

Лабораторная работа №6

Адресация IPv4 и IPv6. Двойной стек

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Цель работы

Основная цель

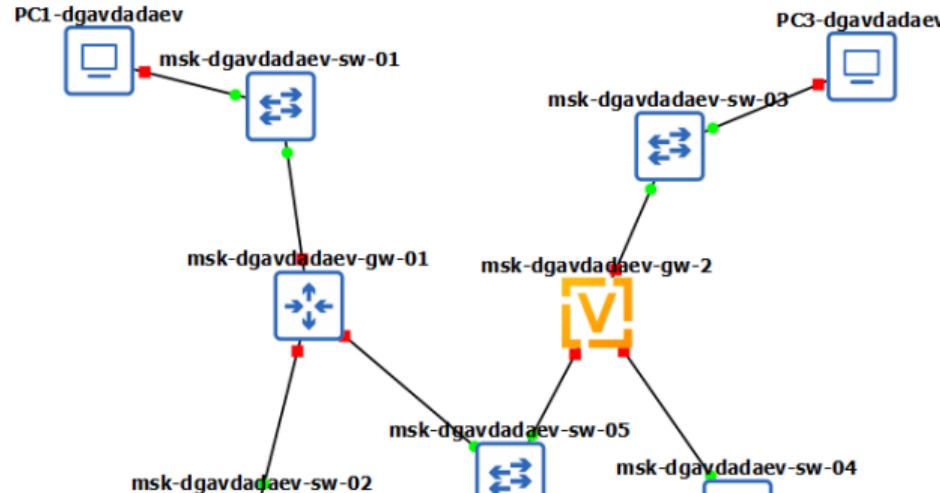
Изучение принципов распределения и настройки адресного пространства на устройствах сети:

- разбиение IPv4 (VLSM)
- разбиение IPv6 (префиксы и диапазоны)
- настройка **Dual Stack** в GNS3
- проверка связности и анализ трафика (ARP / ICMP / ICMPv6)

Dual Stack в GNS3

Топология и именование

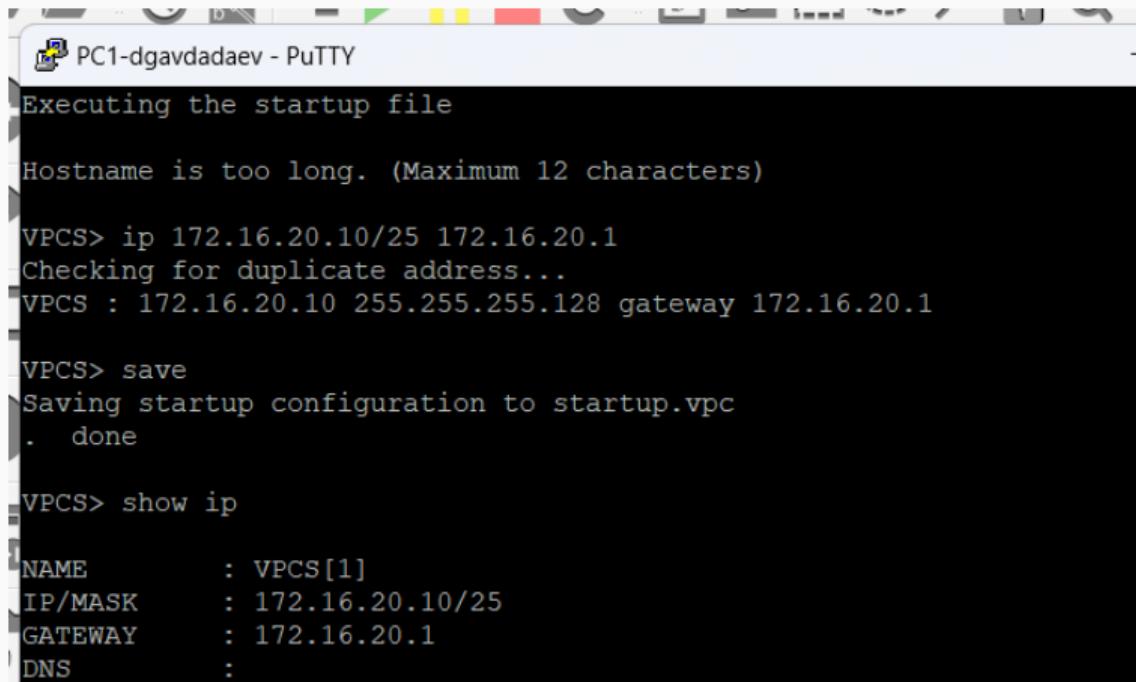
- Использованы:
 - VPCS: PC1–PC4
 - коммутаторы
 - маршрутизатор FRR (IPv4)
 - маршрутизатор VyOS (IPv6)
 - сервер (Dual Stack)



Настройка IPv4: конечные узлы

Адресация (фрагмент)

- PC1: 172.16.20.10/25, GW 172.16.20.1
- PC2: 172.16.20.138/25, GW 172.16.20.129
- Server: 64.100.1.10/24, GW 64.100.1.1



```
Executing the startup file

Hostname is too long. (Maximum 12 characters)

VPCS> ip 172.16.20.10/25 172.16.20.1
Checking for duplicate address...
VPCS : 172.16.20.10 255.255.255.128 gateway 172.16.20.1

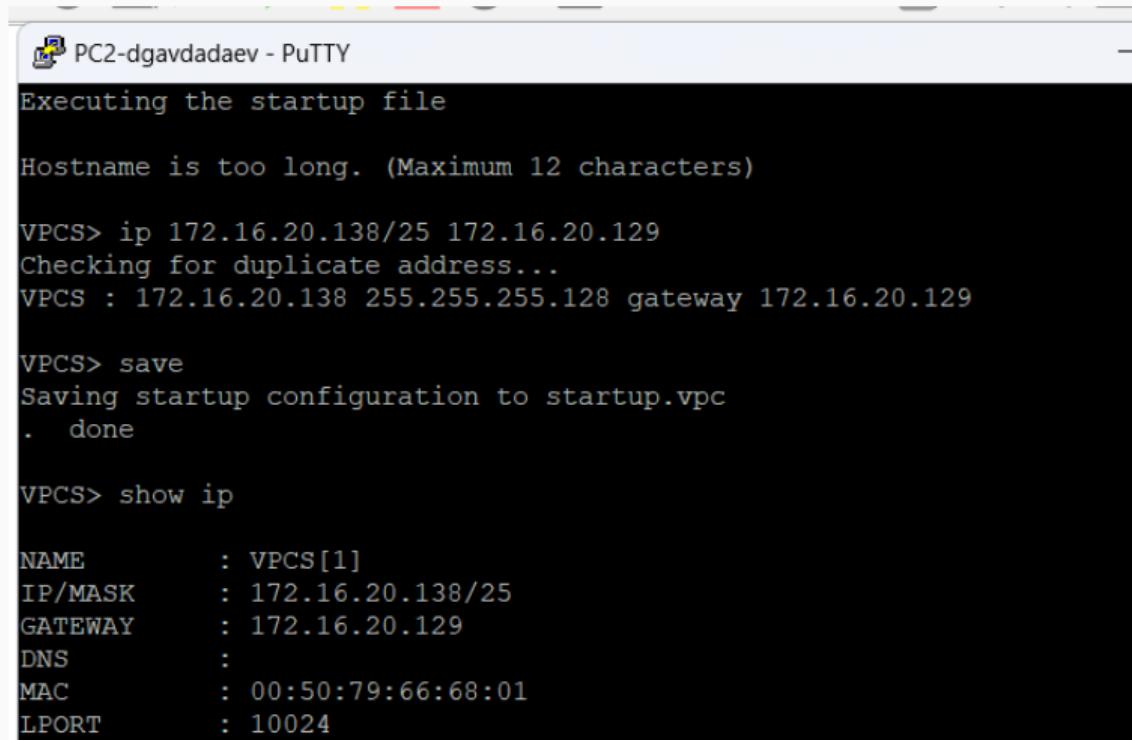
VPCS> save
Saving startup configuration to startup.vpc
. done

VPCS> show ip

NAME      : VPCS[1]
IP/MASK   : 172.16.20.10/25
GATEWAY   : 172.16.20.1
DNS       :
```

