



C o m m u n i t y E x p e r i e n c e D i s t i l l e d

Mastering Ansible

Design, develop, and solve real world automation and orchestration needs by unlocking the automation capabilities of Ansible

Jesse Keating

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Jesse Keating



BIRMINGHAM - MUMBAI

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He is currently stationed at F5 Networks, where he is involved in Solution development as a senior software engineer. Additionally, he spends time assisting colleagues in various knowledge-sharing situations revolving around OpenStack and Ansible.

I'd like to thank my family for encouraging me to take risks and supporting me along the way. Without their support, I would have never come out of my shell to explore new opportunities. I'd also like to thank my girlfriend for putting up with my angry beaver moments as I balance work with life.

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He loves to write code and keeps learning new ways to write optimal solutions. He blogs his experiences and opinions regarding programming and technology on his personal website, <http://www.sawantshah.com>, and on Medium, <https://medium.com/@sawant>. You can follow him on Twitter, where he shares learning resources and other useful tech material at @sawant.

Patrik Uytterhoeven has over 16 years of experience in IT. Most of this time was spent on HP Unix and Red Hat Linux. In late 2012, he joined Open-Future, a leading open source integrator and the first Zabbix reseller and training partner in Belgium.

When he joined Open-Future, he gained the opportunity to certify himself as a Zabbix Certified trainer. Since then, he has provided training and public demonstrations not only in Belgium but also around the world, in countries such as the Netherlands, Germany, Canada, and Ireland. His next step was to write a book about Zabbix. *Zabbix Cookbook* was born in March 2015 and was published by Packt Publishing.

As he also has a deep interest in configuration management, he wrote some Ansible roles for Red Hat 6.x and 7.x to deploy and update Zabbix. These roles, and some others, can be found in the Ansible Galaxy at <https://galaxy.ansible.com/list#/users/1375>.

He is also a technical reviewer of *Learning Ansible* and the upcoming book, *Ansible Configuration Management, Second Edition*, both by Packt Publishing.

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Preface

Welcome to Mastering Ansible, your guide to a variety of advanced features and functionality provided by Ansible, which is an automation and orchestration tool. This book will provide you with the knowledge and skills to truly understand how Ansible functions at the fundamental level. This will allow you to master the advanced capabilities required to tackle the complex automation challenges of today and beyond. You will gain knowledge of Ansible workflows, explore use cases for advanced features, troubleshoot unexpected behavior, and extend Ansible through customization.

What this book covers

Chapter 1, System Architecture and Design of Ansible, provides a detailed look at the ins and outs of how Ansible goes about performing tasks on behalf of an engineer, how it is designed, and how to work with inventories and variables.

Chapter 2, Protecting Your Secrets with Ansible, explores the tools available to encrypt data at rest and prevent secrets from being revealed at runtime.

Chapter 3, Unlocking the Power of Jinja2 Templates, states the varied uses of the Jinja2 templating engine within Ansible, and discusses ways to make the most out of its capabilities.

Chapter 4, Controlling Task Conditions, describes the changing of default behavior of Ansible to customize task error and change conditions.

Chapter 5, Composing Reusable Ansible Content with Roles, describes the approach to move beyond executing loosely organized tasks on hosts to encapsulating clean reusable abstractions to applying the specific functionality of a target set of hosts.

Chapter 6, Minimizing Downtime with Rolling Deployments, explores the common deployment and upgrade strategies to showcase relevant Ansible features.

Chapter 7, Troubleshooting Ansible, explores the various methods that can be employed to examine, introspect, modify, and debug the operations of Ansible.

Chapter 8, Extending Ansible, discovers the various ways in which new capabilities can be added to Ansible via modules, plugins, and inventory sources.

What you need for this book

To follow the examples provided in this book, you will need access to a computer platform capable of running Ansible. Currently, Ansible can be run from any machine with Python 2.6 or 2.7 installed (Windows isn't supported for the control machine). This includes Red Hat, Debian, CentOS, OS X, any of the BSDs, and so on.

This book uses the Ansible 1.9.x series release.

Ansible installation instructions can be found at http://docs.ansible.com/ansible/intro_installation.html.

Who this book is for

This book is intended for Ansible developers and operators who have an understanding of the core elements and applications but are now looking to enhance their skills in applying automation using Ansible.

Conventions

In this book, you will find a number of text styles that distinguish between different kinds of information. Here are some examples of these styles and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows:

"When `ansible` or `ansible-playbook` is directed at an executable file for an inventory source, Ansible will execute that script with a single argument, `--list`."

A block of code is set as follows:

```
- name: add new node into runtime inventory
  add_host:
    name: newmastery.example.name
    groups: web
    ansible_ssh_host: 192.168.10.30
```

New terms and **important words** are shown in bold. Words that you see on the screen, for example, in menus or dialog boxes, appear in the text like this: "The first is an SSH feature, **ControlPersist**, which provides a mechanism to create persistent sockets when first connecting to a remote host that can be reused in subsequent connections to bypass some of the handshaking required when creating a connection."



Warnings or important notes appear in a box like this.



Tips and tricks appear like this.

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1

System Architecture and Design of Ansible

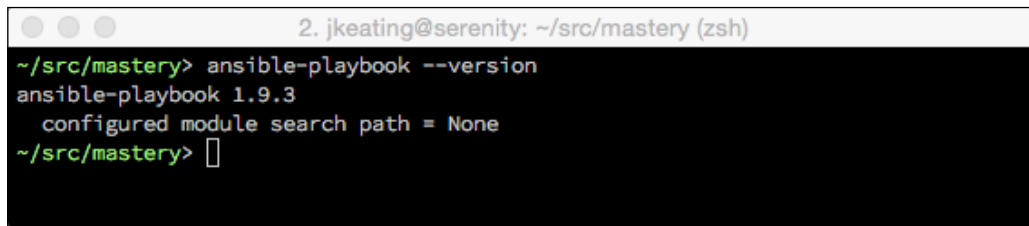
This chapter provides a detailed exploration of the architecture and design of how **Ansible** goes about performing tasks on your behalf. We will cover basic concepts of inventory parsing and how the data is discovered, and then dive into playbook parsing. We will take a walk through module preparation, transportation, and execution. Lastly, we will detail variable types and find out where variables can be located, the scope they can be used for, and how precedence is determined when variables are defined in more than one location. All these things will be covered in order to lay the foundation for mastering Ansible!

In this chapter, we will cover the following topics:

- Ansible version and configuration
- Inventory parsing and data sources
- Playbook parsing
- Module transport and execution
- Variable types and locations
- Variable precedence

Ansible version and configuration

It is assumed that you have Ansible installed on your system. There are many documents out there that cover installing Ansible in a way that is appropriate for the operating system and version that you might be using. This book will assume the use of the Ansible 1.9.x version. To discover the version in use on a system with Ansible already installed, make use of the version argument, that is, either `ansible` or `ansible-playbook`:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook --version
ansible-playbook 1.9.3
  configured module search path = None
~/src/mastery> 
```



Note that `ansible` is the executable for doing ad-hoc one-task executions and `ansible-playbook` is the executable that will process playbooks for orchestrating many tasks.

The configuration for Ansible can exist in a few different locations, where the first file found will be used. The search order changed slightly in version 1.5, with the new order being:

- `ANSIBLE_CFG`: This is an environment variable
- `ansible.cfg`: This is in the current directory
- `ansible.cfg`: This is in the user's home directory
- `/etc/ansible/ansible.cfg`

Some installation methods may include placing a **config** file in one of these locations. Look around to check whether such a file exists and see what settings are in the file to get an idea of how Ansible operation may be affected. This book will assume no settings in the `ansible.cfg` file that would affect the default operation of Ansible.

Inventory parsing and data sources

In Ansible, nothing happens without an inventory. Even ad hoc actions performed on localhost require an inventory, even if that inventory consists just of the localhost. The inventory is the most basic building block of Ansible architecture. When executing `ansible` or `ansible-playbook`, an inventory must be referenced. Inventories are either files or directories that exist on the same system that runs `ansible` or `ansible-playbook`. The location of the inventory can be referenced at runtime with the `-inventory-file` (`-i`) argument, or by defining the path in an Ansible config file.

Inventories can be static or dynamic, or even a combination of both, and Ansible is not limited to a single inventory. The standard practice is to split inventories across logical boundaries, such as *staging* and *production*, allowing an engineer to run a set of plays against their staging environment for validation, and then follow with the same exact plays run against the production inventory set.

Variable data, such as specific details on how to connect to a particular host in your inventory, can be included along with an inventory in a variety of ways as well, and we'll explore the options available to you.

The static inventory

The static inventory is the most basic of all the inventory options. Typically, a static inventory will consist of a single file in the `ini` format. Here is an example of a static inventory file describing a single host, `mastery.example.name`:

```
mastery.example.name
```

That is all there is to it. Simply list the names of the systems in your inventory. Of course, this does not take full advantage of all that an inventory has to offer. If every name were listed like this, all plays would have to reference specific host names, or the special `all` group. This can be quite tedious when developing a playbook that operates across different sets of your infrastructure. At the very least, hosts should be arranged into groups. A design pattern that works well is to arrange your systems into groups based on expected functionality. At first, this may seem difficult if you have an environment where single systems can play many different roles, but that is perfectly fine. Systems in an inventory can exist in more than one group, and groups can even consist of other groups! Additionally, when listing groups and hosts, it's possible to list hosts without a group. These would have to be listed first, before any other group is defined.

Let's build on our previous example and expand our inventory with a few more hosts and some groupings:

```
[web]
mastery.example.name

[dns]
backend.example.name

[database]
backend.example.name

[frontend:children]
web

[backend:children]
dns
database
```

What we have created here is a set of three groups with one system in each, and then two more groups, which logically group all three together. Yes, that's right; you can have groups of groups. The syntax used here is `[groupname:children]`, which indicates to Ansible's inventory parser that this group by the name of `groupname` is nothing more than a grouping of other groups. The children in this case are the names of the other groups. This inventory now allows writing plays against specific hosts, low-level role-specific groups, or high-level logical groupings, or any combination.

By utilizing generic group names, such as `dns` and `database`, Ansible plays can reference these generic groups rather than the explicit hosts within. An engineer can create one inventory file that fills in these groups with hosts from a preproduction staging environment and another inventory file with the production versions of these groupings. The playbook content does not need to change when executing on either staging or production environment because it refers to the generic group names that exist in both inventories. Simply refer to the right inventory to execute it in the desired environment.

Inventory variable data

Inventories provide more than just system names and groupings. Data about the systems can be passed along as well. This can include:

- Host-specific data to use in templates
- Group-specific data to use in task arguments or conditionals
- Behavioral parameters to tune how Ansible interacts with a system

Variables are a powerful construct within Ansible and can be used in a variety of ways, not just the ways described here. Nearly every single thing done in Ansible can include a variable reference. While Ansible can discover data about a system during the setup phase, not all data can be discovered. Defining data with the inventory is how to expand the dataset. Note that variable data can come from many different sources, and one source may override another source. Variable precedence order is covered later in this chapter.

Let's improve upon our existing example inventory and add to it some variable data. We will add some host-specific data as well as group specific data:

```
[web]
mastery.example.name ansible_ssh_host=192.168.10.25

[dns]
backend.example.name

[database]
backend.example.name

[frontend:children]
web

[backend:children]
dns
database

[web:vars]
http_port=88
proxy_timeout=5

[backend:vars]
ansible_ssh_port=314

[all:vars]
ansible_ssh_user=otto
```

In this example, we defined `ansible_ssh_host` for `mastery.example.name` to be the IP address of `192.168.10.25`. An `ansible_ssh_host` is a **behavioral inventory parameter**, which is intended to alter the way Ansible behaves when operating with this host. In this case, the parameter instructs Ansible to connect to the system using the provided IP address rather than performing a DNS lookup on the name `mastery.example.name`. There are a number of other behavioral inventory parameters, which are listed at the end of this section along with their intended use.

Our new inventory data also provides group level variables for the web and backend groups. The web group defines `http_port`, which may be used in an `nginx` configuration file, and `proxy_timeout`, which might be used to determine **HAProxy** behavior. The backend group makes use of another behavioral inventory parameter to instruct Ansible to connect to the hosts in this group using port 314 for SSH, rather than the default of 22.

Finally, a construct is introduced that provides variable data across all the hosts in the inventory by utilizing a built-in *all* group. Variables defined within this group will apply to every host in the inventory. In this particular example, we instruct Ansible to log in as the `otto` user when connecting to the systems. This is also a behavioral change, as the Ansible default behavior is to log in as a user with the same name as the user executing `ansible` or `ansible-playbook` on the control host.

Here is a table of behavior inventory parameters and the behavior they intend to modify:

Inventory parameters	Behaviour
<code>ansible_ssh_host</code>	This is the name of the host to connect to, if different from the alias you wish to give to it.
<code>ansible_ssh_port</code>	This is the SSH port number, if not 22.
<code>ansible_ssh_user</code>	This is the default SSH username to use.
<code>ansible_ssh_pass</code>	This is the SSH password to use (this is insecure, we strongly recommend using <code>--ask-pass</code> or the SSH keys)
<code>ansible_sudo_pass</code>	This is the sudo password to use (this is insecure, we strongly recommend using <code>--ask-sudo-pass</code>)
<code>ansible_sudo_exe</code>	This is the sudo command path.
<code>ansible_connection</code>	This is the connection type of the host. Candidates are local, smart, ssh, or paramiko. The default is paramiko before Ansible 1.2, and smart afterwards, which detects whether the usage of ssh will be feasible based on whether the ssh feature ControlPersist is supported
<code>ansible_ssh_private_key_file</code>	This is the private key file used by SSH. This is useful if you use multiple keys and you don't want to use SSH agent

Inventory parameters	Behaviour
<code>ansible_shell_type</code>	This is the shell type of the target system. By default, commands are formatted using the <code>sh</code> -style syntax. Setting this to <code>csh</code> or <code>fish</code> will cause commands to be executed on target systems to follow those shell's syntax instead
<code>ansible_python_interpreter</code>	This is the target host Python path. This is useful for systems with more than one Python, systems that are not located at <code>/usr/bin/python</code> (such as <code>*BSD</code>), or for systems where <code>/usr/bin/python</code> is not a 2.X series Python. We do not use the <code>/usr/bin/env</code> mechanism as it requires the remote user's path to be set right and also assumes that the Python executable is named <code>Python</code> , where the executable might be named something like <code>python26</code> .
<code>ansible_*_interpreter</code>	This works for anything such as Ruby or Perl and works just like <code>ansible_python_interpreter</code> . This replaces the shebang of modules which run on that host

Dynamic inventories

A static inventory is great and enough for many situations. But there are times when a statically written set of hosts is just too unwieldy to manage. Consider situations where inventory data already exists in a different system, such as **LDAP**, a cloud computing provider, or an in-house **CMDB** (inventory, asset tracking, and data warehousing) system. It would be a waste of time and energy to duplicate that data, and in the modern world of on-demand infrastructure, that data would quickly grow stale or disastrously incorrect.

Another example of when a dynamic inventory source might be desired is when your site grows beyond a single set of playbooks. Multiple playbook repositories can fall into the trap of holding multiple copies of the same inventory data, or complicated processes have to be created to reference a single copy of the data. An external inventory can easily be leveraged to access the common inventory data stored outside of the playbook repository to simplify the setup. Thankfully, Ansible is not limited to static inventory files.

A dynamic inventory source (or plugin) is an executable script that Ansible will call at runtime to discover real-time inventory data. This script may reach out into external data sources and return data, or it can just parse local data that already exists but may not be in the Ansible inventory `ini` format. While it is possible and easy to develop your own dynamic inventory source, which we will cover in a later chapter, Ansible provides a number of example inventory plugins, including but not limited to:

- OpenStack Nova
- Rackspace Public Cloud
- DigitalOcean
- Linode
- Amazon EC2
- Google Compute Engine
- Microsoft Azure
- Docker
- Vagrant

Many of these plugins require some level of configuration, such as user credentials for EC2 or authentication endpoint for OpenStack Nova. Since it is not possible to configure additional arguments for Ansible to pass along to the inventory script, the configuration for the script must either be managed via an `ini` config file read from a known location, or environment variables read from the shell environment used to execute `ansible` or `ansible-playbook`.

When `ansible` or `ansible-playbook` is directed at an executable file for an inventory source, Ansible will execute that script with a single argument, `--list`. This is so that Ansible can get a listing of the entire inventory in order to build up its internal objects to represent the data. Once that data is built up, Ansible will then execute the script with a different argument for every host in the data to discover variable data. The argument used in this execution is `--host <hostname>`, which will return any variable data specific to that host.

In *Chapter 8, Extending Ansible*, we will develop our own custom inventory plugin to demonstrate how they operate.

Run-time inventory additions

Just like static inventory files, it is important to remember that Ansible will parse this data once, and only once, per `ansible` or `ansible-playbook` execution. This is a fairly common stumbling point for users of cloud dynamic sources, where frequently a playbook will create a new cloud resource and then attempt to use it as if it were part of the inventory. This will fail, as the resource was not part of the inventory when the playbook launched. All is not lost though! A special module is provided that allows a playbook to temporarily add inventory to the in-memory inventory object, the `add_host` module.

The `add_host` module takes two options, `name` and `groups`. The `name` should be obvious, it defines the hostname that Ansible will use when connecting to this particular system. The `groups` option is a comma-separated list of groups to add this new system to. Any other option passed to this module will become the host variable data for this host. For example, if we want to add a new system, name it `newmastery.example.name`, add it to the `web` group, and instruct Ansible to connect to it by way of IP address `192.168.10.30`, we will create a task like this:

```
- name: add new node into runtime inventory
  add_host:
    name: newmastery.example.name
    groups: web
    ansible_ssh_host: 192.168.10.30
```

This new host will be available to use, by way of the name provided, or by way of the `web` group, for the rest of the `ansible-playbook` execution. However, once the execution has completed, this host will not be available unless it has been added to the inventory source itself. Of course, if this were a new cloud resource created, the next `ansible` or `ansible-playbook` execution that sourced inventory from that cloud would pick up the new member.

Inventory limiting

As mentioned earlier, every execution of `ansible` or `ansible-playbook` will parse the entire inventory it has been directed at. This is even true when a limit has been applied. A limit is applied at run time by making use of the `--limit` runtime argument to `ansible` or `ansible-playbook`. This argument accepts a pattern, which is basically a mask to apply to the inventory. The entire inventory is parsed, and at each play the supplied limit mask further limits the host pattern listed for the play.

Let's take our previous inventory example and demonstrate the behavior of Ansible with and without a limit. If you recall, we have the special group `all` that we can use to reference all the hosts within an inventory. Let's assume that our inventory is written out in the current working directory in a file named `mastery-hosts`, and we will construct a playbook to demonstrate the host on which Ansible is operating. Let's write this playbook out as `mastery.yaml`:

```
---
- name: limit example play
  hosts: all
  gather_facts: false

  tasks:
    - name: tell us which host we are on
      debug:
        var: inventory_hostname
```

The debug module is used to print out text, or values of variables. We'll use this module a lot in this book to simulate actual work being done on a host.

Now, let's execute this simple playbook without supplying a limit. For simplicity's sake, we will instruct Ansible to utilize a local connection method, which will execute locally rather than attempting to SSH to these nonexistent hosts. Let's take a look at the following screenshot:

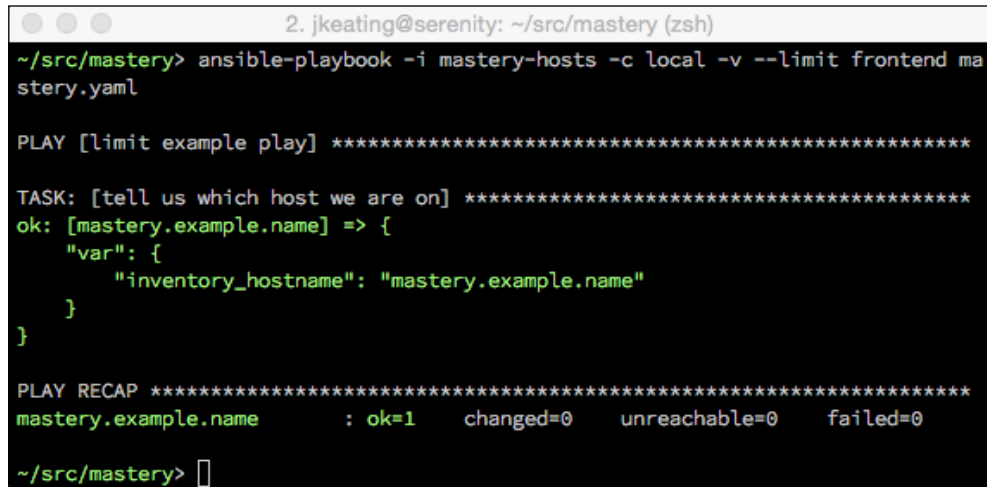
```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts -c local -v mastery.yaml

PLAY [limit example play] *****

TASK: [tell us which host we are on] *****
ok: [mastery.example.name] => {
  "var": {
    "inventory_hostname": "mastery.example.name"
  }
}
ok: [backend.example.name] => {
  "var": {
    "inventory_hostname": "backend.example.name"
  }
}

PLAY RECAP *****
backend.example.name      : ok=1    changed=0    unreachable=0    failed=0
mastery.example.name      : ok=1    changed=0    unreachable=0    failed=0
~/src/mastery> 
```

As we can see, both hosts `backend.example.name` and `mastery.example.name` were operated on. Let's see what happens if we supply a limit, specifically to limit our run to only frontend systems:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts -c local -v --limit frontend ma
stery.yaml

PLAY [limit example play] *****

TASK: [tell us which host we are on] *****
ok: [mastery.example.name] => {
  "var": {
    "inventory_hostname": "mastery.example.name"
  }
}

PLAY RECAP *****
mastery.example.name      : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

We can see that only `mastery.example.name` was operated on this time. While there are no visual clues that the entire inventory was parsed, if we dive into the Ansible code and examine the inventory object, we will indeed find all the hosts within, and see how the limit is applied every time the object is queried for items.

It is important to remember that regardless of the host's pattern used in a play, or the limit supplied at runtime, Ansible will still parse the entire inventory set during each run. In fact, we can prove this by attempting to access host variable data for a system that would otherwise be masked by our limit. Let's expand our playbook slightly and attempt to access the `ansible_ssh_port` variable from `backend.example.name`:

```

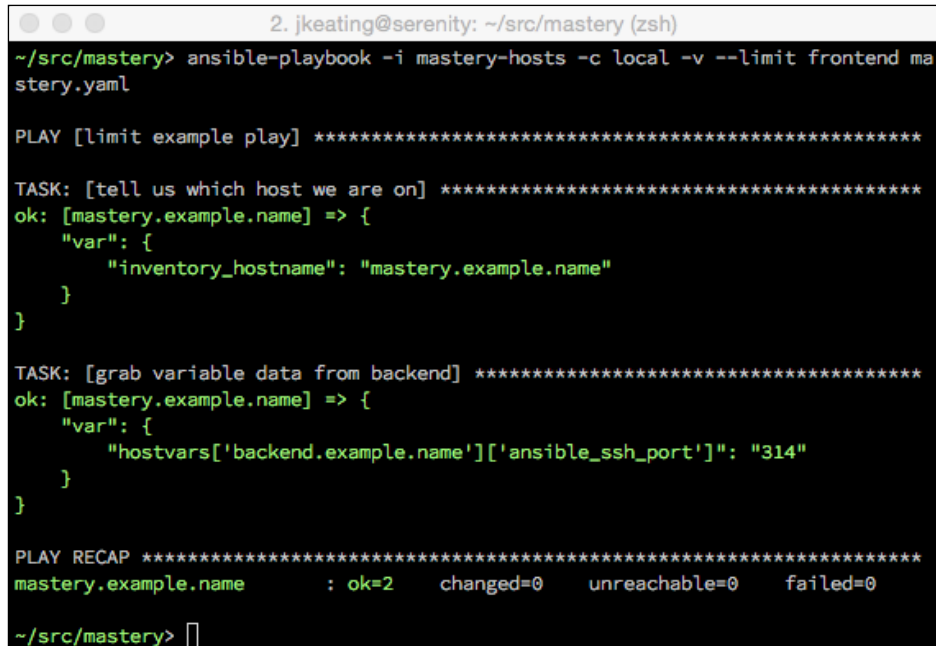
---
- name: limit example play
  hosts: all
  gather_facts: false

  tasks:
    - name: tell us which host we are on
      debug:
        var: inventory_hostname

    - name: grab variable data from backend
      debug:
        var: hostvars['backend.example.name']['ansible_ssh_port']

```

We will still apply our limit, which will restrict our operations to just `mastery.example.name`:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The command is 'ansible-playbook -i mastery-hosts -c local -v --limit frontend mastery.yaml'. The output shows a play for 'limit example play' with two tasks. The first task, '[tell us which host we are on]', returns a dictionary with 'inventory_hostname' set to 'mastery.example.name'. The second task, '[grab variable data from backend]', returns a dictionary with 'hostvars[\'backend.example.name\'][\'ansible_ssh_port\']' set to '314'. A recap line shows 'mastery.example.name' with 'ok=2', 'changed=0', 'unreachable=0', and 'failed=0'. The prompt '~ /src/mastery>' is visible at the bottom.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts -c local -v --limit frontend mastery.yaml

PLAY [limit example play] *****

TASK: [tell us which host we are on] *****
ok: [mastery.example.name] => {
  "var": {
    "inventory_hostname": "mastery.example.name"
  }
}

TASK: [grab variable data from backend] *****
ok: [mastery.example.name] => {
  "var": {
    "hostvars['backend.example.name']['ansible_ssh_port']": "314"
  }
}

PLAY RECAP *****
mastery.example.name      : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> █
```

We have successfully accessed the host variable data (by way of group variables) for a system that was otherwise limited out. This is a key skill to understand, as it allows for more advanced scenarios, such as directing a task at a host that is otherwise limited out. Delegation can be used to manipulate a load balancer to put a system into maintenance mode while being upgraded without having to include the load balancer system in your limit mask.

Playbook parsing

The whole purpose of an inventory source is to have systems to manipulate. The manipulation comes from playbooks (or in the case of `ansible` ad hoc execution, simple single task plays). You should already have a base understanding of playbook construction so we won't spend a lot of time covering that, however, we will delve into some specifics of how a playbook is parsed. Specifically, we will cover the following:

- Order of operations
- Relative path assumptions
- Play behavior keys

- Host selection for plays and tasks
- Play and task names

Order of operations

Ansible is designed to be as easy as possible for a human to understand. The developers strive to strike the best balance between human comprehension and machine efficiency. To that end, nearly everything in Ansible can be assumed to be executed in a top to bottom order; that is the operation listed at the top of a file will be accomplished before the operation listed at the bottom of a file. Having said that, there are a few caveats and even a few ways to influence the order of operations.

A playbook has only two main operations it can accomplish. It can either run a play, or it can include another playbook from somewhere on the filesystem. The order in which these are accomplished is simply the order in which they appear in the playbook file, from top to bottom. It is important to note that while the operations are executed in order, the entire playbook, and any included playbooks, is completely parsed before any executions. This means that any included playbook file has to exist at the time of the playbook parsing. They cannot be generated in an earlier operation.

Within a play, there are a few more operations. While a playbook is strictly ordered from top to bottom, a play has a more nuanced order of operations. Here is a list of the possible operations and the order in which they will happen:

- Variable loading
- Fact gathering
- The `pre_tasks` execution
- Handlers notified from the `pre_tasks` execution
- Roles execution
- Tasks execution
- Handlers notified from roles or tasks execution
- The `post_tasks` execution
- Handlers notified from `post_tasks` execution

Here is an example play with most of these operations shown:

```
---
- hosts: localhost
  gather_facts: false

  vars:
```

```
- a_var: derp

pre_tasks:
  - name: pretask
    debug: msg="a pre task"
    changed_when: true
    notify: say hi

roles:
  - role: simple
    derp: newval

tasks:
  - name: task
    debug: msg="a task"
    changed_when: true
    notify: say hi

post_tasks:
  - name: posttask
    debug: msg="a post task"
    changed_when: true
    notify: say hi
```

Regardless of the order in which these blocks are listed in a play, this is the order in which they will be processed. Handlers (the tasks that can be triggered by other tasks that result in a change) are a special case. There is a utility module, `meta`, which can be used to trigger handler processing at that point:

```
- meta: flush_handlers
```

This will instruct Ansible to process any pending handlers at that point before continuing on with the next task or next block of actions within a play. Understanding the order and being able to influence the order with `flush_handlers` is another key skill to have when there is a need to orchestrate complicated actions, where things such as service restarts are very sensitive to order. Consider the initial rollout of a service. The play will have tasks that modify `config` files and indicate that the service should be restarted when these files change. The play will also indicate that the service should be running. The first time this play happens, the config file will change and the service will change from not running to running. Then, the handlers will trigger, which will cause the service to restart immediately. This can be disruptive to any consumers of the service. It would be better to flush the handlers before a final task to ensure the service is running. This way, the restart will happen before the initial start, and thus the service will start up once and stay up.

Relative path assumptions

When Ansible parses a playbook, there are certain assumptions that can be made about the relative paths of items referenced by the statements in a playbook. In most cases, paths for things such as variable files to include, task files to include, playbook files to include, files to copy, templates to render, scripts to execute, and so on, are all relative to the directory where the file referencing them lives. Let's explore this with an example playbook and directory listing to show where the things are.

- Directory structure:

```
.
├─ a_vars_file.yaml
├─ mastery-hosts
├─ relative.yaml
└─ tasks
    ├─ a.yaml
    └─ b.yaml
```

- Contents of `_vars_file.yaml`:

```
---
something: "better than nothing"
```

- Contents of `relative.yaml`:

```
---
- name: relative path play
  hosts: localhost
  gather_facts: false

  vars_files:
    - a_vars_file.yaml

  tasks:
    - name: who am I
      debug:
        msg: "I am mastery task"

    - name: var from file
      debug: var=something

    - include: tasks/a.yaml
```


- Contents of tasks/a.yaml:

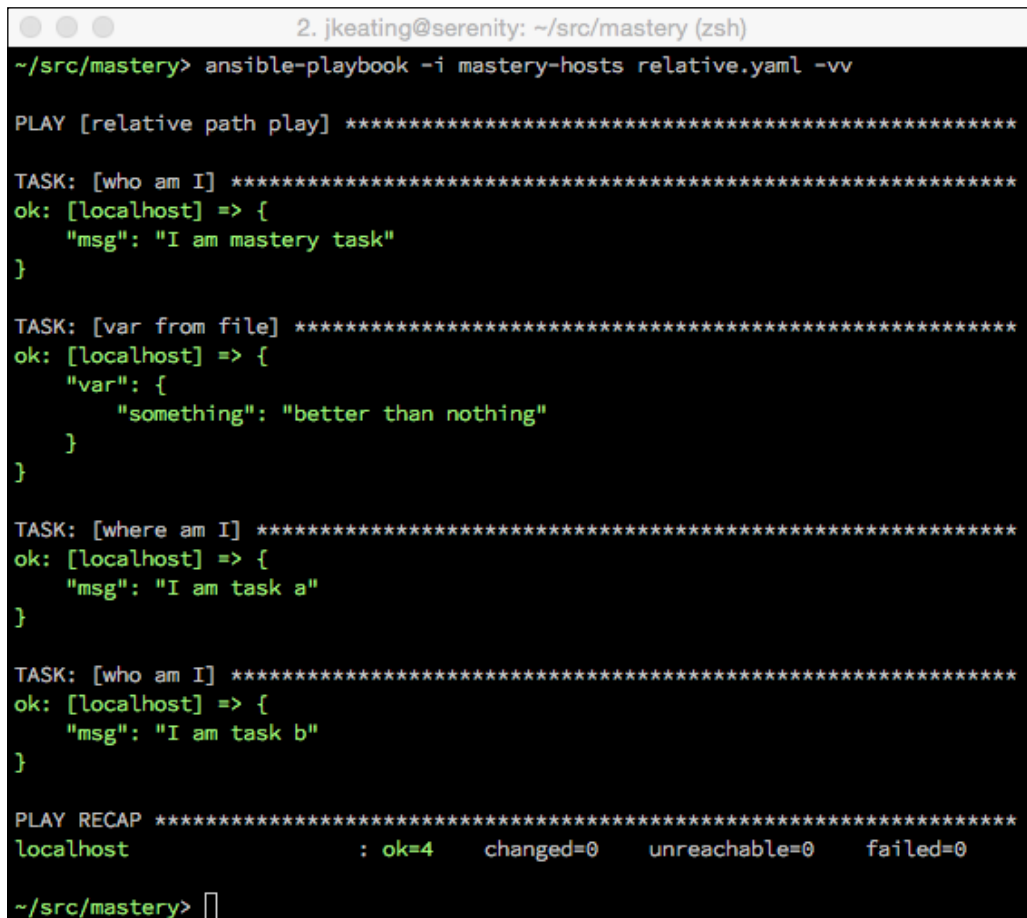
```
---
- name: where am I
  debug:
    msg: "I am task a"

- include: b.yaml
```

- Contents of tasks/b.yaml:

```
---
- name: who am I
  debug:
    msg: "I am task b"
```

Here the execution of the playbook is shown as follows:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The command is 'ansible-playbook -i mastery-hosts relative.yaml -vv'. The output shows the playbook 'relative path play' being executed on 'localhost'. It lists four tasks: '[who am I]', '[var from file]', '[where am I]', and '[who am I]', all of which are successful. The final output is a 'PLAY RECAP' showing 4 tasks were OK, with no changes, unreachable, or failed tasks.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts relative.yaml -vv

PLAY [relative path play] *****

TASK: [who am I] *****
ok: [localhost] => {
  "msg": "I am mastery task"
}

TASK: [var from file] *****
ok: [localhost] => {
  "var": {
    "something": "better than nothing"
  }
}

TASK: [where am I] *****
ok: [localhost] => {
  "msg": "I am task a"
}

TASK: [who am I] *****
ok: [localhost] => {
  "msg": "I am task b"
}

PLAY RECAP *****
localhost                : ok=4    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

We can clearly see the relative reference to paths and how they are relative to the file referencing them. When using roles there are some additional relative path assumptions, however we'll cover that in detail in a later chapter.

Play behavior keys

When Ansible parses a play, there are a few keys it looks for to define various behaviors for a play. These keys are written at the same level as `hosts:` key. Here are the keys that can be used:

- **any_errors_fatal:** This Boolean key is used to instruct Ansible to treat any failure as a fatal error to prevent any further tasks from being attempted. This changes the default where Ansible will continue until all the tasks are complete or all the hosts have failed.
- **connection:** This string key defines which connection system to use for a given play. A common choice to make here is `local`, which instructs Ansible to do all the operations locally, but with the context of the system from the inventory.
- **gather_facts:** This Boolean key controls whether or not Ansible will perform the fact gathering phase of operation, where a special task will run on a host to discover various facts about the system. Skipping fact gathering, when you are sure that you do not need any of the discovered data, can be a significant time saver in a larger environment.
- **max_fail_percentage:** This number key is similar to `any_errors_fatal`, but is more fine-grained. This allows you to define just what percentage of your hosts can fail before the whole operation is halted.
- **no_log:** This is a Boolean key to control whether or not Ansible will log (to the screen and/or a configured log file) the command given or the results received from a task. This is important if your task or return deal with secrets. This key can also be applied to a task directly.
- **port:** This is a number key to define what port SSH (or an other remote connection plugin) should use to connect unless otherwise configured in the inventory data.
- **remote_user:** This is a string key that defines which user to log in with on the remote system. The default is to connect as the same user that `ansible-playbook` was started with.

- **serial:** This key takes a number and controls how many systems Ansible will execute a task on before moving to the next task in a play. This is a drastic change from the normal order of operation, where a task is executed across every system in a play before moving to the next. This is very useful in rolling update scenarios, which will be detailed in later chapters.
- **sudo:** This is a Boolean key used to configure whether sudo should be used on the remote host to execute tasks. This key can also be defined at a task level. A second key, `sudo_user`, can be used to configure which user to sudo to (instead of root).
- **su:** Much like sudo, this key is used to su instead of sudo. This key also has a companion, `su_user`, to configure which user to su to (instead of root).

Many of these keys will be used in example playbooks through this book.

Host selection for plays and tasks

The first thing most plays define (after a name, of course) is a host pattern for the play. This is the pattern used to select hosts out of the inventory object to run the tasks on. Generally this is straightforward; a host pattern contains one or more blocks indicating a host, group, wildcard pattern, or regex to use for the selection. Blocks are separated by a colon, wildcards are just an asterisk, and regex patterns start with a tilde:

```
hostname:groupname:* .example:~(web|db)\.example\.com
```

Advanced usage can include group index selection or even ranges within a group:

```
Webservers[0]:webserver[2:4]
```

Each block is treated as an inclusion block, that is, all the hosts found in the first pattern are added to all the hosts found in the next pattern, and so on. However, this can be manipulated with control characters to change their behavior. The use of an ampersand allows an inclusion selection (all the hosts that exist in both patterns). The use of an exclamation point allows exclusion selection (all the hosts that exist in the previous patterns that are NOT in the exclusion pattern):

```
Webservers:&dbservers  
Webservers:!dbservers
```

Once Ansible parses the patterns, it will then apply restrictions, if any. Restrictions come in the form of limits or failed hosts. This result is stored for the duration of the play, and it is accessible via the `play_hosts` variable. As each task is executed, this data is consulted and an additional restriction may be placed upon it to handle serial operations. As failures are encountered, either failure to connect or a failure in execute tasks, the failed host is placed in a restriction list so that the host will be bypassed in the next task. If, at any time, a host selection routine gets restricted down to zero hosts, the play execution will stop with an error. A caveat here is that if the play is configured to have a `max_fail_precentage` or `any_errors_fatal` parameter, then the playbook execution stops immediately after the task where this condition is met.

Play and task names

While not strictly necessary, it is a good practice to label your plays and tasks with names. These names will show up in the command line output of `ansible-playbook`, and will show up in the log file if `ansible-playbook` is directed to log to a file. Task names also come in handy to direct `ansible-playbook` to start at a specific task and to reference handlers.

There are two main points to consider when naming plays and tasks:

- Names of plays and tasks should be unique
- Beware of what kind of variables can be used in play and task names

Naming plays and tasks uniquely is a best practice in general that will help to quickly identify where a problematic task may reside in your hierarchy of playbooks, roles, task files, handlers, and so on. Uniqueness is more important when notifying a handler or when starting at a specific task. When task names have duplicates, the behavior of Ansible may be nondeterministic or at least not obvious.

With uniqueness as a goal, many playbook authors will look to variables to satisfy this constraint. This strategy may work well but authors need to take care as to the source of the variable data they are referencing. Variable data can come from a variety of locations (which we will cover later in this chapter), and the values assigned to variables can be defined at a variety of times. For the sake of play and task names, it is important to remember that only variables for which the values can be determined at playbook parse time will parse and render correctly. If the data of a referenced variable is discovered via a task or other operation, the variable string will be displayed unparsed in the output. Let's look at an example playbook that utilizes variables for play and task names:

```
---
- name: play with a {{ var_name }}
  hosts: localhost
  gather_facts: false

  vars:
    - var_name: not-mastery

  tasks:
    - name: set a variable
      set_fact:
        task_var_name: "defined variable"

    - name: task with a {{ task_var_name }}
      debug:
        msg: "I am mastery task"

- name: second play with a {{ task_var_name }}
  hosts: localhost
  gather_facts: false

  tasks:
    - name: task with a {{ runtime_var_name }}
      debug:
        msg: "I am another mastery task"
```

At first glance, one might expect at least `var_name` and `task_var_name` to render correctly. We can clearly see `task_var_name` being defined before its use. However, armed with our knowledge that playbooks are parsed in their entirety before execution, we know better:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts names.yaml -vv

PLAY [play with a not-mastery] *****

TASK: [set a variable] *****
ok: [localhost] => {"ansible_facts": {"task_var_name": "defined variable"}}

TASK: [task with a {{ task_var_name }}] *****
ok: [localhost] => {
  "msg": "I am mastery task"
}

PLAY [second play with a {{ task_var_name }}] *****

TASK: [task with a {{ runtime_var_name }}] *****
ok: [localhost] => {
  "msg": "I am another mastery task"
}

PLAY RECAP *****
localhost          : ok=3    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

As we can see, the only variable name that is properly rendered is `var_name`, as it was defined as a static play variable.

Module transport and execution

Once a playbook is parsed and the hosts are determined, Ansible is ready to execute a task. Tasks are made up of a name (optional, but please don't skip it), a module reference, module arguments, and task control keywords. A later chapter will cover task control keywords in detail, so we will only concern ourselves with the module reference and arguments.

Module reference

Every task has a module reference. This tells Ansible which bit of work to do. Ansible is designed to easily allow for custom modules to live alongside a playbook. These custom modules can be a wholly new functionality, or they can replace modules shipped with Ansible itself. When Ansible parses a task and discovers the name of the module to use for a task, it looks into a series of locations in order to find the module requested. Where it looks also depends on where the task lives, whether in a role or not.

If a task is in a role, Ansible will first look for the module within a directory tree named `library` within the role the task resides in. If the module is not found there, Ansible looks for a directory named `library` at the same level as the main playbook (the one referenced by the `ansible-playbook` execution). If the module is not found there, Ansible will finally look in the configured library path, which defaults to `/usr/share/ansible/`. This library path can be configured in an Ansible config file, or by way of the `ANSIBLE_LIBRARY` environment variable.

This design, allowing modules to be bundled with roles and playbooks, allows for adding functionality, or quickly repairing problems very easily.

Module arguments

Arguments to a module are not always required; the help output of a module will indicate which models are required and which are not. Module documentation can be accessed with the `ansible-doc` command:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-doc debug |cat -
> DEBUG

This module prints statements during execution and can be useful for
debugging variables or expressions without necessarily halting the
playbook. Useful for debugging together with the 'when:' directive.

Options (= is mandatory):

- msg
    The customized message that is printed. If omitted, prints a
    generic message. [Default: Hello world!]

- var
    A variable name to debug. Mutually exclusive with the 'msg'
    option.

