PORTFOLIO DOCUMENTATION
SIMULATION AND DESIGN OF MIKROTIK-BASED RT/RW NETWORK IN GNS3

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1. INTRODUCTION

As someone who studies computer networks, I am always inspired by innovations that have a real impact on society. One of the concepts I admire most is RT/RW Net, a brilliant idea pioneered by figures such as Onno W. Purbo in Indonesia. This innovation provides independent internet networks at the RT or RW level, especially in areas that are not yet covered by conventional internet service providers (ISPs). This concept is not just about connectivity, but also about digital inclusion and equitable access to information, a crucial pillar of the Tri Dharma of Higher Education, namely Community Service.

The objective of this project is to conduct a case study of the design and simulation of the implementation of the RT/RW Net concept on a small scale. This project includes several main stages, starting from the design of a scalable network topology, the preparation of an IP addressing scheme using VLAN for network segmentation, to the implementation of basic configurations on virtual devices. All core configurations, particularly in terms of routing, DHCP, NAT, and bandwidth management (QoS), will be centered on the MikroTik router (CHR) simulated using GNS3.

This project demonstrates how network innovation can have a direct impact and become a work program for several KKN students. One example is the research by Husaini & Sari from the University of Muhammadiyah North Sumatra, which documents the implementation of RT/RW Net using MikroTik devices as a connectivity solution in Dusun V Suka Damai, Sei Meran Village[1]. It was the inspiration from this real-world impact that motivated me to design RT/RW Net as my portfolio.

[1] Husaini, A., & Sari, I. P. (2023). Konfigurasi dan Implementasi RB750Gr3 sebagai RT-RWNet pada DusunV Suka Damai Desa Sei Meran. Jurnal Teknik Informatika, 2(4), 1-8.

2. THE CONCEPT OF RT/RW NET IN INDONESIA

RT/RW Net first appeared around 1996, initiated by students at Muhammadiyah University Malang (UMM) who wanted to connect boarding houses to the UMM campus, which at that time was already connected to the AI3 Indonesia network. At that time, the connection was made using walkie-talkies on the 2-meter VHF band at a speed of 1200 bps.

This idea was born out of a simple need: the cost of internet rental from conventional ISPs was very expensive, reaching around Rp1,300,000 per month for individuals. Through the concept of cost sharing, seven people could enjoy the internet by paying only around Rp200,000 per month, which was much more affordable. The limitations of wireless devices, which were still expensive at the time, led to the use of more economical walkie-talkies, becoming the foundation of the RT/RW Net philosophy: smart solutions amid limitations.

As time went by, especially in the 2000s when social media became popular and internet cafes mushroomed, the demand for internet access skyrocketed. RT/RW Net became a “savior” by providing affordable internet access to the community, and many local network communities adopted this concept.

Today, RT/RW Net remains highly relevant and continues to be an innovative solution, especially in remote areas, as often discussed by Mr. Onno W. Purbo. Its business model is flexible; some administrators connect to the main cable from the nearest ISP in the city and then manage distribution independently in their area. However, in many areas with geographical challenges—whether mountains, vast plantations, or long distances—where laying fiber optic cables is not economical, wireless solutions become the key.

To reach these areas, it is often necessary to build towers to create stable Point-to-Point (PtP) connections to the internet source location. High-reach antennas are installed on these towers to ‘bridge’ the signal from the city to the village. The benefits of this independent infrastructure are truly felt, allowing the community to enjoy affordable internet.