Проверка настройки (пример)

- корректность адреса/маски/шлюза
- сохранение конфигурации на узлах



```
Executing the startup file

Hostname is too long. (Maximum 12 characters)

VPCS> ip 172.16.20.138/25 172.16.20.129
Checking for duplicate address...
VPCS : 172.16.20.138 255.255.255.128 gateway 172.16.20.129

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

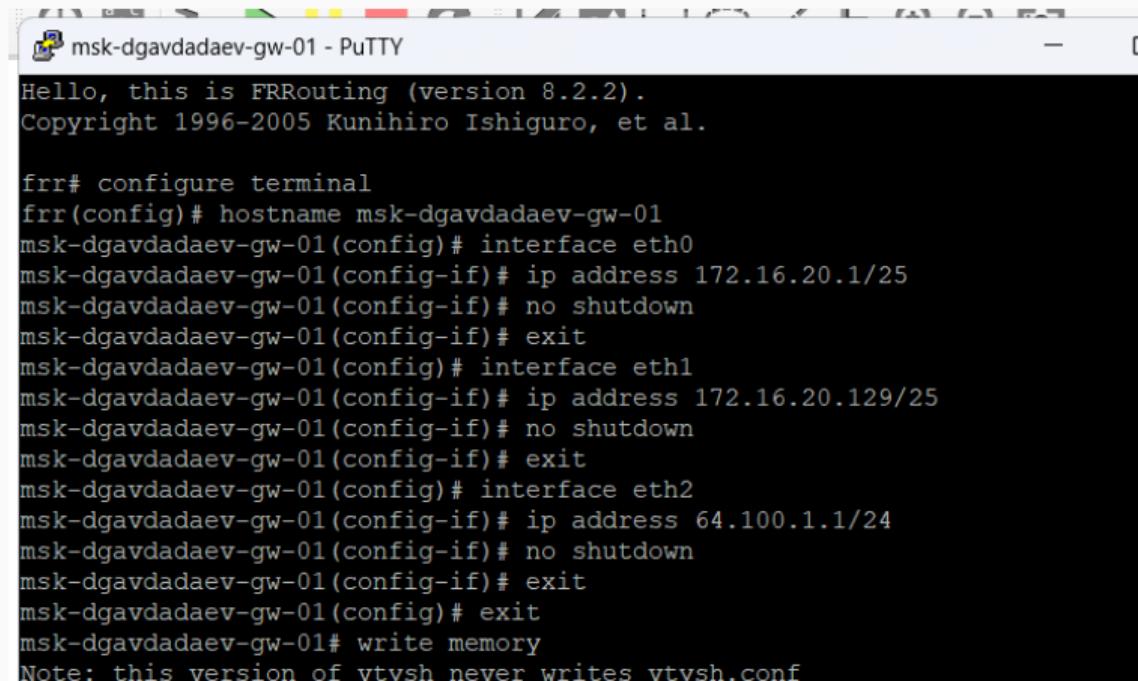
VPCS> show ip

NAME      : VPCS[1]
IP/MASK   : 172.16.20.138/25
GATEWAY   : 172.16.20.129
DNS       :
MAC       : 00:50:79:66:68:01
LPORT     : 10024
```

Настройка FRR (IPv4-маршрутизация)

Конфигурация и контроль

- назначены IPv4 на интерфейсы LAN
- интерфейсы подняты
- конфигурация сохранена



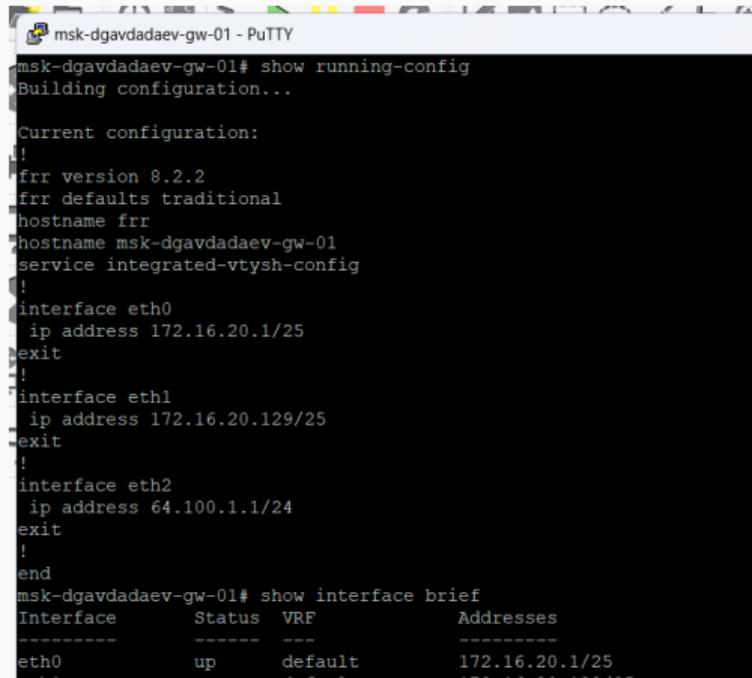
```
Hello, this is FRRouting (version 8.2.2).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

frr# configure terminal
frr(config)# hostname msk-dgavdadaev-gw-01
msk-dgavdadaev-gw-01(config)# interface eth0
msk-dgavdadaev-gw-01(config-if)# ip address 172.16.20.1/25
msk-dgavdadaev-gw-01(config-if)# no shutdown
msk-dgavdadaev-gw-01(config-if)# exit
msk-dgavdadaev-gw-01(config)# interface eth1
msk-dgavdadaev-gw-01(config-if)# ip address 172.16.20.129/25
msk-dgavdadaev-gw-01(config-if)# no shutdown
msk-dgavdadaev-gw-01(config-if)# exit
msk-dgavdadaev-gw-01(config)# interface eth2
msk-dgavdadaev-gw-01(config-if)# ip address 64.100.1.1/24
msk-dgavdadaev-gw-01(config-if)# no shutdown
msk-dgavdadaev-gw-01(config-if)# exit
msk-dgavdadaev-gw-01(config)# exit
msk-dgavdadaev-gw-01# write memory

Note: this version of vtysh never writes vtysh.conf
```

