入無人之径

於 MikroTik 蟄伏九載的 Pre-Auth RCE

NiNi Chen

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- Member of Balsn CTF Team
- Member of UNDEFINED

@terrynini38514

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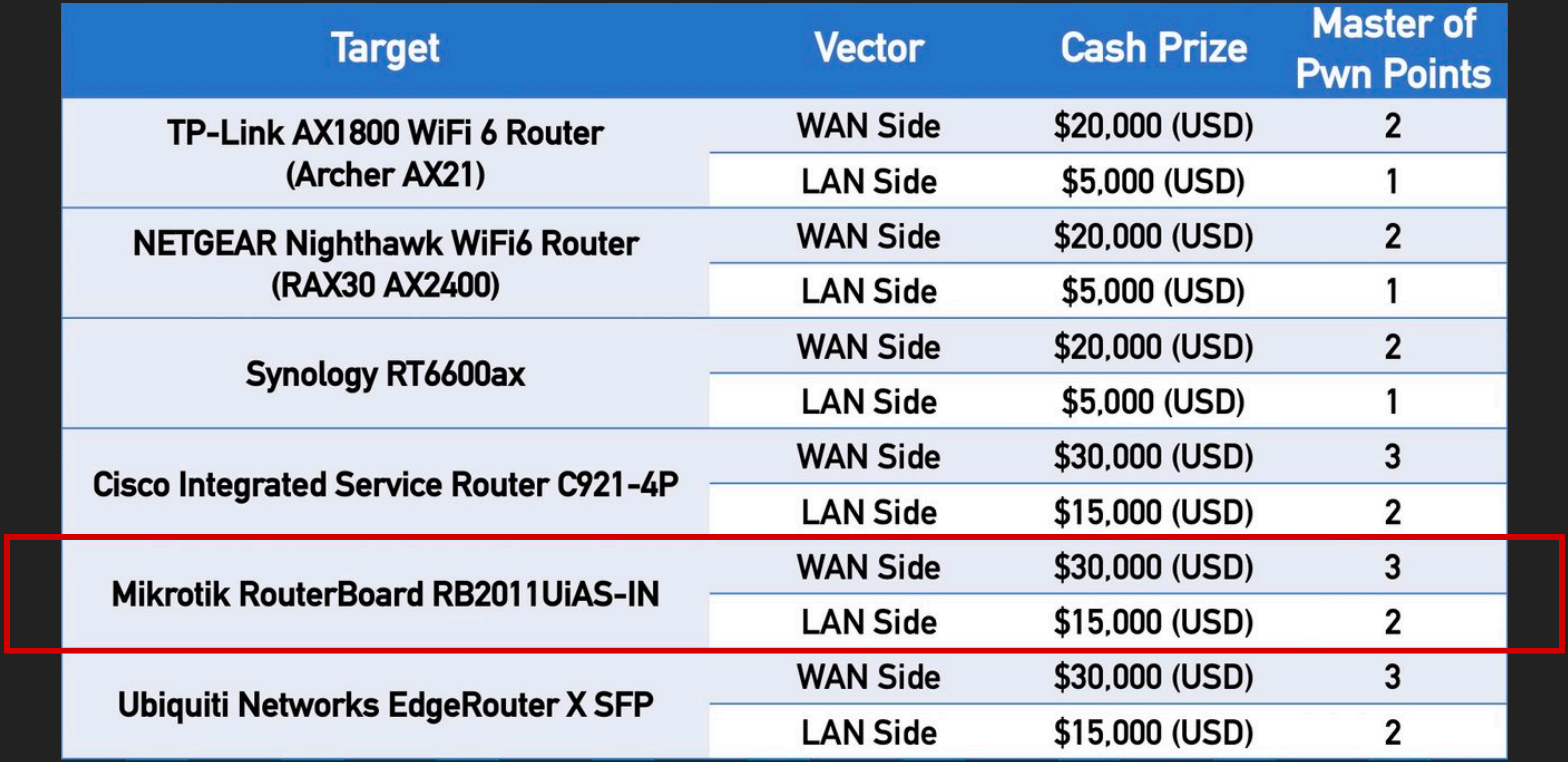
nini@undefined.zip

DEVCORE

Why?

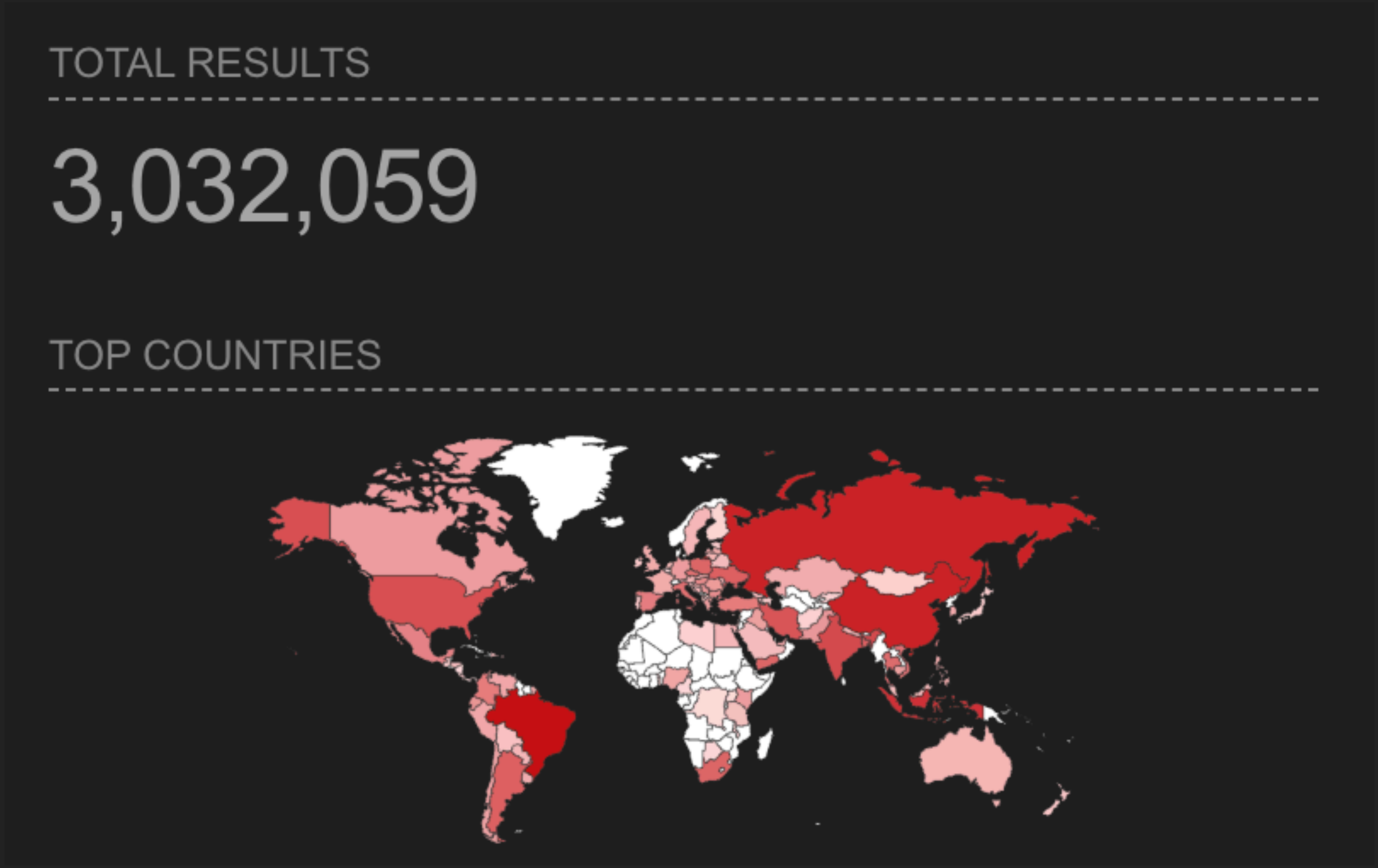


Target	Vector	Cash Prize	Master of Pwn Points
TP-Link AX1800 WiFi 6 Router (Archer AX21)	WAN Side	$20,000 (USD)	2
	LAN Side	$5,000 (USD)	1
NETGEAR Nighthawk WiFi6 Router (RAX30 AX2400)	WAN Side	$20,000 (USD)	2
	LAN Side	$5,000 (USD)	1
Synology RT6600ax	WAN Side	$20,000 (USD)	2
	LAN Side	$5,000 (USD)	1
Cisco Integrated Service Router C921-4P	WAN Side	$30,000 (USD)	3
	LAN Side	$15,000 (USD)	2
Mikrotik RouterBoard RB2011UiAS-IN	WAN Side	$30,000 (USD)	3
	LAN Side	$15,000 (USD)	2
Ubiquiti Networks EdgeRouter X SFP	WAN Side	$30,000 (USD)	3
	LAN Side	$15,000 (USD)	2

Why?

Target		Point
Initial Stage	Final Stage	
TP-Link AX1800 WiFi 6 Router NETGEAR Nighthawk WiFi6 Router Synology RT6600ax Cisco Integrated Service Router C921-4P Mikrotik RouterBoard RB2011UiAS-IN Ubiquiti Networks EdgeRouter X SFP	Meta Portal Go Amazon Echo Show 15 Google Nest Max Sonos One Speaker Apple HomePod mini Amazon Echo Studio HP Color LaserJet Pro M479fdw Lexmark MC3224i Canon imageCLASS MF743Cdw Synology DiskStation DS920+ My Cloud Pro Series PR4100 from WD	10

RouterOS



TOTAL RESULTS

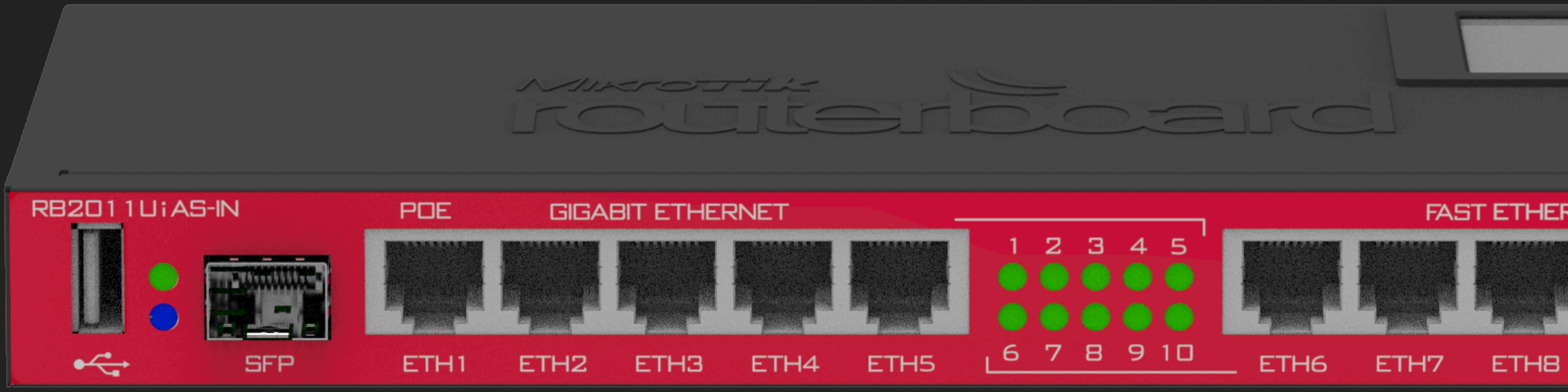
3,032,059

TOP COUNTRIES

2023/07/03 - https://www.shodan.io/search?query=MikroTik

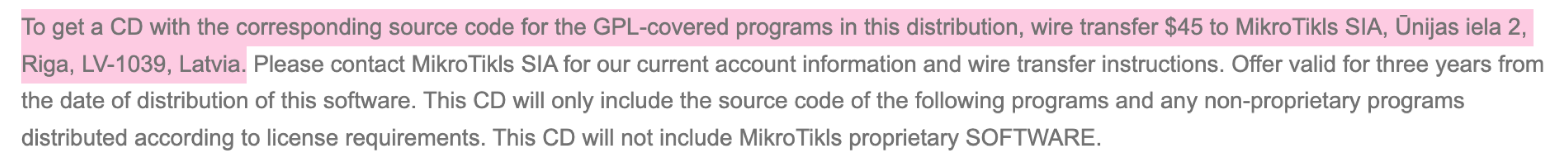
RouterOS

- A stand-alone operating system based on the Linux kernel
- Also available for virtual machines to turn a PC into a router



RouterOS

- A stand-alone operating system based on the Linux kernel
- Also available for virtual machines to turn a PC into a router
- Closed source and also a closed ecosystem.
  (It is said that you can get GPL sources used in RouterOS if you ask them)

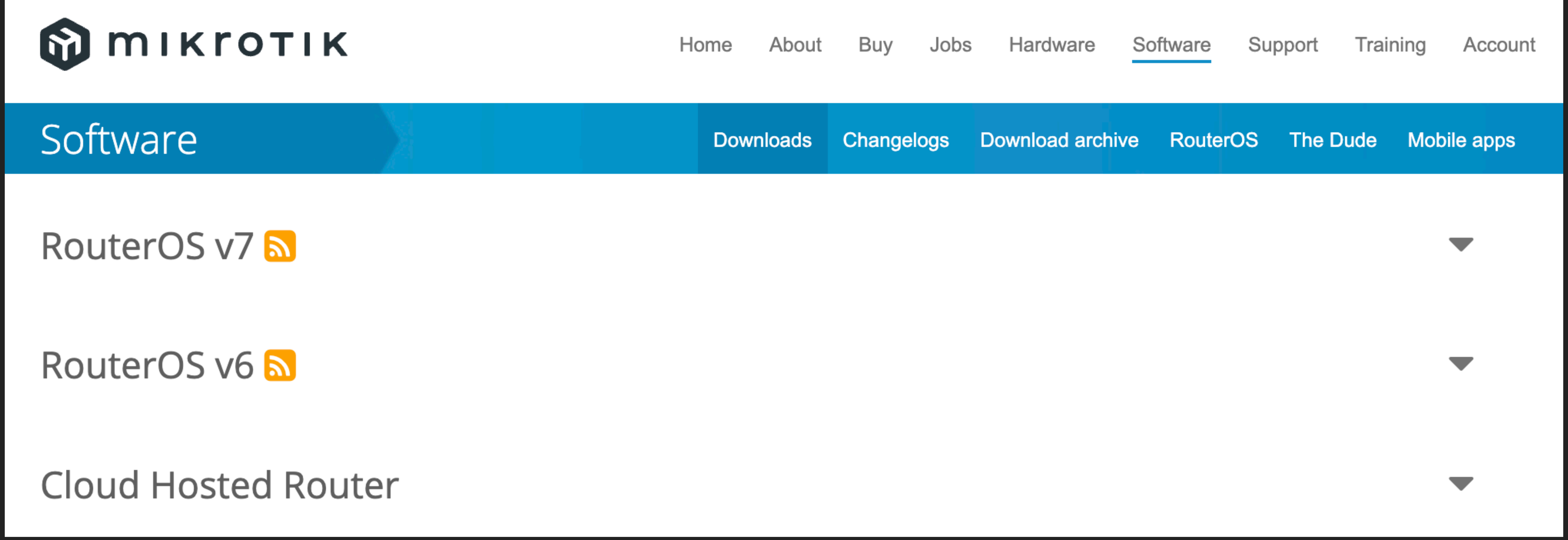


To get a CD with the corresponding source code for the GPL-covered programs in this distribution, wire transfer $45 to MikroTikls SIA, Ūnijas iela 2, Riga, LV-1039, Latvia. Please contact MikroTikls SIA for our current account information and wire transfer instructions. Offer valid for three years from the date of distribution of this software. This CD will only include the source code of the following programs and any non-proprietary programs distributed according to license requirements. This CD will not include MikroTikls proprietary SOFTWARE.

https://mikrotik.com/downloadterms.html

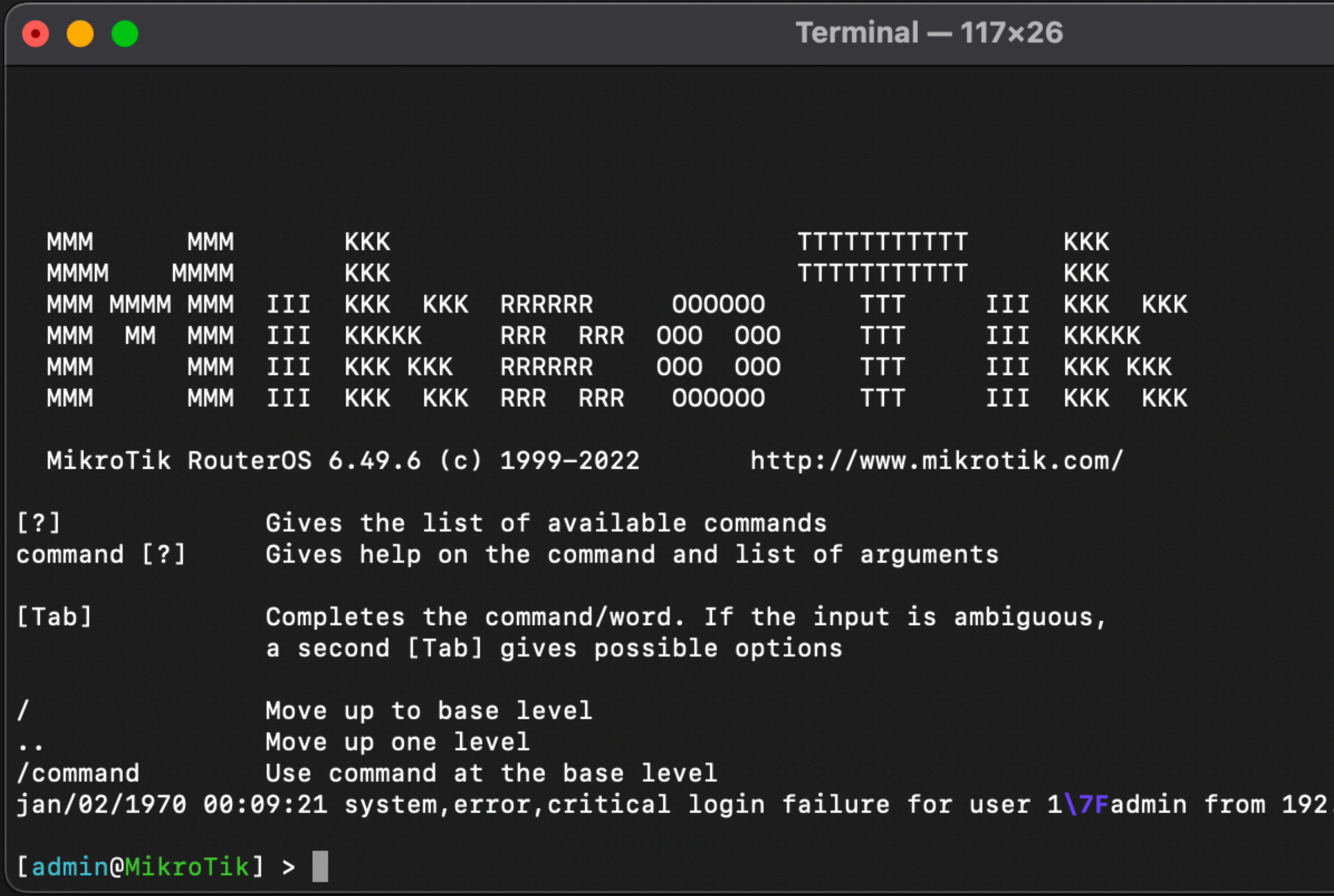
RouterOS

- RouterOS v6 and RouterOS v7 can be considered two different branches
- CHR is the RouterOS image for VM, x86_64 only



RouterOS

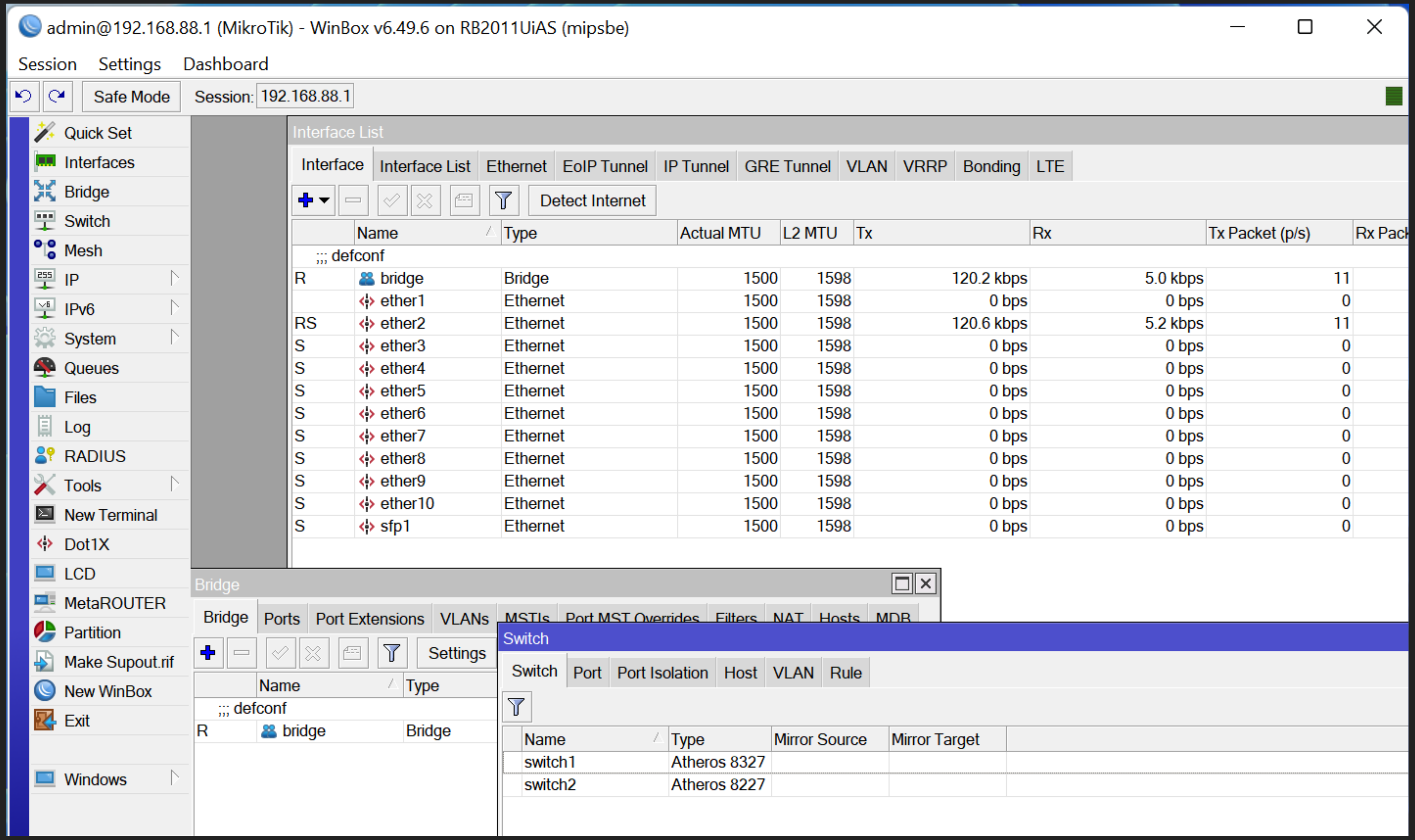
- Most binaries are “Nova binary”
- No official method to access the linux system.



```
  MMM      MMM       KKK                          TTTTTTTTTTT      KKK
  MMMM    MMMM       KKK                          TTTTTTTTTTT      KKK
  MMM MMMM MMM  III  KKK  KKK  RRRRRR     OOOOOO      TTT     III  KKK  KKK
  MMM  MM  MMM  III  KKKKK     RRR  RRR  OOO  OOO     TTT     III  KKKKK
  MMM      MMM  III  KKK KKK   RRRRRR    OOO  OOO     TTT     III  KKK KKK
  MMM      MMM  III  KKK  KKK  RRR  RRR   OOOOOO      TTT     III  KKK  KKK

  MikroTik RouterOS 6.49.6 (c) 1999-2022       http://www.mikrotik.com/

[?]             Gives the list of available commands
command [?]     Gives help on the command and list of arguments

[Tab]           Completes the command/word. If the input is ambiguous,
                a second [Tab] gives possible options

/               Move up to base level
..              Move up one level
/command        Use command at the base level
jan/02/1970 00:09:21 system,error,critical login failure for user 1\7Fadmin from 192

[admin@MikroTik] >
```

Winbox

- Winbox is a native Win32 GUI binary used for managing and configuring MikroTik routers on Windows.