3. TOPOLOGY DESIGN

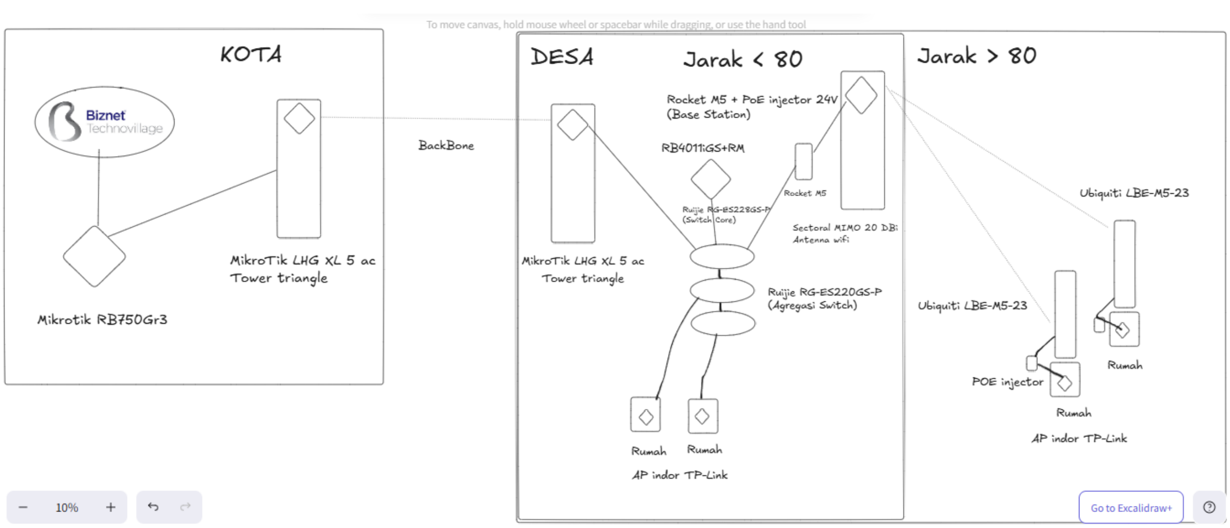
3.1 General Description

This chapter details the proposed RT/RW Net network topology design, from conceptual architecture to hardware selection. The main objective of this design is to build an efficient and scalable network infrastructure to distribute a single internet connection source from the CITY area to approximately 100 end users in the VILLAGE area (initial target).

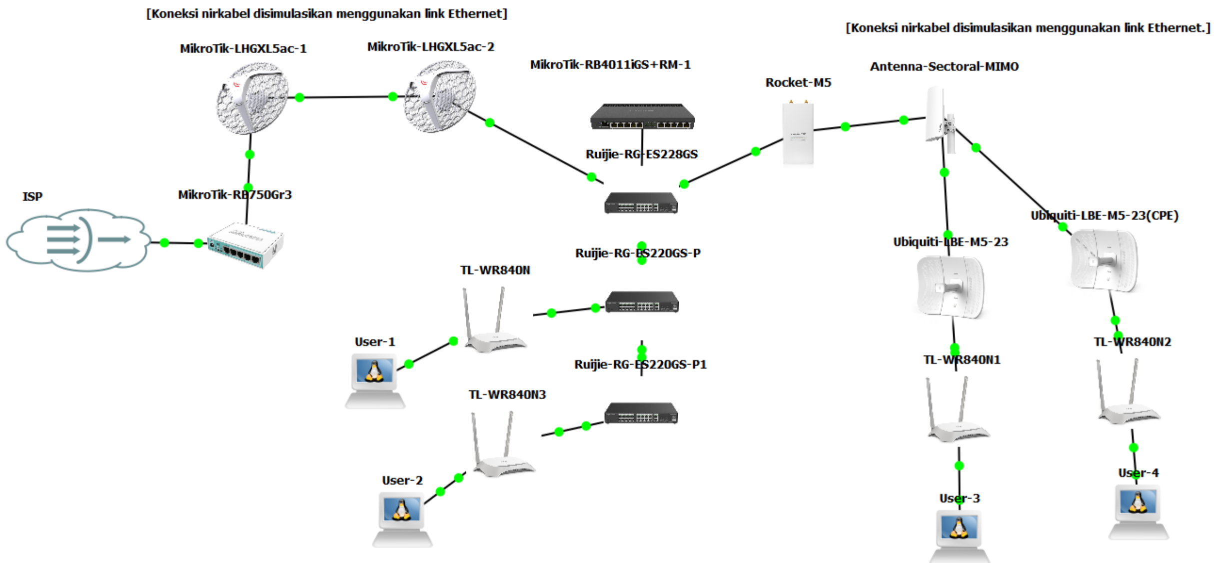
To achieve these objectives, this architecture implements several core technologies. A Point-to-Point (PtP) wireless link is used as the main backbone. On the village side, the network is distributed through wired and wireless Point-to-MultiPoint (PtMP) mechanisms. The entire network is segmented using VLANs to separate management and user traffic, and is centrally managed by a Core Router that is also responsible for DHCP, NAT, and Quality of Service (QoS) services.

3.2 Topology Design

The visualization of the architecture described above is represented in the following two diagrams: the conceptual design as a blueprint and the simulation implementation in GNS3 as a functional model for configuration testing.



Picture 1. Conceptual Topology Design



Picture 2. Topology implementation on GNS3

As illustrated in the diagram above, the data flow in this topology starts from the ISP in the CITY, crosses the wireless backbone, and is distributed in the VILLAGE area.

