Oracle Linux 9

Setting Up Load Balancing

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Preface

Oracle Linux 9: Setting Up Load Balancing describes how to configure the Keepalived and HAProxy load balancer technologies for balanced access to network services.

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

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About Load Balancing in Oracle Linux

This chapter provides an overview of the load balancer technologies that are used in Oracle Linux. Installation and configuration information is also provided in this chapter.

About Load Balancing

The term *load balancing* refers to the efficient distribution of incoming network traffic across a group of back-end servers. The use of load balancing ensures that your infrastructure is highly available, reliable, and that performance is not degraded. Load balancers can typically handle traffic for the HTTP, HTTPS, TCP, and UDP protocols.

Load balancers manage network traffic by routing client requests across all of the servers that can fulfill those requests. This routing maximizes speed and capacity utilization so that no one particular server becomes overloaded, thereby improving overall performance. In situations where a server may become unavailable or goes down, the load balancer redirects any incoming traffic to other servers that are online. In this way, server downtime is minimized. When a new server is added to the server group, the load balancer automatically redistributes the workload and starts to send requests to that new server.

In Oracle Linux, load balancing of network traffic is primarily handled by two integrated software components: HAProxy and Keepalived. The HAProxy feature provides load balancing and high-availability services to TCP and HTTP, while Keepalived performs load balancing and failover tasks on both active and passive routers. The NGINX feature can also be used in Oracle Linux for load balancing.

About HAProxy

HAProxy, or High Availability Proxy, is an application layer (Layer 7) load balancer and high-availability solution that you can use to implement a reverse proxy for HTTP and TCP-based Internet services. An application layer load balancer often includes many features, because it is able to inspect the content of the traffic that it is routing and can either modify content within each packet, as required, or can make decisions about how to handle each packet based on its content. This makes it simple to implement session persistence, TLS, ACLs, and HTTP rewrites and redirection.

The configuration file for the `haproxy` daemon is `/etc/haproxy/haproxy.cfg`. This file must be present on each server on which you configure HAProxy for load balancing or high availability.

For more information, see http://www.haproxy.org/#docs, the `/usr/share/doc/haproxy-`*`version`* documentation, and the `haproxy(1)` manual page.

About Keepalived

Keepalived uses the IP Virtual Server (IPVS) kernel module to provide transport layer (Layer 4) load balancing by redirecting requests for network-based services to individual members of a server cluster. IPVS monitors the status of each server and uses the Virtual Router

Redundancy Protocol (VRRP) to implement high availability. A load balancer that functions at the transport layer is less aware of the content of the packets that it re-routes, which has the advantage of being able to perform this task significantly faster than a reverse proxy system functioning at the application layer.

The configuration file for the `keepalived` daemon is `/etc/keepalived/keepalived.conf`. This file must be present on each server on which you configure Keepalived for load balancing or high availability.

For more information, see https://www.keepalived.org/documentation.html, the `/usr/share/doc/keepalive-`*`version`* documentation, and the `keepalived(8)` and `keepalived.conf(5)` manual pages.

Using Keepalived With VRRP

VRRP is a networking protocol that automatically assigns routers that are available to handle inbound traffic. A detailed standard document for this protocol can be found at https://tools.ietf.org/html/rfc5798.

Keepalived uses VRRP to ascertain the current state of all of the routers on the network. The protocol enables routing to switch between primary and backup routers automatically. The backup routers detect when the primary router becomes unavailable and then sends multicast packets to each other until one of the routers is "elected" as the new primary router A floating virtual IP address can be used to always direct traffic to the primary router. When the original primary router is back online, it detects the new routing state and returns to the network as a backup router.

The benefit of using VRRP is that you can rely on multiple routers to provide high availability and redundancy without requiring a separate software service or hardware device to manage this process. On each router, Keepalived configures the VRRP settings and ensures that the network routing continues to function correctly.

For more information, see https://www.keepalived.org/documentation.html, the `/usr/share/doc/keepalive-`*`version`* documentation, and the `keepalived(8)` and `keepalived.conf(5)` manual pages.

About Combining Keepalived With HAProxy for High-Availability Load Balancing

You can combine the Keepalived and HAProxy load balancer features to achieve a high-availability, load-balancing environment. HAProxy provides scalability, application-aware functionality, and ease of configuration when configuring load balancing services. Keepalived provides failover services for backup routers, as well as the ability to distribute loads across servers for increased availability.

This complex configuration scenario illustrates how you can use different load balancing applications with each other to achieve better redundancy and take advantage of features at different layers of the stack. While this example shows how Keepalived can be used to provide redundancy for HAProxy, you can also achieve similar results by using Keepalived with alternate application layer proxy systems, like NGINX.

For more details, see Enhancing Load Balancing by Using Keepalived With HAProxy.

About NGINX

NGINX is a well-known HTTP server that provides modular functionality for reverse proxying, traffic routing, and application-layer load balancing for HTTP, HTTPS or TCP/UDP connections. You can use NGINX load balancing and proxy services to distribute traffic for improved performance, scalability, and reliability of your applications.

NGINX provides capability for the following load balancing methods:

- **Round Robin**. This method is one of the simplest for implementing load balancing and is the default method that is used by NGINX. Round Robin distributes requests to application servers by going down the list of the servers that are within the group, then forwarding client requests to each server, in turn. After reaching the end of the list, the load balancer repeats this same sequence.
- **Least Connected**. This methods works by assigning the next request to the server that has the least number of active connections. With the least-connected method, the load balancer compares the number of currently active connections to each server, then sends the request to the server with the fewest connections. You set the configuration by using the `least_conn` directive.
- **IP Hash**. This method uses a hash-function to determine which server to select for the next request, which is based on the client's IP address. You set the configuration by using the `ip_hash` directive.

For more information, see Setting Up Load Balancing by Using NGINX.

See also https://docs.nginx.com/nginx/.

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Setting Up Load Balancing by Using HAProxy

This chapter describes how to configure load balancing by using HAProxy. The chapter also includes configuration scenarios and examples.

Installing and Configuring HAProxy

Before you can set up load balancing by using HAProxy, you must first install and configure the feature.