	Name	Type	Actual MTU	L2 MTU	Tx	Rx	Tx Packet (p/s)	Rx Pack
	;;; defconf							
R	bridge	Bridge	1500	1598	120.2 kbps	5.0 kbps	11	
	ether1	Ethernet	1500	1598	0 bps	0 bps	0	
RS	ether2	Ethernet	1500	1598	120.6 kbps	5.2 kbps	11	
S	ether3	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether4	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether5	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether6	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether7	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether8	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether9	Ethernet	1500	1598	0 bps	0 bps	0	
S	ether10	Ethernet	1500	1598	0 bps	0 bps	0	
S	sfp1	Ethernet	1500	1598	0 bps	0 bps	0	

	Name	Type
	;;; defconf	
R	bridge	Bridge

Name	Type	Mirror Source	Mirror Target
switch1	Atheros 8327		
switch2	Atheros 8227		

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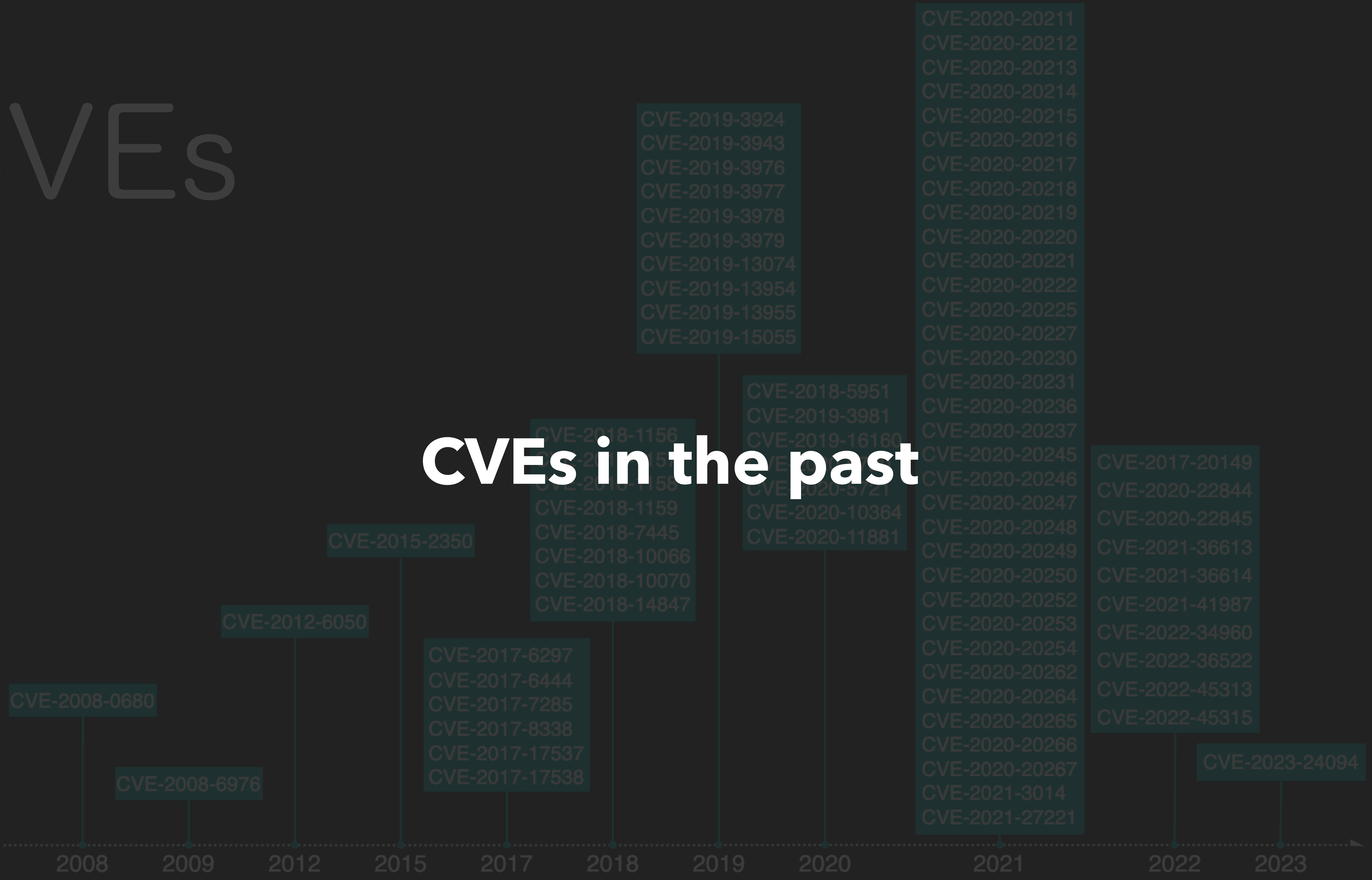
CVEs

CVEs in the past



2008
CVE-2008-0680

2009
CVE-2008-6976

2012
CVE-2012-6050

2015
CVE-2015-2350

2017
CVE-2017-6297
CVE-2017-6444
CVE-2017-7285
CVE-2017-8338
CVE-2017-17537
CVE-2017-17538

2018
CVE-2018-1156
CVE-2018-1157
CVE-2018-1158
CVE-2018-1159
CVE-2018-7445
CVE-2018-10066
CVE-2018-10070
CVE-2018-14847

2019
CVE-2019-3924
CVE-2019-3943
CVE-2019-3976
CVE-2019-3977
CVE-2019-3978
CVE-2019-3979
CVE-2019-13074
CVE-2019-13954
CVE-2019-13955
CVE-2019-15055

2020
CVE-2018-5951
CVE-2019-3981
CVE-2019-16160
[illegible]
CVE-2020-5721
CVE-2020-10364
CVE-2020-11881

2021
CVE-2020-20211
CVE-2020-20212
CVE-2020-20213
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CVE-2020-20254
CVE-2020-20262
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CVE-2020-20267
CVE-2021-3014
CVE-2021-27221

2022
CVE-2017-20149
CVE-2020-22844
CVE-2020-22845
CVE-2021-36613
CVE-2021-36614
CVE-2021-41987
CVE-2022-34960
CVE-2022-36522
CVE-2022-45313
CVE-2022-45315

2023
CVE-2023-24094

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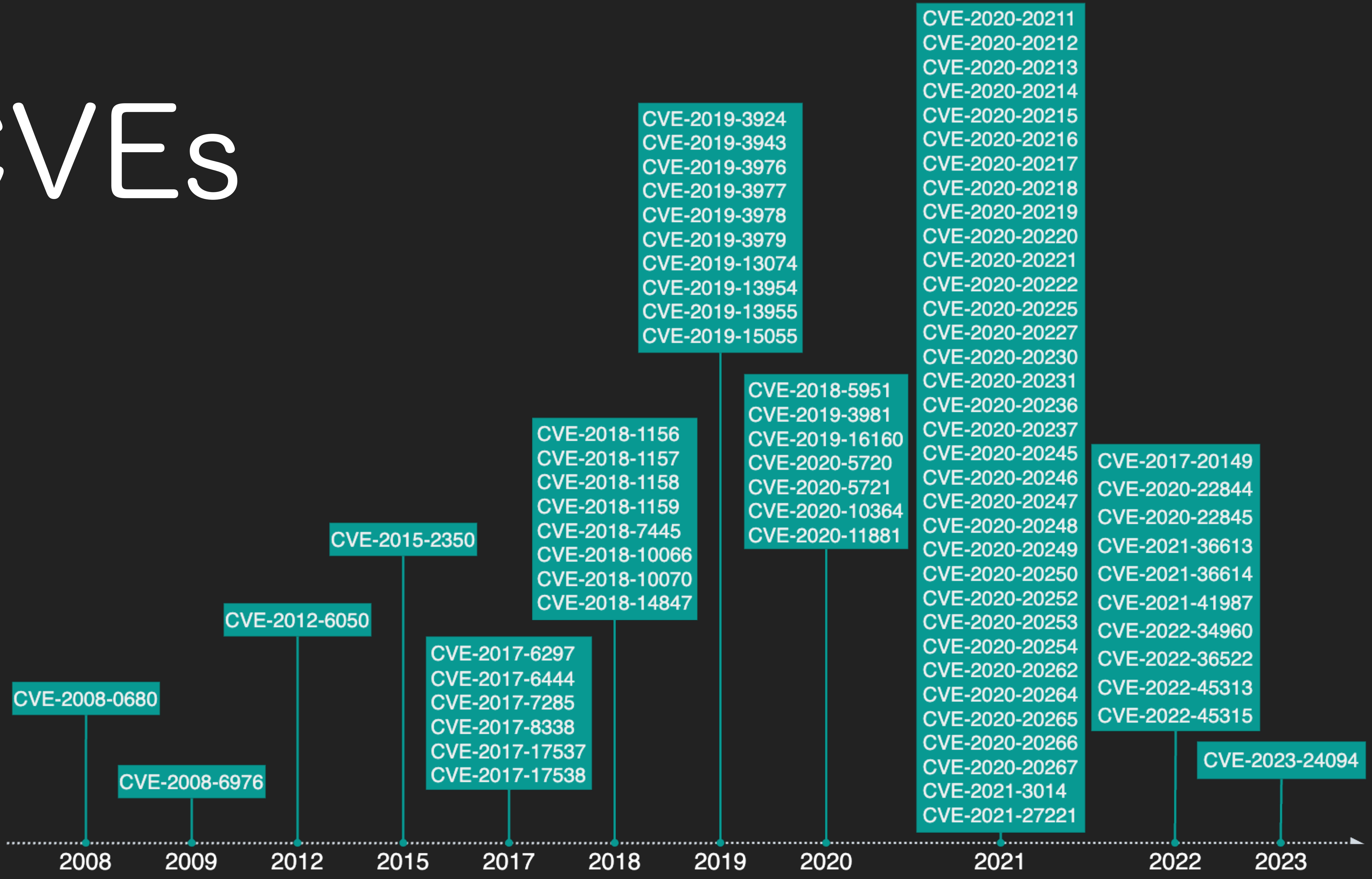
CVEs



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CVE-2017-17538

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CVE-2018-1159
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CVE-2018-10066
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CVE-2018-14847

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CVE-2019-15055

2020
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CVE-2020-10364
CVE-2020-11881

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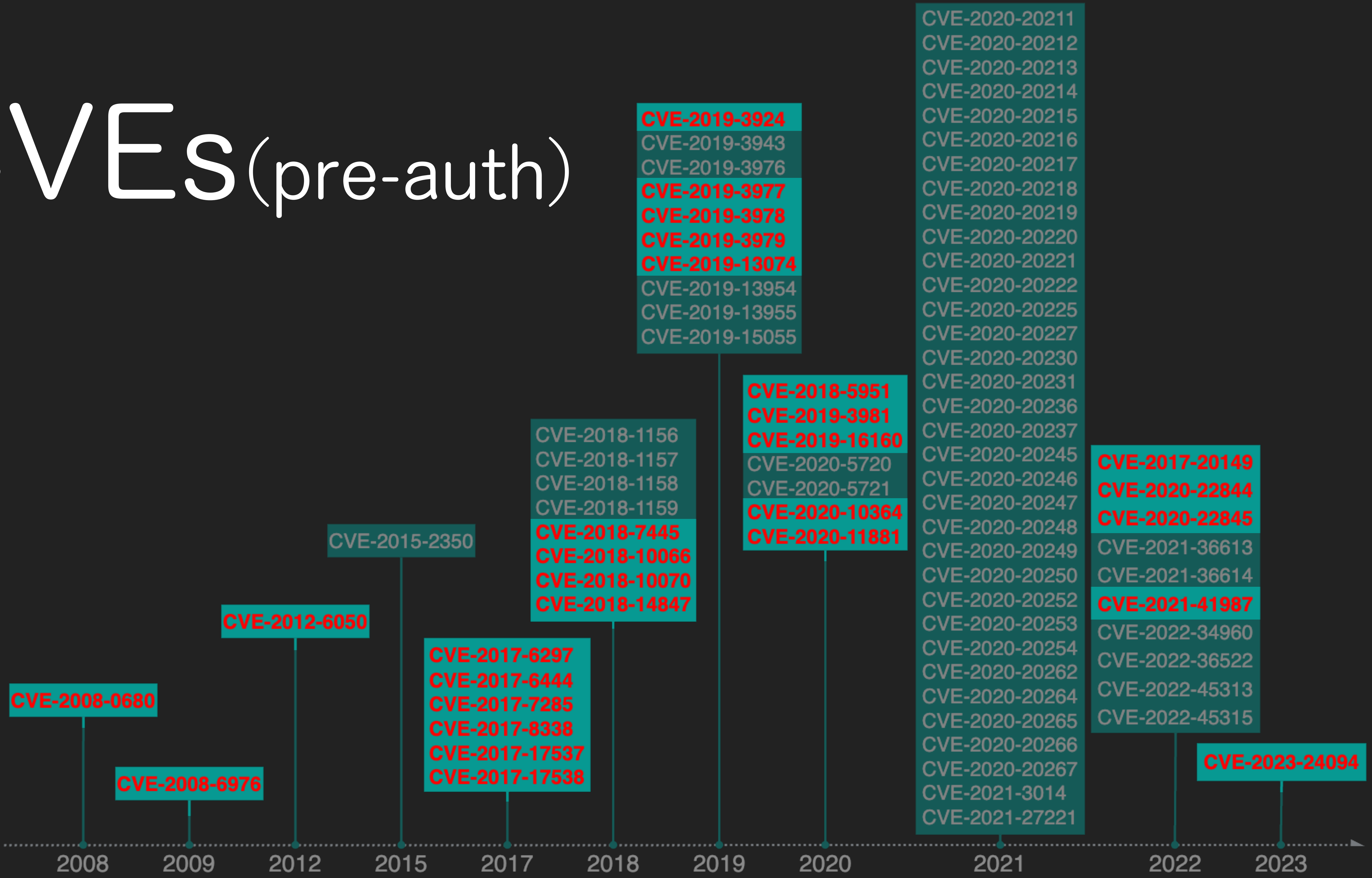
CVE-2022-45313
CVE-2022-45315

2023
CVE-2023-24094

CVEs(pre-auth)



2008

CVE-2008-0680

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CVE-2012-6050

2015

CVE-2015-2350

2017

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CVE-2017-6444
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CVE-2017-17537
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CVE-2018-10066
CVE-2018-10070
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2020

CVE-2018-5951
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2022

CVE-2017-20149
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CVE-2022-36522
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CVE-2022-45315

2023

CVE-2023-24094

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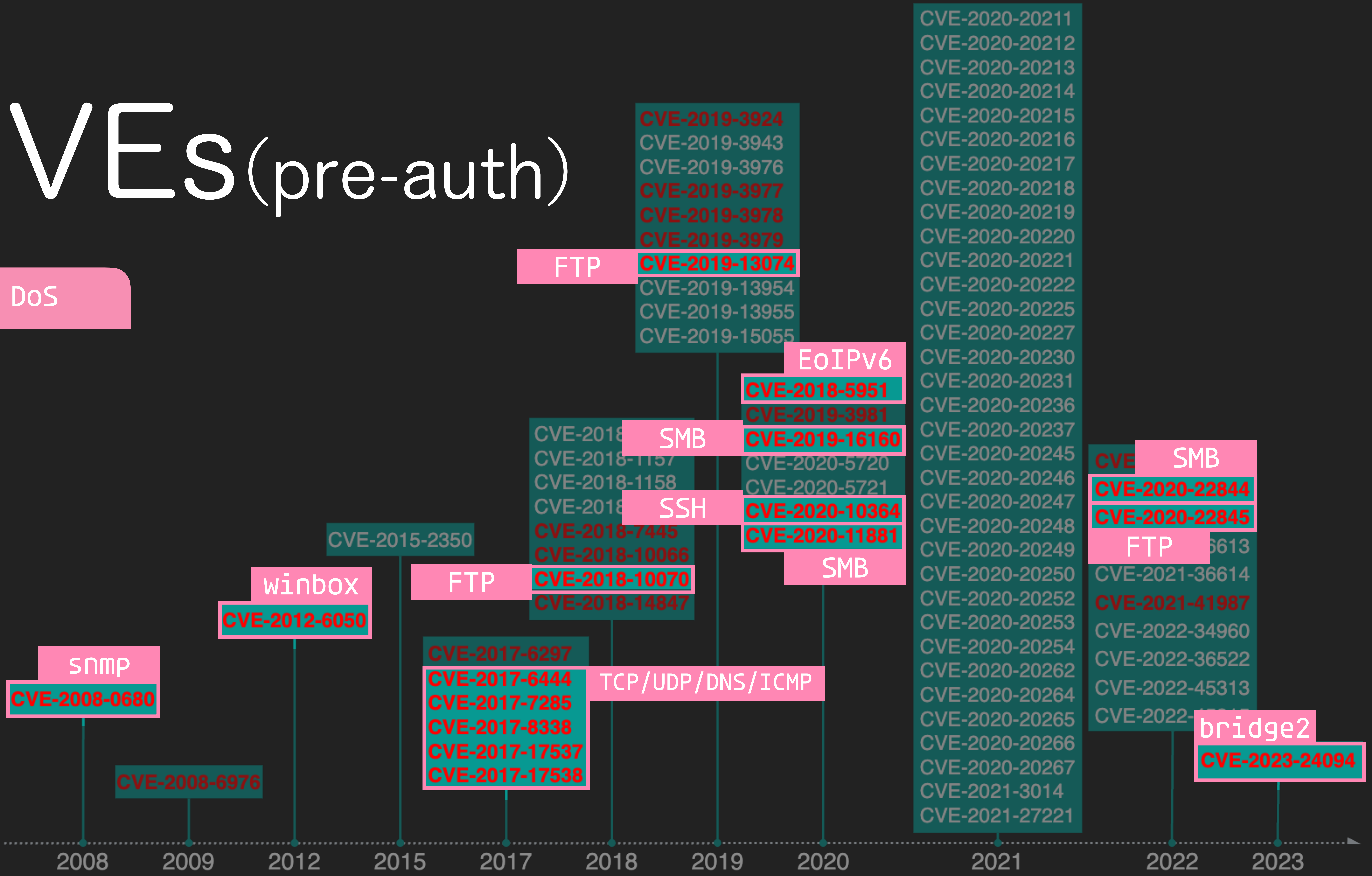
CVEs(pre-auth)

DoS



2008
snmp
CVE-2008-0680

2009
CVE-2008-6976

2012
winbox
CVE-2012-6050

2015
CVE-2015-2350

2017
CVE-2017-6297
CVE-2017-6444
CVE-2017-7285
CVE-2017-8338
CVE-2017-17537
CVE-2017-17538
TCP/UDP/DNS/ICMP

2018
CVE-2018
SMB
CVE-2018-1157
CVE-2018-1158
CVE-2018
SSH
CVE-2018-7445
CVE-2018-10066
FTP
CVE-2018-10070
CVE-2018-14847

2019
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CVE-2019-3943
CVE-2019-3976
CVE-2019-3977
CVE-2019-3978
CVE-2019-3979
FTP
CVE-2019-13074
CVE-2019-13954
CVE-2019-13955
CVE-2019-15055

2020
EoIPv6
CVE-2018-5951
CVE-2019-3981
CVE-2019-16160
CVE-2020-5720
CVE-2020-5721
CVE-2020-10364
CVE-2020-11881
SMB

2021
CVE-2020-20211
CVE-2020-20212
CVE-2020-20213
CVE-2020-20214
CVE-2020-20215
CVE-2020-20216
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bridge2
CVE-2023-24094

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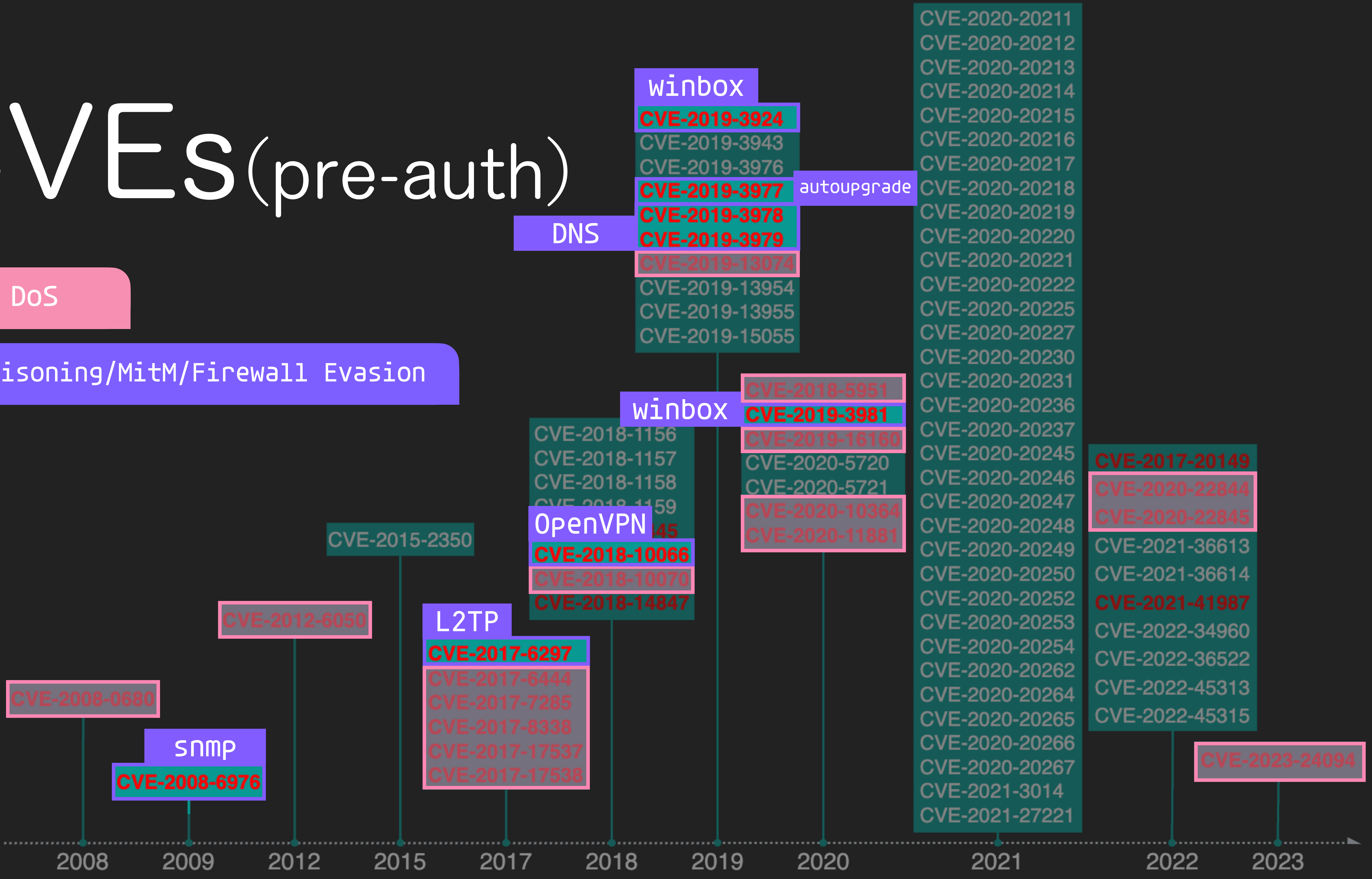
CVEs(pre-auth)

DoS

Poisoning/MitM/Firewall Evasion



2008
CVE-2008-0680

2009
snmp
CVE-2008-6976

2012
CVE-2012-6050

2015
CVE-2015-2350

2017
L2TP
CVE-2017-6297
CVE-2017-6444
CVE-2017-7285
CVE-2017-8338
CVE-2017-17537
CVE-2017-17538

2018
CVE-2018-1156
CVE-2018-1157
CVE-2018-1158
CVE-2018-1159
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OpenVPN
CVE-2018-10066
CVE-2018-10070
CVE-2018-14847

2019
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CVE-2019-3977
autoupgrade
DNS
CVE-2019-3978
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CVE-2019-15055

2020
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CVE-2020-10364
CVE-2020-11881

