

## Лабораторная работа №8

Адресация IPv4 и IPv6. Настройка маршрутизации

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04 февраля 2026

## Цель работы

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## Основная цель

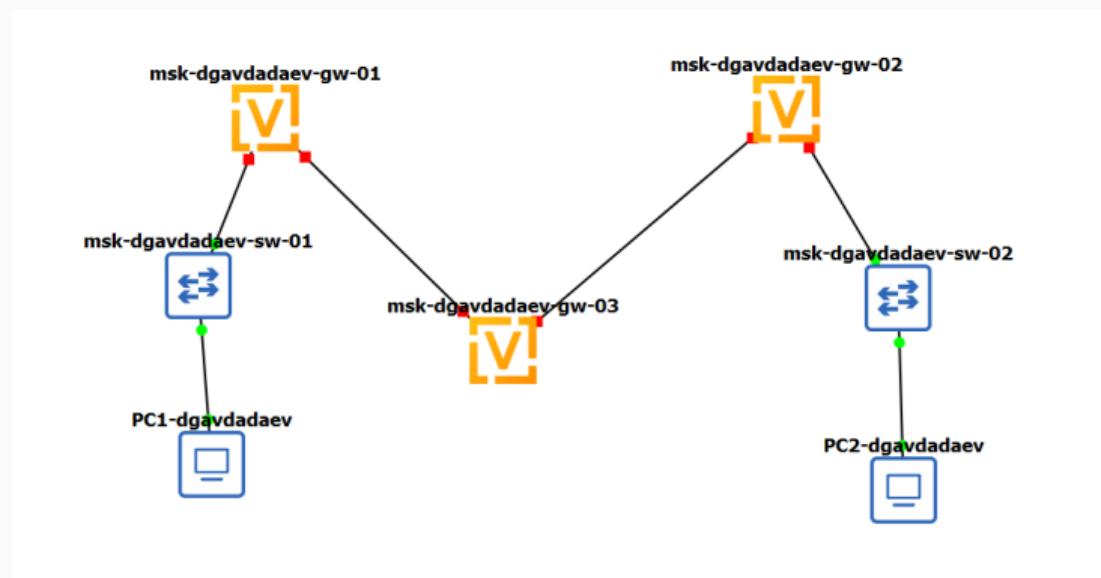
Изучение принципов маршрутизации в IPv4- и IPv6-сетях и практическая настройка сетевого оборудования в среде моделирования **GNS3**.

## Ход выполнения работы

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## Топология IPv6–IPv4

- Построена сеть в GNS3:
  - 3 маршрутизатора VyOS
  - 2 коммутатора Ethernet
  - 2 окончательных устройства VPCS
- Подключён анализатор трафика между gw-01 и gw-03



# Настройка IPv6 на PC1

- Назначен адрес: **1000::a/64**
- Конфигурация сохранена (**save**)
- Проверка параметров (**show ipv6**)

```
Executing the startup file

Hostname is too long. (Maximum 12 characters)

VPCS> ip 1000::a/64
PC1 : 1000::a/64

VPCS> save
Saving startup configuration to startup.vpc
. done

VPCS> show ipv6

NAME          : VPCS[1]
LINK-LOCAL SCOPE : fe80::250:79ff:fe66:6800/64
GLOBAL SCOPE    : 1000::a/64
DNS           :
ROUTER LINK-LAYER :
MAC            : 00:50:79:66:68:00
LPORT          : 10012
RHOST:PORT     : 127.0.0.1:10013
```

## Настройка IPv6 на PC2

- Назначен адрес: **1002::a/64**
- Конфигурация сохранена (**save**)
- Проверка параметров (**show ipv6**)

```
PC2-dgavdadaev - PuTTY
Executing the startup file

Hostname is too long. (Maximum 12 characters)

VPCS> ip 1002::a/64
PC1 : 1002::a/64

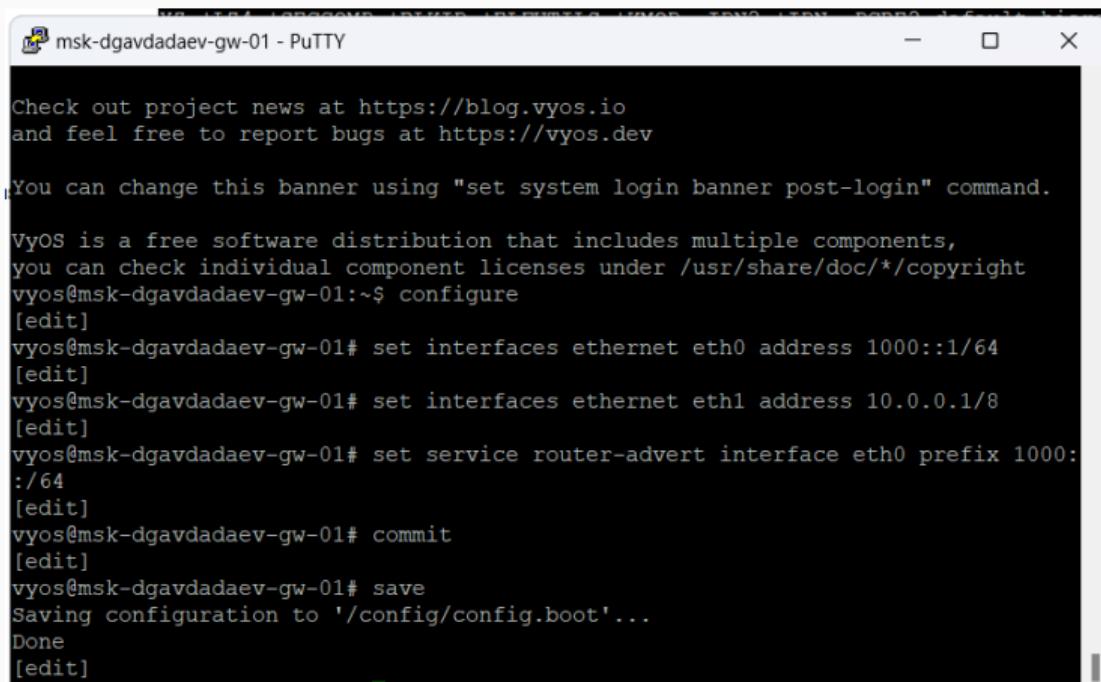
VPCS> save
Saving startup configuration to startup.vpc
. done

VPCS> show ipv6

NAME          : VPCS[1]
LINK-LOCAL SCOPE : fe80::250:79ff:fe66:6801/64
GLOBAL SCOPE   : 1002::a/64
DNS           :
ROUTER LINK-LAYER :
MAC           : 00:50:79:66:68:01
```