To install HAProxy:

1. Install the haproxy package on each front-end server:

   ```
   sudo dnf install haproxy
   ```

2. Edit the /etc/haproxy/haproxy.cfg file to configure HAProxy on each server.

   See HAProxy Configuration Directives.

3. Enable access to the services or ports that you want HAProxy to handle.

   To allow incoming TCP requests on port 80, use the following command:

   ```
   sudo firewall-cmd --zone=zone --add-port=80/tcp
   ```

   ```
   sudo firewall-cmd --permanent --zone=zone --add-port=80/tcp
   ```

4. Enable and start the haproxy service on each server:

   ```
   sudo systemctl enable --now haproxy
   ```

   If you change the HAProxy configuration, reload the haproxy service:

   ```
   sudo systemctl reload haproxy
   ```

HAProxy Configuration Directives

The /etc/haproxy/haproxy.cfg configuration file is divided into the following sections:

global
Defines global settings, such as the syslog facility and level to use for logging, the maximum number of concurrent connections that are allowed, and how many processes to start in daemon mode.

defaults
Defines the default settings for subsequent sections.

listen
Defines a complete proxy, which implicitly includes the frontend and backend components.

frontend
Defines the ports that accept client connections.

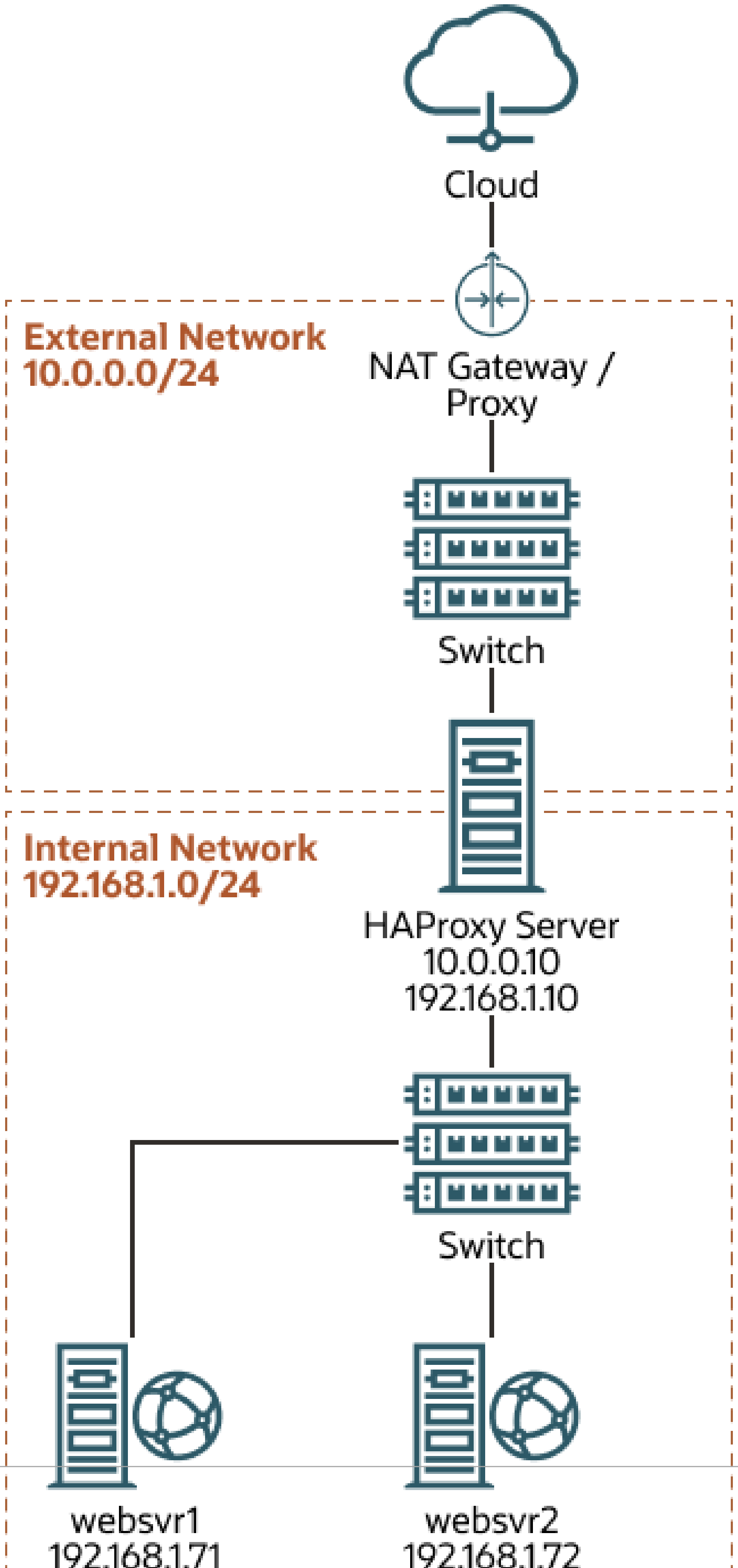
backend
Defines the servers to which the proxy forwards client connections.

Configuring Round Robin Load Balancing by Using HAProxy

The following example uses HAProxy to implement a front-end server that balances incoming requests between two back-end web servers, and which also handles service outages on the back-end servers.

The following figure shows an HAProxy server (`10.0.0.10`), which is connected to an externally facing network (`10.0.0.0/24`) and to an internal network (`192.168.1.0/24`). Two web servers, `websrv1` (`192.168.1.71`) and `websrv2` (`192.168.1.72`), are accessible on the internal network. The IP address `10.0.0.10` is in the private address range `10.0.0.0/24`, which cannot be routed on the Internet. An upstream Network Address Translation (NAT) gateway or a proxy server provides access to and from the Internet.