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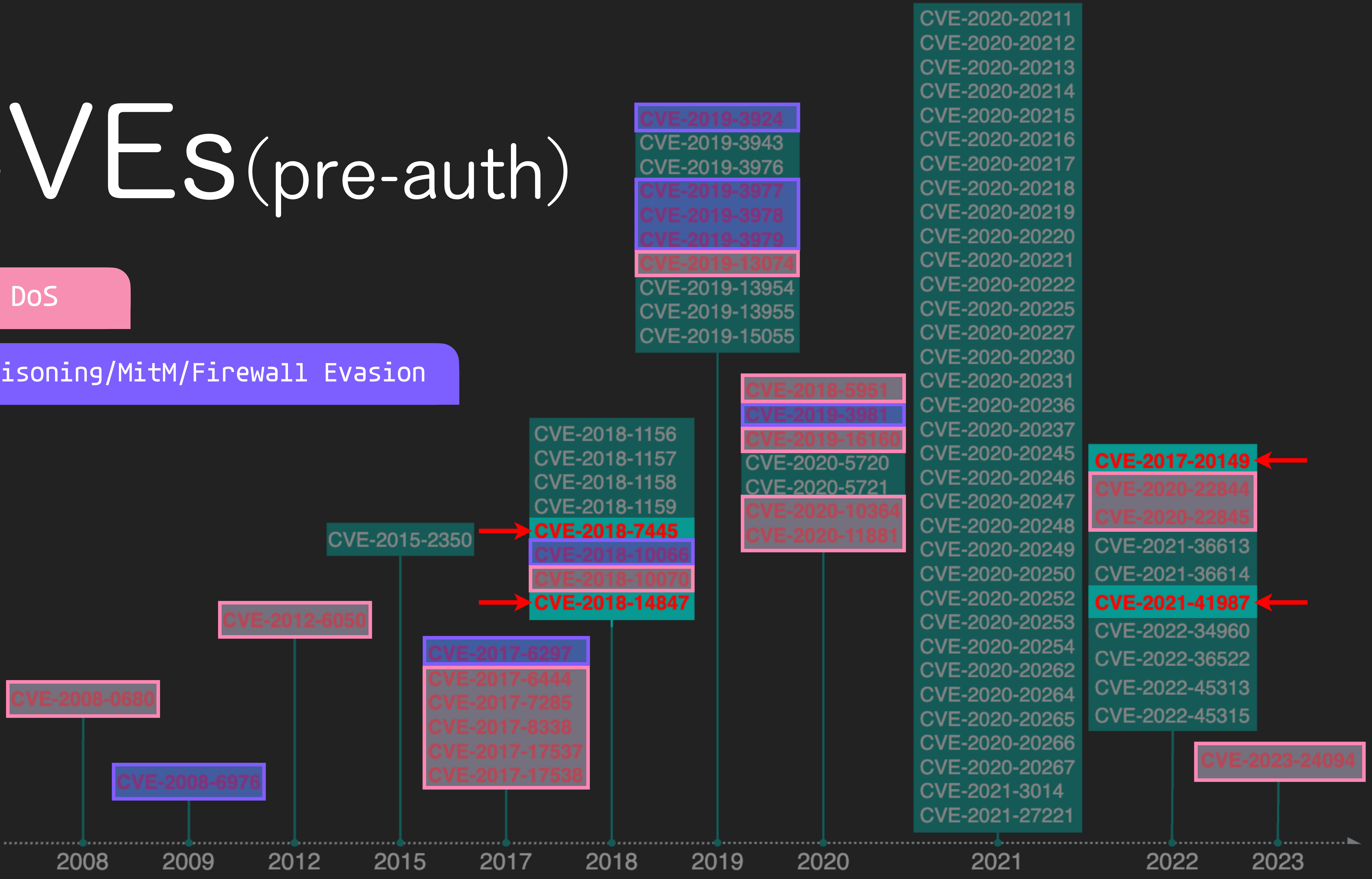
2023
CVE-2023-24094

DEVCORE

CVEs(pre-auth)

DoS

Poisoning/MitM/Firewall Evasion



2008
CVE-2008-0680

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2012
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CVE-2017-6297
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2018
CVE-2018-1156
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2019
CVE-2019-3924
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CVE-2019-15055

2020
CVE-2018-5951
CVE-2019-3981
CVE-2019-16160
CVE-2020-5720
CVE-2020-5721
CVE-2020-10364
CVE-2020-11881

2021
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CVE-2020-20217
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CVE-2020-20267
CVE-2021-3014
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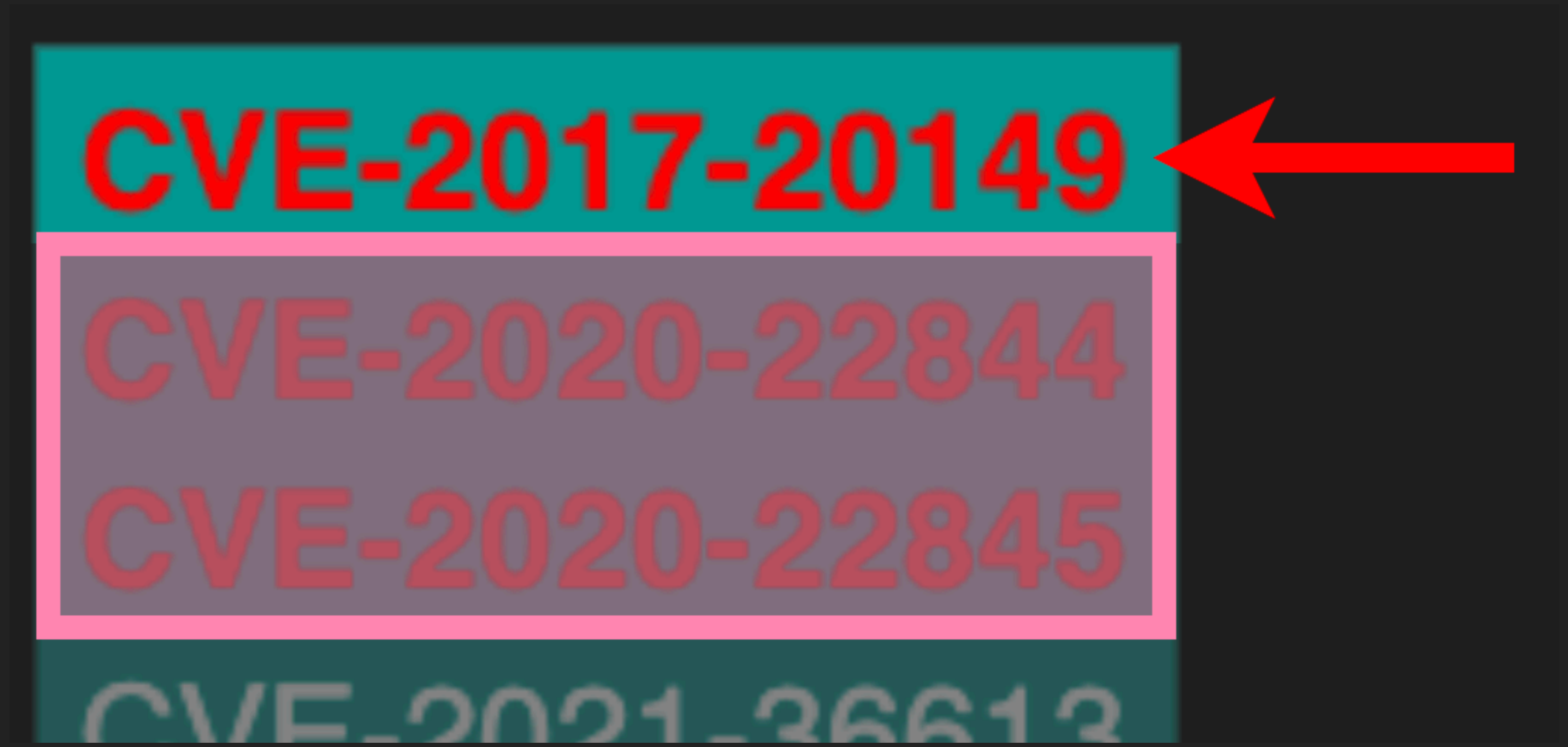
2023
CVE-2023-24094

CVEs(pre-auth)



CVE-2017-20149

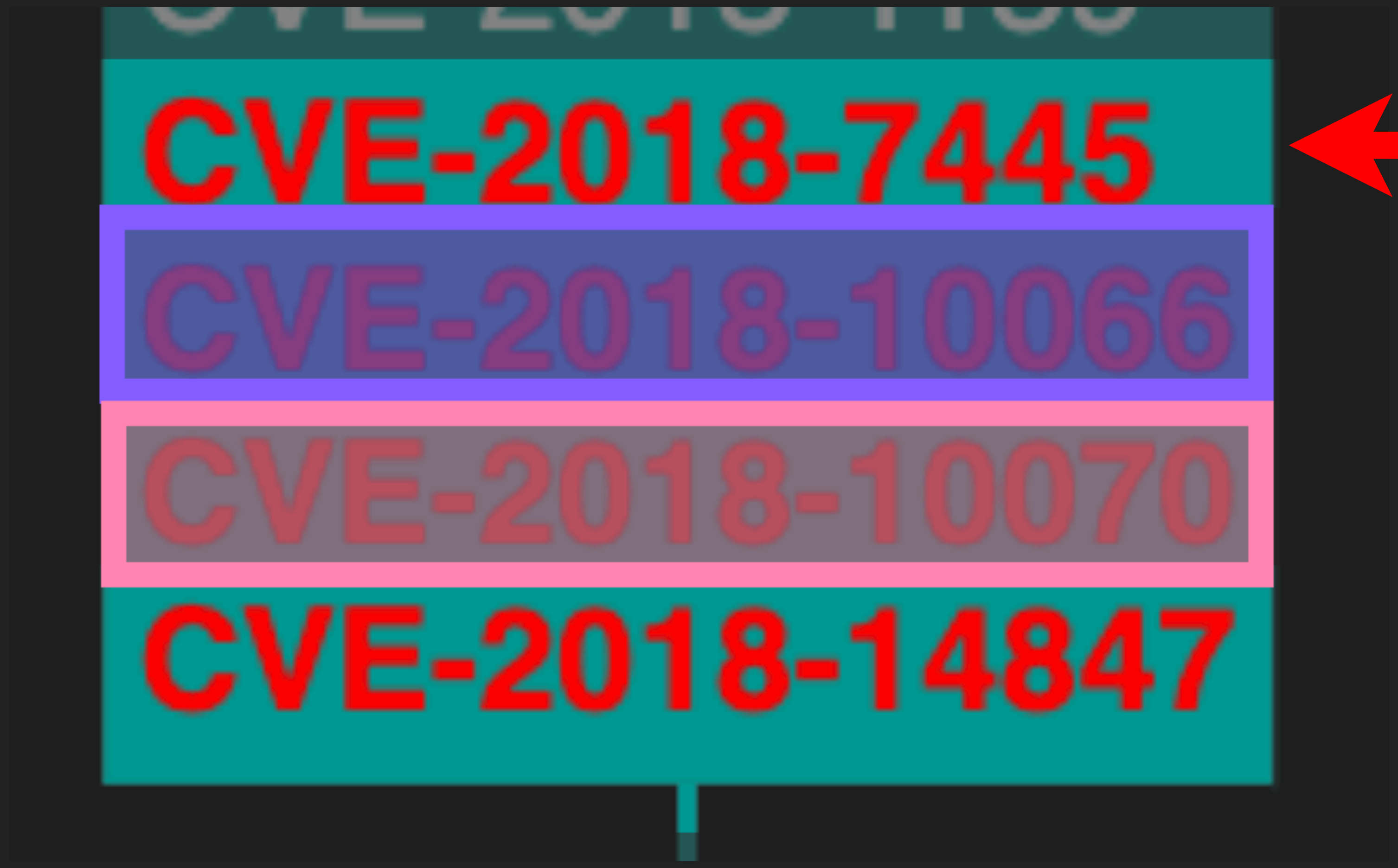
CVE-2020-22844

CVE-2020-22845

CVE-2021-36613

- aka Chimay-Red
- One of the exploits leaked from the CIA
- Lacking input validation on Content-Length in HTTP request cause the stack clash attack.

CVEs(pre-auth)



CVE-2018-7445

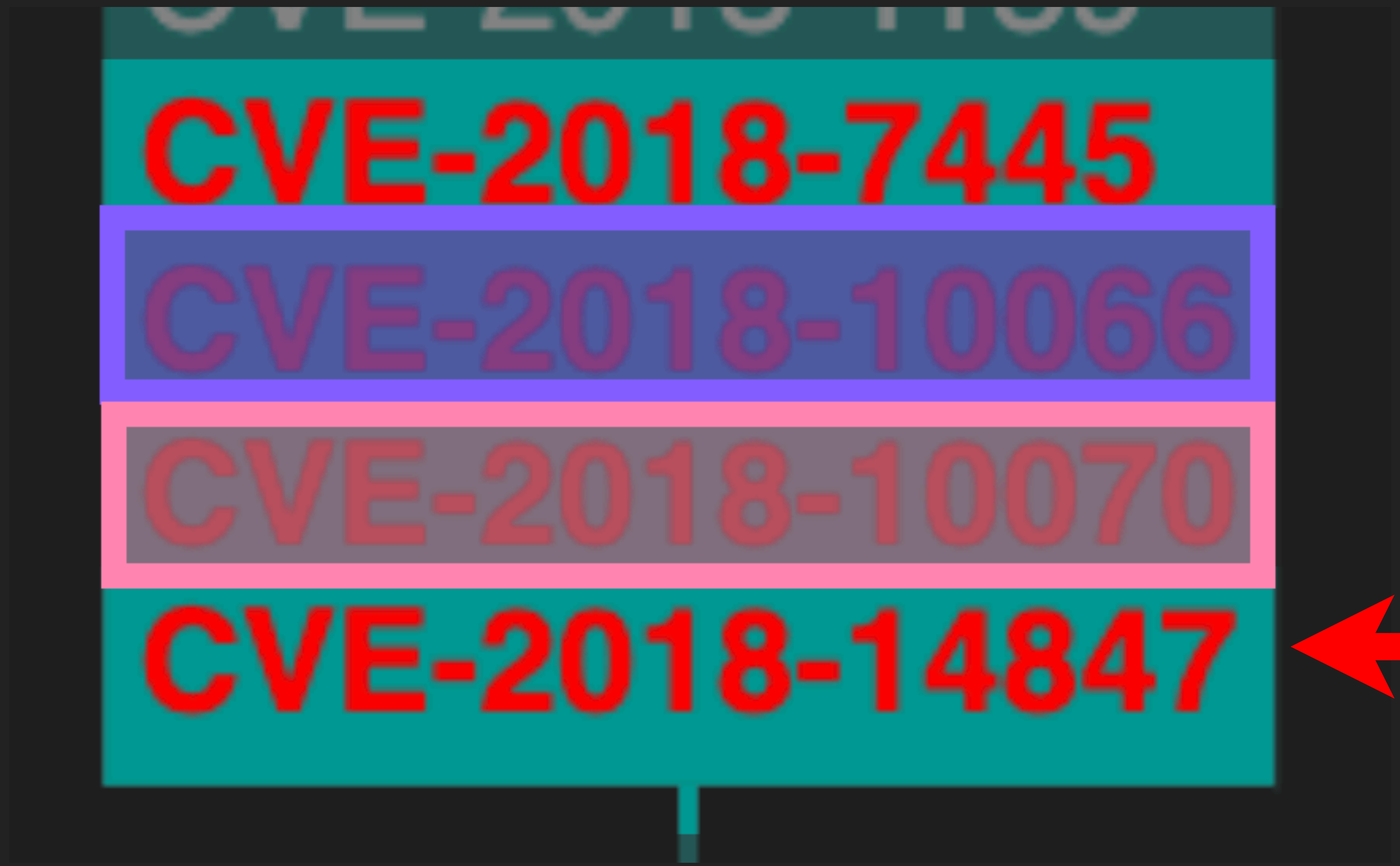
CVE-2018-10066

CVE-2018-10070

CVE-2018-14847

- Buffer overflow in SMB
- It was found by blackbox fuzzing

CVEs(pre-auth)



CVE-2018-7445

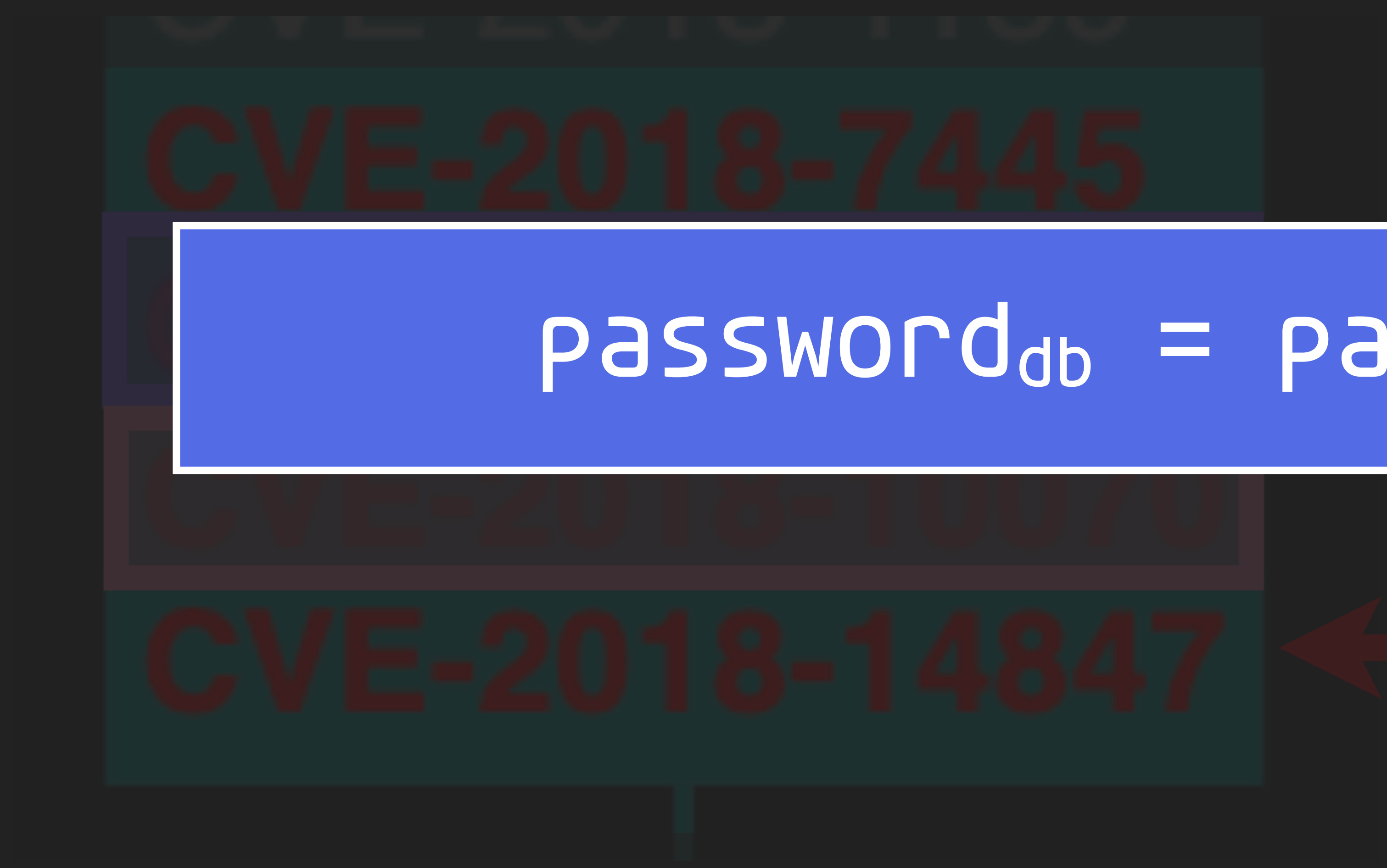
CVE-2018-10066

CVE-2018-10070

CVE-2018-14847

- One of the exploits leaked from the CIA
- A directory traversal vulnerability in the WinBox interface
- Allows unauthenticated attackers to read arbitrary files on RouterOS

CVEs(pre-auth)

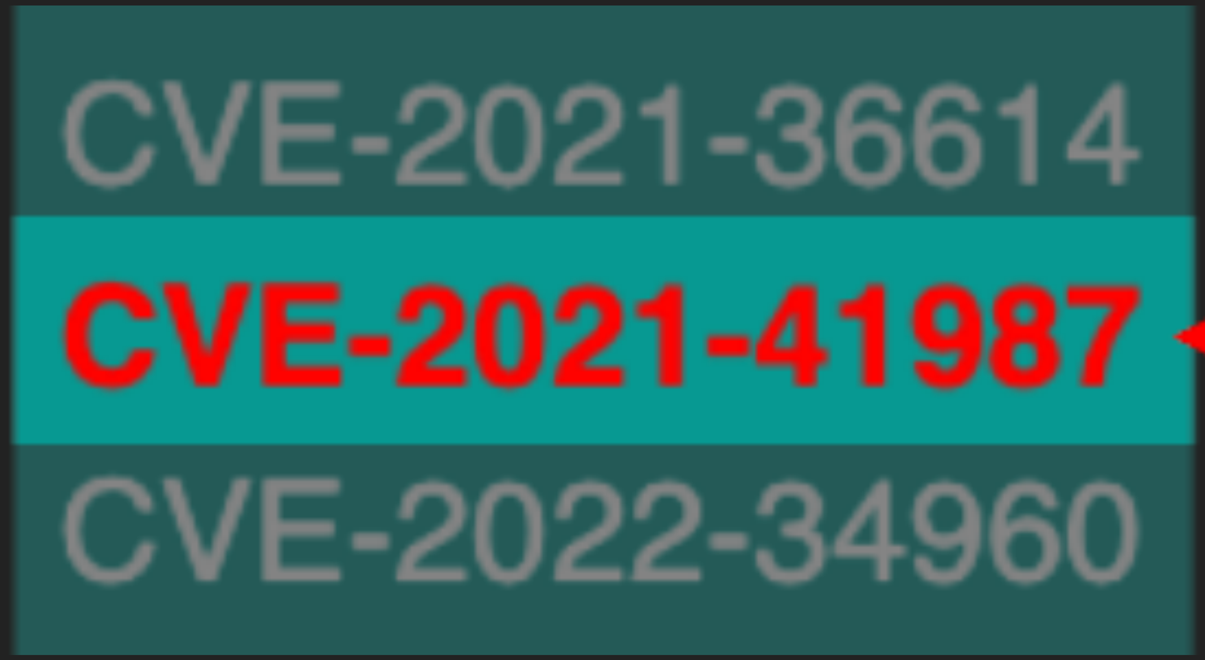


$$\text{password}_{db} = \text{password}_{raw} \text{ xor md5(username + "283i4jfkai3389")}$$

- Allows unauthenticated attackers to read arbitrary files on RouterOS

DEVCORE

CVEs(pre-auth)



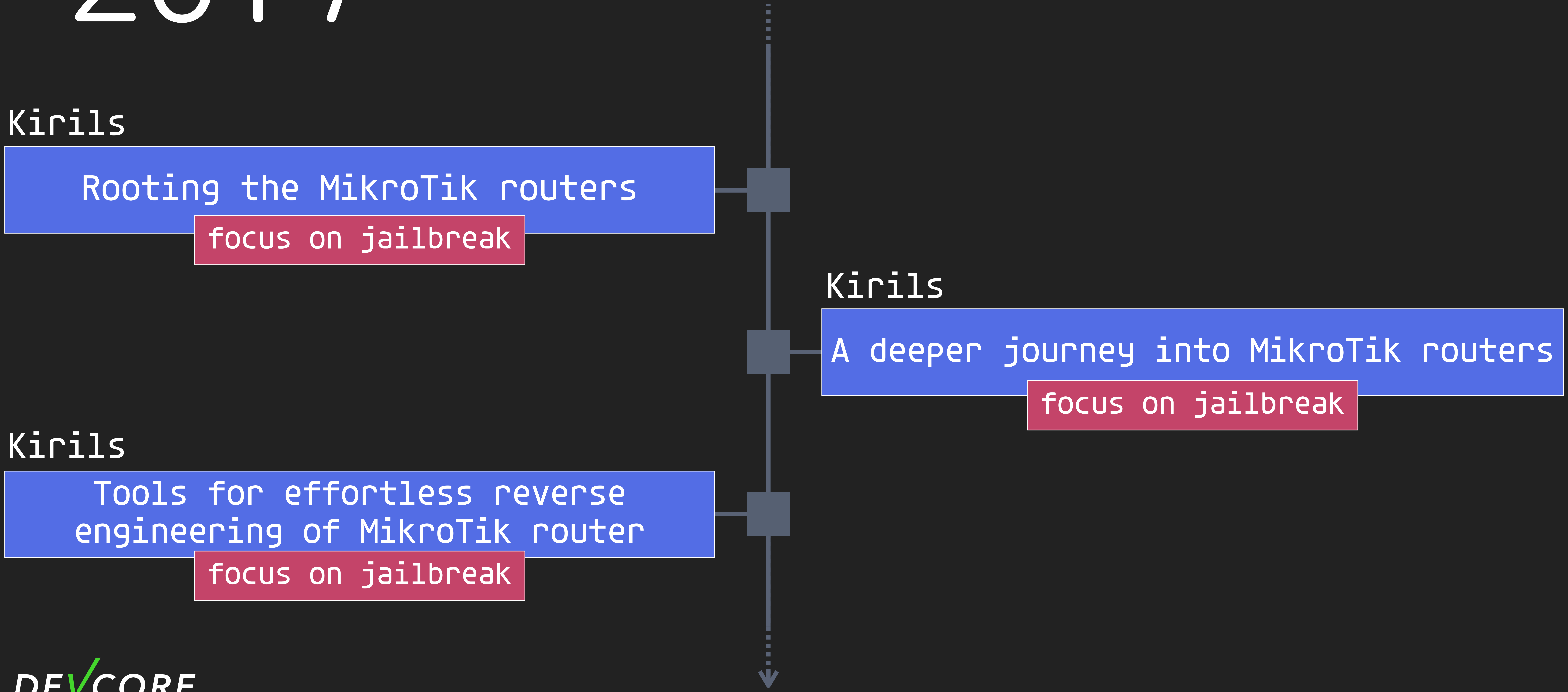
CVE-2021-36614

CVE-2021-41987

CVE-2022-34960

- OOB in the base64decode of SCEP service
- The attacker must know the scep_server_name
- It was discovered on an APT’s C2 server