# Настройка VyOS gw-01

- eth0: IPv6 1000::1/64 (LAN)
- eth1: IPv4 10.0.0.1/8 (к gw-03)
- Включён Router Advertisement для 1000::/64



The screenshot shows a PuTTY terminal window titled "msk-dgavdadaev-gw-01 - PuTTY". The terminal displays the following configuration steps:

```
Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

You can change this banner using "set system login banner post-login" command.

VyOS is a free software distribution that includes multiple components,
you can check individual component licenses under /usr/share/doc/*/copyright
vyos@msk-dgavdadaev-gw-01:~$ configure
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces ethernet eth0 address 1000::1/64
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces ethernet eth1 address 10.0.0.1/8
[edit]
vyos@msk-dgavdadaev-gw-01# set service router-advert interface eth0 prefix 1000:
:/64
[edit]
vyos@msk-dgavdadaev-gw-01# commit
[edit]
vyos@msk-dgavdadaev-gw-01# save
Saving configuration to '/config/config.boot'...
Done
[edit]
```

## Настройка VyOS gw-02

- eth0: IPv6 1002::1/64 (LAN)
- eth1: IPv4 20.0.0.2/8 (к gw-03)
- Включён Router Advertisement для 1002::/64

```
mks-dgavdadaev-gw-02 - PuTTY
msk-dgavdadaev-gw-02 ~

Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

You can change this banner using "set system login banner post-login" command.

VyOS is a free software distribution that includes multiple components,
you can check individual component licenses under /usr/share/doc/*copyright
vyos@msk-dgavdadaev-gw-02:~$ configure
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces ethernet eth0 address 1002::1/64
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces ethernet eth1 address 20.0.0.2/8
[edit]
vyos@msk-dgavdadaev-gw-02# set service router-advert interface eth0 prefix 1002::/64
[edit]
vyos@msk-dgavdadaev-gw-02# commit
[edit]
vyos@msk-dgavdadaev-gw-02# save
Saving configuration to '/config/config.boot'...
Done
[edit]
```

# Настройка VyOS gw-03

- Транзитный IPv4-узел
- eth0: 10.0.0.2/8
- eth1: 20.0.0.1/8

```
msk-dgavdadaev-gw-03 - PuTTY
msk-dgavdadaev-gw-03 login: vyos
Password:
Welcome to VyOS!

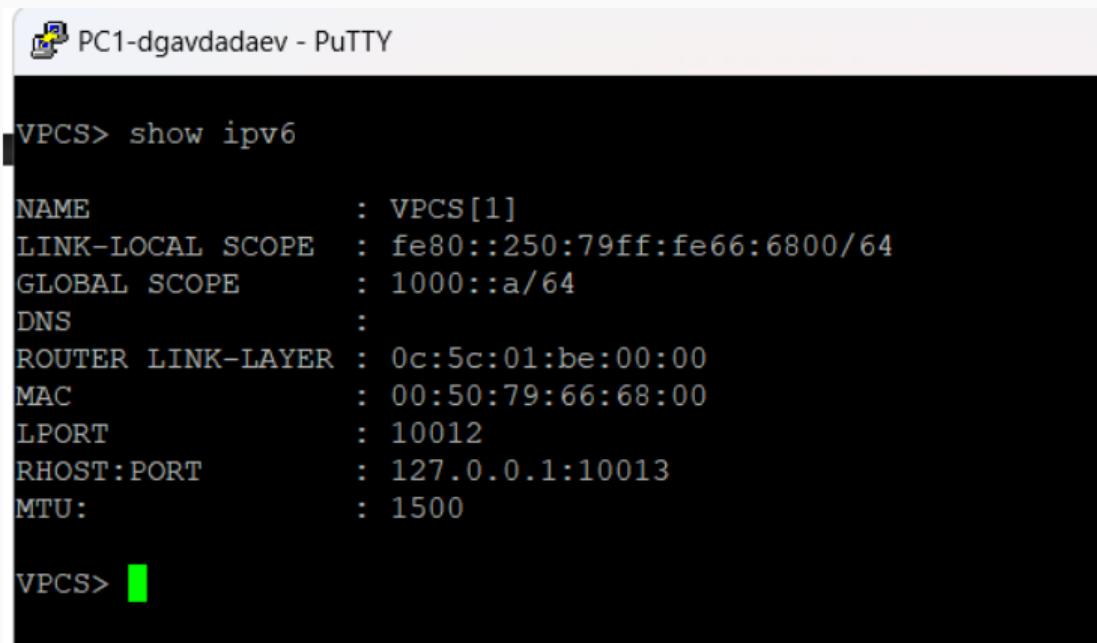
Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

You can change this banner using "set system login banner post-login" command.

VyOS is a free software distribution that includes multiple components,
you can check individual component licenses under /usr/share/doc/*/copyright
vyos@msk-dgavdadaev-gw-03:~$ configure
[edit]
vyos@msk-dgavdadaev-gw-03# set interfaces ethernet eth0 address 10.0.0.2/8
[edit]
vyos@msk-dgavdadaev-gw-03# set interfaces ethernet eth1 address 20.0.0.1/8
[edit]
vyos@msk-dgavdadaev-gw-03# commit
[edit]
vyos@msk-dgavdadaev-gw-03# save
Saving configuration to '/config/config.boot'...
Done
[edit]
```