Проверка (show / состояние интерфейсов)

- адреса присутствуют
- интерфейсы активны
- маршрутизация готова к тестам

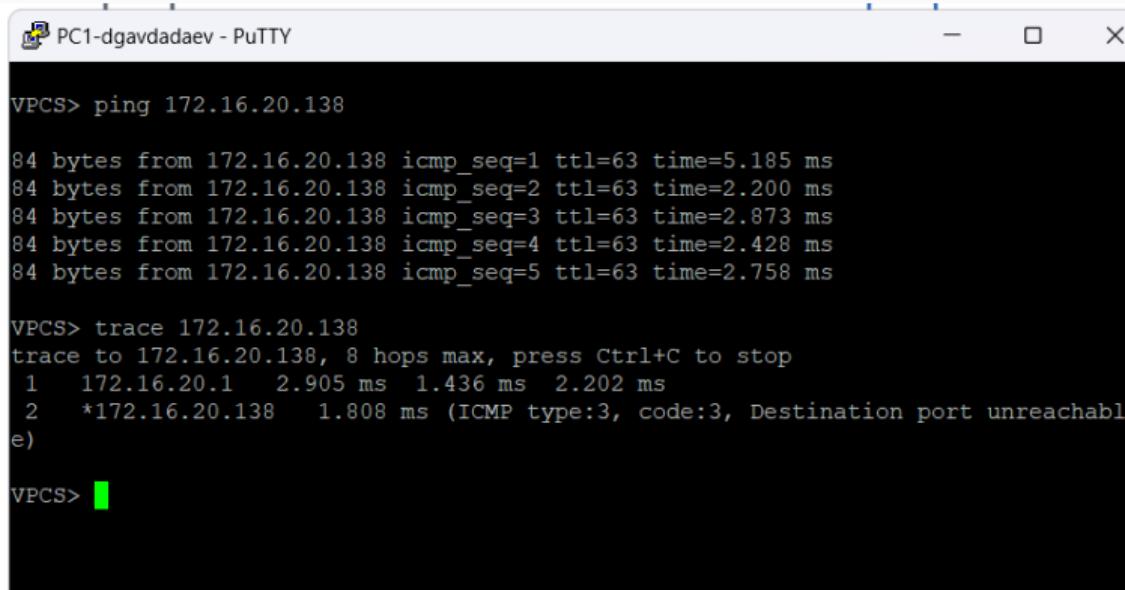


```
msk-dgavdadaev-gw-01 - PuTTY
msk-dgavdadaev-gw-01# show running-config
Building configuration...

Current configuration:
!
frr version 8.2.2
frr defaults traditional
hostname frr
hostname msk-dgavdadaev-gw-01
service integrated-vtysh-config
!
interface eth0
 ip address 172.16.20.1/25
exit
!
interface eth1
 ip address 172.16.20.129/25
exit
!
interface eth2
 ip address 64.100.1.1/24
exit
!
end
msk-dgavdadaev-gw-01# show interface brief
Interface      Status    VRF      Addresses
-----        -----    ---      -----
eth0          up       default   172.16.20.1/25
eth1          up       default   172.16.20.129/25
eth2          up       default   64.100.1.1/24
```

Ping / Trace

- PC1 → PC2: ответы получены, маршрут через шлюз
- PC1 → Server: доставка успешна, межсетевой обмен корректен



The screenshot shows a PuTTY terminal window with the title "PC1-dgavdadaev - PuTTY". The window contains the following command-line session:

```
VPCS> ping 172.16.20.138
84 bytes from 172.16.20.138 icmp_seq=1 ttl=63 time=5.185 ms
84 bytes from 172.16.20.138 icmp_seq=2 ttl=63 time=2.200 ms
84 bytes from 172.16.20.138 icmp_seq=3 ttl=63 time=2.873 ms
84 bytes from 172.16.20.138 icmp_seq=4 ttl=63 time=2.428 ms
84 bytes from 172.16.20.138 icmp_seq=5 ttl=63 time=2.758 ms

VPCS> trace 172.16.20.138
trace to 172.16.20.138, 8 hops max, press Ctrl+C to stop
 1  172.16.20.1    2.905 ms  1.436 ms  2.202 ms
 2  *172.16.20.138  1.808 ms (ICMP type:3, code:3, Destination port unreachable)

VPCS>
```