EXAMPLES:
# Example that prints the loopback address and gateway for each host
- debug: msg="System {{ inventory_hostname }} has uuid {{ ansible_product_uuid }}
}"

- debug: msg="System {{ inventory_hostname }} has gateway {{ ansible_default_ipv
4.gateway }}"
  when: ansible_default_ipv4.gateway is defined

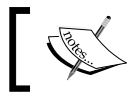
- shell: /usr/bin/uptime
  register: result

- debug: var=result

- name: Display all variables/facts known for a host
  debug: var=hostvars[inventory_hostname]

~/src/mastery> 

```



This command was piped into `cat` to prevent shell paging from being used.

Arguments can be templated with **Jinja2**, which will be parsed at module execution time, allowing for data discovered in a previous task to be used in later tasks; this is a very powerful design element.

Arguments can be supplied in a `key = value` format, or in a complex format that is more native to YAML. Here are two examples of arguments being passed to a module showcasing the two formats:

```
- name: add a keypair to nova
  nova_keypair: login_password={{ pass }} login_tenant_name=admin
                name=admin-key

- name: add a keypair to nova
  nova_keypair: login_password: "{{ pass }}" login_tenant_name: admin
                name: admin-key
```

Both formats will lead to the same result in this example; however, the complex format is required if you wish to pass complex arguments into a module. Some modules expect a list object or a hash of data to be passed in; the complex format allows for this. While both formats are acceptable for many tasks, the complex format is the format used for the majority of examples in this book.

Module transport and execution

Once a module is found, Ansible has to execute it in some way. How the module is transported and executed depends on a few factors, however the common process is to locate the module file on the local filesystem and read it into memory, and then add in the arguments passed to the module. Finally, the boilerplate module code from core Ansible is added to complete the file object in memory. What happens next really depends on the connection method and runtime options (such as leaving the module code on the remote system for review).

The default connection method is `smart`, which most often resolves to the `ssh` connection method. With a default configuration, Ansible will open an SSH connection to the remote host, create a temporary directory, and close the connection. Ansible will then open another SSH connection in order to write out the task object from memory (the result of local module file, task module arguments, and Ansible boilerplate code) into a file within the temporary directory that we just created and close the connection.

Finally, Ansible will open a third connection in order to execute the module and delete the temporary directory and all its contents. The module results are captured from `stdout` in the JSON format, which Ansible will parse and handle appropriately. If a task has an `async` control, Ansible will close the third connection before the module is complete, and SSH back in to the host to check the status of the task after a prescribed period until the module is complete or a prescribed timeout has been reached.

Task performance

Doing the math from the above description, that's at least three SSH connections per task, per host. In a small fleet with a small number of tasks, this may not be a concern; however, as the task set grows and the fleet size grows, the time required to create and tear down SSH connections increases. Thankfully, there are a couple ways to mitigate this.

The first is an SSH feature, **ControlPersist**, which provides a mechanism to create persistent sockets when first connecting to a remote host that can be reused in subsequent connections to bypass some of the handshaking required when creating a connection. This can drastically reduce the amount of time Ansible spends on opening new connections. Ansible automatically utilizes this feature if the host platform where Ansible is run from supports it. To check whether your platform supports this feature, check the SSH main page for **ControlPersist**.

The second performance enhancement that can be utilized is an Ansible feature called pipelining. Pipelining is available to SSH-based connection methods and is configured in the Ansible configuration file within the `ssh_connection` section:

```
[ssh_connection]
pipelining=true
```

This setting changes how modules are transported. Instead of opening an SSH connection to create a directory, another to write out the composed module, and a third to execute and clean up, Ansible will instead open an SSH connection and start the Python interpreter on the remote host. Then, over that live connection, Ansible will pipe in the composed module code for execution. This reduces the connections from three to one, which can really add up. By default, pipelining is disabled.

Utilizing the combination of these two performance tweaks can keep your playbooks nice and fast even as you scale your fleet. However, keep in mind that Ansible will only address as many hosts at once as the number of forks Ansible is configured to run. Forks are the number of processes Ansible will split off as a worker to communicate with remote hosts. The default is five forks, which will address up to five hosts at once. Raise this number to address more hosts as your fleet grows by adjusting the `forks=` parameter in an Ansible configuration file, or by using the `-forks (-f)` argument with `ansible` or `ansible-playbook`.

Variable types and location

Variables are a key component of the Ansible design. Variables allow for dynamic play content and reusable plays across different sets of inventory. Anything beyond the very basics of Ansible use will utilize variables. Understanding the different variable types and where they can be located, as well as learning how to access external data or prompt users to populate variable data, is the key to mastering Ansible.

Variable types

Before diving into the precedence of variables, we must first understand the various types and subtypes of variables available to Ansible, their location, and where they are valid for use.

The first major variable type is **inventory variables**. These are the variables that Ansible gets by way of the inventory. These can be defined as variables that are specific to `host_vars` to individual hosts or applicable to entire groups as `group_vars`. These variables can be written directly into the inventory file, delivered by the dynamic inventory plugin, or loaded from the `host_vars/<host>` or `group_vars/<group>` directories.

These types of variables might be used to define Ansible behavior when dealing with these hosts, or site-specific data related to the applications that these hosts run. Whether a variable comes from `host_vars` or `group_vars`, it will be assigned to a host's `hostvars`, and it can be accessed from the playbooks and template files. Accessing a host's own variables can be done just by referencing the name, such as `{{ foobar }}`, and accessing another host's variables can be accomplished by accessing `hostvars`. For example, to access the `foobar` variable for `examplehost`: `{{ hostvars['examplehost']['foobar'] }}`. These variables have global scope.

The second major variable type is **role variables**. These are variables specific to a role that are utilized by the role tasks and have scope only within the role that they are defined in, which is to say that they can only be used within the role. These variables are often supplied as a **role default**, and are meant to provide a default value for the variable, but can easily be overridden when applying the role. When roles are referenced, it is possible to supply variable data at the same time, either by overriding role defaults or creating wholly new data. We'll cover roles in-depth in later chapters. These variables apply to all hosts within the role and can be accessed directly, much like a host's own `hostvars`.

The third major variable type is **play variables**. These variables are defined in the control keys of a play, either directly by the `vars` key or sourced from external files via the `vars_files` key. Additionally, the play can interactively prompt the user for variable data using `vars_prompt`. These variables are to be used within the scope of the play and in any tasks or included tasks of the play. The variables apply to all hosts within the play and can be referenced as if they are `hostvars`.

The fourth variable type is **task variables**. Task variables are made from data discovered while executing tasks or in the fact gathering phase of a play. These variables are host-specific and are added to the host's `hostvars` and can be used as such, which also means they have global scope *after* the point at which they were discovered or defined. Variables of this type can be discovered via `gather_facts` and **fact modules** (modules that do not alter state but rather return data), populated from task return data via the `register` task key, or defined directly by a task making use of the `set_fact` or `add_host` modules. Data can also be interactively obtained from the operator using the `prompt` argument to the `pause` module and registering the result:

```
- name: get the operators name
  pause:
    prompt: "Please enter your name"
  register: opname
```

There is one last variable type, the **extra variables**, or `extra-vars` type. These are variables supplied on the command line when executing `ansible-playbook` via `--extra-vars`. Variable data can be supplied as a list of `key=value` pairs, a quoted JSON data, or a reference to a YAML-formatted file with variable data defined within:

```
--extra-vars "foo=bar owner=fred"
--extra-vars '{"services":["nova-api","nova-conductor"]}'
--extra-vars @/path/to/data.yaml
```

Extra variables are considered global variables. They apply to every host and have scope throughout the entire playbook.

Accessing external data

Data for role variables, play variables, and task variables can also come from external sources. Ansible provides a mechanism to access and evaluate data from the **control machine** (the machine running `ansible-playbook`). The mechanism is called a **lookup plugin**, and a number of them come with Ansible. These plugins can be used to lookup or access data by reading files, generate and locally store passwords on the Ansible host for later reuse, evaluate environment variables, pipe data in from executables, access data in the Redis or etcd systems, render data from template files, query `dnstxt` records, and more. The syntax is as follows:

```
lookup('<plugin_name>', 'plugin_argument')
```

for example, to use the `mastery` value from `etcd` in a debug task:

```
- name: show data from etcd
  debug: msg="{{ lookup('etcd', 'mastery') }}"
```

Lookups are evaluated when the task referencing them is executed, which allows for dynamic data discovery. To reuse a particular lookup in multiple tasks and reevaluate it each time, a playbook variable can be defined with a lookup value. Each time the playbook variable is referenced the lookup will be executed, potentially providing different values over time.

Variable precedence

As you learned in the previous section, there are a few major types of variables that can be defined in a myriad of locations. This leads to a very important question, what happens when the same variable name is used in multiple locations? Ansible has a precedence for loading variable data, and thus it has an order and a definition to decide which variable will "win". Variable value overriding is an advanced usage of Ansible, so it is important to fully understand the semantics before attempting such a scenario.

Precedence order

Ansible defines the precedence order as follows:

1. Extra vars (from command line) always win
2. Connection variables defined in inventory
3. Most everything else

4. Rest of the variables defined in inventory
5. Facts discovered about a system
6. Role defaults

This list is a useful starting point, however things are a bit more nuanced, as we will explore.

Extra-vars

Extra-vars, as supplied on the command line, certainly overrides anything else. Regardless of where else a variable might be defined, even if it's explicitly set in a play with `set_fact`, the value provided on the command line will be the value used.

Connection variables

Next up are **connection variables**, the behavioral variables outlined earlier. These are variables that influence how Ansible will connect to and execute tasks on a system. These are variables like `ansible_ssh_user`, `ansible_ssh_host`, and others as described in the earlier section regarding behavioral inventory parameters. The Ansible documentation states that these come from the inventory, however, they *can* be overridden by tasks such as `set_fact`. A `set_fact` module on a variable such as `ansible_ssh_user` will override the value that came from the inventory source. There is a precedence order within the inventory as well. Host-specific definitions will override group definitions, and child group definitions will override parent of group definitions. This allows for having a value that applies to most things in a group and overrides it on specific hosts that would be different. When a host belongs to multiple groups and each group defines the same variable with different values, the behavior is less defined and strongly discouraged.

Most everything else

The "most everything else" block is a big grouping of sources. These include:

- Command line switches
- Play variables
- Task variables
- Role variables (not defaults)

These sets of variables can override each other as well, with the rule being that the last supplied variable wins. The role variables in this set refer to the variables provided in a role's `vars/main.yaml` file and the variables defined when assigning a role or a role dependency. In this example, we will provide a variable named `role_var` at the time we assign the role:

```
- role: example_role
  role_var: var_value_here
```

An important nuance here is that a definition provided at role assignment time will override the definition within a role's `vars/main.yaml` file. Also remember the last provided rule; if within the role `example_role`, the `role_var` variable is redefined via a task, that definition will win from that point on.

The rest of the inventory variables

The next lower set of variables is the remaining inventory variables. These are variables that can be defined within the inventory data, but do not alter the behavior of Ansible. The rules from connection variables apply here.

Facts discovered about a system

Discovered facts variables are the variables we get when gathering facts. The exact list of variables depends on the platform of the host and the extra software that can be executed to display system information, which might be installed on said host. Outside of role defaults, these are the lowest level of variables and are most likely to be overridden.

Role defaults

Roles can have default variables defined within them. These are reasonable defaults for use within the role and are customization targets for role applications. This makes roles much more reusable, flexible, and tuneable to the environment and conditions in which the role will be applied.

Merging hashes

In the previous section, we focused on the order of precedence in which variables will override each other. The default behavior of Ansible is that any overriding definition for a variable name will completely mask the previous definition of that variable. However, that behavior can be altered for one type of variable, the hash. A hash variable (a "dictionary" in Python terms) is a dataset of keys and values. Values can be of different types for each key, and can even be hashes themselves for complex data structures.

In some advanced scenarios, it is desirable to replace just one bit of a hash or add to an existing hash rather than replacing the hash altogether. To unlock this ability, a configuration change is necessary in an Ansible config file. The config entry is `hash_behavior`, which takes one of **replace**, or **merge**. A setting of `merge` will instruct Ansible to merge or blend the values of two hashes when presented with an override scenario rather than the default of `replace`, which will completely replace the old variable data with the new data.

Let's walk through an example of the two behaviors. We will start with a hash loaded with data and simulate a scenario where a different value for the hash is provided as a higher priority variable.

Starting data:

```
hash_var:
  fred:
    home: Seattle
    transport: Bicycle
```

New data loaded via `include_vars`:

```
hash_var:
  fred:
    transport: Bus
```

With the default behavior, the new value for `hash_var` will be:

```
hash_var:
  fred:
    transport: Bus
```

However, if we enable the `merge` behavior we would get the following result:

```
hash_var:
  fred:
    home: Seattle
    transport: Bus
```

There are even more nuances and undefined behaviors when using `merge`, and as such, it is strongly recommended to only use this setting if absolutely needed.

Summary

While the design of Ansible focuses on simplicity and ease of use, the architecture itself is very powerful. In this chapter, we covered key design and architecture concepts of Ansible, such as version and configuration, playbook parsing, module transport and execution, variable types and locations, and variable precedence.

You learned that playbooks contain variables and tasks. Tasks link bits of code called modules with arguments, which can be populated by variable data. These combinations are transported to selected hosts from provided inventory sources. A fundamental understanding of these building blocks is the platform on which you can build a mastery of all things Ansible!

In the next chapter, you will learn how to secure secret data while operating Ansible.

2

Protecting Your Secrets with Ansible

Secrets are meant to stay secret. Whether they are login credentials to a cloud service or passwords to database resources, they are secret for a reason. Should they fall into the wrong hands, they can be used to discover trade secrets and private customer data, create infrastructure for nefarious purposes, or worse. All of which could cost you or your organization a lot of time and money and cause a headache! In this chapter, we cover how to keep your secrets safe with Ansible.

- Encrypting data at rest
- Protecting secrets while operating

Encrypting data at rest

As a configuration management system or an orchestration engine, Ansible has great power. In order to wield that power, it is necessary to entrust secret data to Ansible. An automated system that prompts the operator for passwords all the time is not very efficient. To maximize the power of Ansible, secret data has to be written to a file that Ansible can read and utilize the data from within.

This creates a risk though! Your secrets are sitting there on your filesystem in plain text. This is a physical and digital risk. Physically, the computer could be taken from you and pawed through for secret data. Digitally, any malicious software that can break the boundaries set upon it could read any data your user account has access to. If you utilize a source control system, the infrastructure that houses the repository is just as much at risk.

Thankfully, Ansible provides a facility to protect your data at rest. That facility is **Vault**, which allows for encrypting text files so that they are stored "at rest" in encrypted format. Without the key or a significant amount of computing power, the data is indecipherable.

The key lessons to learn while dealing with encrypting data at rest are:

- Valid encryption targets
- Creating new encrypted files
- Encrypting existing unencrypted files
- Editing encrypted files
- Changing the encryption password on files
- Decrypting encrypted files
- Running the `ansible-playbook` command to reference encrypted files

Things Vault can encrypt

Vault can be used to encrypt any structured data file used by Ansible. This is essentially any YAML (or JSON) file that Ansible uses during its operation.

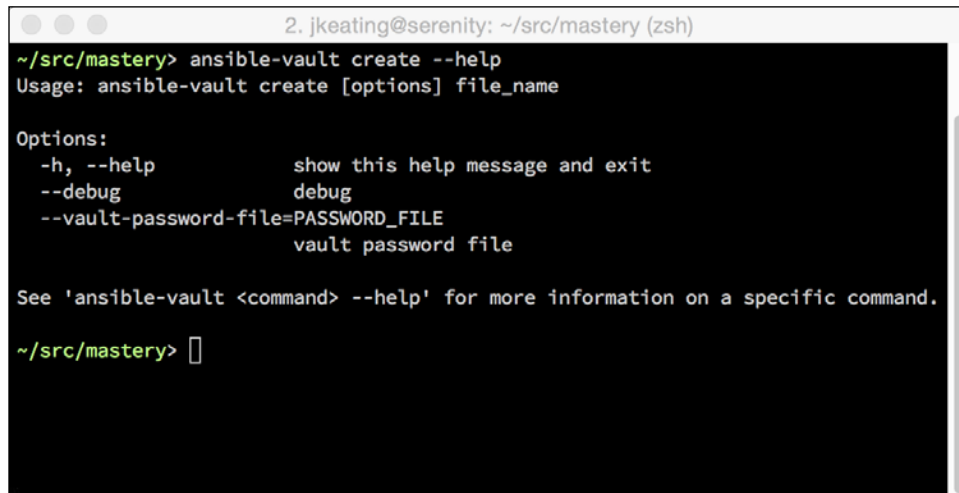
This can include:

- `group_vars/` files
- `host_vars/` files
- `include_vars` targets
- `vars_files` targets
- `--extra-vars` targets
- `role` variables
- Role defaults
- Task files
- Handler files

If the file can be expressed in YAML and read by Ansible, it is a valid file to encrypt with Vault. Because the entire file will be unreadable at rest, care should be taken to not be overzealous in picking which files to encrypt. Any source control operations with the files will be done with the encrypted content, making it very difficult to peer review. As a best practice, the smallest amount of data possible should be encrypted; this may even mean moving some variables into a file all by themselves.

Creating new encrypted files

To create new files, Ansible provides a new program, `ansible-vault`. This program is used to create and interact with Vault encrypted files. The subroutine to create encrypted files is the `create` subroutine. Lets have a look at the following screenshot:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault create --help
Usage: ansible-vault create [options] file_name


Options:
  -h, --help            show this help message and exit
  --debug               debug
  --vault-password-file=PASSWORD_FILE
                        vault password file

See 'ansible-vault <command> --help' for more information on a specific command.

~/src/mastery> 

```

To create a new file, you'll need to know two things ahead of time. The first is the password Vault should use to encrypt the file, and the second is the file name. Once provided with this information, `ansible-vault` will launch a text editor, whichever editor is defined in the environment variable `EDITOR`. Once you save the file and exit the editor, `ansible-vault` will use the supplied password as a key to encrypt the file with the **AES256** cipher.

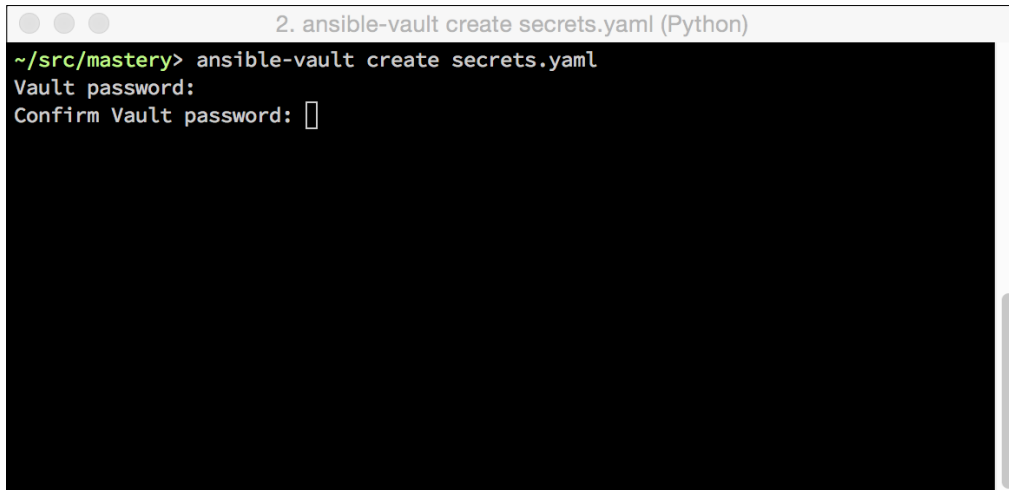
 All Vault encrypted files referenced by a playbook need to be encrypted with the same key or `ansible-playbook` will be unable to read them.

The `ansible-vault` program will prompt for a password unless the path to a file is provided as an argument. The password file can either be a plain text file with the password stored as a single line, or it can be an executable file that outputs the password as a single line to standard out.

Let's walk through a few examples of creating encrypted files. First, we'll create one and be prompted for a password; then we will provide a password file; and finally we'll create an executable to deliver the password.

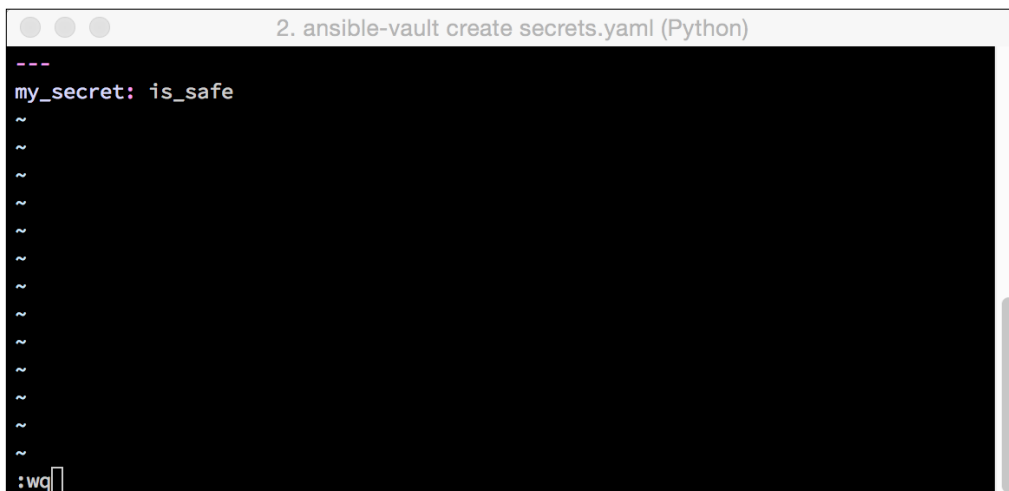
The password prompt

On opening, the editor asks for the passphrase, as shown in the following screenshot:




```
2. ansible-vault create secrets.yaml (Python)
~/src/mastery> ansible-vault create secrets.yaml
Vault password:
Confirm Vault password: 
```

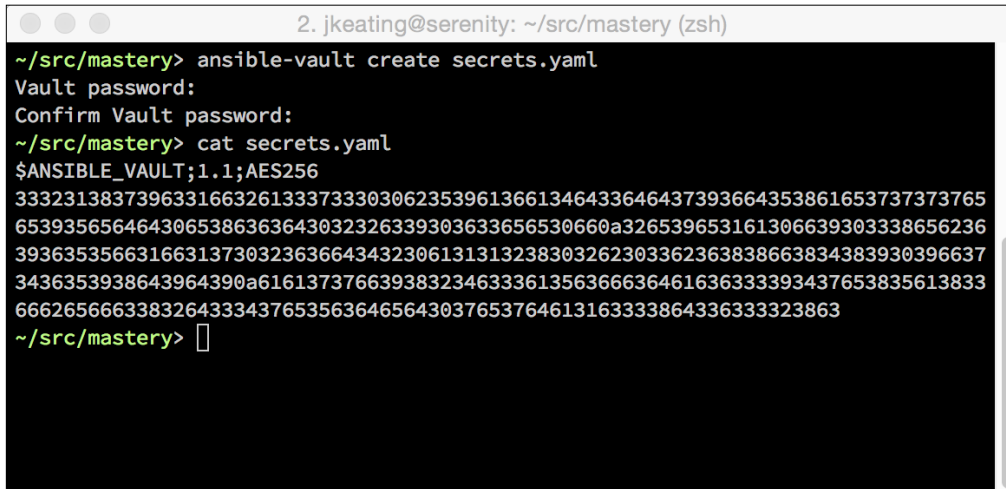
Once the passphrase is confirmed, our editor opens and we're able to put content into the file:



```
2. ansible-vault create secrets.yaml (Python)
---
my_secret: is_safe
~
~
~
~
~
~
~
~
~
~
~
~
~
:wq
```

 On my system, the configured editor is `vim`. Your system may be different, and you may need to set your preferred editor as the value for the `EDITOR` environment variable.

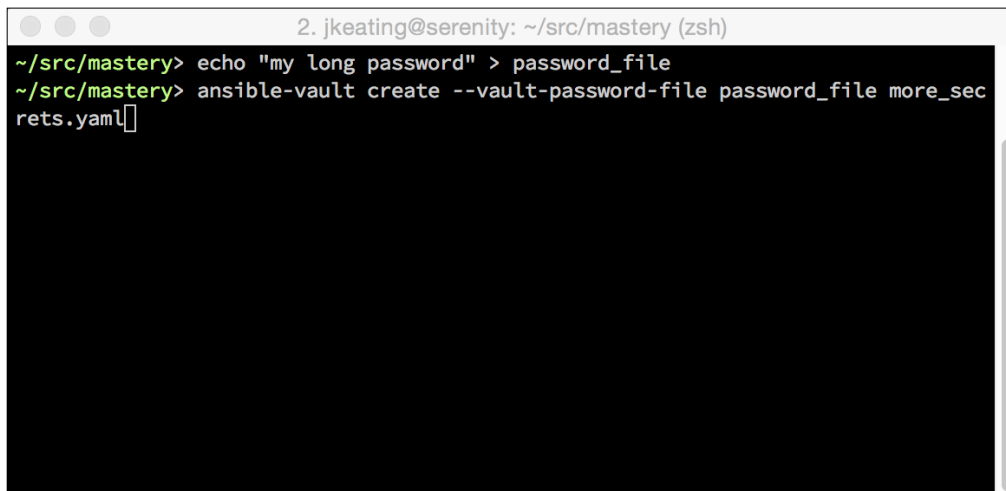
Now we save the file. If we try to read the contents, we'll see that they are in fact encrypted, with a small header hint for Ansible to use later:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the following commands and output:

```
~/src/mastery> ansible-vault create secrets.yaml
Vault password:
Confirm Vault password:
~/src/mastery> cat secrets.yaml
$ANSIBLE_VAULT;1.1;AES256
333231383739633166326133373330306235396136613464336464373936643538616537373765
6539356564643065386363643032326339303633656530660a326539653161306639303338656236
39363535663166313730323636643432306131313238303262303362363838663834383930396637
3436353938643964390a616137376639383234633361356366636461636333393437653835613833
66626566633832643334376535636465643037653764613163333864336333323863
~/src/mastery>
```

The password file

In order to use `ansible-vault` with a password file, we first need to create the password file. Simply echoing a password in a file can do this. Then we can reference this file while calling `ansible-vault` to create another encrypted file:

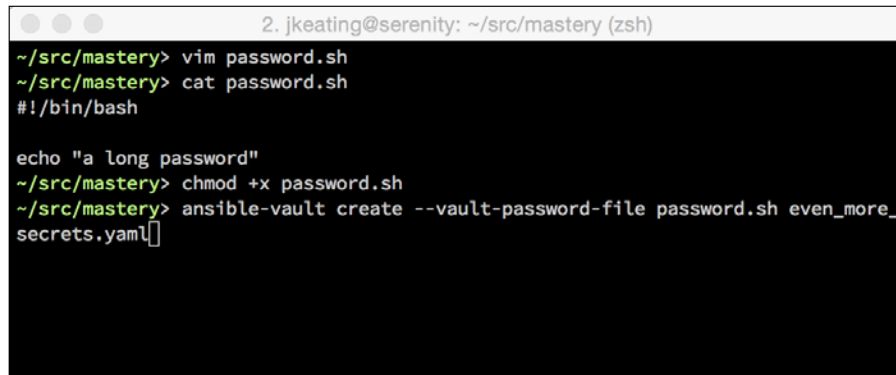
A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the following commands and output:

```
~/src/mastery> echo "my long password" > password_file
~/src/mastery> ansible-vault create --vault-password-file password_file more_secrets.yaml
```

Just as when being prompted for a password, the editor will open and we can write out our data.

The password script

This last example uses a password script. This is useful for designing a system in which a password can be stored in a central system for storing credentials and shared with contributors to the playbook tree. Each contributor could have their own password to the shared credentials store, from where the Vault password can be retrieved. Our example will be far simpler: just simple output to standard out with a password. This file will be saved as `password.sh`. The file needs to be marked as an executable for Ansible to treat it as such. Lets have a look at the following screenshot:

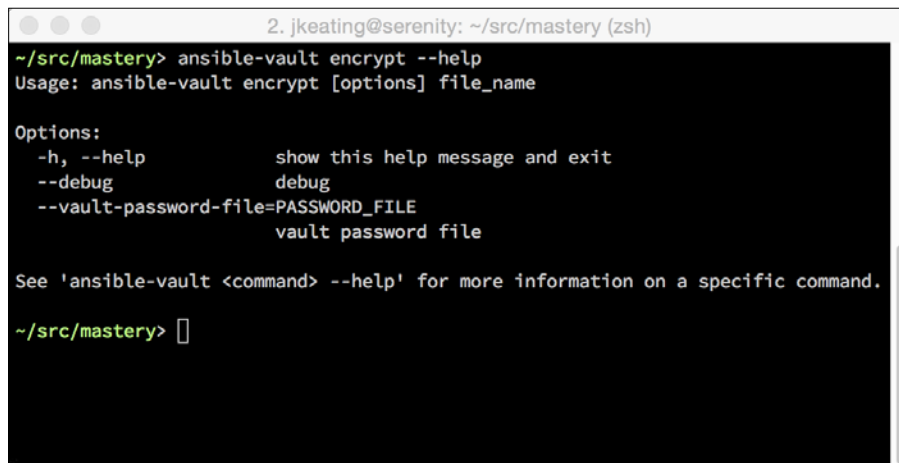


```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> vim password.sh
~/src/mastery> cat password.sh
#!/bin/bash

echo "a long password"
~/src/mastery> chmod +x password.sh
~/src/mastery> ansible-vault create --vault-password-file password.sh even_more_
secrets.yaml
```

Encrypting existing files

The previous examples all dealt with creating new encrypted files using the `create` subroutine. But what if we want to take an established file and encrypt it? A subroutine exists for this as well. It is named `encrypt`, and it is outlined in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault encrypt --help
Usage: ansible-vault encrypt [options] file_name

Options:
  -h, --help            show this help message and exit
  --debug               debug
  --vault-password-file=PASSWORD_FILE
                        vault password file

See 'ansible-vault <command> --help' for more information on a specific command.

~/src/mastery>
```

As with `create`, `encrypt` expects a password (or password file) and the path to a file. In this case, however, the file must already exist. Let's demonstrate this by encrypting an existing file, `a_vars_file.yaml`, we have from a previous chapter:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> cat a_vars_file.yaml
---
something: "better than nothing"
~/src/mastery> ansible-vault encrypt --vault-password-file password.sh a_vars_file.yaml
Encryption successful
~/src/mastery> cat a_vars_file.yaml
$ANSIBLE_VAULT;1.1;AES256
39636263656662373164383139393738313633393266633832613238653831393030363863623537
3739666361336633313636326134363331363432346638620a366239383433313865323737613231
62323536653339613732653833383033316263373364303933396564653464363965656561326632
6637633164393631610a666133373035356630363933326636373965393661336439663837356662
30386130633138633463373365333434313964353464613465626461336261313037646439346663
6137373536666535386566666561643337336231666637663336
~/src/mastery>

```

We can see the file contents before and after the call to `encrypt`. After the call, the contents are indeed encrypted. Unlike the `create` subroutine, `encrypt` can operate on multiple files, making it easy to protect all the important data in one action. Simply list all the files to be encrypted, separated by spaces.



Attempting to encrypt already encrypted files will result in an error.

Editing encrypted files

Once a file has been encrypted with `ansible-vault`, it cannot be edited directly. Opening the file in an editor would result in the encrypted data being shown. Making any changes to the file would damage the file and Ansible would be unable to read the contents correctly. We need a subroutine that will first decrypt the contents of the file, allow us to edit these contents, and then encrypt the new contents before saving it back to the file. Such a subroutine exists and is called `edit`. Here is a screenshot showing the available options:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault edit --help
Usage: ansible-vault edit [options] file_name

Options:
  -h, --help                show this help message and exit
  --debug                   debug
  --vault-password-file=PASSWORD_FILE
                           vault password file

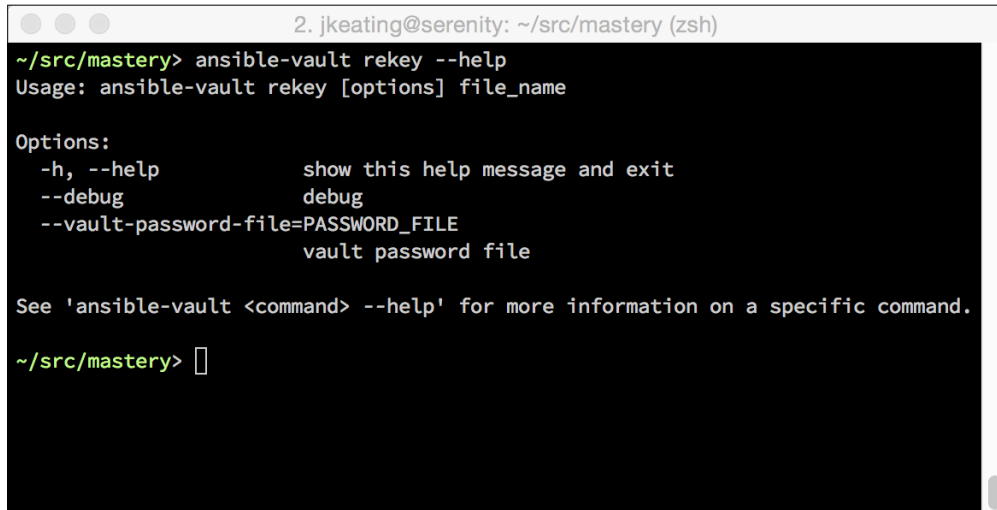
See 'ansible-vault <command> --help' for more information on a specific command.

~/src/mastery> 
```

All our familiar options are back, an optional password file/script and the file to edit. If we edit the file we just encrypted, we'll notice that `ansible-vault` opens our editor with a temporary file as the file path:

[illegible]

The editor will save this and `ansible-vault` will then encrypt it and move it to replace the original file as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault rekey --help
Usage: ansible-vault rekey [options] file_name

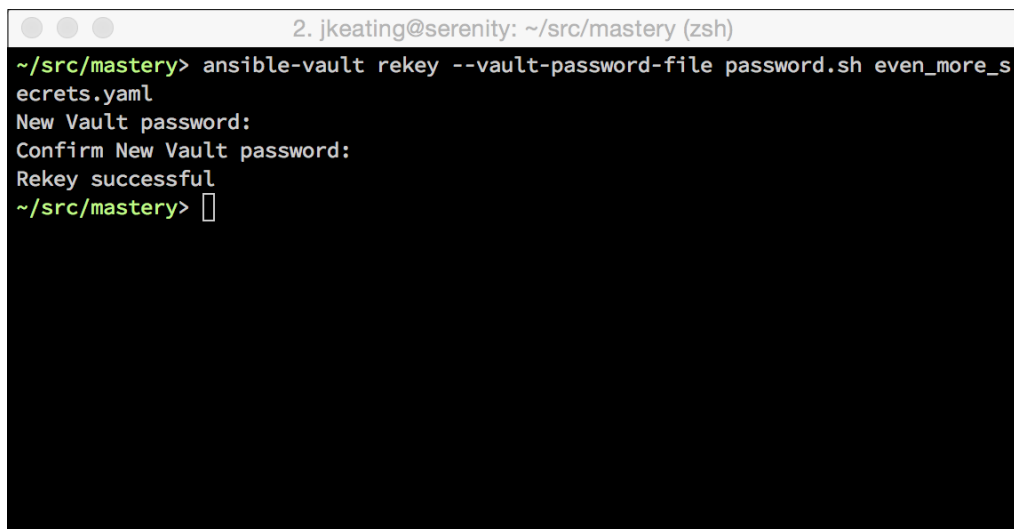
Options:
  -h, --help            show this help message and exit
  --debug               debug
  --vault-password-file=PASSWORD_FILE
                        vault password file

See 'ansible-vault <command> --help' for more information on a specific command.

~/src/mastery> 
```

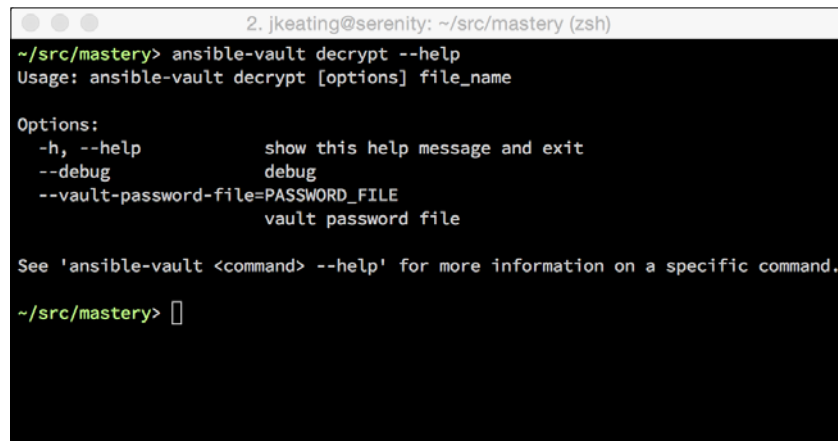
Password rotation for encrypted files

Over time, as contributors come and go, it is a good idea to rotate the password used to encrypt your secrets. Encryption is only as good as the other layers of protection of the password. `ansible-vault` provides a subroutine, named `rekey`, that allows us to change the password as shown here:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault rekey --vault-password-file password.sh even_more_s
ecrets.yaml
New Vault password:
Confirm New Vault password:
Rekey successful
~/src/mastery> 
```

The `rekey` subroutine operates much like the `edit` subroutine. It takes in an optional password file/script and one or more files to `rekey`. Note that while you can supply a file/script for decryption of the existing files, you cannot supply one for the new passphrase. You will be prompted to input the new passphrase. Let's `rekey` our `even_more_secrets.yaml` file:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-vault decrypt --help
Usage: ansible-vault decrypt [options] file_name

Options:
  -h, --help            show this help message and exit
  --debug               debug
  --vault-password-file=PASSWORD_FILE
                        vault password file

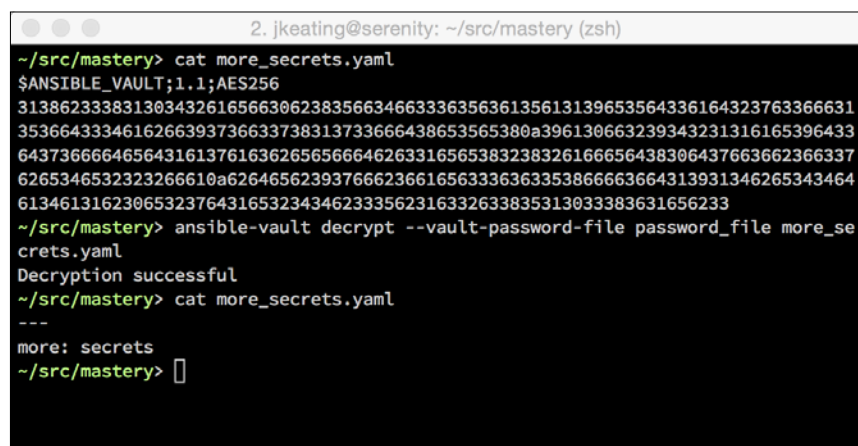
See 'ansible-vault <command> --help' for more information on a specific command.

~/src/mastery> 
```

Remember that all the encrypted files need to have a matching key. Be sure to re-key all the files at the same time.