- Source & Gateway (CITY): The internet source from the ISP is received by MikroTik RB750Gr3, which functions as a gateway router. Its task is to serve as the termination point for the ISP connection before it is forwarded to the internal network.
- Backbone (CITY → VILLAGE): The connection from the gateway is bridged to the village location via a PtP wireless link using a pair of MikroTik LHG XL 5 ac antennas. This device was chosen for its ability to provide a stable, high-speed connection over long distances.
- Core Network (VILLAGE): On the village side, the connection from the backbone is received and forwarded to the MikroTik RB4011iGS+RM. This device acts as the Core Router or the “brain” of the network. This is where all major management processes such as inter-VLAN routing, firewall, NAT, DHCP Server, and bandwidth management (QoS) are centrally controlled.

- Distribution & Access (VILLAGE → USER): From the Core Router, traffic is distributed through the Core Switch (Ruijie RG-ES228GS-P). For nearby users (<80m), the connection is routed through LAN cables, extended with an Aggregation Switch. For remote users (>80m), the connection is broadcast by the Base Station (Ubiquiti Rocket M5) to the CPE (Ubiquiti LBE-M5-23) at the customer's home. Finally, the connection in each home is distributed as a Wi-Fi signal by the Indoor AP (TL-WR840N3).

3.3 IP Address Allocation

To create a well-managed network, this topology implements network segmentation using two main VLANs managed by the Core Router.

VLAN ID	IP Network	Gateway	Functions
10	172.16.0.0/24	172.16.0.1	Used only for management devices. Therefore, the IP address configuration for each device can be done **statically**.
20	172.16.1.0/24	172.16.1.1	Used for all users, whether they are connected directly via cable or via a Sectoral antenna, so DHCP Server configuration is **required**.

3.4 Device Specifications

The following are the details of the network devices required to build the RT/RW Net network infrastructure in accordance with the designed topology.

No	Device Name	Quantity	Estimated Unit Price (Rp)	Estimated Total (Rp)
1	Mikrotik RB750Gr3 (Gateway Router to ISP)	1	1.020.000	1.020.000
2	Mikrotik RB4011iGS+RM (Internal Core Router)	1	4.099.000	4.099.000
3	MikroTik LHG XL 5 ac	2	2.109.000	4.218.000
4	Tower Triangle	2	1.200.000	2.400.000
5	Ruijie RG-ES228GS-P (Switch Core)	1	5.500.000	5.500.000

6	Ruijie RG-ES220GS-P (Agregasi Switch)	2	9.011.000	18.022.000
7	Sectoral MIMO 20 dBi	1	3.100.000	3.100.000
8	Rocket M5 (Base Station)	1	831.979	831.979
9	Ubiquiti LBE-M5-23 (CPE)	-	1.020.000	-
10	TP-Link TL-WR840N	-	199.000	-
11	Cable LAN (FTP) Cat 6	-	584.500 / roll	-
12	Cable LAN (UTP) Cat 6	-	2.572.300 / roll	-
13	POE Injector 24 V	-	150.000	-

Based on the table above, the total estimated initial cost for procuring core infrastructure equipment is **approximately Rp 41.190.000**. It should be noted that this total **does not include the cost of procuring equipment for each customer**, such as CPE and Indoor AP units, the number of which will be adjusted according to the number of customers who join.

4. IMPLEMENTATION AND CONFIGURATION

Simulation Notes:

Since GNS3 does not support wireless device simulation, some devices such as antennas, indoor Access Points (APs), and CPEs (Client Premises Equipment) are simulated using GNS3's built-in standard switches. However, the main function of data traffic forwarding is still well represented.

4.1 MikroTik RB4011iGS+RM Configuration (Core Router)

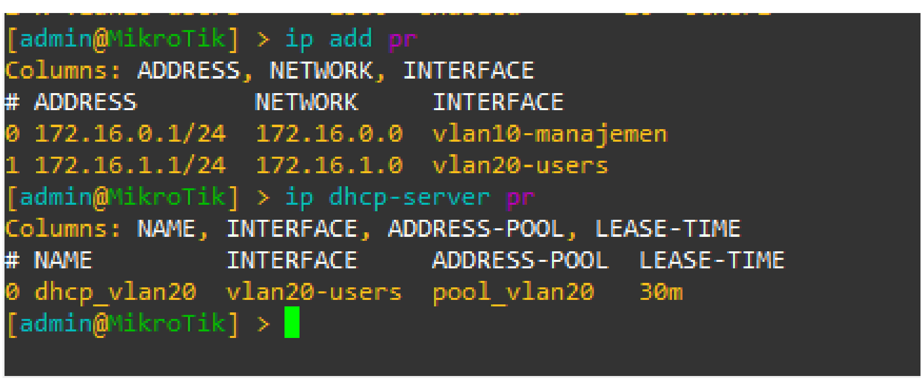
Step 1: Create VLAN 10 and VLAN 20 interfaces through the ether1 physical interface.