Рис. 6: PC1 ↔ PC2

Доступ к серверу

- подтверждена корректная маршрутизация между подсетями IPv4

```
VPCS> ping 64.100.1.10

84 bytes from 64.100.1.10 icmp_seq=1 ttl=63 time=9.618 ms
84 bytes from 64.100.1.10 icmp_seq=2 ttl=63 time=4.630 ms
84 bytes from 64.100.1.10 icmp_seq=3 ttl=63 time=1.251 ms
84 bytes from 64.100.1.10 icmp_seq=4 ttl=63 time=1.485 ms
84 bytes from 64.100.1.10 icmp_seq=5 ttl=63 time=1.594 ms

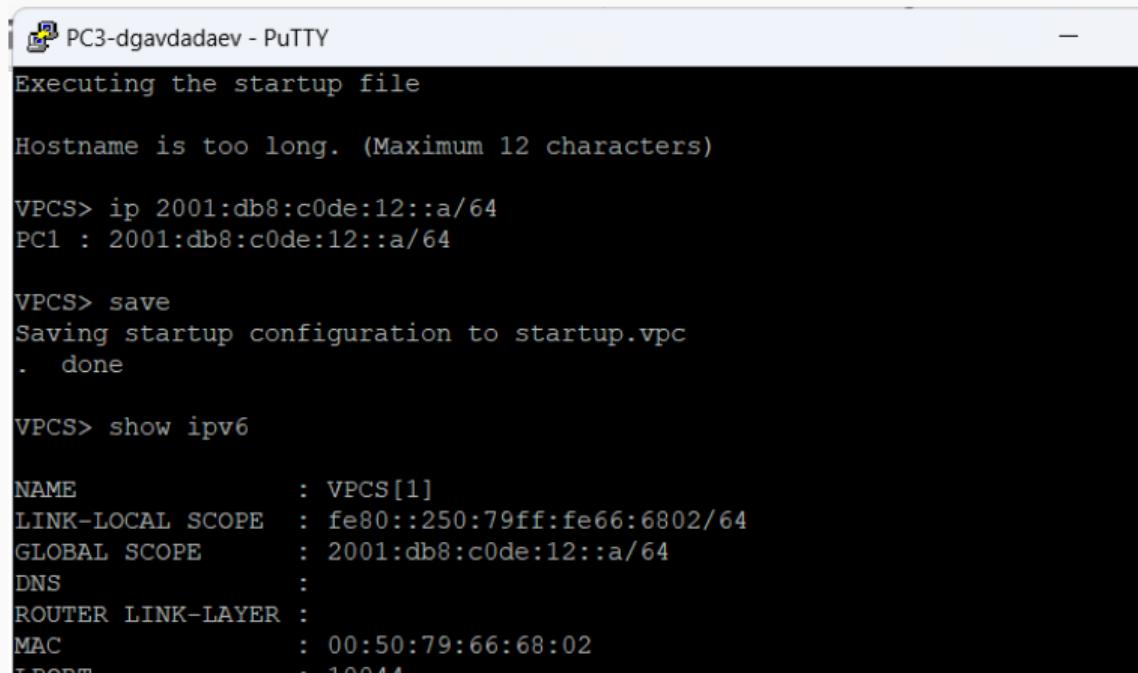
VPCS> trace 64.100.1.10
trace to 64.100.1.10, 8 hops max, press Ctrl+C to stop
 1  172.16.20.1    5.124 ms  1.000 ms  0.442 ms
 2  *64.100.1.10   1.160 ms (ICMP type:3, code:3, Destination port unreachable)

VPCS>
```

Рис. 7: PC1 ↔ Server

Назначение адресов (вручную)

- PC3: 2001:db8:c0de:12::a/64
- PC4: 2001:db8:c0de:13::a/64
- Server (Dual Stack): 2001:db8:c0de:11::a/64



```
Executing the startup file

Hostname is too long. (Maximum 12 characters)

VPCS> ip 2001:db8:c0de:12::a/64
PC1 : 2001:db8:c0de:12::a/64

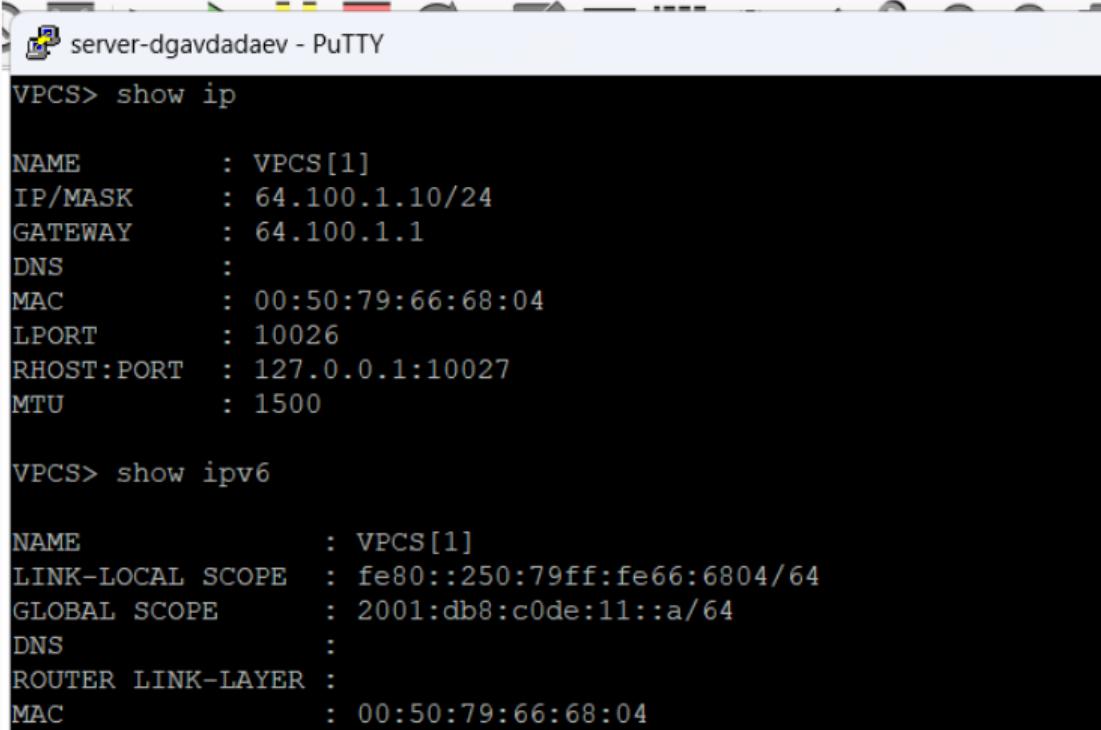
VPCS> save
Saving startup configuration to startup.vpc
. done

VPCS> show ipv6

NAME          : VPCS[1]
LINK-LOCAL SCOPE : fe80::250:79ff:fe66:6802/64
GLOBAL SCOPE    : 2001:db8:c0de:12::a/64
DNS           :
ROUTER LINK-LAYER :
MAC           : 00:50:79:66:68:02
LPORT         : 10044
```