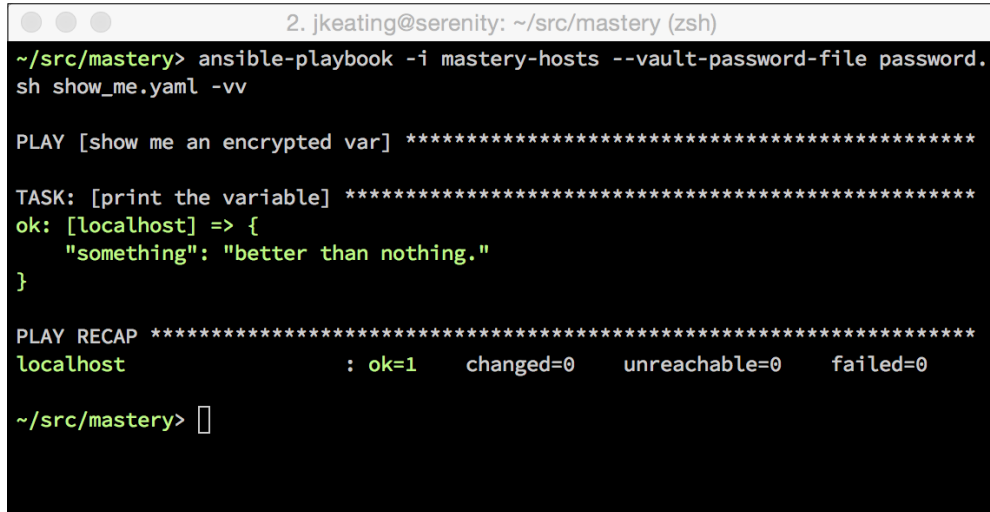
Decrypting encrypted files

If, at some point, the need to encrypt data files goes away, `ansible-vault` provides a subroutine that can be used to remove encryption for one or more encrypted files. This subroutine is (unsurprisingly) named `decrypt` as shown here:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> cat more_secrets.yaml
$ANSIBLE_VAULT;1.1;AES256
31386233383130343261656630623835663466333635636135613139653564336164323763366631
3536643334616266393736633738313733666438653565380a396130663239343231316165396433
64373666646564316137616362656566646263316565383238326166656438306437663662366337
6265346532323266610a626465623937666236616563336363353866663664313931346265343464
61346131623065323764316532343462333562316332633835313033383631656233
~/src/mastery> ansible-vault decrypt --vault-password-file password_file more_se
crets.yaml
Decryption successful
~/src/mastery> cat more_secrets.yaml
---
more: secrets
~/src/mastery> 
```

Once again, we have an optional argument for a password file/script and then one or more file paths to decrypt. Let's decrypt the file we created earlier using our password file:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts --vault-password-file password.
sh show_me.yaml -vv

PLAY [show me an encrypted var] *****

TASK: [print the variable] *****
ok: [localhost] => {
  "something": "better than nothing."
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Executing ansible-playbook with Vault-encrypted files

To make use of our encrypted content, we need to be able to inform `ansible-playbook` how to access any encrypted data it might encounter. Unlike `ansible-vault`, which exists solely to deal with file encryption/decryption, `ansible-playbook` is more general purpose and will not assume it is dealing with encrypted data by default. There are two ways to indicate that encrypted data may be encountered. The first is the argument `--ask-vault-pass`, which will prompt for the vault password required to unlock any encountered encrypted files at the very beginning of a playbook execution. Ansible will hold this provided password in memory for the duration of the playbook execution. The second method is to reference a password file or script via the familiar `--vault-password-file` argument.

Let's create a simple playbook named `show_me.yaml` that will print out the value of the variable inside `a_vars_file.yaml`, which we encrypted in a previous example:

```

---
- name: show me an encrypted var
  hosts: localhost

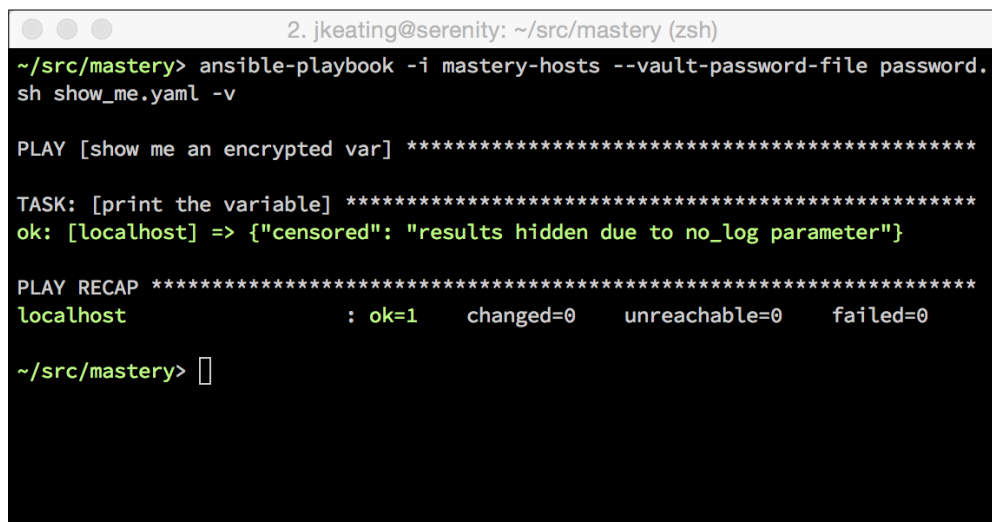
```

```
gather_facts: false

vars_files:
  - a_vars_file.yaml

tasks:
  - name: print the variable
    debug:
      var: something
```

The output is as follows:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The user runs 'ansible-playbook -i mastery-hosts --vault-password-file password. sh show_me.yaml -v'. The output shows a play 'show me an encrypted var' with a task 'print the variable'. The task output is 'ok: [localhost] => {"censored": "results hidden due to no_log parameter"}'. A play recap shows 'localhost' with 'ok=1', 'changed=0', 'unreachable=0', and 'failed=0'. The prompt returns to '~/.src/mastery>'.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts --vault-password-file password.
sh show_me.yaml -v

PLAY [show me an encrypted var] *****

TASK: [print the variable] *****
ok: [localhost] => {"censored": "results hidden due to no_log parameter"}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Protecting secrets while operating

In the previous section of this chapter, we covered protecting your secrets at rest on the filesystem. However, that is not the only concern while operating Ansible with secrets. Secret data is going to be used in tasks as module arguments or loop inputs or any number of other things. This may cause the data to be transmitted to remote hosts, logged to local or remote log files, or displayed on screen. This section of the chapter discusses strategies for protecting your secrets during operation.

Secrets transmitted to remote hosts

As we learned in *Chapter 1, System Architecture and Design of Ansible*, Ansible will combine module code and arguments and write this out to a temporary directory on the remote host. This means your secret data is transferred over the wire AND written to the remote filesystem. Unless you are using a connection plugin other than `ssh`, the data over the wire is already encrypted, preventing your secrets from being discovered by simple snooping. If you are using a connection plugin other than `ssh`, be aware of whether or not data is encrypted while in transit. Using any connection method that is not encrypted is *strongly* discouraged.

Once the data is transmitted, Ansible may write this data out in clear form to the filesystem. This can happen if `pipelining` (which we learned about in *Chapter 1, System Architecture and Design of Ansible*) is not in use, OR if Ansible has been instructed to leave remote files in place via the `ANSIBLE_KEEP_REMOTE_FILES` environment variable. Without `pipelining`, Ansible will write out the module code plus arguments into a temporary directory that is to be deleted, upon execution. Should there be a loss of connectivity between writing out the file and executing it, the file will be left on the remote filesystem until manually removed. If Ansible is explicitly instructed to keep remote files in place, Ansible will write out and leave a remote file in place, even if `pipelining` is enabled. Care should be taken with these options when dealing with highly sensitive secrets, even though typically only the user Ansible logs in as (or `sudo`s to) on the remote host should have access to the leftover file. Simply deleting anything in the `~/.ansible/tmp/` path for the remote user will suffice to clean secrets.

Secrets logged to remote or local files

When Ansible operates on a host, it will attempt to log the action to `syslog`. If this action is being carried out by a user with appropriate rights, it will cause a message to appear in the `syslog` file of the host. This message includes the module name and the arguments passed along to that command, which could include your secrets. To prevent this from happening, a play and task key named `no_log` has been created. Setting `no_log` to `true` will prevent Ansible from logging the action to `syslog`.

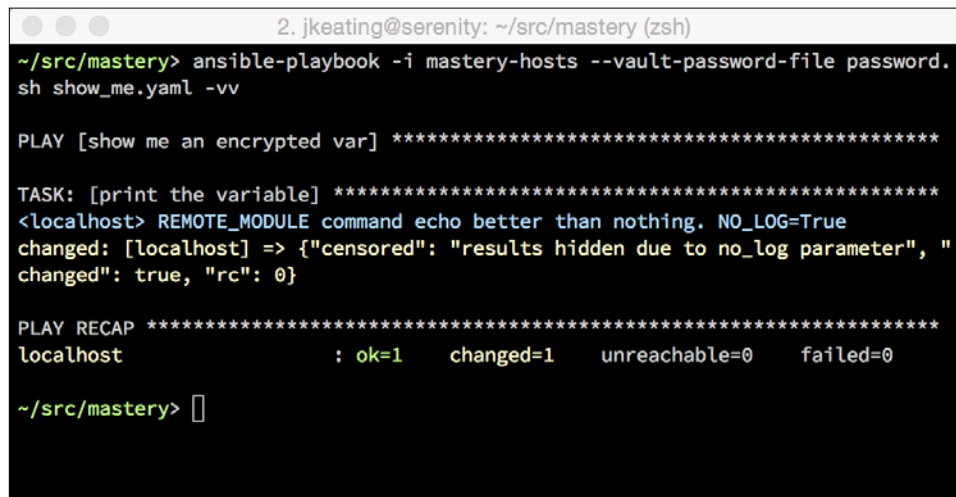
Locally, Ansible can be instructed to log its actions as well. An environment variable called `ANSIBLE_LOG_PATH` controls this. Without this variable set, Ansible will only log to standard out. Setting this variable to a path that can be written to by the user running `ansible-playbook` will cause Ansible to log actions to this path. The verbosity of this logging matches that of the verbosity shown on screen. By default, no variables or return details are displayed on screen. With a verbosity level of one (`-v`), input data and return data is displayed on screen (and potentially in the local log file). Since this can include secrets, the `no_log` setting applies to the on-screen display as well. Let's take our previous example of displaying an encrypted secret and add a `no_log` key to the task to prevent it showing its value:

```
---
- name: show me an encrypted var
  hosts: localhost
  gather_facts: false

  vars_files:
    - a_vars_file.yaml

  tasks:
    - name: print the variable
      debug:
        var: something
      no_log: true
```

If we execute this playbook we should see that our secret data is protected, as follows:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The command is 'ansible-playbook -i mastery-hosts --vault-password-file password.sh show_me.yaml -vv'. The output shows the play 'show me an encrypted var' and the task 'print the variable'. The task output indicates that the variable 'something' is censored due to the 'no_log' parameter. The final output shows a recap of the play results for localhost, indicating that the task was successful (ok=1) and changed the state (changed=1).

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts --vault-password-file password.
sh show_me.yaml -vv

PLAY [show me an encrypted var] *****

TASK: [print the variable] *****
<localhost> REMOTE_MODULE command echo better than nothing. NO_LOG=True
changed: [localhost] => {"censored": "results hidden due to no_log parameter", "
changed": true, "rc": 0}

PLAY RECAP *****
localhost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> []
```

Ansible censored itself to prevent showing sensitive data.

Summary

Ansible can deal with sensitive data. It is important to understand how this data is stored at rest and how this data is treated when utilized. With a little care and attention, Ansible can keep your secrets secret. Encrypting secrets with `ansible-vault` can protect them while dormant on your filesystem or in a shared source control repository. Preventing Ansible from logging task data can protect against leaking data to remote log files or on-screen displays.

In the next chapter, we will explore the powers of the Jinja2 templating engine used by Ansible.

3

Unlocking the Power of Jinja2 Templates

Templating is the lifeblood of Ansible. From configuration file content to variable substitution in tasks, to conditional statements and beyond, templating comes into play with nearly every Ansible facet. The templating engine of Ansible is Jinja2, a modern and designer-friendly templating language for Python. This chapter will cover a few advanced features of Jinja2 templating.

- Control structures
- Data manipulation
- Comparisons

Control structures

In Jinja2, a control structure refers to things in a template that control the flow of the engine parsing the template. These structures include, but are not limited to, conditionals, loops, and macros. Within Jinja2 (assuming the defaults are in use), a control structure will appear inside blocks of `{% ... %}`. These opening and closing blocks alert the Jinja2 parser that a control statement is provided instead of a normal string or variable name.

Conditionals

A conditional within a template creates a decision path. The engine will consider the conditional and choose from two or more potential blocks of code. There is always a minimum of two: a path if the conditional is met (evaluated as true), and an implied `else` path of an empty block.

The statement for conditionals is the `if` statement. This statement works much like it does in Python. An `if` statement can be combined with one or more optional `elif` with an optional final `else`, and unlike Python, requires an explicit `endif`. The following example shows a config file template snippet combining both a regular variable replacement and an `if else` structure:

```
setting = {{ setting }}
{% if feature.enabled %}
feature = True
{% else %}
feature = False
{% endif %}
another_setting = {{ another_setting }}
```

In this example, the variable `feature.enabled` is checked to see if it exists and is not set to `False`. If this is true, then the text `feature = True` is used; otherwise, the text `feature = False` is used. Outside of this control block, the parser does the normal variable substitution for the variables inside the mustache brackets. Multiple paths can be defined by using an `elif` statement, which presents the parser, with another test to perform should the previous tests equate to `false`.

To demonstrate rendering the template, we'll save the example template as `demo.j2`. We'll then make a playbook named `template-demo.yaml` that defines the variables in use and then uses a template lookup as part of a `pause` task to display the rendered template on screen:

```
---
- name: demo the template
  hosts: localhost
  gather_facts: false
  vars:
    setting: a_val
    feature:
      enabled: true
    another_setting: b_val
  tasks:
    - name: pause with render
      pause:
        prompt: "{{ lookup('template', 'demo.j2') }}"
```

Executing this playbook will show the rendered template on screen while it waits for input. We can simply press Enter to complete the playbook:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat
ed_seconds=None, prompt=[localhost] setting = a_val feature = True another_setti
ng = b_val :
[localhost]
setting = a_val
feature = True
another_setting = b_val
:

ok: [localhost] => {"changed": false, "delta": 5, "rc": 0, "start": "2015-09-29
20:49:30.206345", "stderr": "", "stdout": "Paused for 0.1 minutes", "stop": "201
5-09-29 20:49:35.926062", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

If we were to change the value of `feature.enabled` to `false`, the output would be slightly different:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat
ed_seconds=None, prompt=[localhost] setting = a_val feature = False another_sett
ing = b_val :
[localhost]
setting = a_val
feature = False
another_setting = b_val
:

ok: [localhost] => {"changed": false, "delta": 3, "rc": 0, "start": "2015-09-29
20:52:29.195308", "stderr": "", "stdout": "Paused for 0.06 minutes", "stop": "20
15-09-29 20:52:32.925926", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Inline conditionals

The `if` statements can be used inside of **inline expressions**. This can be useful in some scenarios where additional newlines are not desired. Let's construct a scenario where we need to define an API as either `cinder` or `cinderv2`:

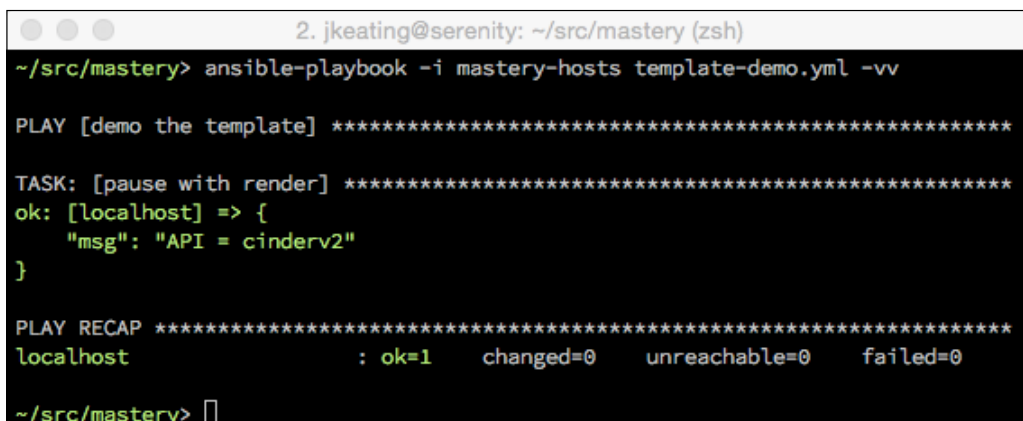
```
API = cinder({ 'v2' if api.v2 else '' })
```

This example assumes `api.v2` is defined as Boolean `True` or `False`. Inline `if` expressions follow the syntax of `<do something> if <conditional is true> else <do something else>`. In an inline `if` expression, there is an implied `else`; however, that implied `else` is meant to evaluate as an undefined object, which will normally create an error. We protect against this by defining an explicit `else`, which renders a zero length string.

Let's modify our playbook to demonstrate an inline conditional. This time, we'll use the `debug` module to render the simple template:

```
---
- name: demo the template
  hosts: localhost
  gather_facts: false
  vars:
    api:
      v2: true
  tasks:
    - name: pause with render
      debug:
        msg: "API = cinder({ 'v2' if api.v2 else '' })"
```

Execution of the playbook will show the template being rendered:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The command is '~ /src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv'. The output shows the playbook 'demo the template' running on 'localhost'. A task 'pause with render' is executed, and the debug module outputs the rendered template: 'API = cinderv2'. The final output is a recap: 'PLAY RECAP localhost : ok=1 changed=0 unreachable=0 failed=0'.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
ok: [localhost] => {
  "msg": "API = cinderv2"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> █
```

Changing the value of `api.v2` to `false` leads to a different result:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
ok: [localhost] => {
  "msg": "API = cinder"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Loops

A loop allows you to create dynamically created sections in template files, and is useful when you know you need to operate on an unknown number of items in the same way. To start a loop control structure, the `for` statement is used. Let's look at a simple way to loop over a list of directories in which a fictional service might find data:

```

# data dirs
{% for dir in data_dirs %}
data_dir = {{ dir }}
{% endfor %}

```

In this example, we will get one `data_dir` = line per item within the `data_dirs` variable, assuming `data_dirs` is a list with at least one item in it. If the variable is not a list (or other iterable type) or is not defined, an error will be generated. If the variable is an iterable type but is empty, then no lines will be generated. Jinja2 allows for the reacting to this scenario and also allows substituting in a line when no items are found in the variable via an `else` statement. In this next example, assume that `data_dirs` is an empty list:

```

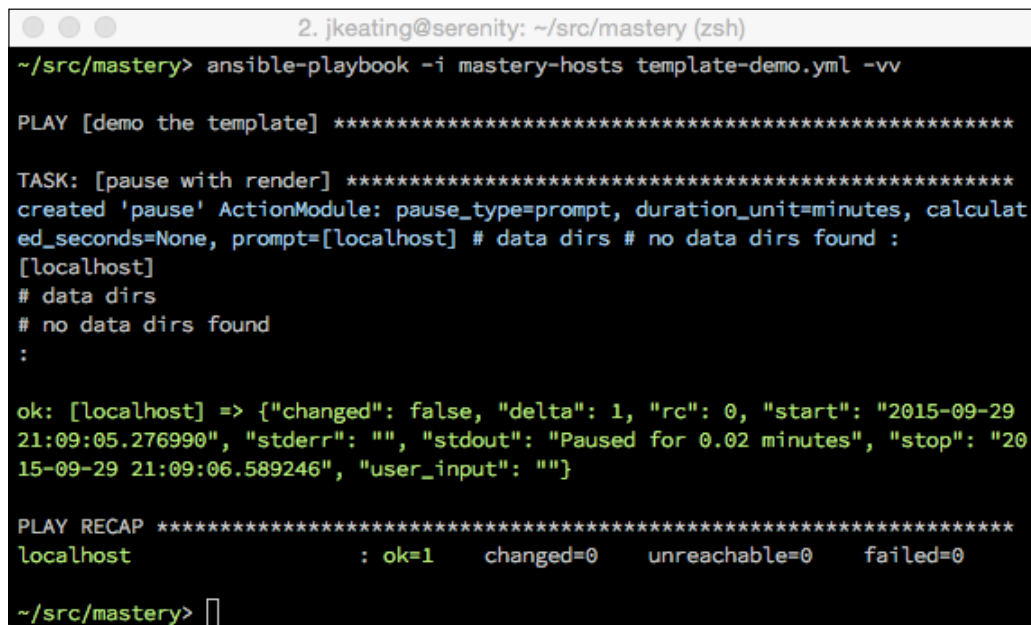
# data dirs
{% for dir in data_dirs %}
data_dir = {{ dir }}
{% else %}
# no data dirs found
{% endfor %}

```

We can test this by modifying our playbook and template file again. We'll update `demo.j2` with the above template content and make use of a prompt in our playbook again:

```
---
- name: demo the template
  hosts: localhost
  gather_facts: false
  vars:
    data_dirs: []
  tasks:
    - name: pause with render
      pause:
        prompt: "{{ lookup('template', 'demo.j2') }}"
```

Running our playbook will show the following result:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat
ed_seconds=None, prompt=[localhost] # data dirs # no data dirs found :
[localhost]
# data dirs
# no data dirs found
:

ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-09-29
21:09:05.276990", "stderr": "", "stdout": "Paused for 0.02 minutes", "stop": "20
15-09-29 21:09:06.589246", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Filtering loop items

Loops can be combined with conditionals as well. Within the loop structure, an `if` statement can be used to check a condition using the current loop item as part of the conditional. Let's extend our example and protect against using `(/)` as a `data_dir`:

```
# data dirs
{% for dir in data_dirs %}
```

```
{% if dir != "/" %}
data_dir = {{ dir }}
{% endif %}
{% else %}
# no data dirs found
{% endfor %}
```

The preceding example successfully filters out any `data_dirs` item that is `(/)` but takes more typing than should be necessary. Jinja2 provides a convenience that allows you to filter loop items easily as part of the `for` statement. Let's repeat the previous example using this convenience:

```
# data dirs
{% for dir in data_dirs if dir != "/" %}
data_dir = {{ dir }}
{% else %}
# no data dirs found
{% endfor %}
```

Not only does this structure require less typing, but it also correctly counts the loops, which we'll learn about in the next section.

Loop indexing

Loop counting is provided *for free*, yielding an index of the current iteration of the loop. As variables, these can be accessed in a few different ways. The following table outlines the ways they can be referenced:

Variable	Description
<code>loop.index</code>	The current iteration of the loop (1 indexed)
<code>loop.index0</code>	The current iteration of the loop (0 indexed)
<code>loop.revindex</code>	The number of iterations until the end of the loop (1 indexed)
<code>loop.revindex0</code>	The number of iterations until the end of the loop (0 indexed)
<code>loop.first</code>	Boolean True if the first iteration
<code>loop.last</code>	Boolean True if the last iteration
<code>loop.length</code>	The number of items in the sequence

Having information related to the position within the loop can help with logic around what content to render. Considering our previous examples, instead of rendering multiple lines of `data_dir` to express each data directory, we could instead provide a single line with comma-separated values. Without having access to loop iteration data, this would be difficult, but when using this data, it can be fairly easy. For the sake of simplicity, this example assumes a trailing comma after the last item is allowed, and that whitespace (newlines) between items is also allowed:

```
# data dirs
{% for dir in data_dirs if dir != "/" %}
{% if loop.first %}
data_dir = {{ dir }},
{% else %}
        {{ dir }},
{% endif %}
{% else %}
# no data dirs found
{% endfor %}
```

The preceding example made use of the `loop.first` variable in order to determine if it needed to render the `data_dir =` part or if it just needed to render the appropriately spaced padded directory. By using a filter in the `for` statement, we get a correct value for `loop.first`, even if the first item in `data_dirs` is the undesired (`/`). To test this, we'll once again modify `demo.j2` with the updated template and modify `template-demo.yaml` to define some `data_dirs`, including one of `/` that should be filtered out:

```
---
- name: demo the template
  hosts: localhost
  gather_facts: false
  vars:
    data_dirs: ['/', '/foo', '/bar']
  tasks:
    - name: pause with render
      pause:
        prompt: "{{ lookup('template', 'demo.j2') }}"
```

Now, we can execute the playbook and see our rendered content:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] # data dirs data_dir = /foo, /bar, :
[localhost]
# data dirs
data_dir = /foo,
           /bar,
:

ok: [localhost] => {"changed": false, "delta": 0, "rc": 0, "start": "2015-09-29
21:30:15.768618", "stderr": "", "stdout": "Paused for 0.02 minutes", "stop": "20
15-09-29 21:30:16.743810", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

If in the preceding example trailing commas were not allowed, we could utilize inline if statements to determine if we're done with the loop and render commas correctly, as shown in the following example:

```

# data dirs.
{% for dir in data_dirs if dir != "/" %}
{% if loop.first %}
data_dir = {{ dir }}{{ ',' if not loop.last else '' }}
{% else %}
        {{ dir }}{{ ',' if not loop.last else '' }}
{% endif %}
{% else %}
# no data dirs found
{% endfor %}

```

Using inline `if` statements allows us to construct a template that will only render a comma if there are more items in the loop that passed our initial filter. Once more, we'll update `demo.j2` with the above content and execute the playbook:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] # data dirs. data_dir = /foo, /bar :
[localhost]
# data dirs.
data_dir = /foo,
           /bar
:

ok: [localhost] => {"changed": false, "delta": 2, "rc": 0, "start": "2015-09-29 21:34:24.701177", "stderr": "", "stdout": "Paused for 0.04 minutes", "stop": "2015-09-29 21:34:26.953696", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Macros

The astute reader will have noticed that in the previous example, we had some repeated code. Repeating code is the enemy of any developer, and thankfully, Jinja2 has a way to help! A macro is like a function in a regular programming language — it's a way to define a reusable idiom. A macro is defined inside a `{% macro ... %}` ... `{% endmacro %}` block and has a name and can take zero or more arguments. Code within a macro does not inherit the namespace of the block calling the macro, so all arguments must be explicitly passed in. Macros are called within mustache blocks by name and with zero or more arguments passed in via parentheses. Let's create a simple macro named `comma` to take the place of our repeating code:

```
{% macro comma(loop) %}
{{ ',' if not loop.last else '' }}
{%- endmacro -%}

# data dirs.
{% for dir in data_dirs if dir != "/" %}
{% if loop.first %}
data_dir = {{ dir }}{{ comma(loop) }}
{% else %}
```

```
        {{ dir }}{{ comma(loop) }}
{% endif %}
{% else %}
# no data dirs found
{% endfor %}
```

Calling `comma` and passing it in the `loop` object allows the macro to examine the loop and decide if a comma should be emitted or not. You may have noticed some special marks on the `endmacro` line. These marks, the `(-)` next to the `(%)`, instruct Jinja2 to strip the whitespace before, and right after the block. This allows us to have a newline between the macro and the start of the template for readability without actually rendering that newline when evaluating the template.

Macro variables

Macros have access inside them to any positional or keyword argument passed along when calling the macro. Positional arguments are arguments that are assigned to variables based on the order they are provided, while keyword arguments are unordered and explicitly assign data to variable names. Keyword arguments can also have a default value if they aren't defined when the macro is called. Three additional special variables are available:

- `varargs`
- `kwargs`
- `caller`

The `varargs` variable is a holding place for additional unexpected positional arguments passed along to the macro. These positional argument values will make up the `varargs` list.

The `kwargs` variable is like `varargs`; however, instead of holding extra positional argument values, it will hold a hash of extra keyword arguments and their associated values.

The `caller` variable can be used to call back to a higher level macro that may have called this macro (yes, macros can call other macros).

In addition to these three special variables are a number of variables that expose internal details regarding the macro itself. These are a bit complicated, but we'll walk through their usage one by one. First, let's take a look at a short description of each variable:

- `name`: The name of the macro itself
- `arguments`: A tuple of the names of the arguments the macro accepts

- `defaults`: A tuple of the default values
- `catch_kwargs`: A Boolean that will be defined as true if the macro accesses (and thus accepts) the `kwargs` variable
- `catch_varargs`: A Boolean that will be defined as true if the macro accesses (and thus accepts) the `varargs` variable
- `caller`: A Boolean that will be defined as true if the macro accesses the `caller` variable (and thus may be called from another macro)

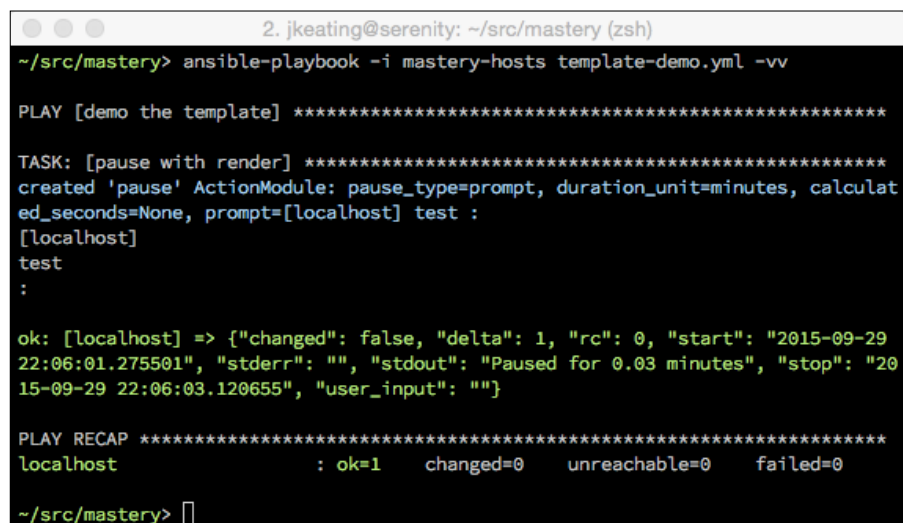
Similar to a class in Python, these variables need to be referenced via the name of the macro itself. Attempting to access these macros without prepending the name will result in undefined variables. Now, let's walk through and demonstrate the usage of each of them.

name

The `name` variable is actually very simple. It just provides a way to access the name of the macro as a variable, perhaps for further manipulation or usage. The following template includes a macro that references the name of the macro in order to render it in the output:

```
{% macro test() %}  
{{ test.name }}  
{%- endmacro -%}  
{{ test() }}
```

If we were to update `demo.j2` with this template and execute the `template-demo.yaml` playbook, the output would be:



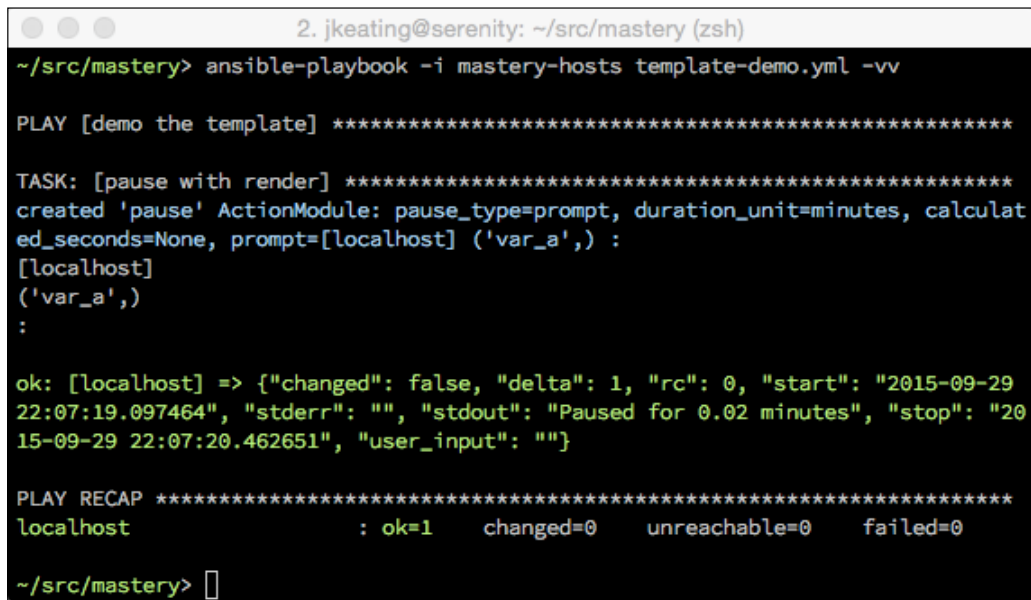
```
2. jkeating@serenity: ~/src/mastery (zsh)  
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv  
  
PLAY [demo the template] *****  
  
TASK: [pause with render] *****  
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat  
ed_seconds=None, prompt=[localhost] test :  
[localhost]  
test  
:  
  
ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-09-29  
22:06:01.275501", "stderr": "", "stdout": "Paused for 0.03 minutes", "stop": "20  
15-09-29 22:06:03.120655", "user_input": ""}  
  
PLAY RECAP *****  
localhost : ok=1 changed=0 unreachable=0 failed=0  
  
~/src/mastery> 
```

arguments

The `arguments` variable is a tuple of the arguments that the macro accepts. These are the explicitly defined arguments, not the special `kwargs` or `varargs`. Our previous example would have rendered an empty tuple `()`, so let's modify it to get something else:

```
{% macro test(var_a='a string') %}
  {{ test.arguments }}
{%- endmacro -%}
{{ test() }}
```

Rendering this template will result in the following:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] ('var_a',) :
[localhost]
('var_a',)
:

ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-09-29 22:07:19.097464", "stderr": "", "stdout": "Paused for 0.02 minutes", "stop": "2015-09-29 22:07:20.462651", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

defaults

The `defaults` variable is a tuple of the default values for any keyword arguments that the macro explicitly accepts. Let's change our macro to display the default values as well as the arguments:

```
{% macro test(var_a='a string') %}
  {{ test.arguments }}
  {{ test.defaults }}
{%- endmacro -%}
{{ test() }}
```

Rendering this version of the template will result in the following:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] ('var_a',) ('a string',) :
[localhost]
('var_a',)
('a string',)
:

ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-09-29 22:08:49.810726", "stderr": "", "stdout": "Paused for 0.03 minutes", "stop": "2015-09-29 22:08:51.575195", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

catch_kwargs

This variable is only defined if the macro itself accesses the `kwargs` variable in order to catch any extra keyword arguments that might have been passed along. Without accessing the `kwargs` variable, any extra keyword arguments in a call to the macro will result in an error when rendering the template. Likewise, accessing `catch_kwargs` without also accessing `kwargs` will result in an undefined error. Let's modify our example template again so that we can pass along extra `kwargs`:

```
{% macro test() %}
  {{ kwargs }}
  {{ test.catch_kwargs }}
{%- endmacro -%}
{{ test(unexpected='surprise') }}
```

The rendered version of this template will be:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat
ed_seconds=None, prompt=[localhost] {'unexpected': 'surprise'} True :
[localhost]
{'unexpected': 'surprise'}
True
:

ok: [localhost] => {"changed": false, "delta": 2, "rc": 0, "start": "2015-09-29
22:10:47.567840", "stderr": "", "stdout": "Paused for 0.03 minutes", "stop": "20
15-09-29 22:10:49.585005", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

catch_varargs

Much like `catch_kwargs`, this variable exists if the macro accesses the `varargs` variable. Modifying our example once more, we can see this in action:

```

{% macro test() %}
{{ varargs }}
{{ test.catch_varargs }}
{%- endmacro -%}
{{ test('surprise') }}

```


The template's rendered result will be:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] ('surprise',) True :
[localhost]
('surprise',)
True
:

ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-10-01 20:54:57.857940", "stderr": "", "stdout": "Paused for 0.02 minutes", "stop": "2015-10-01 20:54:59.256801", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

caller

The `caller` variable takes a bit more explaining. A macro can call out to another macro. This can be useful if the same chunk of the template is to be used multiple times, but part of the inside changes more than could easily be passed as a macro parameter. The `Caller` variable isn't exactly a variable, it's more of a reference back to the call in order to get the contents of that calling macro. Let's update our template to demonstrate the usage:

```
{% macro test() %}
The text from the caller follows:
{{ caller() }}
{%- endmacro -%}
{% call test() %}
This is text inside the call
{% endcall %}
```

The rendered result will be:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculated_seconds=None, prompt=[localhost] The text from the caller follows: This is text inside the call :
[localhost]
The text from the caller follows:
This is text inside the call
:

ok: [localhost] => {"changed": false, "delta": 2, "rc": 0, "start": "2015-10-01 20:56:44.589871", "stderr": "", "stdout": "Paused for 0.04 minutes", "stop": "2015-10-01 20:56:46.923247", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

A call to a macro can still pass arguments to that macro—any combination of arguments or keyword arguments can be passed. If the macro utilizes `varargs` or `kwargs`, then extras of those can be passed along as well. Additionally, a macro can pass arguments back to the caller too! To demonstrate this, let's create a larger example. This time, our example will generate out a file suitable for an Ansible inventory:

```

{% macro test(group, hosts) %}
[{{ group }}]
{% for host in hosts %}
[{{ host }}] {{ caller(host) }}
{%- endfor %}
{%- endmacro %}
{% call(host) test('web', ['host1', 'host2', 'host3']) %}
ssh_host_name={{ host }}.example.name ansible_sudo=true
{% endcall %}
{% call(host) test('db', ['db1', 'db2']) %}
ssh_host_name={{ host }}.example.name
{% endcall %}

```

Once rendered, the result will be:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the template] *****

TASK: [pause with render] *****
created 'pause' ActionModule: pause_type=prompt, duration_unit=minutes, calculat
ed_seconds=None, prompt=[localhost] [web] host1 ssh_host_name=host1.example.name
ansible_sudo=true host2 ssh_host_name=host2.example.name ansible_sudo=true host
3 ssh_host_name=host3.example.name ansible_sudo=true [db] db1 ssh_host_name=db1.
example.name db2 ssh_host_name=db2.example.name :
[localhost]
[web]
host1 ssh_host_name=host1.example.name ansible_sudo=true
host2 ssh_host_name=host2.example.name ansible_sudo=true
host3 ssh_host_name=host3.example.name ansible_sudo=true

[db]
db1 ssh_host_name=db1.example.name
db2 ssh_host_name=db2.example.name
:

ok: [localhost] => {"changed": false, "delta": 1, "rc": 0, "start": "2015-10-01
21:05:39.584425", "stderr": "", "stdout": "Paused for 0.03 minutes", "stop": "20
15-10-01 21:05:41.503232", "user_input": ""}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> █
```

We called the test macro twice, once per each group we wanted to define. Each group had a subtly different set of host variables to apply, and those were defined in the call itself. We saved ourselves some typing by having the macro call back to the caller passing along the host from the current loop.

Control blocks provide programming power inside of templates, allowing template authors to make their templates efficient. The efficiency isn't necessarily in the initial draft of the template. Instead, the efficiency really comes into play when a small change to a repeating value is needed.

Data manipulation

While control structures influence the flow of template processing, another tool exists to modify the contents of a variable. This tool is called a **filter**. Filters are like small functions, or methods, that can be run on the variable. Some filters operate without arguments, some take optional arguments, and some require arguments. Filters can be chained together as well, where the result of one filter action is fed into the next filter and the next. Jinja2 comes with many built-in filters, and Ansible extends these with many custom filters available to you when using Jinja2 within templates, tasks, or any other place Ansible allows templating.

Syntax

A filter is applied to a variable by way of the pipe symbol (`|`), followed by the name of the filter and then any arguments for the filter inside parentheses. There can be a space between the variable name and the pipe symbol, as well as a space between the pipe symbol and the filter name. For example, if we wanted to apply the filter `lower` (which makes all the characters lowercase) to the variable `my_word`, we would use the following syntax:

```
{{ my_word | lower }}
```

Because the `lower` filter does not take any arguments, it is not necessary to attach an empty parentheses set to it. If we use a different filter, one that requires arguments, we can see how that looks. Let's use the `replace` filter, which allows us to replace all occurrences of a substring with another substring. In this example, we want to replace all occurrences of the substring `no` with `yes` in the variable `answers`:

```
{{ answers | replace('no', 'yes') }}
```

Applying multiple filters is accomplished by simply adding more pipe symbols and more filter names. Let's combine both `replace` and `lower` to demonstrate the syntax:

```
{{ answers | replace('no', 'yes') | lower }}
```

We can easily demonstrate this with a simple play that uses the `debug` command to render the line:

```
---
- name: demo the template
  hosts: localhost
  gather_facts: false
  tasks:
    - name: debug the template
      debug:
        msg: "{{ answers | replace('no', 'yes') | lower }}"
```

Now, we can execute the playbook and provide a value for answers at run time:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv -e "answers='no so yes no'"

PLAY [demo the template] *****

TASK: [debug the template] *****
ok: [localhost] => {
  "msg": "yes so yes yes"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Useful built-in filters

A full list of the filters built into Jinja2 can be found in the Jinja2 documentation. At the time of writing this book, there are over 45 built-in filters, too many to describe here. Instead, we'll take a look at some of the more commonly used filters.

default

The `default` filter is a way of providing a default value for an otherwise undefined variable, which will prevent Ansible from generating an error. It is shorthand for a complex `if` statement checking if a variable is defined before trying to use it, with an `else` clause to provide a different value. Let's look at two examples that render the same thing. One will use the `if / else` structure, while the other uses the `default` filter:

```
{% if some_variable is defined %}
{{ some_variable }}
{% else %}
default_value
{% endif %}
{{ some_variable | default('default_value') }}
```

The rendered result of each of these examples is the same; however, the example using the `default` filter is much quicker to write and easier to read.

While `default` is very useful, proceed with caution if you are using the same variable in multiple locations. Changing a default value can become a hassle, and it may be more efficient to define the variable with a default at the play or role level.

count

The `count` filter will return the length of a sequence or hash. In fact, `length` is an alias of `count` to accomplish the same thing. This filter can be useful for performing any sort of math around the size of a set of hosts or any other case where the count of some set needs to be known. Let's create an example in which we set a `max_threads` configuration entry to match the count of hosts in the play:

```
max_threads: {{ play_hosts | count }}
```

random

The `random` filter is used to make a random selection from a sequence. Let's use this filter to delegate a task to a random selection from the `db_servers` group:

```
- name: backup the database
  shell: mysqldump -u root nova > /data/nova.backup.sql
  delegate_to: "{{ groups['db_servers'] | random }}"
  run_once: true
```

round

The `round` filter exists to round a number. This can be useful if you need to perform floating-point math and then turn the result into a rounded integer. The `round` filter takes optional arguments to define a precision (default of 0) and a rounding method. The possible rounding methods are `common` (rounds up or down, the default), `ceil` (always round up), and `floor` (always round down). In this example, we'll round a math result to zero precision:

```
{{ math_result | round | int }}
```

Useful Ansible provided custom filters

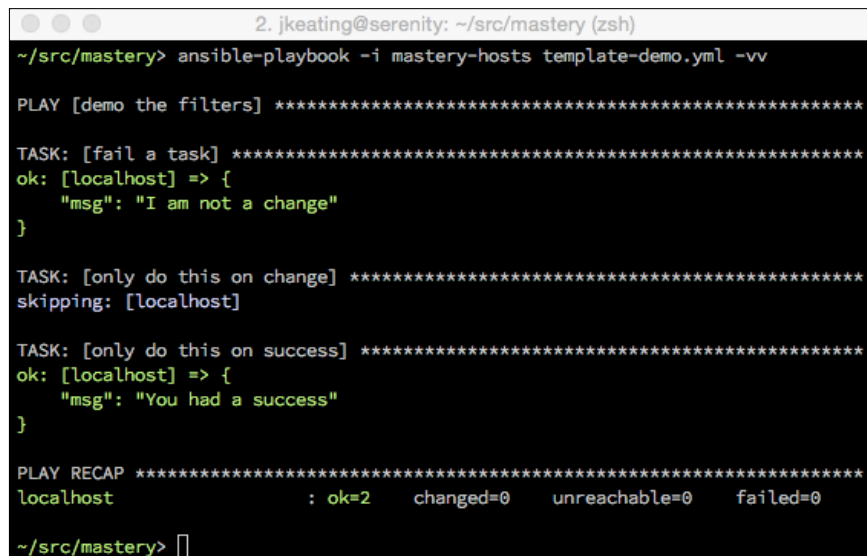
While there are many provided filters with Jinja2, Ansible includes some additional filters that playbook authors may find particularly useful. We'll outline a few of them here.

