\w+\s+)+)$"
      replace_with => value(
        "hosts: $(match.1) myhostname");
}
```

CFEngine will not let you substitute a regexp with a string that matches the same regexp! Need to learn what "negative lookahead assertions" are...

Contexts / Classes

Contexts[3] are just boolean **constants**. The context "`any`" is CFEngine's alias for "true".

CFEngine has a concise syntax for "if" clauses using contexts:

```
vars:
  os_centos|os_rhel::
    "rules"     string => "/etc/sysconfig/iptables";
  os_debian|os_ubuntu::
    "rules"     string => "/etc/iptables/rules.v4";
```

[3] Previously called "Classes"

Contexts / Classes

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CFEngine has a concise syntax for "if" clauses using contexts:

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vars:
  os_centos|os_rhel::
    "rules"     string => "/etc/sysconfig/iptables";
  os_debian|os_ubuntu::
    "rules"     string => "/etc/iptables/rules.v4";
```

This part will only be executed when the context `os_centos` or the context `os_rhel` have the "true" value.

[3] Previously called "Classes"

Example: deploy template file, I

```
bundle agent iptables {
vars:
  os_centos|os_rhel::
    "rules"     string => "/etc/sysconfig/iptables";
  os_debian|os_ubuntu::
    "rules"     string => "/etc/iptables/rules.v4";
  any::
    "www_ports" ilist => { "80", "443" };
files:
  "$(rules)"
  edit_template  => "iptables.tmpl",
  edit_defaults  => empty,
  perms          => secret,
  create         => "true";
}
```

What template file to use and the initial content of the editing buffer.

Example: deploy template file, II

The actual contents of the template file:

```
# iptables.tmpl
[% CFEngine www:: %]
-A INPUT -p tcp -dport $(www_ports) -j ACCEPT
[% CFEngine am_policy_hub:: %]
-A INPUT -p tcp -dport 5308 -j ACCEPT
```

This is the way contexts are applied to templates. All subsequent lines are inserted if and only if context `www` is defined.

Example: deploy template file, II

The actual contents of the template file:

```
# iptables.tmpl
[% CFEngine www:: %]
-A INPUT -p tcp -dport $(www_ports) -j ACCEPT
[% CFEngine am_policy_hub:: %]
-A INPUT -p tcp -dport 5308 -j ACCEPT
```

Since `www_ports` is a list, this implicitly loops over all values.

Contexts / Classes, II

Additionally, contexts can be defined with specific promises, which evaluate a boolean expression:

```
classes:
  "os_debian"
  expression => "debian.!ubuntu";

  "os_debian6"
  expression => "os_debian&(debian_6|debian_squeeze)";
```

Class `os_debian` will be defined if class `debian` is defined and class `ubuntu` is not.

Contexts / Classes, II

Additionally, contexts can be defined with specific promises, which evaluate a boolean expression:

```
classes:
  "os_debian"
  expression => "debian.!ubuntu";

  "os_debian6"
  expression => "os_debian&(debian_6|debian_squeeze)";
```

Example: install an updated package

```
bundle agent cve_2014_0160 {
  vars:
      "to_update" slist => {"openssl", "libssl1.0.0"};
    ubuntu_12_04::
      "ok_version" string => "1.0.1-4ubuntu5.12";
    debian_wheezy::
      "ok_version" string => "1.0.1e-2+deb7u5";

  packages:
      "$(to_update)"
      package_policy  => "update",
      package_version => "$(ok_version)",
      package_select  => "<=",
      package_method  => generic;
}
```

Action to perform. Also available: `install`, `remove`, etc.

Example: install an updated package

```
bundle agent cve_2014_0160 {
  vars:
      "to_update" slist => {"openssl", "libssl1.0.0"};
    ubuntu_12_04::
      "ok_version" string => "1.0.1-4ubuntu5.12";
    debian_wheezy::
      "ok_version" string => "1.0.1e-2+deb7u5";

  packages:
      "$(to_update)"
      package_policy  => "update",
      package_version => "$(ok_version)",
      package_select  => "<=",
      package_method  => generic;
}
```

When to perform the action. Read: if the installed version is <= of the promised version.

Example: install an updated package

```
bundle agent cve_2014_0160 {
  vars:
      "to_update" slist => {"openssl", "libssl1.0.0"};
    ubuntu_12_04::
      "ok_version" string => "1.0.1-4ubuntu5.12";
    debian_wheezy::
      "ok_version" string => "1.0.1e-2+deb7u5";

  packages:
      "$(to_update)"
      package_policy  => "update",
      package_version => "$(ok_version)",
      package_select  => "<=",
      package_method  => generic;
}
```

Let CFEngine figure out what package manager to use.

