DECLARATION OF SANDY GINOZA FOR IETF

RFC 2338: Virtual Router Redundancy Protocol

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Date: 30 March 2021

By: _____
Sandy Ginoza

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Network Working Group
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Virtual Router Redundancy Protocol

Status of this Memo

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Abstract

This memo defines the Virtual Router Redundancy Protocol (VRRP). VRRP specifies an election protocol that dynamically assigns responsibility for a virtual router to one of the VRRP routers on a LAN. The VRRP router controlling the IP address(es) associated with a virtual router is called the Master, and forwards packets sent to these IP addresses. The election process provides dynamic fail over in the forwarding responsibility should the Master become unavailable. This allows any of the virtual router IP addresses on the LAN to be used as the default first hop router by end-hosts. The advantage gained from using VRRP is a higher availability default path without requiring configuration of dynamic routing or router discovery protocols on every end-host.

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1. Introduction

There are a number of methods that an end-host can use to determine its first hop router towards a particular IP destination. These include running (or snooping) a dynamic routing protocol such as Routing Information Protocol [RIP] or OSPF version 2 [OSPF], running an ICMP router discovery client [DISC] or using a statically configured default route.

Running a dynamic routing protocol on every end-host may be infeasible for a number of reasons, including administrative overhead, processing overhead, security issues, or lack of a protocol implementation for some platforms. Neighbor or router discovery

protocols may require active participation by all hosts on a network, leading to large timer values to reduce protocol overhead in the face of large numbers of hosts. This can result in a significant delay in the detection of a lost (i.e., dead) neighbor, which may introduce unacceptably long "black hole" periods.

The use of a statically configured default route is quite popular; it minimizes configuration and processing overhead on the end-host and is supported by virtually every IP implementation. This mode of operation is likely to persist as dynamic host configuration protocols [DHCP] are deployed, which typically provide configuration for an end-host IP address and default gateway. However, this creates a single point of failure. Loss of the default router results in a catastrophic event, isolating all end-hosts that are unable to detect any alternate path that may be available.

The Virtual Router Redundancy Protocol (VRRP) is designed to eliminate the single point of failure inherent in the static default routed environment. VRRP specifies an election protocol that dynamically assigns responsibility for a virtual router to one of the VRRP routers on a LAN. The VRRP router controlling the IP address(es) associated with a virtual router is called the Master, and forwards packets sent to these IP addresses. The election process provides dynamic fail-over in the forwarding responsibility should the Master become unavailable. Any of the virtual router's IP addresses on a LAN can then be used as the default first hop router by end-hosts. The advantage gained from using VRRP is a higher availability default path without requiring configuration of dynamic routing or router discovery protocols on every end-host.

VRRP provides a function similar to a Cisco Systems, Inc. proprietary protocol named Hot Standby Router Protocol (HSRP) [HSRP] and to a Digital Equipment Corporation, Inc. proprietary protocol named IP Standby Protocol [IPSTB].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119].

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1.1 Scope

The remainder of this document describes the features, design goals, and theory of operation of VRRP. The message formats, protocol processing rules and state machine that guarantee convergence to a single Virtual Router Master are presented. Finally, operational issues related to MAC address mapping, handling of ARP requests, generation of ICMP redirect messages, and security issues are addressed.

This protocol is intended for use with IPv4 routers only. A separate specification will be produced if it is decided that similar functionality is desirable in an IPv6 environment.

1.2 Definitions

VRRP Router	A router running the Virtual Router Redundancy Protocol. It may participate in one or more virtual routers.
Virtual Router	An abstract object managed by VRRP that acts as a default router for hosts on a shared LAN. It consists of a Virtual Router Identifier and a set of associated IP address(es) across a common LAN. A VRRP Router may backup one or more virtual routers.
IP Address Owner	The VRRP router that has the virtual router's IP address(es) as real interface address(es). This is the router that, when up, will respond to packets addressed to one of these IP addresses for ICMP pings, TCP connections, etc.
Primary IP Address	An IP address selected from the set of real interface addresses. One possible selection algorithm is to always select the first address. VRRP advertisements are always sent using the primary IP address as the source of the IP packet.
Virtual Router Master	The VRRP router that is assuming the responsibility of forwarding packets sent to the IP address(es) associated with the virtual router, and answering ARP requests for these IP addresses. Note that if the IP address owner is available, then it will always become the Master.

Virtual Router Backup	The set of VRRP routers available to assume forwarding responsibility for a virtual router should the current Master fail.

2.0 Required Features

This section outlines the set of features that were considered mandatory and that guided the design of VRRP.