Filters related to task status

Ansible tracks task data for each task. This data is used to determine if a task has failed, resulted in a change, or was skipped all together. Playbook authors can register the results of a task and then use filters to easily check the task status. These are most often used in conditionals with later tasks. The filters are aptly named `failed`, `success`, `changed`, and `skipped`. They each return a Boolean value. Here is a playbook that demonstrates the use of a couple of these:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false
  tasks:
    - name: fail a task
      debug:
        msg: "I am not a change"
      register: derp
    - name: only do this on change
      debug:
        msg: "You had a change"
      when: derp | changed
    - name: only do this on success
      debug:
        msg: "You had a success"
      when: derp | success
```

The output is as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

TASK: [fail a task] *****
ok: [localhost] => {
  "msg": "I am not a change"
}

TASK: [only do this on change] *****
skipping: [localhost]

TASK: [only do this on success] *****
ok: [localhost] => {
  "msg": "You had a success"
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

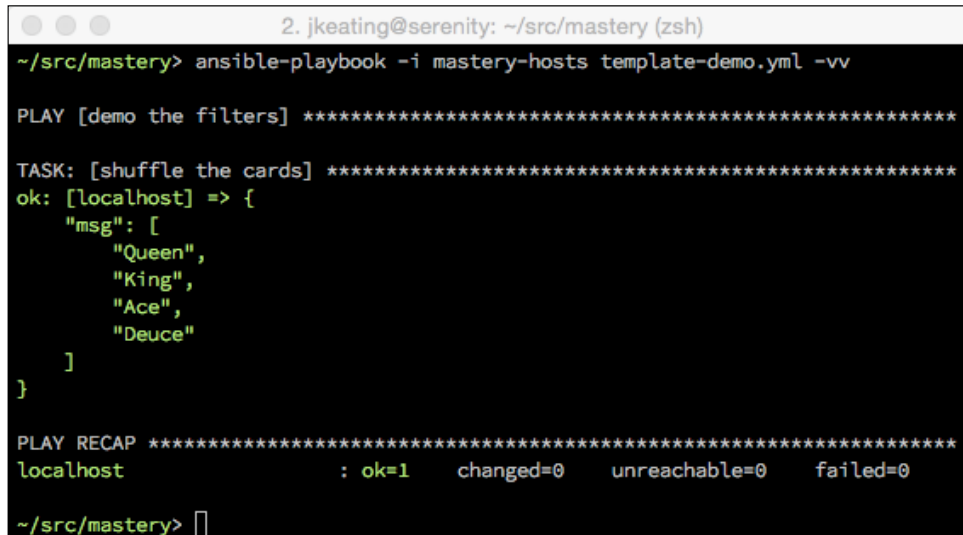
~/src/mastery> 
```

shuffle

Similar to the `random` filter, the `shuffle` filter can be used to produce randomized results. Unlike the `random` filter, which selects one random choice from a list, the `shuffle` filter will shuffle the items in a sequence and return the full sequence back:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false
  tasks:
    - name: shuffle the cards
      debug:
        msg: "{{ ['Ace', 'Queen', 'King', 'Deuce'] | shuffle }}"
```

The output is as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

TASK: [shuffle the cards] *****
ok: [localhost] => {
  "msg": [
    "Queen",
    "King",
    "Ace",
    "Deuce"
  ]
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Filters dealing with path names

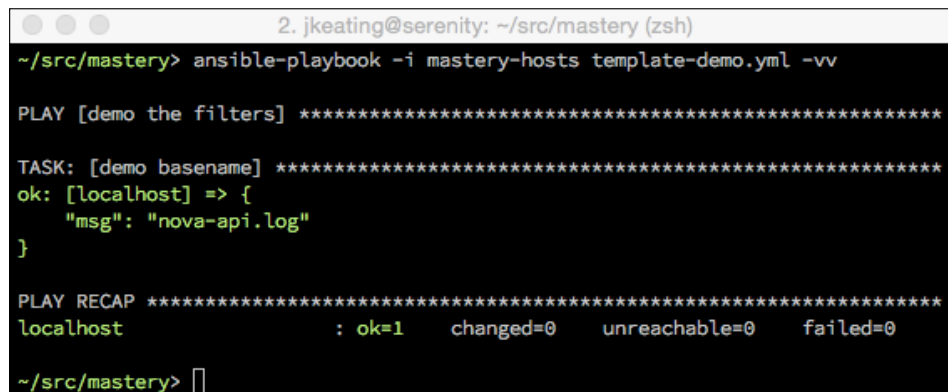
Configuration management and orchestration frequently refers to path names, but often only part of the path is desired. Ansible provides a few filters to help.

basename

To obtain the last part of a file path, use the `basename` filter. For example:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false
  tasks:
    - name: demo basename
      debug:
        msg: "{{ '/var/log/nova/nova-api.log' | basename }}"
```

The output is as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

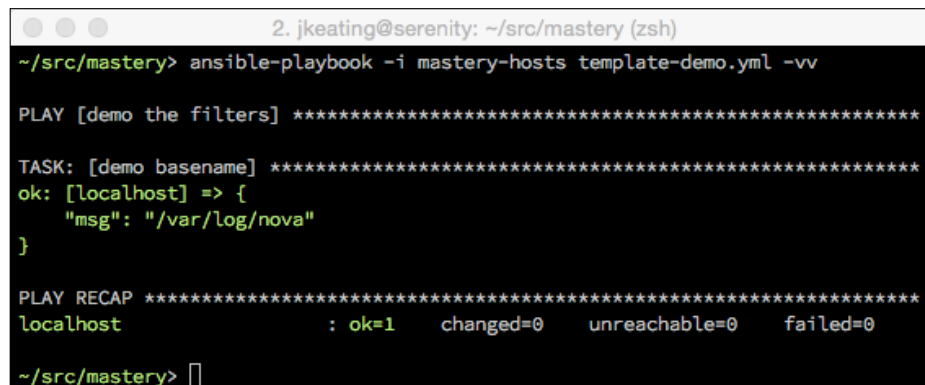
TASK: [demo basename] *****
ok: [localhost] => {
  "msg": "nova-api.log"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

dirname

The inverse of `basename` is `dirname`. Instead of returning the final part of a path, `dirname` will return everything except the final part. Let's change our previous play to use `dirname`, and run it again:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

TASK: [demo basename] *****
ok: [localhost] => {
  "msg": "/var/log/nova"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

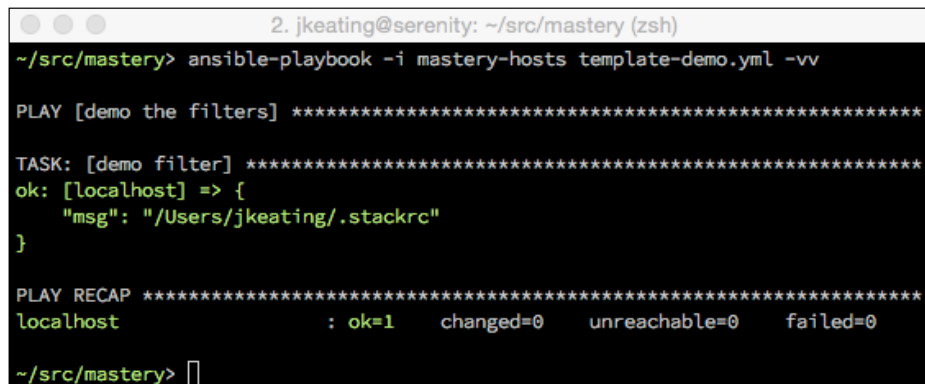
~/src/mastery> []
```

expanduser

Often, paths to various things are supplied with a user shortcut, such as `~/ .stackrc`. However some uses may require the full path to the file. Rather than the complicated `command` and `register` call to use the shell to expand the path, the `expanduser` filter provides a way to expand the path to the full definition. In this example, the user name is `jkeating`:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false
  tasks:
    - name: demo filter
      debug:
        msg: "{{ ' ~/.stackrc' | expanduser }}"
```

The output is as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

TASK: [demo filter] *****
ok: [localhost] => {
  "msg": "/Users/jkeating/.stackrc"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

Base64 encoding

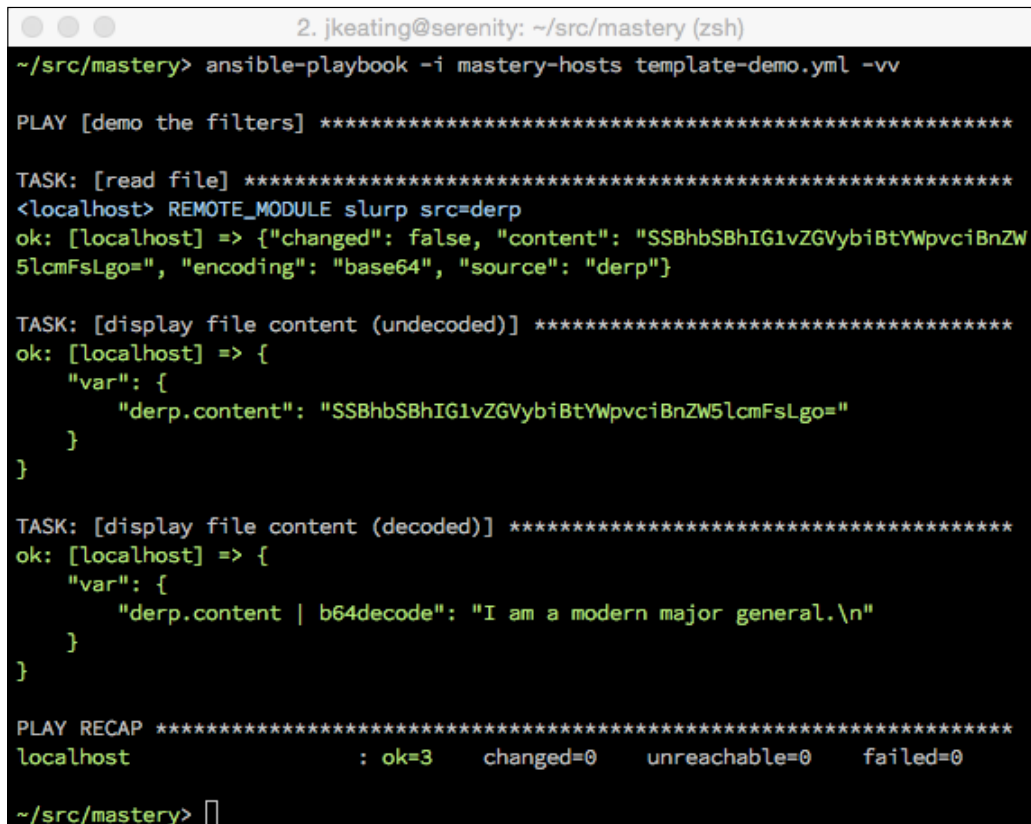
When reading content from remote hosts, like with the `slurp` module (used to read file content from remote hosts into a variable), the content will be Base64 encoded. To decode such content, Ansible provides a `b64decode` filter. Similarly, when running a task that requires Base64 encoded input, regular strings can be encoded with the `b64encode` filter.

Let's read content from the file `derp`:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false
```

```
tasks:
  - name: read file
    slurp:
      src: derp
    register: derp
  - name: display file content (undecoded)
    debug:
      var: derp.content
  - name: display file content (decoded)
    debug:
      var: derp.content | b64decode
```

The output is as shown in the following screenshot:

A screenshot of a terminal window with a dark background and light-colored text. The window title is '2. jkeating@serenity: ~/src/mastery (zsh)'. The user has run the command 'ansible-playbook -i mastery-hosts template-demo.yml -vv'. The output shows three tasks: 'read file', 'display file content (undecoded)', and 'display file content (decoded)'. The first task shows the file content as a base64-encoded string. The second task shows the same content as a JSON object. The third task shows the content decoded to 'I am a modern major general.\n'. The output ends with a 'PLAY RECAP' section showing 'localhost' with 'ok=3', 'changed=0', 'unreachable=0', and 'failed=0'.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the filters] *****

TASK: [read file] *****
<localhost> REMOTE_MODULE slurp src=derp
ok: [localhost] => {"changed": false, "content": "SSBhbSBhIG1vZGVybiBtYWpvc iBnZW5lcmFsLgo=", "encoding": "base64", "source": "derp"}

TASK: [display file content (undecoded)] *****
ok: [localhost] => {
  "var": {
    "derp.content": "SSBhbSBhIG1vZGVybiBtYWpvc iBnZW5lcmFsLgo="
  }
}

TASK: [display file content (decoded)] *****
ok: [localhost] => {
  "var": {
    "derp.content | b64decode": "I am a modern major general.\n"
  }
}

PLAY RECAP *****
localhost                : ok=3    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Searching for content

It is fairly common in Ansible to search a string for a substring. In particular, the common administrator task of running a command and grepping the output for a particular key piece of data is a reoccurring construct in many playbooks. While it's possible to replicate this with a `shell` task to execute a command and pipe the output into `grep`, and use careful handling of `failed_when` to catch `grep` exit codes, a far better strategy is to use a `command` task, register the output, and then utilize Ansible-provided regex filters in later conditionals. Let's look at two examples, one using the `shell`, `pipe`, `grep` method, and another using the `search` filter:

```
- name: check database version
  shell: neutron-manage current |grep junio
  register: neutron_db_ver
  failed_when: false
- name: upgrade db
  command: neutron-manage db_sync
  when: neutron_db_ver|failed
```

The above example works by forcing Ansible to always see the task as successful, but assumes that if the exit code from the shell is non-zero then the string `juno` was not found in the output of the `neutron-manage` command. This construct is functional, but a bit clunky, and could mask real errors from the command. Let's try again using the `search` filter:

```
- name: check database version
  command: neutron-manage current
  register: neutron_db_ver
- name: upgrade db
  command: neutron-manage db_sync
  when: not neutron_db_ver.stdout | search('juno')
```

This version is much cleaner to follow and does not mask errors from the first task.

The `search` filter searches a string and will return `True` if the substring is found anywhere within the input string. If an exact complete match is desired instead, the `match` filter can be used. Full Python regex syntax can be utilized inside the `search` / `match` string.

Omitting undefined arguments

The `omit` variable takes a bit of explaining. Sometimes, when iterating over a hash of data to construct task arguments, it may be necessary to only provide some arguments for some of the items in the hash. Even though Jinja2 supports in-line `if` statements to conditionally render parts of a line, this does not work well in an Ansible task. Traditionally, playbook authors would create multiple tasks, one for each set of potential arguments passed in, and use conditionals to sort the loop members between each task set. A recently added magic variable named `omit` solves this problem when used in conjunction with the `default` filter. The `omit` variable will remove the argument that the variable was used with altogether.

To illustrate how this works, let's consider a scenario where we need to install a set of Python packages with `pip`. Some of the packages have a specific version, while others do not. These packages are in a list of hashes named `pips`. Each hash has a `name` key and potentially a `ver` key. Our first example utilizes two different tasks to complete the installs:

```
- name: install pips with versions
  pip:
    name: "{{ item.name }}"
    version: "{{ item.ver }}"
  with_items: pips
  when: item.ver is defined
- name: install pips without versions
  pip:
    name: "{{ item.name }}"
  with_items: pips
  when: item.ver is undefined
```

This construct works, but the loop is iterated twice and some of the iterations will be skipped in each task. This next example collapses the two tasks into one and utilizes the `omit` variable:

```
- name: install pips
  pip:
    name: "{{ item.name }}"
    version: "{{ item.ver | default(omit) }}"
  with_items: pips
```

This example is shorter, cleaner, and doesn't generate extra skipped tasks.

Python object methods

Jinja2 is a Python-based template engine. Because of this, Python object methods are available within templates. Object methods are methods, or functions, that are directly accessible by the variable object (typically a `string`, `list`, `int`, or `float`). A good way to think about this is if you were writing Python code and could write the variable, then a period, then a method call, you would then have access to do the same in Jinja2. Within Ansible, only methods that return modified content or a Boolean are typically used. Let's explore some common object methods that might be useful in Ansible.

String methods

String methods can be used to return new strings or a list of strings modified in some way, or to test the string for various conditions and return a Boolean. Some useful methods are as follows:

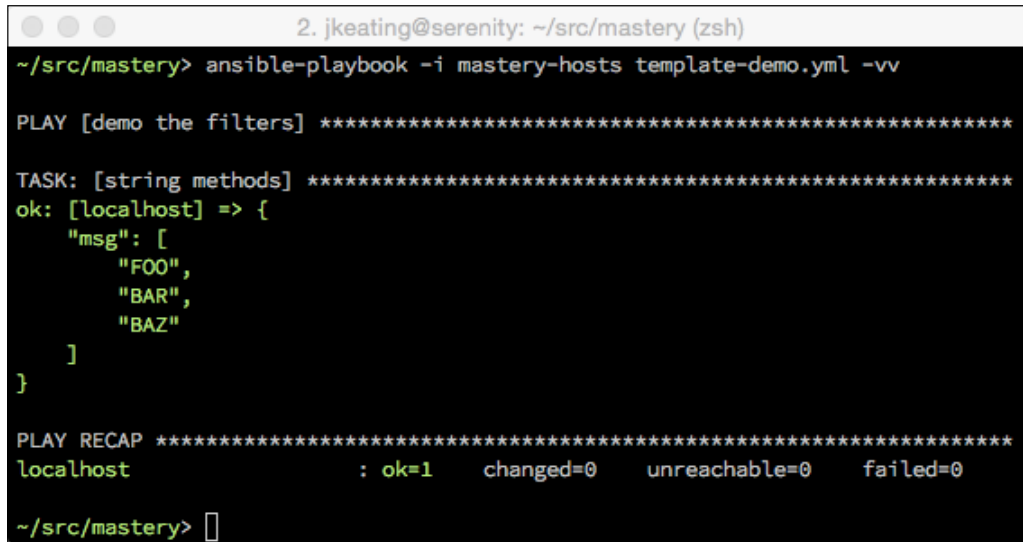
- `endswith`: Determines if the string ends with a substring
- `startswith`: Like `endswith`, but from the start
- `split`: Splits the string on characters (default is space) into a list of substrings
- `rsplit`: The same as `split`, but starts from the end of the string and works backwards
- `splitlines`: Splits the string at newlines into a list of substrings
- `upper`: Returns a copy of the string all in uppercase
- `lower`: Returns a copy of the string all in lowercase
- `capitalize`: Returns a copy of the string with just the first character in uppercase

We can create a simple play that will utilize some of these methods in a single task:

```
---
- name: demo the filters
  hosts: localhost
  gather_facts: false

  tasks:
    - name: string methods
      debug:
        msg: "{{ 'foo bar baz'.upper().split() }}"
```

The output is as shown in the following screenshot:

A screenshot of a terminal window with a dark background. The window title is '2. jkeating@serenity: ~/src/mastery (zsh)'. The prompt is '~/src/mastery>'. The command entered is 'ansible-playbook -i mastery-hosts template-demo.yml -vv'. The output shows 'PLAY [demo the filters]' followed by a separator line of asterisks. Then 'TASK: [string methods]' followed by another separator line. The task status is 'ok: [localhost] => {' with a list of strings: 'msg': ['FOO', 'BAR', 'BAZ']}. Below this is a 'PLAY RECAP' section with a separator line, showing 'localhost : ok=1 changed=0 unreachable=0 failed=0'. The prompt returns to '~/src/mastery> '.

Because these are object methods, we need to access them with dot notation rather than as a filter via (`|`).

List methods

Only a couple methods do something other than modify the list in-place rather than returning a new list, and they are as follows:

- `index`: Returns the first index position of a provided value
- `count`: Counts the items in the list

int and float methods

Most `int` and `float` methods are not useful for Ansible.

Sometimes, our variables are not exactly in the format we want them in. However, instead of defining more and more variables that slightly modify the same content, we can make use of Jinja2 filters to do the manipulation for us in the various places that require that modification. This allows us to stay efficient with the definition of our data, preventing many duplicate variables and tasks that may have to be changed later.

Comparing values

Comparisons are used in many places with Ansible. Task conditionals are comparisons. Jinja2 control structures often use comparisons. Some filters use comparisons as well. To master Ansible's usage of Jinja2, it is important to understand which comparisons are available.

Comparisons

Like most languages, Jinja2 comes equipped with the standard set of comparison expressions you would expect, which will render a Boolean `true` or `false`.

The expressions in Jinja2 are as follows:

Expression	Definition
<code>==</code>	Compares two objects for equality
<code>!=</code>	Compares two objects for inequality
<code>></code>	True if the left-hand side is greater than the right-hand side
<code><</code>	True if the left-hand side is less than the right-hand side
<code>>=</code>	True if the left-hand side is greater than or equal to the right-hand side
<code><=</code>	True if the left-hand side is less than or equal to the right-hand side

Logic

Logic helps group two or more comparisons together. Each comparison is referred to as an operand:

- `and`: Returns `true` if the left and the right operand are true
- `or`: Returns `true` if the left or the right operand is true
- `not`: Negates an operand
- `()`: Wraps a set of operands together to form a larger operand

Tests

A test in Jinja2 is used to see if a value is something. In fact, the `is` operator is used to initiate a test. Tests are used any place a Boolean result is desired, such as with `if` expressions and task conditionals. There are many built-in tests, but we'll highlight a few of the particularly useful ones.

- `defined`: Returns `true` if the variable is defined
- `undefined`: The opposite of `defined`

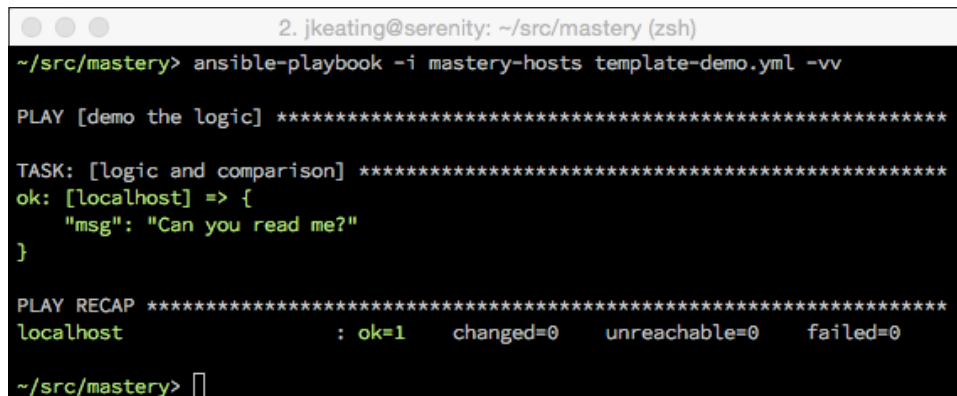
- `none`: Returns true if the variable is defined, but the value is none
- `even`: Returns true if the number is divisible by 2
- `odd`: Returns true if the number is not divisible by 2

To test if a value is not something, simply use `is not`.

We can create a playbook that will demonstrate some of these value comparisons:

```
---
- name: demo the logic
  hosts: localhost
  gather_facts: false
  vars:
    num1: 10
    num3: 10
  tasks:
    - name: logic and comparison
      debug:
        msg: "Can you read me?"
      when: num1 >= num3 and num1 is even and num2 is not defined
```

The output is as shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts template-demo.yml -vv

PLAY [demo the logic] *****

TASK: [logic and comparison] *****
ok: [localhost] => {
  "msg": "Can you read me?"
}

PLAY RECAP *****
localhost : ok=1  changed=0  unreachable=0  failed=0

~/src/mastery> 
```

Summary

Jinja2 is a powerful language that is used by Ansible. Not only is it used to generate file content, but it is also used to make portions of playbooks dynamic. Mastering Jinja2 is vital for creating and maintaining elegant and efficient playbooks and roles.

In the next chapter, we will explore more in depth Ansible's capability to define what constitutes a change or failure for tasks within a play.

4

Controlling Task Conditions

Ansible fundamentally operates on the concept of task statuses: **Ok**, **Changed**, **Failed**, or **Skipped**. These statuses determine whether any further tasks should be executed on a host, and whether handlers should be notified due of any changes. Tasks can also make use of conditionals that check the status of previous tasks to control operation.

In this chapter, we'll explore ways to influence Ansible when determining the task status:

- Controlling what defines a failure
- Controlling what defines a change

Defining a failure

Most modules that ship with Ansible have an opinion on what constitutes an error. An error condition is highly dependent upon the module and what the module is attempting to accomplish. When a module returns an error, the host will be removed from the set of available hosts, preventing any further tasks or handlers from being executed on that host. Furthermore, the `ansible-playbook` function or Ansible execution will exit with nonzero, indicating failure. However, we are not limited by a module's opinion of what an error is. We can ignore errors or redefine the error condition.

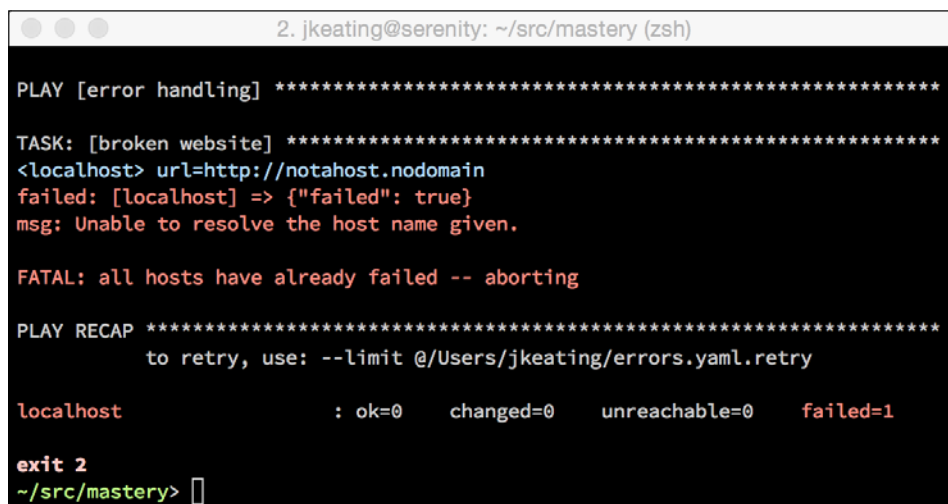
Ignoring errors

A task argument, named `ignore_errors`, is used to ignore errors. This argument is a Boolean, meaning that the value should be something Ansible understands to be true, such as `yes`, `on`, `true`, or `1` (string or integer).

To demonstrate how to use `ignore_errors`, let's create a playbook named `errors.yaml`, in which we attempt to query a webserver that doesn't exist. Normally, this would be an error, and if we don't define `ignore_errors`, we get the default behavior, that is, the host will be marked as failed and no further tasks will be attempted on that host. Let's take a look at the following code snippet:

```
- name: broken website
  uri:
    url: http://notahost.nodomain
```

Running the task as is will give us an error:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' displays the output of an Ansible play. The output shows a task 'broken website' failing on 'localhost' due to an inability to resolve the host name. The play then aborts with the message 'FATAL: all hosts have already failed -- aborting'. A recap shows the task failed on localhost. The terminal output is as follows:

```
PLAY [error handling] *****

TASK: [broken website] *****
<localhost> url=http://notahost.nodomain
failed: [localhost] => {"failed": true}
msg: Unable to resolve the host name given.

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
      to retry, use: --limit @/Users/jkeating/errors.yaml.retry

localhost                : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery> █
```

Now, let's imagine that we didn't want Ansible to stop here, and instead we wanted it to continue. We can add the `ignore_errors` condition to our task like this:

```
- name: broken website
  uri:
    url: http://notahost.nodomain
    ignore_errors: true
```

This time when we run the playbook, our error will be ignored, as we can see here:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [broken website] *****
<localhost> url=http://notahost.nodomain
failed: [localhost] => {"failed": true}
msg: Unable to resolve the host name given.
...ignoring

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Our task error is ignored. Any further tasks for that host will still be attempted and the playbook does not register any failed hosts.

Defining an error condition

The `ignore_errors` argument is a bit of a blunt hammer. Any error generated from the module used by the task will be ignored. Furthermore, the output, at first glance, still appears like an error, and may be confusing to an operator attempting to discover a real failure. A more subtle tool is the `failed_when` argument. This argument is more like a fine scalpel, allowing a playbook author to be very specific as to what constitutes an error for a task. This argument performs a test to generate a Boolean result, much like the `when` argument. If the test results in a Boolean truth, the task will be considered a failure. Otherwise, the task will be considered successful.

The `failed_when` argument is quite useful when used in combination with the `command` or `shell` module, and when registering the result of the execution. Many programs that are executed can have detailed nonzero exit codes that mean different things; however, these modules all consider an exit code of anything other than zero to be a failure. Let's look at the `iscsiadm` utility. This utility can be used for many things related to iSCSI. For the sake of our demonstration, we'll use it to discover any active `iscsi` sessions:

```

- name: query sessions
  command: /sbin/iscsiadm -m sessions
  register: sessions

```

If this were to be run on a system where there were no active sessions, we'd see output like this:

```
2. jkeating@serenity: ~/src/mastery (zsh)

TASK: [query sessions] *****
<scsihost>
failed: [scsihost] => {"changed": true, "cmd": ["/sbin/iscsiadm", "-m", "session"], "delta": "0:00:00.010991", "end": "2015-03-25 22:45:07.250198", "rc": 21, "start": "2015-03-25 22:45:07.239207", "warnings": []}
stderr: iscsiadm: No active sessions.

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
                to retry, use: --limit @/Users/jkeating/errors.yaml.retry

scsihost          : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery> 
```

We can just use the `ignore_errors` argument, but that would mask other problems with `iscsi`. So, instead of this, we want to instruct Ansible that an exit code of 21 is acceptable. To that end, we can make use of a registered variable to access the `rc` variable, which holds the return code. We'll make use of this in a `failed_when` statement:

```
- name: query sessions
  command: /sbin/iscsiadm -m sessions
  register: sessions
  failed_when: sessions.rc not in (0, 21)
```

We simply stated that any exit code other than 0 or 21 should be considered a failure. Let's see the new output after this modification:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [query sessions] *****
<scsihost>
changed: [scsihost] => {"changed": true, "cmd": ["/sbin/iscsiadm", "-m", "session"], "delta": "0:00:00.010259", "end": "2015-03-25 22:52:42.461434", "failed": false, "failed_when_result": false, "rc": 21, "start": "2015-03-25 22:52:42.451175", "stderr": "iscsiadm: No active sessions.", "stdout": "", "stdout_lines": [], "warnings": []}

PLAY RECAP *****
scsihost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> 

```

The output now shows no error, and, in fact, we see a new data key in the results — `failed_when_result`. This shows whether our `failed_when` statement rendered true or false. It was false in this case.

Many command-line tools do not have detailed exit codes. In fact, most typically use 0 for success and one other non-zero code for all failure types. Thankfully, the `failed_when` argument is not just limited to the exit code of the application; it is a free form Boolean statement that can access any sort of data required. Let's look at a different problem, one involving `git`. We'll imagine a scenario in which we want to ensure that a particular branch does not exist in a `git` checkout. This task assumes a `git` repository checked out in the `/srv/app` directory. The command to delete a `git` branch is `git branch -D`. Let's have a look at the following code snippet:

```

- name: delete branch bad
  command: git branch -D badfeature
  args:
    chdir: /srv/app

```



The `command` and `shell` modules use a different format for providing module arguments. The command itself is provided a free form, while module arguments go into an `args` hash.

If we start with just this command, we'll get an error, an exit code of 1 if the branch does not exist:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****


TASK: [delete branch bad] *****
<localhost> REMOTE_MODULE command chdir=/srv/app git branch -D badfeature
failed: [localhost] => {"changed": true, "cmd": ["git", "branch", "-D", "badfeature"], "delta": "0:00:00.005515", "end": "2015-10-06 21:40:15.130667", "rc": 1, "start": "2015-10-06 21:40:15.125152", "warnings": ["Consider using git module rather than running git"]}
stderr: error: branch 'badfeature' not found.

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
to retry, use: --limit @/Users/jkeating/errors.yaml.retry

localhost                : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery> 
```

 Ansible gave us a warning and suggestion to use the `git` module instead of using the `command` module to run the `git` commands. We're using the `command` module to easily demonstrate our topic despite the existence of the `git` module.

Without the `failed_when` and `changed_when` argument, we would have to create a two-step task combo to protect ourselves from errors:

```
- name: check if branch badfeature exists
  command: git branch
  args:
    chdir: /srv/app
  register: branches
- name: delete branch bad
  command: git branch -D badfeature
  args:
    chdir: /srv/app
  when: branches.stdout | search('badfeature')
```

In the scenario in which the branch doesn't exist, running these tasks looks as follows:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [check if branch badfeature exists] *****
<localhost> REMOTE_MODULE command chdir=/srv/app git branch
changed: [localhost] => {"changed": true, "cmd": ["git", "branch"], "delta": "0:
00:00.011830", "end": "2015-10-06 21:51:55.844094", "rc": 0, "start": "2015-10-0
6 21:51:55.832264", "stderr": "", "stdout": "* master", "warnings": ["Consider u
sing git module rather than running git"]}

TASK: [delete branch bad] *****
skipping: [localhost]

PLAY RECAP *****
localhost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> 

```

While the task set is functional, it is not efficient. Let's improve upon this and leverage the `failed_when` functionality to reduce the two tasks into one:

```

- name: delete branch bad
  command: git branch -D badfeature
  args:
    chdir: /srv/app
    register: gitout
    failed_when: gitout.rc != 0 and not gitout.stderr |
search('branch.*not found')

```


We check the command return code for anything other than 0 and then use the search filter to search the `stderr` value with a regex `branch.*not found`. We use the Jinja2 logic to combine the two conditions, which will evaluate to an inclusive `true` or `false` option:

```
2. jkeating@serenity: ~/src/mastery (zsh)

~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [delete branch bad] *****
<localhost> REMOTE_MODULE command chdir=/srv/app git branch -D badfeature
changed: [localhost] => {"changed": true, "cmd": ["git", "branch", "-D", "badfea
ture"], "delta": "0:00:00.021344", "end": "2015-10-06 21:55:09.035861", "failed"
: false, "failed_when_result": false, "rc": 1, "start": "2015-10-06 21:55:09.014
517", "stderr": "error: branch 'badfeature' not found.", "stdout": "", "stdout_l
ines": [], "warnings": ["Consider using git module rather than running git"]}

PLAY RECAP *****
localhost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> 
```

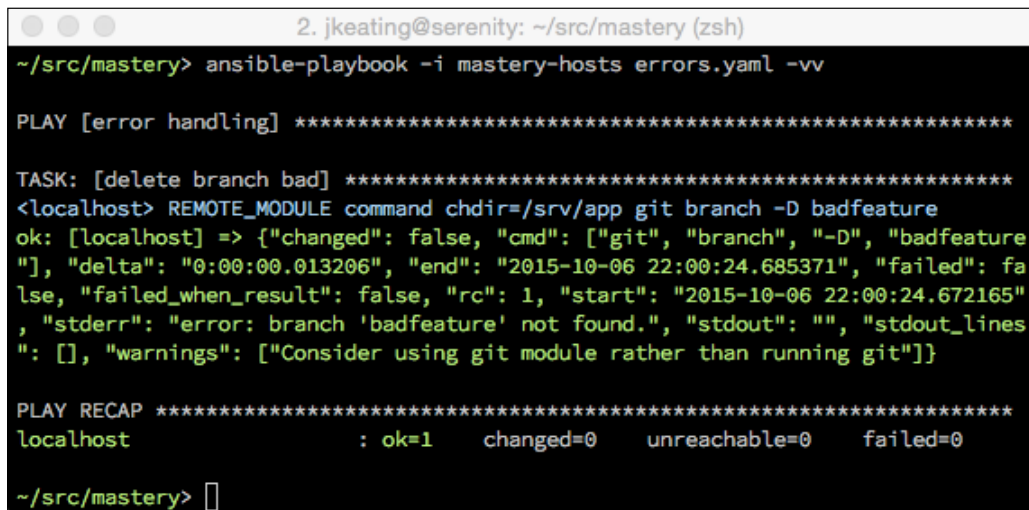
Defining a change

Similar to defining a task failure, it is also possible to define what constitutes a changed task result. This capability is particularly useful with the `command` family of modules (`command`, `shell`, `raw`, and `script`). Unlike most other modules, the modules of this family do not have an inherent idea of what a change may be. In fact, unless otherwise directed, these modules *only* result in **failed**, **changed**, or **skipped**. There is simply no way for these modules to assume a changed condition versus unchanged.

The `changed_when` argument allows a playbook author to instruct a module on how to interpret a change. Just like `failed_when`, `changed_when` performs a test to generate a Boolean result. Frequently, the tasks used with `changed_when` are commands that will exit nonzero to indicate that no work is needed to be done. So authors will often combine `changed_when` and `failed_when` to fine-tune the task result evaluation. In our previous example, the `failed_when` argument caught the case in which there was no work to be done but the task still showed a change. We want to register a change on the exit code 0, but not on any other exit code. Let's expand our example task to accomplish this:

```
- name: delete branch bad
  command: git branch -D badfeature
  args:
    chdir: /srv/app
  register: gitout
  failed_when: gitout.rc != 0 and not gitout.stderr |
search('branch.*not found')
  changed_when: gitout.rc == 0
```

Now, if we run our task when the branch still does not exist, we'll see the following output:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [delete branch bad] *****
<localhost> REMOTE_MODULE command chdir=/srv/app git branch -D badfeature
ok: [localhost] => {"changed": false, "cmd": ["git", "branch", "-D", "badfeature"], "delta": "0:00:00.013206", "end": "2015-10-06 22:00:24.685371", "failed": false, "failed_when_result": false, "rc": 1, "start": "2015-10-06 22:00:24.672165", "stderr": "error: branch 'badfeature' not found.", "stdout": "", "stdout_lines": [], "warnings": ["Consider using git module rather than running git"]}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Note how the key `changed` now has the value `false`.

Just to be complete, we'll change the scenario so that the branch does exist and run it again. To create the branch, simply run `git branch badfeature` from the `/srv/app` directory. Now we can execute our playbook once again to see the output, which is as follows:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [delete branch bad] *****
<localhost> REMOTE_MODULE command chdir=/srv/app git branch -D badfeature
changed: [localhost] => {"changed": true, "cmd": ["git", "branch", "-D", "badfeature"], "delta": "0:00:00.009566", "end": "2015-10-06 22:05:12.902146", "failed": false, "failed_when_result": false, "rc": 0, "start": "2015-10-06 22:05:12.892580", "stderr": "", "stdout": "Deleted branch badfeature (was 08077d5).", "stdout_lines": ["Deleted branch badfeature (was 08077d5)."], "warnings": ["Consider using git module rather than running git"]}

PLAY RECAP *****
localhost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> █
```

This time, our output is different. It's registering a change, and the `stdout` data shows the branch being deleted.

Special handling of the command family

A subset of the command family of modules (`command`, `shell`, and `script`) has a pair of special arguments that will influence whether or not the task work has already been done, and thus, whether or not a task will result in a change. The options are `creates` and `removes`. These two arguments expect a file path as a value. When Ansible attempts to execute a task with the `creates` or `removes` arguments, it will first check whether the referenced file path exists. If the path exists and the `creates` argument was used, Ansible will consider that the work has already been completed and will return `ok`. Conversely, if the path does not exist and the `removes` argument is used, then Ansible will again consider the work to be complete, and it will return `ok`. Any other combination will cause the work to actually happen. The expectation is that whatever work the task is doing will result in either the creation or removal of the file that is referenced.

The convenience of `creates` and `removes` saves developers from having to do a two-task combo. Let's create a scenario in which we want to run the script `frobitz` from the `files/` subdirectory of our project root. In our scenario, we know that the `frobitz` script will create a path `/srv/whiskey/tango`. In fact, the source of `frobitz` is the following:

```
#!/bin/bash
rm -rf /srv/whiskey/tango
mkdir /srv/whiskey/tango
```

We don't want this script to run twice as it can be destructive to any existing data. The two-task combo will look like this:

```
- name: discover tango directory
  stat:
    path: /srv/whiskey/tango
  register: tango

- name: run frobitz
  script: files/frobitz --initialize /srv/whiskey/tango
  when: not tango.stat.exists
```

Assuming that the file already exists, the output will be as follows:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [discover tango directory] *****
<localhost> REMOTE_MODULE stat path=/srv/whiskey/tango
ok: [localhost] => {"changed": false, "stat": {"atime": 1444194872.0, "ctime": 1444194872.0, "dev": 16777220, "exists": true, "gid": 0, "gr_name": "wheel", "ino": 3181585, "isblk": false, "ischr": false, "isdir": true, "isfifo": false, "isgid": false, "islnk": false, "isreg": false, "issock": false, "isuid": false, "mode": "0755", "mtime": 1444194872.0, "nlink": 2, "path": "/srv/whiskey/tango", "pw_name": "root", "rgrp": true, "roth": true, "rusr": true, "size": 68, "uid": 0, "wgrp": false, "woth": false, "wusr": true, "xgrp": true, "xoth": true, "xusr": true}}

TASK: [run frobitz] *****
skipping: [localhost]

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

If the `/srv/whiskey/tango` path did not exist, the `stat` module would have returned far less data, and the `exists` key would have a value of `false`. Thus, our `frobitz` script would have been run.

Now, we'll use `creates` to reduce this down to a single task:

```
- name: run frobitz
  script: files/frobitz creates=/srv/whiskey/tango
```



The `script` module is actually an `action_plugin`, which will be discussed in *Chapter 8, Extending Ansible*. The `script` `action_plugin` only accepts arguments in the `key=value` format.