Сервер в режиме Dual Stack

- IPv4 и IPv6 активны одновременно
- сервер доступен из обеих сред (при наличии маршрутизации)



```
VPCS> show ip

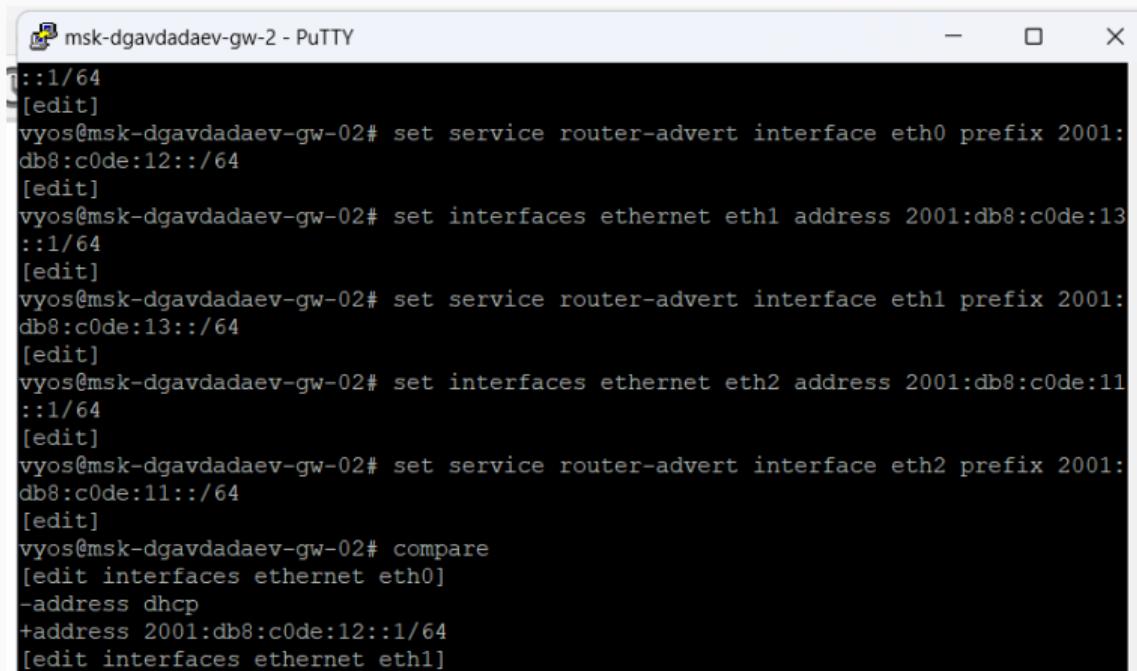
NAME          : VPCS[1]
IP/MASK       : 64.100.1.10/24
GATEWAY       : 64.100.1.1
DNS           :
MAC           : 00:50:79:66:68:04
LPORT          : 10026
RHOST:PORT    : 127.0.0.1:10027
MTU           : 1500

VPCS> show ipv6

NAME          : VPCS[1]
LINK-LOCAL SCOPE : fe80::250:79ff:fe66:6804/64
GLOBAL SCOPE   : 2001:db8:c0de:11::a/64
DNS           :
ROUTER LINK-LAYER :
MAC           : 00:50:79:66:68:04
```

Настройка VyOS (IPv6-маршрутизация)

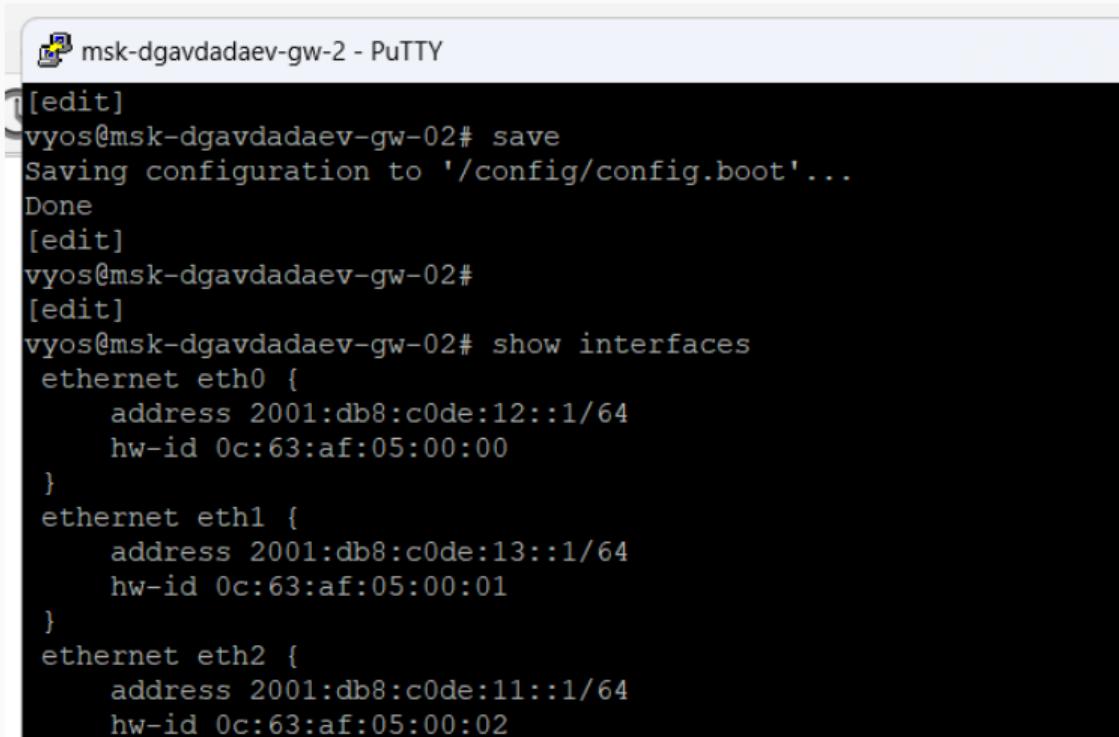
- имя устройства
- IPv6-адреса на eth0/eth1/eth2
- Router Advertisement для распространения префиксов в сегментах



```
msk-dgavdadaev-gw-2 - PuTTY
::1/64
[edit]
vyos@msk-dgavdadaev-gw-02# set service router-advert interface eth0 prefix 2001:db8:c0de:12::/64
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces ethernet eth1 address 2001:db8:c0de:13::1/64
[edit]
vyos@msk-dgavdadaev-gw-02# set service router-advert interface eth1 prefix 2001:db8:c0de:13::/64
[edit]
vyos@msk-dgavdadaev-gw-02# set interfaces ethernet eth2 address 2001:db8:c0de:11::1/64
[edit]
vyos@msk-dgavdadaev-gw-02# set service router-advert interface eth2 prefix 2001:db8:c0de:11::/64
[edit]
vyos@msk-dgavdadaev-gw-02# compare
[edit interfaces ethernet eth0]
-address dhcp
+address 2001:db8:c0de:12::1/64
[edit interfaces ethernet eth1]
```