Figure 2-1   Example HAProxy Configuration for Load Balancing



The following is an example configuration in `/etc/haproxy/haproxy.cfg` on the server:

```
global
    daemon
    log 127.0.0.1 local0 debug
    maxconn 50000
    nbproc 1

defaults
    mode http
    timeout connect 5s
    timeout client 25s
    timeout server 25s
    timeout queue 10s

# Handle Incoming HTTP Connection Requests
listen  http-incoming
    mode http
    bind 10.0.0.10:80
# Use each server in turn, according to its weight value
    balance roundrobin
# Verify that service is available
    option httpchk HEAD / HTTP/1.1\r\nHost:\ www
# Insert X-Forwarded-For header
    option forwardfor
# Define the back-end servers, which can handle up to 512 concurrent connections 
each
    server websrv1 192.168.1.71:80 maxconn 512 check
    server websrv2 192.168.1.72:80 maxconn 512 check
```

This configuration balances HTTP traffic between the two back-end web servers `websrv1` and `websrv2`, whose firewalls are configured to accept incoming TCP requests on port 80. The traffic is distributed equally between the servers and each server can handle a maximum of 512 concurrent connections. A health-check is also configured and this performs a request for the HTTP headers on a request for the web root on each backend server.

After implementing basic `/var/www/html/index.html` files on the web servers and using `curl` to test connectivity, the following output demonstrate how HAProxy balances the traffic between the servers and how it handles the `httpd` service stopping on `websrv1`:

```
while true; do curl http://10.0.0.10; sleep 1; done

This is HTTP server websrv1 (192.168.1.71).
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv1 (192.168.1.71).
This is HTTP server websrv2 (192.168.1.72).
...
This is HTTP server websrv2 (192.168.1.72).
<html><body><h1>503 Service Unavailable</h1>
No server is available to handle this request.
</body></html>
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv2 (192.168.1.72).
...
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv1 (192.168.1.71).
This is HTTP server websrv2 (192.168.1.72).
This is HTTP server websrv1 (192.168.1.71).
...
```

In this example, HAProxy detected that the `httpd` service had restarted on `websrv1` and resumed using that server in addition to `websrv2`.

By combining the load balancing capability of HAProxy with the high-availability capability of Keepalived , you can configure a backup load balancer that ensures continuity of service in the event that the primary load balancer fails. See Enhancing Load Balancing by Using Keepalived With HAProxy for more information on how this configuration can be extended.

Using Weighted Round Robin Load Balancing with HAProxy

HAProxy can also be configured to use the weighted round-robin algorithm to distribute traffic. This algorithm selects servers in turns, according to their weights, and distributes the server load without implementing certain other factors such as server response time. Weighted round-robin allows you to balance traffic proportionally between servers based on processing power and resources available to a server.

To implement weighted round-robin, simply append weight values to each server in your configuration. For example, to distribute twice the amount of traffic to `websrv1`, change the configuration to include different weight ratios, as follows:

```
server websrv1 192.168.1.71:80 weight 2 maxconn 512 check
server websrv2 192.168.1.72:80 weight 1 maxconn 512 check
```

Adding Session Persistence for HAProxy

HAProxy provides a multitude of load balancing algorithms, some of which provide features that automatically help to make sure that web sessions have persistent connections to the same back-end server. For instance, you can configure a `balance` algorithm such as `hdr`, `rdp-cookie`, `source`, `uri`, or `url_param` to ensure that traffic is always routed to the same web server for a particular incoming connection during the session. For example, the `source` algorithm creates a hash of the source IP address and maps it to a particular back-end server. If you use the `rdp-cookie`, or `url_param` algorithms, you may need to configure your back-end web servers or your web applications to facilitate these mechanisms.

If your implementation requires the use of the `leastconn`, `roundrobin`, or `static-rr` algorithm, you can achieve session persistence by using server-dependent cookies.

To enable session persistence for all pages on a web server, use the `cookie` directive to define the name of the cookie to be inserted and add the `cookie` option and server name to the `server` lines, for example:

```
cookie WEBSVR insert
server websrv1 192.168.1.71:80 weight 1 maxconn 512 cookie 1 check
server websrv2 192.168.1.72:80 weight 1 maxconn 512 cookie 2 check
```

HAProxy includes an additional `Set-Cookie:` header that identifies the web server in its response to the client, for example: `Set-Cookie: WEBSVR=`*`N`*`; path=`*`page_path`* . If a client subsequently specifies the `WEBSVR` cookie in a request, HAProxy forwards the request to the web server whose `server cookie`value matches the value of `WEBSVR`.

To enable persistence selectively on a web server, use the `cookie` directive to specify that HAProxy should expect the specified cookie, usually a session ID cookie or other existing cookie, to be prefixed with the `server cookie` value and a `~` delimiter, for example:

```
cookie SESSIONID prefix
server websrv1 192.168.1.71:80 weight 1 maxconn 512 cookie 1 check
server websrv2 192.168.1.72:80 weight 1 maxconn 512 cookie 2 check
```

If the value of `SESSIONID` is prefixed with a `server cookie` value, for example: `Set-Cookie: SESSIONID=`*`N`*`~`*`Session_ID`*`;`, HAProxy strips the prefix and delimiter from the `SESSIONID` cookie before forwarding the request to the web server whose `server cookie` value matches the prefix.

The following example demonstrates how using a prefixed cookie enables session persistence:

```
while true; do curl http://10.0.0.10 cookie "SESSIONID=1~1234;"; sleep 1; done

This is HTTP server websrv1 (192.168.1.71).
This is HTTP server websrv1 (192.168.1.71).
This is HTTP server websrv1 (192.168.1.71).
...
```

A real web application would usually set the session ID on the server side, in which case the first HAProxy response would include the prefixed cookie in the `Set-Cookie:` header.

3 Setting Up Load Balancing by Using Keepalived

This chapter includes tasks and examples that describe how to configure load balancing NAT mode by using Keepalived. The chapter also includes a configuration scenario that demonstrates how to combine the use of Keepalived and HAProxy for high-availability load balancing.

Installing and Configuring Keepalived

Before you can set up load balancing by using Keepalived, you must install and configure the feature.

1. Install the `keepalived` package on each server:

   ```
   sudo dnf install keepalived
   ```

2. Edit `/etc/keepalived/keepalived.conf` to configure Keepalived on each server. See Keepalived Configuration Directives.