This time, our output will be slightly different:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [run frobitz] *****
ok: [localhost] => {"changed": false, "msg": "skipped, since /srv/whiskey/tango
exists"}

PLAY RECAP *****
localhost          : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> []
```



Making good use of `creates` and `removes` will keep your playbooks concise and efficient.

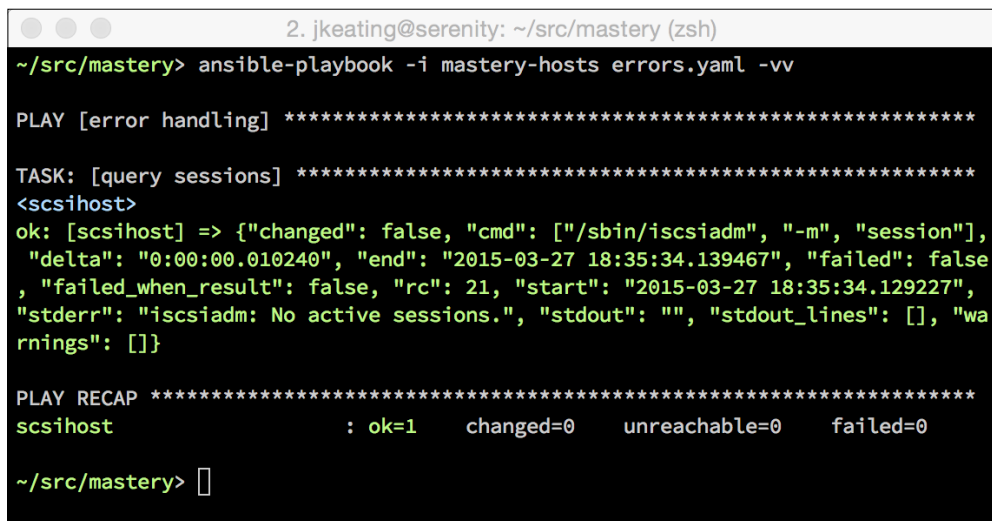
Suppressing a change

Sometimes it can be desirable to completely suppress changes. This is often used when executing a command in order to gather data. The command execution isn't actually changing anything; instead, it's just gathering info, like the `setup` module. Suppressing changes on such tasks can be helpful for quickly determining whether a playbook run resulted in any actual change in the fleet.

To suppress change, simply use `false` as an argument to the `changed_when` task key. Let's extend one of our previous examples to discover the active `iscsi` sessions to suppress changes:

```
- name: discover iscsi sessions
  command: /sbin/iscsiadm -m sessions
  register: sessions
  failed_when: sessions.rc != 0 and not sessions.stderr | search('No
active sessions')
  changed_when: false
```

Now, no matter what comes in the return data, Ansible will treat the task as `ok` rather than `changed`:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts errors.yaml -vv

PLAY [error handling] *****

TASK: [query sessions] *****
<scsihost>
ok: [scsihost] => {"changed": false, "cmd": ["/sbin/iscsiadm", "-m", "session"],
"delta": "0:00:00.010240", "end": "2015-03-27 18:35:34.139467", "failed": false
, "failed_when_result": false, "rc": 21, "start": "2015-03-27 18:35:34.129227",
"stderr": "iscsiadm: No active sessions.", "stdout": "", "stdout_lines": [], "wa
rnings": []}

PLAY RECAP *****
scsihost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

Summary

In general, Ansible does a great job at determining when there are failures or actual changes made by a task. However, sometimes Ansible is either incapable or just needs some fine-tuning based on the situation. To facilitate this, a set of task constructs exist for playbook authors to utilize. In the next chapter, we'll explore the use of Roles to organize tasks, files, variables, and other content.

5

Composing Reusable Ansible Content with Roles

For many projects, a simple, single Ansible playbook may suffice. As time goes on and projects grow, additional playbooks and variable files are added, and task files may be split out. Other projects within an organization may want to reuse some of the content; either the projects get added to the directory tree or the desired content may get copied between multiple projects. As the complexity and size of the scenario grows, something more than a loosely organized handful of playbooks, task files, and variable files is highly desired. Creating such a hierarchy can be daunting and may explain why many uses of Ansible start simple and only grow into a better organization once the scattered files become unwieldy and a hassle to maintain. Making the migration can be difficult and may require rewriting significant portions of playbooks, which can further delay reorganization efforts.

In this chapter, we will cover the best practices for composable, reusable, and well-organized content within Ansible. Lessons learned in this chapter will help developers design Ansible content that grows well with the project, avoiding the need for difficult redesign work later. The following is an outline of what we will cover:

- Task, handler, variable, and playbook include concepts
- Roles
- Designing top level playbooks to utilize roles
- Sharing roles across projects

Task, handler, variable, and playbook include concepts

The first step to understanding how to efficiently organize an Ansible project structure is to master the concept of including files. The act of including files allows content to be defined in a topic specific file that can be included into other files one or more times within a project. This inclusion feature supports the concept of **DRY (Don't Repeat Yourself)**.

Including tasks

Task files are YAML files that define one or more tasks. These tasks are not directly tied to any particular play or playbook; they exist purely as a list of tasks. These files can be referenced by playbooks or other task files by way of the `include` operator. This operator takes a path to a task file, and as we learned in *Chapter 1, System Architecture and Design of Ansible*, the path can be relative from the file referencing it.

To demonstrate how to use the `include` operator to include tasks, let's create a simple play that includes a task file with some debug tasks within it. First, let's write our playbook file, and we'll call it `includer.yaml`:

```
---
- name: task inclusion
  hosts: localhost
  gather_facts: false

  tasks:
    - name: non-included task
      debug:
        msg: "I am not included"

    - include: more-tasks.yaml
```

Next, we'll create `more-tasks.yaml` in the same directory that holds `includer.yaml`:

```
---
- name: included task 1
  debug:
    msg: "I am the first included task"

- name: include task 2
  debug:
    msg: "I am the second included task"
```

Now, we can execute our playbook to observe the output:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [task inclusion] *****

TASK: [non-included task] *****
ok: [localhost] => {
  "msg": "I am not included"
}

TASK: [included task 1] *****
ok: [localhost] => {
  "msg": "I am the first included task"
}

TASK: [included task 2] *****
ok: [localhost] => {
  "msg": "I am the second included task"
}

PLAY RECAP *****
localhost          : ok=3    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

We can clearly see our tasks from the `include` file execution. Because the `include` operator was used within the play's tasks section, the included tasks were executed within that play. In fact, if we were to add a task to the play after the `include` operator, we would see that the order of execution follows as if all the tasks from the included file existed at the spot at which the `include` operator was used:

```
tasks:
  - name: non-included task
    debug:
      msg: "I am not included"

  - include: more-tasks.yaml

  - name: after-included tasks
    debug:
      msg: "I run last"
```

If we run our modified playbook, we will see the task order we expect:

```
2. jkeating@serenity: ~/src/mastery (zsh)
ok: [localhost] => {
  "msg": "I am not included"
}

TASK: [included task 1] *****
ok: [localhost] => {
  "msg": "I am the first included task"
}

TASK: [included task 2] *****
ok: [localhost] => {
  "msg": "I am the second included task"
}

TASK: [after-included tasks] *****
ok: [localhost] => {
  "msg": "I run last"
}

PLAY RECAP *****
localhost                : ok=4    changed=0    unreachable=0    failed=0

~/src/mastery> []
```

By breaking these tasks into their own file, we could include them multiple times or in multiple playbooks. If we ever have to alter one of the tasks, we only have to alter a single file, no matter how many places this file gets referenced.

Passing variable values to included tasks

Sometimes we want to split out a set of tasks but have those tasks act slightly differently depending on variable data. The `include` operator allows us to define and override variable data at the time of inclusion. The scope of the definition is only within the included task file (and any other files that the file may itself include). To illustrate this capability, let's create a new scenario in which we need to touch a couple of files, each in their own directory path. Instead of writing two file tasks for each file (one to create the directory and another to touch the file), we'll create a task file with each task that will use variable names in the tasks. Then, we'll include the task file twice, each time passing different data in. First, we'll do this with the task file `files.yaml`:

```
---
- name: create leading path
  file:
    path: "{{ path }}"
    state: directory

- name: touch the file
  file:
    path: "{{ path + '/' + file }}"
    state: touch
```

Next, we'll create the play to include the task file we've just created, passing along variable data for the path and file variables:

```
---
- name: touch files
  hosts: localhost
  gather_facts: false

  tasks:
    - include: files.yaml
      path: /tmp/foo
      file: herp

    - include: files.yaml
      path: /tmp/foo
      file: derp
```



Variable definitions provided when including files can either be in the inline format of `key=value` or in the illustrated YAML format of `key: value`.

When we run this playbook, we'll see four tasks get executed, the two tasks from within `files.yaml` twice. The second set should result in only one change, as the path is the same for both sets:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [touch files] *****

TASK: [create leading path] *****
<localhost> path=/tmp/foo state=directory
changed: [localhost] => {"changed": true, "gid": 0, "group": "wheel", "mode": "0755", "owner": "jkeating", "path": "/tmp/foo", "size": 68, "state": "directory", "uid": 502}

TASK: [touch the file] *****
<localhost> path=/tmp/foo/herp state=touch
changed: [localhost] => {"changed": true, "dest": "/tmp/foo/herp", "gid": 0, "group": "wheel", "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid": 502}

TASK: [create leading path] *****
<localhost> path=/tmp/foo state=directory
ok: [localhost] => {"changed": false, "gid": 0, "group": "wheel", "mode": "0755", "owner": "jkeating", "path": "/tmp/foo", "size": 102, "state": "directory", "uid": 502}

TASK: [touch the file] *****
<localhost> path=/tmp/foo/derp state=touch
changed: [localhost] => {"changed": true, "dest": "/tmp/foo/derp", "gid": 0, "group": "wheel", "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid": 502}

PLAY RECAP *****
localhost                : ok=4    changed=3    unreachable=0    failed=0

~/src/mastery> 
```

Passing complex data to included tasks

When wanting to pass complex data to included tasks, such as a list or hash, an alternative syntax can be used when including the file. Let's repeat the last scenario, only this time, instead of including the task file twice, we'll include it once and pass a hash of the paths and files in. First, we'll work the task file:

```
---
- name: create leading path
  file:
    path: "{{ item.value.path }}"
    state: directory
  with_dict: files

- name: touch the file
  file:
    path: "{{ item.value.path + '/' + item.key }}"
    state: touch
  with_dict: files
```

Now, we'll alter our playbook to provide the files hash in a single include statement:

```
---
- name: touch files
  hosts: localhost
  gather_facts: false

  tasks:
    - include: files.yaml
      vars:
        files:
          herp:
            path: /tmp/foo
          derp:
            path: /tmp/foo
```



When supplying variable data to an include statement and using YAML syntax, the variables can be listed with or without a top-level vars key. The vars key is useful if any variable name might conflict with an existing Ansible control argument.

If we run this new playbook and task file, we should see similar but slightly different output, the end result of which is the `/tmp/foo` directory already in place and the two files `herp` and `derp` being touched within:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [touch files] *****

TASK: [create leading path] *****
<localhost> REMOTE_MODULE file path=/tmp/foo state=directory
ok: [localhost] => (item={'key': 'herp', 'value': {'path': '/tmp/foo'}}) => {"changed": false, "gid": 0, "group": "wheel", "item": {"key": "herp", "value": {"path": "/tmp/foo"}}, "mode": "0755", "owner": "jkeating", "path": "/tmp/foo", "size": 136, "state": "directory", "uid": 502}
<localhost> REMOTE_MODULE file path=/tmp/foo state=directory
ok: [localhost] => (item={'key': 'derp', 'value': {'path': '/tmp/foo'}}) => {"changed": false, "gid": 0, "group": "wheel", "item": {"key": "derp", "value": {"path": "/tmp/foo"}}, "mode": "0755", "owner": "jkeating", "path": "/tmp/foo", "size": 136, "state": "directory", "uid": 502}

TASK: [touch the file] *****
<localhost> REMOTE_MODULE file path=/tmp/foo/herp state=touch
changed: [localhost] => (item={'key': 'herp', 'value': {'path': '/tmp/foo'}}) => {"changed": true, "dest": "/tmp/foo/herp", "gid": 0, "group": "wheel", "item": {"key": "herp", "value": {"path": "/tmp/foo"}}, "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid": 502}
<localhost> REMOTE_MODULE file path=/tmp/foo/derp state=touch
changed: [localhost] => (item={'key': 'derp', 'value': {'path': '/tmp/foo'}}) => {"changed": true, "dest": "/tmp/foo/derp", "gid": 0, "group": "wheel", "item": {"key": "derp", "value": {"path": "/tmp/foo"}}, "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid": 502}


PLAY RECAP *****
localhost                : ok=2    changed=1    unreachable=0    failed=0

~/src/mastery> 
```

Using this manner of passing in a hash of data allows for the growing of the set of things created without the need to grow the number of `include` statements in the main playbook.

Conditional task includes

Similar to passing data into included files, conditionals can also be passed into included files. This is accomplished by attaching a `when` statement to the `include` operator. This conditional does not cause Ansible to evaluate the test to determine whether or not the file should be included; rather, it instructs Ansible to add the conditional to each and every task within the included file (and any other files that said file may include).

 It is not possible to conditionally include a file. Files will always be included; however, a task conditional can be applied to every task within.

Let's demonstrate this by modifying our first example that includes simple debug statements. We'll add a conditional and pass along some data for the conditional to use. First, let's modify the playbook:

```
---
- name: task inclusion
  hosts: localhost
  gather_facts: false

  tasks:
    - include: more-tasks.yaml
      when: item | bool
      a_list:
        - true
        - false
```

Next, let's modify `more-tasks.yaml` to loop over the `a_list` variable in each task:

```
---
- name: included task 1
  debug:
    msg: "I am the first included task"
  with_items: a_list

- name: include task 2
  debug:
    msg: "I am the second included task"
  with_items: a_list
```


Now, let's run the playbook and see our new output:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [touch files] *****

TASK: [included task 1] *****
ok: [localhost] => (item=True) => {
  "item": true,
  "msg": "I am the first included task"
}
skipping: [localhost]

TASK: [included task 2] *****
ok: [localhost] => (item=True) => {
  "item": true,
  "msg": "I am the second included task"
}
skipping: [localhost]

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

We can see a skipped iteration per task, the iteration where the item evaluated to a Boolean false. It's important to remember that all hosts will evaluate all included tasks. There is no way to influence Ansible to not include a file for a subset of hosts. At most, a conditional can be applied to every task within an include hierarchy so that included tasks may be skipped. One method to include tasks based on host facts is to utilize the `group_by` action plugin to create dynamic groups based on host facts. Then, you can give the groups their own plays to include specific tasks. This is an exercise left up to the reader.

Tagging included tasks

When including task files, it is possible to tag all the tasks within the file. The `tags` key is used to define one or more tags to apply to all the tasks within the include hierarchy. The ability to tag at include time can keep the task file itself unopinionated about how the tasks should be tagged, and can allow for a set of tasks to be included multiple times but with different data and tags passed along.



Tags can be defined at the `include` statement or at the play itself to cover all includes (and other tasks) in a given play.

Let's create a simple demonstration to illustrate how tags can be used. We'll start with a playbook that includes a task file twice, each with a different tag name and different variable data:

```
---
- name: task inclusion
  hosts: localhost
  gather_facts: false

  tasks:
    - include: more-tasks.yaml
      data: first
      tags: first

    - include: more-tasks.yaml
      data: second
      tags: second
```

Now, we'll update `more-tasks.yaml` to do something with the data being provided:

```
---
- name: included task
  debug:
    msg: "My data is {{ data }}"
```

If we run this playbook without selecting tags, we'll see this task run twice:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [task inclusion] *****

TASK: [included task] *****
ok: [localhost] => {
  "msg": "My data is first"
}

TASK: [included task] *****
ok: [localhost] => {
  "msg": "My data is second"
}

PLAY RECAP *****
localhost           : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> █
```

Now, if we select which tag to run, say the second tag, by altering our ansible-playbook arguments, we should see only that occurrence of the included task being run:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv --tags second

PLAY [task inclusion] *****

TASK: [included task] *****
ok: [localhost] => {
  "msg": "My data is second"
}

PLAY RECAP *****
localhost           : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> █
```

Our example used the `--tags` command line argument to indicate which tagged tasks to run. A different argument, `--skip-tags`, allows the expression of the opposite: which tagged tasks to not run.

Including handlers

Handlers are essentially tasks. They're a set of potential tasks to trigger by way of notifications from other tasks. As such, handler tasks can be included just like regular tasks can. The `include` operator is legal within the `handlers` block.

Unlike with task includes, variable data cannot be passed along when including handler tasks. However, it is possible to attach a conditional to a handler inclusion to apply the conditional to every handler within the file.

Let's create an example to demonstrate. First, we'll create a playbook that has a task that will always change and that includes a handler task file and attaches a conditional to that inclusion:

```
---
- name: touch files
  hosts: localhost
  gather_facts: false

  tasks:
    - name: a task
      debug:
        msg: "I am a changing task"
      changed_when: true
      notify: a handler

  handlers:
    - include: handlers.yaml
      when: foo | default('true') | bool
```

Next, we'll create `handlers.yaml` to define our handler task:

```
---
- name: a handler
  debug:
    msg: "handling a thing"
```

If we execute this playbook without providing any further data, we should see our handler trigger:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [touch files] *****

TASK: [a task] *****
changed: [localhost] => {
  "changed": true,
  "msg": "I am a changing task"
}

NOTIFIED: [a handler] *****
ok: [localhost] => {
  "msg": "handling a thing"
}

PLAY RECAP *****
localhost                : ok=2    changed=1    unreachable=0    failed=0

~/src/mastery> 
```

Now, let's run the playbook again. This time we'll define `foo` as `false` and as an extra-var in our ansible-playbook execution arguments:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv -e foo=false

PLAY [touch files] *****

TASK: [a task] *****
changed: [localhost] => {
  "changed": true,
  "msg": "I am a changing task"
}

NOTIFIED: [a handler] *****
skipping: [localhost]

PLAY RECAP *****
localhost                : ok=1    changed=1    unreachable=0    failed=0

~/src/mastery> 
```

This time, since `foo` evaluates to `false`, our included handler gets skipped.

Including variables

Variable data can also be separated into loadable files. This allows for sharing variables across multiple plays or playbooks or including variable data that lives outside the project directory (such as secret data). Variable files are simple YAML formatted files providing keys and values. Unlike task include files, variable include files cannot further include more files.

Variables can be included in three different ways: via `vars_files`, via `include_vars`, or via `--extra-vars (-e)`.

`vars_files`

The `vars_files` key is a play directive. It defines a list of files to read from to load variable data. These files are read and parsed at the time the playbook itself is parsed. Just as with including tasks and handlers, the path is relative to the file referencing the file.

Here is an example play that loads variables from a file:

```
---
- name: vars
  hosts: localhost
  gather_facts: false

  vars_files:
    - variables.yaml

  tasks:
    - name: a task
      debug:
        msg: "I am a {{ name }}"
```

Now, we need to create `variables.yaml` in the same directory as our playbook:

```
name: derp
```

Running the playbook will show that the name variable value is properly sourced from the `variables.yaml` file:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [vars] *****

TASK: [a task] *****
ok: [localhost] => {
  "msg": "I am a derp"
}

PLAY RECAP *****
localhost          : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Dynamic vars_files inclusion

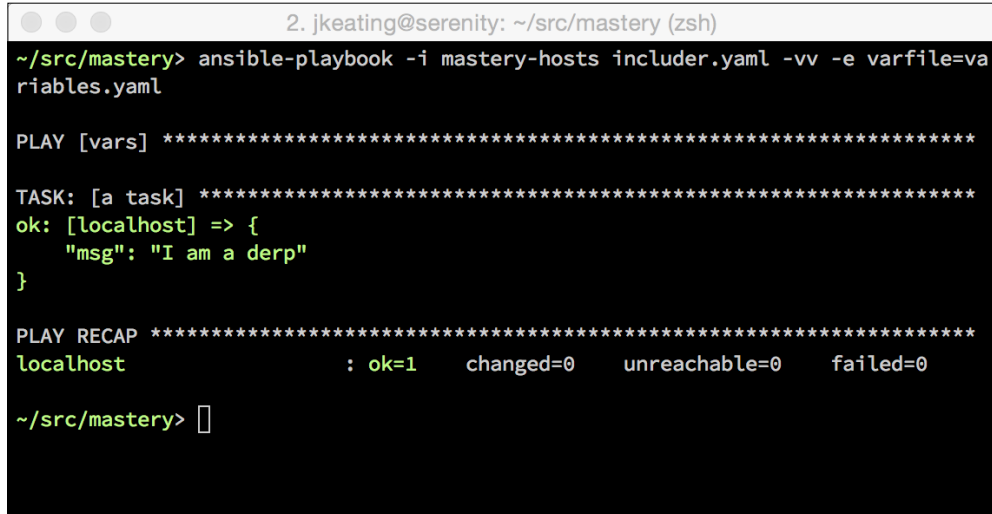
In certain scenarios, it may be desirable to parameterize the variable files to be loaded. It is possible to do this by using a variable as part of the filename; however, the variable must have a value defined at the time the playbook is parsed, just like when using variables in task names. Let's update our example play to load a variable file based on the data provided at execution time:

```
---
- name: vars
  hosts: localhost
  gather_facts: false

  vars_files:
    - "{{ varfile }}"

  tasks:
    - name: a task
      debug:
        msg: "I am a {{ name }}"
```

Now, when we execute the playbook, we'll provide the value for `varfile` with the `-e` argument:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv -e varfile=variables.yaml

PLAY [vars] *****

TASK: [a task] *****
ok: [localhost] => {
  "msg": "I am a derp"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery>

```

In addition to the variable value needing to be defined at execution time, the file to be loaded must also exist at execution time. Even if a reference to a file is four plays down in a playbook and the file itself is generated by the first play, unless the file exists at execution time, `ansible-playbook` will report an error.

include_vars

The second method to include variable data from files is the `include_vars` module. This module will load variables as a task action and will be done for each host. Unlike most modules, this module is executed locally on the Ansible host; therefore, all paths are still relative to the play file itself. Because the variable loading is done as a task, evaluation of variables in the filename happens when the task is executed. Variable data in the `file` name can be host-specific and defined in a preceding task. Additionally, the file itself does not have to exist at execution time, it can be generated by a preceding task as well. This is a very powerful and flexible concept that can lead to very dynamic playbooks if used properly.

Before getting ahead of ourselves, let's demonstrate a simple usage of `include_vars` by modifying our existing play to load the variable file as a task:

```

---
- name: vars
  hosts: localhost

```



```
gather_facts: false

tasks:
  - name: load variables
    include_vars: "{{ varfile }}"

  - name: a task
    debug:
      msg: "I am a {{ name }}"
```

Execution of the playbook remains the same, and our output differs only slightly from previous iterations:

A terminal window titled '2. jkeating@serenity: ~/src/mastery (zsh)' shows the execution of an Ansible playbook. The command is 'ansible-playbook -i mastery-hosts includer.yaml -vv -e varfile=variables.yaml'. The output shows the 'vars' section, followed by two tasks: 'load variables' and 'a task'. Both tasks are successful on localhost. The 'load variables' task outputs 'ansible_facts' with 'name: derp'. The 'a task' task outputs a debug message 'I am a derp'. The 'PLAY RECAP' section shows 'localhost' with 'ok=2', 'changed=0', 'unreachable=0', and 'failed=0'.

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv -e varfile=variables.yaml

PLAY [vars] *****

TASK: [load variables] *****
ok: [localhost] => {"ansible_facts": {"name": "derp"}}

TASK: [a task] *****
ok: [localhost] => {
  "msg": "I am a derp"
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Just like with other tasks, looping can be done to load more than one file in a single task. This is particularly effective when using the special `with_first_found` loop to iterate through a list of increasingly more generic file names until a file is found to be loaded. Let's demonstrate this by changing our play to use gathered host facts to try to load a variable file specific to the distribution, specific to the distribution family, or finally, a default file:

```
---
- name: vars
  hosts: localhost
  gather_facts: true

  tasks:
    - name: load variables
      include_vars: "{{ item }}"
```

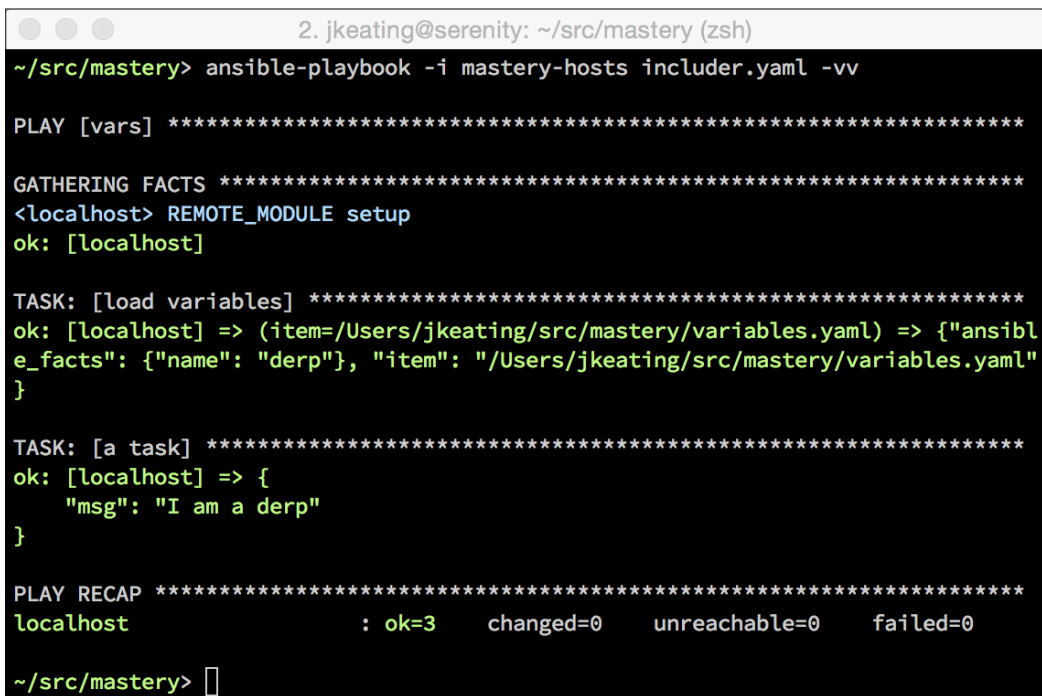
```

with_first_found:
  - "{{ ansible_distribution }}.yaml"
  - "{{ ansible_os_family }}.yaml"
  - variables.yaml

- name: a task
  debug:
    msg: "I am a {{ name }}"

```

Execution should look very similar to previous runs, only this time we'll see a fact-gathering task, and we will not pass along extra variable data in the execution:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv

PLAY [vars] *****

GATHERING FACTS *****
<localhost> REMOTE_MODULE setup
ok: [localhost]

TASK: [load variables] *****
ok: [localhost] => (item=/Users/jkeating/src/mastery/variables.yaml) => {"ansible_facts": {"name": "derp"}, "item": "/Users/jkeating/src/mastery/variables.yaml"}

TASK: [a task] *****
ok: [localhost] => {
  "msg": "I am a derp"
}

PLAY RECAP *****
localhost                : ok=3    changed=0    unreachable=0    failed=0

~/src/mastery>

```

We can also see from the output which file was found to load. In this case, `variables.yaml` was loaded, as the other two files did not exist. This practice is commonly used to load variables that are operating system specific to the host in question. Variables for a variety of operating systems can be written out to appropriately named files. By utilizing the variable `ansible_distribution`, which is populated by fact gathering, variable files that use `ansible_distribution` values as part of their name can be loaded by way of a `with_first_found` argument. A default set of variables can be provided in a file that does not use any variable data as a failsafe.

extra-vars

The final method of loading variable data from a file is to reference a file path with the `--extra-vars` (or `-e`) argument to `ansible-playbook`. Normally, this argument expects a set of `key=value` data; however, if a file path is provided and prefixed with the `@` symbol, Ansible will read the entire file to load variable data. Let's alter one of our earlier examples in which we used `-e`, and instead of defining a variable directly on the command line, we'll include the variable file we've already written out:

```
---
- name: vars
  hosts: localhost
  gather_facts: false

  tasks:
    - name: a task
      debug:
        msg: "I am a {{ name }}"
```

When we provide a path after the `@` symbol, the path is relative to the current working directory, regardless of where the playbook itself lives. Let's execute our playbook and provide a path to `variables.yaml`:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts includer.yaml -vv -e @variables.yaml

PLAY [vars] *****

TASK: [a task] *****
ok: [localhost] => {
  "msg": "I am a derp"
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```



When including a variable file with the `--extra-vars` argument, the file must exist at `ansible-playbook` execution time.

Including playbooks

Playbook files can include other whole playbook files. This construct can be useful to tie together a few independent playbooks into a larger, more comprehensive playbook. Playbook inclusion is a bit more primitive than task inclusion. You cannot perform variable substitution when including a playbook, you cannot apply conditionals, and you cannot apply tags either. The playbook files to be included must exist at the time of execution as well.

Roles

With a functional understanding of the inclusion of variables, tasks, handlers, and playbooks, we can move on to the more advanced topic of **Roles**. Roles move beyond the basic structure of a few playbooks and a few broken-out files to reference. Roles provide a framework for fully independent, or interdependent, collections of variables, tasks, files, templates, and modules. Each role is typically limited to a particular theme or desired end result, with all the necessary steps to reach that result either within the role itself or in other roles listed as dependencies. Roles themselves are not playbooks. There is no way to directly execute a role. Roles have no setting for which host the role will apply to. Top-level playbooks are the glue that binds the hosts from your inventory to roles that should be applied to those hosts.

Role structure

Roles have a structured layout on the file system. This structure exists to provide automation around, including tasks, handlers, variables, modules, and role dependencies. The structure also allows for easy reference of files and templates from anywhere within the role.

Roles all live in a subdirectory of a playbook archive, in the `roles/` directory. This is, of course, configurable by way of the `roles_path` general configuration key, but let's stick to the defaults. Each role is itself a directory tree. The role name is the directory name within `roles/`. Each role can have a number of subdirectories with special meaning that are processed when a role is applied to a set of hosts.

A role may contain all these elements, or as few as just one of them. Missing elements are simply ignored. Some roles exist just to provide common handlers across a project. Other roles exist as a single dependency point that, in turn just depends on numerous other roles.

Tasks

The task file is the main meat of a role. If `roles/<role_name>/tasks/main.yaml` exists, all the tasks therein and any other files it includes will be embedded in the play and executed.

Handlers

Similar to tasks, handlers are automatically loaded from `roles/<role_name>/handlers/main.yaml`, if the file exists. These handlers can be referenced by any task within the role, or by any tasks within any other role that lists this role as a dependency.

Variables

There are two types of variables that can be defined in a role. There are role variables, loaded from `roles/<role_name>/vars/main.yaml`, and there are role defaults, which are loaded from `roles/<role_name>/defaults/main.yaml`. The difference between `vars` and `defaults` has to do with precedence order. Refer to *Chapter 1, System Architecture and Design of Ansible*, for a detailed description of the order. Role defaults are the lowest order variables. Literally, any other definition of a variable will take precedence over a role default. Role defaults can be thought of as place holders for actual data, a reference of what variables a developer may be interested in defining with site-specific values. Role variables, on the other hand, have a higher order of precedence. Role variables can be overridden, but generally they are used when the same data set is referenced more than once within a role. If the data set is to be redefined with site-local values, then the variable should be listed in the role defaults rather than the role variables.

Modules

A role can include custom modules. While the Ansible project is quite good at reviewing and accepting submitted modules, there are certain cases where it may not be advisable, or even legal, to submit a custom module upstream. In those cases, delivering the module with the role may be a better option. Modules can be loaded from `roles/<role_name>/library/` and can be used by any task in the role, or any later role. Modules provided in this path will override any other copies of the same module name anywhere else on the file system, which can be a way of distributing added functionality to a core module before the functionality has been accepted upstream and released with a new version of Ansible.

Dependencies

Roles can express a dependency upon another role. It is common practice for sets of roles to all depend on a common role so that any tasks, handlers, modules, and so on. Those roles may depend upon need only having to be defined once in the common role. When Ansible processes a role for a set of hosts, it will first look for any dependencies listed in `roles/<role_name>/meta/main.yaml`. If any are defined, those roles will be processed and the tasks within will be executed (after also checking for any dependencies listed within) until all dependencies have been completed before starting on the initial role tasks. We will describe role dependencies more in depth later in this chapter.

Files and templates

Task and handler modules can reference files relatively within `roles/<role_name>/files/`. The filename can be provided without any prefix and will be sourced from `roles/<role_name>/files/<file_name>`. Relative prefixes are allowed as well, in order to access files within subdirectories of `roles/<role_name>/files/`. Modules such as `template`, `copy`, and `script` may take advantage of this.

Similarly, templates used by the `template` module can be referenced relatively within `roles/<role_name>/templates/`. This sample code uses a relative path to load the template `derp.j2` from the full `roles/<role_name>/templates/herp/derp.j2` path:

```
- name: configure herp
  template:
    src: herp/derp.j2
    dest: /etc/herp/derp.j2
```

Putting it all together

To illustrate what a full role structure might look like, here is an example role by the name of `demo`:

```
roles/demo
├── defaults
│   └── main.yaml
├── files
│   └── foo
├── handlers
│   └── main.yaml
├── library
│   └── samplemod.py
├── meta
│   └── main.yaml
```

```
├─ tasks
│   └─ main.yaml
├─ templates
│   └─ bar.j2
└─ vars
    └─ main.yaml
```

When creating a role, not every directory or file is required. Only the files that exist will be processed.

Role dependencies

As stated before, roles can depend on other roles. These relationships are called *dependencies* and they are described in a role's `meta/main.yaml` file. This file expects a top-level data hash with a key of `dependencies`; the data within is a list of roles:

```
---
dependencies:
  - role: common
  - role: apache
```

In this example, Ansible will fully process the `common` role first (and any dependencies it may express) before continuing with the `apache` role, and then finally starting on the role's own tasks.

Dependencies can be referenced by name without any prefix if they exist within the same directory structure or live within the configured `roles_path`. Otherwise, full paths can be used to locate roles:

```
role: /opt/ansible/site-roles/apache
```

When expressing a dependency, it is possible to pass along data to the dependency. The data can be variables, tags, or even conditionals.

Role dependency variables

Variables that are passed along when listing a dependency will override values for matching variables defined in `defaults/main.yaml` or `vars/main.yaml`. This can be useful for using a common role like an `apache` role as a dependency while providing application-specific data such as what ports to open in the firewall, or what `apache` modules to enable. Variables are expressed as additional keys to the role listing. Let's update our example to add simple and complex variables to our two dependencies:

```
---
dependencies:
```

```
- role: common
  simple_var_a: True
  simple_var_b: False
- role: apache
  complex_var:
    key1: value1
    key2: value2
  short_list:
    - 8080
    - 8081
```

When providing dependency variable data, two names are reserved and should not be used as role variables: `tags` and `when`. The former is used to pass tag data into a role, and the latter is used to pass a conditional into the role.

Tags

Tags can be applied to all the tasks found within a dependency role. This functions much in the same way as tags being applied to included task files, as described earlier in this chapter. The syntax is simple: the `tags` key can be a single item or a list. To demonstrate, let's add some tags to our example dependency list:

```
---
dependencies:
- role: common
  simple_var_a: True
  simple_var_b: False
  tags: common_demo
- role: apache
  complex_var:
    key1: value1
    key2: value2
  short_list:
    - 8080
    - 8081
  tags:
    - apache_demo
    - 8080
    - 8181
```

As with adding tags to included task files, all the tasks found within a dependency (and any dependency within that hierarchy) will gain the provided tags.

Role dependency conditionals

While it is not possible to prevent the processing of a dependency role with a conditional, it is possible to skip all the tasks within a dependency role hierarchy by applying a conditional to a dependency. This mirrors the functionality of task inclusion with conditionals as well. The `when` key is used to express the conditional. Once again, we'll grow our example by adding a dependency to demonstrate the syntax:

```
---
dependencies:
  - role: common
    simple_var_a: True
    simple_var_b: False
    tags: common_demo
  - role: apache
    complex_var:
      key1: value1
      key2: value2
    short_list:
      - 8080
      - 8081
    tags:
      - apache_demo
      - 8080
      - 8181
    when: backend_server == 'apache'
```

Role application

Roles are not plays. They do not possess any opinions about which hosts the role tasks should run on, what connection methods to use, whether or not to operate serially, or any other play behaviors described in *Chapter 1, System Architecture and Design of Ansible*. Roles must be applied inside of a play within a playbook, where all these opinions can be expressed.

To apply a role within a play, the `roles` operator is used. This operator expects a list of roles to apply to the hosts in the play. Much like describing role dependencies, when describing roles to apply, data can be passed along such as variables, tags, and conditionals. The syntax is exactly the same.

To demonstrate applying roles within a play, let's create a simple role and apply it in a simple playbook. Let's build the role named `simple`, which will have a single debug task in `roles/simple/tasks/main.yaml` that prints the value of a role default variable defined in `roles/simple/defaults/main.yaml`. First, let's create the task file:

```
---
- name: print a variable
  debug:
    var: derp
```

Next, we'll write our default file with a single variable, `derp`:

```
---
derp: herp
```

To execute this role, we'll write a playbook with a single play to apply the role. We'll call our playbook `roleplay.yaml`, and it'll live at the same directory level as the `roles/` directory:

```
---
- hosts: localhost
  gather_facts: false

  roles:
    - role: simple
```

[



If no data is provided with the role, an alternative syntax that just lists the roles to apply can be used, instead of the shown hash. However, for consistency, I feel it's best to always use the same syntax within a project.

]

We'll re-use our `mastery-hosts` inventory from earlier chapters and execute the playbook:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts roleplay.yaml -vv

PLAY [localhost] *****

TASK: [simple | print a variable] *****
ok: [localhost] => {
  "var": {
    "derp": "herp"
  }
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Thanks to the magic of roles, the `derp` variable value was automatically loaded from the role defaults. Of course, we can override the default value when applying the role. Let's modify our playbook and supply a new value for `derp`:

```
---
- hosts: localhost
  gather_facts: false

  roles:
    - role: simple
      derp: newval
```

This time when we execute, we'll see newval as the value for derp:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts roleplay.yaml -vv

PLAY [localhost] *****

TASK: [simple | print a variable] *****
ok: [localhost] => {
  "var": {
    "derp": "newval"
  }
}

PLAY RECAP *****
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Multiple roles can be applied within a single play. The `roles:` key expects a list value. Just add more roles to apply more roles:

```
---
- hosts: localhost
  gather_facts: false

  roles:
    - role: simple
      derp: newval
    - role: second_role
      othervar: value
    - role: third_role
    - role: another_role
```

Mixing roles and tasks

Plays that use roles are not limited to just roles. These plays can have `tasks` of their own, as well as two other blocks of tasks: `pre_tasks` and `post_tasks`. The order in which these are executed is not dependent upon which order these sections are listed in the play itself; rather, there is a strict order to block execution within a play. See *Chapter 1, System Architecture and Design of Ansible*, for details on the playbook order of operations.

Handlers for a play are flushed at multiple points. If there is a `pre_tasks` block, handlers are flushed after all `pre_tasks` are executed. Then, the roles and tasks blocks are executed (roles first, then tasks, regardless of the order they are written in the playbook), after which, handlers will be flushed again. Finally, if a `post_tasks` block exists, handlers will be flushed once again after all `post_tasks` have executed. Of course, handlers can be flushed at any time with the `meta: flush_handlers` call. Let's expand on our `roleplay.yaml` to demonstrate all the different times handlers can be triggered:

```
---
- hosts: localhost
  gather_facts: false

  pre_tasks:
    - name: pretask
      debug: msg="a pre task"
      changed_when: true
      notify: say hi

  roles:
    - role: simple
      derp: newval

  tasks:
    - name: task
      debug: msg="a task"
      changed_when: true
      notify: say hi

  post_tasks:
    - name: posttask
      debug: msg="a post task"
      changed_when: true
      notify: say hi

  handlers:
    - name: say hi
      debug: msg="hi"
```

We'll also modify our simple role's tasks to notify the `say hi` handler as well:

```
---
- name: print a variable
  debug: var: derp
  changed_when: true
  notify: say hi
```



Note that this only works because the `say hi` handler has been defined in the play that is calling the `simple` role. If the handler is not defined, an error will occur. It's best practice to only notify handlers that exist within the same role or any role marked as a dependency.

Running our playbook should result in the `say hi` handler being called a total of three times: once for `pre_tasks`, once for `roles` and `tasks`, and once for `post_tasks`:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts roleplay.yaml -vv

PLAY [localhost] *****

TASK: [pretask] *****
changed: [localhost] => {
  "changed": true,
  "msg": "a pre task"
}

NOTIFIED: [say hi] *****
ok: [localhost] => {
  "msg": "hi"
}

TASK: [simple | print a variable] *****
changed: [localhost] => {
  "changed": true,
  "var": {
    "derp": "newval"
  }
}

TASK: [task] *****
changed: [localhost] => {
  "changed": true,
  "msg": "a task"
}

NOTIFIED: [say hi] *****
ok: [localhost] => {
  "msg": "hi"
}

TASK: [posttask] *****
changed: [localhost] => {
  "changed": true,
  "msg": "a post task"
}

NOTIFIED: [say hi] *****
ok: [localhost] => {
  "msg": "hi"
}

PLAY RECAP *****
localhost                : ok=7    changed=4    unreachable=0    failed=0

~/src/mastery> 
```

While the order in which `pre_tasks`, `roles`, `tasks`, and `post_tasks` are written into a play does not impact the order in which those sections are executed, it's best practice to write them in the order that they will be executed. This is a visual cue to help remember the order and to avoid confusion when reading the playbook later.

Role sharing

One of the advantages of using roles is the ability to share the role across plays, playbooks, entire project spaces, and even across organizations. Roles are designed to be self-contained (or to clearly reference dependent roles) so that they can exist outside of a project space in which the playbook that applies the role lives. Roles can be installed in shared paths on an Ansible host, or they can be distributed via source control.

Ansible Galaxy

Ansible Galaxy (<https://galaxy.ansible.com/>) is a community hub for finding and sharing Ansible roles. Anybody can visit the website to browse the roles and reviews. Plus, users who create a login can provide reviews of the roles they've tested. Roles from Galaxy can be downloaded using the `ansible-galaxy` utility provided with Ansible.

The `ansible-galaxy` utility can connect to and install roles from the Ansible Galaxy website. This utility will default to installing roles into `/etc/ansible/roles`. If `roles_path` is configured, or if a run-time path is provided with the `--roles-path` (or `-p`) option, the roles will be installed there instead. If any roles have been installed to the `roles_path` or the provided path, `ansible-galaxy` can list those and show information about those as well. To demonstrate the usage of `ansible-galaxy`, let's use it to install a role for managing `known_hosts` for `ssh` from Ansible Galaxy into the roles directory we've been working with. Installing roles from Ansible Galaxy requires a `username.rolename`, as multiple users may have uploaded roles with the same name. In this case, we want the `ssh_known_hosts` role from the user `bfmartin`:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy install -p roles/ bfmartin.ssh_known_hosts
- downloading role 'ssh_known_hosts', owned by bfmartin
- downloading role from https://github.com/bfmartin/ansible-sshknownhosts-role/archive/master.tar.gz
- extracting bfmartin.ssh_known_hosts to roles/bfmartin.ssh_known_hosts
- bfmartin.ssh_known_hosts was installed successfully
~/src/mastery> █
```

Now we can make use of this role by referencing `bfmartin.ssh_known_hosts` in a play or another role's dependencies block. We can also list it and gain information about it using the `ansible-galaxy` utility:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy list -p roles/
- bfmartin.ssh_known_hosts, master
~/src/mastery> ansible-galaxy info -p roles/ bfmartin.ssh_known_hosts
- bfmartin.ssh_known_hosts:
  average_composite:
    avg_code_quality: 4.0
    avg_documentation: 4.0
    avg_reliability: 4.0
    avg_wow_factor: 4.0
  average_score: 4.0
  bayesian_score: 0.0
  company:
  created: 2014-08-22T23:40:38.599Z
  dependencies: []
  description: This is an ansible role that manages the SSH known hosts fi
le usually located at /etc/ssh/ssh_known_hosts or ~user/.ssh/known_hosts.
  galaxy_info:
    author: Byron F. Martin
    categories: ['networking', 'system']
    description: This is an ansible role that manages the SSH known
hosts file usually located at /etc/ssh/ssh_known_hosts or ~user/.ssh/known_hosts
.
    license: BSD
    min_ansible_version: 1.1
    github_repo: ansible-sshknownhosts-role
    github_user: bfmartin
    id: 1456
    install_date: Fri Apr 24 04:39:29 2015
    installed_version: master
    issue_tracker_url: https://github.com/bfmartin/ansible-sshknownhosts-rol
e/issues
  license: BSD
  min_ansible_version: 1.1
  modified: 2014-08-22T23:40:39.394Z
  name: bfmartin.ssh_known_hosts
  num_aw_ratings: 0
  num_ratings: 1
  scm: None
  src: bfmartin.ssh_known_hosts
  version:
~/src/mastery> 
```


Some of the data being displayed by the `info` command lives within the role itself, in the `meta/main.yml` file. Previously, we've only seen dependency information in this file and it may not have made much sense to name the directory `meta`, but now we see that other metadata lives in this file as well:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> cat roles/bfmartin.ssh_known_hosts/meta/main.yml
---
galaxy_info:
  author: Byron F. Martin
  description: This is an ansible role that manages the SSH known hosts file usu
ally located at /etc/ssh/ssh_known_hosts or ~user/.ssh/known_hosts.
  license: BSD
  min_ansible_version: 1.1
  platforms:
    - name: GenericBSD
      versions:
        - all
    - name: GenericLinux
      versions:
        - all
  categories:
    - networking
    - system
  dependencies: []
~/src/mastery>
```

The `ansible-galaxy` utility can also help in the creation of new roles. The `init` method will create a skeleton directory tree for the role, as well as populate the `meta/main.yml` file with placeholders for Galaxy-related data. The `init` method takes a variety of options, as shown in the help output:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy init --help
Usage: ansible-galaxy init [options] role_name

Options:
  -h, --help                show this help message and exit
  -p INIT_PATH, --init-path=INIT_PATH
                           The path in which the skeleton role will be created.
                           The default is the current working directory.
  --offline                 Don't query the galaxy API when creating roles
  -s API_SERVER, --server=API_SERVER
                           The API server destination
  -f, --force               Force overwriting an existing role

See 'ansible-galaxy <command> --help' for more information on a specific command.
~/src/mastery>
```

Let's demonstrate this capability by creating a new role in our working directory named `autogen`:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy init -p roles/ autogen
- autogen was created successfully
~/src/mastery> tree roles/autogen
roles/autogen
├── README.md
├── defaults
│   └── main.yml
├── files
├── handlers
│   └── main.yml
├── meta
│   └── main.yml
├── tasks
│   └── main.yml
├── templates
└── vars
    └── main.yml

7 directories, 6 files
~/src/mastery> 
```

For roles that are not suitable for Ansible Galaxy, such as roles dealing with in-house systems, `ansible-galaxy` can install directly from a git URL. Instead of just providing a role name to the install method, a full git URL with an optional version can be provided instead. For example, if we wanted to install the `foowhiz` role from our internal git server, we could simply do the following:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy install -p /opt/ansible/roles git@git.internal.site:ansible-roles/foowhiz
```

Without version info, the `master` branch will be used. Without name data, the name will be determined from the URL itself. To provide a version, append a comma and the version string that git can understand, such as a tag or branch name, like `v1`:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy install -p /opt/ansible/roles git@git.internal.site:ansible-roles/foowhiz,v1
```

A name for the role can be added with another comma followed by the name string. If you need to supply a name but do not wish to supply a version, an empty slot is still required for the version. For example:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy install -p /opt/ansible/roles git@git.internal.site:ansible-roles/foowhiz,,foo-whiz-common
```

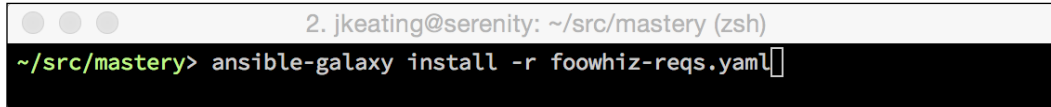
Roles can also be installed directly from tarballs as well, by providing a URL to the tarball in lieu of a full git URL, or a role name to fetch from Ansible Galaxy.