## Проверка RA и шлюза по умолчанию

- На VPCS отображаются link-local адреса маршрутизаторов
- Подтверждена работа Router Advertisement



```
PC1-dgavdadaev - PuTTY

VPCS> show ipv6

NAME          : VPCS[1]
LINK-LOCAL SCOPE : fe80::250:79ff:fe66:6800/64
GLOBAL SCOPE    : 1000::a/64
DNS           :
ROUTER LINK-LAYER : 0c:5c:01:be:00:00
MAC            : 00:50:79:66:68:00
LPORT          : 10012
RHOST:PORT     : 127.0.0.1:10013
MTU:           : 1500

VPCS>
```

Рис. 7: Проверка IPv6 на PC1

## Проверка IPv4 до маршрутизации

- Успешный ping: 10.0.0.2
- Ошибка *Network is unreachable* для 20.0.0.1 и 20.0.0.2
- Причина: нет маршрутов к 20.0.0.0/8

```
vyos@msk-dgavdadaev-gw-01:~$  
vyos@msk-dgavdadaev-gw-01:~$ ping 10.0.0.2  
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.  
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=1.09 ms  
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.98 ms  
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.51 ms  
^C  
--- 10.0.0.2 ping statistics ---  
3 packets transmitted, 3 received, 0% packet loss, time 5ms  
rtt min/avg/max/mdev = 1.091/1.529/1.982/0.363 ms  
vyos@msk-dgavdadaev-gw-01:~$ ping 20.0.0.1  
connect: Network is unreachable  
vyos@msk-dgavdadaev-gw-01:~$ ping 20.0.0.2  
connect: Network is unreachable  
vyos@msk-dgavdadaev-gw-01:~$
```

Рис. 9: Проверка ping с gw-01

# Анализ ICMP и ARP

- Зафиксированы:
  - ICMP Echo Request / Reply
  - ARP-запросы и ответы

No.	Time	Source	Destination	Protocol	Length	Info
13	5.0008882	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=6/153
14	5.010653	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=6/153
15	5.277145	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2
16	5.277389	0c:5c:01:be:00:01	0c:f6:4a:e9:00:00	ARP	60	10.0.0.1 is at 0c:5c:01:be:00:01
17	6.010888	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=7/179
18	6.012828	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=7/179
19	7.012195	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=8/204
20	7.012895	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=8/204
21	8.014522	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=9/230
22	8.015906	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=9/230
23	9.016657	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=10/25
24	9.017603	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=10/25
25	19.091609	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0871, seq=1/256
26	19.092227	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0871, seq=1/256
27	20.093444	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0871, seq=2/512
28	20.094623	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0871, seq=2/512
→	29.21.094823	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0871, seq=3/768
←	30.21.095494	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0871, seq=3/768

Ethernet II, Src: 0c:f6:4a:e9:00:00 (0c:f6:4a:e9:00:00), Dst: 10.0.0.1 (08:00:2p:0.0.1) [00:0c:f6:4a:e9:00] T

Internet Protocol Version 4, Src: 10.0.0.2, Dst: 10.0.0.1 (08:00:2p:0.0.1) [00:00:00:00:00:00] ...

Internet Control Message Protocol

Type: Echo (ping) reply (0)

Code: 0

Checksum: 0xbacc [correct]

[Checksum Status: Good]

Identifier (BE): 2161 (0x0871)

0000 0c 5c 01 be 00 01 0c f6 4a e9 00 00 08 00 45 00 ..\n0010 00 54 0a e0 00 00 40 01 5b c7 0a 00 00 02 0a 00 ..T\n0020 00 01 00 00 ba cc 08 71 00 03 1d 71 84 69 00 00 ...

0030 00 00 d6 11 06 00 00 00 00 00 10 11 12 13 14 15 ...

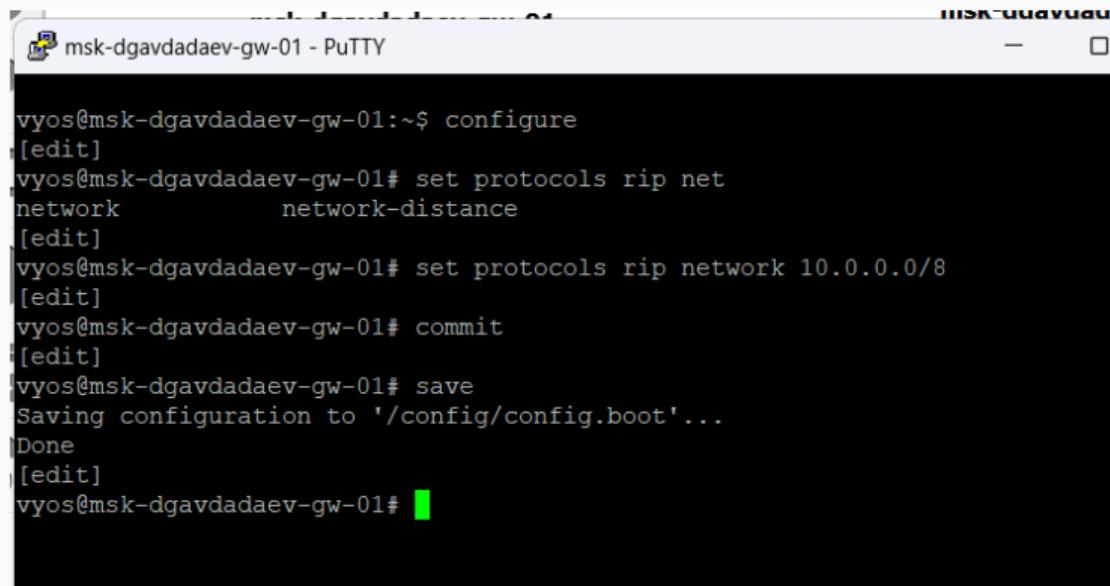
0040 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25 ...