3. Enable IP forwarding in `/etc/sysctl.conf`:

   ```
   net.ipv4.ip_forward = 1
   ```

4. Verify that the IP forwarding has been applied:

   ```
   sudo sysctl -p
   ```

   ```
   net.ipv4.ip_forward = 1
   ```

5. Add firewall rules to allow VRRP communication by using the multicast IP address `224.0.0.18` and the VRRP protocol (`112`) on each network interface that Keepalived will control, for example:

   ```
   sudo firewall-cmd --direct --permanent --add-rule ipv4 filter INPUT 0 \
     --in-interface enp0s8 --destination 224.0.0.18 --protocol vrrp -j ACCEPT

   sudo firewall-cmd --direct --permanent --add-rule ipv4 filter OUTPUT 0 \
     --out-interface enp0s8 --destination 224.0.0.18 --protocol vrrp -j ACCEPT

   sudo firewall-cmd --reload
   ```

6. Enable and start the `keepalived` service on each server:

   ```
   sudo systemctl enable --now keepalived
   ```

   If you change the Keepalived configuration, reload the `keepalived` service:

   ```
   sudo systemctl reload keepalived
   ```

Keepalived Configuration Directives

The `/etc/keepalived/keepalived.conf` configuration file is divided into the following sections:

`global_defs`
Defines global settings such as the email addresses for sending notification messages, the IP address of an SMTP server, the timeout value for SMTP connections in seconds, a string that identifies the host machine, the VRRP IPv4 and IPv6 multicast addresses, and whether SNMP traps should be enabled.

`static_ipaddress`
`static_routes`
Define static IP addresses and routes, which VRRP cannot change. These sections are not required if the addresses and routes are already defined on the servers and these servers already have network connectivity.

`vrrp_sync_group`
Defines a VRRP synchronization group of VRRP instances that fail over together.

`vrrp_instance`
Defines a moveable virtual IP address for a member of a VRRP synchronization group's internal or external network interface, which accompanies other group members during a state transition. Each VRRP instance must have a unique value of `virtual_router_id`, which identifies which interfaces on the primary and backup servers can be assigned a given virtual IP address. You can also specify scripts that are run on state transitions to `BACKUP`, `MASTER`, and `FAULT`, and whether to trigger SMTP alerts for state transitions.

`vrrp_script`
Defines a tracking script that Keepalived can run at regular intervals to perform monitoring actions from a `vrrp_instance` or `vrrp_sync_group` section.

`virtual_server_group`
Defines a virtual server group, which allows a real server to be a member of several virtual server groups.

`virtual_server`
Defines a virtual server for load balancing, which is composed of several real servers.

For more information about setting up load balancing with Keepalived, see Setting Up Load Balancing by Using Keepalived

Setting Up Load Balancing in NAT Mode

The following example shows how you would use Keepalived in NAT mode to implement a basic failover and load balancing configuration on two servers. One server acts as the primary, the other acts as a backup, with the primary server having a higher priority than the backup server. They use VRRP to monitor the current routing state, and you can read more about how that works and why it is useful in Using Keepalived With VRRP.

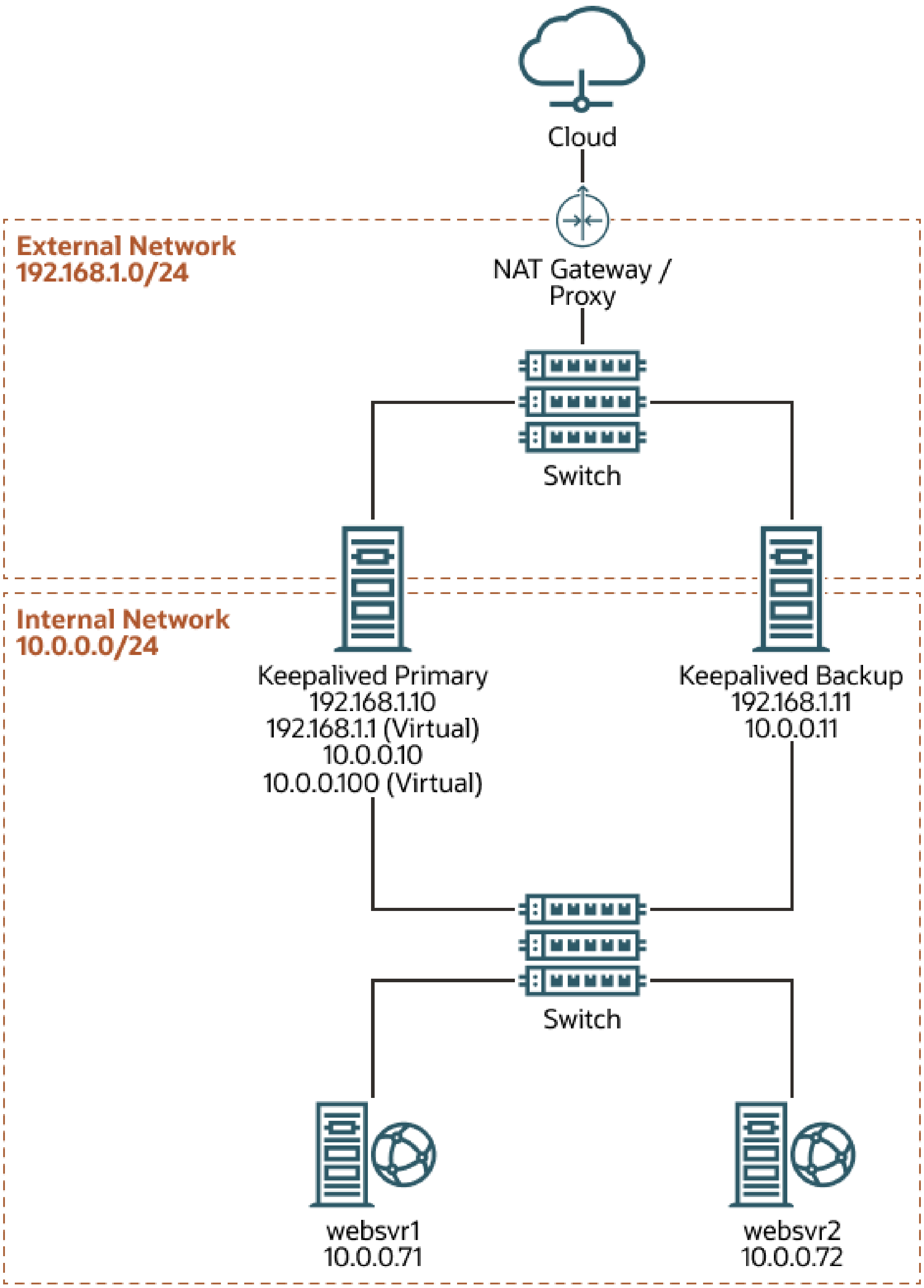
Each of the servers has two network interfaces, where one interface is connected to the side-facing an external network (`192.168.1.0/24`), and the other interface is connected to an internal network (`10.0.0.0/24`), on which two web servers are accessible.