Or you can be explicit and say: `apt`, `yum`, `rpm`, etc.

Contexts / Classes, III

Contexts can be set depending on the outcome of single promises:

```
files:
  "/etc/locale.gen"
  create     => "false",
  edit_line => uncomment_lines_matching(
                    "(de|en|fr|it)_.+", "#"),
  classes    => if_repaired("run_localegen");
```

Context `run_locale_gen` will be set if this promise is "repaired". One should use it to conditionally run the `locale-gen` command:

```
commands:
  os_debian.run_localegen::
    "/usr/sbin/locale-gen";
```

Example: extend CFEngine via modules

CFEngine can read back the output of any command and set/unset contexts or variables depending on it.

```
bundle local_ctx {
  commands:
    "cat locals.txt"
    module => "true";
}
```

```
# /var/cfengine/locals.txt
+pizza_box
=location[rack]=10
=location[height]=2
```

Instructs CFEngine to read and parse the command output.

Example: extend CFEngine via modules

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```

```
# /var/cfengine/locals.txt
+pizza_box
=location[rack]=10
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```

Sets context `pizza_box`

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```
bundle local_ctx {
  commands:
    "cat locals.txt"
    module => "true";
}
```

```
# /var/cfengine/locals.txt
+pizza_box
=location[rack]=10
=location[height]=2
```

Sets variables `location[rack]` and `location[height]`

Example: extend CFEngine via modules

CFEngine can read back the output of any command and set/unset contexts or variables depending on it.

```
bundle local_ctx {
  commands:
    "cat locals.txt"
    module => "true";
}
```

```
# /var/cfengine/locals.txt
+pizza_box
=location[rack]=10
=location[height]=2
```

Any line not starting with +, −, or = is ignored.

Normal ordering

> *"Within a bundle, the promise types are executed in a round-robin fashion according to so-called normal ordering [...]. The actual sequence continues for up to three iterations of the following, converging towards a final state:* `meta`, `vars`, `defaults`, `classes`, `users`, `files`, `packages`, `guest_environments`, `methods`, `processes`, `services`, `commands`, `storage`, `databases`, `reports`"

Promises in a bundle are **not** executed in the order they are written; rather CFEngine groups them by type and executes types in a fixed order.

Reference: https://docs.cfengine.com/latest/guide-language-concepts-normal-ordering.html

Normal ordering

> *"Within a bundle, the promise types are executed in a round-robin fashion according to so-called normal ordering [...]. The actual sequence continues for up to three iterations of the following, converging towards a final state:* `meta`, `vars`, `defaults`, `classes`, `users`, `files`, `packages`, `guest_environments`, `methods`, `processes`, `services`, `commands`, `storage`, `databases`, `reports`"

Note this! In other words, each promise may be re-evaluated up to three times during each bundle run.

Reference: https://docs.cfengine.com/latest/guide-language-concepts-normal-ordering.html

Example: send email

```
bundle agent send_email(to, subj, body) {
  vars:
      "tmpfile"
      string => execresult("/bin/mktemp", "noshell");
  methods:
      "Write body contents into temp file"
      usebundle  => append_to_file("$(tmpfile)",
                                   "$(body)");
  commands:
      "/usr/bin/mail $(to) -s $(subj) <$(tmpfile)";
      "/bin/rm -f '$(tmpfile)'";
}
```

Example: send email

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bundle agent send_email(to, subj, body) {
  vars:
      "tmpfile"
      string => execresult("/bin/mktemp", "noshell");
  methods:
      "Write body contents into temp file"
      usebundle  => append_to_file("$(tmpfile)",
                                   "$(body)");
  commands:
      "/usr/bin/mail $(to) -s $(subj) <$(tmpfile)";
      "/bin/rm -f '$(tmpfile)'";
}
```

This results in a new file name at each pass. Hence, the bundle never "converges" and three emails are sent!

What other promise types are there?

meta	Information about the bundle, mainly useful for documentation purposes.
vars	**Definition of variables**
defaults	"Default" values for bundle parameters
classes	Definition of additional contexts
users	Create or delete users in `/etc/passwd`
files	**Create, edit, or audit files**
packages	**Install or remove software packages**
guest_environments	Control VMs using *libvirt*
methods	Invoke other bundles
processes	Stop or signal running processes.
services	Start or stop system services.
commands	**Run arbitrary commands.**
storage	Mount NFS filesystems.
databases	Create, alter, or manage DBs and tables on SQL, LDAP, or MS Registry
reports	Print lines to the log file.

(The good, the bad, and the ugly) *.reverse()*

The ugly

It's (slowly) becoming a programming language, but the syntax is verbose and awkward, and is not getting better with time and releases:

```
bundle agent sysctl_data {
vars:
  "parms_vars[net.ipv4.tcp_tw_reuse]" string => "1";
  "parms_test_file" string => "/etc/sysctl";
  "parms_debug" string => "on";
  "parms_mgmt_policy" string => "ensure_present";
methods:
  "test" usebundle => sysctl("sysctl_data.parms_");
}
```

The bad

After more than 6 years, there are still serious bugs in the core functionality.