0050 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 32 33 34 35 &(

0060 36 37 67

## Настройка RIP на gw-01

- Добавлена сеть: **10.0.0.0/8**
- Конфигурация применена и сохранена



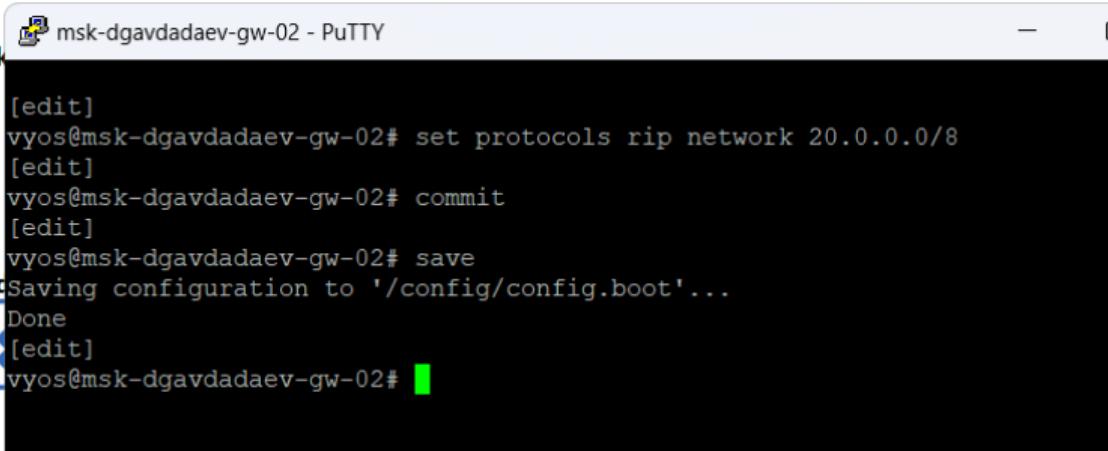
```
msk-dgavdadaev-gw-01 - PuTTY

vyos@msk-dgavdadaev-gw-01:~$ configure
[edit]
vyos@msk-dgavdadaev-gw-01# set protocols rip net
network          network-distance
[edit]
vyos@msk-dgavdadaev-gw-01# set protocols rip network 10.0.0.0/8
[edit]
vyos@msk-dgavdadaev-gw-01# commit
[edit]
vyos@msk-dgavdadaev-gw-01# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-01#
```

Рис. 11: Настройка RIP на msk-dgavdadaev-gw-01

## Настройка RIP на gw-02

- Добавлена сеть: 20.0.0.0/8
- Конфигурация применена и сохранена

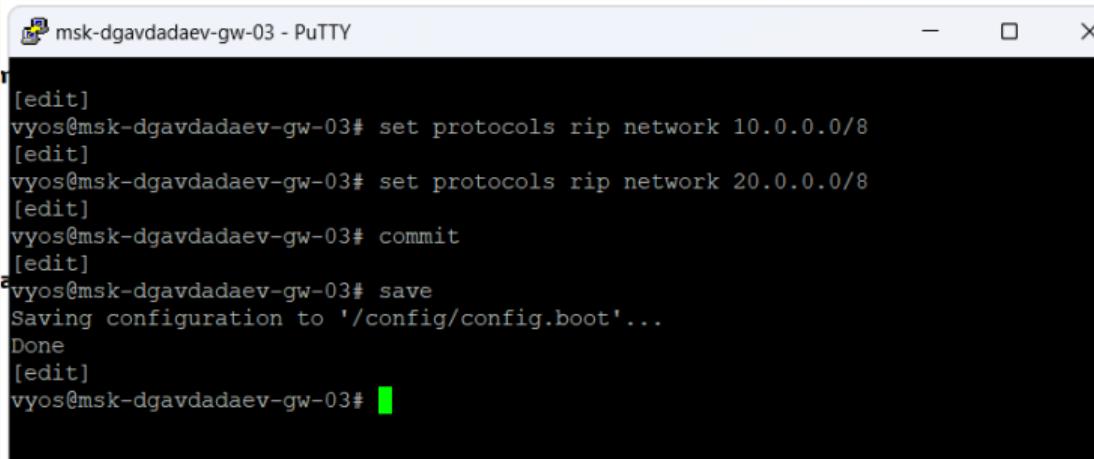


```
[edit]
vyos@msk-dgavdadaev-gw-02# set protocols rip network 20.0.0.0/8
[edit]
vyos@msk-dgavdadaev-gw-02# commit
[edit]
vyos@msk-dgavdadaev-gw-02# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-02#
```

