

# Лабораторная работа №8

Адресация IPv4 и IPv6. Настройка маршрутизации

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04 февраля 2026

## Цель работы

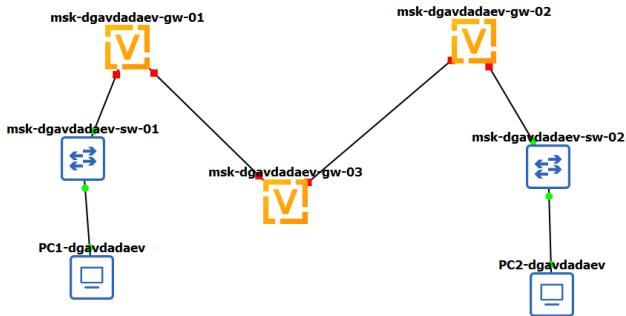
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Изучение принципов маршрутизации в IPv4- и IPv6-сетях и практическая настройка сетевого оборудования в среде моделирования **GNS3**.

## Ход выполнения работы

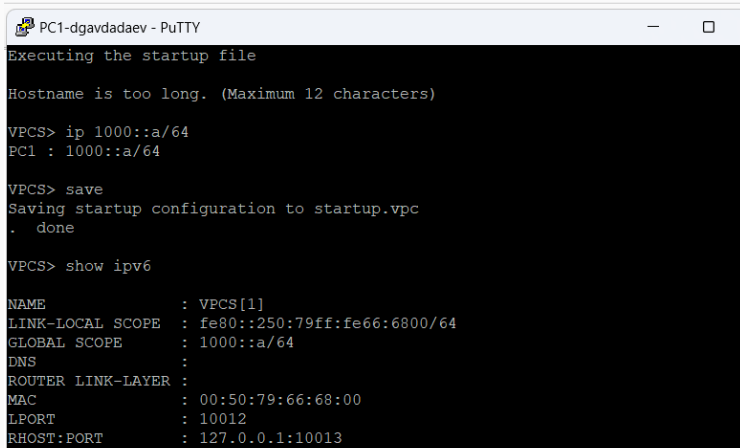
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- Построена сеть в GNS3:
  - 3 маршрутизатора VyOS
  - 2 коммутатора Ethernet
  - 2 оконечных устройства VPCS
- Подключён анализатор трафика между gw-01 и gw-03



## Настройка IPv6 на PC1

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



```
PC1-dgavdadaev - PuTTY
Executing the startup file

Hostname is too long. (Maximum 12 characters)

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

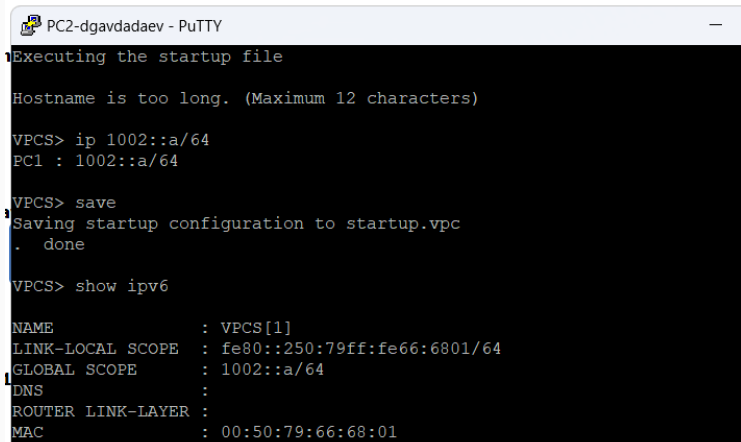
VPCS> save
Saving startup configuration to startup.vpc
. done

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

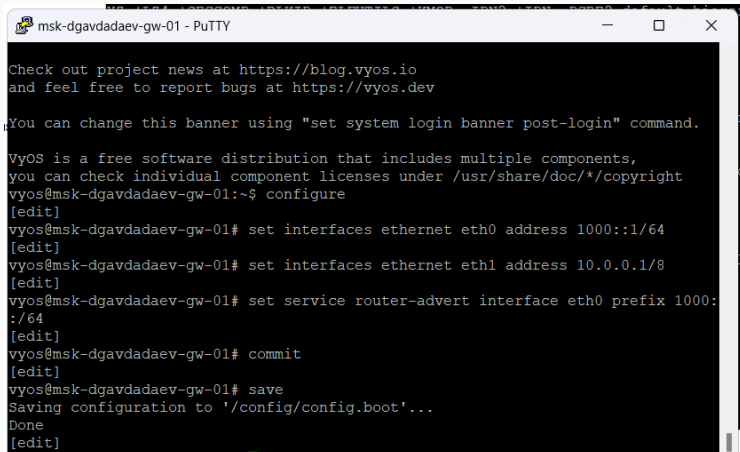
VPCS> save
Saving startup configuration to startup.vpc
. done

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