When you need to install many roles for a project, it's possible to define multiple roles to download and install using a YAML formatted file that ends with `.yaml` (or `.yml`). The format of this file allows you to specify multiple roles from multiple sources and retain the ability to specify versions and role names. In addition, the install path can be defined per-role, and finally, the source control method can be listed (currently only `git` and `hg` are supported):

```
---
- src: <name or url>
  path: <optional install path>
  version: <optional version>
  name: <optional name override>
  scm: <optional defined source control mechanism>

- src: <name or url>
```

To install all the roles within a file, use the `--roles-file (-r)` option with the `install` method:

A terminal window with a light gray title bar showing three window control buttons and the text "2. jkeating@serenity: ~/src/mastery (zsh)". The terminal has a black background with green text. The prompt is "~/src/mastery>" and the command entered is "ansible-galaxy install -r foowhiz-reqs.yaml".

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-galaxy install -r foowhiz-reqs.yaml
```

Summary

Ansible provides the capability to divide content logically into separate files. This capability helps project developers to not repeat the same code over and over again. Roles within Ansible take this capability a step further and wrap some magic around the paths to the content. Roles are tunable, reusable, portable, and shareable blocks of functionality. Ansible Galaxy exists as a community hub for developers to find, rate, and share roles. The `ansible-galaxy` command-line tool provides a method of interacting with the Ansible Galaxy site or other role-sharing mechanisms. These capabilities and tools help with the organization and utilization of common code.

In the next chapter, we'll cover different deployment and upgrade strategies and the Ansible features useful for each strategy.

6

Minimizing Downtime with Rolling Deployments

Application deployments and upgrades can be approached in a variety of different strategies. The best approach depends on the application itself, the capabilities of the infrastructure the application runs on, and any promised service-level agreements with the users of the application. Whatever strategy you use, Ansible is well suited to facilitate the deployment. In this chapter, we'll walk through a couple of common deployment strategies and showcase the Ansible features that will be useful within those strategies. We'll also discuss a couple of other deployment considerations that are common across both deployment strategies, which are:

- In-place upgrades
- Expanding and contracting
- Failing fast
- Minimizing disruptive actions

In-place upgrades

The first type of deployment we'll cover is in-place upgrades. This style of deployment operates on infrastructure that already exists in order to upgrade the existing application. This model can be seen as a traditional model that existed when the creation of new infrastructure was a costly endeavor in terms of both time and money.

To minimize the downtime during this type of an upgrade, a general design pattern is to deploy the application across multiple hosts behind a load balancer. The load balancer will act as a gateway between users of the application and the servers that run the application. Requests for the application will come to the load balancer, and depending on configuration, the load balancer will decide which backend server to direct the request to.

To perform a rolling in-place upgrade of an application deployed with this pattern, each server (or a small subset of the servers) will be disabled at the load balancer, upgraded, and then re-enabled to take on new requests. This process will be repeated for the remaining servers in the pool until all servers have been upgraded. As only a portion of the available application servers is taken offline to be upgraded, the application as a whole remains available for requests. Of course, this assumes that an application can perform well with mixed versions running at the same time.

Let's build a playbook to upgrade a fictional application. Our fictional application will run on servers `foo-app01` through `foo-app08`, which exist in the group `foo-app`. These servers will have a simple website being served via the `nginx` webserver, with the content coming from a `foo-app` git repository, defined by the variable `foo-app.repo`. A load balancer server, `foo-lb`, running the `haproxy` software, will front these app servers.

In order to operate on a subset of our `foo-app` servers, we need to employ the serial mode. This mode changes how Ansible will execute a play. By default, Ansible will execute tasks of a play across each host in the order that the tasks are listed. Each task of the play is executed across every host before moving on to the next task. If we were to use the default method, our first task would remove every server from the load balancer, which would result in a complete outage of our application. The serial mode, instead, lets us operate on a subset so that the application as a whole stays available, even if some of the members are offline. In our example, we'll use a serial amount of two in order to keep the majority of the application members online:

```
---
- name: Upgrade foo-app in place
  hosts: foo-app
  serial: 2
```

Now, we can start creating our tasks. The first task will be to disable the host from the load balancer. The load balancer runs on the `foo-lb` host; however, we're operating on the `foo-app` hosts. Therefore, we need to delegate the task using the `delegate_to` task operator. This operator redirects where Ansible will connect in order to execute the task, but keeps all the variable context of the original host. We'll use the `haproxy` module to disable the current host from the `foo-app` backend pool:

```
tasks:
  - name: disable member in balancer
    haproxy:
      backend: foo-app
      host: "{{ inventory_hostname }}"
      state: disabled
    delegate_to: foo-lb
```

With the host disabled, we can now update the `foo-app` content. We'll use the `git` module to update the content path with the desired version defined as `foo-version`. We'll add a `notify` handler to this task to reload the `nginx` server if the content update results in a change. This can be done every time, but we're using this as an example of `notify`:

```
- name: pull stable foo-app
  git:
    repo: "{{ foo-app.repo }}"
    dest: /srv/foo-app/
    version: "{{ foo-version }}"
  notify:
    - reload nginx
```

Our next step would be to re-enable the host in the load balancer; however, if we did that task next, we'd put the old version back in place, as our notified handler hasn't run yet. So, we need to trigger our handlers early by way of the `meta: flush_handlers` call, which we learned about in the previous chapter:

```
- meta: flush_handlers
```


Now, we can re-enable the host in the load balancer. We can just enable it straight away and rely on the load balancer to wait until the host is healthy before sending requests to it. However, because we are running with a reduced number of available hosts, we need to ensure that all the remaining hosts are healthy. We can make use of a `wait_for` task to wait until the `nginx` service is once again serving connections. The `wait_for` module will wait for a condition on either a port or a file path. In our example, we will wait for port 80 and the condition that port should be in. If it is started (the default), this means it is accepting connections:

```
- name: ensure healthy service
  wait_for:
    port: 80
```

Finally, we can re-enable the member within `haproxy`. Once again, we'll delegate the task to `foo-lb`:

```
- name: enable member in balancer
  haproxy:
    backend: foo-app
    host: "{{ inventory_hostname }}"
    state: enabled
  delegate_to: foo-lb
```

Of course, we still need to define our `reload nginx` handler:

```
handlers:
- name: reload nginx
  service:
    name: nginx
    state: restarted
```

This playbook, when run, will now perform a rolling in-place upgrade of our application.

Expanding and contracting

An alternative to the in-place upgrade strategy is the expand and contract strategy. This strategy has become popular of late thanks to the self-service nature of on-demand infrastructure, such as cloud computing or virtualization pools. The ability to create new servers on demand from a large pool of available resources means that every deployment of an application can happen on brand new systems. This strategy avoids a host of issues. These include a build up of cruft on long running systems, such as:

- The configuration files no longer managed by Ansible are left behind

- The run-away processes consume resources in the background
- Things manually changed by humans with shell access to the server

Starting afresh each time also removes differences between an initial deployment and an upgrade. The same code path can be used, reducing the risk of surprises while upgrading an application. This type of an install can also make it extremely easy to roll back if the new version does not perform as expected. In addition to this, as new systems are created to replace old systems, the application does not need to go into a degraded state during the upgrade.

Let's reapproach our previous upgraded playbook with the expand and contract strategy. Our pattern will be to create new servers, deploy our application, verify our application, add new servers to the load balancer, and remove old servers from the load balancer. First, let's start with creating new servers. For this example, we'll make use of an OpenStack Compute Cloud to launch new instances:

```
---
- name: Create new foo servers
  hosts: localhost

  tasks:
    - name: launch instances
      os_server:
        name: foo-appv{{ version }}-{{ item }}
        image: foo-appv{{ version }}
        flavor: 4
        key_name: ansible-prod
        security_groups: foo-app
        auto_floating_ip: false
        state: present
        auth:
          auth_url: https://me.openstack.blueboxgrid.com:5001/v2.0
          username: jlk
          password: FAKEPASSWORD
          project_name: mastery
      register: launch
      with_sequence: count=8
```

In this task, we're looping over a count of 8 using `with_sequence`. Each loop in the `item` variable will be replaced with a number. This allows us to create eight new server instances with a name based on the version of our application and the number of the loop. We're also assuming a prebuilt image to use so that we do not need to do any further configuration of the instance. In order to use the servers in future plays, we need to add their details to the inventory. To accomplish this, we register the results of the run in the `launch` variable, which we'll use next to create runtime inventory entries:

```
- name: add hosts
  add_host:
    name: "{{ item.openstack.name }}"
    ansible_ssh_host: "{{ item.openstack.private_v4 }}"
    groups: new-foo-app
  with_items: launch.results
```

This task will create new inventory items with the same name as that of our server instance. To help Ansible know how to connect, we'll set `ansible_ssh_host` to the IP address that our cloud provider assigned to the instance (this is assuming that the address is reachable by the host running Ansible). Finally, we'll add the hosts to the group `new-foo-app`. As our `launch` variable comes from a task with a loop, we need to iterate over the results of that loop by accessing the `results` key. This allows us to loop over each launch action to access the data specific to that task.

Next, we'll operate on the servers to ensure that the new service is ready for use. We'll use `wait_for` again, just like we did earlier, as part of a new play on our `new-foo-app` group:

```
- name: Ensure new app
  hosts: new-foo-app
  tasks:
    - name: ensure healthy service
      wait_for:
        port: 80
```

Once they're all ready to go, we can reconfigure the load balancer to make use of our new servers. For the sake of simplicity, we will assume a template for the `haproxy` configuration that expects hosts in a `new-foo-app` group, and the end result will be a configuration that knows all about our new hosts and forgets about our old hosts. This means that we can simply call a template task on the load balancer system itself rather than attempting to manipulate the running state of the balancer:

```
- name: Configure load balancer
  hosts: foo-lb
  tasks:
```

```
- name: haproxy config
  template:
    dest: /etc/haproxy/haproxy.cfg
    src: templates/etc/haproxy/haproxy.cfg

- name: reload haproxy
  service:
    name: haproxy
    state: reloaded
```

Once the new configuration file is in place, we can issue a reload of the haproxy service. This will parse the new configuration file and start new listening processes for new incoming connections. The existing connections will eventually close and the old processes will terminate. All new connections will be routed to the new servers running our new application version.

This playbook can be extended to decommission the old version of the servers, or that action may happen at a different time, when it has been decided that a rollback to the old version capability is no longer necessary.

The expand and contract strategy can involve more tasks, and even separate playbooks for creating a golden image set, but the benefits of fresh infrastructure for every release far outweigh the extra tasks or added complexity of creation followed by deletion.

Failing fast

When performing an upgrade of an application, it may be desirable to fully stop the deployment at any sign of error. A partially upgraded system with mixed versions may not work at all, so continuing with part of the infrastructure while leaving the failed systems behind can lead to big problems. Fortunately, Ansible provides a mechanism to decide when to reach a fatal error scenario.

By default, when Ansible is running through a playbook and encounters an error, Ansible will remove the failed host from the list of play hosts and continue with the tasks or plays. Ansible will stop executing once either all the requested hosts for a play have failed, or all the plays have been completed. To change this behavior, there are a couple of play controls that can be employed. Those controls are `any_errors_fatal` and `max_fail_percentage`.

The `any_errors_fatal` option

This setting instructs Ansible to consider the entire operation to be fatal and stop executing immediately if any host encounters an error. To demonstrate this, we'll add a new group to our `mastery-hosts` inventory using a pattern that will expand up to 10 new hosts:

```
[failtest]
failer[01:10]
```

Then we'll create a play on this group with `any_errors_fatal` set to `true`. We'll also turn off fact gathering since these hosts do not exist:

```
---
- name: any errors fatal
  hosts: failtest
  gather_facts: false
  any_errors_fatal: true
```

We want a task that will fail for one of the hosts but not the others. Then, we'll want a second task as well to demonstrate that the playbook will stop executing tasks after the first error:

```
tasks:
- name: fail last host
  fail:
    msg: "I am last"
  when: inventory_hostname == play_hosts[-1]
- name: never ran
  debug:
    msg: "I should never be ran"
  when: inventory_hostname == play_hosts[-1]
```

Now when we execute, we'll see one host fail but the entire play will stop after the first task:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts failtest.yaml -vv

PLAY [any errors fatal] *****

TASK: [fail last host] *****
skipping: [failer01]
skipping: [failer02]
skipping: [failer03]
skipping: [failer06]
skipping: [failer07]
skipping: [failer04]
skipping: [failer09]
skipping: [failer08]
skipping: [failer05]
failed: [failer10] => {"failed": true}
msg: I am last

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
to retry, use: --limit @/Users/jkeating/failtest.yaml.retry

failer01      : ok=0    changed=0    unreachable=0    failed=0
failer02      : ok=0    changed=0    unreachable=0    failed=0
failer03      : ok=0    changed=0    unreachable=0    failed=0
failer04      : ok=0    changed=0    unreachable=0    failed=0
failer05      : ok=0    changed=0    unreachable=0    failed=0
failer06      : ok=0    changed=0    unreachable=0    failed=0
failer07      : ok=0    changed=0    unreachable=0    failed=0
failer08      : ok=0    changed=0    unreachable=0    failed=0
failer09      : ok=0    changed=0    unreachable=0    failed=0
failer10      : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery> 

```

We can see that just one host failed; however, Ansible reported all hosts to have failed and aborted the playbook before getting to the next play.

The max_fail_percentage option

This setting allows play developers to define a percentage of hosts that can fail before the whole operation is aborted. At the end of each task, Ansible will perform a math operation to determine the number of hosts targeted by the play that have reached a failure state, and if that number is greater than the number allowed, Ansible will abort the playbook. This is similar to `any_errors_fatal`, in fact, `any_errors_fatal` internally just expresses a `max_fail_percentage` parameter of 0, where any failure is considered fatal. Let's edit our play from the preceding code and change our `max_fail_percentage` parameter to 20:

```
---
- name: any errors fatal
  hosts: failtest
  gather_facts: false
  max_fail_percentage: 20
```

By making that change, our play should complete both tasks without aborting:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts failtest.yaml -vv

PLAY [any errors fatal] *****

TASK: [fail last host] *****
skipping: [failer01]
skipping: [failer04]
skipping: [failer02]
skipping: [failer03]
skipping: [failer06]
skipping: [failer07]
skipping: [failer08]
skipping: [failer09]
failed: [failer10] => {"failed": true}
msg: I am last
skipping: [failer05]

TASK: [never ran] *****
skipping: [failer02]
skipping: [failer03]
skipping: [failer01]
skipping: [failer06]
skipping: [failer07]
skipping: [failer04]
skipping: [failer08]
skipping: [failer05]
ok: [failer09] => {
  "msg": "I should never be ran"
}

PLAY RECAP *****
to retry, use: --limit @/Users/jkeating/failtest.yaml.retry

failer01      : ok=0    changed=0    unreachable=0    failed=0
failer02      : ok=0    changed=0    unreachable=0    failed=0
failer03      : ok=0    changed=0    unreachable=0    failed=0
failer04      : ok=0    changed=0    unreachable=0    failed=0
failer05      : ok=0    changed=0    unreachable=0    failed=0
failer06      : ok=0    changed=0    unreachable=0    failed=0
failer07      : ok=0    changed=0    unreachable=0    failed=0
failer08      : ok=0    changed=0    unreachable=0    failed=0
failer09      : ok=1    changed=0    unreachable=0    failed=0
failer10      : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery>
```

Now, if we change our conditional so that we fail on over 20 percent of the hosts, we'll see the playbook abort early:

```
- name: fail last host
  fail:
    msg: "I am last"
  when: inventory_hostname in play_hosts[0:3]
```

We're setting up three hosts to fail, which will give us a failure rate of greater than 20 percent. The `max_fail_percentage` setting is the maximum allowed, so our setting of 20 would allow 2 out of the 10 hosts to fail. With three hosts failing, we will see a fatal error before the second task:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts failtest.yaml -vv

PLAY [any errors fatal] *****

TASK: [fail last host] *****
failed: [failer02] => {"failed": true}
msg: I am last
failed: [failer01] => {"failed": true}
msg: I am last
skipping: [failer04]
skipping: [failer06]
skipping: [failer05]
skipping: [failer07]
skipping: [failer08]
failed: [failer03] => {"failed": true}
msg: I am last
skipping: [failer10]
skipping: [failer09]

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
  to retry, use: --limit @/Users/jkeating/failtest.yaml.retry

failer01      : ok=0    changed=0    unreachable=0    failed=1
failer02      : ok=0    changed=0    unreachable=0    failed=1
failer03      : ok=0    changed=0    unreachable=0    failed=1
failer04      : ok=0    changed=0    unreachable=0    failed=0
failer05      : ok=0    changed=0    unreachable=0    failed=0
failer06      : ok=0    changed=0    unreachable=0    failed=0
failer07      : ok=0    changed=0    unreachable=0    failed=0
failer08      : ok=0    changed=0    unreachable=0    failed=0
failer09      : ok=0    changed=0    unreachable=0    failed=0
failer10      : ok=0    changed=0    unreachable=0    failed=0

exit 2
~/src/mastery> 
```


Forcing handlers

Normally, when Ansible encounters a fatal state, it exits immediately. This means that any pending handlers will not be run. This can be undesirable, and there is a play control that will force Ansible to process pending handlers even when reaching a fatal scenario. This play control is `force_handlers`, which must be set to the Boolean `true`. When `force_handlers` is `true`, handlers are immediately flushed once a fatal condition is experienced. Any pending handlers for a failed host will also be processed.

Let's modify our preceding example a little to demonstrate this functionality. We'll change our `max_fail_percentage` parameter to 0 (the equivalent of `any_errors_fatal`) and change the first task a bit. Instead of simply failing, we now want to create some form of change. We can do this with the `debug` module using the `changed_when` task control, even though the `debug` module will never register a change by default. In the interest of shorter output, we'll also want to apply a conditional to the execution of the `debug` module to limit the execution to the last two hosts in the group. We'll use the `failed_when` control to create a failure on the second-to-last host. Finally, we'll notify our critical handler of any changes:

```
---
- name: any errors fatal
  hosts: failtest
  gather_facts: false
  max_fail_percentage: 0
  tasks:
    - name: change a host
      debug:
        msg: "I am last"
      when: inventory_hostname in play_hosts[-2:]
      changed_when: true
      failed_when: inventory_hostname == play_hosts[-2]
      notify: critical handler
```

Our second task remains unchanged, but we will define our critical handler:

```
- name: never ran
  debug:
    msg: "I should never be ran"
  when: inventory_hostname == play_hosts[-1]
handlers:
  - name: critical handler
    debug:
      msg: "I really need to run"
```

Let's run this new play to show the default behavior of the handler not being executed:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts failtest.yaml -vv

PLAY [any errors fatal] *****

TASK: [change a host] *****
skipping: [failer02]
skipping: [failer01]
skipping: [failer03]
skipping: [failer06]
skipping: [failer05]
skipping: [failer07]
skipping: [failer04]
skipping: [failer08]
failed: [failer09] => {"changed": true, "failed": true, "failed_when_result": true, "verbose_always": true}
msg: I am last
changed: [failer10] => {
    "changed": true,
    "failed": false,
    "failed_when_result": false,
    "msg": "I am last"
}

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
to retry, use: --limit @/Users/jkeating/failtest.yaml.retry

failer01      : ok=0    changed=0    unreachable=0    failed=0
failer02      : ok=0    changed=0    unreachable=0    failed=0
failer03      : ok=0    changed=0    unreachable=0    failed=0
failer04      : ok=0    changed=0    unreachable=0    failed=0
failer05      : ok=0    changed=0    unreachable=0    failed=0
failer06      : ok=0    changed=0    unreachable=0    failed=0
failer07      : ok=0    changed=0    unreachable=0    failed=0
failer08      : ok=0    changed=0    unreachable=0    failed=0
failer09      : ok=0    changed=0    unreachable=0    failed=1
failer10      : ok=1    changed=1    unreachable=0    failed=0

exit 2
~/src/mastery> 

```

Now, we add the `force_handlers` play control and set it to `true`:

```

---
- name: any errors fatal
  hosts: failtest

```

```
gather_facts: false
max_fail_percentage: 0
force_handlers: true
```

This time, when we run the playbook, we should see the handler run even for the failed hosts:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts failtest.yaml -vv

PLAY [any errors fatal] *****

TASK: [change a host] *****
skipping: [failer02]
skipping: [failer03]
skipping: [failer01]
skipping: [failer04]
skipping: [failer06]
skipping: [failer07]
skipping: [failer05]
skipping: [failer08]
failed: [failer09] => {"changed": true, "failed": true, "failed_when_result": true, "verbose_always": true}
msg: I am last
changed: [failer10] => {
  "changed": true,
  "failed": false,
  "failed_when_result": false,
  "msg": "I am last"
}

NOTIFIED: [critical handler] *****
ok: [failer09] => {
  "msg": "I really need to run"
}
ok: [failer10] => {
  "msg": "I really need to run"
}

PLAY RECAP *****
to retry, use: --limit @/Users/jkeating/failtest.yaml.retry

failer01      : ok=0    changed=0    unreachable=0    failed=0
failer02      : ok=0    changed=0    unreachable=0    failed=0
failer03      : ok=0    changed=0    unreachable=0    failed=0
failer04      : ok=0    changed=0    unreachable=0    failed=0
failer05      : ok=0    changed=0    unreachable=0    failed=0
failer06      : ok=0    changed=0    unreachable=0    failed=0
failer07      : ok=0    changed=0    unreachable=0    failed=0
failer08      : ok=0    changed=0    unreachable=0    failed=0
failer09      : ok=1    changed=0    unreachable=0    failed=1
failer10      : ok=2    changed=1    unreachable=0    failed=0

exit 2
~/src/mastery> 
```

Forcing handlers to run can really be useful for repeated playbook runs. The first run may result in some changes, but if a fatal error is encountered before the handlers are flushed, those handler calls will be lost. Repeated runs will not result in the same changes, so the handler will never run without manual interaction. Forcing handlers to execute will make some attempt at ensuring that those handler calls are not lost.

Minimizing disruptions

During deployments, there are often tasks that can be considered disruptive or destructive. These tasks may include restarting services, performing database migrations, and so on. Disruptive tasks should be clustered together to minimize the overall impact on an application, while destructive tasks should only be performed once.

Delaying a disruption

Restarting services for a new code version is a very common need. When viewed in isolation, a single service can be restarted whenever the code and configuration for the application has changed without concern for the overall distributed system health. Typically, a distributed system will have roles for each part of the system, and each role will operate essentially in isolation on the hosts targeted to perform those roles. When deploying an application for the first time, there is no existing uptime of the whole system to worry about, so services can be restarted at will. However, during an upgrade, it may be desirable to delay all service restarts until every service is ready to minimize interruptions.

Reuse of role code is strongly encouraged rather than designing a completely separate upgrade code path. To accommodate a coordinated upgrade, the role code for a particular service needs protection around the service restart. A common pattern is to put a conditional statement on the disruptive tasks that check a variable's value. When performing an upgrade, this variable can be defined at runtime to trigger this alternative behavior. This variable can also trigger a coordinated restart of services at the end of the main playbook once all roles have completed, to cluster the disruption and minimize the total outage.

Let's create a fictional application upgrade that involves two roles with simulated service restarts. We'll call these roles `microA` and `microB`:

```
roles/microA
├── handlers
│   └── main.yaml
└── tasks
    └── main.yaml
```

```
roles/microB
├── handlers
│   └── main.yaml
└── tasks
    └── main.yaml
```

For both of these roles, we'll have a simple debug task that simulates the installation of a package. We'll notify a handler to simulate the restart of a service. And, to ensure that the handler will trigger, we'll force the task to always register as changed:

```
roles/microA/tasks/main.yaml:
---
- name: install microA package
  debug:
    msg: "This is installing A"
    changed_when: true
    notify: restart microA
  roles/microB/tasks/main.yaml:
---
- name: install microB package
  debug:
    msg: "This is installing B"
    changed_when: true
    notify: restart microB
```

The handlers for these roles will be debug actions as well, and we'll attach a conditional to the handler task to only restart if the upgrade variable evaluates to the Boolean false. We'll also use the default filter to give this variable a default value of false:

```
roles/microA/handlers/main.yaml:
---
- name: restart microA
  debug:
    msg: "microA is restarting"
    when: not upgrade | default(false) | bool

roles/microB/handlers/main.yaml:
---
- name: restart microB
  debug:
    msg: "microB is restarting"
    when: upgrade | default(false) | bool
```

For our top-level playbook, we'll create four plays. The first two plays will apply each of the micro roles and the last two plays will do the restarts. The last two plays will only be executed if performing an upgrade, so they will make use of the upgrade variable as a condition. Let's have a look at the following code snippet:

```
micro.yaml:
---
- name: apply microA
  hosts: localhost
  gather_facts: false

  roles:
    - role: microA

- name: apply microB
  hosts: localhost
  gather_facts: false

  roles:
    - role: microB

- name: restart microA
  hosts: localhost
  gather_facts: false

  tasks:
    - name: restart microA for upgrade
      debug:
        msg: "microA is restarting"
      when: upgrade | default(false) | bool

- name: restart microB
  hosts: localhost
  gather_facts: false

  tasks:
    - name: restart microB for upgrade
      debug:
        msg: "microB is restarting"
      when: upgrade | default(false) | bool
```

If we execute this playbook without defining the upgrade module, we will see the execution of each role and the handlers within. The final two plays will just have skipped tasks:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts micro.yaml -vv

PLAY [apply microA] *****

TASK: [microA | install microA package] *****
changed: [localhost] => {
  "changed": true,
  "msg": "This is installing A"
}

NOTIFIED: [microA | restart microA] *****
ok: [localhost] => {
  "msg": "microA is restarting"
}

PLAY [apply microB] *****

TASK: [microB | install microB package] *****
changed: [localhost] => {
  "changed": true,
  "msg": "This is installing B"
}

NOTIFIED: [microB | restart microB] *****
ok: [localhost] => {
  "msg": "microB is restarting"
}

PLAY [restart microA] *****

TASK: [restart microA for upgrade] *****
skipping: [localhost]

PLAY [restart microB] *****

TASK: [restart microB for upgrade] *****
skipping: [localhost]

PLAY RECAP *****
localhost                : ok=4    changed=2    unreachable=0    failed=0

~/src/mastery> 
```

Now, let's execute the playbook again, and this time, we'll define the upgrade as true at runtime:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts micro.yaml -vv -e upgrade=true

PLAY [apply microA] *****

TASK: [microA | install microA package] *****
changed: [localhost] => {
  "changed": true,
  "msg": "This is installing A"
}

NOTIFIED: [microA | restart microA] *****
skipping: [localhost]

PLAY [apply microB] *****

TASK: [microB | install microB package] *****
changed: [localhost] => {
  "changed": true,
  "msg": "This is installing B"
}

NOTIFIED: [microB | restart microB] *****
skipping: [localhost]

PLAY [restart microA] *****

TASK: [restart microA for upgrade] *****
ok: [localhost] => {
  "msg": "microA is restarting"
}

PLAY [restart microB] *****

TASK: [restart microB for upgrade] *****
ok: [localhost] => {
  "msg": "microB is restarting"
}

PLAY RECAP *****
localhost                : ok=4    changed=2    unreachable=0    failed=0

~/src/mastery> 

```


This time, we can see that our handlers are skipped but the final two plays have tasks that execute. In a real world scenario, where many more things are happening in the `microA` and `microB` roles, and potentially other micro-service roles on other hosts, the difference could be of many minutes or more. Clustering the restarts at the end can reduce the interruption period significantly.

Running destructive tasks only once

Destructive tasks come in many flavors. They can be one-way tasks that are extremely difficult to roll back, one-time tasks that cannot easily be rerun, or they can be race condition tasks that, if performed in parallel, would result in catastrophic failure. For these reasons and more, it is essential that these tasks are performed only once from a single host. Ansible provides a mechanism to accomplish this by way of the `run_once` task control.

The `run_once` task control will ensure that the task only executes a single time from a single host, regardless of how many hosts happen to be in a play. While there are other methods to accomplish this goal, such as using a conditional to make the task only execute on the first host of a play, the `run_once` control is the simplest and most direct way to express this desire. Additionally, any variable data registered from a task controlled by `run_once` will be made available to all hosts of the play, not just the host that was selected by Ansible to perform the action. This can simplify later retrieval of the variable data.

Let's create an example playbook to demonstrate this functionality. We'll reuse our `failtest` hosts created in an earlier example to have a pool of hosts, and select two of them using a host pattern. We'll do a debug task set to `run_once` and register the results, then access the results in a different task by a different host:

```
runonce.yaml:
---
- name: run once test
  hosts: failtest[0-2]
  gather_facts: false

  tasks:
    - name: do a thing
      debug:
        msg: "I am groot"
        register: groot
        run_once: true

    - name: what is groot
      debug:
        var: groot
        when: inventory_hostname == play_hosts[-1]
```

When we run this play, we'll pay special attention to the hostnames listed for each task operation:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts runonce.yaml -vv

PLAY [run once test] *****

TASK: [do a thing] *****
ok: [failer01] => {
  "msg": "I am groot"
}

TASK: [what is groot] *****
skipping: [failer01]
ok: [failer02] => {
  "var": {
    "groot": {
      "invocation": {
        "module_args": "",
        "module_name": "debug"
      },
      "msg": "I am groot",
      "verbose_always": true
    }
  }
}

PLAY RECAP *****
failer01          : ok=1    changed=0    unreachable=0    failed=0
failer02          : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

We can see that the `do a thing` task is executed on the host `failer01`, while the `what is groot` task, which examines the data from the `do a thing` task, operates on host `failer02`.

Summary

Deployment and upgrade strategies are a matter of taste. Each come with distinct advantages and disadvantages. Ansible does not possess an opinion on which is better, and therefore is well suited to perform deployments and upgrades regardless of the strategy. Ansible provides features and design patterns that facilitate a variety of styles with ease. Understanding the nature of each strategy and how Ansible can be tuned for that strategy will empower you to decide and design deployments for each of your applications.

In the next chapter, we'll cover topics that will help when things don't quite go as expected when executing Ansible playbooks.

7

Troubleshooting Ansible

Ansible is simple but powerful. The simplicity of Ansible means that the operation is easy to understand and follow. Being able to understand and follow is critically important when debugging unexpected behavior. In this chapter, we will explore the various methods that can be employed to examine, introspect, modify, and, otherwise debug the operation of Ansible:

- Playbook logging and verbosity
- Variable introspection
- Debugging local code execution
- Debugging remote code execution

Playbook logging and verbosity

Increasing the verbosity of Ansible output can solve many problems. From invalid module arguments to incorrect connection commands, increased verbosity can be critical to pinpointing the source of an error. Playbook logging and verbosity were briefly discussed in *Chapter 2, Protecting Your Secrets with Ansible*, with regards to protecting secret values while executing playbooks. This section will cover verbosity and logging further in-depth.

Verbosity

When executing playbooks with `ansible-playbook`, the output is displayed on standard out. With the default level of verbosity, very little information is displayed. As a play is executed, `ansible-playbook` will print a PLAY header with the name of the play. Then, for each task, a TASK header is printed with the name of the task. As each host executes the task, the name of the host is displayed along with the task state, which can be `ok`, `fatal`, or `changed`. No further information about the task is displayed, such as the module being executed, the arguments provided to the module, or the return data from the execution. While this is fine for well-established playbooks, I tend to want a little more information about my plays. In all previous examples in this book, we've used a verbosity level of 2 (`-vv`) so that we can see the module, module arguments, and return data. There are five total levels of verbosity: none, which is the default level; 1 (`-v`), where the return data is displayed; 2 (`-vv`) for input data as well, 3 (`-vvv`), which provides details of the connection attempts; and 4 (`-vvvv`), which will pass along extra verbosity options to the connection plugins (such as passing `-vvv` to the `ssh` commands). Increasing the verbosity can help pinpoint where errors might be occurring, as well as provide extra insight into how Ansible is performing its operations.

As mentioned in *Chapter 2, Protecting Your Secrets with Ansible*, verbosity beyond one can leak sensitive data to standard out and log files, so care should be taken when using increased verbosity in a potentially shared environment.

Logging

While the default is for `ansible-playbook` to log to standard out, the amount of output may be greater than the buffer of the terminal emulator being used; therefore, it may be necessary to save all the output to a file. While various shells provide some mechanism to redirect output, a more elegant solution is to direct `ansible-playbook` to log to a file. This is accomplished by way of either a `log_path` definition in the `ansible.cfg` file or by setting `ANSIBLE_LOG_PATH` as an environment variable. The value of either should be the path to a file. If the path does not exist, Ansible will attempt to create the file. If the file *does* exist, Ansible will append to the file, allowing consolidation of multiple `ansible-playbook` execution logs.

The use of a log file is not mutually exclusive with logging to standard output. Both can happen at the same time, and the verbosity level provided has an effect on both.

Variable introspection

A common set of problems encountered when developing Ansible playbooks is the improper use or invalid assumption of the value of variables. This is particularly common when registering the results of one task in a variable and later using that variable in a task or template. If the desired element of the result is not accessed properly, the end result will be unexpected or, perhaps, even harmful.

To troubleshoot improper variable usage, inspection of the variable value is the key. The easiest way to inspect a variable's value is with the `debug` module. The `debug` module allows for displaying free form text on screen, and like with other tasks, the arguments to the module can take advantage of the Jinja2 template syntax as well. Let's demonstrate this usage by creating a sample play that executes a task, registers the result, and then shows the result in a debug statement using the Jinja2 syntax to render the variable:

```
---
- name: variable introspection demo
  hosts: localhost
  gather_facts: false

  tasks:
    - name: do a thing
      uri:
        url: https://derpops.bike
        register: derpops

    - name: show derpops
      debug:
        msg: "derpops value is {{ derpops }}"
```

Now, when we run this play, we'll see the displayed value for derpops:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts vintro.yaml -vv

PLAY [variable introspection demo] *****

TASK: [do a thing] *****
<localhost> REMOTE_MODULE uri url=https://derpops.bike
ok: [localhost] => {"changed": false, "content_location": "https://derpops.bike",
"content_type": "text/html; charset=UTF-8", "date": "Sun, 31 May 2015 04:57:56
GMT", "link": "<http://wp.me/4H3Bf>; rel=shortlink", "redirected": false, "serv
er": "Apache/2.4.6 (CentOS) OpenSSL/1.0.1e-fips PHP/5.4.16", "status": 200, "tra
nsfer_encoding": "chunked", "x_pingback": "https://derpops.bike/xmlrpc.php", "x_
powered_by": "PHP/5.4.16"}

TASK: [show derpops] *****
ok: [localhost] => {
  "msg": "derpops value is {'status': 200, 'changed': False, 'x_pingback': 'ht
tps://derpops.bike/xmlrpc.php', 'transfer_encoding': 'chunked', 'x_powered_by':
'PHP/5.4.16', 'server': 'Apache/2.4.6 (CentOS) OpenSSL/1.0.1e-fips PHP/5.4.16',
'date': 'Sun, 31 May 2015 04:57:56 GMT', 'link': '<http://wp.me/4H3Bf>; rel=shor
tlink', 'content_type': 'text/html; charset=UTF-8', 'content_location': 'https:/
/derpops.bike', 'invocation': {'module_name': 'uri', 'module_args': ''}, 'redir
ected': False}"
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

The debug module has a different option that may be useful as well. Instead of printing a free form string to debug template usage, the module can simply print the value of any variable. This is done using the `var` argument instead of the `msg` argument. Let's repeat our example, but this time, we'll use the `var` argument, and we'll access just the `server` subelement of the `derpops` variable:

```

---
- name: variable introspection demo
  hosts: localhost
  gather_facts: false

  tasks:
    - name: do a thing
      uri:
        url: https://derpops.bike
        register: derpops

    - name: show derpops
      debug:
        var: derpops.server

```

Running this modified play will show just the server portion of the derpops variable:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts vintro.yaml -vv

PLAY [variable introspection demo] *****

TASK: [do a thing] *****
<localhost> REMOTE_MODULE uri url=https://derpops.bike
ok: [localhost] => {"changed": false, "content_location": "https://derpops.bike", "content_type": "text/html; charset=UTF-8", "date": "Sun, 31 May 2015 05:20:13 GMT", "link": "<http://wp.me/4H3Bf>; rel=shortlink", "redirected": false, "server": "Apache/2.4.6 (CentOS) OpenSSL/1.0.1e-fips PHP/5.4.16", "status": 200, "transfer_encoding": "chunked", "x_pingback": "https://derpops.bike/xmlrpc.php", "x_powered_by": "PHP/5.4.16"}

TASK: [show derpops] *****
ok: [localhost] => {
  "var": {
    "derpops.server": "Apache/2.4.6 (CentOS) OpenSSL/1.0.1e-fips PHP/5.4.16"
  }
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

In our example, which used the `msg` argument to debug, the variable needed to be expressed inside mustache brackets, but when using `var`, it did not. This is because `msg` expects a string, so Ansible needs to render the template as a string. However, `var` expects a single unrendered variable.

Variable sub elements

Another frequent mistake in playbooks is to improperly reference a subelement of a **complex variable**. A complex variable is one that is more than simply a string; it is either a list or a hash. Often the wrong subelement will be referenced, or the element will be improperly referenced expecting a different type.

While lists are fairly easy to work with, hashes present some unique challenges. A hash is an unordered key-value set of potentially mixed types, which could also be nested. A hash can have one element that is a single string, while another element can be a list of strings, and a third element can be another hash with further elements inside of it. Knowing how to properly access the right subelement is critical to success.

For an example, let's modify our previous play a bit more. This time we'll allow Ansible to gather facts, and then we'll show the value of `ansible_default_ipv4`:

```
---
- name: variable introspection demo
  hosts: localhost

  tasks:
    - name: show a complex hash
      debug:
        var: ansible_default_ipv4
```

The output is shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts vintro.yaml -vv

PLAY [variable introspection demo] *****

GATHERING FACTS *****
<localhost> REMOTE_MODULE setup
ok: [localhost]

TASK: [show a complex hash] *****
ok: [localhost] => {
  "var": {
    "ansible_default_ipv4": {
      "address": "192.168.10.101",
      "broadcast": "192.168.10.255",
      "device": "en0",
      "flags": [
        "Up",
        "BROADCAST",
        "SMART",
        "RUNNING",
        "SIMPLEX",
        "MULTICAST"
      ],
      "gateway": "192.168.10.10",
      "interface": "en0",
      "macaddress": "6c:40:08:a5:b9:92",
      "media": "Unknown",
      "media_select": "autoselect",
      "mtu": "1500",
      "netmask": "255.255.255.0",
      "network": "192.168.10.0",
      "options": [
        "PERFORMNUD"
      ],
      "status": "active",
      "type": "unknown"
    }
  }
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

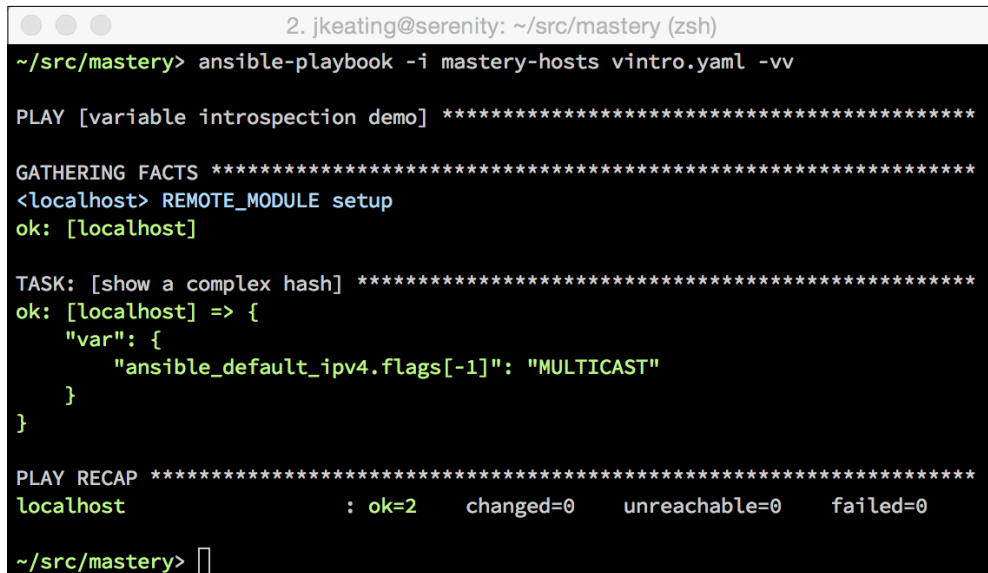
Using debug to display the entire complex variable is a great way to learn all the names of the subelements.

This variable has elements that are strings, along with elements that are lists of strings. Let's access the last item in the list of flags:

```
---
- name: variable introspection demo
  hosts: localhost

  tasks:
    - name: show a complex hash
      debug:
        var: ansible_default_ipv4.flags[-1]
```

The output is shown in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts vintro.yaml -vv

PLAY [variable introspection demo] *****

GATHERING FACTS *****
<localhost> REMOTE_MODULE setup
ok: [localhost]

TASK: [show a complex hash] *****
ok: [localhost] => {
  "var": {
    "ansible_default_ipv4.flags[-1]": "MULTICAST"
  }
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

Because `flags` is a list, we can use the list index method to select a specific item from the list. In this case, `-1` will give us the very last item in the list.

Subelement versus Python object method

A less common but confusing gotcha comes from a quirk of the Jinja2 syntax. Complex variables within Ansible playbooks and templates can be referenced in two ways. The first style is to reference the base element by the name, followed by a bracket and the subelement within quotes inside the brackets. This is the standard subscript syntax. For example, to access the `herp` subelement of the `derp` variable, we use the following:

```
{{ derp['herp'] }}
```

The second style is a convenience method that Jinja2 provides, which is to use a period to separate the elements. This is called **dot notation**:

```
{{ derp.herp }}
```

There is a subtle difference in how these styles work that has to do with Python objects and object methods. As Jinja2 is at its heart a Python utility, variables in Jinja2 have access to their native Python methods. A string variable has access to Python string methods, a list has access to list methods, and a dictionary has access to dictionary methods. When using the first style, Jinja2 will first search the element for a subelement of the provided name. If none is found, Jinja2 will then attempt to access a Python method of the provided name. However, the order is reversed when using the second style: first a Python object method is searched for and if not found, then a subelement is searched for. This difference matters when there is a name collision between a subelement and a method. Imagine a variable named `derp`, which is a complex variable. This variable has a subelement named `keys`. Using each style to access the `keys` element will result in different values. Let's build a playbook to demonstrate this:

```
---
- name: sub-element access styles
  hosts: localhost
  gather_facts: false
  vars:
    - derp:
        keys:
          - c
          - d
  tasks:
    - name: subscript style
      debug:
        var: derp['keys']
    - name: dot notation style
      debug:
        var: derp.keys
```

When running this play, we clearly see the difference between the two styles. The first style successfully references the `keys` subelement, while the second style references the `keys` method of Python dictionaries:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts objmethod.yaml -vv

PLAY [sub-element access styles] *****

TASK: [subscript style] *****
ok: [localhost] => {
  "var": {
    "derp['keys']": [
      "c",
      "d"
    ]
  }
}

TASK: [dot notation style] *****
ok: [localhost] => {
  "var": {
    "derp.keys": "<built-in method keys of dict object at 0x7fa7cb30edf0>"
  }
}

PLAY RECAP *****
localhost                : ok=2    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Generally, it's best to avoid using subelement names that conflict with Python object methods. However, if that's not possible, the next best thing to do is to be aware of the difference in subelement reference styles and choose the appropriate one.