The following figure shows that the Keepalived primary server has the following network addresses: `192.168.1.10`, `192.168.1.1` (virtual), `10.0.0.10`, and `10.0.0.100` (virtual).

The Keepalived backup server has he following network addresses: `192.168.1.11` and `10.0.0.11`.

The web servers `websrv1` and `websrv2` have the network addresses `10.0.0.71` and `10.0.0.72`, respectively.

Figure 3-1   Keepalived Configuration for Load Balancing in NAT Mode



The following is an example of the configuration in the `/etc/keepalived/keepalived.conf` file on the primary server:

```
global_defs {
   notification_email {
     root@example.com
   }
   notification_email_from srv1@example.com
   smtp_server localhost
   smtp_connect_timeout 30
}

vrrp_sync_group VRRP1 {
#   Group the external and internal VRRP instances so they fail over together
    group {
        external
        internal
        }
}

vrrp_instance external {
    state MASTER
    interface enp0s8
    virtual_router_id 91
    priority 200
    advert_int 1
    authentication {
        auth_type PASS
        auth_pass 1215
    }
#   Define the virtual IP address for the external network interface
    virtual_ipaddress {
        192.168.1.1/24
    }
}

vrrp_instance internal {
    state MASTER
    interface enp0s9
    virtual_router_id 92
    priority 200
    advert_int 1
    authentication {
        auth_type PASS
        auth_pass 1215
    }
#   Define the virtual IP address for the internal network interface
    virtual_ipaddress {
        10.0.0.100/24
    }
}

# Define a virtual HTTP server on the virtual IP address 192.168.1.1
virtual_server 192.168.1.1 80 {
    delay_loop 10
    protocol TCP
#   Use round-robin scheduling in this example
    lb_algo rr
#   Use NAT to hide the back-end servers
    lb_kind NAT
#   Persistence of client sessions times out after 2 hours
    persistence_timeout 7200
    real_server 10.0.0.71 80 {
        weight 1
        TCP_CHECK {
          connect_timeout 5
          connect_port 80
        }
    }

    real_server 10.0.0.72 80 {
       weight 1
       TCP_CHECK {
          connect_timeout 5
          connect_port 80
        }
    }
}
```

The previous configuration includes an additional `vrrp_sync_group` section so that the network interfaces are assigned together on failover, as well as a `virtual_server` section to define the real back-end servers that Keepalived uses for load balancing. The value of `lb_kind` is set to use NAT, which means the Keepalived server handles both inbound and outbound network traffic from and to the client on behalf of the back-end servers.

The configuration of the backup server is the same, except for the values of `notification_email_from`, `state`, `priority`, and possibly `interface`, if the system hardware configuration is different:

```
global_defs {
   notification_email {
     root@example.com
   }
   notification_email_from srv2@example.com
   smtp_server localhost
   smtp_connect_timeout 30
}

vrrp_sync_group VRRP1 {
#   Group the external and internal VRRP instances so they fail over together
    group {
        external
        internal
        }
}

vrrp_instance external {
    state BACKUP
    interface enp0s8
    virtual_router_id 91
    priority 100
    advert_int 1
    authentication {
        auth_type PASS
        auth_pass 1215
    }
#   Define the virtual IP address for the external network interface
    virtual_ipaddress {
        192.168.1.1/24
    }
}

vrrp_instance internal {
    state BACKUP
    interface enp0s9
    virtual_router_id 92
    priority 100
    advert_int 1
    authentication {
        auth_type PASS
        auth_pass 1215
    }
#   Define the virtual IP address for the internal network interface
    virtual_ipaddress {
        10.0.0.100/24
    }
}

# Define a virtual HTTP server on the virtual IP address 192.168.1.1
virtual_server 192.168.1.1 80 {
    delay_loop 10
    protocol TCP
#   Use round-robin scheduling in this example
    lb_algo rr
#   Use NAT to hide the back-end servers
    lb_kind NAT
#   Persistence of client sessions times out after 2 hours
    persistence_timeout 7200

    real_server 10.0.0.71 80 {
        weight 1
        TCP_CHECK {
          connect_timeout 5
          connect_port 80
        }
    }

    real_server 10.0.0.72 80 {
        weight 1
        TCP_CHECK {
          connect_timeout 5
          connect_port 80
        }
    }
}
```

The following additional configuration changes are required:

- Configure the firewall rules on each Keepalived server (primary and backup) that you are configuring as a load balancer. See Configuring Firewall Rules for Keepalived NAT-Mode Load Balancing.
- Configure a default route for the virtual IP address of the load balancer's internal network interface on each back-end server that you intend to use with the Keepalived load balancer. See Configuring Back-End Server Routing for Keepalived NAT-Mode Load Balancing.

See Installing and Configuring Keepalived for more information.

Configuring Firewall Rules for Keepalived NAT-Mode Load Balancing

If you configure Keepalived to use NAT mode for load balancing with the servers on the internal network, the Keepalived server handles all inbound and outbound network traffic and hides the existing back-end servers by rewriting the source IP address of the *real* back-end server in outgoing packets with the virtual IP address of the external network interface.

The following example demonstrates how to move interface `enp0s9` to the `internal` zone, while interface `enp0s8` remains in the `public` zone.

To configure a Keepalived server to use NAT mode for load balancing:

1. Check the state of any currently active firewall zones on your system:

   ```
   sudo firewall-cmd --get-active-zones

   public
     interfaces: enp0s8 enp0s9
   ```

2. Configure the firewall so that the interfaces on the external network side are in a zone that is different from the interfaces on the internal network side.