```
msh-dgavdadaev-gw-01 - PuTTY
Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

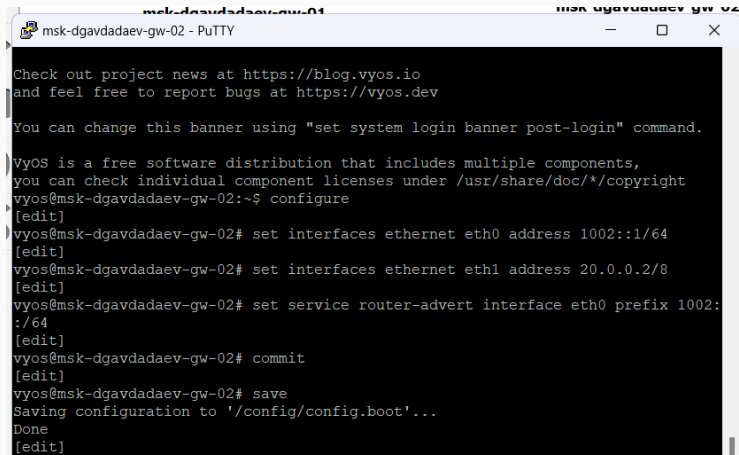
You can change this banner using "set system login banner post-login" command.

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



```
msk-dgavdadaev-gw-02 - PuTTY

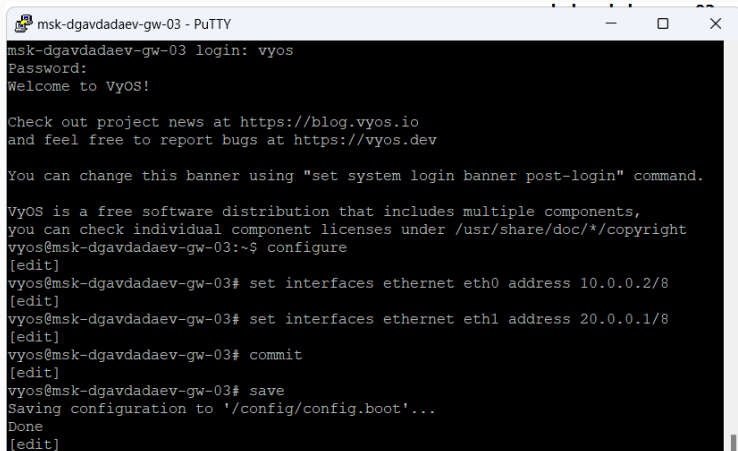
Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

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!

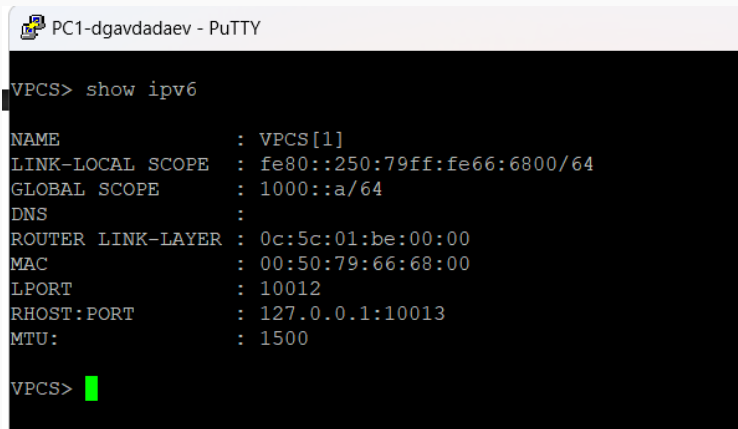
Check out project news at https://blog.vyos.io
and feel free to report bugs at https://vyos.dev

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

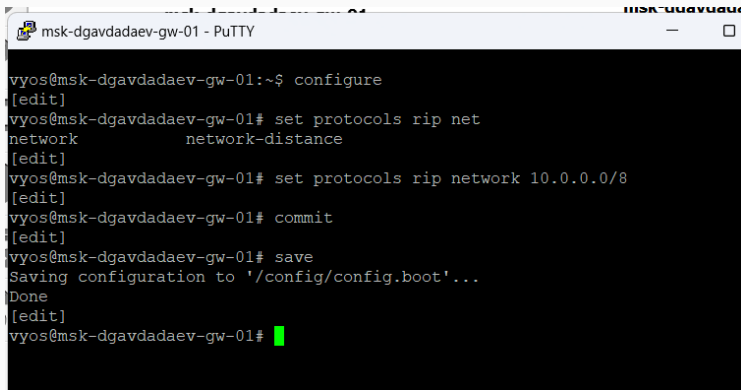
No.	Time	Source	Destination	Protocol	Length	Info
13	5.008882	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x0849, seq=6/153
14	5.010653	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0849, seq=6/153
15	5.277145	0c:f6:4a:e9:00:00	0c:5c:01:be:00:01	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2
16	5.277389	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),
> Internet Protocol Version 4, Src: 10.0.0.2, Dst: 10.0.0.1
v 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  -\
0010 00 54 0a e0 00 00 40 01 5b c7 0a 00 00 02 0a 00  -T
0020 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

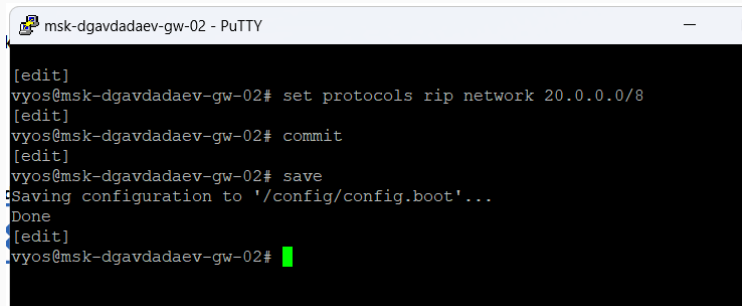