Step 2: Assign an IP address to each VLAN as the main gateway:

- VLAN 10: 172.16.0.1/24
- VLAN 20: 172.16.1.1/24

Step 3: Configure the DHCP Server on VLAN 20 so that users (user side) obtain IP addresses automatically. Address pool: 172.16.1.2 – 172.16.1.254

Step 4: Set the default route to the RB750Gr3 router gateway (internet source). Gateway address: IP used by RB750Gr3 on the VLAN 10 network.



```
[admin@MikroTik] > ip add pr
Columns: ADDRESS, NETWORK, INTERFACE
# ADDRESS        NETWORK     INTERFACE
0 172.16.0.1/24  172.16.0.0  vlan10-manajemen
1 172.16.1.1/24  172.16.1.0  vlan20-users
[admin@MikroTik] > ip dhcp-server pr
Columns: NAME, INTERFACE, ADDRESS-POOL, LEASE-TIME
# NAME         INTERFACE     ADDRESS-POOL  LEASE-TIME
0 dhcp_vlan20  vlan20-users  pool_vlan20   30m
[admin@MikroTik] >
```

Picture 3. VLAN and DHCP Server configuration display on MikroTik RB4011 in GNS3

4.2 MikroTik RB750Gr3 Configuration (Gateway Router to ISP)

Step 1: Enable the DHCP Client on the ether1 interface to receive an IP address from the ISP.

Step 2: Assign a static IP address to the ether2 interface for the VLAN 10 network (172.16.0.4/24).

Step 3: Configure the NAT firewall to allow internet forwarding to all local network devices.

Step 4: Add a public DNS server (Google 8.8.8.8) so that devices on the network can perform ping name resolution.

```
[admin@MikroTik] > ip add pr
Flags: D - DYNAMIC
Columns: ADDRESS, NETWORK, INTERFACE
#   ADDRESS            NETWORK        INTERFACE
0   172.16.0.4/24      172.16.0.0     ether2
1 D 192.168.122.62/24  192.168.122.0  ether1
[admin@MikroTik] > ip firewall nat pr
Flags: X - disabled, I - invalid; D - dynamic
 0    chain=srcnat action=masquerade out-interface=ether1
[admin@MikroTik] > ip dns pr
                      servers: 8.8.8.8
                               1.1.1.1
              dynamic-servers: 192.168.122.1
               use-doh-server:
              verify-doh-cert: no
```

Picture 4. IP Address, NAT, and DNS configuration display on MikroTik RB750Gr3

4.3 Mikrotik LHG XL 5 ac Configuration – Transceiver (City)

Step 1: Create a bridge interface to combine ether1 and ether2 so that they can work on Layer 2.

Step 2: Assign an IP address to the bridge according to the VLAN 10 network ID (172.16.0.3/24).

```
[admin@MikroTik] > int bridge pr
Flags: D - dynamic; X - disabled, R - running
 0  R name="bridge-ptp" mtu=auto actual-mtu=1500 l2mtu=65535
      protocol-mode=rstp fast-forward=yes igmp-snooping=no au
      max-message-age=20s forward-delay=15s transmit-hold-cou
      mvrp=no max-learned-entries=auto
[admin@MikroTik] > ip add pr
Columns: ADDRESS, NETWORK, INTERFACE
# ADDRESS        NETWORK     INTERFACE
0 172.16.0.3/24  172.16.0.0  bridge-ptp
[admin@MikroTik] >
```

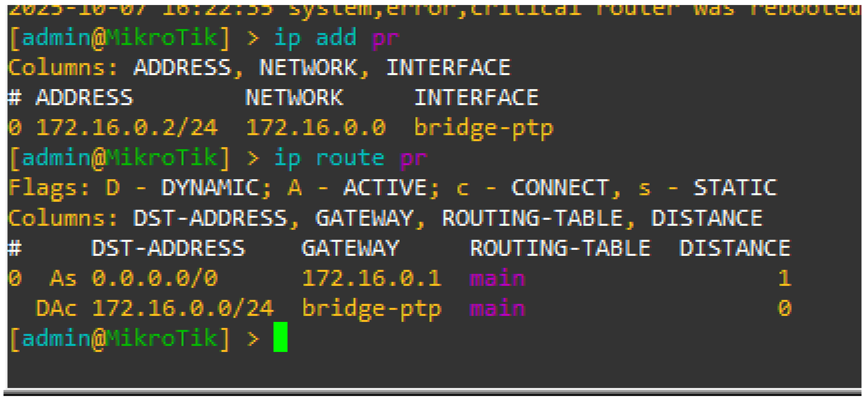
Picture 5. Bridge interface configuration on Mikrotik LHG XL 5 ac (Transceiver – City)

4.4 Mikrotik LHG XL 5 ac Configuration – Receiver (Village)

Step 1: Create a bridge interface to combine ether1 and ether2.