```
$ cat test.cf
 [...]
bundle agent test {
  vars:
      "variables" slist => variablesmatching(".+");
  reports:
    linux::
      "$(variables)=$($(variables))";
}

$ time cf-agent -f ./test.cf -b test
 [...]
real 43m5.345s
```

That, and “normal ordering.”

The good

Strives to provide *idempotent primitives*, upon which to build your own systems administration DSL.

Can react to changing conditions: facts are not gathered at the beginning of the run.

Can *really* be extended using any language.

Runs 3'200 (and counting) promises on the top of every hour on $O(100)$ hosts in the S^3IT server room, and *keeps all of them.* (Really, it can deploy and configure the entire OpenStack software suite at a whim.)

Appendix

Further reading

Learning CFEngine 3 The one and only beginners' book.

https://docs.cfengine.com/docs/3.6/reference-promise-types.html
The Reference Manual, you need this every time. . .

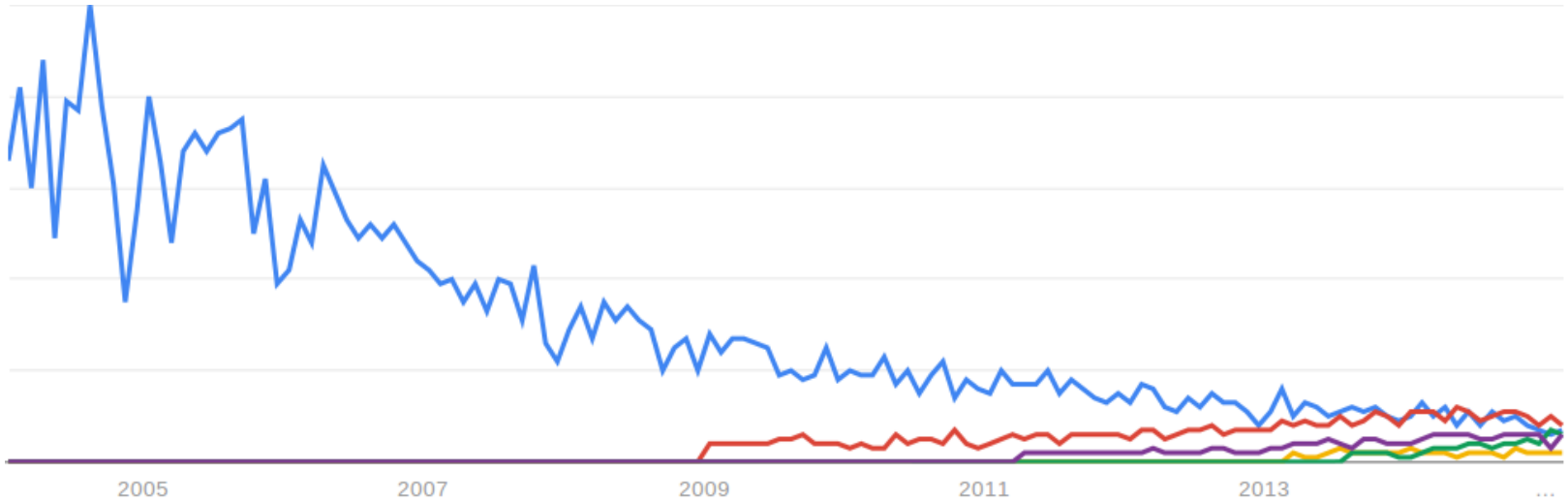
https://docs.cfengine.com/latest/guide-introduction.html What the various components are, and how they interact.

https://docs.cfengine.com/latest/guide-language-concepts.html
Overview of the CFEngine language syntax.

https://docs.cfengine.com/latest/guide-writing-and-serving-policy-promise
Overview of the promise types and best practices for structing a CFEngine code base.

https://docs.cfengine.com/latest/guide-design-center-configure-sketches-
Desgin Center / Sketches: how to re-use CFEngine code packaged and shared by others.

CFEngine Puppet Salt Stack Ansible Chef



Google trends: 2004–today (▲), 2009–today (▼)