Рис. 12: Настройка RIP на msk-dgavdadaev-gw-02

## Настройка RIP на gw-03

- Участие сразу в двух сетях:
  - 10.0.0.0/8
  - 20.0.0.0/8

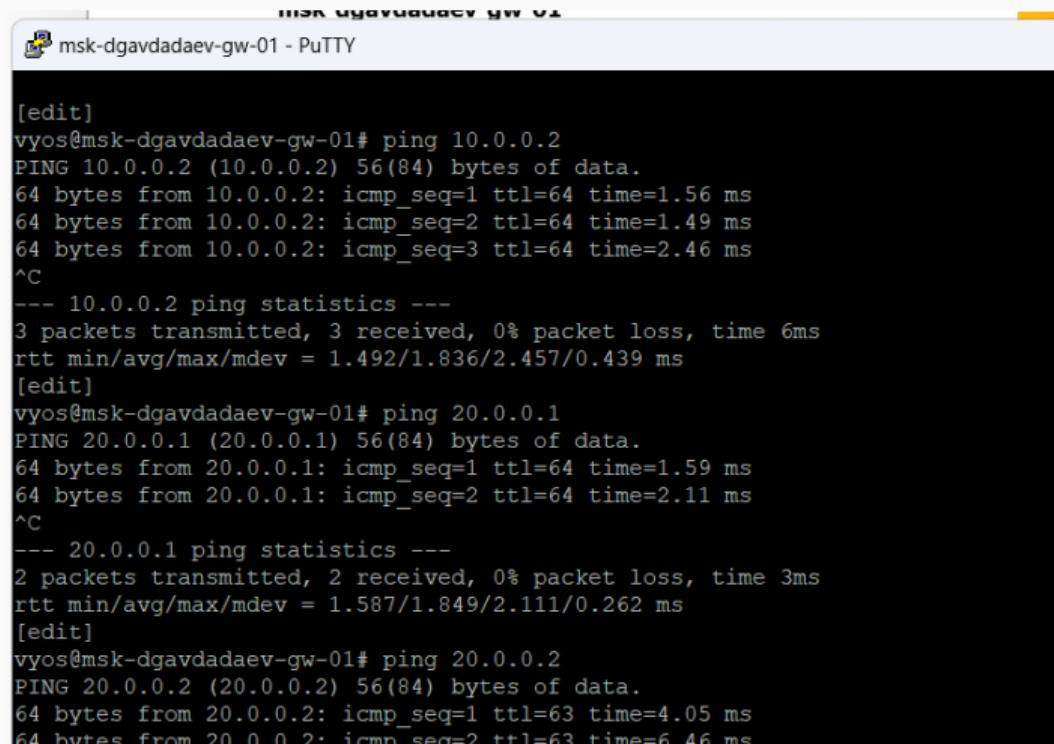


```
[edit]
vyos@msk-dgavdadaev-gw-03# set protocols rip network 10.0.0.0/8
[edit]
vyos@msk-dgavdadaev-gw-03# set protocols rip network 20.0.0.0/8
[edit]
vyos@msk-dgavdadaev-gw-03# commit
[edit]
vyos@msk-dgavdadaev-gw-03# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-03#
```

Рис. 13: Настройка RIP на msk-dgavdadaev-gw-03

## Проверка IPv4 после RIP

- Узлы 20.0.0.1 и 20.0.0.2 стали доступны
- Подтверждена корректная динамическая маршрутизация



```
[edit]
vyos@msk-dgavdadaev-gw-01# ping 10.0.0.2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=1.56 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.49 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=2.46 ms
^C
--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 6ms
rtt min/avg/max/mdev = 1.492/1.836/2.457/0.439 ms
[edit]
vyos@msk-dgavdadaev-gw-01# ping 20.0.0.1
PING 20.0.0.1 (20.0.0.1) 56(84) bytes of data.
64 bytes from 20.0.0.1: icmp_seq=1 ttl=64 time=1.59 ms
64 bytes from 20.0.0.1: icmp_seq=2 ttl=64 time=2.11 ms
^C
--- 20.0.0.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 3ms
rtt min/avg/max/mdev = 1.587/1.849/2.111/0.262 ms
[edit]
vyos@msk-dgavdadaev-gw-01# ping 20.0.0.2
PING 20.0.0.2 (20.0.0.2) 56(84) bytes of data.
64 bytes from 20.0.0.2: icmp_seq=1 ttl=63 time=4.05 ms
64 bytes from 20.0.0.2: icmp_seq=2 ttl=63 time=6.46 ms
```

# Анализ RIP и ICMP трафика

- В трафике наблюдаются:
  - RIPv2 на 224.0.0.9
  - ICMP Echo Request / Reply
  - ARP

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.0.0.2	224.0.0.9	RIPv2	66	Response
2	16.106195	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x097f, seq=1/256, ttl=64 (reply in progress)
3	16.107161	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=1/256, ttl=64 (request in progress)
4	17.108633	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x097f, seq=2/512, ttl=64 (reply in progress)
5	17.109468	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=2/512, ttl=64 (request in progress)
6	18.110575	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x097f, seq=3/768, ttl=64 (reply in progress)
7	18.111881	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=3/768, ttl=64 (request in progress)
8	21.374460	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2
9	21.377104	0c:5c:01:be:00:01	0c:f6:4a:e9:00:00	ARP	60	10.0.0.1 is at 0c:5c:01:be:00:01
10	21.409632	0c:5c:01:be:00:01	0c:f6:4a:e9:00:00	ARP	60	Who has 10.0.0.2? Tell 10.0.0.1
11	21.410577	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	10.0.0.2 is at 0c:f6:4a:e9:00:00
12	22.936415	10.0.0.1	20.0.0.1	ICMP	98	Echo (ping) request id=0x0980, seq=1/256, ttl=64 (reply in progress)
13	22.937379	20.0.0.1	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0980, seq=1/256, ttl=64 (request in progress)
14	23.938829	10.0.0.1	20.0.0.1	ICMP	98	Echo (ping) request id=0x0980, seq=2/512, ttl=64 (reply in progress)
15	23.939911	20.0.0.1	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0980, seq=2/512, ttl=64 (request in progress)
16	28.072811	10.0.0.1	20.0.0.2	ICMP	98	Echo (ping) request id=0x0981, seq=1/256, ttl=64 (reply in progress)
17	28.075541	20.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0981, seq=1/256, ttl=63 (request in progress)
18	29.074066	10.0.0.1	20.0.0.2	ICMP	98	Echo (ping) request id=0x0981, seq=2/512, ttl=64 (reply in progress)
19	29.079071	20.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0981, seq=2/512, ttl=63 (request in progress)
20	33.002513	10.0.0.2	224.0.0.9	RIPv2	66	Response
21	63.004054	10.0.0.2	224.0.0.9	RIPv2	66	Response