Step 2: Assign an IP address according to the VLAN 10 network ID (172.16.0.2/24).

Step 3: Set the default route to IP 172.16.0.1 as the VLAN 10 gateway.

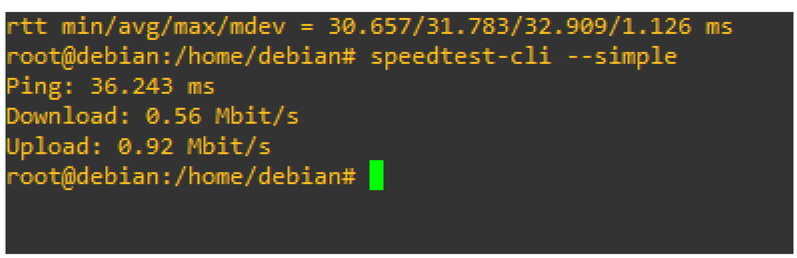


Picture 6. Mikrotik LHG XL 5 ac configuration (Receiver – Village)

4.5 Bandwidth Management Using PCQ

Step 1: Initial Testing

Before bandwidth management was implemented, connection testing was conducted between users to determine the baseline throughput value, resulting in a bandwidth of 560k for downloads and 920k for uploads.



Picture 7. Connection test results before bandwidth management implementation

Step 2: PCQ Implementation

At this stage, bandwidth restrictions are configured using the Per Connection Queue (PCQ) method on the RB4011 core router. The goal is to ensure proportional bandwidth distribution for all active users.

The Per Connection Queue (PCQ) method is used because it can automatically divide bandwidth for each active connection without the need for manual configuration based on static IP addresses. In the context of RT/RW Net networks that use a dynamic DHCP system, this method is very effective because each connected device will receive a fair share of bandwidth.

Conceptually, PCQ functions as a template that determines how bandwidth is divided among users. It is implemented through **Simple Queue**, so that this bandwidth division applies globally to all user subnets, namely **VLAN 20 (172.16.1.0/24)**.

The bandwidth distribution ratio is set at **1:3** between download and upload. Based on the total ISP connection capacity of **0.56 Mbps (download)** and **0.92 Mbps (upload)**, the effective bandwidth limit used in the configuration is:

- Download: **0.56 Mbps (560 kbps)**
- Upload: **0.186 Mbps (186 kbps)**

This value becomes the maximum limit that will be applied to the Simple Queue. Since the simulation involves **four active hosts**, each host receives an average bandwidth allocation of **0.14 Mbps (140 kbps)** for downloads and **0.046 Mbps (46 kbps)** for uploads. This value is used in the PCQ Rate configuration in the PCQ template.

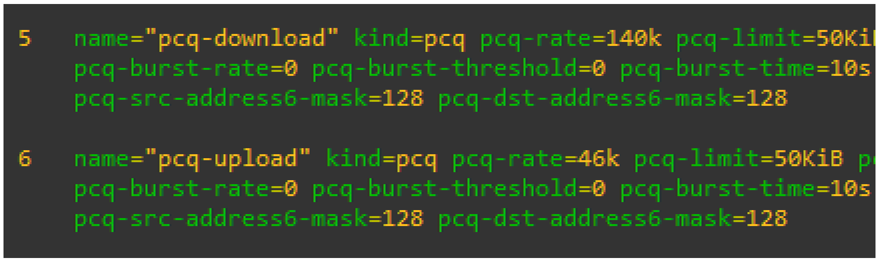
PCQ (Queue Type) Configuration

- pcq-download
    - Classifier: dst-address
    - PCQ Rate: 140 kbps
- pcq-upload
    - Classifier: src-address
    - PCQ Rate: 46 kbps