2017



Kirils

Rooting the MikroTik routers

focus on jailbreak

Kirils

A deeper journey into MikroTik routers

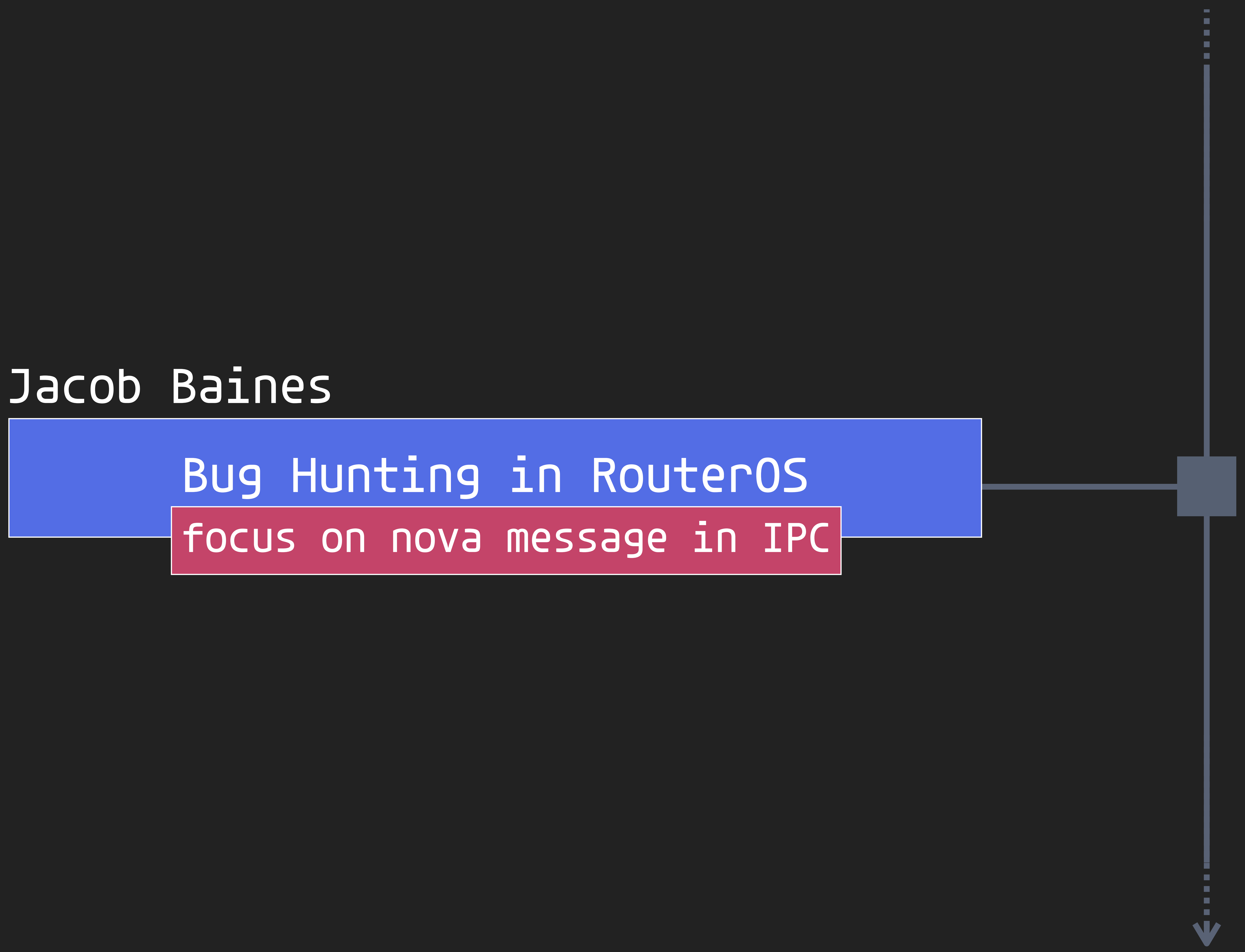
focus on jailbreak

Kirils

Tools for effortless reverse engineering of MikroTik router

focus on jailbreak

2018

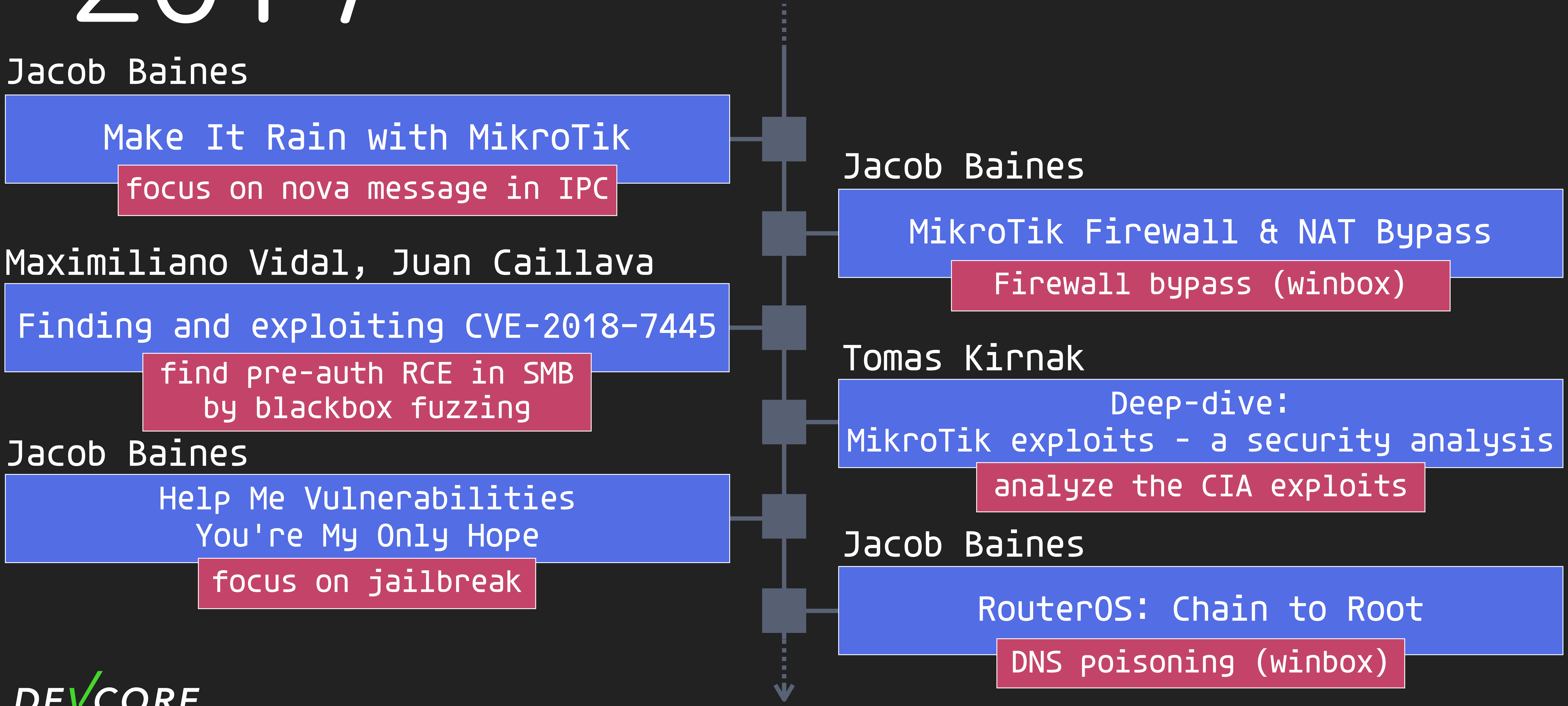


Jacob Baines

Bug Hunting in RouterOS

focus on nova message in IPC

2019



Jacob Baines

Make It Rain with MikroTik

focus on nova message in IPC

Jacob Baines

MikroTik Firewall & NAT Bypass

Firewall bypass (winbox)

Maximiliano Vidal, Juan Caillava

Finding and exploiting CVE-2018-7445

find pre-auth RCE in SMB
by blackbox fuzzing

Tomas Kirnak

Deep-dive:
MikroTik exploits - a security analysis

analyze the CIA exploits

Jacob Baines

Help Me Vulnerabilities
You're My Only Hope

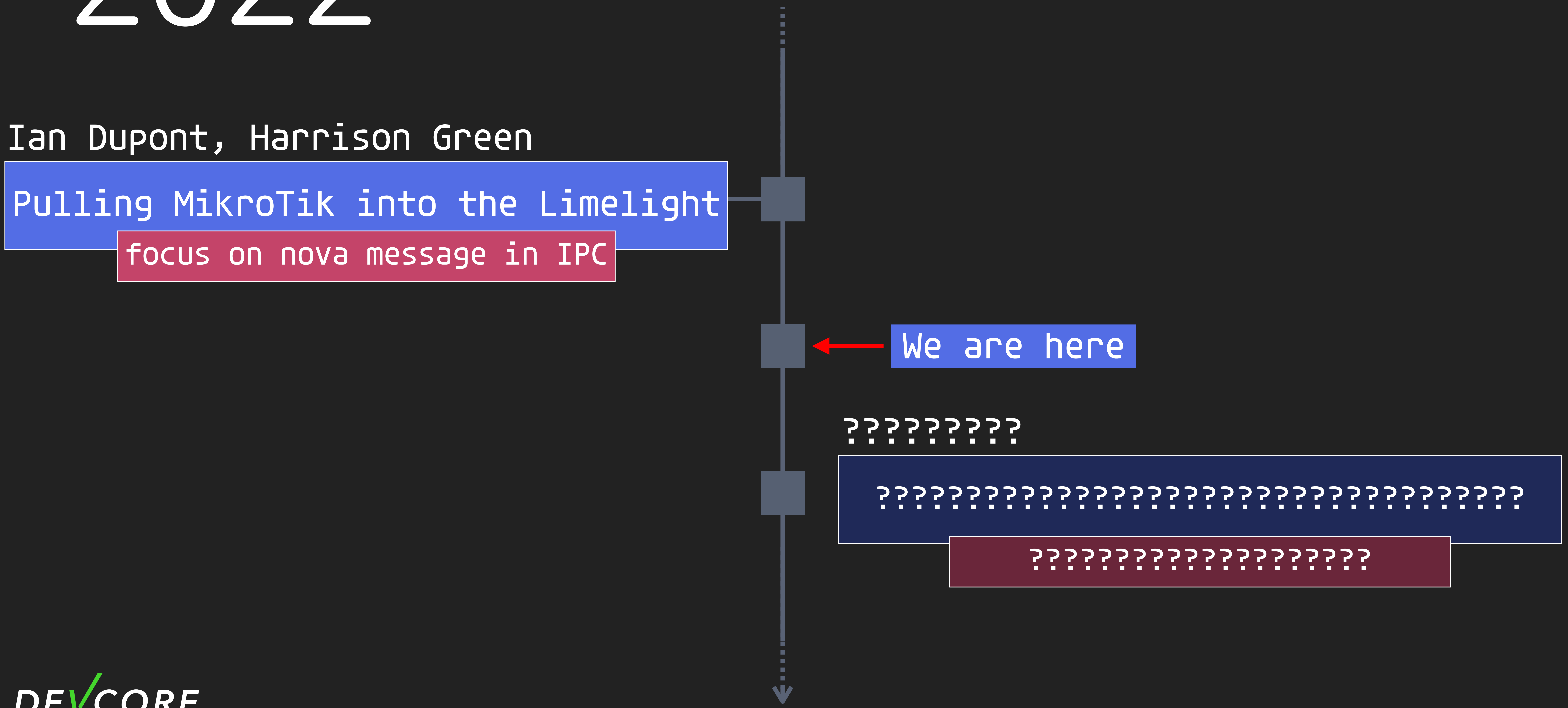
focus on jailbreak

Jacob Baines

RouterOS: Chain to Root

DNS poisoning (winbox)

2022



Ian Dupont, Harrison Green

Pulling MikroTik into the Limelight

focus on nova message in IPC

We are here

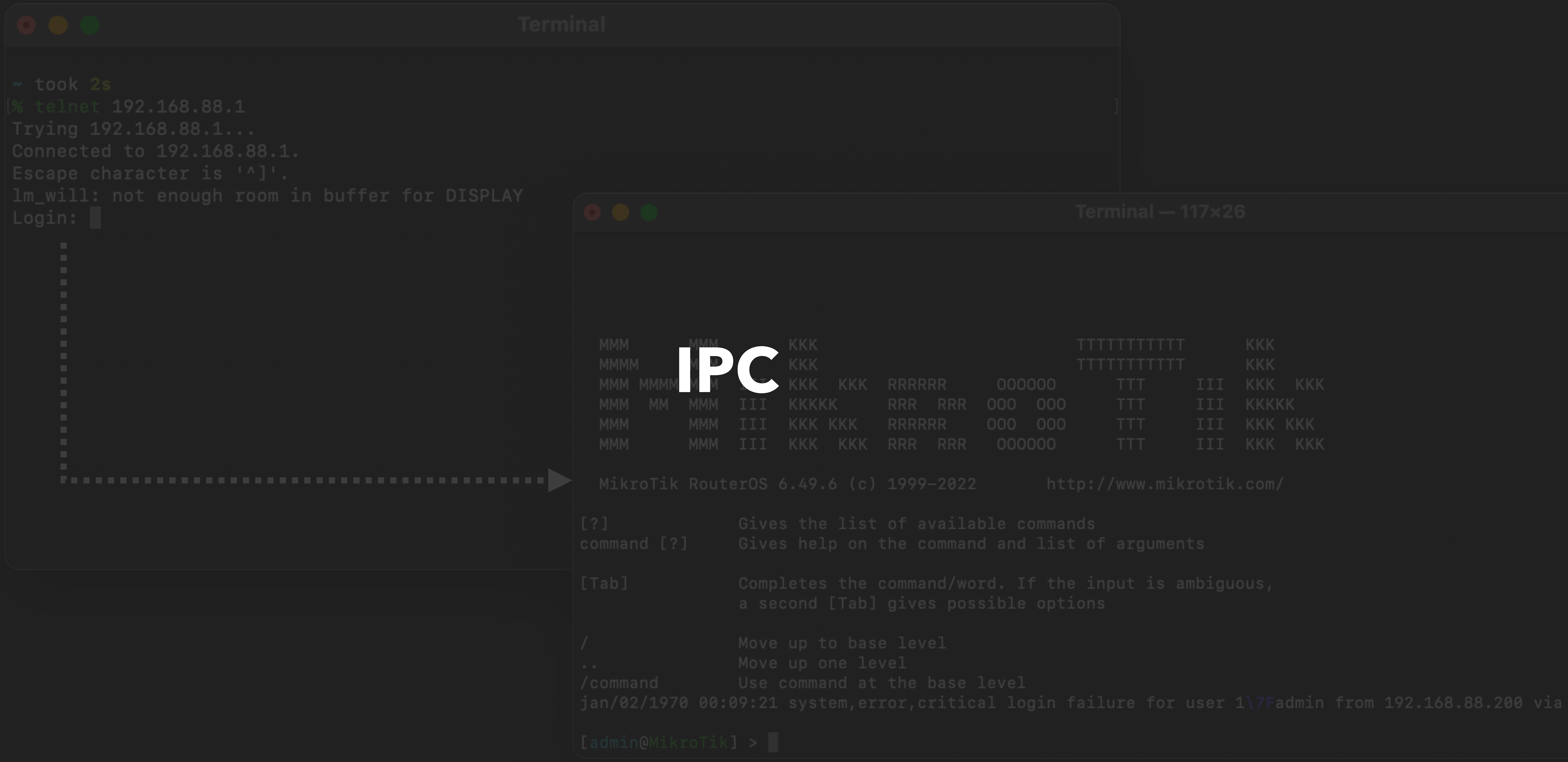
?????????

????????????????????????????????????

????????????????????

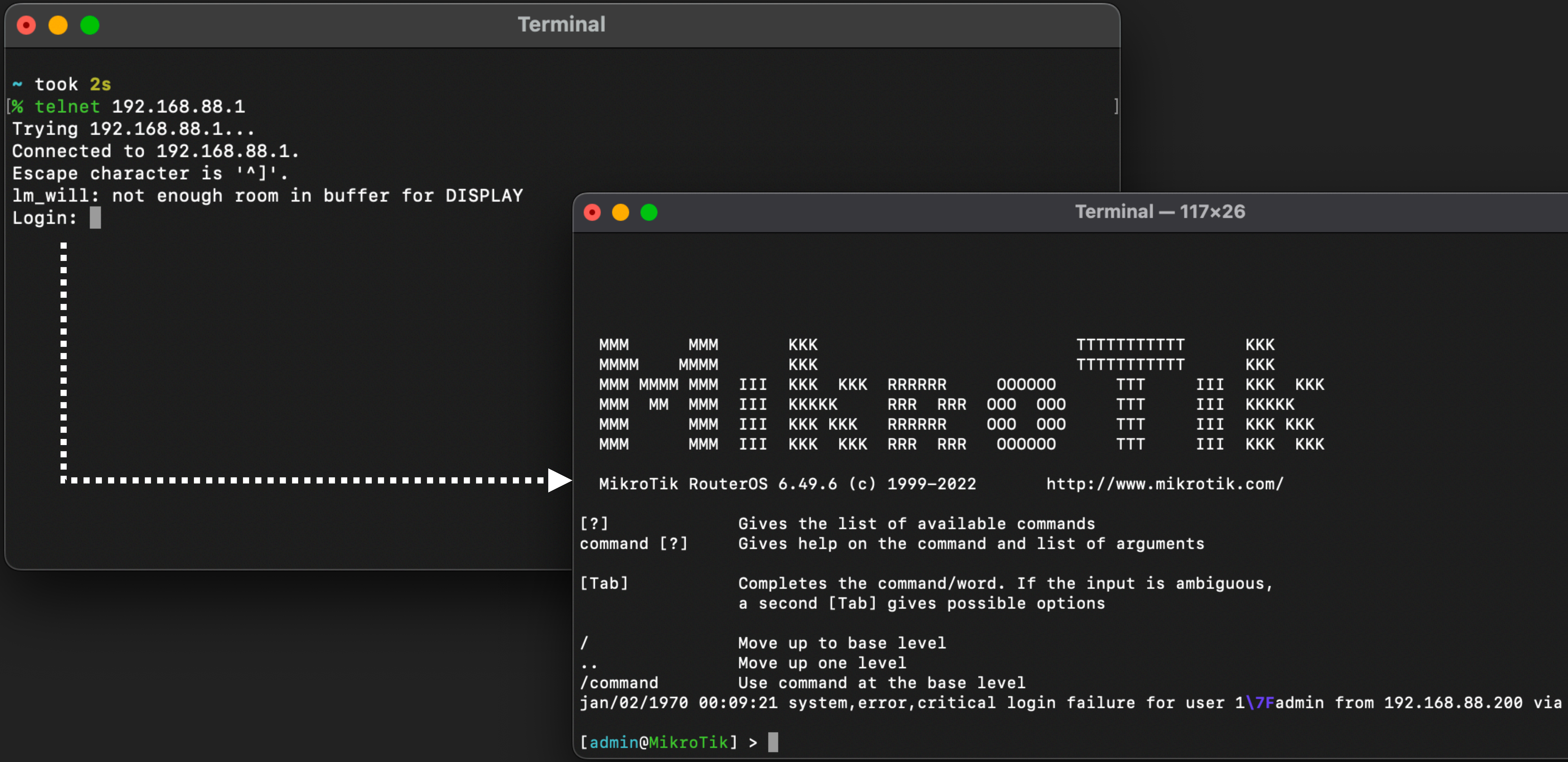
DEVCORE

IPC



```
~ took 2s
[% telnet 192.168.88.1
Trying 192.168.88.1...
Connected to 192.168.88.1.
Escape character is '^]'.
lm_will: not enough room in buffer for DISPLAY
Login: 
```

```
  MMM      MMM       KKK                          TTTTTTTTTTT      KKK
  MMMM    MMMM       KKK                          TTTTTTTTTTT      KKK
  MMM MMMM MMM  III  KKK  KKK  RRRRRR     OOOOOO      TTT     III  KKK  KKK
  MMM  MM  MMM  III  KKKKK     RRR  RRR  OOO  OOO     TTT     III  KKKKK
  MMM      MMM  III  KKK KKK   RRRRRR    OOO  OOO     TTT     III  KKK KKK
  MMM      MMM  III  KKK  KKK  RRR  RRR   OOOOOO      TTT     III  KKK  KKK

  MikroTik RouterOS 6.49.6 (c) 1999-2022       http://www.mikrotik.com/

[?]             Gives the list of available commands
command [?]     Gives help on the command and list of arguments

[Tab]           Completes the command/word. If the input is ambiguous,
                a second [Tab] gives possible options

/               Move up to base level
..              Move up one level
/command        Use command at the base level
jan/02/1970 00:09:21 system,error,critical login failure for user 1\7Fadmin from 192.168.88.200 via

[admin@MikroTik] > 
```



```
~ took 2s
[% telnet 192.168.88.1
Trying 192.168.88.1...
Connected to 192.168.88.1.
Escape character is '^]'.
lm_will: not enough room in buffer for DISPLAY
Login: 
```

```
  MMM      MMM       KKK                          TTTTTTTTTTT      KKK
  MMMM    MMMM       KKK                          TTTTTTTTTTT      KKK
  MMM MMMM MMM  III  KKK  KKK  RRRRRR     OOOOOO      TTT     III  KKK  KKK
  MMM  MM  MMM  III  KKKKK     RRR  RRR  OOO  OOO     TTT     III  KKKKK
  MMM      MMM  III  KKK KKK   RRRRRR    OOO  OOO     TTT     III  KKK KKK
  MMM      MMM  III  KKK  KKK  RRR  RRR   OOOOOO      TTT     III  KKK  KKK

  MikroTik RouterOS 6.49.6 (c) 1999-2022       http://www.mikrotik.com/

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[Tab]           Completes the command/word. If the input is ambiguous,
                a second [Tab] gives possible options

/               Move up to base level
..              Move up one level
/command        Use command at the base level
jan/02/1970 00:09:21 system,error,critical login failure for user 1\7Fadmin from 192.168.88.200 via

[admin@MikroTik] > 
```
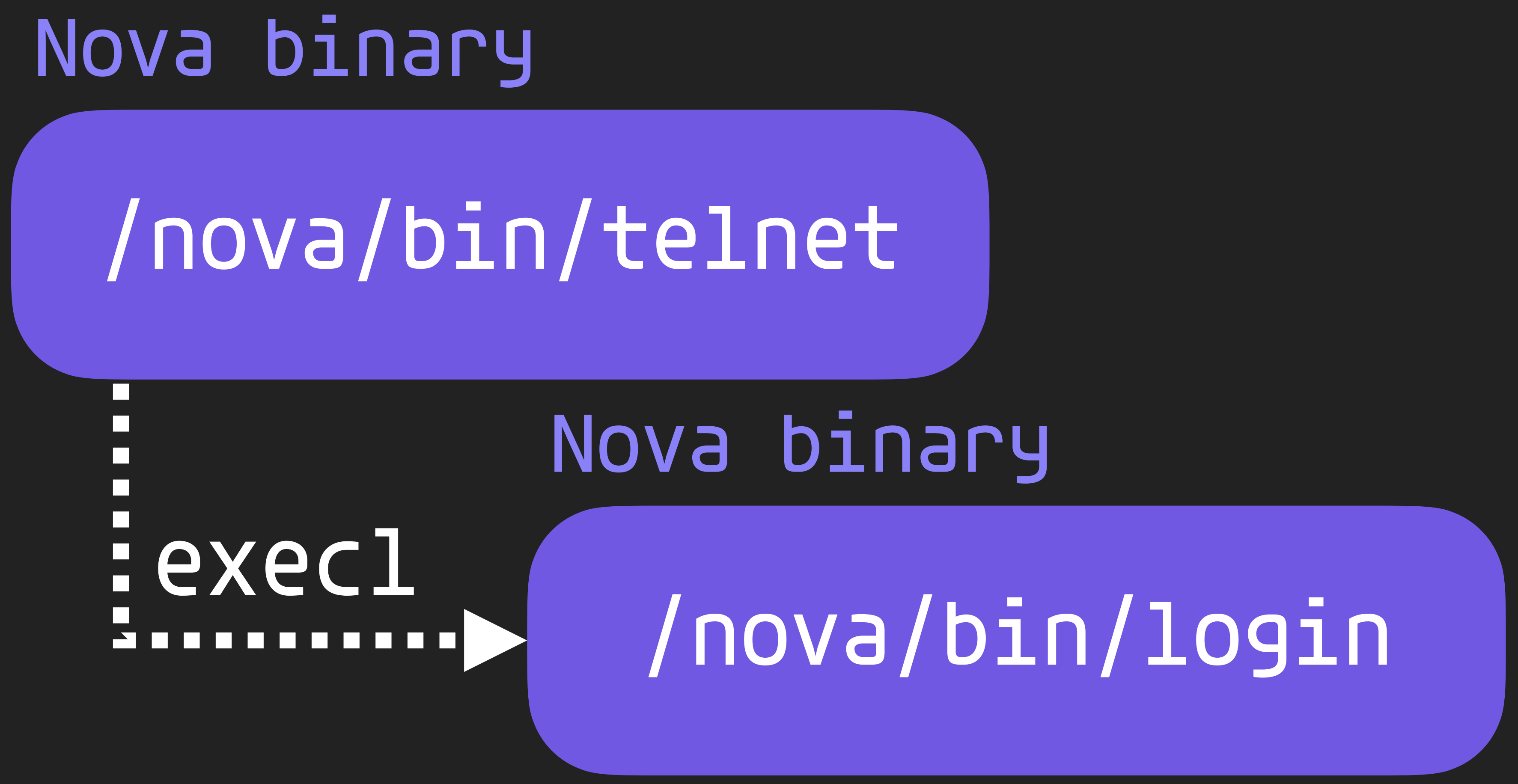
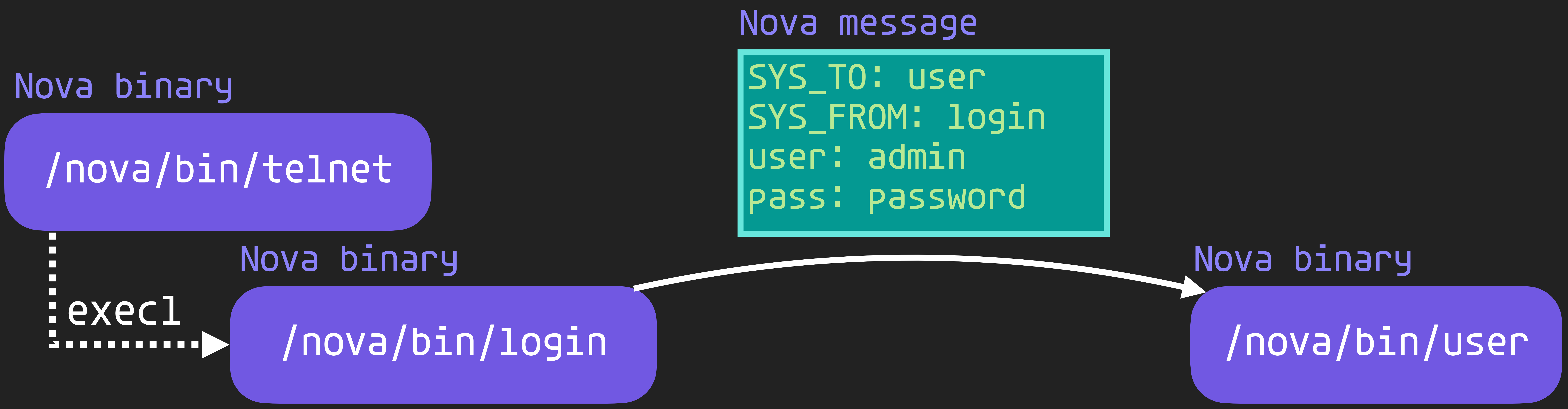

