Implementation of Hot Standby Router Protocol (HSRP) And Virtual Router Redundancy Protocol (VRRP)

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Abstract

The rapid evolution of computer network technology mandates the provision of stable and efficient network services. A significant operational vulnerability arises when a primary router, responsible for network stabilization, operates without a redundant backup router to maintain continuity in the event of its failure. Consequently, this study proposes the addition of a Cisco router to mitigate potential operational constraints associated with the primary router. The backup router is configured to automatically assume the primary router's tasks upon the detection of an operational issue, thereby preserving network stability. The primary objective of this research is to implement the Hot Standby Router Protocol (HSRP) and the Virtual Router Redundancy Protocol (VRRP) to enhance network availability at the Palembang Office of the Personnel and Human Resources Development Agency (BKPSDM). The research methodology is based on Action Research, comprising five distinct phases: Diagnosing, Action Planning, Action Taking, Evaluating, and Learning. Data were collected through field observations, interviews, and a comprehensive literature review. The study involved deploying a redundant network solution utilizing HSRP and VRRP within the BKPSDM's network infrastructure. Quality of Service (QoS) performance was evaluated using standard network utilities, specifically ping and traceroute, to test the implemented HSRP and VRRP methods. The successful implementation of HSRP and VRRP is projected to result in a measurable improvement in network availability at the Palembang Office of the Personnel and Human Resources Development Agency compared to the previous configuration.

Keywords

HSRP, Ping, QoS, Redundancy, Traceroute, VRRP

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Introduction

Data transmission within a network infrastructure requires a stable, well-defined routing mechanism to ensure that information reaches its destination efficiently and accurately. In this context, the router serves as a fundamental device that interconnects multiple network segments and determines the optimal pathway for each data packet, enabling seamless communication between users across various locations (Sofana, 2013b). As organizational dependence on digital systems continues to grow, the reliability of routing devices becomes increasingly essential for ensuring uninterrupted services and maintaining high-performance network operations.

At the Palembang Office of the Personnel and Human Resources Development Agency (BKPSDM), the Cisco 1841 router operates as a primary gateway for managing data traffic across the local network. This device runs continuously throughout working hours and frequently experiences high loads due to activities such as large-scale file transfers, video streaming, and simultaneous access by multiple users. Prolonged periods of heavy usage generate excessive heat within the router, which, if unmanaged, leads to thermal stress and may trigger performance degradation. In severe cases, overheating can cause the router to malfunction, resulting in temporary network outages and disconnections that disrupt administrative operations and essential public services. While powering down the router allows it to cool temporarily, such solutions are only reactive and do not support sustainable network availability.

To ensure continuous network operations and mitigate the risk of link failure, modern network infrastructures adopt redundancy mechanisms. Redundancy protocols provide automated failover capabilities by preparing one or more backup routers to immediately take over when the primary router becomes unavailable. Two widely used redundancy protocols—Hot Standby Router Protocol (HSRP) and Virtual Router Redundancy Protocol (VRRP)—offer robust solutions for achieving network resilience and high availability.

HSRP, designed by Cisco, functions by assigning roles to routers as either active or standby. These routers periodically exchange hello packets every 3 seconds, which allows the standby router to continuously monitor the status of the active router. If the standby router detects a failure—such as a loss of hello messages—it automatically transitions into the active role to maintain uninterrupted service (Purwanto & Risnanto, 2018). This protocol ensures that end users remain connected even when the primary device encounters issues.

Similarly, VRRP, an open standard protocol, operates through a hierarchical structure consisting of a master router and one or more backup routers. The master router sends advertisement packets every second to indicate its availability. If these advertisements cease, the backup router immediately assumes the master role to preserve network continuity (Amanda, 2017). VRRP's rapid failover capability makes it particularly effective for environments that require minimal downtime and real-time service availability.

Given the operational challenges experienced at BKPSDM, implementing and comparing both HSRP and VRRP offers valuable insights into achieving a more reliable, stable, and resilient network infrastructure. This research aims to evaluate the performance, failover response, and operational effectiveness of the two redundancy protocols within the BKPSDM environment. The expected outcome is the identification of the most suitable protocol for supporting a high-availability network that can ensure continuous public service delivery at the Palembang Office of the Personnel and Human Resources Development Agency.