   ```
   sudo firewall-cmd --zone=public --remove-interface=enp0s9

   sudo firewall-cmd --zone=internal --add-interface=enp0s9

   sudo firewall-cmd --permanent --zone=public --remove-interface=enp0s9

   sudo firewall-cmd --permanent --zone=internal --add-interface=enp0s9
   ```

   Confirm that your changes have been applied:

   ```
   sudo firewall-cmd --get-active-zones

   internal
     interfaces: enp0s9
   public
     interfaces: enp0s8
   ```

3. Configure NAT mode (masquerading) on the external network interface, for example:

   ```
   sudo firewall-cmd --zone=public --add-masquerade

   sudo firewall-cmd --permanent --zone=public --add-masquerade
   ```

   Optionally, you can query each NAT mode to ensure that both of them have been set correctly. The query for `public` zone should return a `yes` response, and the query for `internal` zone should return a `no` response.

   ```
   sudo firewall-cmd --zone=public --query-masquerade

   sudo firewall-cmd --zone=internal --query-masquerade
   ```

4. If not already enabled for your firewall, configure forwarding rules between the external and internal network interfaces, for example:

   ```
   sudo firewall-cmd --direct --permanent --add-rule ipv4 filter FORWARD 0 \
     -i enp0s8 -o enp0s9 -m state --state RELATED,ESTABLISHED -j ACCEPT

   sudo firewall-cmd --direct --permanent --add-rule ipv4 filter FORWARD 0 \
     -i enp0s9 -o enp0s8 -j ACCEPT

   sudo firewall-cmd --direct --permanent --add-rule ipv4 filter FORWARD 0 \
     -j REJECT --reject-with icmp-host-prohibited

   sudo firewall-cmd --reload
   ```

5. Enable access to the services or ports that you want Keepalived to handle.

Configuring Back-End Server Routing for Keepalived NAT-Mode Load Balancing

On each back-end real servers that you intend to use with the Keepalived load balancer, ensure that the routing table contains a default route for the virtual IP address of the load balancer's internal network interface.

For example, if the virtual IP address is `10.0.0.100`, use the `ip` command to examine the routing table:

```
sudo ip route show

10.0.0.0/24 dev enp0s8  proto kernel  scope link  src 10.0.0.71
```

You can also use the `ip` command to add the default route, and then confirm your changes:

```
sudo ip route add default via 10.0.0.100 dev enp0s8

sudo ip route show

default via 10.0.0.100 dev enp0s8
10.0.0.0/24 dev enp0s8  proto kernel  scope link  src 10.0.0.71
```

To make the default route for `enp0s8` persist across sysem reboots, create the `/etc/sysconfig/network-scripts/route-enp0s8` file:

```
sudo echo "default via 10.0.0.100 dev enp0s8" |sudo tee /etc/sysconfig/network-scripts/
route-enp0s8
```

Enhancing Load Balancing by Using Keepalived With HAProxy

You can use Keepalived to provide failover services for backup routers, while at the same time also using HAProxy for load balancing and to achieve high availability across distributed servers. The advantage of this approach is that the packet and application layers are separated, which means the health checks that are performed by Keepalived for the load-balancing servers are not impacted by the inbound HTTP or TCP traffic that HAproxy is managing. Also, failover routing, which is achieved by using VRRP, can be activated automatically without waiting for a client response to time out. To learn more about the usefulness of VRRP, see Using Keepalived With VRRP.

The practicality of using this method is that if your public-facing HAProxy load balancer goes offline, Keepalived automatically detects that the load balancer has gone offline and dynamically switches to another HAProxy server. If the Keepalived primary router goes offline, you can safely rely on the VRRP settings that you configured to ensure that traffic is automatically handled by your Keepalived backup router.

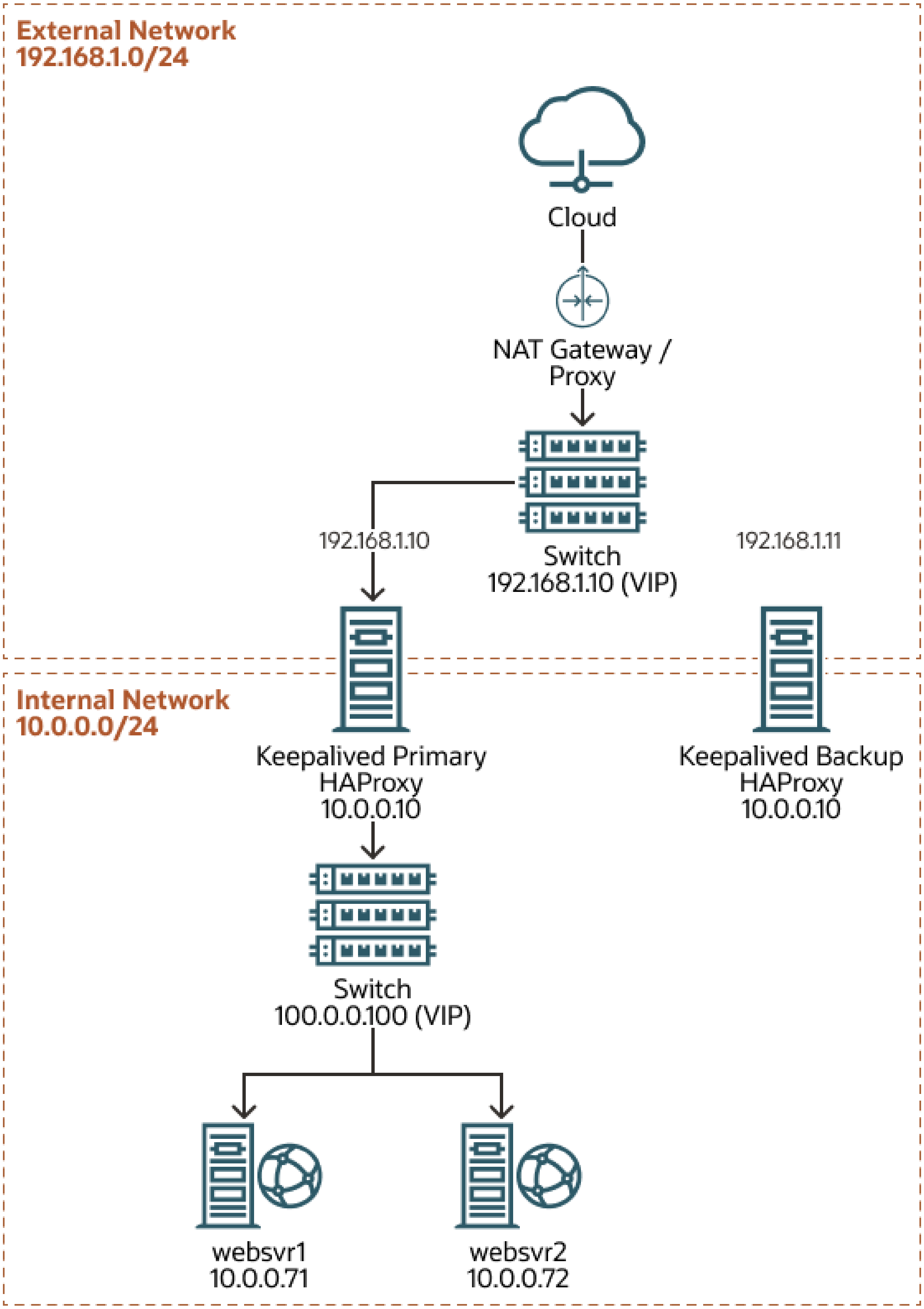
The role of HAProxy in the setup is to provide inbound load balancing and session persistence to your back-end servers: Keepalived is solely responsible for monitoring the status of HAProxy and providing an alternative routing mechanism. Using both tools in combination provides a highly-available and resilient load-balancing solution.