Контроль состояния

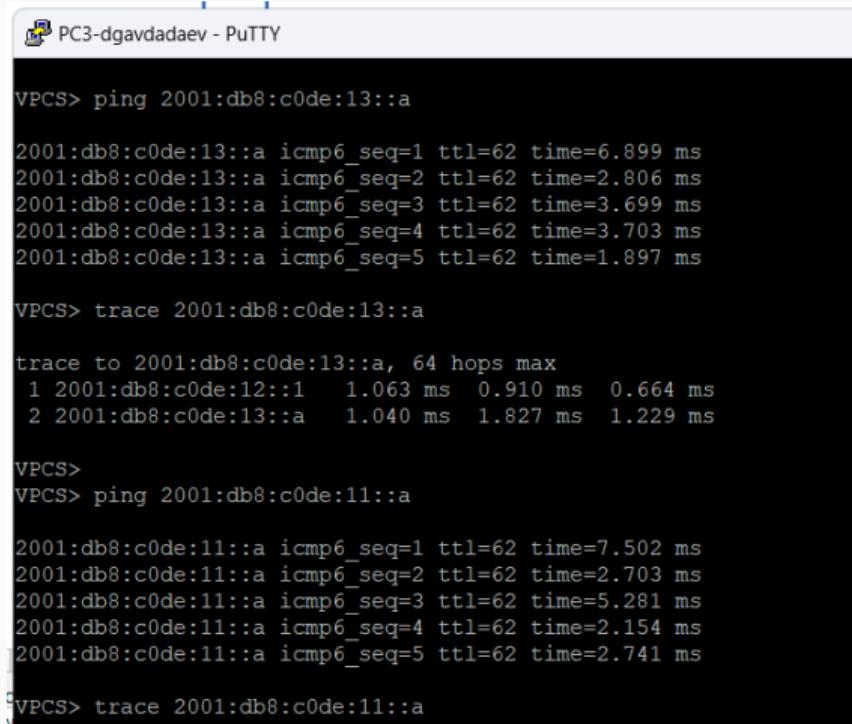
- интерфейсы активны
- IPv6-адреса назначены корректно



```
[edit]
vyos@msk-dgavdadaev-gw-02# save
Saving configuration to '/config/config.boot'...
Done
[edit]
vyos@msk-dgavdadaev-gw-02#
[edit]
vyos@msk-dgavdadaev-gw-02# show interfaces
  ethernet eth0 {
    address 2001:db8:c0de:12::1/64
    hw-id 0c:63:af:05:00:00
  }
  ethernet eth1 {
    address 2001:db8:c0de:13::1/64
    hw-id 0c:63:af:05:00:01
  }
  ethernet eth2 {
    address 2001:db8:c0de:11::1/64
    hw-id 0c:63:af:05:00:02
  }
```

Ping / Trace

- PC3 → PC4: ответы получены, маршрут через VyOS
- PC3 → Server: доставка успешна



```
VPCS> ping 2001:db8:c0de:13::a
2001:db8:c0de:13::a icmp6_seq=1 ttl=62 time=6.899 ms
2001:db8:c0de:13::a icmp6_seq=2 ttl=62 time=2.806 ms
2001:db8:c0de:13::a icmp6_seq=3 ttl=62 time=3.699 ms
2001:db8:c0de:13::a icmp6_seq=4 ttl=62 time=3.703 ms
2001:db8:c0de:13::a icmp6_seq=5 ttl=62 time=1.897 ms

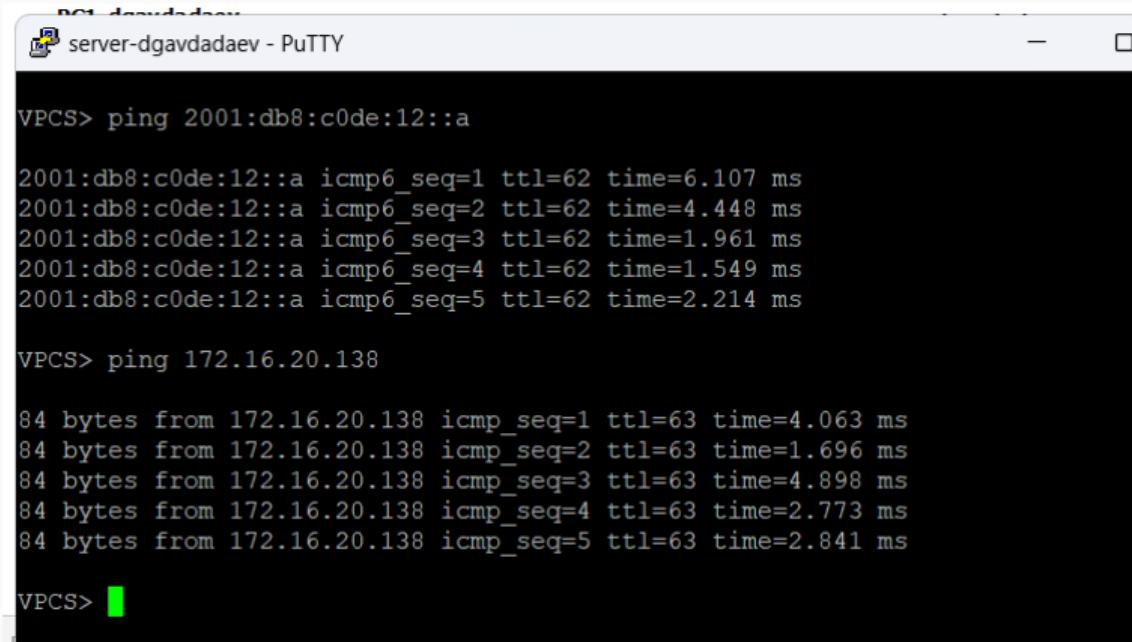
VPCS> trace 2001:db8:c0de:13::a
trace to 2001:db8:c0de:13::a, 64 hops max
 1 2001:db8:c0de:12::1    1.063 ms  0.910 ms  0.664 ms
 2 2001:db8:c0de:13::a    1.040 ms  1.827 ms  1.229 ms

VPCS>
VPCS> ping 2001:db8:c0de:11::a
2001:db8:c0de:11::a icmp6_seq=1 ttl=62 time=7.502 ms
2001:db8:c0de:11::a icmp6_seq=2 ttl=62 time=2.703 ms
2001:db8:c0de:11::a icmp6_seq=3 ttl=62 time=5.281 ms
2001:db8:c0de:11::a icmp6_seq=4 ttl=62 time=2.154 ms
2001:db8:c0de:11::a icmp6_seq=5 ttl=62 time=2.741 ms

VPCS> trace 2001:db8:c0de:11::a
```

Изоляция IPv4 и IPv6 сегментов

- PC4 (IPv6-сегмент) не обращается к IPv4-узлам
- доступ к Dual Stack Server по IPv6 — успешен



The screenshot shows a PuTTY terminal window titled "PC1_dgavdadaev". The session name is "server-dgavdadaev". The terminal displays two sets of ping results. The first set is to an IPv6 address: "VPCS> ping 2001:db8:c0de:12::a". The second set is to an IPv4 address: "VPCS> ping 172.16.20.138". Both sets show multiple ICMP echo requests being sent, with their sequence numbers, TTL values, and round-trip times.

```
VPCS> ping 2001:db8:c0de:12::a
2001:db8:c0de:12::a icmp6_seq=1 ttl=62 time=6.107 ms
2001:db8:c0de:12::a icmp6_seq=2 ttl=62 time=4.448 ms
2001:db8:c0de:12::a icmp6_seq=3 ttl=62 time=1.961 ms
2001:db8:c0de:12::a icmp6_seq=4 ttl=62 time=1.549 ms
2001:db8:c0de:12::a icmp6_seq=5 ttl=62 time=2.214 ms

VPCS> ping 172.16.20.138
84 bytes from 172.16.20.138 icmp_seq=1 ttl=63 time=4.063 ms
84 bytes from 172.16.20.138 icmp_seq=2 ttl=63 time=1.696 ms
84 bytes from 172.16.20.138 icmp_seq=3 ttl=63 time=4.898 ms
84 bytes from 172.16.20.138 icmp_seq=4 ttl=63 time=2.773 ms
84 bytes from 172.16.20.138 icmp_seq=5 ttl=63 time=2.841 ms
```