Methodology

Research method

This study employs the Action Research methodology. Action research is a method that allows the researcher to simultaneously interpret and describe a situation while executing a change (intervention) with the primary goal of achieving systemic improvement or increased participation. The action research process is structured into five sequential stages (Davison and Martinsons, 1980):

1. Diagnosing
2. Action Planning
3. Action Taking
4. Evaluating
5. Learning

Data collection utilized multiple methods, including: field observations, formal interviews, and a comprehensive literature review.

Theoretical Review: Router

A router is a network device that connects one network to another. It is used to interconnect multiple segments or networks, regardless of whether they employ the same or different networking technologies. Consequently, a router can facilitate communication across networks using various topologies, such as Bus, Star, and Ring.

A router operates by constructing a routing table, which clarifies the addressing path for data packets (Lintang, 2022). Its function is to determine the optimal route to forward data packets from the source to the destination. A router must identify the best available route for the data packet (Ulfa and Fatoni, 2017). A router is also susceptible to operational issues, such as overheating or physical network cable failures. The implementation of redundancy protocols, specifically HSRP and VRRP, is therefore necessary to address these potential router failures (Sofana, 2013a).

Hot Standby Router Protocol (HSRP)

HSRP is a proprietary technology designed to address router failure issues. Its mechanism establishes a backup path that automatically activates upon a primary device failure, preventing excessive load on the remaining network infrastructure. When an HSRP-configured primary router fails, the router with the standby status seamlessly transitions to the active role (Pamungkas and Prayitno, 2018).

HSRP provides high network availability by introducing redundancy for IP traffic originating from hosts on the network. Within a group of router interfaces, the active routter is the preferred device for packet routing, while the standby router assumes the routing tasks when the active router fails or when predefined conditions are met. HSRP is particularly beneficial for hosts that do not support router protocols and cannot dynamically switch to a new router when the primary device fails or loses power.

When HSRP is configured, it provides a virtual MAC address and a virtual IP address shared among the router interfaces within the HSRP group. The active router routes packets destined for the group's virtual MAC address. HSRP detects when the designated active router fails, prompting the standby router to assume control of the virtual MAC and IP addresses of the hot standby group. A new standby router is then selected. HSRP devices use multicast UDP-based "hello" packets to detect router failures and to appoint the active and standby routers. Furthermore, when HSRP is enabled on an interface, Internet Control Message Protocol (ICMP) redirect messages are automatically activated for that interface (Cisco System, 2018).

Virtual Router Redundancy Protocol (VRRP)

VRRP is an open standard protocol, making it suitable for environments where equipment from different vendors is present. Its operation is fundamentally similar to HSRP but incorporates several key distinctions. In a VRRP group, a set of routers is configured, electing one to be the master router and the others as backup routers. The master router's physical IP address is used by clients as their default gateway.

Backup members of the VRRP group communicate with the master gateway using "Hello" packets. The backup router takes over the primary's duties when the master router fails or an error occurs. Critically, the IP address utilized always belongs to the primary router, which is referred to as the IP Address Owner. When the master router recovers from a fault, it reclaims its responsibility and resumes forwarding network traffic. VRRP effectively aggregates a group of routers to act as a single network gateway, allowing traffic to pass through that gateway. The master router is chosen from the group via the VRRP election mechanism to serve as the gateway (Imelda et al., 2020).

Results Discussion

HSRP Configuration Implementation

This stage involved configuring HSRP on the Active and Standby network routers to establish a redundant link. This method was applied to resolve the network reliability issues present at the Palembang Office of the Personnel and Human Resources Development Agency.

1. HSRP Configuration on the Active
   Router The configuration establishes two HSRP groups (Group 1 and Group 2) for two different network segments, with the router set to actively reclaim its role (preempt) upon recovery.