IPC


Nova binary
/nova/bin/telnet
execl
Nova binary
/nova/bin/login

IPC



Nova binary

/nova/bin/telnet

execl

Nova binary

/nova/bin/login

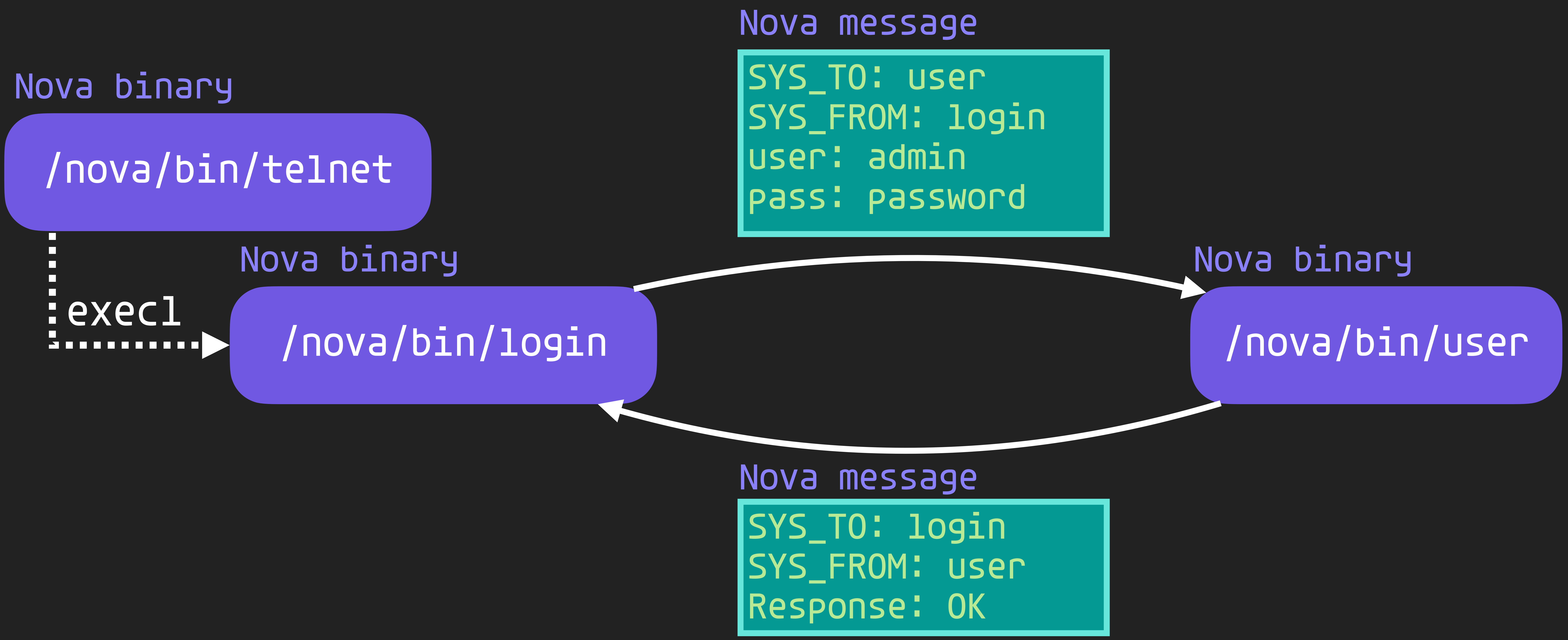
Nova message

```
SYS_TO: user
SYS_FROM: login
user: admin
pass: password
```

Nova binary

/nova/bin/user

IPC



Nova message

SYS_TO: user
SYS_FROM: login
user: admin
pass: password

Nova message

SYS_TO: login
SYS_FROM: user
Response: OK

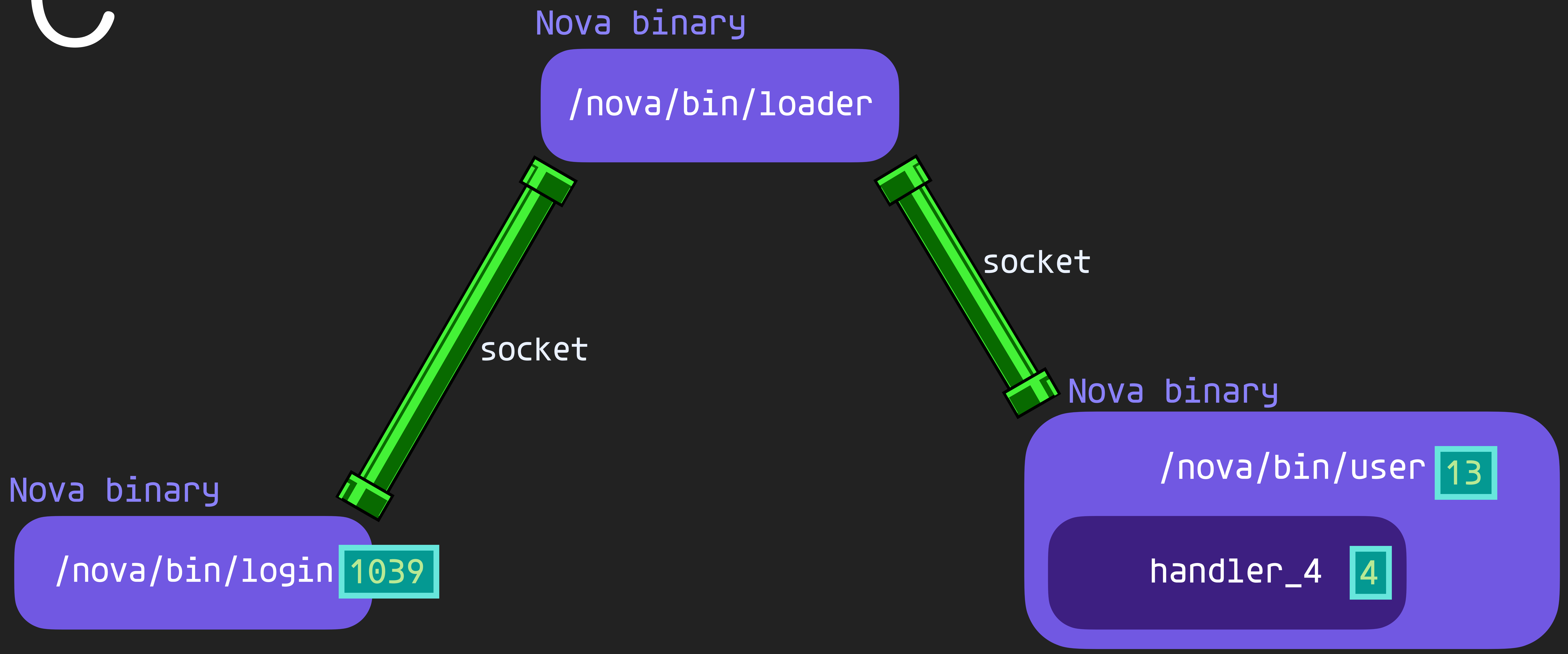
Nova Message

```
SYS_TO: user
SYS_FROM: login
user: admin
pass: password
```

=

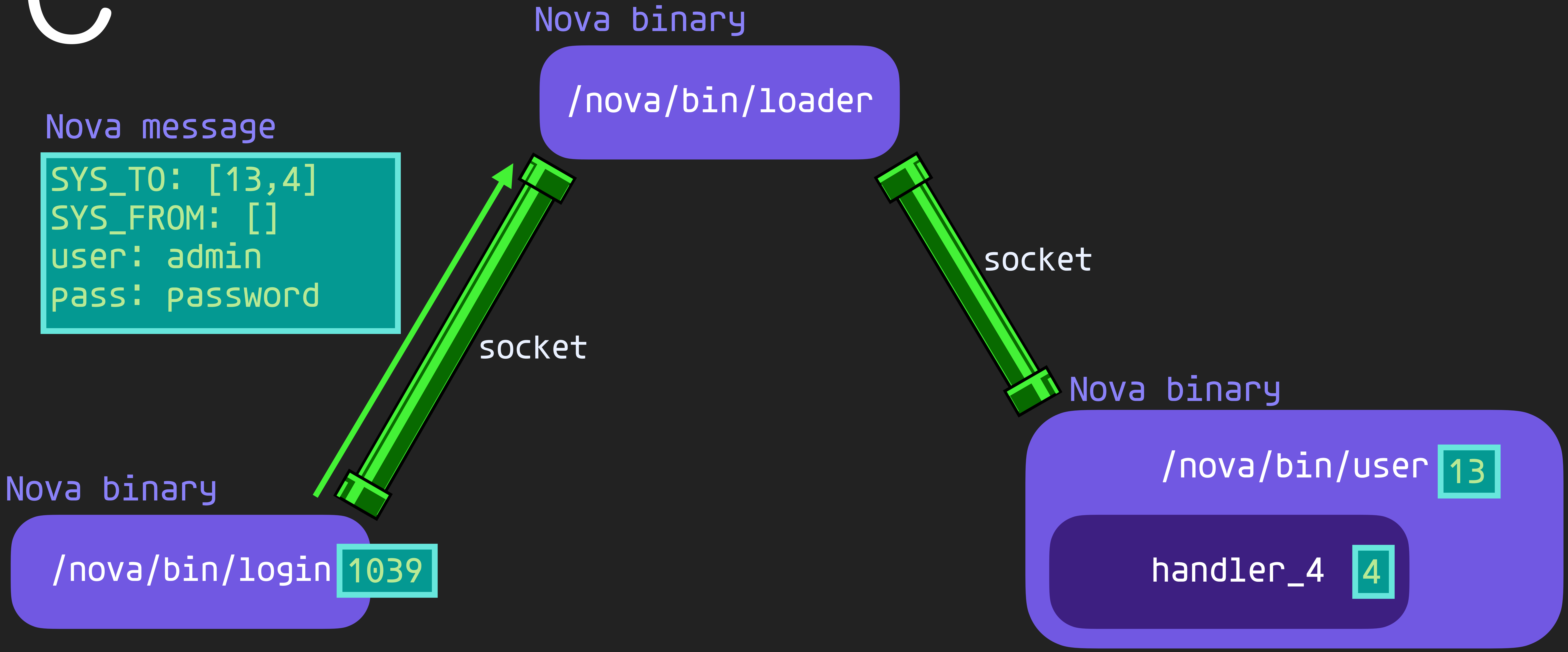
```
0xFF0001: [13,4]
0xFF0002: [1039]
1: admin
3: password
```

IPC


Nova binary
/nova/bin/loader
socket
socket
Nova binary
/nova/bin/user
13
handler_4
4
Nova binary
/nova/bin/login
1039

DEVCORE

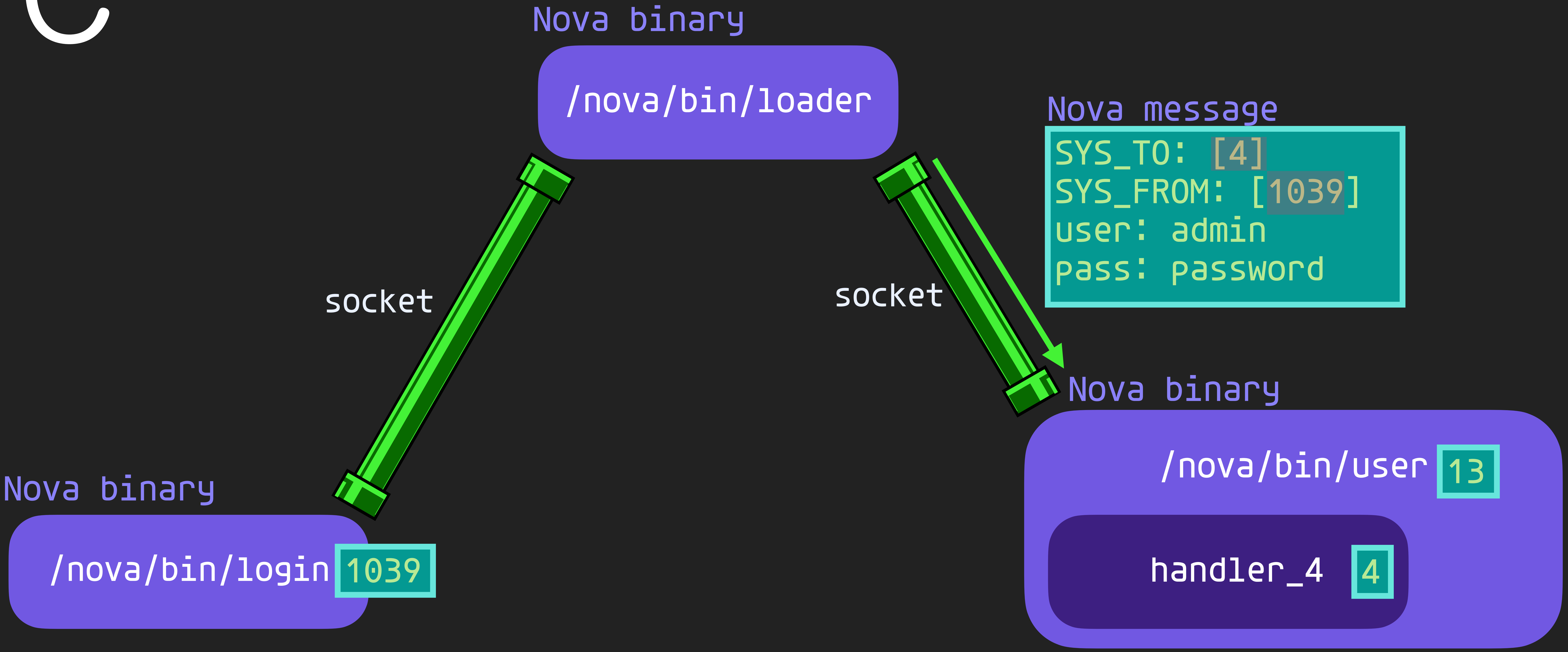
IPC


Nova message

```
SYS_TO: [13,4]
SYS_FROM: []
user: admin
pass: password
```

DEVCORE

IPC

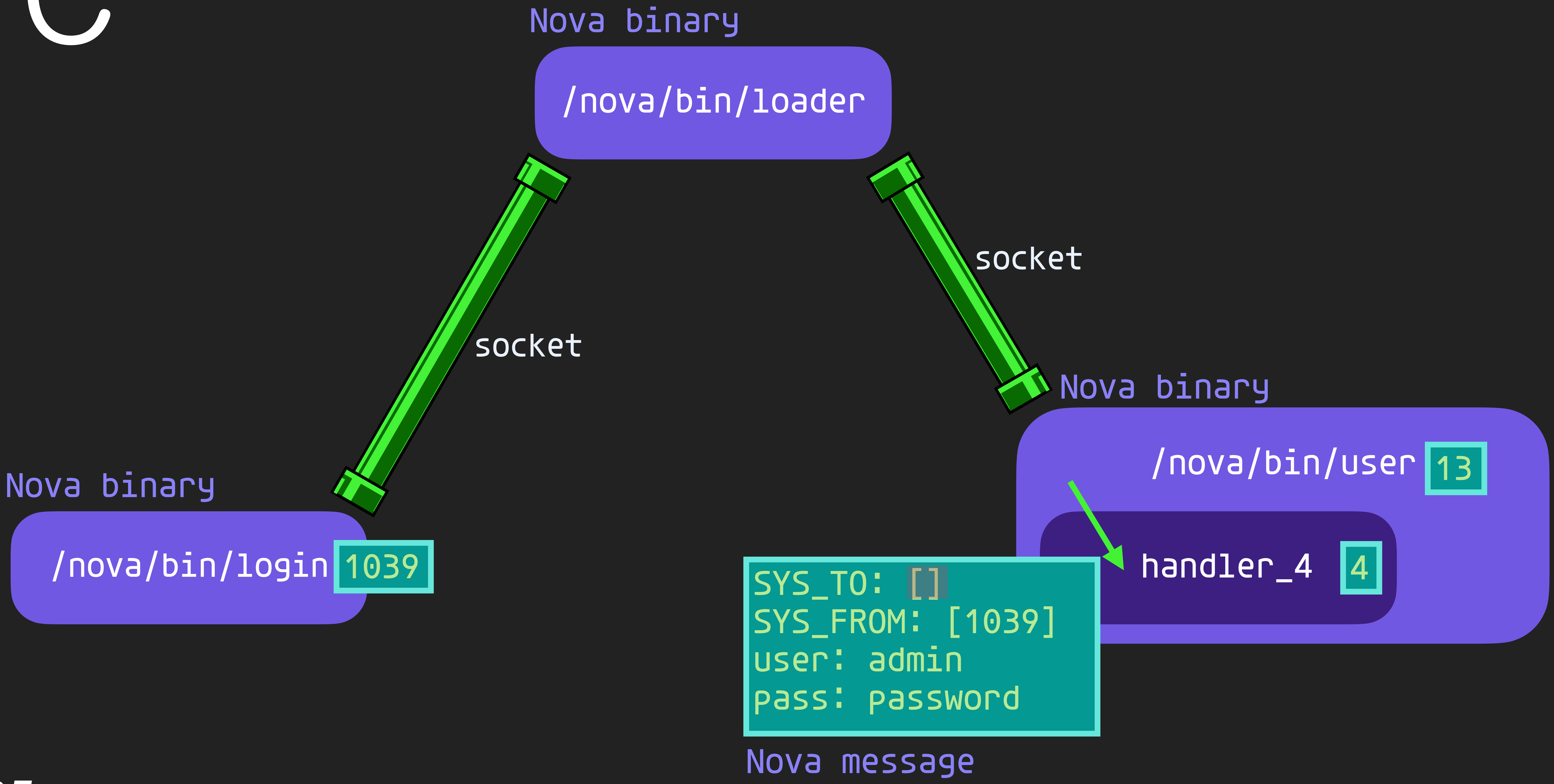


Nova message

```
SYS_TO: [4]
SYS_FROM: [1039]
user: admin
pass: password
```

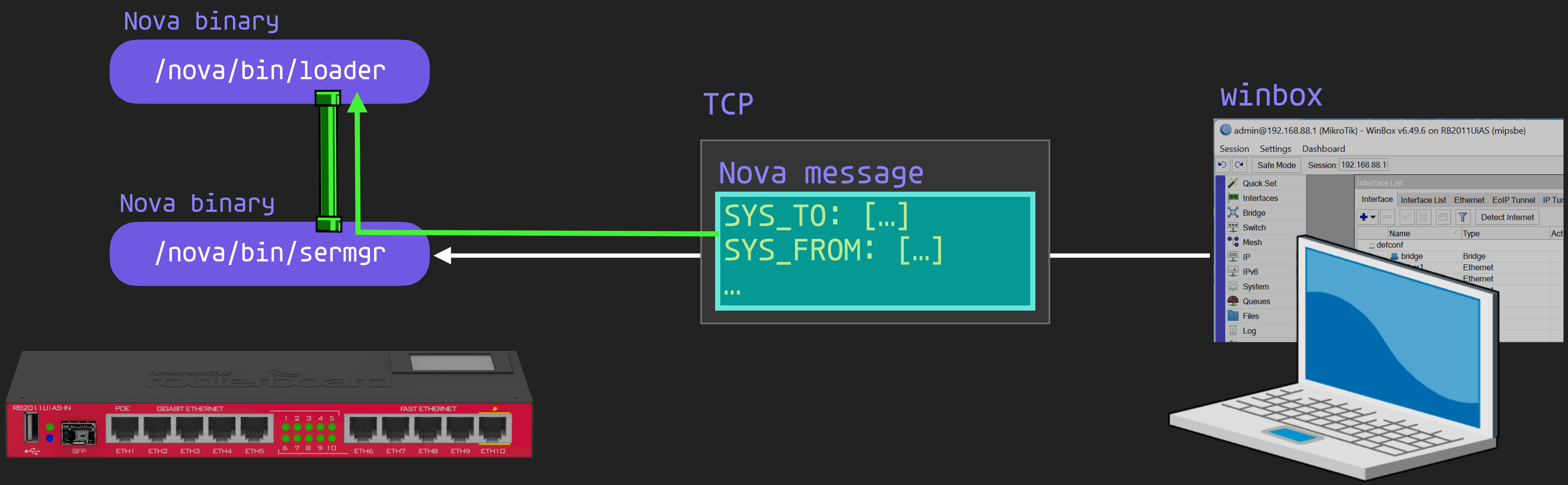
DEVCORE

IPC



```
SYS_TO: []
SYS_FROM: [1039]
user: admin
pass: password
```

IPC



Nova binary

/nova/bin/loader

Nova binary

/nova/bin/sermgr

TCP

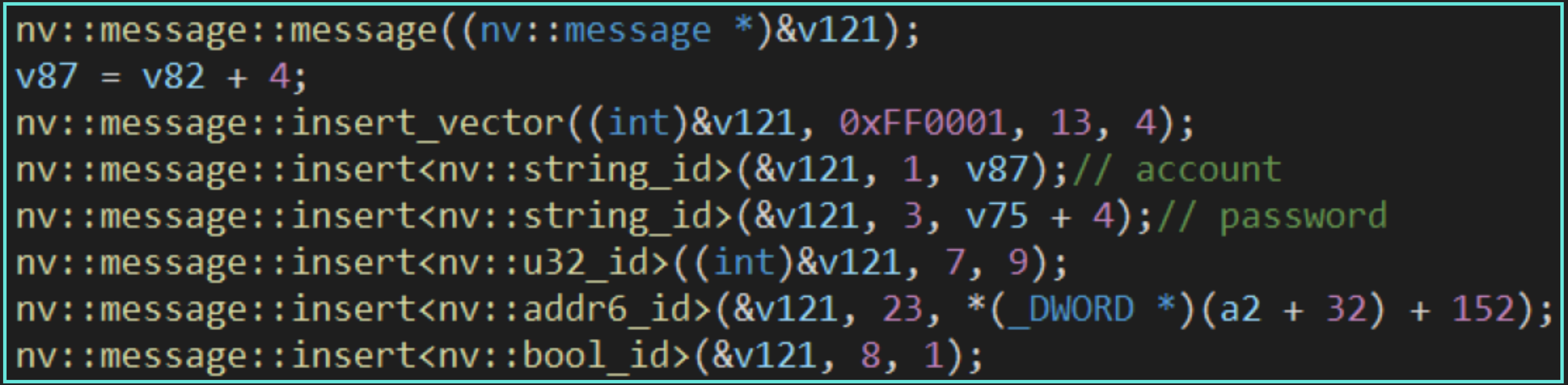
Nova message

SYS_TO: [...]
SYS_FROM: [...]
...

winbox

Nova Message

- The message used in IPC is constructed by `nv::message` and relative functions
- Nova message is typed key-value mapping and can contain u32, u64, bool, string, bytes, IP, and nova message.