The following example provides instructions that are similar to the instructions in Setting Up Load Balancing in NAT Mode. However, in the following example, HAProxy is installed on both the Keepalived primary server, as well as the Keepalived backup server.

Like the other example, the external virtual IP address is `192.168.1.1`, which is on the `192.168.1.0/24` external network. This IP address is dynamically assigned through NAT (between the Keepalived primary server), with the IP address `192.168.1.10` (and the Keepalived backup server), with the external IP address `192.168.1.11`.

The internal network is hosted on the `10.0.0.0/24` subnet, with `websvr1` and `websvr2` assigned the `10.0.0.71` and `10.0.0.72` IP addresses, respectively.

Figure 3-2 Keepalived and HAProxy Configuration for High Availability Load Balancing



The following example shows the configuration in the `/etc/keepalived/keepalived.conf` file on the primary server

```
global_defs {

  notification_email {
    root@example.com
  }

  notification_email_from srv1@example.com
  smtp_server localhost
  smtp_connect_timeout 30
}

vrrp_sync_group vg1 {
  group {
    external
    internal
  }
}

vrrp_script chk_haproxy {
  script "killall -0 haproxy" # check the haproxy process
  interval 2 # every 2 seconds
  weight 2 # add 2 points if OK
}

vrrp_instance external {
  state MASTER
  interface enp0s8
  virtual_router_id 91
  priority 200
  advert_int 1
  authentication {
    auth_type PASS
    auth_pass 1215
  }
  virtual_ipaddress {
    192.168.1.1/24
  }
  track_script {
    chk_haproxy
  }
}

vrrp_instance internal {
  state MASTER
  interface enp0s9
  virtual_router_id 92
  priority 200
  advert_int 1
  authentication {
    auth_type PASS
    auth_pass 1215
  }
  virtual_ipaddress {
    10.0.0.100/24
  }
}
```

In the previous example, the configuration for the backup Keepalived server is identical, but the state value must be set to BACKUP. You do not need to set up a virtual_server, because in this scenario, Keepalived is only used to route traffic, not to perform load balancing.

For more information about configuring Keepalived and setting the appropriate firewall rules, see Setting Up Load Balancing by Using Keepalived.

The HAProxy settings are configured in the /etc/haproxy/haproxy.cfg file. For both HAProxy installations they should be identical, as Keepalived dynamically routes from one configuration to the other automatically, as needed:

```
global
  daemon
  log 127.0.0.1 local0 debug
  maxconn 4000
  nbproc 1

defaults
  mode          http
  retries       3
  timeout connect 5s
  timeout client 25s
  timeout server 25s
  timeout queue 10s

listen http-incoming
  mode http
  bind internal-server-ip:80
  option http-server-close
  option forwardfor
  default_backend app

backend app
  balance roundrobin
  option httpchk HEAD / HTTP/1.1\r\nHost:\ localhost
  option httpclose
  option forwardfor
  server websrv1 192.168.1.71:80 weight 1 maxconn 512 check
  server websrv2 192.168.1.72:80 weight 1 maxconn 512 check
```

In the previous example the option http-server-close and option httpclose options are used to terminate idle connections. This configuration demonstrates the round-robin, load-balancing strategy. If no option is specified, then HAProxy defaults to using the option http-keep-alive option, which keeps any new connections open until every request and response journey that is associated with them is processed.

For more information about configuring HAProxy and setting the appropriate firewall rules, see Setting Up Load Balancing by Using HAProxy.

4

Setting Up Load Balancing by Using NGINX

This chapter describes how to configure NGINX as a load balancer and includes installation instructions and configuration directives. For an overview of NGINX, see About NGINX.

Installing NGINX

Before you can use NGINX for load balancing, you must first install the software and configure the environment.

1. Install the `nginx` package on each server:

   ```
   sudo dnf install nginx
   ```

   Depending on your intended configuration, you may need to install additional modules. The `nginx-all-modules` metapackage installs all of the packages. To see a listing of all of the available modules in the package manager, use the following command:

   ```
   sudo dnf search nginx-mod*
   ```

   Note that if you intend to do TCP/UDP load balancing, you must install the `nginx-mod-stream` module package.

2. Enable access to the services or ports that you want NGINX to handle.

   For example, you would allow incoming TCP requests on port 80 as follows:

   ```
   sudo firewall-cmd --zone=zone --add-port=80/tcp
   ```

   ```
   sudo firewall-cmd --permanent --zone=zone --add-port=80/tcp
   ```

3. If SELinux is set to enforcing mode on the system, add a rule to allow NGINX to relay HTTP traffic to any configured back-end servers:

   ```
   sudo setsebool httpd_can_network_relay on
   ```

4. Enable and start the `nginx` service on the server:

   ```
   sudo systemctl enable --now nginx
   ```

   If you change the NGINX configuration, reload the `nginx` service:

   ```
   sudo systemctl reload nginx
   ```

NGINX Configuration Directives

NGINX configuration can be spread across several files to specify different configuration directives and set the values for configuration variables. Configuration is stored in `/etc/nginx`. The base configuration is stored in `/etc/nginx/nginx.conf`, while site specific configuration tends to be created within distinct files in `/etc/nginx/conf.d/`. By convention, site configurations tend to use the full domain name for the file name and should have a `.conf` suffix.