2.1 IP Address Backup

Backup of IP addresses is the primary function of the Virtual Router Redundancy Protocol. While providing election of a Virtual Router Master and the additional functionality described below, the protocol should strive to:

- Minimize the duration of black holes.
- Minimize the steady state bandwidth overhead and processing complexity.
- Function over a wide variety of multiaccess LAN technologies capable of supporting IP traffic.
- Provide for election of multiple virtual routers on a network for load balancing
- Support of multiple logical IP subnets on a single LAN segment.

2.2 Preferred Path Indication

A simple model of Master election among a set of redundant routers is to treat each router with equal preference and claim victory after converging to any router as Master. However, there are likely to be many environments where there is a distinct preference (or range of preferences) among the set of redundant routers. For example, this preference may be based upon access link cost or speed, router performance or reliability, or other policy considerations. The protocol should allow the expression of this relative path preference in an intuitive manner, and guarantee Master convergence to the most preferential router currently available.

2.3 Minimization of Unnecessary Service Disruptions

Once Master election has been performed then any unnecessary transitions between Master and Backup routers can result in a disruption in service. The protocol should ensure after Master election that no state transition is triggered by any Backup router of equal or lower preference as long as the Master continues to function properly.

Some environments may find it beneficial to avoid the state transition triggered when a router becomes available that is more preferential than the current Master. It may be useful to support an override of the immediate convergence to the preferred path.

2.4 Extensible Security

The virtual router functionality is applicable to a wide range of internetworking environments that may employ different security policies. The protocol should require minimal configuration and overhead in the insecure operation, provide for strong authentication when increased security is required, and allow integration of new security mechanisms without breaking backwards compatible operation.

2.5 Efficient Operation over Extended LANs

Sending IP packets on a multiaccess LAN requires mapping from an IP address to a MAC address. The use of the virtual router MAC address in an extended LAN employing learning bridges can have a significant effect on the bandwidth overhead of packets sent to the virtual router. If the virtual router MAC address is never used as the source address in a link level frame then the station location is never learned, resulting in flooding of all packets sent to the virtual router. To improve the efficiency in this environment the protocol should: 1) use the virtual router MAC as the source in a packet sent by the Master to trigger station learning; 2) trigger a message immediately after transitioning to Master to update the station learning; and 3) trigger periodic messages from the Master to maintain the station learning cache.

3.0 VRRP Overview

VRRP specifies an election protocol to provide the virtual router function described earlier. All protocol messaging is performed using IP multicast datagrams, thus the protocol can operate over a variety of multiaccess LAN technologies supporting IP multicast. Each VRRP virtual router has a single well-known MAC address allocated to it. This document currently only details the mapping to networks using the IEEE 802 48-bit MAC address. The virtual router MAC address is used as the source in all periodic VRRP messages sent by the Master router to enable bridge learning in an extended LAN.

A virtual router is defined by its virtual router identifier (VRID) and a set of IP addresses. A VRRP router may associate a virtual router with its real addresses on an interface, and may also be configured with additional virtual router mappings and priority for virtual routers it is willing to backup. The mapping between VRID and addresses must be coordinated among all VRRP routers on a LAN.

However, there is no restriction against reusing a VRID with a different address mapping on different LANs. The scope of each virtual router is restricted to a single LAN.

To minimize network traffic, only the Master for each virtual router sends periodic VRRP Advertisement messages. A Backup router will not attempt to pre-empt the Master unless it has higher priority. This eliminates service disruption unless a more preferred path becomes available. It's also possible to administratively prohibit all pre-emption attempts. The only exception is that a VRRP router will always become Master of any virtual router associated with addresses it owns. If the Master becomes unavailable then the highest priority Backup will transition to Master after a short delay, providing a controlled transition of the virtual router responsibility with minimal service interruption.