   Router-Active(config-if)#int fa0/0

Router-Active(config-if)#standby 1 ip 103.131.4.1
Router-Active(config-if)#standby 1 preempt
*Mar 1 00:07:11.523:&HSRP-5-STATECHANGE: FastEthernet0/0 Grp 1 state Standby ->
Active
Router-Active(config-if)#exit
Router-Active(config)#int fa0/1
Router-Active(config-if)#standby 2 ip 192.168.100.1
Router-Active(config-if)#standby 2 preempt
*Mar 1 00:08:30.719:&HSRP-5-STATECHANGE: FastEthernet0/1 Grp 2 state Standby ->
Active

2. HSRP Configuration on the Standby
Router The standby router is configured with the same virtual IPs but with a lower priority (95) than the default (100) on the Active router, ensuring it remains in the Standby state unless the Active router fails.
Router-Standby(config)#int fa0/0
Router-Standby(config-if)#standby 1 ip 103.131.4.1
Router-Standby(config-if)#standby 1 priority 95
Router-Standby(config-if)#standby 1 preempt
*Mar 1 00:10:08.991:&HSRP-5-STATECHANGE: FastEthernet0/0 Grp 1 state Speak ->
Standby
Router-Standby(config-if)#exit
Router-Standby(config)#int fa0/1
Router-Standby(config-if)#standby 2 ip 192.168.100.1
Router-Standby(config-if)#standby 2 priority 95
Router-Standby(config-if)#standby 2 preempt
*Mar 1 00:11:20.063:&HSRP-5-STATECHANGE: FastEthernet0/1 Grp 2 state Speak ->
Standby

VRRP Configuration Implementation

This stage details the VRRP configuration to serve as a comparative baseline against the HSRP implementation, as both protocols function as redundant links.

1. VRRP Configuration on the Master Router
The master router is configured with a high priority (200) to ensure it is always the forwarding router when operational.

Router-Master(config)#int fa0/0
Router-Master(config-if)#vrrp 1 ip 103.131.4.1
*Mar 1 00:04:05.995:&VRRP-6-STATECHANGE: Fa0/0 Grp 1 state Backup -> Master

Router- Master (config-if)#vrrp 1 priority 200
Router- Master(config-if)#exit
Router- Master(config)#int fa0/1
Router- Master(config-if)#vrrp 2 ip 192.168.100.1
*Mar 1 00:06:44.099:&VRRP-6-STATECHANGE: Fa0/1 Grp 2 state Backup -> Master
Router- Master(config-if)#vrrp 2 priority 200
Router- Master(config-if)#exit

2. VRRP Configuration on the Backup Router The backup router is configured with the same virtual IPs but with a lower priority (100)
Router-Backup(config)#int fa0/0
Router-Backup(config-if)#vrrp 1 ip 103.131.4.1
*Mar 1 00:09:32.799:&VRRP-6-STATECHANGE: Fa0/0 Grp 1 state Init -> Backup
Router-Backup(config-if)#vrrp 1 priority 100
Router-Backup(config-if)#exit
Router-Backup(config)#int fa0/1
Router-Backup(config-if)#vrrp 2 ip 192.168.100.1
*Mar 1 00:10:17.387:&VRRP-6-STATECHANGE: Fa0/1 Grp 2 state Init -> Backup
Router-Backup(config-if)#vrrp 2 priority 100
Router-Backup(config-if)#exit

Network Topology Design

The network topologies for the VRRP and HSRP modes share similar designs and are both intended to provide router redundancy to solve the network problems at the Palembang BKPSDM office. The design proposes a redundant router setup within the network.

The visual representations of the HSRP and VRRP network topologies are provided in the figures below.