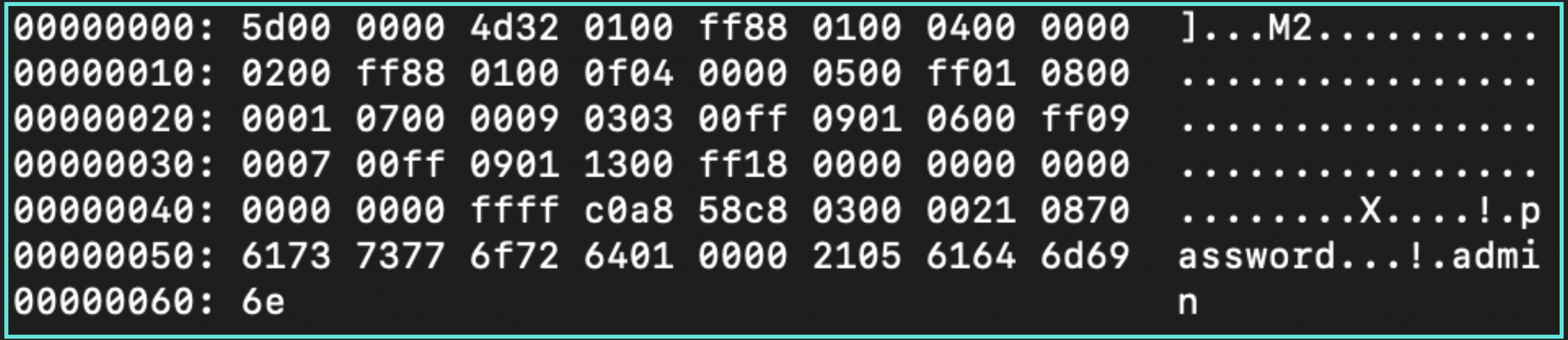


```
nv::message::message((nv::message *)&v121);
v87 = v82 + 4;
nv::message::insert_vector((int)&v121, 0xFF0001, 13, 4);
nv::message::insert<nv::string_id>(&v121, 1, v87);// account
nv::message::insert<nv::string_id>(&v121, 3, v75 + 4);// password
nv::message::insert<nv::u32_id>((int)&v121, 7, 9);
nv::message::insert<nv::addr6_id>(&v121, 23, *(_DWORD *)(a2 + 32) + 152);
nv::message::insert<nv::bool_id>(&v121, 8, 1);
```

Nova Message

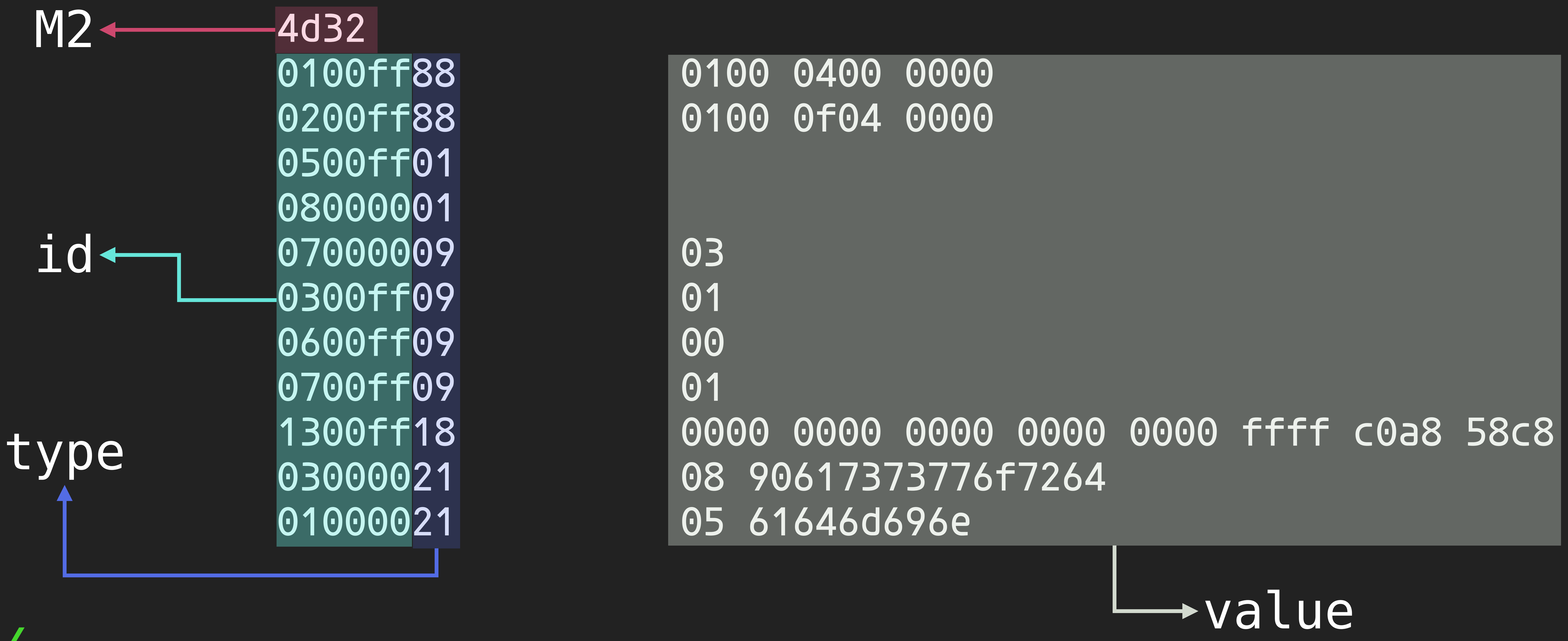
```
0xFF0001: [13,4]
0xFF0002: [1039]
1: admin
3: password
```

=



```
00000000: 5d00 0000 4d32 0100 ff88 0100 0400 0000  ]...M2..........
00000010: 0200 ff88 0100 0f04 0000 0500 ff01 0800  ................
00000020: 0001 0700 0009 0303 00ff 0901 0600 ff09  ................
00000030: 0007 00ff 0901 1300 ff18 0000 0000 0000  ................
00000040: 0000 0000 ffff c0a8 58c8 0300 0021 0870  ........X....!.p
00000050: 6173 7377 6f72 6401 0000 2105 6164 6d69  assword...!.admi
00000060: 6e                                       n
```

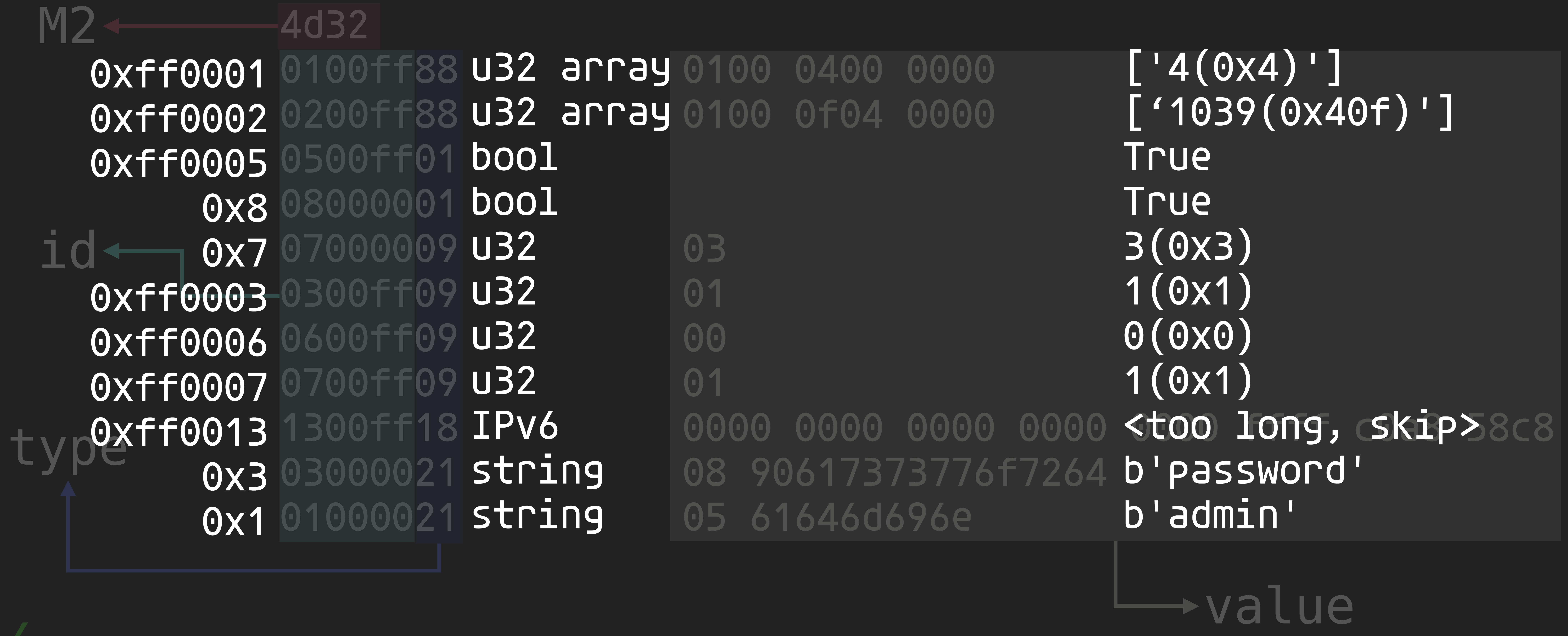
Nova Message



```
4d32
0100ff88  0100 0400 0000
0200ff88  0100 0f04 0000
0500ff01
08000001
07000009  03
0300ff09  01
0600ff09  00
0700ff09  01
1300ff18  0000 0000 0000 0000 0000 ffff c0a8 58c8
03000021  08 90617373776f7264
01000021  05 61646d696e
```

DEVCORE

Nova Message

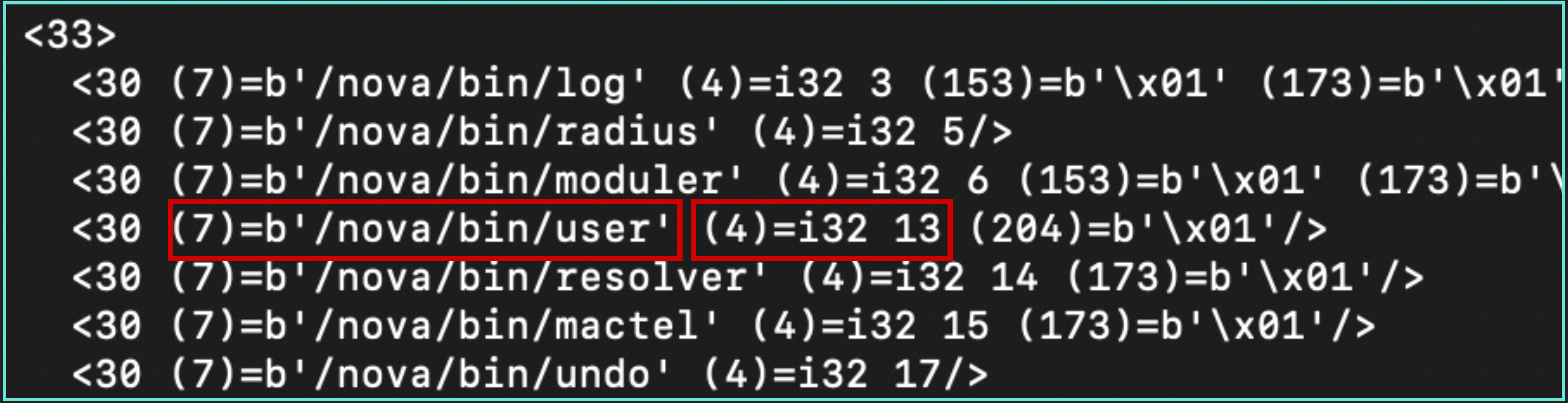


```
             4d32
0xff0001 0100ff88 u32 array 0100 0400 0000                  ['4(0x4)']
0xff0002 0200ff88 u32 array 0100 0f04 0000                  ['1039(0x40f)']
0xff0005 0500ff01 bool                                      True
     0x8 08000001 bool                                      True
     0x7 07000009 u32       03                              3(0x3)
0xff0003 0300ff09 u32       01                              1(0x1)
0xff0006 0600ff09 u32       00                              0(0x0)
0xff0007 0700ff09 u32       01                              1(0x1)
0xff0013 1300ff18 IPv6      0000 0000 0000 0000 <too long, skip>58c8
     0x3 03000021 string    08 9061737377 6f7264 b'password'
     0x1 01000021 string    05 61646d696e           b'admin'
```

DEVCORE

Nova Message

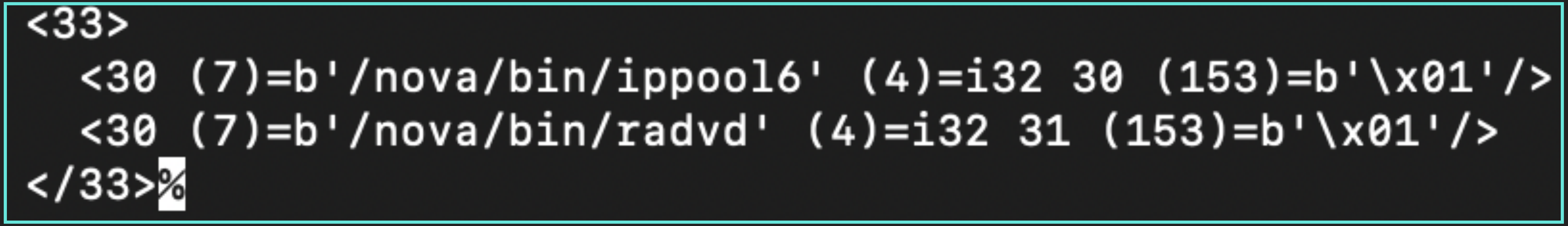
- To understand which binary corresponds to the id in the SYS_FROM or SYS_TO of the nova message, we need to parse the *.x3 file under the /nova/etc/loader/system.x3



```
<33>
  <30 (7)=b'/nova/bin/log' (4)=i32 3 (153)=b'\x01' (173)=b'\x01'
  <30 (7)=b'/nova/bin/radius' (4)=i32 5/>
  <30 (7)=b'/nova/bin/moduler' (4)=i32 6 (153)=b'\x01' (173)=b'\
  <30 (7)=b'/nova/bin/user' (4)=i32 13 (204)=b'\x01'/>
  <30 (7)=b'/nova/bin/resolver' (4)=i32 14 (173)=b'\x01'/>
  <30 (7)=b'/nova/bin/mactel' (4)=i32 15 (173)=b'\x01'/>
  <30 (7)=b'/nova/bin/undo' (4)=i32 17/>
```

Nova Message

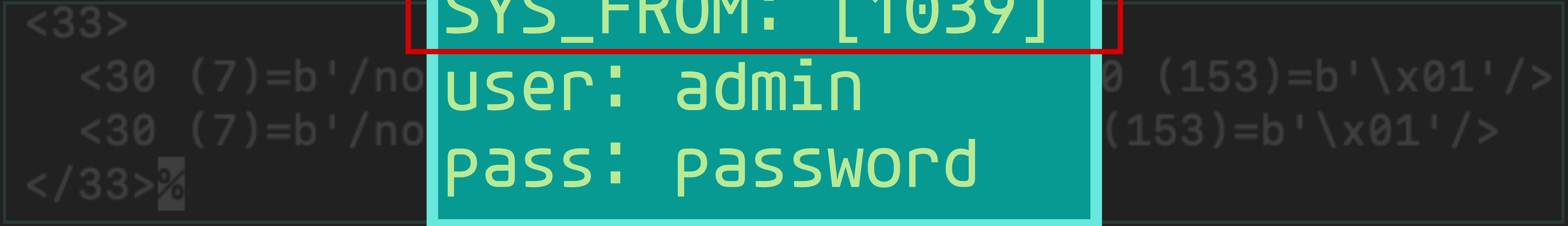
- If the binary was introduced by installing a package, its id is in the /ram/pckg/<package_name>/nova/etc/loader/<package_name>.x3



```
<33>
  <30 (7)=b'/nova/bin/ippool6' (4)=i32 30 (153)=b'\x01'/>
  <30 (7)=b'/nova/bin/radvd' (4)=i32 31 (153)=b'\x01'/>
</33>%
```

Nova Message

- If the binary was introduced by install a packet, it’s id is in the /ram/pckg/<package_name>/nova/etc/loader/<package_name>.x

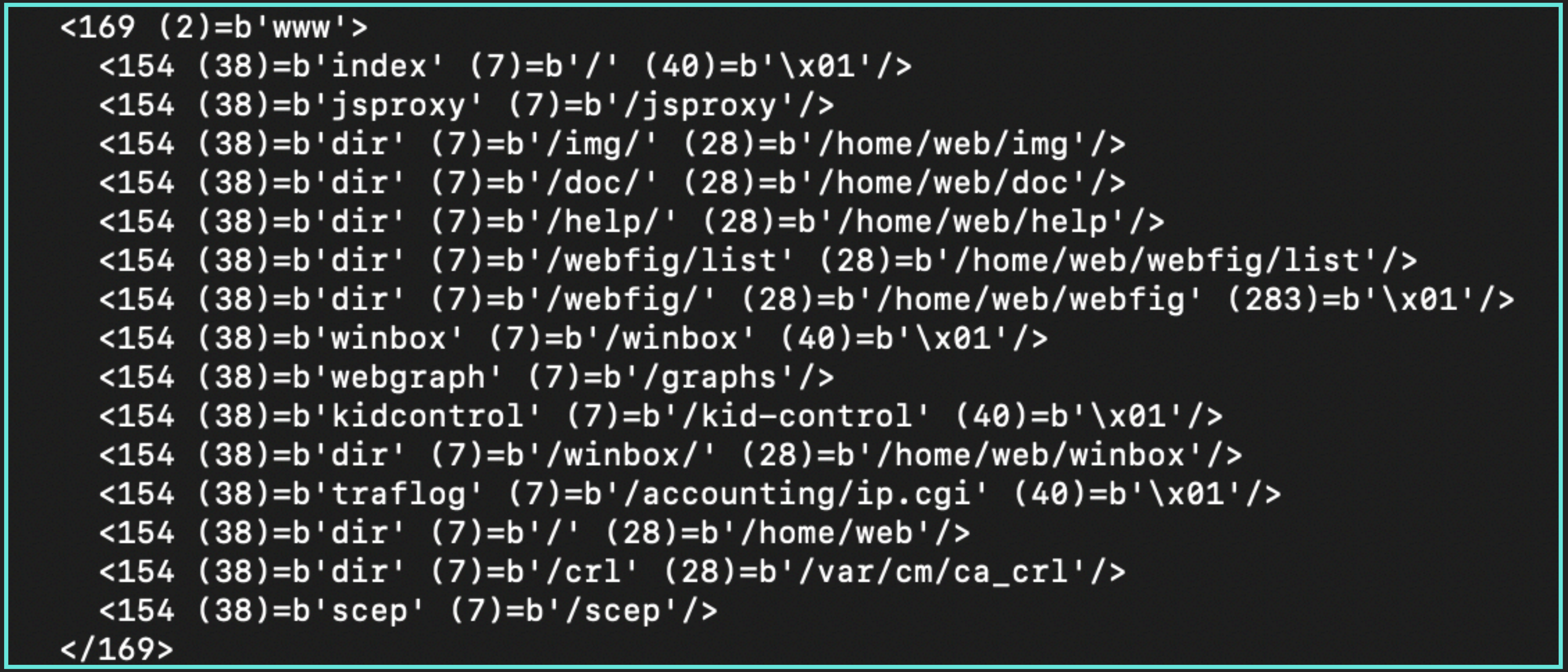


```
<33>
  <30 (7)=b'/no                                    0 (153)=b'\x01'/>
  <30 (7)=b'/no                                    (153)=b'\x01'/>
</33>%
```

```
SYS_TO: [13, 4]
SYS_FROM: [1039]
user: admin
pass: password
```

Nova Message

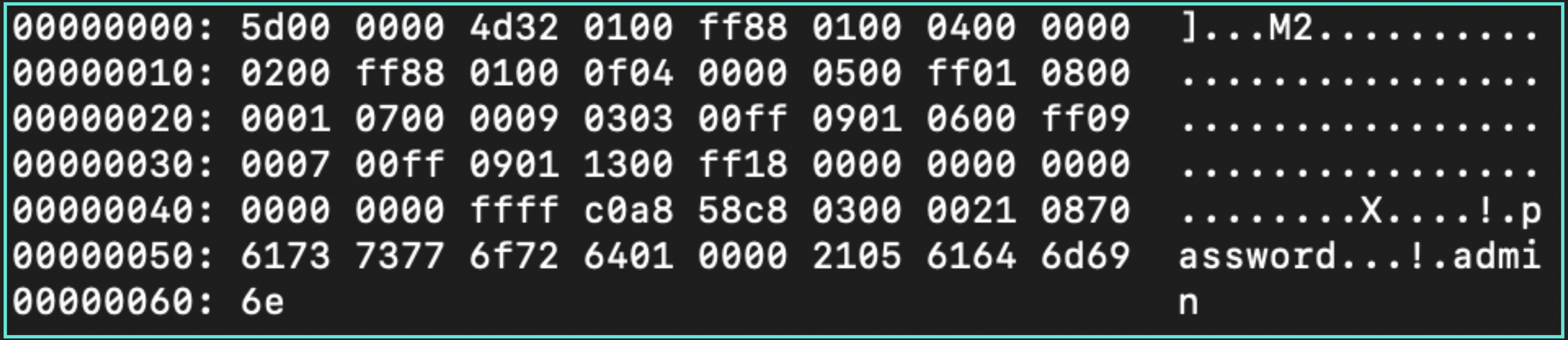
- Other binaries also have their .x3 files for different purposes.



```
<169 (2)=b'www'>
  <154 (38)=b'index' (7)=b'/' (40)=b'\x01'/>
  <154 (38)=b'jsproxy' (7)=b'/jsproxy'/>
  <154 (38)=b'dir' (7)=b'/img/' (28)=b'/home/web/img'/>
  <154 (38)=b'dir' (7)=b'/doc/' (28)=b'/home/web/doc'/>
  <154 (38)=b'dir' (7)=b'/help/' (28)=b'/home/web/help'/>
  <154 (38)=b'dir' (7)=b'/webfig/list' (28)=b'/home/web/webfig/list'/>
  <154 (38)=b'dir' (7)=b'/webfig/' (28)=b'/home/web/webfig' (283)=b'\x01'/>
  <154 (38)=b'winbox' (7)=b'/winbox' (40)=b'\x01'/>
  <154 (38)=b'webgraph' (7)=b'/graphs'/>
  <154 (38)=b'kidcontrol' (7)=b'/kid-control' (40)=b'\x01'/>
  <154 (38)=b'dir' (7)=b'/winbox/' (28)=b'/home/web/winbox'/>
  <154 (38)=b'traflog' (7)=b'/accounting/ip.cgi' (40)=b'\x01'/>
  <154 (38)=b'dir' (7)=b'/' (28)=b'/home/web'/>
  <154 (38)=b'dir' (7)=b'/crl' (28)=b'/var/cm/ca_crl'/>
  <154 (38)=b'scep' (7)=b'/scep'/>
</169>
```

Nova Message

- It seems like it’s a good target for fuzzing.
- But we can’t just fuzz it and expect we can get a pre-auth RCE after two months.



```
00000000: 5d00 0000 4d32 0100 ff88 0100 0400 0000  ]...M2..........
00000010: 0200 ff88 0100 0f04 0000 0500 ff01 0800  ................
00000020: 0001 0700 0009 0303 00ff 0901 0600 ff09  ................
00000030: 0007 00ff 0901 1300 ff18 0000 0000 0000  ................
00000040: 0000 0000 ffff c0a8 58c8 0300 0021 0870  ........X....!.p
00000050: 6173 7377 6f72 6401 0000 2105 6164 6d69  assword...!.admi
00000060: 6e                                       n
```