Debugging code execution

Sometimes logging and inspection of variable data is not enough to troubleshoot a problem. When this happens, it can be necessary to dig deeper into the internals of Ansible. There are two main sets of Ansible code: the code that runs locally on the Ansible host, and the module code that runs remotely on the target host.

Debugging local code

The local Ansible code is the lion's share of the code that comes with Ansible. All the playbook, play, role, and task parsing code live locally. All the task result processing code and transport code live locally. All the code except for the assembled module code that is transported to the remote host lives locally.

Local Ansible code can be broken down into three major sections: inventory, playbook, and runner. Inventory code deals with parsing inventory data from host files, dynamic inventory scripts, or combinations of the two in directory trees. Playbook code is used to parse the playbook YAML code into Python objects within Ansible. Runner code is the core API and deals with forking processes, connecting to hosts, executing modules, handling results, and most other things. Learning the general area to start debugging comes with practice, but the general areas described here are a starting point.

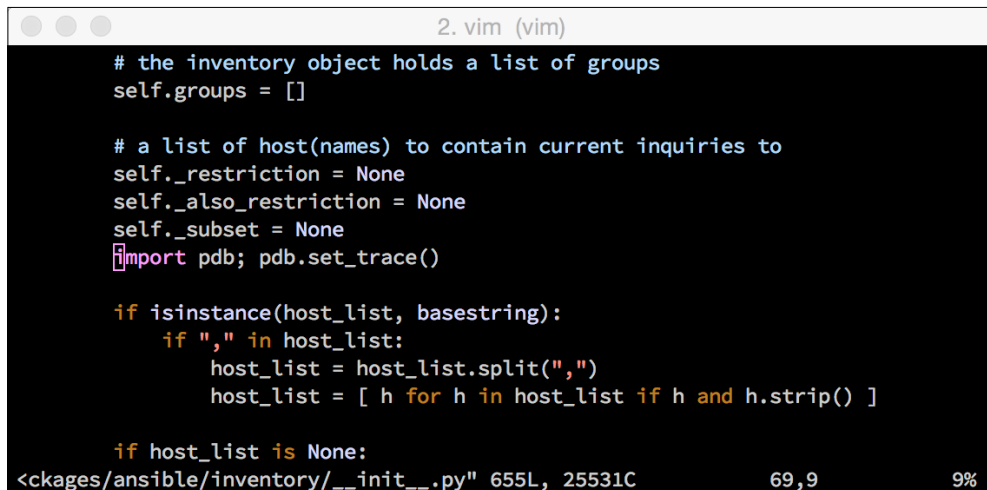
As Ansible is written in Python, the tool for debugging local code execution is the Python debugger, `pdb`. This tool allows us to insert break points inside the Ansible code and interactively walk through the execution of the code, line by line. This is very useful for examining the internal state of Ansible as the local code executes. There are many books and websites that cover the usage of `pdb`, and these can be found with a simple web search for an introduction to Python `pdb`, so we will not repeat them here. The basics are to edit the source file to be debugged, insert a new line of code to create a break point, and then execute the code. Code execution will stop where the breakpoint was created and a prompt will be provided to explore the code state.

Debugging inventory code

Inventory code deals with finding inventory sources, reading or executing the discovered files, parsing the inventory data into inventory objects, and loading variable data for the inventory. To debug how Ansible will deal with an inventory, a breakpoint must be added inside `inventory/__init__.py` or one of the other files within the `inventory/` subdirectory. This directory will be located on the local filesystem wherever Ansible has been installed. On a Linux system, this is typically stored in the path `/usr/lib/python2.7/site-packages/ansible/inventory/`. This path may be inside of a Python virtual environment if Ansible has been installed that way. To discover where Ansible is installed, simply type `which ansible` from the command line. This command will show where the `ansible` executable is installed, and may indicate a Python virtual environment. For this book, Ansible has been installed in a Python virtual environment with the path `/Users/jkeating/.virtualenvs/ansible/`.

To discover the path to the ansible python code, simply type `python -c "import ansible; print(ansible)"`. On my system this shows `<module 'ansible' from '/Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/__init__.pyc'>`, from which we can deduce that the inventory subdirectory is located at `/Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/inventory/`.

Within `inventory/__init__.py` there is a class definition for the `Inventory` class. This is the inventory object that will be used throughout a playbook run, and it is created when `ansible-playbook` parses the options provided to it for an inventory source. The `__init__` method of the `Inventory` class does all the inventory discovery, parsing, and variable loading. To troubleshoot an issue in those three areas, a breakpoint should be added within the `__init__()` method. A good place to start would be after all of the class variables are given an initial value and just before any data is processed. In version 1.9.x of Ansible, this would be line 69 of `inventory/__init__.py`. To insert a breakpoint, we must first import the `pdb` module and then call the `set_trace()` function:



```
2. vim (vim)

# the inventory object holds a list of groups
self.groups = []

# a list of host(names) to contain current inquiries to
self._restriction = None
self._also_restriction = None
self._subset = None
import pdb; pdb.set_trace()

if isinstance(host_list, basestring):
    if "," in host_list:
        host_list = host_list.split(",")
        host_list = [ h for h in host_list if h and h.strip() ]

    if host_list is None:
<ckages/ansible/inventory/__init__.py" 655L, 25531C          69,9          9%
```

To start debugging, save the source file and then execute `ansible-playbook` as normal. When the breakpoint is reached, the execution will stop and a `pdb` prompt will be displayed:

```
2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)
~/src/mastery> ansible-playbook -i mastery-hosts objmethod.yaml -vv
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/inven
tory/__init__.py(71)__init__()
-> if isinstance(host_list, basestring):
(Pdb) █
```

From here, we can issue any number of debugger commands, such as the `help` command:

```
2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/inven
tory/__init__.py(71)__init__()
-> if isinstance(host_list, basestring):
(Pdb) help

Documented commands (type help <topic>):
=====
EOF      bt          cont        enable      jump      pp         run        unt
a        c          continue   exit        l         q         s         until
alias    cl         d          h          list      quit      step      up
args     clear     debug     help       n         r         tbreak    w
b        commands disable   ignore     next      restart   u         whatis
break    condition down      j          p         return    unalias   where

Miscellaneous help topics:
=====
exec  pdb

Undocumented commands:
=====
retval rv

(Pdb) █
```

The `where` and the `list` commands can help us determine where we are in the stack, and where we are in the code:

```

2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)

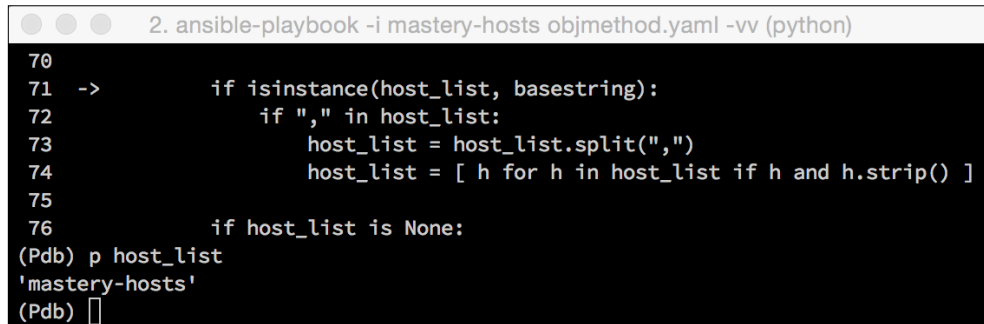
(Pdb) where
/Users/jkeating/.virtualenvs/ansible/bin/ansible-playbook(324)<module>()
-> sys.exit(main(sys.argv[1:]))
/Users/jkeating/.virtualenvs/ansible/bin/ansible-playbook(157)main()
-> inventory = ansible.inventory.Inventory(options.inventory, vault_password=vault_pass)
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/inventory/__init__.py(71)__init__()
-> if isinstance(host_list, basestring):
(Pdb) list
66         self._restriction = None
67         self._also_restriction = None
68         self._subset = None
69         import pdb; pdb.set_trace()
70
71     ->         if isinstance(host_list, basestring):
72             if "," in host_list:
73                 host_list = host_list.split(",")
74                 host_list = [ h for h in host_list if h and h.strip() ]
75
76         if host_list is None:
(Pdb) 

```

The `where` command showed us that we're in `inventory/__init__.py` in the `__init__()` method calling the `isinstance` function. The next frame up is in a different file, the `ansible-playbook` executable file, and the function in that file is `main()`; this line calls to `ansible.inventory.Inventory` to create the inventory object. Above that is a different line from the same file, the call to `main()` itself inside a call to `sys.exit()`.

The `list` command shows the source code around our current point of execution, five lines before and five lines after.

From here, we can guide `pdb` through the function line by line with the `next` command. And, if we chose to, we can trace into other function calls with the `step` command. We can also print variable data to inspect values:

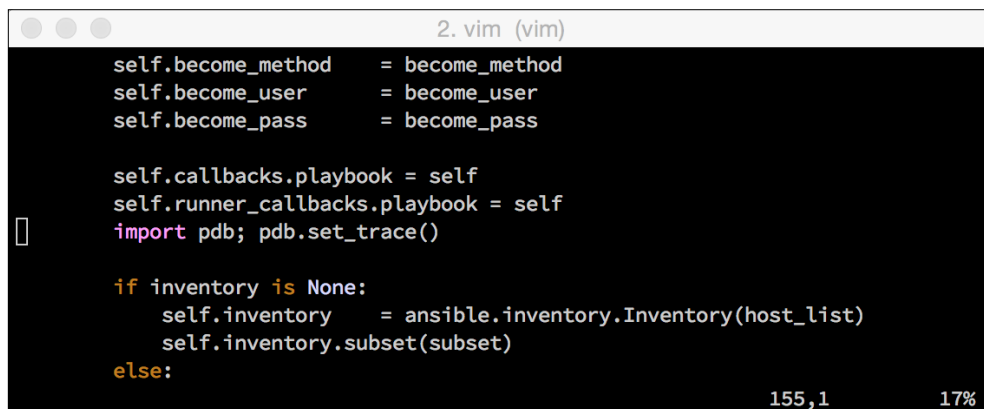


```
2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)
70
71 ->         if isinstance(host_list, basestring):
72             if "," in host_list:
73                 host_list = host_list.split(",")
74                 host_list = [ h for h in host_list if h and h.strip() ]
75
76             if host_list is None:
(Pdb) p host_list
'mastery-hosts'
(Pdb) █
```

We can see that the `host_list` variable is defined as `mastery-hosts`, which is the string we gave `ansible-playbook` for our inventory data. We can continue to walk through or jump around, or just use the `continue` command to run until the next breakpoint or the completion of the code.

Debugging Playbook code

Playbook code is responsible for loading, parsing, and executing playbooks. The main entry point for playbook handling is `playbook/__init__.py`, inside of which lives the `PlayBook` class. A good starting point for debugging playbook handling is line 155:



```
2. vim (vim)
self.become_method = become_method
self.become_user   = become_user
self.become_pass   = become_pass

self.callbacks.playbook = self
self.runner_callbacks.playbook = self
import pdb; pdb.set_trace()

if inventory is None:
    self.inventory = ansible.inventory.Inventory(host_list)
    self.inventory.subset(subset)
else:
155,1 17%
```

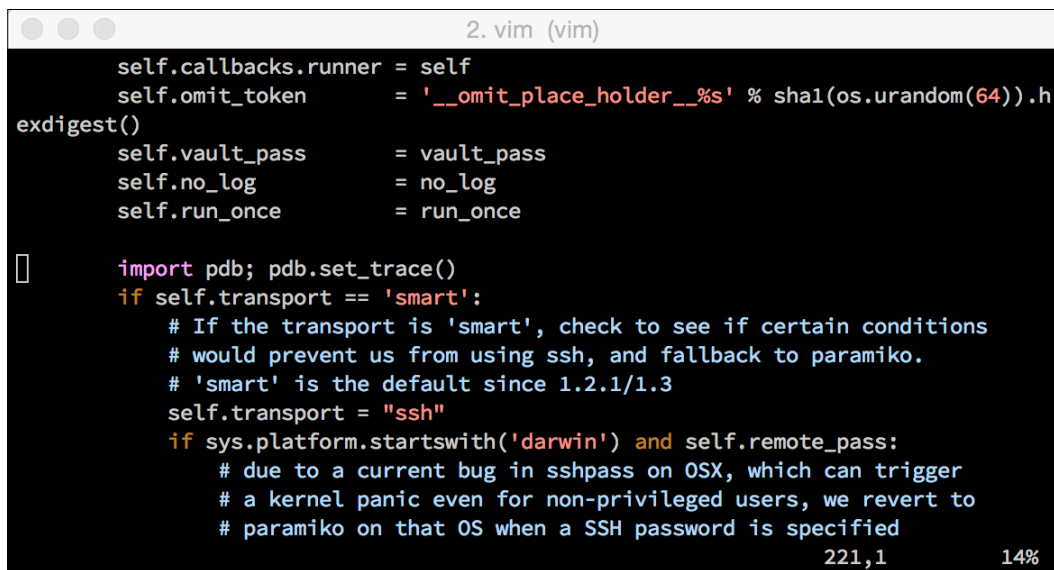
Putting a breakpoint here will allow us to trace through finding the playbook file and parsing it. Specifically, stepping into the `_load_playbook_from_file()` function, we will be able to follow the parsing in action.

The `PlayBook` class `__init__()` function just does the initial parsing. Other functions within the class are used for the execution of plays and tasks. A particularly interesting function is the `run()` method. This method will loop through all of the plays in the playbook and execute the plays, which will, in turn, execute the individual tasks. This is the function to walk through if facing an issue related to play parsing, play or task callbacks, tags, play host selection, serial operation, handler running, or anything in between.

Debugging runner code

Runner code in Ansible is the connector code that binds together inventory data, playbooks, plays, tasks, and the connection methods. While each of those other code bits can be individually debugged, how they interact can be examined within runner code.

The `Runner` class is defined in `runner/__init__.py`. This class is the core interface to Ansible. The class creation function, `__init__()`, creates a series of placeholder attributes, as well as sets some default values. Of interest in this function is the code path that sets up the connection method. The default connection method is `smart`, which actually examines the system running Ansible to determine which set of features to use. Let's put in a break point here to walk through the execution:



```

2. vim (vim)
self.callbacks.runner = self
self.omit_token       = '__omit_place_holder__%s' % sha1(os.urandom(64)).hexdigest()
self.vault_pass       = vault_pass
self.no_log           = no_log
self.run_once         = run_once

import pdb; pdb.set_trace()
if self.transport == 'smart':
    # If the transport is 'smart', check to see if certain conditions
    # would prevent us from using ssh, and fallback to paramiko.
    # 'smart' is the default since 1.2.1/1.3
    self.transport = "ssh"
    if sys.platform.startswith('darwin') and self.remote_pass:
        # due to a current bug in sshpass on OSX, which can trigger
        # a kernel panic even for non-privileged users, we revert to
        # paramiko on that OS when a SSH password is specified

```

221,1 14%

Now we can run our `objmethod.yml` playbook again to get into a debugging state:

```
2. ansible-playbook -i mastery-hosts objmethod.yml -vv (python)
~/src/mastery> ansible-playbook -i mastery-hosts objmethod.yml -vv

PLAY [sub-element access styles] *****

TASK: [subscript style] *****
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/runner/
__init__.py(222).__init__()
-> if self.transport == 'smart':
(Pdb) []
```

We can check the value of `self.transport` by printing it out, but we know it'll be `smart`. What's more interesting is what comes next. The transport is first set to `ssh` as a default outcome, and then the platform is checked to ascertain whether it's a darwin system, which means an Apple OS X, and whether there is a `remote_password` defined. A remote password would be defined if we were using password authentication with the `ssh` rather than `ssh keys`:

```
2. ansible-playbook -i mastery-hosts objmethod.yml -vv (python)
__init__.py(226).__init__()
-> self.transport = "ssh"
(Pdb) l
221         import pdb; pdb.set_trace()
222         if self.transport == 'smart':
223             # If the transport is 'smart', check to see if certain conditi
ons
224             # would prevent us from using ssh, and fallback to paramiko.
225             # 'smart' is the default since 1.2.1/1.3
226     ->         self.transport = "ssh"
227             if sys.platform.startswith('darwin') and self.remote_pass:
228                 # due to a current bug in sshpass on OSX, which can trigge
r
229                 # a kernel panic even for non-privileged users, we revert
to
230                 # paramiko on that OS when a SSH password is specified
231                 self.transport = "paramiko"
(Pdb) []
```

My development system is a Mac laptop running OS X, so the first half of this statement should evaluate to `true`; however, this playbook execution is not using a remote password, so the code that would set the transport to `paramiko` is skipped over.

The next code block is the `else` block, where the `Runner` code will construct an `ssh` command to determine whether the host `ssh` supports `ControlPersist`—the feature of `ssh` that keeps sockets to remote hosts open for a period of time for fast reuse. Let's have a look at the following screenshot:

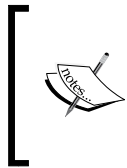
```
2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)
-> cmd = subprocess.Popen(['ssh','-o','ControlPersist'], stdout=subprocess.PIPE, s
tderr=subprocess.PIPE)
(Pdb) l
229             # a kernel panic even for non-privileged users, we revert
to
230             # paramiko on that OS when a SSH password is specified
231             self.transport = "paramiko"
232         else:
233             # see if SSH can support ControlPersist if not use paramik
o
234     ->         cmd = subprocess.Popen(['ssh','-o','ControlPersist'], stdo
ut=subprocess.PIPE, stderr=subprocess.PIPE)
235             (out, err) = cmd.communicate()
236             if "Bad configuration option" in err:
237                 self.transport = "paramiko"
238
239             # save the original transport, in case it gets
(Pdb) 
```

Let's walk through the next couple of lines and then print out what the value of `err` is. This will show us the result of the `ssh` execution and the whole string that Ansible will be searching within:

```
2. ansible-playbook -i mastery-hosts objmethod.yaml -vv (python)
234 ->         cmd = subprocess.Popen(['ssh','-o','ControlPersist'], stdo
ut=subprocess.PIPE, stderr=subprocess.PIPE)
235             (out, err) = cmd.communicate()
236             if "Bad configuration option" in err:
237                 self.transport = "paramiko"
238
239             # save the original transport, in case it gets
(Pdb) n
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/runner/
__init__.py(235) __init__()
-> (out, err) = cmd.communicate()
(Pdb) n
> /Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/runner/
__init__.py(236) __init__()
-> if "Bad configuration option" in err:
(Pdb) p err
'command-line line 0: Missing ControlPersist argument.\r\n'
(Pdb) 
```

As we can see, the search string is not within the `err` variable, so the transport remains `ssh` instead of being set to `paramiko`.

There are many other functions within the `Runner` class, such as the task delegation setup in `_compute_delegate()`, the task module transport and execution in `_execute_module()`, searching for a module file in `_configure_module()`, dealing with multiprocessing when there is more than one fork in `_parallel_exec()`, and many more.



A quick note on forks and debugging: when Ansible uses multiprocessing for multiple forks, debugging becomes difficult. A debugger may be attached to one fork and not another, which will make it very difficult to debug the code. Unless specifically debugging the multiprocessing code, a best practice is to stick to a single fork.

Debugging remote code

The remote code is the code that Ansible transports to a remote host in order to execute. This is typically module code, or in the case of `action_plugins`, other snippets of code. Using the debugging method discussed in the previous section to debug module execution will not work, as Ansible simply copies the code over and then executes it. There is no terminal attached to the remote code execution, and thus, no way to attach to a debugging prompt. That is, without editing the module code.

To debug module code, we need to edit the module code itself to insert a debugger break point. Instead of directly editing the installed module file, create a copy of the file in a `library/` directory relative to the playbooks. This copy of the module code will be used instead of the installed file, which makes it easy to temporarily edit a module without disrupting other users of modules on the system.

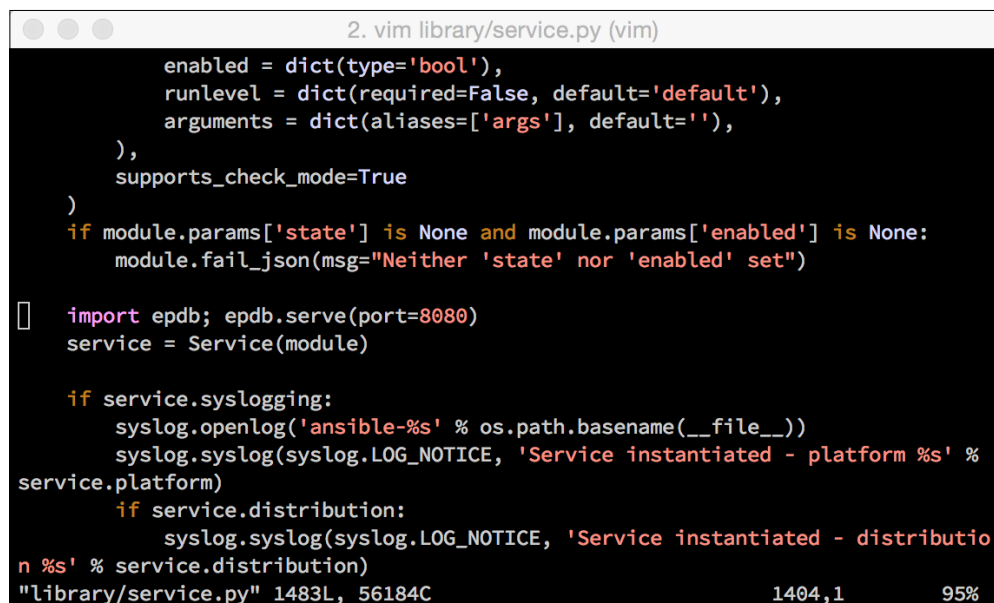
Unlike with other Ansible code, module code cannot be directly debugged with `pdb`, because the module code is assembled and then transported to a remote host. Thankfully, there is a solution in the form of a slightly different debugger named `epdb`—the Enhanced Python Debugger. This debugger has the ability to start a listening service on a provided port in order to allow remote connections into the Python process. Connecting to the process remotely will allow debugging the code line by line, just as we did with other Ansible code.

To demonstrate how this debugger works, first we're going to need a remote host. For this example, we're using a remote host by the name of `debug.example.com`, and setting the IP address to a host that is already set up and waiting. Next, we need a playbook to execute a module that we'd like to debug:

```
---
- name: remote code debug
  hosts: debug.example.com
  gather_facts: false

  tasks:
    - name: a remote module execution
      service:
        name: dnsmasq
        state: stopped
        enabled: no
```

This play simply calls the `service` module to ensure that the `dnsmasq` service is stopped and will not start up upon boot. As stated above, we need to make a copy of the `service` module and place it in `library/`. The location of the `service` module to copy from will vary based on the way Ansible is installed. Typically, this module will be located in the `modules/core/system/` subdirectory of where the Ansible Python code lives, like `/Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/modules/core/system/service.py` on my system. Then, we can edit it to put in our break point:



The screenshot shows a vim editor window titled "2. vim library/service.py (vim)". The code is as follows:

```

    enabled = dict(type='bool'),
    runlevel = dict(required=False, default='default'),
    arguments = dict(aliases=['args'], default=''),
),
supports_check_mode=True
)
if module.params['state'] is None and module.params['enabled'] is None:
    module.fail_json(msg="Neither 'state' nor 'enabled' set")

import epdb; epdb.serve(port=8080)
service = Service(module)

if service.syslogging:
    syslog.openlog('ansible-%s' % os.path.basename(__file__))
    syslog.syslog(syslog.LOG_NOTICE, 'Service instantiated - platform %s' %
service.platform)
    if service.distribution:
        syslog.syslog(syslog.LOG_NOTICE, 'Service instantiated - distributio
n %s' % service.distribution)
"library/service.py" 1483L, 56184C                                1404,1          95%
```

We'll put the break point just before the `service` object gets created, near line 1404. First, the `epdb` module must be imported (meaning that the `epdb` Python library needs to exist on the remote host), then the server needs to be started with the `serve()` function. This function takes an optional port argument to define which port to use instead of the default 8080. Now, we can run this playbook to set up the server that will wait for a client connection:

```
2. ansible-playbook -i mastery-debug epdb.yml -vv (sftp)
~/src/mastery> ansible-playbook -i mastery-debug epdb.yml -vv
PLAY [remote code debug] *****

TASK: [a remote module execution] *****
<173.247.105.30> REMOTE_MODULE service name=dnsmasq state=stopped
█
```

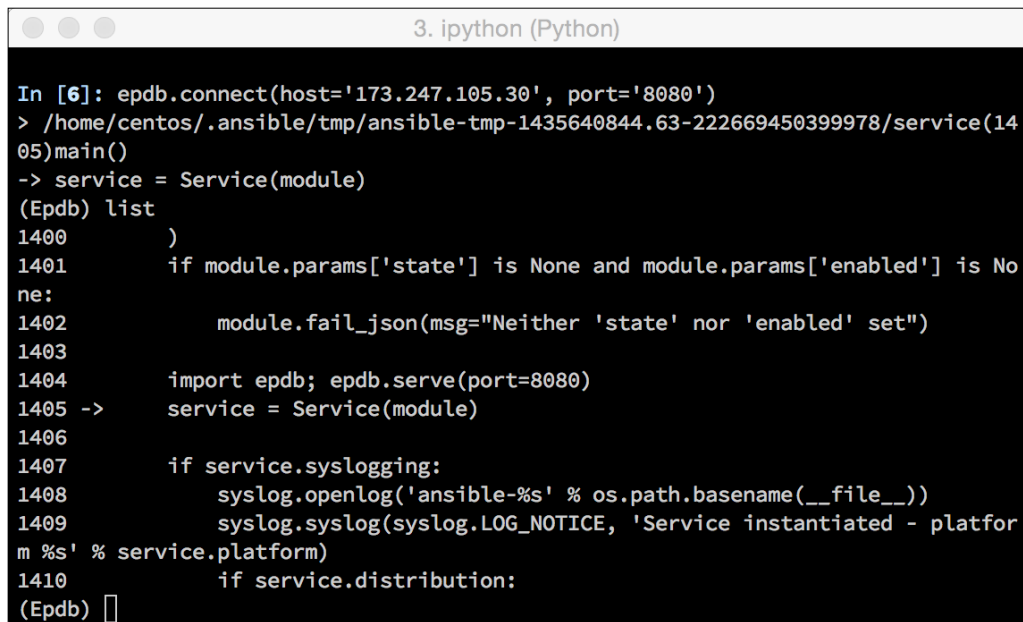
Now that the server is running, we can connect to it from another terminal. Connecting to the running process requires the `epdb` software as well, which supplies client code. I find it easiest to use the `edb` client software within an interactive `ipython` session. First, import the `epdb` library and then call the `connect()` method with the address of the server and port as arguments:

```
3. ipython (Python)

In [5]: import epdb

In [6]: epdb.connect(host='173.247.105.30', port='8080')
> /home/centos/.ansible/tmp/ansible-tmp-1435638948.49-226810210773673/service(1405)main()
-> service = Service(module)
(Epdb) █
```

From this point on, we can debug as normal. The commands we've used before still exist, such as `list` to show where in the code the current frame is:



```

3. ipython (Python)

In [6]: epdb.connect(host='173.247.105.30', port='8080')
> /home/centos/.ansible/tmp/ansible-tmp-1435640844.63-222669450399978/service(1405)main()
-> service = Service(module)
(Epdb) list
1400     )
1401     if module.params['state'] is None and module.params['enabled'] is None:
1402         module.fail_json(msg="Neither 'state' nor 'enabled' set")
1403
1404     import epdb; epdb.serve(port=8080)
1405 ->     service = Service(module)
1406
1407     if service.syslogging:
1408         syslog.openlog('ansible-%s' % os.path.basename(__file__))
1409         syslog.syslog(syslog.LOG_NOTICE, 'Service instantiated - platform %s' % service.platform)
1410         if service.distribution:
(Epdb)

```

Using the debugger, we can walk through the `service` module to track how it decides which underlying tool to use to interact with services on a host, trace which commands are executed on the host, determine how a change is computed, and so on. The entire file can be stepped through, including any other external libraries the module may make use of, allowing debugging of other non-module code on the remote host as well.

An unfortunate side effect of using `epdb` is that when exiting the debugger, the task itself will fail due to some output printed by `epdb` when it starts the server:

```
2. jkeating@serenity-2: ~/src/mastery (zsh)
TASK: [a remote module execution] *****
failed: [debug.example.com] => {"failed": true, "parsed": false}
Serving on port 8080
OpenSSH_6.2p2, OpenSSL 0.9.8r 8 Dec 2011
debug1: Reading configuration data /Users/jkeating/.ssh/config
debug1: /Users/jkeating/.ssh/config line 53: Applying options for *
debug1: /Users/jkeating/.ssh/config line 69: Applying options for 173.247.105.*
debug1: Reading configuration data /etc/ssh_config
debug1: /etc/ssh_config line 20: Applying options for *
debug1: /etc/ssh_config line 102: Applying options for *
debug1: auto-mux: Trying existing master
debug1: mux_client_request_session: master session id: 2
Shared connection to 173.247.105.30 closed.

FATAL: all hosts have already failed -- aborting

PLAY RECAP *****
      to retry, use: --limit @/Users/jkeating/epdb.retry

debug.example.com      : ok=0    changed=0    unreachable=0    failed=1

exit 2
~/src/mastery> █
```

Because of this side effect, it is not possible to debug more than one task per host in a given `ansible-playbook` run.

Debugging the action plugins

Some modules are actually action plugins. These are tasks that will execute some code locally before transporting code to the remote host. Some examples of action plugins include `copy`, `fetch`, `script`, and `template`. The source to these plugins can be found in `runner/action_plugins/`. Each plugin will have its own file in this directory that can be edited to have break points inserted to debug the code executed prior to (or in lieu of) sending code to the remote host. Debugging these is typically done with `pdb`, as most of the code is executed locally.

Summary

Ansible is software, and software breaks. It's not a matter of if, but when. Invalid input, improper assumptions, unexpected environments — all things that can lead to a frustrating situation when tasks and plays are just not performing as expected. Introspection and debugging are troubleshooting techniques that can quickly turn frustration into elation when a root cause is discovered.

In our last chapter, we will learn how to extend the functionality of Ansible by writing our own modules, plugins, and inventory sources.

8

Extending Ansible

Ansible takes the kitchen sink approach to functionality. There are nearly 300 modules available for use within Ansible at the time of writing this book. In addition, there are numerous callback plugins, lookup plugins, filter plugins, and dynamic inventory plugins. Even with all of that functionality, there still can exist a need to add new functionality.

This chapter will explore the following ways in which new capabilities can be added to Ansible:

- Developing modules
- Developing plugins
- Developing dynamic inventory plugins

Developing modules

Modules are the workhorses of Ansible. They provide just enough abstraction to enable playbooks to be stated simply and clearly. There are nearly 150 core modules maintained by the core Ansible development team covering clouds, commands, databases, files, network, packaging, source control, system, utilities, web infrastructure and more. In addition, there are more than 100 other extra modules, largely maintained by community contributors, that expand functionality in many of these categories. The real magic happens inside the module code, which takes in the arguments passed to it and works to establish the desired outcome.

Modules in Ansible are the bits of code that get transported to the remote host to be executed. They can be written in any language that the remote host can execute; however, Ansible provides some very useful shortcuts if writing the module in Python.

The basic module construct

A module exists to satisfy a need — the need to do some piece of work on a host. Modules usually, but not always, expect input, and will return some sort of output. Modules also strive to be idempotent, allowing rerunning the module over and over again without having a negative impact. In Ansible, the input is in the form of command-line arguments to the module, and output is delivered as JSON to standard out.

Input is generally provided in the space-separated `key=value` syntax, and it's up to the module to deconstruct these into the usable data. If using Python, there are convenience functions to manage this, and if using a different language, then it is up to the module code to fully process the input.

The output is JSON formatted. Convention dictates that in a success scenario, the JSON output should have at least one key, `changed`, which is a Boolean to indicate whether the module execution resulted in a change or not. Additional data can be returned as well, which may be useful to define specifically what changed, or provide important information back to the playbook for later use. Additionally, host facts can be returned in the JSON data to automatically create host variables based on the module execution results. We will see more on this later.

Custom modules

Ansible provides an easy mechanism to utilize custom modules outside of what comes with Ansible. As we learned in *Chapter 1, System Architecture and Design of Ansible*, Ansible will search many locations to find a requested module. One such location, the first location, is the `library/` subdirectory of the path where the top-level playbook resides. This is where we will place our custom module so that we can use it in our example playbook.

Modules can also be embedded within roles to deliver the added functionality that a role may depend upon. These modules are only available to the role that contains them or any other roles or tasks executed after the role containing the module. To deliver a module with a role, place the module in the `library/` subdirectory of the role's root.

Simple module

To demonstrate the ease of writing Python-based modules, let's create a simple module. The purpose of this module will be to remotely copy a source file to a destination file, a simple task that we can build up from. To start our module, we need to create the module file. For easy access to our new module, we'll create the file in the `library/` subdirectory of the working directory we've already been using. We'll call this module `remote_copy.py`, and to start it off, we'll need to put in a `sha-bang` line to indicate that this module is to be executed with Python:

```
#!/usr/bin/python
#
```

For Python-based modules, the convention is to use `/usr/bin/python` as the listed executable. When executed on a remote system, the configured Python interpreter for the remote host is used to execute the module, so fret not if your Python doesn't exist in this path. Next, we'll import a Python library we'll use later in the module, called `shutil`:

```
import shutil
```

Now, we're ready to create our main function. The main function is essentially the entry point to the module, where the arguments to the module will be defined and where the execution will start. When creating modules in Python, we can take some shortcuts in this main function to bypass a lot of boilerplate code, and get straight to the argument definitions. We do this by creating an `AnsibleModule` object and giving it an `argument_spec` dictionary for the arguments:

```
def main():
    module = AnsibleModule(
        argument_spec = dict(
            source=dict(required=True, type='str'),
            dest=dict(required=True, type='str')
        )
    )
```

In our module, we're providing two arguments. The first argument is `source`, which we'll use to define the source file for the copy. The second argument is `dest`, the destination for the copy. Both of these arguments are marked as `required`, which will cause an error from Ansible if one of the two is not provided. Both arguments are of the type `string`. The location of the `AnsibleModule` class has not yet been defined, as that happens later in the file.

With a module object at our disposal, we can now create the code that will do the actual work on the remote host. We'll make use of `shutil.copy` and our provided arguments to accomplish the copy:

```
shutil.copy(module.params['source'],
            module.params['dest'])
```

The `shutil.copy` function expects a source and a destination, which we've provided by accessing `module.params`. The `module.params` dictionary holds all of the parameters for the module. Having completed the copy, now we are ready to return the results to Ansible. This is done via another `AnsibleModule` method, `exit_json`. This method expects a set of `key=value` arguments and will format it appropriately for a JSON return. Since we're always performing a copy, we will always return a change for simplicity's sake:

```
module.exit_json(changed=True)
```

This line will exit the function, and thus the module. This function assumes a successful action and will exit the module with the appropriate return code for success: 0. We're not done with our module's code though, we still have to account for the `AnsibleModule` location. This is where a bit of magic happens, where we tell Ansible what other code to combine with our module to create a complete work that can be transported:

```
from ansible.module_utils.basic import *
```

That's all it takes! That one line gets us access to all of the basic `module_utils`, a decent set of helper functions and classes. There is one last thing we should put into our module, a couple of lines of code telling the interpreter to execute the `main()` function when the module file is executed:

```
if __name__ == '__main__':
    main()
```

Now our module file is complete and we can test it with a playbook. We'll call our playbook `simple_module.yaml`, and store it in the same directory as the `library/` directory where we've just written our module file. We'll run the play on `localhost` for simplicity's sake and use a couple of filenames in `/tmp` for the source and destination. We'll also use a task to ensure that we have a source file to begin with:

```
---
- name: test remote_copy module
  hosts: localhost
  gather_facts: false

  tasks:
```

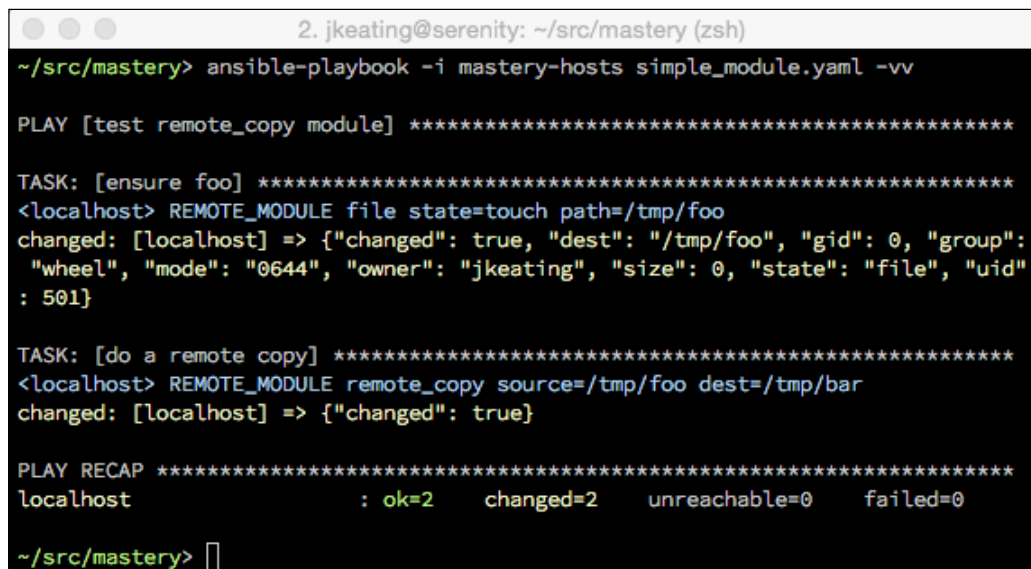
```

- name: ensure foo
  file:
    path: /tmp/foo
    state: touch

- name: do a remote copy
  remote_copy:
    source: /tmp/foo
    dest: /tmp/bar

```

To run this playbook, we'll reference our `mastery-hosts` file. If the `remote_copy` module file is written to the correct location, everything will work just fine, and the screen output will look as follows:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts simple_module.yaml -vv

PLAY [test remote_copy module] *****

TASK: [ensure foo] *****
<localhost> REMOTE_MODULE file state=touch path=/tmp/foo
changed: [localhost] => {"changed": true, "dest": "/tmp/foo", "gid": 0, "group":
"wheel", "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid"
: 501}

TASK: [do a remote copy] *****
<localhost> REMOTE_MODULE remote_copy source=/tmp/foo dest=/tmp/bar
changed: [localhost] => {"changed": true}

PLAY RECAP *****
localhost                : ok=2    changed=2    unreachable=0    failed=0

~/src/mastery>

```

Our first task touches the `/tmp/foo` path to ensure that it exists, and then our second task makes use of `remote_copy` to copy `/tmp/foo` to `/tmp/bar`. Both tasks are successful, resulting in a change each time.

Module documentation

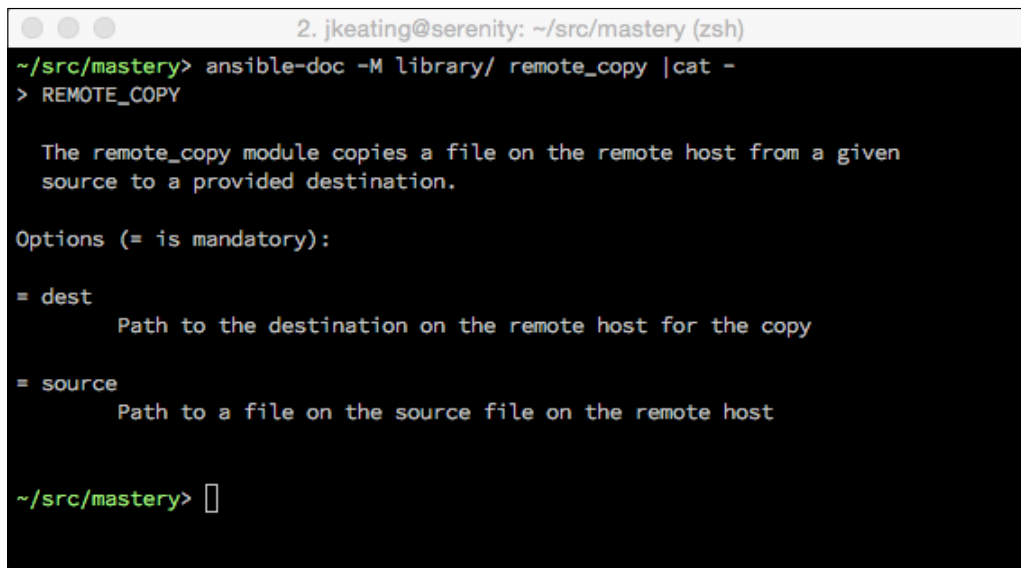
No module should be considered complete unless it contains documentation on how to operate the module. Documentation for modules exists within the module itself, in special variables called `DOCUMENTATION`, `EXAMPLES`, and `RETURN`.

The `DOCUMENTATION` variable contains a specially formatted string describing the module name, the version at which it was added to Ansible (if it is in Ansible proper), a short description of the module, a longer description, a description of the module arguments, author and license information, and any extra notes useful to users of the module. Let's add a `DOCUMENTATION` string to our module:

```
import shutil

DOCUMENTATION = '''
---
module: remote_copy
version_added: future
short_description: Copy a file on the remote host
description:
    - The remote_copy module copies a file on the remote host from a
      given source to a provided destination.
options:
    source:
        description:
            - Path to a file on the source file on the remote host
        required: True
    dest:
        description:
            - Path to the destination on the remote host for the copy
        required: True
author:
    - Jesse Keating
'''
```

The format of the string is essentially YAML, with some top-level keys containing hash structures (like the `options` key). Each option has subelements to describe the option, indicate whether the option is required, list any aliases for the option, list static choices for the option, or indicate a default value for the option. With this string saved to the module, we can test our formatting to ensure that the documentation will render correctly. This is done via the `ansible-doc` tool with an argument to indicate where to search for modules. If we run it from the same place as our playbook, the command will be `ansible-doc -M library/ remote_copy`, and the output will be as follows:



```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-doc -M library/ remote_copy |cat -
> REMOTE_COPY

The remote_copy module copies a file on the remote host from a given
source to a provided destination.