Simple Queue Configuration

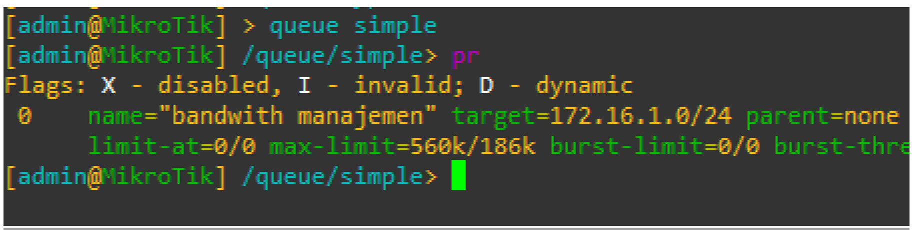
- Target: 172.16.1.0/24
- Queue Type: pcq-download / pcq-upload
- Max Limit: 560k / 186k

The Max Limit parameter indicates the total bandwidth capacity divided based on the download and upload ratio. Meanwhile, the PCQ Rate determines the average allocation limit per active connection.



```
5   name="pcq-download" kind=pcq pcq-rate=140k pcq-limit=50Ki
    pcq-burst-rate=0 pcq-burst-threshold=0 pcq-burst-time=10s
    pcq-src-address6-mask=128 pcq-dst-address6-mask=128

6   name="pcq-upload" kind=pcq pcq-rate=46k pcq-limit=50KiB p
    pcq-burst-rate=0 pcq-burst-threshold=0 pcq-burst-time=10s
    pcq-src-address6-mask=128 pcq-dst-address6-mask=128
```



```
[admin@MikroTik] > queue simple
[admin@MikroTik] /queue/simple> pr
Flags: X - disabled, I - invalid; D - dynamic
 0    name="bandwith manajemen" target=172.16.1.0/24 parent=none
      limit-at=0/0 max-limit=560k/186k burst-limit=0/0 burst-thre
[admin@MikroTik] /queue/simple>
```

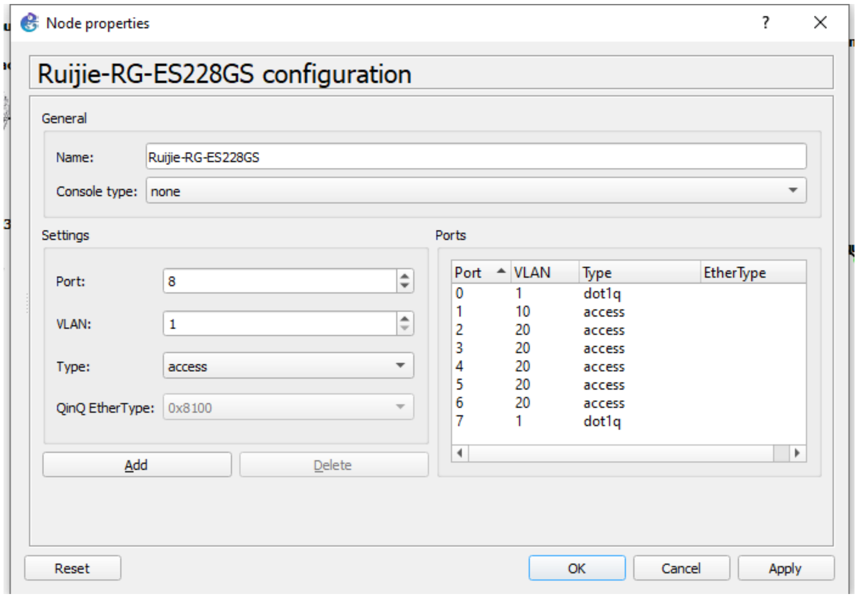
Picture 8. Bandwidth management on MikroTik RB4011.

4.6 Ruijie RG-ES228GS Switch Configuration (Core Switch)

Step 1: Set the Trunk Port (dotiq) on ether0 to receive VLAN 10 and VLAN 20 from the Core Router and uplink to Rocket M5.

Step 2: Set Access VLAN 10 on ether1 connected to the PTP (Point-to-Point) device.