Рис. 13: Изоляция и доступ к Dual Stack

ARP (IPv4)

- разрешение IP → MAC в канальном сегменте
- пример: запрос от шлюза 64.100.1.1 к серверу 64.100.1.10
- подтверждает L2-соседство и работу шлюза

No.	Time	Source	Destination	Protocol	Length	Info
20	20.811595	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xfa22, seq=3/768, ttl=63 (r)
21	21.812950	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xfb22, seq=4/1024, ttl=64 (i)
22	21.815370	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xfb22, seq=4/1024, ttl=63 (i)
23	22.817037	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xfc22, seq=5/1280, ttl=64 (i)
24	22.819412	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xfc22, seq=5/1280, ttl=63 (i)
25	23.806401	0c:bc:cb:ac:00:02	Private_66:68:04	ARP	60	Who has 64.100.1.10? Tell 64.100.1.1
26	23.806882	Private_66:68:04	0c:bc:cb:ac:00:02	ARP	60	64.100.1.10 is at 00:50:79:66:68:04


```
> Frame 25: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface -, id 0
└酝 Ethernet II, Src: 0c:bc:cb:ac:00:02 (0c:bc:cb:ac:00:02), Dst: Private_66:68:04 (00:50:79:66:68:04)
  └酝 Destination: Private_66:68:04 (00:50:79:66:68:04)
  └酝 Source: 0c:bc:cb:ac:00:02 (0c:bc:cb:ac:00:02)
    └酝 Type: ARP (0x0806)
      └酝 [Stream index: 3]
        └酝 Padding: 0000000000000000000000000000000000000000000000000000000000000000
      └酝 Address Resolution Protocol (request)
        └酝 Hardware type: Ethernet (1)
          └酝 Protocol type: IPv4 (0x0800)
          └酝 Hardware size: 6
          └酝 Protocol size: 4
          └酝 Opcode: request (1)
          └酝 Sender MAC address: 0c:bc:cb:ac:00:02 (0c:bc:cb:ac:00:02)
          └酝 Sender IP address: 64.100.1.1
          └酝 Target MAC address: 00:00:00_00:00:00 (00:00:00:00:00:00)
          └酝 Target IP address: 64.100.1.10
```

ICMP (IPv4)

- Echo Request / Reply
- по TTL видно прохождение маршрутизатора
- подтверждает корректную маршрутизацию IPv4 между подсетями

No.	Time	Source	Destination	Protocol	Length	Info
14	18.798205	0c:bc:cb:ac:00:02	Private_66:68:04	ARP	60	64.100.1.1 is at 0c:bc:cb:ac:00:02
→ 15	18.799457	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xf822, seq=1/256, ttl=64 (r)
← 16	18.803014	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xf822, seq=1/256, ttl=63 (r)
17	19.804571	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xf922, seq=2/512, ttl=64 (r)
18	19.805952	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xf922, seq=2/512, ttl=63 (r)
19	20.807396	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xfa22, seq=3/768, ttl=64 (r)
20	20.811595	172.16.20.138	64.100.1.10	ICMP	98	Echo (ping) reply id=0xfa22, seq=3/768, ttl=63 (r)
21	21.812950	64.100.1.10	172.16.20.138	ICMP	98	Echo (ping) request id=0xfb22, seq=4/1024, ttl=64 (r)

▼ Internet Protocol Version 4, Src: 64.100.1.10, Dst: 172.16.20.138
0100 = Version: 4
.... 0101 = Header Length: 20 bytes (5)
➤ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
Total Length: 84
Identification: 0x22f8 (8952)
➤ 000. = Flags: 0x0
...0 0000 0000 0000 = Fragment Offset: 0
Time to Live: 64
Protocol: ICMP (1)
Header Checksum: 0x55a9 [validation disabled]
[Header checksum status: Unverified]
Source Address: 64.100.1.10
Destination Address: 172.16.20.138
[Stream index: 0]
▼ Internet Control Message Protocol
Type: 8 (Echo (ping) request)
Code: 0
Checksum: 0x27e8 [correct]
[Checksum Status: Good]

ICMPv6 (IPv6)

- Echo Request / Reply (диагностика)
- Neighbor Solicitation / Advertisement (аналог ARP)
- Hop Limit – аналог TTL

Index	Time	Source	Destination	Type	Length	Description
1	0.000000	2001:db8:c0de:11::a	2001:db8:c0de:12::a	ICMPv6	118	Echo (ping) request id=0xe622, seq=1, hop limit=64 (
2	0.004516	fe80::e63:afff:fe05..	ff02::1:ff00:a	ICMPv6	86	Neighbor Solicitation for 2001:db8:c0de:11::a from 0:
3	0.004882	2001:db8:c0de:11::a	fe80::e63:afff:fe05..	ICMPv6	86	Neighbor Advertisement 2001:db8:c0de:11::a (sol, ovr
*	4 0.005663	2001:db8:c0de:12::a	2001:db8:c0de:11::a	ICMPv6	118	Echo (ping) reply id=0xe622, seq=1, hop limit=62 (re
5	1.007398	2001:db8:c0de:11::a	2001:db8:c0de:12::a	ICMPv6	118	Echo (ping) request id=0xe622, seq=2, hop limit=64 (
6	1.011009	2001:db8:c0de:12::a	2001:db8:c0de:11::a	ICMPv6	118	Echo (ping) reply id=0xe622, seq=2, hop limit=62 (re
7	2.013499	2001:db8:c0de:11::a	2001:db8:c0de:12::a	ICMPv6	118	Echo (ping) request id=0xe622, seq=3, hop limit=64 (
8	2.014997	2001:db8:c0de:12::a	2001:db8:c0de:11::a	ICMPv6	118	Echo (ping) reply id=0xe622, seq=3, hop limit=62 (re


```
> Frame 1: 118 bytes on wire (944 bits), 118 bytes captured (944 bits) on interface -, id 0
> Ethernet II, Src: Private_66:68:04 (00:50:79:66:68:04), Dst: 0c:63:af:05:00:02 (0c:63:af:05:00:02)
  Internet Protocol Version 6, Src: 2001:db8:c0de:11::a, Dst: 2001:db8:c0de:12::a
    Version = Version: 6
    .... 0000 0000 .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 0000 0000 0000 0000 0000 = Flow Label: 0x000000
    Payload Length: 64
    Next Header: ICMPv6 (58)
    Hop Limit: 64
    Source Address: 2001:db8:c0de:11::a
    Destination Address: 2001:db8:c0de:12::a
      [Stream index: 0]
  Internet Control Message Protocol v6
    Type: Echo (ping) request (128)
    Code: 0
    Checksum: 0xc4e7 [correct]
      [Checksum Status: Good]
    Identifier: 0xe622
    Sequence: 1
      [Response In: 4]
    Data (56 bytes)
```