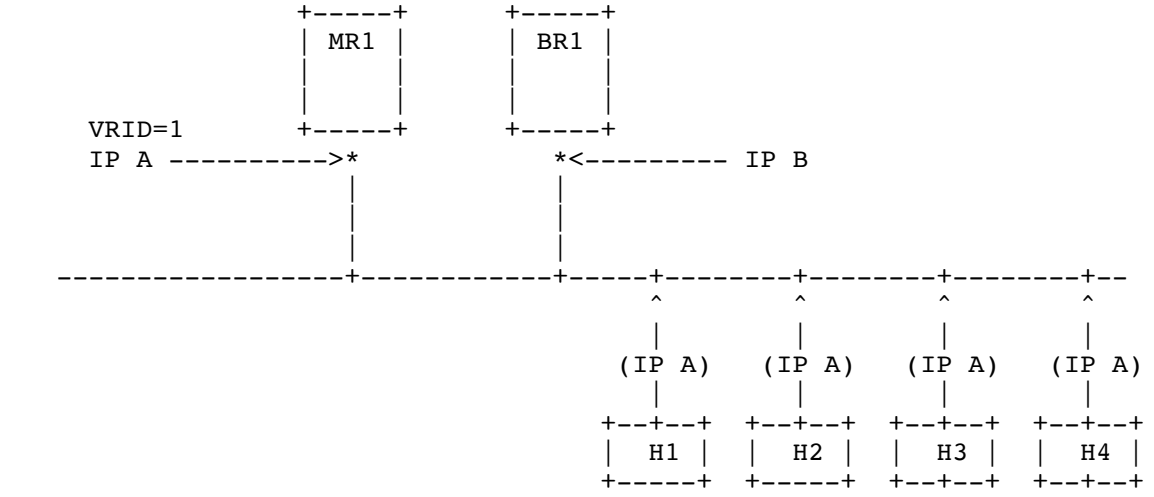
VRRP defines three types of authentication providing simple deployment in insecure environments, added protection against misconfiguration, and strong sender authentication in security conscious environments. Analysis of the protection provided and vulnerability of each mechanism is deferred to Section 10.0 Security Considerations. In addition new authentication types and data can be defined in the future without affecting the format of the fixed portion of the protocol packet, thus preserving backward compatible operation.

The VRRP protocol design provides rapid transition from Backup to Master to minimize service interruption, and incorporates optimizations that reduce protocol complexity while guaranteeing controlled Master transition for typical operational scenarios. The optimizations result in an election protocol with minimal runtime state requirements, minimal active protocol states, and a single message type and sender. The typical operational scenarios are defined to be two redundant routers and/or distinct path preferences among each router. A side effect when these assumptions are violated (i.e., more than two redundant paths all with equal preference) is that duplicate packets may be forwarded for a brief period during Master election. However, the typical scenario assumptions are likely to cover the vast majority of deployments, loss of the Master router is infrequent, and the expected duration in Master election convergence is quite small (<< 1 second). Thus the VRRP optimizations represent significant simplifications in the protocol design while incurring an insignificant probability of brief network degradation.

4. Sample Configurations

4.1 Sample Configuration 1

The following figure shows a simple network with two VRRP routers implementing one virtual router. Note that this example is provided to help understand the protocol, but is not expected to occur in actual practice.



Legend:

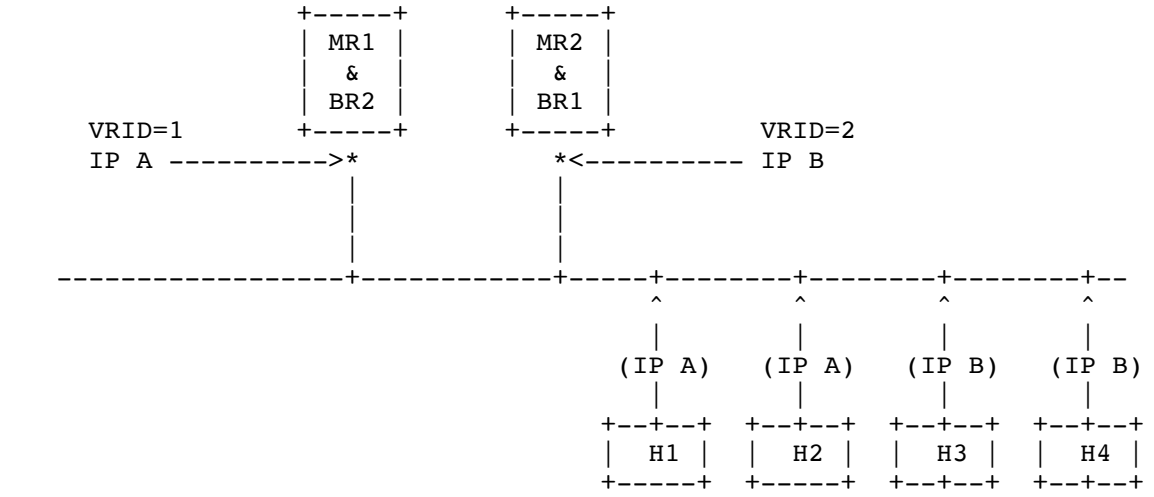
```
---+---+---+--  =  Ethernet, Token Ring, or FDDI
             H  =  Host computer
            MR  =  Master Router
            BR  =  Backup Router
             *  =  IP Address
          (IP)  =  default router for hosts
```

The above configuration shows a very simple VRRP scenario. In this configuration, the end-hosts install a default route to the IP address of virtual router #1 (IP A) and both routers run VRRP. The router on the left becomes the Master for virtual router #1 (VRID=1) and the router on the right is the Backup for virtual router #1. If the router on the left should fail, the other router will take over virtual router #1 and its IP addresses, and provide uninterrupted service for the hosts.