2022

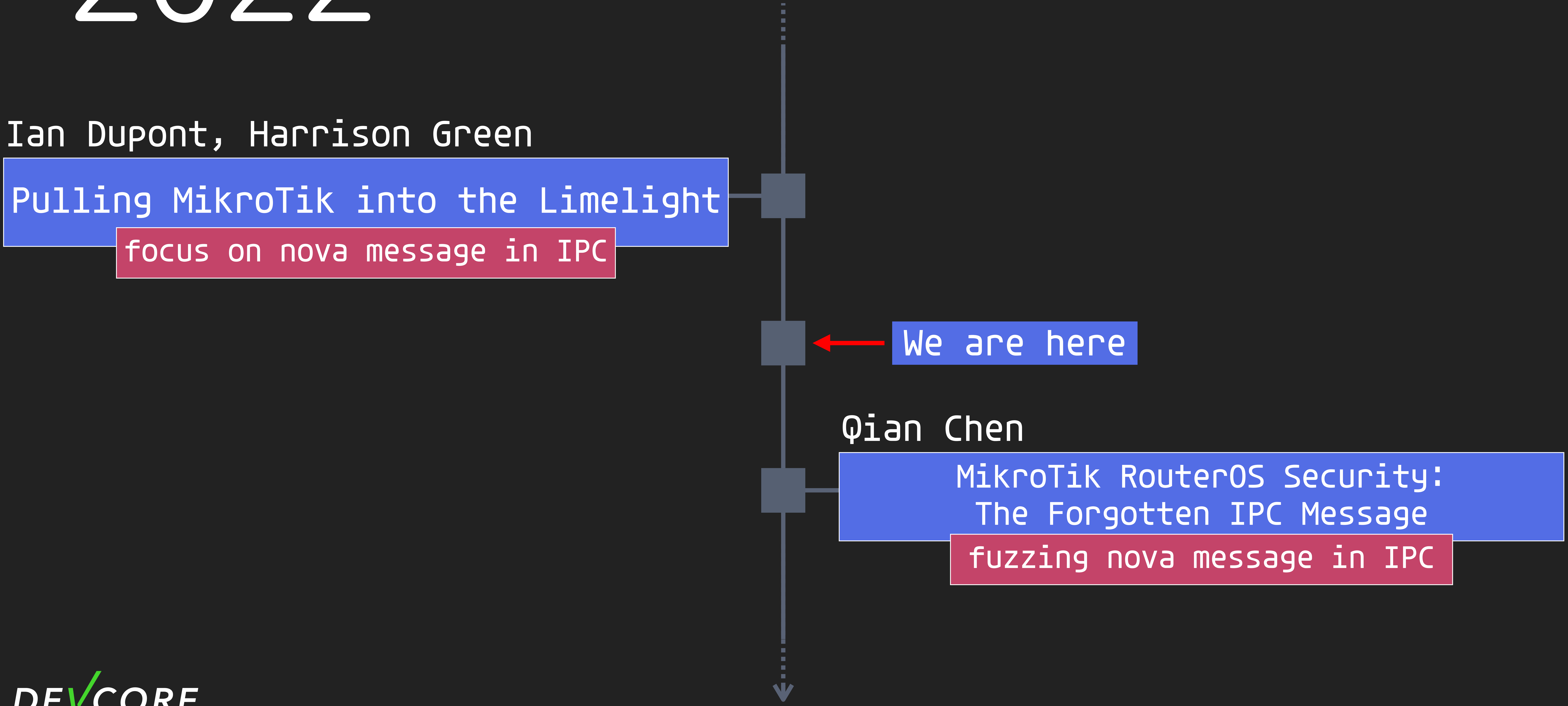
Ian Dupont, H

poiler!Spoiler!Spoiler!Spoil

er!Spoiler!Spoi

oiler!Spoiler!Spoiler!Spoiler

2022



Ian Dupont, Harrison Green

Pulling MikroTik into the Limelight

focus on nova message in IPC

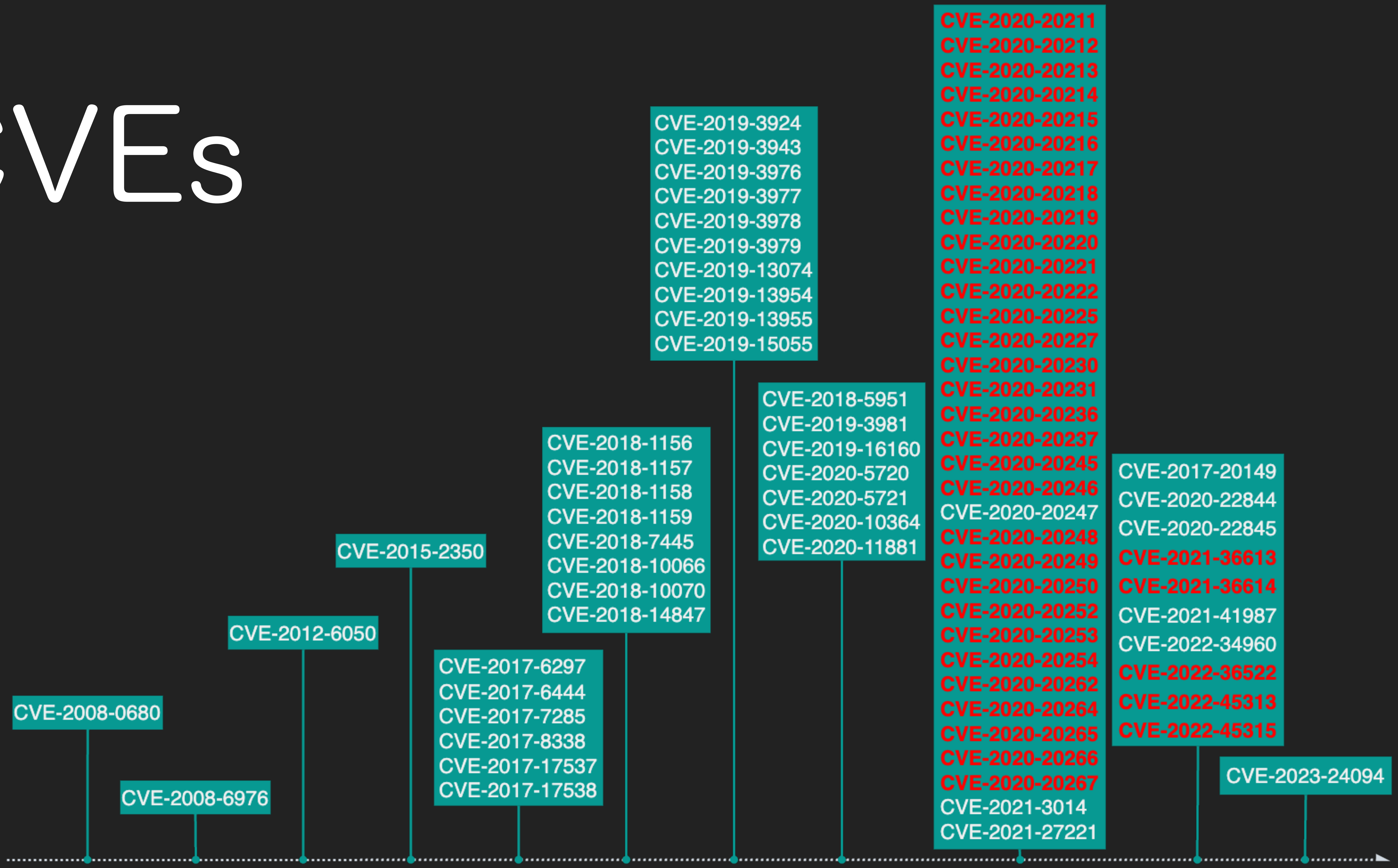
We are here

Qian Chen

MikroTik RouterOS Security: The Forgotten IPC Message

fuzzing nova message in IPC

CVEs



CVE-2008-0680

CVE-2008-6976

CVE-2012-6050

CVE-2015-2350

CVE-2017-6297
CVE-2017-6444
CVE-2017-7285
CVE-2017-8338
CVE-2017-17537
CVE-2017-17538

CVE-2018-1156
CVE-2018-1157
CVE-2018-1158
CVE-2018-1159
CVE-2018-7445
CVE-2018-10066
CVE-2018-10070
CVE-2018-14847

CVE-2019-3924
CVE-2019-3943
CVE-2019-3976
CVE-2019-3977
CVE-2019-3978
CVE-2019-3979
CVE-2019-13074
CVE-2019-13954
CVE-2019-13955
CVE-2019-15055

CVE-2018-5951
CVE-2019-3981
CVE-2019-16160
CVE-2020-5720
CVE-2020-5721
CVE-2020-10364
CVE-2020-11881

CVE-2020-20211
CVE-2020-20212
CVE-2020-20213
CVE-2020-20214
CVE-2020-20215
CVE-2020-20216
CVE-2020-20217
CVE-2020-20218
CVE-2020-20219
CVE-2020-20220
CVE-2020-20221
CVE-2020-20222
CVE-2020-20225
CVE-2020-20227
CVE-2020-20230
CVE-2020-20231
CVE-2020-20236
CVE-2020-20237
CVE-2020-20245
CVE-2020-20246
CVE-2020-20247
CVE-2020-20248
CVE-2020-20249
CVE-2020-20250
CVE-2020-20252
CVE-2020-20253
CVE-2020-20254
CVE-2020-20262
CVE-2020-20264
CVE-2020-20265
CVE-2020-20266
CVE-2020-20267
CVE-2021-3014
CVE-2021-27221

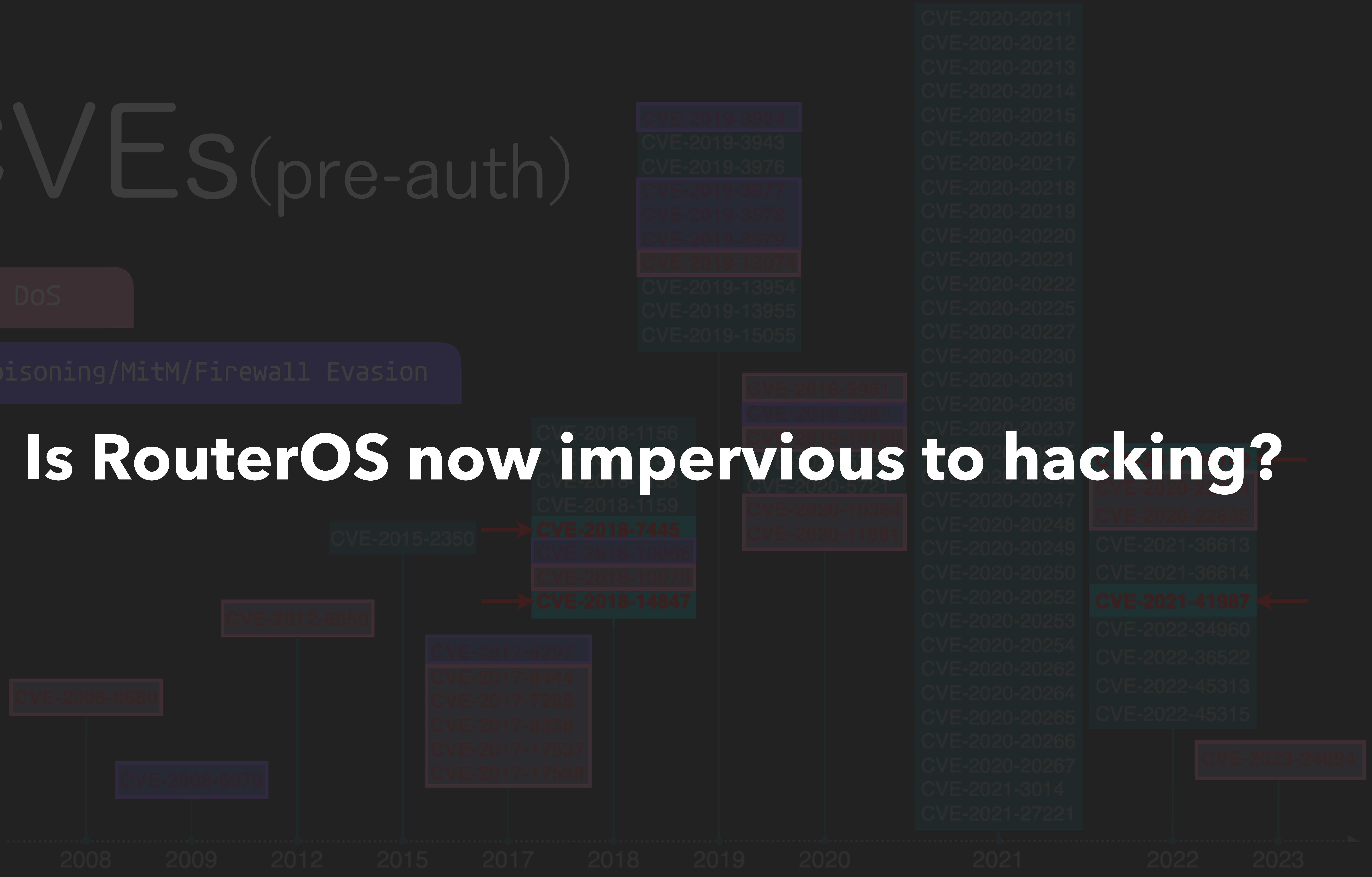
CVE-2017-20149
CVE-2020-22844
CVE-2020-22845
CVE-2021-36613
CVE-2021-36614
CVE-2021-41987
CVE-2022-34960
CVE-2022-36522
CVE-2022-45313
CVE-2022-45315

CVE-2023-24094

CVEs(pre-auth)

DoS

Poisoning/MitM/Firewall Evasion

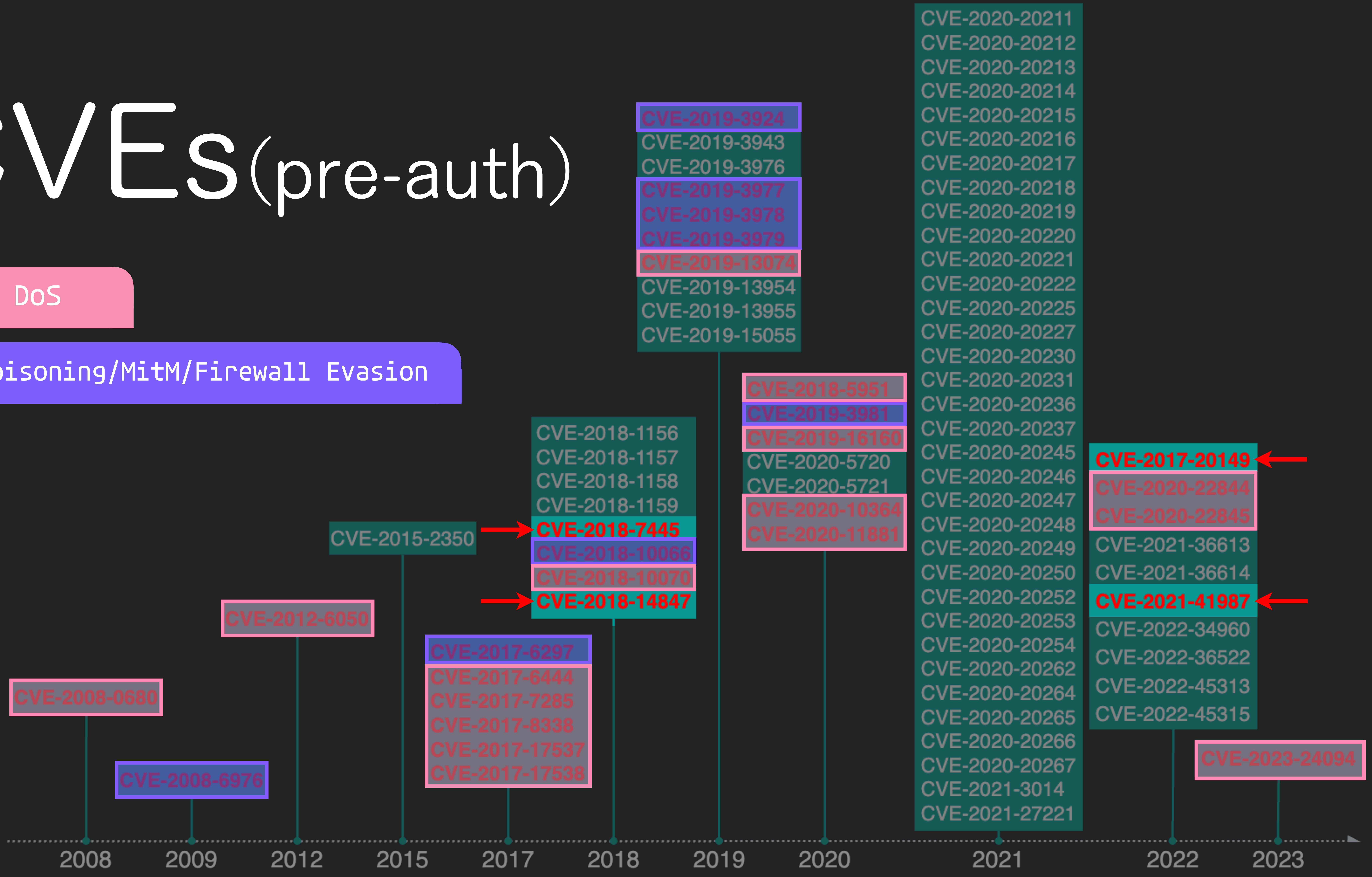


Is RouterOS now impervious to hacking?

CVEs(pre-auth)

DoS

Poisoning/MitM/Firewall Evasion



2008
CVE-2008-0680

2009
CVE-2008-6976

2012
CVE-2012-6050

2015
CVE-2015-2350

2017
CVE-2017-6297
CVE-2017-6444
CVE-2017-7285
CVE-2017-8338
CVE-2017-17537
CVE-2017-17538

2018
CVE-2018-1156
CVE-2018-1157
CVE-2018-1158
CVE-2018-1159
CVE-2018-7445
CVE-2018-10066
CVE-2018-10070
CVE-2018-14847

2019
CVE-2019-3924
CVE-2019-3943
CVE-2019-3976
CVE-2019-3977
CVE-2019-3978
CVE-2019-3979
CVE-2019-13074
CVE-2019-13954
CVE-2019-13955
CVE-2019-15055

2020
CVE-2018-5951
CVE-2019-3981
CVE-2019-16160
CVE-2020-5720
CVE-2020-5721
CVE-2020-10364
CVE-2020-11881

2021
CVE-2020-20211
CVE-2020-20212
CVE-2020-20213
CVE-2020-20214
CVE-2020-20215
CVE-2020-20216
CVE-2020-20217
CVE-2020-20218
CVE-2020-20219
CVE-2020-20220
CVE-2020-20221
CVE-2020-20222
CVE-2020-20225
CVE-2020-20227
CVE-2020-20230
CVE-2020-20231
CVE-2020-20236
CVE-2020-20237
CVE-2020-20245
CVE-2020-20246
CVE-2020-20247
CVE-2020-20248
CVE-2020-20249
CVE-2020-20250
CVE-2020-20252
CVE-2020-20253
CVE-2020-20254
CVE-2020-20262
CVE-2020-20264
CVE-2020-20265
CVE-2020-20266
CVE-2020-20267
CVE-2021-3014
CVE-2021-27221

2022
CVE-2017-20149
CVE-2020-22844
CVE-2020-22845
CVE-2021-36613
CVE-2021-36614
CVE-2021-41987
CVE-2022-34960
CVE-2022-36522
CVE-2022-45313
CVE-2022-45315

2023
CVE-2023-24094

Observation

- Most researches are about
    - Jailbreaking
    - Analyzing the ITW exploits
    - Nova message in IPC

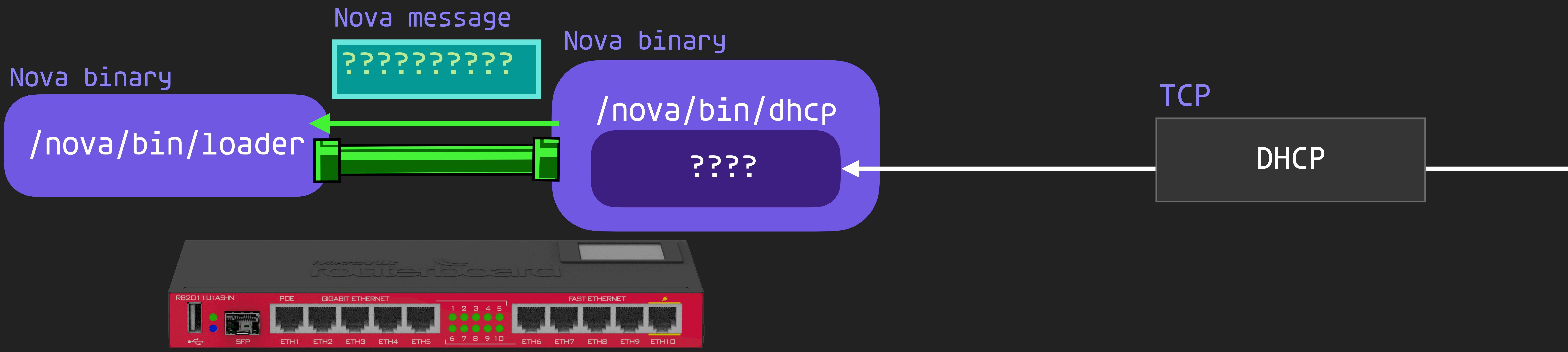
Brief Summary

No one with sanity
would like to dive into the details of Nova Binary

Where to start ?

Where to start ?

- Where are the entry points to the customize IPC ?

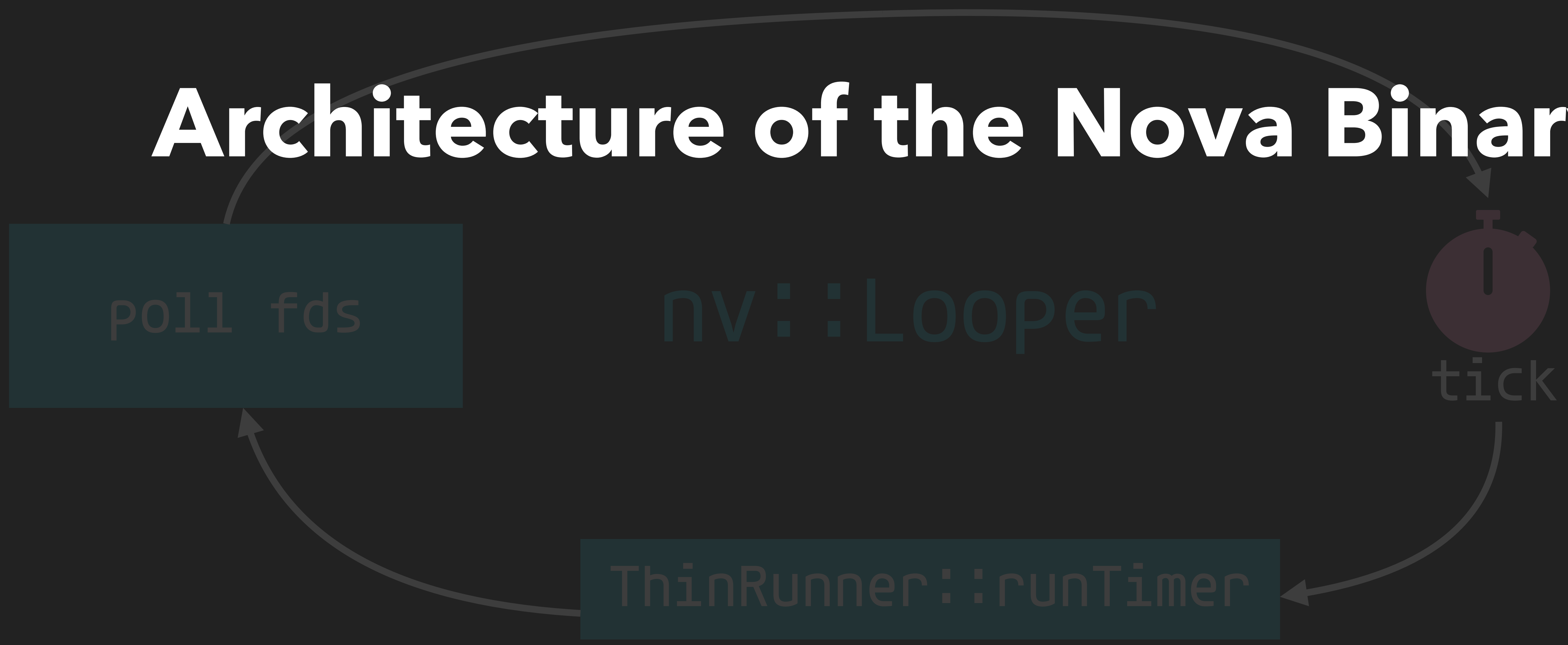


DEVCORE

Nova Binary

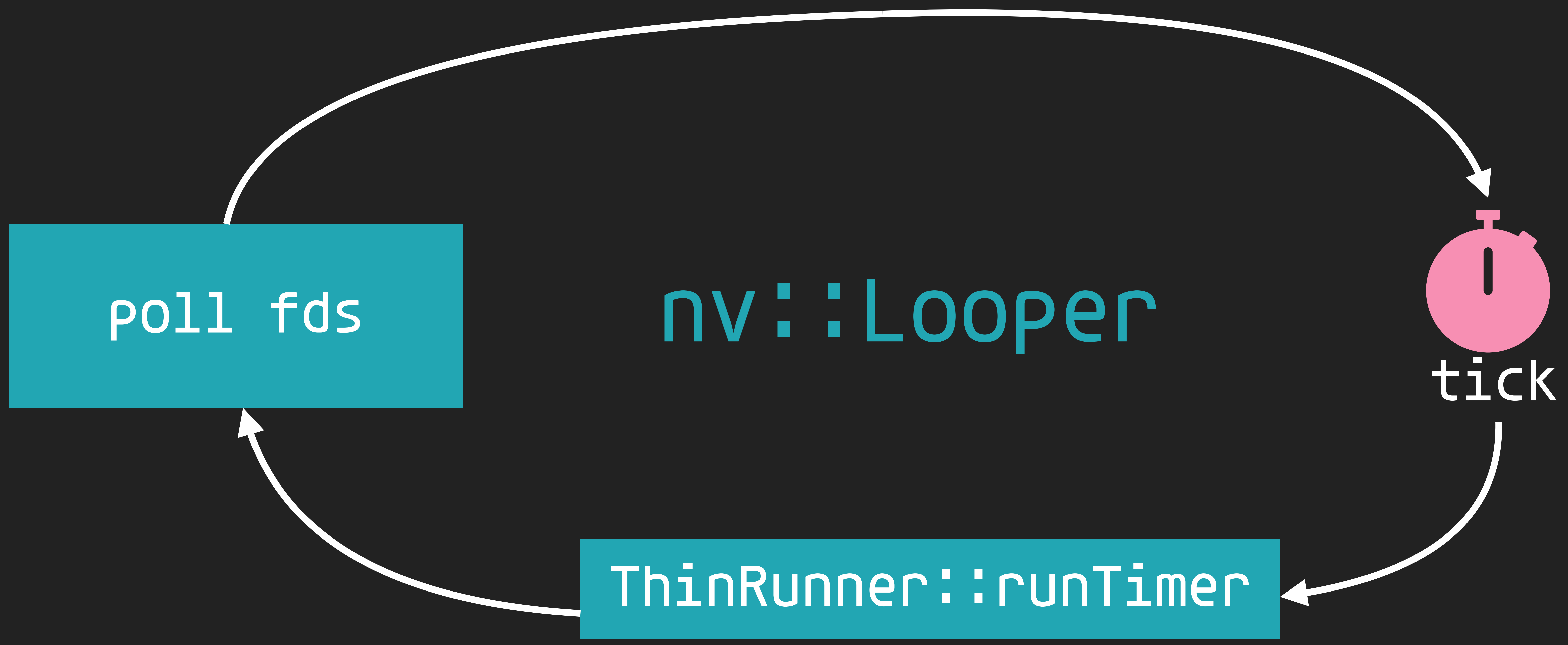
- Every Nova binary has a Looper or MultifiberLooper.