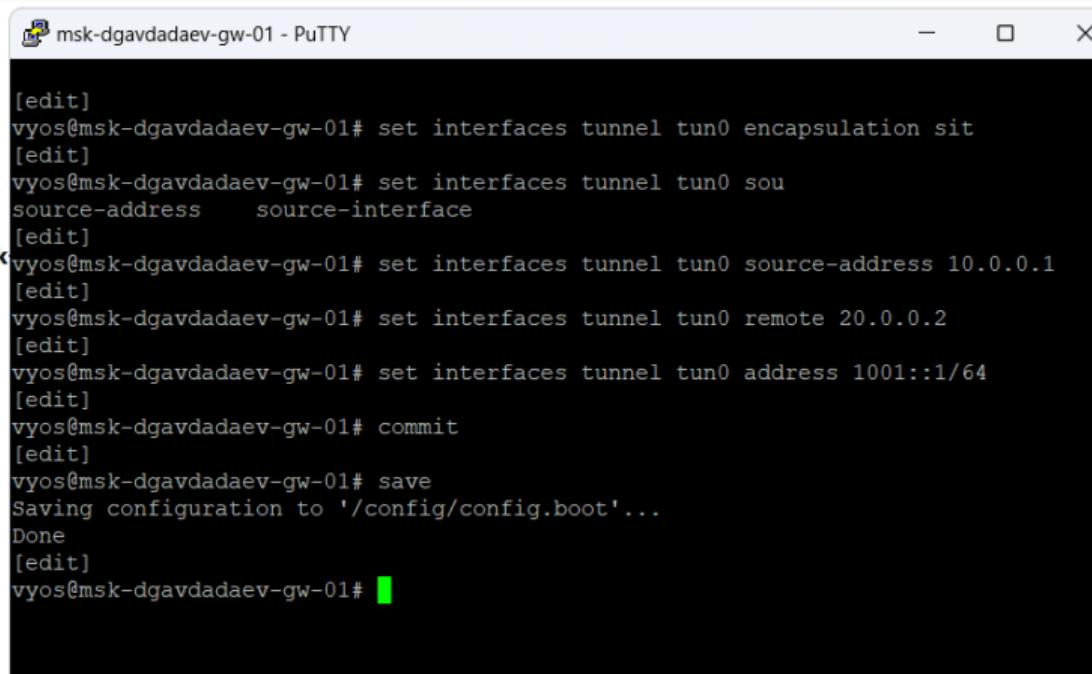
  

```
> Frame 1: Packet, 66 bytes on wire (528 bits), 66 bytes captured (528 bits)
> Ethernet II, Src: 0c:f6:4a:e9:00:00 (0c:f6:4a:e9:00:00), Dst: IPv4 (00:00:00:00:00:00)
> Internet Protocol Version 4, Src: 10.0.0.2, Dst: 224.0.0.9
> User Datagram Protocol, Src Port: 520, Dst Port: 520
> Routing Information Protocol
```

0000	01 05 5e 00 00 09 0c f6 4a e9 00 00 00 00 45 c0 ..^.... J
0010	00 34 30 03 40 00 01 11 5e eb 0a 00 00 02 e0 00 .40 @... ^.
0020	00 05 02 08 02 08 00 20 fc 8c 02 02 00 00 00 02 ..^.....
0030	00 00 14 00 00 00 ff 00 00 00 00 00 00 00 00 00 ..
0040	00 01 ..

# Настройка туннеля на gw-01

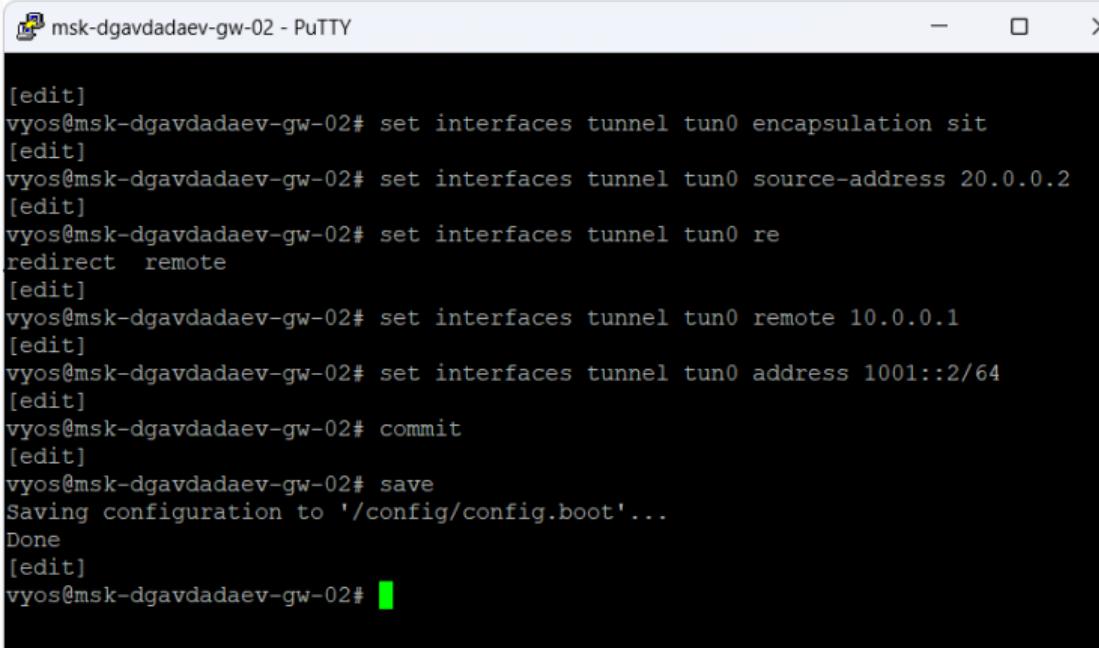
- Интерфейс: **tun0**
- SIT, источник IPv4: **10.0.0.1**, удалённый: **20.0.0.2**
- IPv6 туннеля: **1001::1/64**



```
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 encapsulation sit
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 source-address source-interface
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 source-address 10.0.0.1
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 remote 20.0.0.2
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 address 1001::1/64
[edit]
vyos@msk-dgavdadaev-gw-01# commit
[edit]
vyos@msk-dgavdadaev-gw-01# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-01#
```