Note that in this example, IP B is not backed up by the router on the left. IP B is only used by the router on the right as its interface address. In order to backup IP B, a second virtual router would have to be configured. This is shown in the next section.

4.2 Sample Configuration 2

The following figure shows a configuration with two virtual routers with the hosts spitting their traffic between them. This example is expected to be very common in actual practice.



Legend:

---+---+---+--	=	Ethernet, Token Ring, or FDDI
H	=	Host computer
MR	=	Master Router
BR	=	Backup Router
*	=	IP Address
(IP)	=	default router for hosts

In the above configuration, half of the hosts install a default route to virtual router #1's IP address (IP A), and the other half of the hosts install a default route to virtual router #2's IP address (IP B). This has the effect of load balancing the outgoing traffic, while also providing full redundancy.

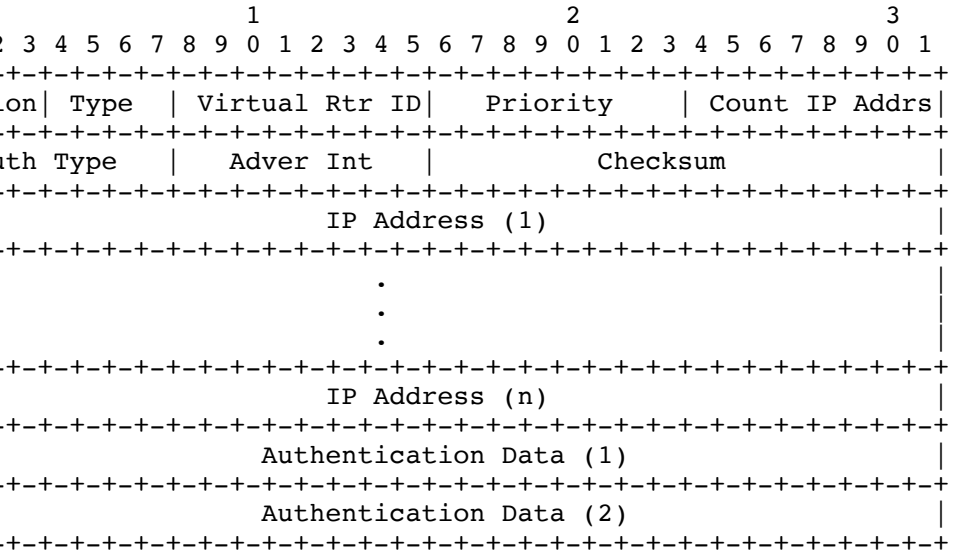
5.0 Protocol

The purpose of the VRRP packet is to communicate to all VRRP routers the priority and the state of the Master router associated with the Virtual Router ID.

VRRP packets are sent encapsulated in IP packets. They are sent to the IPv4 multicast address assigned to VRRP.

5.1 VRRP Packet Format

This section defines the format of the VRRP packet and the relevant fields in the IP header.



5.2 IP Field Descriptions

5.2.1 Source Address

The primary IP address of the interface the packet is being sent from.

5.2.2 Destination Address

The IP multicast address as assigned by the IANA for VRRP is:

224.0.0.18

This is a link local scope multicast address. Routers MUST NOT forward a datagram with this destination address regardless of its TTL.

5.2.3 TTL

The TTL MUST be set to 255. A VRRP router receiving a packet with the TTL not equal to 255 MUST discard the packet.

5.2.4 Protocol

The IP protocol number assigned by the IANA for VRRP is 112 (decimal).

5.3 VRRP Field Descriptions

5.3.1 Version

The version field specifies the VRRP protocol version of this packet. This document defines version 2.

5.3.2 Type

The type field specifies the type of this VRRP packet. The only packet type defined in this version of the protocol is:

1 ADVERTISEMENT

A packet with unknown type MUST be discarded.

5.3.3 Virtual Rtr ID (VRID)

The Virtual Router Identifier (VRID) field identifies the virtual router this packet is reporting status for.

5.3.4 Priority

The priority field specifies the sending VRRP router's priority for the virtual router. Higher values equal higher priority. This field is an 8 bit unsigned integer field.

The priority value for the VRRP router that owns the IP address(es) associated with the virtual router MUST be 255 (decimal).

VRRP routers backing up a virtual router MUST use priority values between 1-254 (decimal). The default priority value for VRRP routers backing up a virtual router is 100 (decimal).

The priority value zero (0) has special meaning indicating that the current Master has stopped participating in VRRP. This is used to trigger Backup routers to quickly transition to Master without having to wait for the current Master to timeout.

5.3.5 Count IP Addrs

The number of IP addresses contained in this VRRP advertisement.