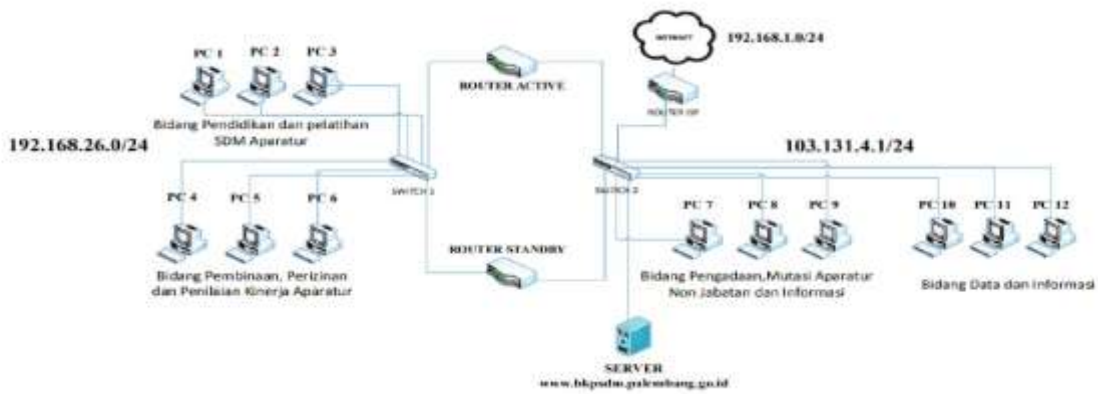

Figure 1. HSRP Network Topology

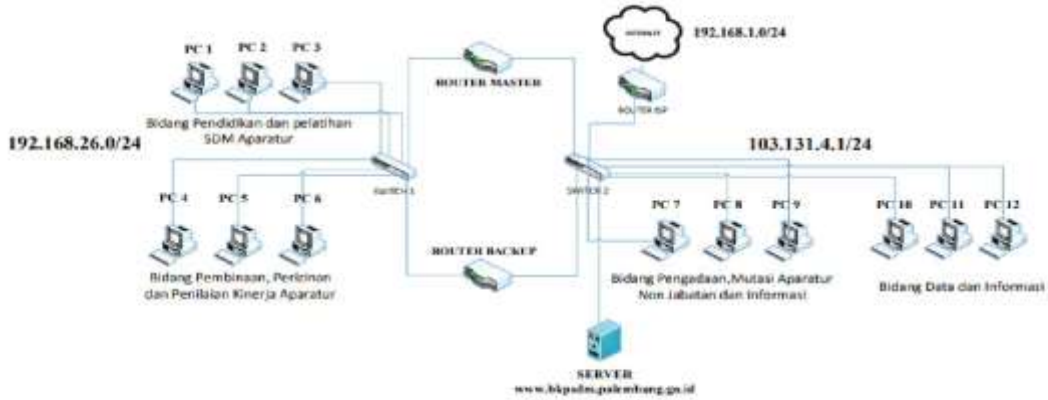

Figure 2. VRRP Network Topology

Measurement Results and Averages

The results obtained from the implementation testing are analyzed against theoretical data. Measurements focused on four key Quality of Service (QoS) parameters: Packet Loss, Delay, Throughput, and Failover (termed Downtime in the original).

Table 1. Individual Measurement Results

Administrative Unit	**Protocol**	**Router Role**	**Packet Loss (%)**	**Delay (ms)**	**Throughput (kbps)**	**Failover Time**
Procurement, Mutation, Non-Position Apparatus & Info	HSRP	Active	12.0	103.2	980.6	00:07.34
	HSRP	Standby	18.8	136.2	948.6	—
	VRRP	Master	21.0	105.8	1038.8	00:07.57
	VRRP	Backup	22.2	130.6	1017.8	—
Data and Information	HSRP	Active	13.4	111.8	915.2	00:08.22
	HSRP	Standby	20.6	146.2	899.4	—
	VRRP	Master	22.8	110.8	962.4	00:07.18

	VRRP	Backup	22.0	141.2	976.2	—
Education and Training of Apparatus HR	HSRP	Active	19.8	172.2	729.2	00:09.31
	HSRP	Standby	24.0	205.4	721.6	—
	VRRP	Master	23.4	156.4	831.8	00:08.22
	VRRP	Backup	24.4	193.6	735.6	—
Apparatus Development, Licensing, and Performance Review	HSRP	Active	17.0	138.8	790.4	00:08.01
	HSRP	Standby	21.4	159.0	768.8	—
	VRRP	Master	21.4	116.6	797.0	00:08.13
	VRRP	Backup	24.0	152.8	798.6	—