Options (= is mandatory):

= dest
    Path to the destination on the remote host for the copy

= source
    Path to a file on the source file on the remote host

~/src/mastery> 

```

In this example, I've piped the output into `cat` to prevent the pager from hiding the execution line. Our documentation string appears to be formatted correctly, and provides the user with important information regarding the usage of the module.

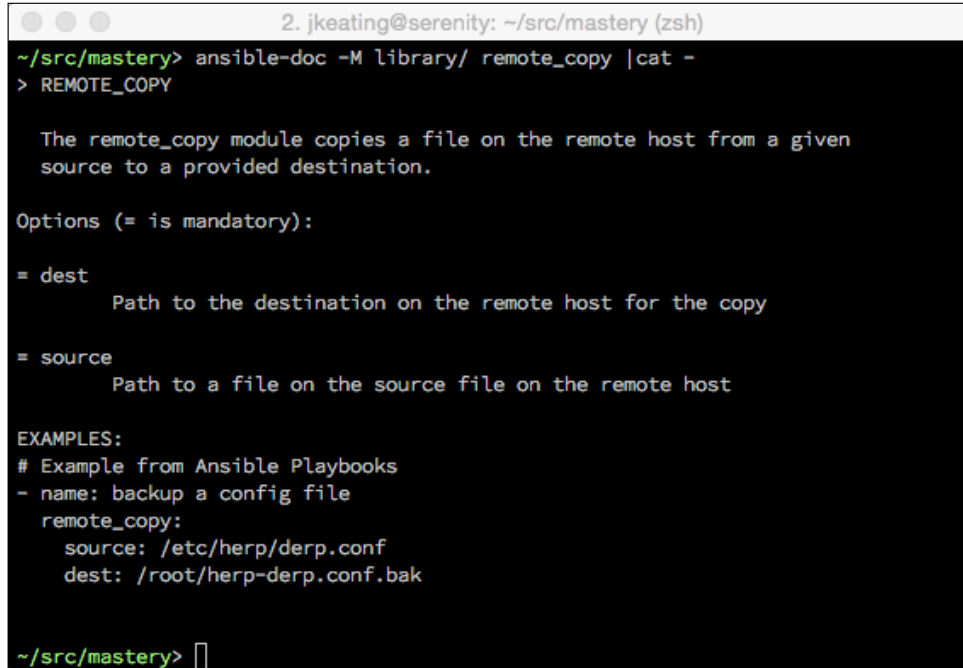
The `EXAMPLES` string is used to provide one or more example uses of the module, snippets of the task code that one would use in a playbook. Let's add an example task to demonstrate the usage. This variable definition traditionally goes below the `DOCUMENTATION` definition:

```

EXAMPLES = '''
# Example from Ansible Playbooks
- name: backup a config file
  remote_copy:
    source: /etc/herp/derp.conf
    dest: /root/herp-derp.conf.bak
'''

```

With this variable defined, our `ansible-doc` output will now include the example, as we can see in the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-doc -M library/ remote_copy | cat -
> REMOTE_COPY

The remote_copy module copies a file on the remote host from a given
source to a provided destination.

Options (= is mandatory):

= dest
    Path to the destination on the remote host for the copy

= source
    Path to a file on the source file on the remote host

EXAMPLES:
# Example from Ansible Playbooks
- name: backup a config file
  remote_copy:
    source: /etc/herp/derp.conf
    dest: /root/herp-derp.conf.bak

~/src/mastery> 
```

The last documentation variable, `RETURN`, is a relatively new feature of module documentation. This variable is used to describe the return data from a module execution. Return data is often useful as a registered variable for later usage, and having documentation of what return data to expect can aid in playbook development. Our module doesn't have any return data yet; so before we can document return data, we first have to add return data. This can be done by modifying the `module.exit_json` line to add more information. Let's add the source and dest data into the return output:

```
module.exit_json(changed=True, source=module.params['source'],
                 dest=module.params['dest'])
```

Rerunning the playbook will show extra data being returned as shown in the following screenshot:

```

2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts simple_module.yaml -vv

PLAY [test remote_copy module] *****

TASK: [ensure foo] *****
<localhost> REMOTE_MODULE file state=touch path=/tmp/foo
changed: [localhost] => {"changed": true, "dest": "/tmp/foo", "gid": 0, "group":
"wheel", "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid"
: 501}

TASK: [do a remote copy] *****
<localhost> REMOTE_MODULE remote_copy source=/tmp/foo dest=/tmp/bar
changed: [localhost] => {"changed": true, "dest": "/tmp/bar", "gid": 0, "group":
"wheel", "mode": "0644", "owner": "jkeating", "size": 0, "source": "/tmp/foo",
"state": "file", "uid": 501}

PLAY RECAP *****
localhost                : ok=2    changed=2    unreachable=0    failed=0

~/src/mastery> 

```

Looking closely at the return data, we can see more data than we put in our module. This is actually a bit of a helper functionality within Ansible; when a return dataset includes a `dest` variable, Ansible will gather more information about the destination file. The extra data gathered is `gid` (group ID), `group` (group name), `mode` (permissions), `uid` (owner ID), `owner` (owner name), `size`, and `state` (file, link, or directory). We can document all of these return items in our `RETURN` variable, which is added after the `EXAMPLES` variable:

```

RETURN = '''
source:
    description: source file used for the copy
    returned: success
    type: string
    sample: "/path/to/file.name"
dest:
    description: destination of the copy
    returned: success
    type: string

```

```
    sample: "/path/to/destination.file"
gid:
  description: group ID of destination target
  returned: success
  type: int
  sample: 502
group:
  description: group name of destination target
  returned: success
  type: string
  sample: "users"
uid:
  description: owner ID of destination target
  returned: success
  type: int
  sample: 502
owner:
  description: owner name of destination target
  returned: success
  type: string
  sample: "fred"
mode:
  description: permissions of the destination target
  returned: success
  type: int
  sample: 0644
size:
  description: size of destination target
  returned: success
  type: int
  sample: 20
state:
  description: state of destination target
  returned: success
  type: string
  sample: "file"
'''
```

Each return item is listed with a description, the cases when the item would be in the return data, the type of item it is, and a sample of the value. The `RETURN` string is essentially repeated verbatim in the `ansible-doc` output, as shown in the following (abbreviated) example:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-doc -M library/ remote_copy |cat -
> REMOTE_COPY

The remote_copy module copies a file on the remote host from a given
source to a provided destination.

Options (= is mandatory):

= dest
    Path to the destination on the remote host for the copy

= source
    Path to a file on the source file on the remote host

EXAMPLES:
# Example from Ansible Playbooks
- name: backup a config file
  remote_copy:
    source: /etc/herp/derp.conf
    dest: /root/herp-derp.conf.bak

RETURN VALUES:
source:
  description: source file used for the copy
  returned: success
  type: string
  sample: "/path/to/file.name"
dest:
  description: destination of the copy
  returned: success
  type: string
  sample: "/path/to/destination.file"
```

Providing fact data

Similar to data returned as part of a module exit, a module can directly create facts for a host by returning data in a key named `ansible_facts`. Providing facts directly from a module eliminates the need to register the return of a task with a subsequent `set_fact` task. To demonstrate this usage, let's modify our module to return the source and dest data as facts. Because these facts will become top-level host variables, we'll want to use more descriptive fact names than `source` and `dest`:

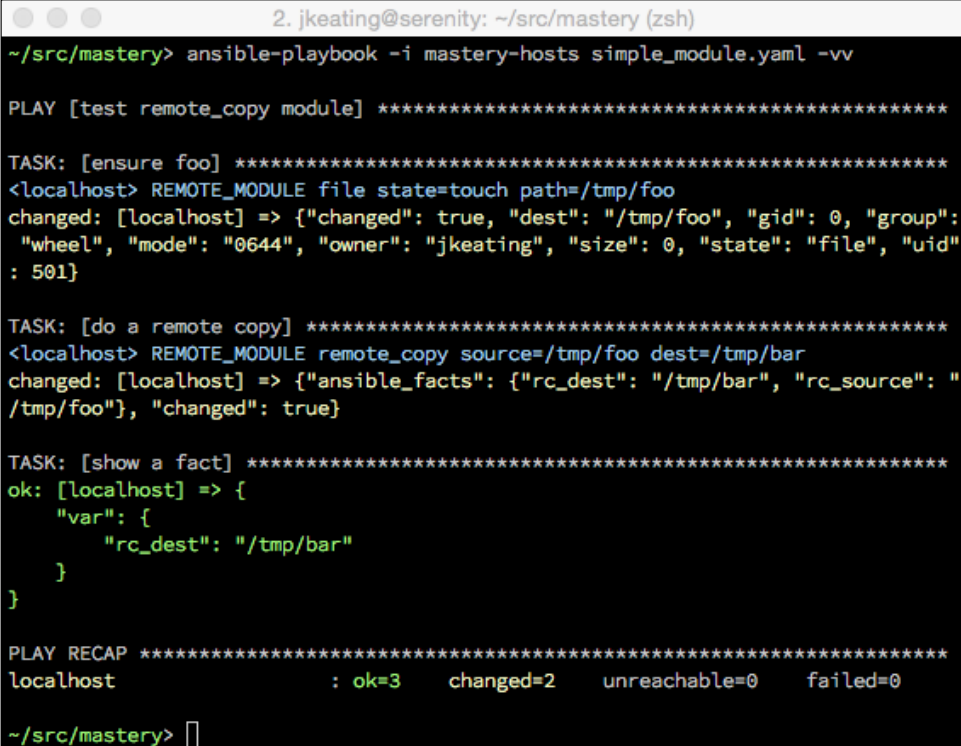
```
facts = {'rc_source': module.params['source'],
        'rc_dest': module.params['dest']}

module.exit_json(changed=True, ansible_facts=facts)
```

We'll also add a task to our playbook to use one of the facts in a debug statement:

```
- name: show a fact
  debug:
    var: rc_dest
```

Now, running the playbook will show the new return data plus the use of the variable:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts simple_module.yaml -vv

PLAY [test remote_copy module] *****

TASK: [ensure foo] *****
<localhost> REMOTE_MODULE file state=touch path=/tmp/foo
changed: [localhost] => {"changed": true, "dest": "/tmp/foo", "gid": 0, "group":
"wheel", "mode": "0644", "owner": "jkeating", "size": 0, "state": "file", "uid"
: 501}

TASK: [do a remote copy] *****
<localhost> REMOTE_MODULE remote_copy source=/tmp/foo dest=/tmp/bar
changed: [localhost] => {"ansible_facts": {"rc_dest": "/tmp/bar", "rc_source": "
/tmp/foo"}, "changed": true}

TASK: [show a fact] *****
ok: [localhost] => {
  "var": {
    "rc_dest": "/tmp/bar"
  }
}

PLAY RECAP *****
localhost                : ok=3    changed=2    unreachable=0    failed=0

~/src/mastery> 
```

If our module does not return facts, we will have to register the output and use `set_fact` to create the fact for us, like this:

```
- name: do a remote copy
  remote_copy:
    source: /tmp/foo
    dest: /tmp/bar
    register: mycopy

- name: set facts from mycopy
  set_fact:
    rc_dest: "{{ mycopy.dest }}"
```

Check mode

Since version 1.1, Ansible has supported check mode, a mode of operation that will pretend to make changes to a system without actually changing the system. Check mode is useful for testing whether a change will actually happen, or if a system state has drifted since the last Ansible run. Check mode depends on modules to support check mode and return data as if it had actually completed the change. Supporting check mode in our module requires two changes; the first is to indicate that the module supports check mode, and the second is to detect when check mode is active and return data before execution.

Supporting check mode

To indicate that a module supports check mode, an argument has to be set when creating the module object. This can be done before or after the `argument_spec` variable is defined in the module object; here, we will do it after it is defined:

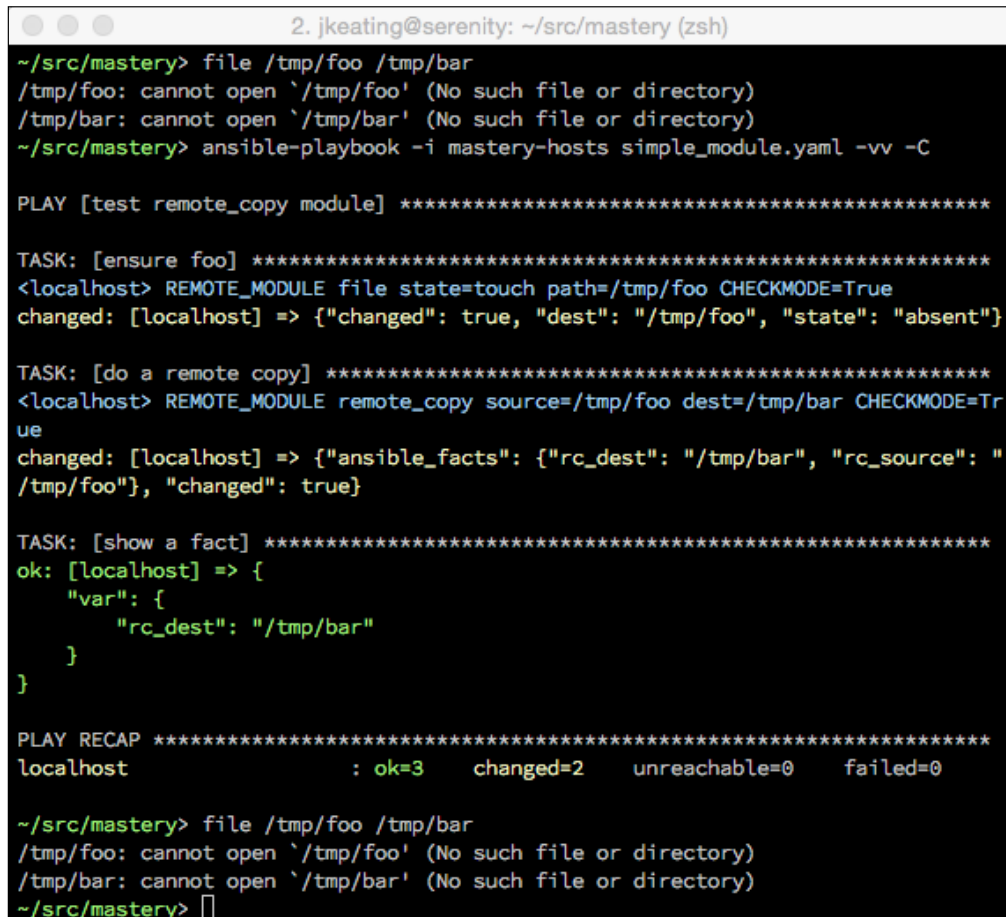
```
module = AnsibleModule(
    argument_spec = dict(
        source=dict(required=True, type='str'),
        dest=dict(required=True, type='str')
    ),
    supports_check_mode=True
)
```


Handling check mode

Detecting when check mode is active is very easy. The module object will have a `check_mode` attribute, which will be set to Boolean value `true` when check mode is active. In our module, we want to detect whether check mode is active before performing the copy. We can simply move the copy action into an `if` statement to avoid copying when check mode is active. The return can happen without any changes:

```
if not module.check_mode:
    shutil.copy(module.params['source'],
                module.params['dest'])
```

Now, we can run our playbook and add the `-c` argument to our execution. This argument engages check mode. We'll also test to ensure that the playbook did not actually create and copy the files. Let's take a look at the following screenshot:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> file /tmp/foo /tmp/bar
/tmp/foo: cannot open `/tmp/foo' (No such file or directory)
/tmp/bar: cannot open `/tmp/bar' (No such file or directory)
~/src/mastery> ansible-playbook -i mastery-hosts simple_module.yaml -vv -C

PLAY [test remote_copy module] *****

TASK: [ensure foo] *****
<localhost> REMOTE_MODULE file state=touch path=/tmp/foo CHECKMODE=True
changed: [localhost] => {"changed": true, "dest": "/tmp/foo", "state": "absent"}

TASK: [do a remote copy] *****
<localhost> REMOTE_MODULE remote_copy source=/tmp/foo dest=/tmp/bar CHECKMODE=True
changed: [localhost] => {"ansible_facts": {"rc_dest": "/tmp/bar", "rc_source": "/tmp/foo"}, "changed": true}

TASK: [show a fact] *****
ok: [localhost] => {
  "var": {
    "rc_dest": "/tmp/bar"
  }
}

PLAY RECAP *****
localhost                : ok=3    changed=2    unreachable=0    failed=0

~/src/mastery> file /tmp/foo /tmp/bar
/tmp/foo: cannot open `/tmp/foo' (No such file or directory)
/tmp/bar: cannot open `/tmp/bar' (No such file or directory)
~/src/mastery> []
```

Although the module output looks like it created and copied files, we can see that the files referenced did not exist before execution and still do not exist after execution.

Developing plugins

Plugins are another way of extending or modifying the functionality of Ansible. While modules are executed as tasks, plugins are utilized in a variety of other places. Plugins are broken down into a few types, based on where they would plug in to the Ansible execution. Ansible ships some plugins for each of these areas, and end users can create their own to extend the functionality of these specific areas.

Connection type plugins

Any time Ansible makes a connection to a host to perform a task, a connection plugin is used. Ansible ships with a few connection plugins, including `ssh`, `docker`, `chroot`, `local`, and `smart`. Additional connection mechanisms can be utilized by Ansible to connect to remote systems by creating a connection plugin, which may be useful if faced with connecting to some new type of system, like a network switch, or maybe your refrigerator some day. Creating connection plugins is a bit beyond the scope of this book; however, the easiest way to get started is to read through the existing plugins that ship with Ansible and pick one to modify it as necessary. The existing plugins can be found in `runner/connection_plugins/` wherever the Ansible Python libraries are installed on your system, such as `/Users/jkeating/.virtualenvs/ansible/lib/python2.7/site-packages/ansible/runner/connection_plugins/` on my system.

Shell plugins

Much like connection plugins, Ansible makes use of shell plugins to execute things in a shell environment. Each shell has subtle differences that Ansible cares about in order to properly execute commands, redirect output, discover errors, and other such interactions. Ansible supports a number of shells, including `sh`, `csh`, `fish`, and `powershell`. We can add more shells by implementing a new shell plugin.

Lookup plugins

Lookup plugins are how Ansible accesses outside data sources from the host system, and implements language features such as looping constructs (`with_*`). A lookup plugin can be created to access data from an existing data store, or to create a new looping mechanism. The existing lookup plugins can be found in `runner/lookup_plugins/`.

Vars plugins

Constructs to inject variable data exist in the form of vars plugins. Data such as `host_vars` and `group_vars` are implemented via plugins. While it's possible to create new variable plugins, most often it is better to create a custom inventory source or a fact module instead.

Fact caching plugins

Recently (as of version 1.8), Ansible gained the ability to cache facts between playbook runs. Where the facts are cached depends on the configured cache plugin that is used. Ansible includes plugins to cache facts in memory (not actually cached between runs), `memcached`, `redis`, and `jsonfile`. Creating a fact caching plugin can enable additional caching mechanisms.

Filter plugins

While Jinja2 includes a number of filters, Ansible has made filters pluggable to extend the Jinja2 functionality. Ansible includes a number of filters that are useful to Ansible operations, and users of Ansible can add more. Existing plugins can be found in `runner/filter_plugins/`.

To demonstrate the development of a filter plugin, we will create a simple filter plugin to do a silly thing to text strings. We will create a filter that will replace any occurrence of "the cloud" with "somebody else's computer". We'll define our filter in a file within a new directory, `filter_plugins/`, in our existing working directory. The name of the file doesn't matter, as we'll define the name of the filter within the file; so, let's name our file `filter_plugins/sample_filter.py`. First, we need to define the function that will perform the translation, and provide the code to translate the strings:

```
def cloud_truth(a):
    return a.replace("the cloud", "somebody else's computer")
```

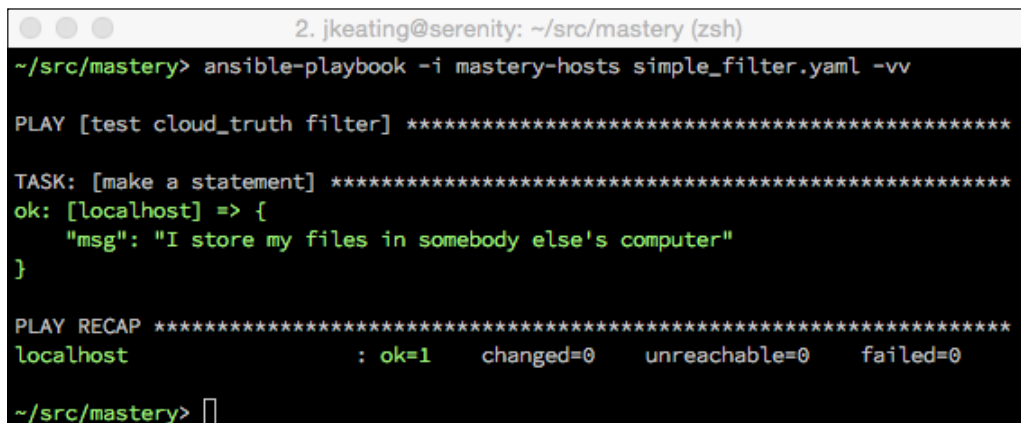
Next, we'll need to construct a `FilterModule` object and define our filter within it. This object is what Ansible will load, and Ansible expects there to be a `filters` function within the object that returns a set of filter names to functions within the file:

```
class FilterModule(object):
    '''Cloud truth filters'''
    def filters(self):
        return {'cloud_truth': cloud_truth}
```

Now, we can use this filter in a playbook, which we'll call `simple_filter.yaml`:

```
---
- name: test cloud_truth filter
  hosts: localhost
  gather_facts: false
  vars:
    statement: "I store my files in the cloud"
  tasks:
    - name: make a statement
      debug:
        msg: "{{ statement | cloud_truth }}"
```

Now, let's run our playbook and see our filter in action:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-hosts simple_filter.yaml -vv

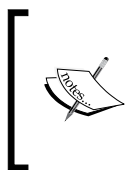
PLAY [test cloud_truth filter] *****

TASK: [make a statement] *****
ok: [localhost] => {
  "msg": "I store my files in somebody else's computer"
}

PLAY RECAP *****
localhost : ok=1 changed=0 unreachable=0 failed=0

~/src/mastery> 
```

Our filter worked, and it turned "the cloud" into "somebody else's computer". This is a silly example without any error handling, but it clearly demonstrates our capability to extend Ansible and Jinja2's filter capabilities.



Although the file name a filter exists in can be whatever the developer wants to name it, a best practice is to name it after the filter itself so that it can easily be found in the future, potentially by other collaborators. This example did not follow this to demonstrate that the file name is not attached to the filter name.

Callback plugins

Callbacks are places in Ansible execution that can be plugged into for added functionality. There are expected callback points that can be registered against to trigger custom actions at those points. Here is a list of possible points to trigger functionality:

- `runner_on_failed`
- `runner_on_ok`
- `runner_on_skipped`
- `runner_on_unreachable`
- `runner_on_no_hosts`
- `runner_on_async_poll`
- `runner_on_async_ok`
- `runner_on_async_failed`
- `playbook_on_start`
- `playbook_on_notify`
- `playbook_on_no_hosts_matched`
- `playbook_on_no_hosts_remaining`
- `playbook_on_task_start`
- `playbook_on_vars_prompt`
- `playbook_on_setup`
- `playbook_on_import_for_host`
- `playbook_on_not_import_for_host`
- `playbook_on_play_start`
- `playbook_on_stats`

As an Ansible run reaches each of these states, any plugins that have code to run at these points will be executed. This provides a tremendous ability to extend Ansible without having to modify the base code.

Callbacks can be utilized in a variety of ways: to change how things are displayed on screen, to update a central status system on progress, to implement a global locking system, or nearly anything imaginable. It's the most powerful way to extend the functionality of Ansible. To demonstrate our ability to develop a callback plugin, we'll create a simple plugin that will print something silly on the screen as a playbook executes:

1. First, we'll need to make a new directory to hold our callback. The location Ansible will look for is `callback_plugins/`. Much like the filter plugin above, we do not need to name our callback plugin anything special, although it is good practice to name the file uniquely.
2. We'll name ours `callback_plugins/simple_callback.py`. Inside this file, we'll need to create a `CallbackModule` class, subclassed from `object`.
3. Within this class, we define one or more of the callback points we'd like to plug into in order to make something happen.
4. We only have to define the points we want to plug in. In our case we'll plug into the `on_any` point so that our plugin runs at every callback spot.
5. We'll also make use of a helper function `display`, which we can use to cause text to show up on the screen.

```
from ansible.callbacks import display

class CallbackModule(object):
    def on_any(self, *args, **kwargs):
        msg = '\xc2\xaf\_(\xe3\x83\x84)\_/\xc2\xaf'
        display(msg * 8)
```

That's all we have to write into our callback. Once it's saved, we can rerun our previous playbook, which exercised our `sample_filter`, but this time we'll see something different on screen:

```

2. jkeating@serenity: ~/src/mastery (zsh)

~/src/mastery> ansible-playbook -i mastery-hosts simple_filter.yaml -vv
^_\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^

PLAY [test cloud_truth filter] *****
^_\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^

TASK: [make a statement] *****
^_\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^
ok: [localhost] => {
    "msg": "I store my files in somebody else's computer"
}
^_\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^

PLAY RECAP *****
^_\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^^\(\U)\_/^
localhost                : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 

```

Very silly, but demonstrates the ability to plug into various points of a playbook execution. We chose to display a series of shrugs on screen, but we could have just as easily interacted with some internal audit and control system to record actions, or to report progress to an IRC or Slack channel.

Action plugins

Action plugins exist to hook into the task construct without actually causing a module to be executed, or to execute code locally on the Ansible host before executing a module on the remote host. A number of action plugins are included with Ansible and can be found in `runner/action_plugins/`. One such action plugin is the `template` plugin used in place of a `template` module. When a playbook author writes a `template` task, that task will actually call the `template` plugin to do the work. The plugin, among other things, will render the template locally before copying the content to the remote host. Because actions have to happen locally, the work is done by an action plugin. Another action plugin we should be familiar with is the `debug` plugin, which we've used heavily in this book to print content. Creating a custom action plugin is useful when trying to accomplish both local work and remote work in the same task.

Distributing plugins

Much like distributing custom modules, there are standard places to store custom plugins alongside playbooks that expect to use plugins. The default locations for plugins are the locations that are shipped with the Ansible code install, subdirectories within `~/.ansible/plugins/`, and subdirectories of the project root (the place where the top-level playbook is stored). To utilize plugins from any other location, we need to define the location to find the plugin for the plugin type in an `ansible.cfg` file.

When distributing plugins inside the project root, each plugin type gets its own top-level directory:

- `action_plugins/`
- `cache_plugins/`
- `callback_plugins/`
- `connection_plugins/`
- `shell_plugins/`
- `lookup_plugins/`
- `vars_plugins/`
- `filter_plugins/`

As with other Ansible constructs, the first plugin with a given name found will be used, and just as with modules, the paths relative to the project root are checked first, allowing a local override of an existing plugin. Simply place the plugin file into the appropriate subdirectory, and it will automatically get used when referenced.

Developing dynamic inventory plugins

Inventory plugins are bits of code that will create inventory data for an Ansible execution. In many environments, the simple `ini` file style inventory source and variable structure is not sufficient to represent the actual infrastructure being managed. In such cases, a dynamic inventory source is desired, one that will discover the inventory and data at runtime for every execution of Ansible. A number of these dynamic sources ship with Ansible, primarily to operate Ansible with the infrastructure built into one cloud computing platform or another. A short, incomplete list of dynamic inventory plugins that ship with Ansible includes:

- `apache-libcloud`
- `cobbler`
- `console_io`

- `digital_ocean`
- `docker`
- `ec2`
- `gce`
- `libvirt_lxc`
- `linode`
- `openshift`
- `openstack`
- `rax`
- `vagrant`
- `vmware`
- `windows_azure`

An inventory plugin is essentially an executable script. Ansible calls the script with set arguments (`--list` or `--host <hostname>`) and expects JSON formatted output on standard out. When the `--list` argument is provided, Ansible expects a list of all the groups to be managed. Each group can list host membership, child group membership, and group variable data. When the script is called with the `--host <hostname>` argument, Ansible expects host-specific data to be returned (or an empty JSON dictionary).

Using a dynamic inventory source is easy. A source can be used directly by referring to it with the `-i` (`--inventory-file`) option to `ansible` and `ansible-playbook`, or by placing the plugin file in the `ansible.cfg` configured inventory path, or by putting the plugin file inside the directory referred to by either the inventory path in `ansible.cfg` or by the `-i` runtime option.

Before creating an inventory plugin, we must understand the expected format for when `--list` or `--host` is used with our script.

Listing hosts

When the `--list` argument is passed to an inventory script, Ansible expects the JSON output data to have a set of top-level keys. These keys are named for the groups in the inventory. Each group gets its own key. The structure within a group key varies depending on what data needs to be represented in the group. If a group just has hosts and no group level variables, the data within the key can simply be a list of host names. If the group has variables or children (group of groups), then the data needs to be a hash, which can have one or more keys named `hosts`, `vars`, or `children`. The `hosts` and `children` subkeys have a list value, a list of the hosts that exist in the group, or a list of the child groups. The `vars` subkey has a hash value, where each variable's name and value is represented by a key and value.

Listing host variables

When the `--host <hostname>` argument is passed to an inventory script, Ansible expects the JSON output data to simply be a hash of the variables, where each variable name and value is represented by a key and a value. If there are no variables for a given host, an empty hash is expected.

Simple inventory plugin

To demonstrate developing an inventory plugin, we'll create one that simply prints the same host data we've been using in our `mastery-hosts` file. Integrating with a custom asset management system or an infrastructure provider is a bit beyond the scope of this book, so we'll simply code the systems into the plugin itself. We'll write our inventory plugin to a file in the top level of our project root named `mastery-inventory.py`, and make it executable. We'll use Python for this file for the ease of handling execution arguments and JSON formatting:

1. First, we'll need to add a `sha-bang` line to indicate that this script is to be executed with Python:

```
#!/usr/bin/env python
#
```

2. Next, we'll need to import a couple of Python modules that we will need later in our plugin:

```
import json
import argparse
```

3. Now, we'll create a Python dictionary to hold all of our groups. Some of our groups just have hosts, while others have variables or children. We'll format each group accordingly:

```
inventory = {}
inventory['web'] = {'hosts': ['mastery.example.name'],
                  'vars': {'http_port': 80,
                          'proxy_timeout': 5}}
inventory['dns'] = {'hosts': ['backend.example.name']}
inventory['database'] = {'hosts': ['backend.example.name'],
                        'vars': {'ansible_ssh_user': 'database'}}
inventory['frontend'] = {'children': ['web']}
inventory['backend'] = {'children': ['dns', 'database'],
                       'vars': {'ansible_ssh_user': 'blotto'}}
inventory['errors'] = {'hosts': ['scsihost']}
inventory['failtest'] = {'hosts': ["failer%02d" % n for n in
                                   range(1,11)]}
```

4. To recreate our `failtest` group, which in our inventory file was represented as `failer[01:10]`, we used a Python list comprehension to produce the list for us, formatting the items in the list just like our original inventory file. Every other group entry is self-explanatory.
5. Our original inventory also had an `all` group variable that provided a default variable `ansible_ssh_user` to all groups (which groups could override) that we'll define here and make use of later in the file:

```
allgroupvars = {'ansible_ssh_user': 'otto'}
```

6. Next, we need to enter the host-specific variables into their own dictionary. Only two nodes in our original inventory have host-specific variables:

```
hostvars = {}
hostvars['web'] = {'ansible_ssh_host': '192.168.10.25'}
hostvars['scsihost'] = {'ansible_ssh_user': 'jkeating'}
```

7. With all our data defined, we can now move on to the code that will handle argument parsing. This is done via the `argparse` module we imported earlier in the file:

```
parser = argparse.ArgumentParser(description='Simple Inventory')
parser.add_argument('--list', action='store_true',
                    help='List all hosts')
parser.add_argument('--host', help='List details of a host')
args = parser.parse_args()
```

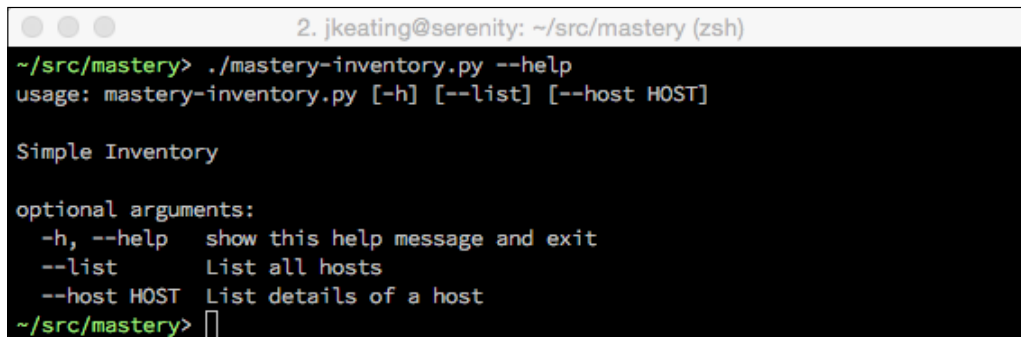
8. After parsing the arguments, we can deal with either the `--list` or `--host` actions. If a list is requested, we simply print a JSON representation of our inventory. This is where we'll take into account the `allgroupvars` data, the default `ansible_ssh_user` for each group. We'll loop through each group, create a copy of the `allgroupvars` data, update that data with any data that may already exist in the group, then replace the group's variable data with the newly updated copy. Finally, we'll print out the end result:

```
if args.list:
    for group in inventory:
        ag = allgroupvars.copy()
        ag.update(inventory[group].get('vars', {}))
        inventory[group]['vars'] = ag
    print(json.dumps(inventory))
```

9. Finally, we'll handle the `--host` action by printing the JSON formatted variable data for the provided host, or an empty hash if there is no host-specific variable data for the provided host:

```
elif args.host:
    print(json.dumps(hostvars.get(args.host, {})))
```

Now, our inventory is ready to test! We can execute it directly and pass the `--help` argument we get for free using `argparse`. This will show us the usage of our script based on the `argparse` data we provided earlier in the file:



```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ./mastery-inventory.py --help
usage: mastery-inventory.py [-h] [--list] [--host HOST]

Simple Inventory

optional arguments:
  -h, --help  show this help message and exit
  --list      List all hosts
  --host HOST List details of a host
~/src/mastery> 
```

If we pass `--list`, we'll get the output of all our groups; and, if we pass `--host` with a couple of hosts, we'll get either the host data or an empty set:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ./mastery-inventory.py --list
{"web": {"hosts": ["mastery.example.name"], "vars": {"ansible_ssh_user": "otto",
"http_port": 80, "proxy_timeout": 5}}, "errors": {"hosts": ["scsihost"], "vars":
: {"ansible_ssh_user": "otto"}}, "frontend": {"children": ["web"], "vars": {"ans
ible_ssh_user": "otto"}}, "database": {"hosts": ["backend.example.name"], "vars"
: {"ansible_ssh_user": "database"}}, "failtest": {"hosts": ["failer01", "failer0
2", "failer03", "failer04", "failer05", "failer06", "failer07", "failer08", "fai
ler09", "failer10"], "vars": {"ansible_ssh_user": "otto"}}, "dns": {"hosts": ["b
ackend.example.name"], "vars": {"ansible_ssh_user": "otto"}}, "backend": {"child
ren": ["dns", "database"], "vars": {"ansible_ssh_user": "blotto"}}}
~/src/mastery>
```

And now with the `--host` argument:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ./mastery-inventory.py --host web
{"ansible_ssh_host": "192.168.10.25"}
~/src/mastery> ./mastery-inventory.py --host mastery.example.name
{}
~/src/mastery>
```

Now, we're ready to use our inventory file with Ansible. Let's make a new playbook (`inventory_test.yaml`) to display the hostname and ssh username data:

```
---
- name: test the inventory
  hosts: all
  gather_facts: false

  tasks:
    - name: hello world
      debug:
        msg: "Hello world, I am {{ inventory_hostname }}.
              My username is {{ ansible_ssh_user }}"
```

To use our new inventory plugin with this playbook, we simply refer to the plugin file with the `-i` argument. Because we are using the `all` hosts group in our playbook, we'll also limit the run to a few groups to save on screen space:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-inventory.py inventory_test.yaml --li
mit backend,frontend,errors

PLAY [test the inventory] *****

TASK: [hello world] *****
ok: [mastery.example.name] => {
  "msg": "Hello world, I am mastery.example.name. My username is otto"
}
ok: [backend.example.name] => {
  "msg": "Hello world, I am backend.example.name. My username is database"
}
ok: [scsihost] => {
  "msg": "Hello world, I am scsihost. My username is jkeating"
}

PLAY RECAP *****
backend.example.name      : ok=1    changed=0    unreachable=0    failed=0
mastery.example.name      : ok=1    changed=0    unreachable=0    failed=0
scsihost                  : ok=1    changed=0    unreachable=0    failed=0

~/src/mastery> 
```

As we can see, we get the hosts we expect, and we get the default ssh user for `master.example.name`. The `backend.example.name` and `scsihost` each show their host-specific ssh username.

Optimizing script performance

With this inventory script, when Ansible starts, it will execute the script once with `--list` to gather the group data. Then, Ansible will execute the script again with `--host <hostname>` for each host it discovered in the first call. With our script, this takes very little time as there are very few hosts, and our execution is very fast. However, in an environment with a large number of hosts or a plugin that takes a while to run, gathering the inventory data can be a lengthy process. Fortunately, there is an optimization that can be made in the return data from a `--list` call that will prevent Ansible from rerunning the script for every host. The host-specific data can be returned all at once inside the group data return, inside of a top-level key named `_meta` that has a subkey named `hostvars` that contains a hash of all the hosts that have host variables and the variable data itself. When Ansible encounters a `_meta` key in the `--list` return, it'll skip the `--host` calls and assume that all of the host-specific data was already returned, potentially saving significant time! Let's modify our inventory script to return host variables inside of `_meta`, and create an error condition inside the `--host` option to show that `--host` is not being called:

1. First, we'll add the `_meta` key to the inventory dictionary after all of the `hostvars` have been defined, just before parsing arguments:

```
hostvars['scsihost'] = {'ansible_ssh_user': 'jkeating'}

inventory['_meta'] = {'hostvars': hostvars}

parser = argparse.ArgumentParser(description='Simple Inventory')
```

2. Next we'll change the `--host` handling to raise an exception:

```
elif args.host:
    raise StandardError("You've been a bad boy")
```

Now, we'll re-run the `inventory_test.yaml` playbook to ensure that we're still getting the right data:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ansible-playbook -i mastery-inventory.py inventory_test.yaml --li
mit backend,frontend,errors

PLAY [test the inventory] *****

TASK: [hello world] *****
ok: [mastery.example.name] => {
  "msg": "Hello world, I am mastery.example.name. My username is otto"
}
ok: [backend.example.name] => {
  "msg": "Hello world, I am backend.example.name. My username is database"
}
ok: [scsihost] => {
  "msg": "Hello world, I am scsihost. My username is jkeating"
}

PLAY RECAP *****
backend.example.name      : ok=1    changed=0    unreachable=0    failed=0
mastery.example.name      : ok=1    changed=0    unreachable=0    failed=0
scsihost                  : ok=1    changed=0    unreachable=0    failed=0
~/src/mastery>
```

Just to be sure, we'll manually run the inventory plugin with the `--hosts` argument to show the exception:

```
2. jkeating@serenity: ~/src/mastery (zsh)
~/src/mastery> ./mastery-inventory.py --host scsihost
Traceback (most recent call last):
  File "./mastery-inventory.py", line 42, in <module>
    raise StandardError("You've been a bad boy")
StandardError: You've been a bad boy
exit 1
~/src/mastery>
```

With this optimization, our simple playbook using our inventory module now runs nearly twice as fast, just because of the gained efficiency in inventory parsing.

Summary

Ansible is a great tool, however, sometimes it doesn't offer all the functionality one might desire. Not every bit of functionality is appropriate to support the main project, nor is it possible to integrate with custom proprietary data sources. For these reasons, there exist facilities within Ansible to extend the functionality. Creating and using custom modules is made easy due to shared module base code. Many different types of plugins can be created and used with Ansible to affect operations in a variety of ways. Inventory sources beyond what Ansible supports can still be used with relative ease and efficiency.

In all cases, there exists a mechanism to provide modules, plugins, and inventory sources alongside the playbooks and roles that depend on the enhanced functionality, making it seamless to distribute.

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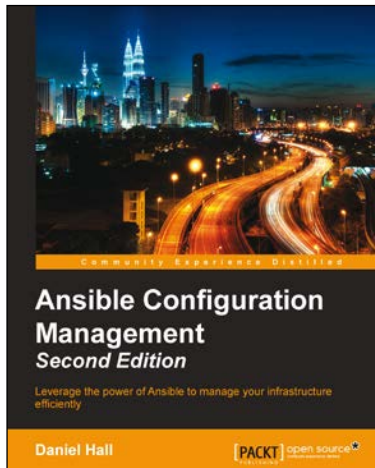
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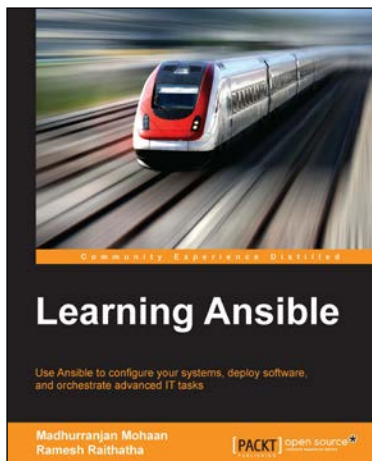
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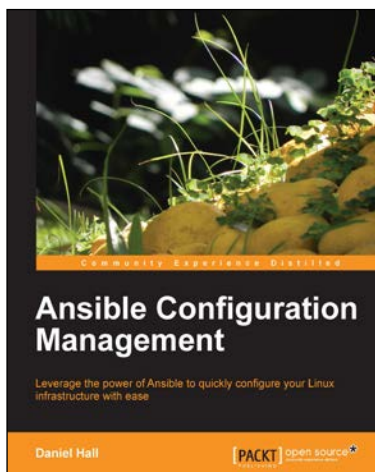
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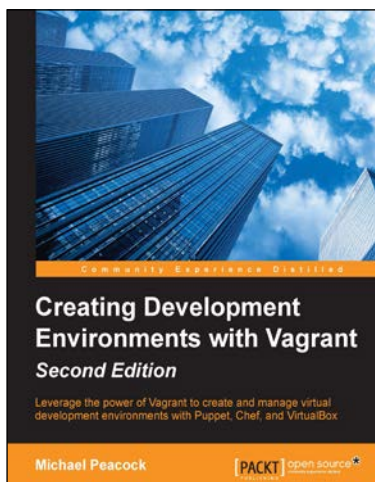
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