5.3.6 Authentication Type

The authentication type field identifies the authentication method being utilized. Authentication type is unique on a per interface basis. The authentication type field is an 8 bit unsigned integer. A packet with unknown authentication type or that does not match the locally configured authentication method MUST be discarded.

The authentication methods currently defined are:

0 - No Authentication
1 - Simple Text Password
2 - IP Authentication Header

5.3.6.1 No Authentication

The use of this authentication type means that VRRP protocol exchanges are not authenticated. The contents of the Authentication Data field should be set to zero on transmission and ignored on reception.

5.3.6.2 Simple Text Password

The use of this authentication type means that VRRP protocol exchanges are authenticated by a clear text password. The contents of the Authentication Data field should be set to the locally configured password on transmission. There is no default password. The receiver MUST check that the Authentication Data in the packet matches its configured authentication string. Packets that do not match MUST be discarded.

Note that there are security implications to using Simple Text password authentication, and one should see the Security Consideration section of this document.

5.3.6.3 IP Authentication Header

The use of this authentication type means the VRRP protocol exchanges are authenticated using the mechanisms defined by the IP Authentication Header [AUTH] using "The Use of HMAC-MD5-96 within ESP and AH" [HMAC]. Keys may be either configured manually or via a key distribution protocol.

If a packet is received that does not pass the authentication check due to a missing authentication header or incorrect message digest, then the packet MUST be discarded. The contents of the Authentication Data field should be set to zero on transmission and ignored on reception.

5.3.7 Advertisement Interval (Adver Int)

The Advertisement interval indicates the time interval (in seconds) between ADVERTISEMENTS. The default is 1 second. This field is used for troubleshooting misconfigured routers.

5.3.8 Checksum

The checksum field is used to detect data corruption in the VRRP message.

The checksum is the 16-bit one's complement of the one's complement sum of the entire VRRP message starting with the version field. For computing the checksum, the checksum field is set to zero.

5.3.9 IP Address(es)

One or more IP addresses that are associated with the virtual router. The number of addresses included is specified in the "Count IP Addrs" field. These fields are used for troubleshooting misconfigured routers.

5.3.10 Authentication Data

The authentication string is currently only utilized for simple text authentication, similar to the simple text authentication found in the Open Shortest Path First routing protocol [OSPF]. It is up to 8 characters of plain text. If the configured authentication string is shorter than 8 bytes, the remaining space MUST be zero-filled. Any VRRP packet received with an authentication string that does not match the locally configured authentication string MUST be discarded. The authentication string is unique on a per interface basis.

There is no default value for this field.

6. Protocol State Machine

6.1 Parameters

6.1.1 Parameters per Interface

Authentication_Type	Type of authentication being used. Values are defined in section 5.3.6.
Authentication_Data	Authentication data specific to the Authentication_Type being used.

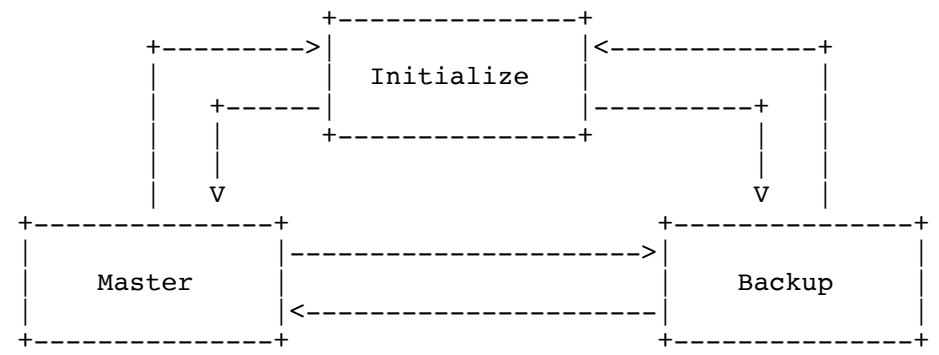
6.1.2 Parameters per Virtual Router

VRID	Virtual Router Identifier. Configured item in the range 1-255 (decimal). There is no default.
Priority	Priority value to be used by this VRRP router in Master election for this virtual router. The value of 255 (decimal) is reserved for the router that owns the IP addresses associated with the virtual router. The value of 0 (zero) is reserved for Master router to indicate it is releasing responsibility for the virtual router. The range 1-254 (decimal) is available for VRRP routers backing up the virtual router. The default value is 100 (decimal).
IP_Addresses	One or more IP addresses associated with this virtual router. Configured item. No default.
Advertisement_Interval	Time interval between ADVERTISEMENTS (seconds). Default is 1 second.
Skew_Time	Time to skew Master_Down_Interval in seconds. Calculated as: ((256 - Priority) / 256)
Master_Down_Interval	Time interval for Backup to declare Master down (seconds). Calculated as: (3 * Advertisement_Interval) + Skew_time
Preempt_Mode	Controls whether a higher priority Backup router preempts a lower priority Master. Values are True to allow preemption and False to not prohibit preemption. Default is True. Note: Exception is that the router that owns the IP address(es) associated with the virtual router always pre-empts independent of the setting of this flag.