```
msk-dgavdadaev-gw-01 - PuTTY
vyos@msk-dgavdadaev-gw-01:~$ configure
[edit]
vyos@msk-dgavdadaev-gw-01# set protocols rip net
network
network-distance
[edit]
vyos@msk-dgavdadaev-gw-01# set protocols rip network 10.0.0.0/8
[edit]
vyos@msk-dgavdadaev-gw-01# commit
[edit]
vyos@msk-dgavdadaev-gw-01# save
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



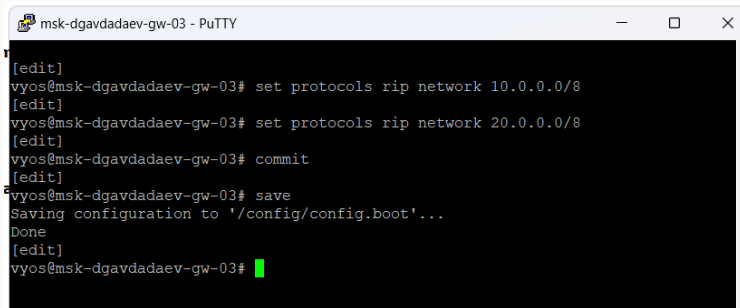
```
msk-dgavdadaev-gw-02 - PuTTY

[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