## Настройка туннеля на gw-02

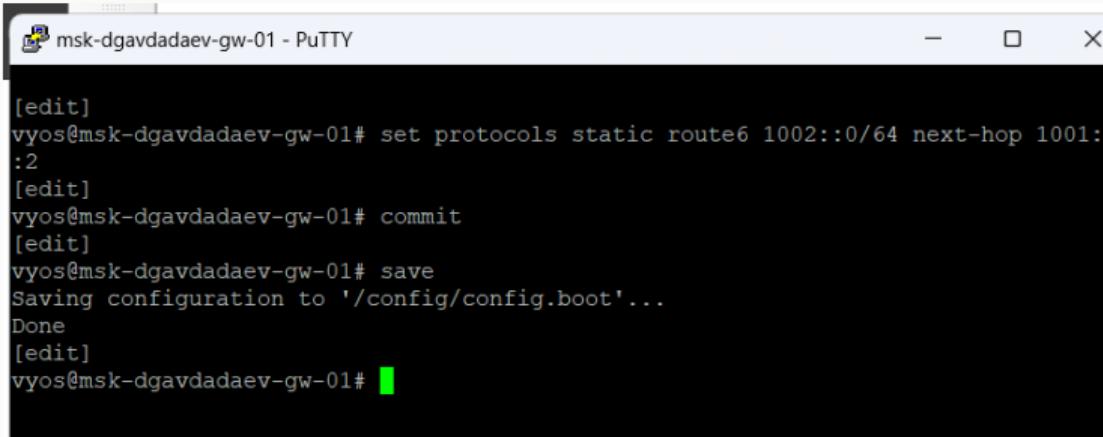
- Интерфейс: **tun0**
- SIT, источник IPv4: **20.0.0.2**, удалённый: **10.0.0.1**
- IPv6 туннеля: **1001::2/64**



```
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces tunnel tun0 encapsulation sit
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces tunnel tun0 source-address 20.0.0.2
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces tunnel tun0 redirect remote
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces tunnel tun0 remote 10.0.0.1
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces tunnel tun0 address 1001::2/64
[edit]
vyos@msk-dgavdadaev-gw-02# commit
[edit]
vyos@msk-dgavdadaev-gw-02# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-02#
```

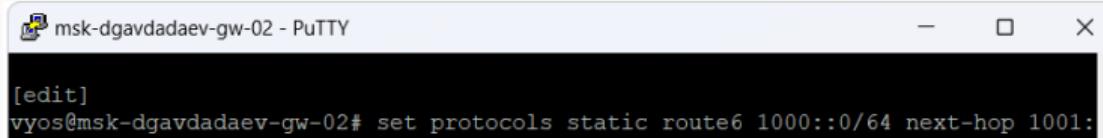
## Статическая маршрутизация IPv6

- На gw-01: маршрут к `1002::/64` через `1001::2`
- На gw-02: маршрут к `1000::/64` через `1001::1`



```
[edit]
vyos@msk-dgavdadaev-gw-01# set protocols static route6 1002::0/64 next-hop 1001::2
[edit]
vyos@msk-dgavdadaev-gw-01# commit
[edit]
vyos@msk-dgavdadaev-gw-01# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-01#
```

Рис. 18: Статический IPv6-маршрут на msk-dgavdadaev-gw-01



```
[edit]
vyos@msk-dgavdadaev-gw-02# set protocols static route6 1000::0/64 next-hop 1001::1
```

## Ping и traceroute с PC1

- Успешный ping до 1002::a
- Трассировка подтверждает прохождение через туннель

```
PC1-dgavdadaev - PuTTY

VPCS> ping 1002::a

1002::a icmp6_seq=1 ttl=60 time=12.768 ms
1002::a icmp6_seq=2 ttl=60 time=11.989 ms
1002::a icmp6_seq=3 ttl=60 time=15.966 ms
1002::a icmp6_seq=4 ttl=60 time=5.754 ms
1002::a icmp6_seq=5 ttl=60 time=7.242 ms

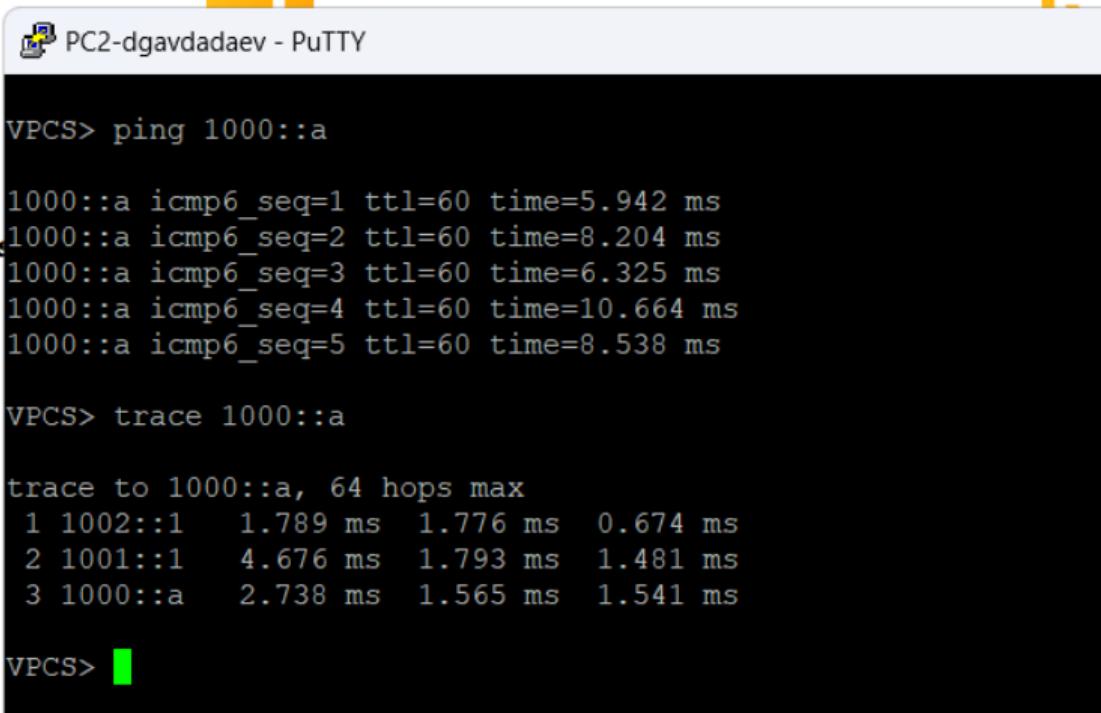
VPCS> trace 1002::a

trace to 1002::a, 64 hops max
 1 1000::1    2.387 ms   1.637 ms   1.200 ms
 2 1001::2    4.100 ms   2.397 ms   3.949 ms
 3 1002::a    2.896 ms   2.368 ms   1.714 ms

VPCS>
```