6.2 Timers

Master_Down_Timer	Timer that fires when ADVERTISEMENT has not been heard for Master_Down_Interval.
Adver_Timer	Timer that fires to trigger sending of ADVERTISEMENT based on Advertisement_Interval.

6.3 State Transition Diagram



6.4 State Descriptions

In the state descriptions below, the state names are identified by {state-name}, and the packets are identified by all upper case characters.

A VRRP router implements an instance of the state machine for each virtual router election it is participating in.

6.4.1 Initialize

The purpose of this state is to wait for a Startup event. If a Startup event is received, then:

- If the Priority = 255 (i.e., the router owns the IP address(es) associated with the virtual router)
  - o Send an ADVERTISEMENT
  - o Broadcast a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router.
  - o Set the Adver_Timer to Advertisement_Interval
  - o Transition to the {Master} state

else

o Set the Master_Down_Timer to Master_Down_Interval
o Transition to the {Backup} state

endif

6.4.2 Backup

The purpose of the {Backup} state is to monitor the availability and state of the Master Router.

While in this state, a VRRP router MUST do the following:

- MUST NOT respond to ARP requests for the IP address(s) associated with the virtual router.

- MUST discard packets with a destination link layer MAC address equal to the virtual router MAC address.

- MUST NOT accept packets addressed to the IP address(es) associated with the virtual router.

- If a Shutdown event is received, then:

o Cancel the Master_Down_Timer
o Transition to the {Initialize} state

endif

- If the Master_Down_Timer fires, then:

o Send an ADVERTISEMENT
o Broadcast a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router
o Set the Adver_Timer to Advertisement_Interval
o Transition to the {Master} state

endif

- If an ADVERTISEMENT is received, then:

If the Priority in the ADVERTISEMENT is Zero, then:

o Set the Master_Down_Timer to Skew_Time

else:

```
            If Preempt_Mode is False, or If the Priority in the
            ADVERTISEMENT is greater than or equal to the local
            Priority, then:

             o Reset the Master_Down_Timer to Master_Down_Interval

            else:

             o Discard the ADVERTISEMENT

            endif
         endif
      endif
```

6.4.3 Master

While in the {Master} state the router functions as the forwarding router for the IP address(es) associated with the virtual router.

While in this state, a VRRP router MUST do the following:

- MUST respond to ARP requests for the IP address(es) associated with the virtual router.

- MUST forward packets with a destination link layer MAC address equal to the virtual router MAC address.

- MUST NOT accept packets addressed to the IP address(es) associated with the virtual router if it is not the IP address owner.

- MUST accept packets addressed to the IP address(es) associated with the virtual router if it is the IP address owner.

- If a Shutdown event is received, then:

  - Cancel the Adver_Timer
  - Send an ADVERTISEMENT with Priority = 0
  - Transition to the {Initialize} state

  endif

- If the Adver_Timer fires, then:

  - Send an ADVERTISEMENT
  - Reset the Adver_Timer to Advertisement_Interval

  endif

```
- If an ADVERTISEMENT is received, then:

     If the Priority in the ADVERTISEMENT is Zero, then:

      o Send an ADVERTISEMENT
      o Reset the Adver_Timer to Advertisement_Interval

     else:

        If the Priority in the ADVERTISEMENT is greater than the
        local Priority,
        or
        If the Priority in the ADVERTISEMENT is equal to the local
        Priority and the primary IP Address of the sender is greater
        than the local primary IP Address, then:

         o Cancel Adver_Timer
         o Set Master_Down_Timer to Master_Down_Interval
         o Transition to the {Backup} state

        else:

         o Discard ADVERTISEMENT

        endif
     endif
  endif
```

7. Sending and Receiving VRRP Packets

7.1 Receiving VRRP Packets

Performed the following functions when a VRRP packet is received:

- MUST verify that the IP TTL is 255.
- MUST verify the VRRP version
- MUST verify that the received packet length is greater than or equal to the VRRP header
- MUST verify the VRRP checksum
- MUST perform authentication specified by Auth Type

If any one of the above checks fails, the receiver MUST discard the packet, SHOULD log the event and MAY indicate via network management that an error occurred.

- MUST verify that the VRID is valid on the receiving interface

If the above check fails, the receiver MUST discard the packet.

- MAY verify that the IP address(es) associated with the VRID are valid

If the above check fails, the receiver SHOULD log the event and MAY indicate via network management that a misconfiguration was detected. If the packet was not generated by the address owner (Priority does not equal 255 (decimal)), the receiver MUST drop the packet, otherwise continue processing.