Самостоятельное задание (2 подсети)

Адресное пространство

- Подсеть 1:
 - IPv4: 10.10.1.96/27 (30 хостов)
 - IPv6: 2001:db8:1:1::/64
- Подсеть 2:
 - IPv4: 10.10.1.16/28 (14 хостов)
 - IPv6: 2001:db8:1:4::/64

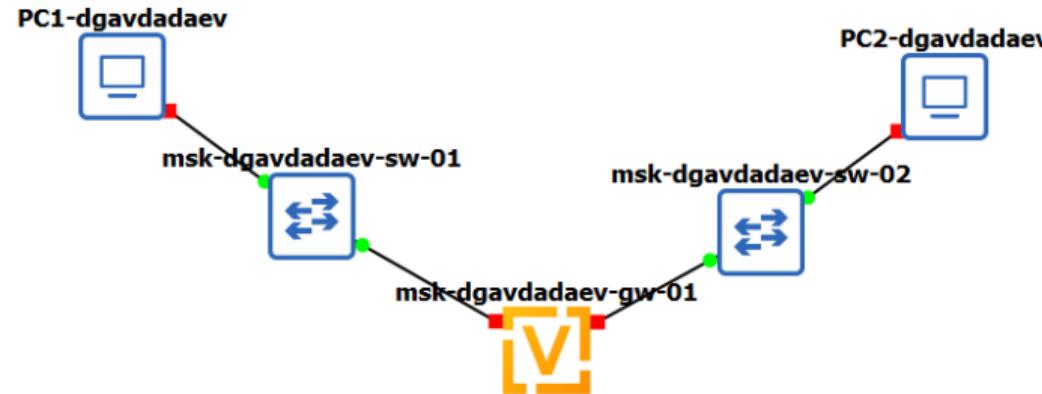
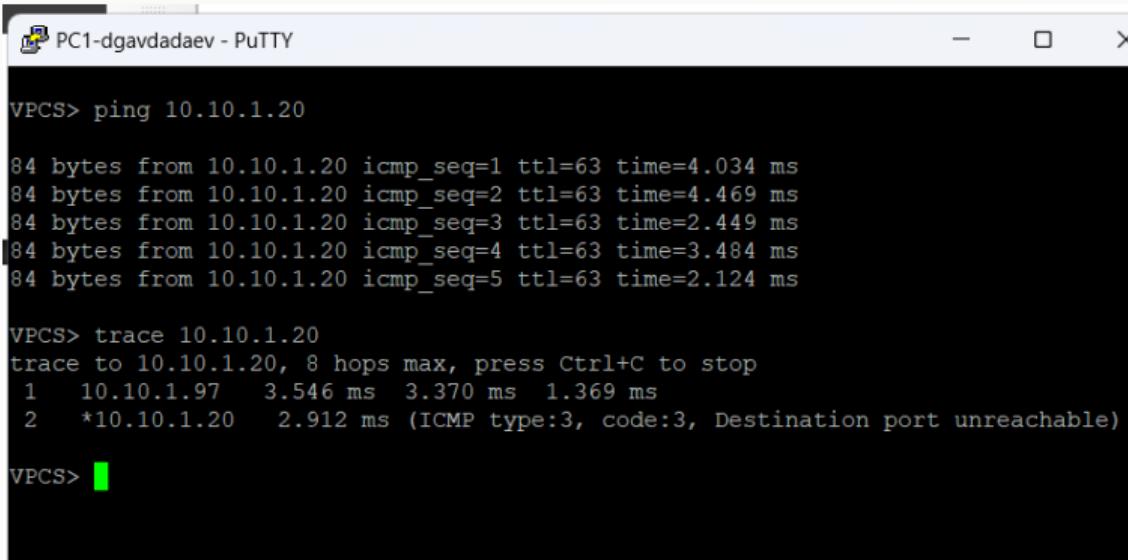


Таблица адресации (минимальные адреса для роутера)

- Router / Subnet 1:
 - IPv4 10.10.1.97/27
 - IPv6 2001:db8:1:1::1/64
- Router / Subnet 2:
 - IPv4 10.10.1.17/28
 - IPv6 2001:db8:1:4::1/64
- PC1:
 - IPv4 10.10.1.100/27, GW 10.10.1.97
 - IPv6 2001:db8:1:1::a/64
- PC2:
 - IPv4 10.10.1.20/28, GW 10.10.1.17
 - IPv6 2001:db8:1:4::a/64

Проверка связности (IPv4/IPv6)

- PC1 → PC2 (IPv4): успешный ping, маршрут через шлюз
- PC1 → PC2 (IPv6): успешный ping/trace через IPv6-интерфейс роутера



```
PC1-dgavdadaev - PuTTY

VPCS> ping 10.10.1.20

84 bytes from 10.10.1.20 icmp_seq=1 ttl=63 time=4.034 ms
84 bytes from 10.10.1.20 icmp_seq=2 ttl=63 time=4.469 ms
84 bytes from 10.10.1.20 icmp_seq=3 ttl=63 time=2.449 ms
84 bytes from 10.10.1.20 icmp_seq=4 ttl=63 time=3.484 ms
84 bytes from 10.10.1.20 icmp_seq=5 ttl=63 time=2.124 ms

VPCS> trace 10.10.1.20
trace to 10.10.1.20, 8 hops max, press Ctrl+C to stop
1 10.10.1.97 3.546 ms 3.370 ms 1.369 ms
2 *10.10.1.20 2.912 ms (ICMP type:3, code:3, Destination port unreachable)

VPCS>
```

Рис. 18: Ping/Trace IPv4

Итоги работы

Выводы

- Выполнено разбиение IPv4 и IPv6 сетей с расчётом диапазонов
- Настроен **Dual Stack**-сервер и маршрутизация:
 - FRR для IPv4
 - VyOS для IPv6 (+ Router Advertisement)
- Подтверждена связность и корректная маршрутизация
- Проанализированы:
 - ARP (IPv4)
 - ICMP (IPv4)
 - ICMPv6 + Neighbor Discovery (IPv6)