## Ping и traceroute с PC2

- Успешный ping до 1000::a
- Подтверждена симметричная IPv6-доступность



```
VPCS> ping 1000::a

1000::a icmp6_seq=1 ttl=60 time=5.942 ms
1000::a icmp6_seq=2 ttl=60 time=8.204 ms
1000::a icmp6_seq=3 ttl=60 time=6.325 ms
1000::a icmp6_seq=4 ttl=60 time=10.664 ms
1000::a icmp6_seq=5 ttl=60 time=8.538 ms

VPCS> trace 1000::a

trace to 1000::a, 64 hops max
 1 1002::1    1.789 ms   1.776 ms   0.674 ms
 2 1001::1    4.676 ms   1.793 ms   1.481 ms
 3 1000::a    2.738 ms   1.565 ms   1.541 ms

VPCS>
```

## Общий вид трафика IPv6 через IPv4

- IPv6-пакеты инкапсулируются в IPv4
- Используется протокол 41
- IPv4-адреса соответствуют концам туннеля

No.	Time	Source	Destination	Protocol	Length	Info
23	13.496483	1002::a	1000::a	ICMPv6	194	Destination Unreachable (Port unreachable)[Malformed Pack]
24	13.497848	1000::a	1002::a	UDP	146	43184 → 43185 Len=64
25	13.499439	1002::a	1000::a	ICMPv6	194	Destination Unreachable (Port unreachable)[Malformed Pack]
26	13.501231	1000::a	1002::a	UDP	146	43184 → 43185 Len=64
27	13.502351	1002::a	1000::a	ICMPv6	194	Destination Unreachable (Port unreachable)[Malformed Pack]
28	39.898232	10.0.0.2	224.0.0.9	RIPv2	66	Response
29	47.318765	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=1, hop limit=63 (request)
30	47.319559	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=1, hop limit=61 (reply)
31	48.324749	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=2, hop limit=63 (request)
32	48.327373	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=2, hop limit=61 (reply)
33	49.334818	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=3, hop limit=63 (request)
34	49.337270	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=3, hop limit=61 (reply)
35	50.341896	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=4, hop limit=63 (request)
36	50.346467	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=4, hop limit=61 (reply)
37	51.352965	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=5, hop limit=63 (request)
38	51.356307	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=5, hop limit=61 (reply)
39	52.757358	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2
40	52.758010	0c:5c:01:be:00:01	0c:f6:4a:e9:00:00	ARP	60	10.0.0.1 is at 0c:5c:01:be:00:01
41	52.790744	0c:5c:01:be:00:01	0c:f6:4a:e9:00:00	ARP	60	Who has 10.0.0.2? Tell 10.0.0.1
42	52.791451	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	10.0.0.2 is at 0c:f6:4a:e9:00:00
43	58.219991	1002::a	1000::a	UDP	146	47152 → 47153 Len=64
44	58.220248	1001::1	1002::a	ICMPv6	194	Time Exceeded (Hop limit exceeded in transit)

Рис. 22: Общий вид трафика IPv6 через IPv4

## Детализация инкапсуляции

- В полезной нагрузке IPv4 содержится полный IPv6-заголовок
- ICMPv6 Echo Request / Reply видны внутри инкапсуляции

```
> Frame 29: Packet, 138 bytes on wire (1104 bits), 138 bytes captured (1104 bits) on interface -, id 0
> Ethernet II, Src: 0c:f6:4a:e9:00:00 (0c:f6:4a:e9:00:00), Dst: 0c:5c:01:be:00:01 (0c:5c:01:be:00:01)
└ Internet Protocol Version 4, Src: 20.0.0.2, Dst: 10.0.0.1
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
        Total Length: 124
        Identification: 0x58d9 (22745)
    > 010. .... = Flags: 0x2, Don't fragment
        ...0 0000 0000 0000 = Fragment Offset: 0
        Time to Live: 63
        Protocol: IPv6 (41)
        Header Checksum: 0xc47d [validation disabled]
        [Header checksum status: Unverified]
        Source Address: 20.0.0.2
        Destination Address: 10.0.0.1
        [Stream index: 0]
└ Internet Protocol Version 6, Src: 1002::a, Dst: 1000::a
    0110 .... = Version: 6
    > .... 0000 0000 .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
        .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
        Payload Length: 64
        Next Header: ICMPv6 (58)
        Hop Limit: 63
    > Source Address: 1002::a
    > Destination Address: 1000::a
        [Stream index: 0]
└ Internet Control Message Protocol v6
    Type: Echo (ping) request (128)
    Code: 0
    Checksum: 0x9de7 [correct]
```

## Итоги работы

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## Заключение

В ходе работы была реализована связность IPv4- и IPv6-сетей в **GNS3**: настроена адресация, динамическая маршрутизация IPv4 (**RIP**) и туннель **IPv6-over-IPv4 (SIT)** со статической маршрутизацией IPv6. Проверка связности и анализ трафика в **Wireshark** подтвердили корректную работу протоколов **ARP**, **ICMP**, **ICMPv6** и **RIP**, а также механизмов инкапсуляции IPv6 в IPv4 (протокол 41).