- MUST verify that the Adver Interval in the packet is the same as the locally configured for this virtual router

If the above check fails, the receiver MUST discard the packet, SHOULD log the event and MAY indicate via network management that a misconfiguration was detected.

7.2 Transmitting VRRP Packets

The following operations MUST be performed when transmitting a VRRP packet.

- Fill in the VRRP packet fields with the appropriate virtual router configuration state
- Compute the VRRP checksum
- Set the source MAC address to Virtual Router MAC Address
- Set the source IP address to interface primary IP address
- Set the IP protocol to VRRP
- Send the VRRP packet to the VRRP IP multicast group

Note: VRRP packets are transmitted with the virtual router MAC address as the source MAC address to ensure that learning bridges correctly determine the LAN segment the virtual router is attached to.

7.3 Virtual Router MAC Address

The virtual router MAC address associated with a virtual router is an IEEE 802 MAC Address in the following format:

00-00-5E-00-01-{VRID} (in hex in internet standard bit-order)

The first three octets are derived from the IANA's OUI. The next two octets (00-01) indicate the address block assigned to the VRRP protocol. {VRID} is the VRRP Virtual Router Identifier. This mapping provides for up to 255 VRRP routers on a network.

8. Operational Issues

8.1 ICMP Redirects

ICMP Redirects may be used normally when VRRP is running between a group of routers. This allows VRRP to be used in environments where the topology is not symmetric.

The IP source address of an ICMP redirect should be the address the end host used when making its next hop routing decision. If a VRRP router is acting as Master for virtual router(s) containing addresses it does not own, then it must determine which virtual router the packet was sent to when selecting the redirect source address. One method to deduce the virtual router used is to examine the destination MAC address in the packet that triggered the redirect.

It may be useful to disable Redirects for specific cases where VRRP is being used to load share traffic between a number of routers in a symmetric topology.

8.2 Host ARP Requests

When a host sends an ARP request for one of the virtual router IP addresses, the Master virtual router MUST respond to the ARP request with the virtual MAC address for the virtual router. The Master virtual router MUST NOT respond with its physical MAC address. This allows the client to always use the same MAC address regardless of the current Master router.

When a VRRP router restarts or boots, it SHOULD not send any ARP messages with its physical MAC address for the IP address it owns, it should only send ARP messages that include Virtual MAC addresses. This may entail:

- When configuring an interface, VRRP routers should broadcast a gratuitous ARP request containing the virtual router MAC address for each IP address on that interface.

- At system boot, when initializing interfaces for VRRP operation; delay gratuitous ARP requests and ARP responses until both the IP address and the virtual router MAC address are configured.

8.3 Proxy ARP

If Proxy ARP is to be used on a VRRP router, then the VRRP router must advertise the Virtual Router MAC address in the Proxy ARP message. Doing otherwise could cause hosts to learn the real MAC address of the VRRP router.

9. Operation over FDDI and Token Ring

9.1 Operation over FDDI

FDDI interfaces remove from the FDDI ring frames that have a source MAC address matching the device's hardware address. Under some conditions, such as router isolations, ring failures, protocol transitions, etc., VRRP may cause there to be more than one Master router. If a Master router installs the virtual router MAC address as the hardware address on a FDDI device, then other Masters' ADVERTISEMENTS will be removed from the ring during the Master convergence, and convergence will fail.

To avoid this an implementation SHOULD configure the virtual router MAC address by adding a unicast MAC filter in the FDDI device, rather than changing its hardware MAC address. This will prevent a Master router from removing any ADVERTISEMENTS it did not originate.

9.2 Operation over Token Ring

Token ring has several characteristics which make running VRRP difficult. These include:

- In order to switch to a new master located on a different bridge token ring segment from the previous master when using source route bridges, a mechanism is required to update cached source route information.

- No general multicast mechanism supported across old and new token ring adapter implementations. While many newer token ring adapters support group addresses, token ring functional address support is the only generally available multicast mechanism. Due to the limited number of token ring functional addresses these may collide with other usage of the same token ring functional addresses.

Due to these difficulties, the preferred mode of operation over token ring will be to use a token ring functional address for the VRID virtual MAC address. Token ring functional addresses have the two high order bits in the first MAC address octet set to B'1'. They range from 03-00-00-00-00-80 to 03-00-02-00-00-00 (canonical format). However, unlike multicast addresses, there is only one unique functional address per bit position. The functional addresses addresses 03-00-00-10-00-00 through 03-00-02-00-00-00 are reserved by the Token Ring Architecture [TKARCH] for user-defined applications. However, since there are only 12 user-defined token ring functional addresses, there may be other non-IP protocols using the same functional address. Since the Novell IPX [IPX] protocol uses

the 03-00-00-10-00-00 functional address, operation of VRRP over token ring will avoid use of this functional address. In general, token ring VRRP users will be responsible for resolution of other user-defined token ring functional address conflicts.