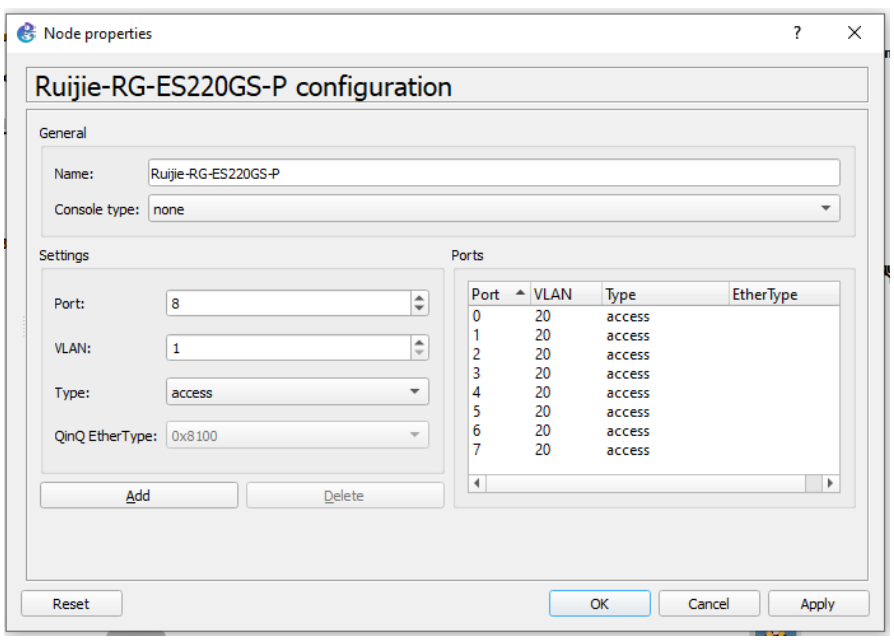
Step 3: Set Access VLAN 20 for the port to the user and uplink to the Aggregation Switch.



Picture 9. Diagram of trunk and access VLAN configuration on the Core Switch

4.7 Ruijie RG-ES220GS-P Switch Configuration (Aggregation Switch)

Step 1: Set all ports as Access VLAN 20 because all connections go to users.



Picture 10. Configuration scheme on the Aggregation Switch

4.8 Wireless Simulation Device Configuration

a. Rocket M5 (Base Station)

- Interface *ether0*: Trunk from Switch Core
- Interface *ether1*: Trunk to Sectoral MIMO Antenna

b. Antena Sectoral MIMO

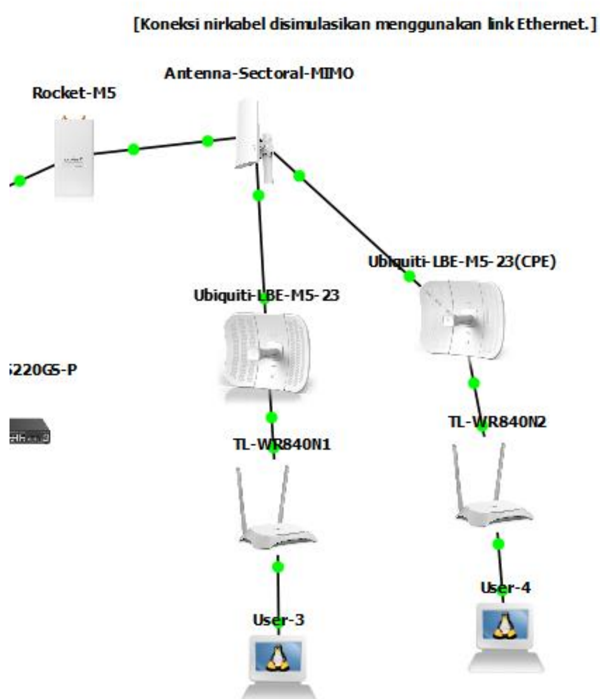
- Interface *ether0*: Trunk to Rocket M5
- Interface *ether1* and *ether2*: Trunk to user CPE

c. Ubiquiti LBE-M5-23 (CPE)

- Interface *ether0*: Trunk from Sectoral MIMO
- Interface *ether1*: Access VLAN 20 to AP user's home

d. TP-Link TL-WR840N (AP Indoor per Rumah)

- All interfaces are set to VLAN 20. This distributes wireless connections to household devices.