Table 2. Average Measurement Results

Scenario	Router Role	Avg. Packet Loss (%)	Avg. Delay (ms)	Avg. Throughput (Kbit/s)	Avg. Failover Time (s)
HSRP	Active	15.55%	122.2	853.85	8.22
HSRP	Standby	21.20%	161.7	834.60	—
VRRP	Master	22.15%	131.5	907.50	7.27
VRRP	Backup	23.15%	154.5	882.05	—

Packet Loss Analysis

The average packet loss for each scenario is categorized into the main router and the backup router. A lower packet loss value indicates better QoS because it quantifies the number of data packets lost during transmission. The highest average packet loss was recorded at 23.15% on the VRRP backup router, which falls into the medium category.

Conversely, the lowest average packet loss was 15.55% on the HSRP active router, also categorized as medium. The data suggests that when the active router path is restored (failback), the resulting packet loss is lower compared to when the active router path initially fails. This phenomenon is attributed to the quicker failback time, which results in fewer lost data packets and a reduced queue for retransmission. A primary cause of packet loss is data collision or contention within the network (Wulandari, 2016). Prolonged congestion in the LAN can cause network device buffers to fill up, leading to the rejection of new data and subsequent packet loss.

Delay Analysis

The average delay measurements across the scenarios revealed that the highest average delay was 161.7 ms on the HSRP standby router, which is classified as Good. The lowest average delay was 122.2 ms on the HSRP active router, categorized as Very Good. According to the TIPHON standardization, delay is categorized as: Very Good (< 150 ms), Good (150 ms to 300 ms), Medium (300 ms to 450 ms), and Poor (> 450 ms).

The elevated delay values occurred specifically when the active router path failed. This increase is due to the process of transferring the congested traffic from the failed active path to the standby router. This handover process requires time for the standby router to assume control, leading to a larger delay and increasing the time required for data retransmission. Furthermore, differences in the physical distance of the transmission media for each measured LAN segment also contribute to variations in delay measurements (Pratama, 2015).

Throughput Analysis

The test results indicate that VRRP generally achieved better throughput values compared to HSRP. This difference is hypothesized to be related to the data encapsulation process occurring at different IP transport layer types during data transmission, which affects the speed at which packets arrive. The highest throughput value was 907.5 Kbps on the VRRP master router, while the lowest was 834.6 Kbps on the HSRP standby router. Both throughput results fall into the Fair category.

Failover (Downtime) Analysis

The average failover (or downtime) value for each scenario is a crucial indicator of network QoS, as it represents the time required to update the routing table following a failure. A smaller failover time correlates with better network QoS. VRRP demonstrated superior performance with an average failover time of 7.27 seconds, compared to HSRP's 8.22 seconds. This aligns with the characteristic hold timers of the protocols, where HSRP typically has a hold timer of approximately 10 seconds, and VRRP ranges from 3 to 7 seconds (Rodiah, 2020).

Conclusion and Recommendations

Based on the Quality of Service analysis conducted at the Palembang Office of the Personnel and Human Resources Development Agency, the following conclusions are drawn:

1. The QoS of the network was measured using four key parameters: Packet Loss, Delay, Throughput, and Downtime (Failover time).
2. Packet Loss (the quantity of lost packets during transmission): The HSRP active router achieved an index value of 15.55% (medium), while the VRRP master router recorded 22.15% (medium).
3. Delay (the time interval between packet arrivals at the destination terminal): The HSRP active router demonstrated the best performance with 122.2 ms (Very Good), followed by the VRRP master router at 131.5 ms (Very Good).
4. Throughput (the time required for a data packet to travel from transmitter to receiver): The VRRP master router yielded the highest throughput at 907.5 Kbps (Fair), compared to the HSRP active router at 853.85 Kbps (Fair).
5. Downtime (Failover) (the total time a system is offline or non-functional): The VRRP method achieved a faster failover time of 7.27 seconds, significantly outperforming the HSRP method, which recorded 8.22 seconds. A lower downtime value indicates a superior QoS network quality.

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