VRIDs are mapped directly to token ring functional addresses. In order to decrease the likelihood of functional address conflicts, allocation will begin with the largest functional address. Most non-IP protocols use the first or first couple user-defined functional addresses and it is expected that VRRP users will choose VRIDs sequentially starting with 1.

VRID	Token Ring Functional Address
1	03-00-02-00-00-00
2	03-00-04-00-00-00
3	03-00-08-00-00-00
4	03-00-10-00-00-00
5	03-00-20-00-00-00
6	03-00-40-00-00-00
7	03-00-80-00-00-00
8	03-00-00-01-00-00
9	03-00-00-02-00-00
10	03-00-00-04-00-00
11	03-00-00-08-00-00

Or more succinctly, octets 3 and 4 of the functional address are equal to (0x4000 >> (VRID - 1)) in non-canonical format.

Since a functional address cannot be used used as a MAC level source address, the real MAC address is used as the MAC source address in VRRP advertisements. This is not a problem for bridges since packets addressed to functional addresses will be sent on the spanning-tree explorer path [802.1D].

The functional address mode of operation MUST be implemented by routers supporting VRRP on token ring.

Additionally, routers MAY support unicast mode of operation to take advantage of newer token ring adapter implementations which support non-promiscuous reception for multiple unicast MAC addresses and to avoid both the multicast traffic and usage conflicts associated with the use of token ring functional addresses. Unicast mode uses the same mapping of VRIDs to virtual MAC addresses as Ethernet. However, one important difference exists. ARP request/reply packets contain the virtual MAC address as the source MAC address. The reason for this is that some token ring driver implementations keep a cache of MAC address/source routing information independent of the ARP cache.

Hence, these implementations need have to receive a packet with the virtual MAC address as the source address in order to transmit to that MAC address in a source-route bridged network.

Unicast mode on token ring has one limitation which should be considered. If there are VRID routers on different source-route bridge segments and there are host implementations which keep their source-route information in the ARP cache and do not listen to gratuitous ARPs, these hosts will not update their ARP source-route information correctly when a switch-over occurs. The only possible solution is to put all routers with the same VRID on the same source-bridge segment and use techniques to prevent that bridge segment from being a single point of failure. These techniques are beyond the scope this document.

For both the multicast and unicast mode of operation, VRRP advertisements sent to 224.0.0.18 should be encapsulated as described in [RFC1469].

10. Security Considerations

VRRP is designed for a range of internetworking environments that may employ different security policies. The protocol includes several authentication methods ranging from no authentication, simple clear text passwords, and strong authentication using IP Authentication with MD5 HMAC. The details on each approach including possible attacks and recommended environments follows.

Independent of any authentication type VRRP includes a mechanism (setting TTL=255, checking on receipt) that protects against VRRP packets being injected from another remote network. This limits most vulnerabilities to local attacks.

10.1 No Authentication

The use of this authentication type means that VRRP protocol exchanges are not authenticated. This type of authentication SHOULD only be used in environments were there is minimal security risk and little chance for configuration errors (e.g., two VRRP routers on a LAN).

10.2 Simple Text Password

The use of this authentication type means that VRRP protocol exchanges are authenticated by a simple clear text password.

This type of authentication is useful to protect against accidental misconfiguration of routers on a LAN. It protects against routers inadvertently backing up another router. A new router must first be configured with the correct password before it can run VRRP with another router. This type of authentication does not protect against hostile attacks where the password can be learned by a node snooping VRRP packets on the LAN. The Simple Text Authentication combined with the TTL check makes it difficult for a VRRP packet to be sent from another LAN to disrupt VRRP operation.

This type of authentication is RECOMMENDED when there is minimal risk of nodes on a LAN actively disrupting VRRP operation. If this type of authentication is used the user should be aware that this clear text password is sent frequently, and therefore should not be the same as any security significant password.

10.3 IP Authentication Header

The use of this authentication type means the VRRP protocol exchanges are authenticated using the mechanisms defined by the IP Authentication Header [AUTH] using "The Use of HMAC-MD5-96 within ESP and AH", [HMAC]. This provides strong protection against configuration errors, replay attacks, and packet corruption/modification.

This type of authentication is RECOMMENDED when there is limited control over the administration of nodes on a LAN. While this type of authentication does protect the operation of VRRP, there are other types of attacks that may be employed on shared media links (e.g., generation of bogus ARP replies) which are independent from VRRP and are not protected.

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