In these examples, a configuration has the following general format:

```
http {
  server {
    listen 80;
    listen [::]:80;
    server_name example.com www.example.com;
    location / {
       root /usr/share/nginx/html/example.com;
       index index.html;
    }
  }
}
```

The previous example shows an HTTP server configuration for a web server that serves content from the web root directory at `/usr/share/nginx/html/example.com`.

The following configuration directives are useful to note for the purpose of configuring load balancing:

http, https, stream
Defines the protocol for which the settings apply. Use `https` for TLS connections to the load balancer and `stream` for generic TCP/UDP traffic.

server
Defines how to handle incoming traffic from the specified ports for the chosen protocol.
To configure at least one listening port for IPv4, use the `listen` keyword:

```
listen 80;
```

To listen on IPv6 interfaces, prepend the `[::]:` directive to the port number, for example:

```
listen [::]:80
```

Note that the `listen` lines can be duplicated to specify more than one port for a `server{}` block.
Use the `server_name` keyword to define the hostname or domain name that the server responds to. If you do not specify this value, the configuration applies to any incoming connection, however you may need to comment out the default server configuration within `/etc/nginx/nginx.conf` to avoid conflicting configuration definitions.

location
The `location` directive defines path mappings and behavior, depending on incoming requests on the server. At minimum, you must have a value for the web root that is indicated with the value `/`. The behavior is defined by setting values within a location block.
For example, to configure a simple web server that serves content from a directory on the server, use the `root` keyword and specify the directory that the content is located.
The `proxy_pass` directive can be used to implement a reverse proxy service. Traffic is proxied onto the specified server or group of servers, as defined in an upstream directive.
For example, you would proxy inbound HTTP traffic to a website that is hosted on `websrv1.example.com` on port `9090` as follows:

```
server {
  location / {
    proxy_pass http://websvr1.example.com:9090
  }
}
```

You can also specify a server group by referencing its defined `upstream` name.

upstream
An `upstream` directive is used to define a group of one or more servers where the content is located and which can be used by the `proxy_pass` directive. For example, you can create an upstream group of servers called `backend` as follows:

```
upstream backend {
    server server1.example.com;
    server server2.example.com;
    server server3.example.com;
  }
```

To use this group, the `proxy_pass` directive is specified:

```
proxy_pass http://backend
```

The upstream directive is the key configuration component that is used to control load-balancing methods and algorithms. For more information, see http://nginx.org/en/docs/http/ngx_http_upstream_module.html.

Configuring Round Robin Load Balancing by Using NGINX

The default load balancing method that is used by NGINX is the round-robin method. This method proxies traffic sequentially to each server in a defined group.

Create a configuration file for the load-balancer at `/etc/nginx/conf.d/example.com.conf`, where *example.com* is the name of the external domain where inbound traffic is directed. The file should contain the following content:

```
http
{
  upstream backend {
    server server1.example.com;
    server server2.example.com;
    server server3.example.com;
  }

  server {
    listen 80;
    server_name example.com
                www.example.com;
    location / {
      proxy_pass  http://backend;
    }
  }
}
```

In the `upstream backend` configuration block, list the back-end servers within your environment. For example, you should substitute *server1.example.com* with the fully qualified domain name or the hostname of a web server instance.

Set the `server_name` directive with the domain name or names that you intend to use publicly for the load balanced service. For example, substitute *example.com* and *www.example.com* to match your own domain.

You can optionally append additional failover options, such as `max_fails` and `fail_timeout`, to the end of each entry to add resilience in the event that any of the servers goes offline.

After ensuring that the configuration is valid, enable it by reloading NGINX on the public-facing and back-end servers:

```
sudo systemctl reload nginx
```

Using Weighted Round Robin Load Balancing With NGINX

When using servers with varying physical locations or differing hardware resources, you can configure NGINX to allocate more of the traffic to servers that provide less latency and can handle more of a load. This method is referred to as the weighted round-robin method.

Weighted round-robin configuration is accomplished by appending a `weight` value to the end of each entry in the server group section of the NGINX site configuration file. Set the weight of your slowest server to `1`, and then set the weight of other servers relative to that setting.

The following example demonstrates how servers can handle multiple times the load of the base server. One server receives twice the amount of traffic, while the other server receives four times the amount:

```
upstream backend {
    server server1.example.com weight=1;
    server server2.example.com weight=2;
    server server3.example.com weight=4;
}
```

Reload NGINX to apply the new configuration:

```
sudo systemctl reload nginx
```

Using Least-Connected Load Balancing With NGINX

The least-connected load balancing method is used to automatically control the load on application instances, mostly in situations where different inbound requests might take longer to process than other requests.

If you are using the least-connected load balancing method, NGINX always directs new incoming requests to the server with the least number of currently active requests. This load balancing strategy is intended to ensure that no busy servers are overloaded with new requests, while other servers that are capable of taking on the load remain idle.

You can activate the least-connected load balancing method for NGINX by specifying the `least-conn` directive as part of the server group configuration, for example:

```
upstream backend {
    least_conn;
    server server1.example.com;
    server server2.example.com;
    server server3.example.com;
}
```

Reload NGINX to apply the new configuration:

```
sudo systemctl reload nginx
```

Adding Session Persistence for NGINX

If you are performing load balancing of a web application, it can be useful to ensure that the same back-end server that handled inbound requests continues to do so for the same source. It is particularly important when a website or web service must preserve log-in sessions between requests, cancel an existing request, or monitor the progress of large back-end transactions.

To achieve this behavior, activate the IP hash method for NGINX by specifying the `ip_hash` directive as part of the server group configuration, for example:

```
upstream backend {
    ip_hash;
    server server1.example.com;
    server server2.example.com;
    server server3.example.com;
}
```

Reload NGINX to apply the new configuration:

```
sudo systemctl reload nginx
```