```
msk-dgavdadaev-gw-03 - PuTTY
[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

```
mikrotik@mikrotik:~$ ssh msk-dgavdadaev-gw-01
msk-dgavdadaev-gw-01 - PuTTY

[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

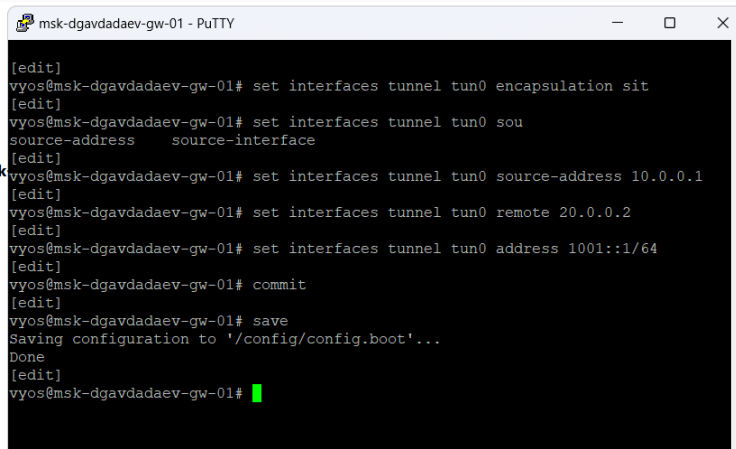
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.0.0.2	224.0.0.9	RIPv2	66	Response
2	16.106195	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x097f, seq=1/256, ttl=64 (reply in
3	16.107161	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=1/256, ttl=64 (request
4	17.108633	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0x097f, seq=2/512, ttl=64 (reply in
5	17.109468	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=2/512, ttl=64 (request
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
7	18.111881	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x097f, seq=3/768, ttl=64 (request
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
13	22.937379	20.0.0.1	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0980, seq=1/256, ttl=64 (request
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
15	23.939911	20.0.0.1	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0980, seq=2/512, ttl=64 (request
16	28.072011	10.0.0.1	20.0.0.2	ICMP	98	Echo (ping) request id=0x0981, seq=1/256, ttl=64 (reply in
17	28.075541	20.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0981, seq=1/256, ttl=63 (request
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
19	29.079071	20.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0x0981, seq=2/512, ttl=63 (request
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) on interface 0
> Ethernet II, Src: 0c:f6:4a:e9:00:00 (0c:f6:4a:e9:00:00), Dst: IPv4mcast, Prio: 0
> 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 00 5e 00 00 09 0c f6 4a e9 00 00 08 00 45 c0  ..@....J.
0010  00 34 30 03 40 00 01 11 5e eb 0a 00 00 02 e0 00  -40@....^
0020  00 09 02 00 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

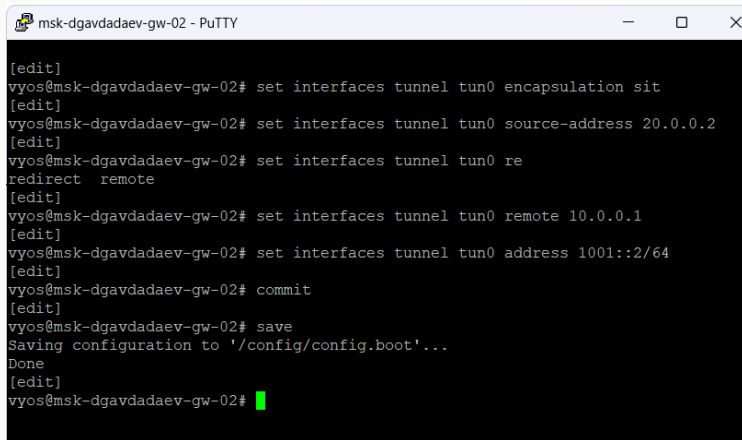


```
msk-dgavdadaev-gw-01 - PuTTY

[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 encapsulation sit
[edit]
vyos@msk-dgavdadaev-gw-01# set interfaces tunnel tun0 sou
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

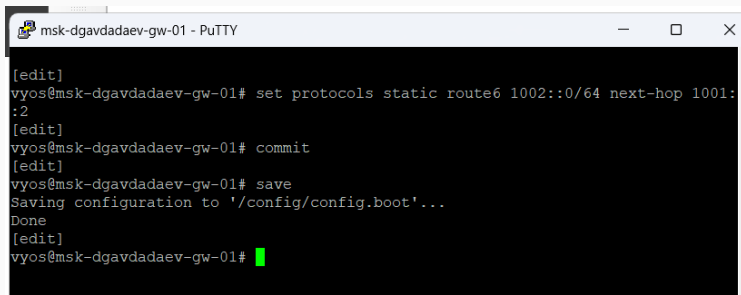


```
msk-dgavdadaev-gw-02 - PuTTY

[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 re
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#
```

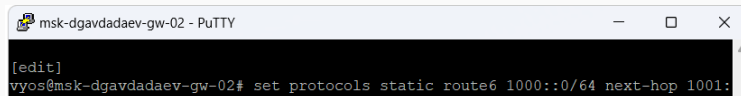
## Статическая маршрутизация IPv6

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



```
msk-dgavdadaev-gw-01 - PuTTY
[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#
```