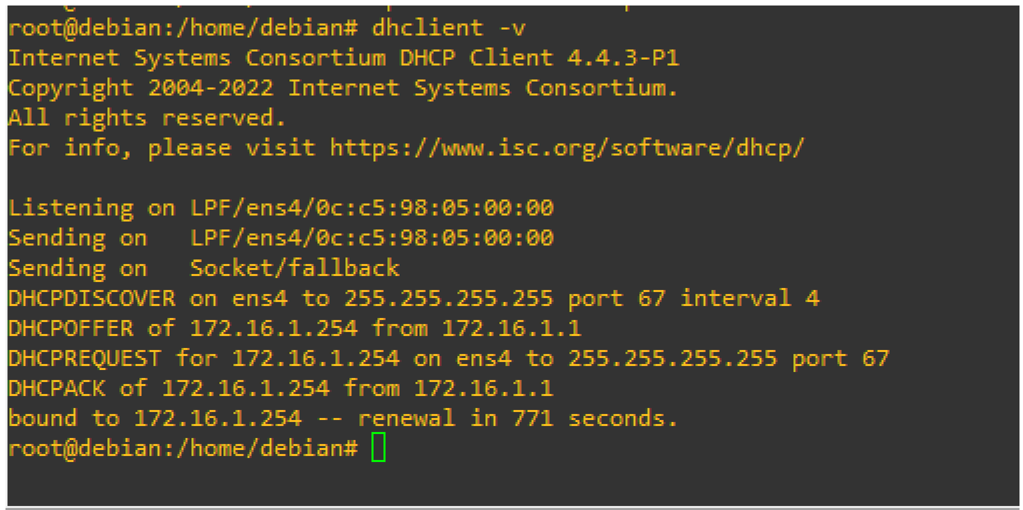


Gambar 11. Illustration of connections between distribution devices on the user side.

5. TESTING AND ANALYSIS

5.1 DHCP Testing and IP Allocation

The first test aims to validate the functionality of the DHCP Server that has been configured on the Core Router (RB4011). The test user (virtual PC) connected to the access VLAN 20 port is expected to obtain an IP address allocation automatically from the specified pool.



Picture 12. DHCP Client Test Results on User PC

5.2 Internet Connectivity Testing

After the user obtains an IP address, testing continues to ensure that the user is successfully connected to the internet by pinging Google's public DNS.

```
oot@debian:/home/debian# ping 8.8.8.8
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=125 time=34.6 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=125 time=32.9 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=125 time=31.5 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=125 time=32.5 ms
64 bytes from 8.8.8.8: icmp_seq=5 ttl=125 time=34.8 ms
64 bytes from 8.8.8.8: icmp_seq=6 ttl=125 time=32.2 ms
64 bytes from 8.8.8.8: icmp_seq=7 ttl=125 time=33.7 ms
64 bytes from 8.8.8.8: icmp_seq=8 ttl=125 time=103 ms
64 bytes from 8.8.8.8: icmp_seq=9 ttl=125 time=43.4 ms
64 bytes from 8.8.8.8: icmp_seq=10 ttl=125 time=49.3 ms
64 bytes from 8.8.8.8: icmp_seq=11 ttl=125 time=56.6 ms
64 bytes from 8.8.8.8: icmp_seq=12 ttl=125 time=55.5 ms
64 bytes from 8.8.8.8: icmp_seq=13 ttl=125 time=33.5 ms
64 bytes from 8.8.8.8: icmp_seq=14 ttl=125 time=32.9 ms
64 bytes from 8.8.8.8: icmp_seq=15 ttl=125 time=270 ms
64 bytes from 8.8.8.8: icmp_seq=16 ttl=125 time=56.9 ms
```

Picture 13. Internet Connectivity Test Results

5.3 Bandwidth Management Testing (QoS)

Next, the Simple Queue rule with the PCQ method, which limits the speed per user to **0.56 Mbps download and 0.14 Mbps upload**, is activated. Testing is performed using the speedtest-cli website, which has been previously installed on the user's PC.

```
root@debian:/home/debian# speedtest-cli --simple
Ping: 55.918 ms
Download: 0.02 Mbit/s
Upload: 0.03 Mbit/s
root@debian:/home/debian#
```

Picture 14. Speed Test Results After QoS Implementation

5.4 Test Result Analysis

Based on the series of tests above, it can be concluded that all core configurations have been running according to design. Users connected to the network successfully obtained IP allocations from the VLAN 20 segment dynamically, and connectivity to the public internet was established without any obstacles.

From the test results, all clients successfully obtained IP addresses from VLAN 20 and bandwidth was distributed evenly according to PCQ parameters. This indicates that the

DHCP and QoS configurations are running effectively. Thus, this simulation validates that the designed topology and configuration scheme have met all the functional objectives set for an RT/RW Net network.

6. CONCLUSION

The simulation and design of the RT/RW Net network based on MikroTik, carried out through GNS3, successfully created a functional topology that effectively represents the community internet distribution system. All configurations, from VLAN, DHCP, NAT, to bandwidth management using the Per Connection Queue (PCQ) method, have been running well according to the design.

The implementation of PCQ through Simple Queue allows for fair bandwidth distribution to each user, so that all clients get equal access speeds without traffic domination from a single device. In addition, the simulation results show that communication between devices across VLANs can run stably, and each node automatically obtains an IP address from the DHCP server located at the central router.

Thus, this simulation project not only demonstrates good network configuration capabilities but also shows a deep understanding of the basic concepts of network management, Quality of Service (QoS), and the implementation of community-based network distribution hierarchies. The topology and methods used in this simulation can be used as a starting point for the development of an efficient, measurable, and easily manageable real RT/RW Net system in a community environment.