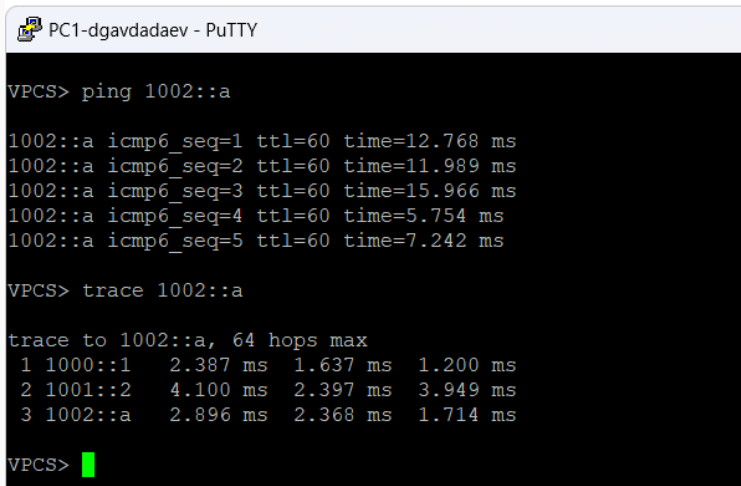
Рис. 18: Статический IPv6-маршрут на msk-dgavdadaev-gw-01



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

## 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

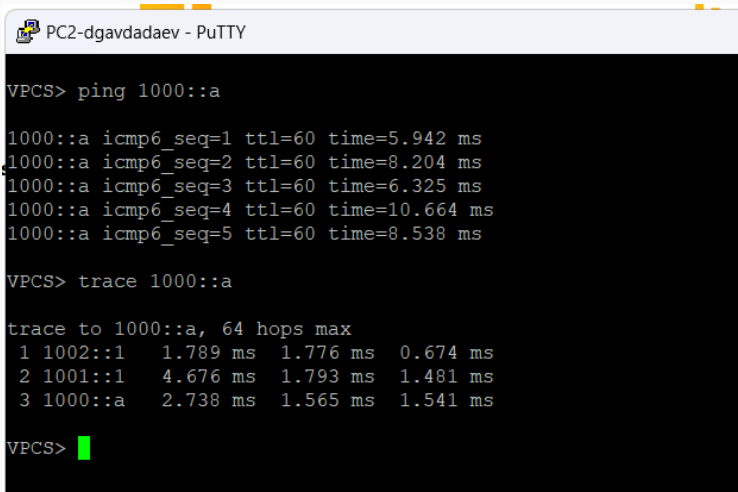
VPCS> trace 1002::a

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

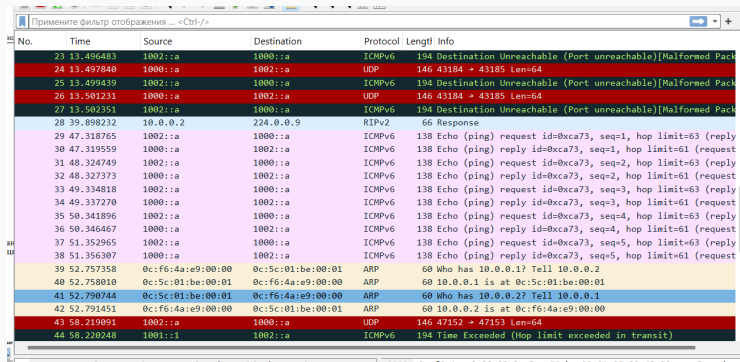
VPCS> trace 1000::a

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	13.497840	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 (reply
30	47.319559	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=1, hop limit=61 (request
31	48.324749	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=2, hop limit=63 (reply
32	48.327373	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=2, hop limit=61 (request
33	49.334818	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=3, hop limit=63 (reply
34	49.337270	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=3, hop limit=61 (request
35	50.341896	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=4, hop limit=63 (reply
36	50.346467	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=4, hop limit=61 (request
37	51.352965	1002::a	1000::a	ICMPv6	138	Echo (ping) request id=0xca73, seq=5, hop limit=63 (reply
38	51.356307	1000::a	1002::a	ICMPv6	138	Echo (ping) reply id=0xca73, seq=5, hop limit=61 (request
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	58.219091	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 = 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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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).