Architecture of the Nova Binary



Nova Binary

- Every Nova binary has a Looper or a MultifiberLooper.



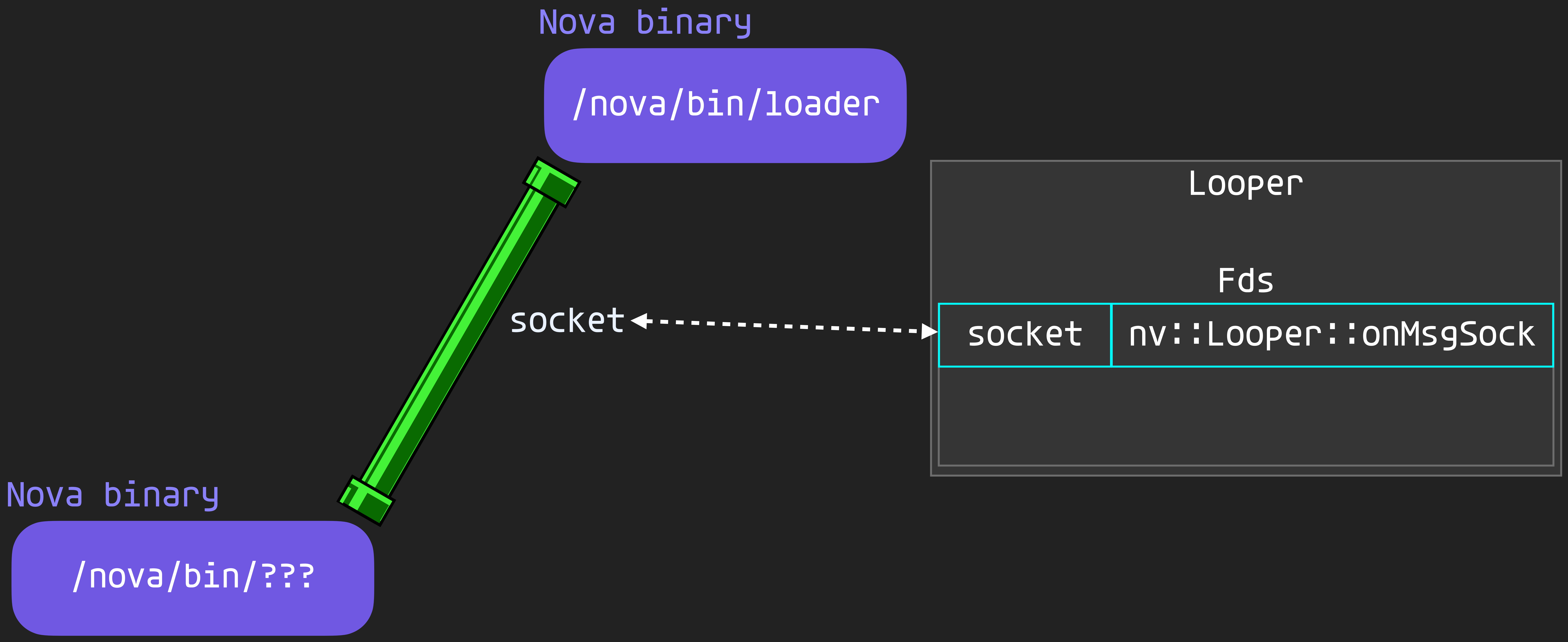
poll fds

nv::Looper

tick

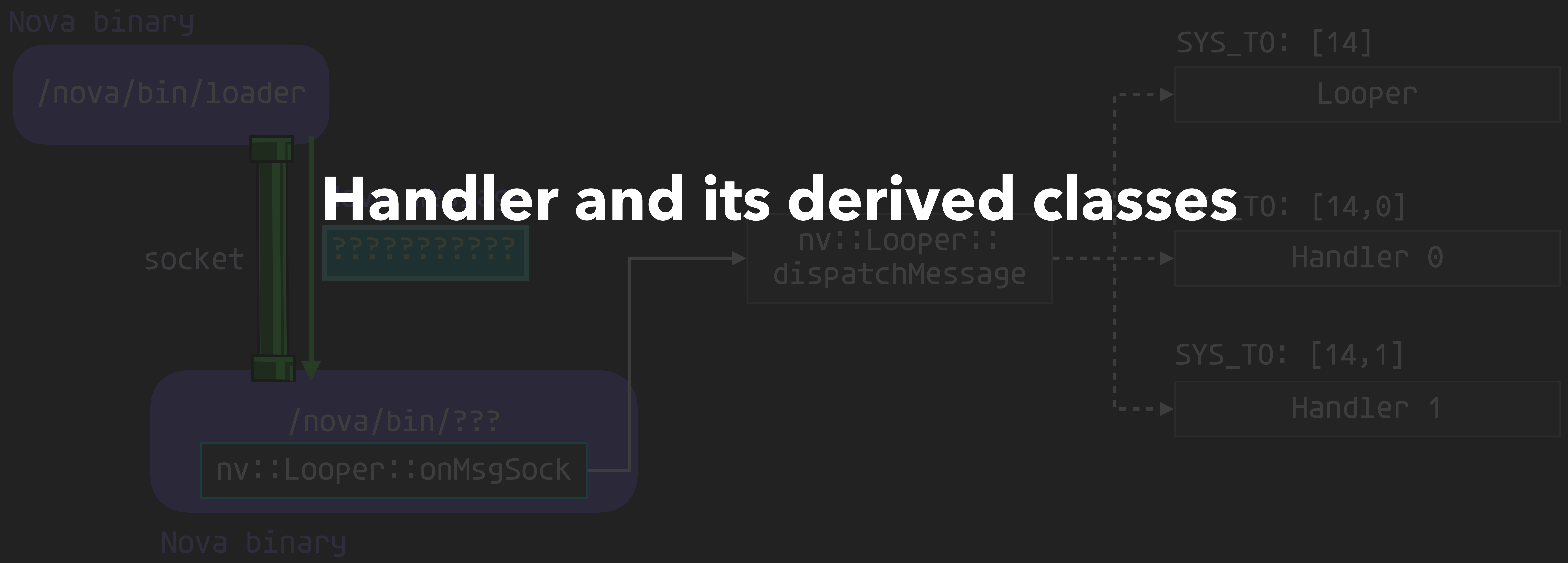
ThinRunner::runTimer

Nova Binary



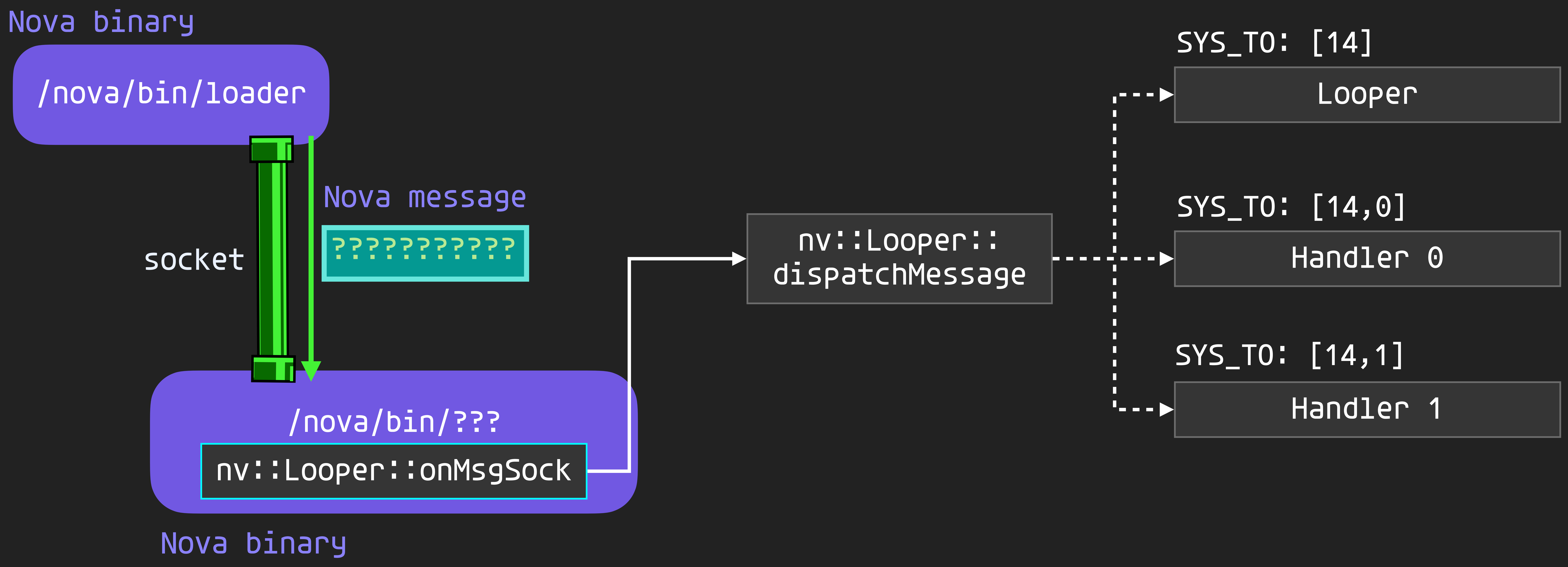
DEVCORE

Nova Binary



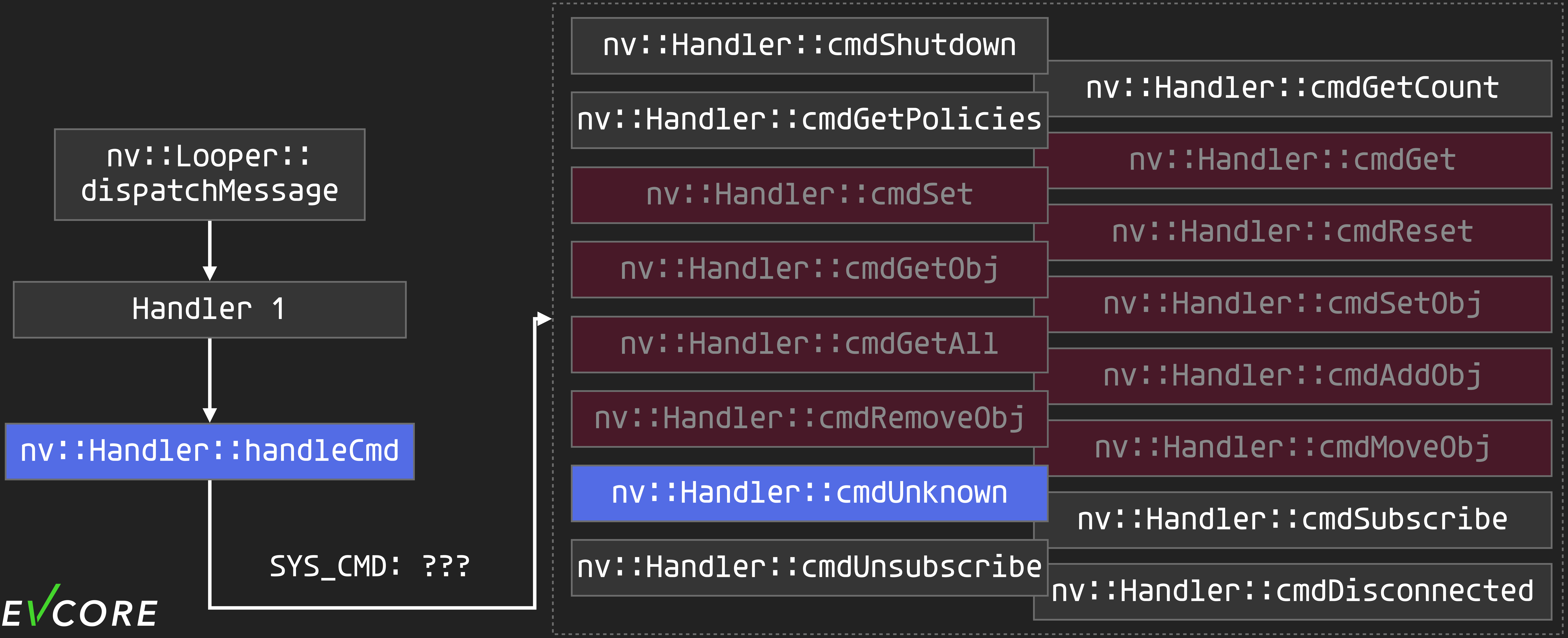
Handler and its derived classes

Nova Binary



DEVCORE

Nova Binary



nv::Looper::dispatchMessage

Handler 1

nv::Handler::handleCmd

SYS_CMD: ???

nv::Handler::cmdShutdown

nv::Handler::cmdGetCount

nv::Handler::cmdGetPolicies

nv::Handler::cmdGet

nv::Handler::cmdSet

nv::Handler::cmdReset

nv::Handler::cmdGetObj

nv::Handler::cmdSetObj

nv::Handler::cmdGetAll

nv::Handler::cmdAddObj

nv::Handler::cmdRemoveObj

nv::Handler::cmdMoveObj

nv::Handler::cmdUnknown

nv::Handler::cmdSubscribe

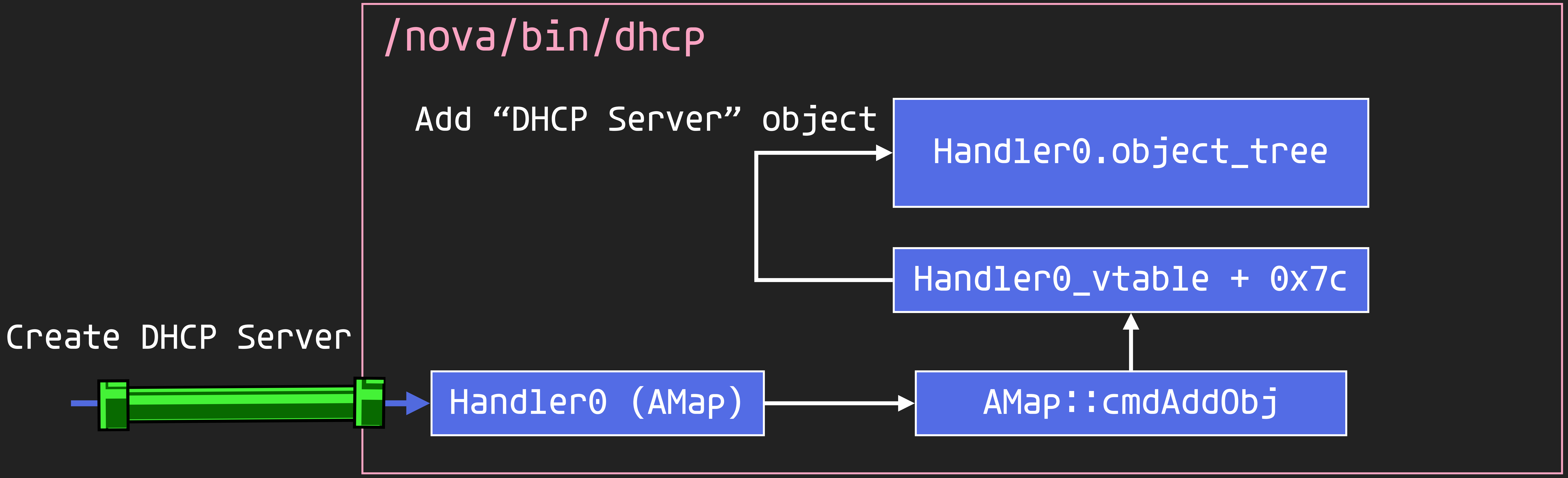
nv::Handler::cmdUnsubscribe

nv::Handler::cmdDisconnected

DEVCORE

Nova Binary

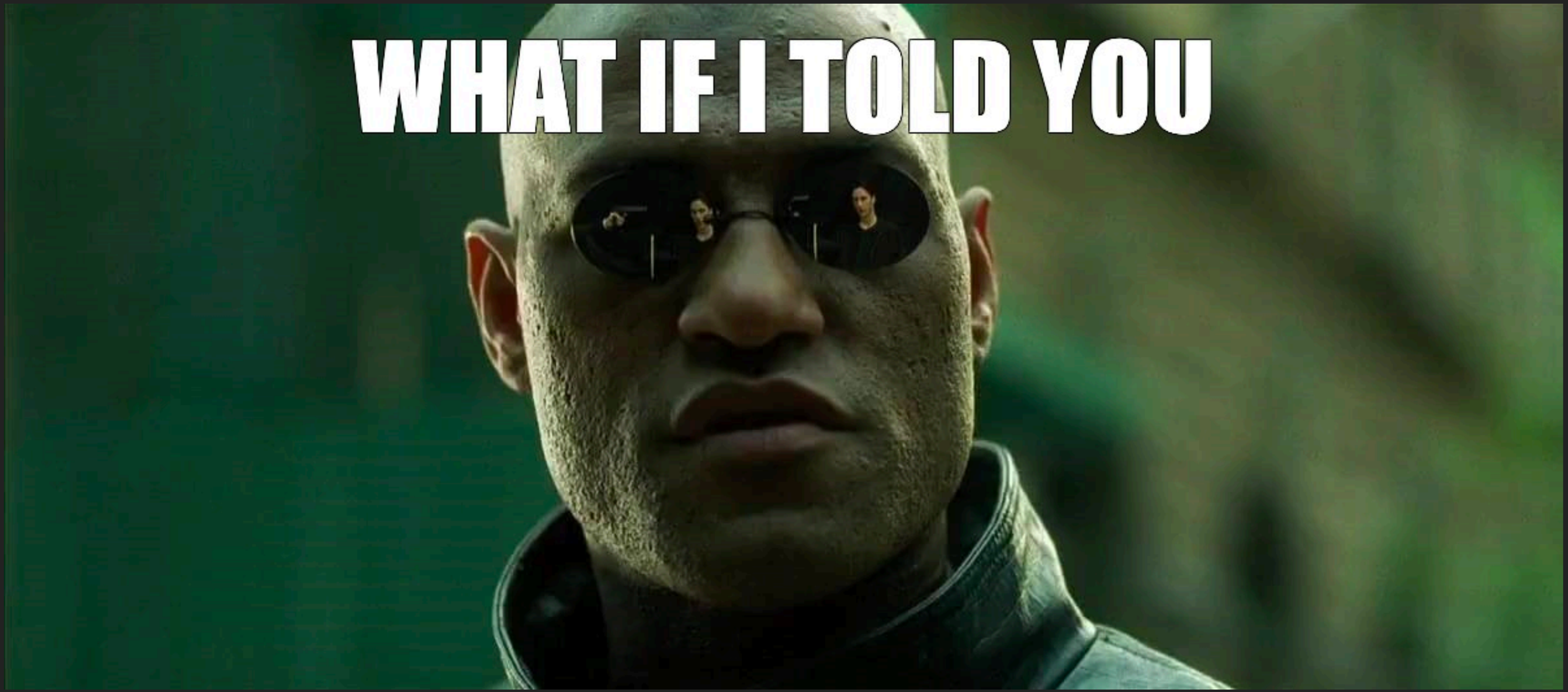
- Base class: Handler
- Derived classes: AMap, AHolder, ASecMap, AOmap, etc



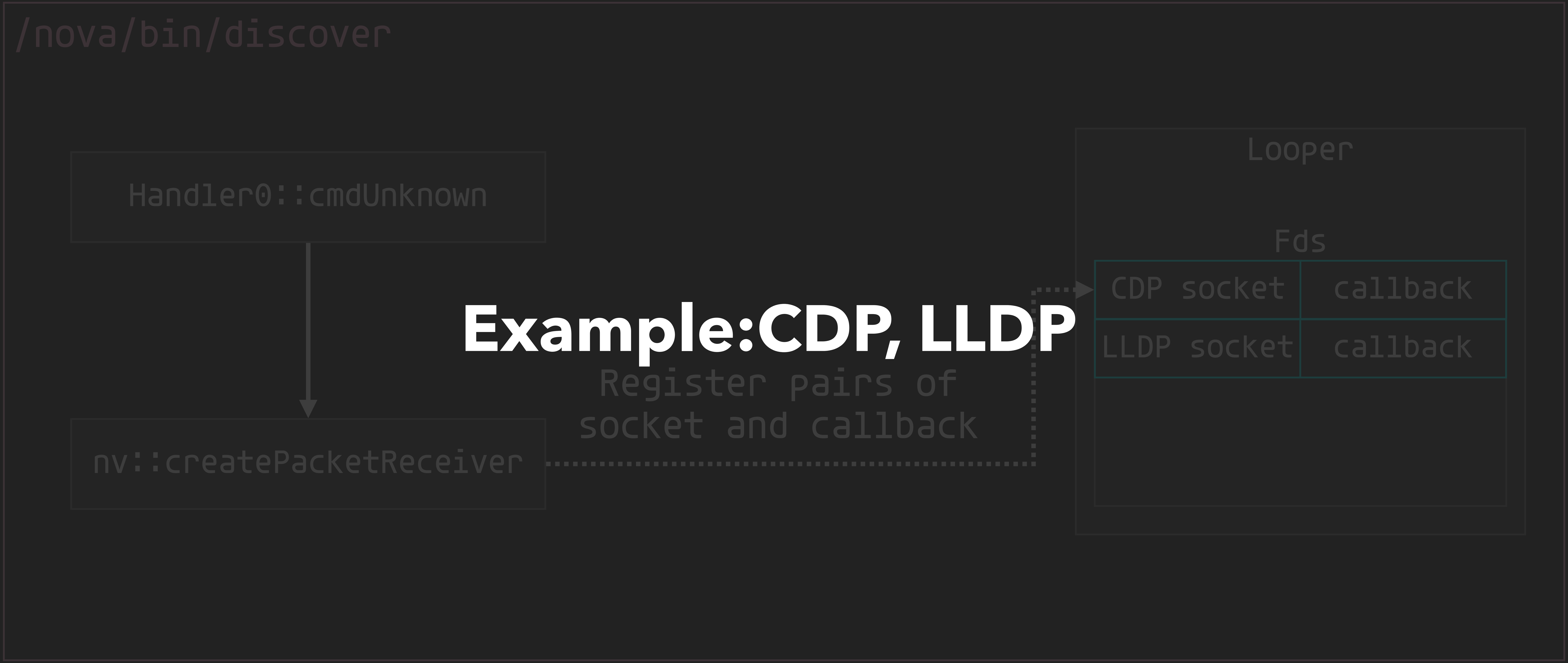
DEVCORE

Nova Message

- Some functionalities don’t even use the Nova message.



Example:CDP, LLDP



/nova/bin/discover

Handler0::cmdUnknown

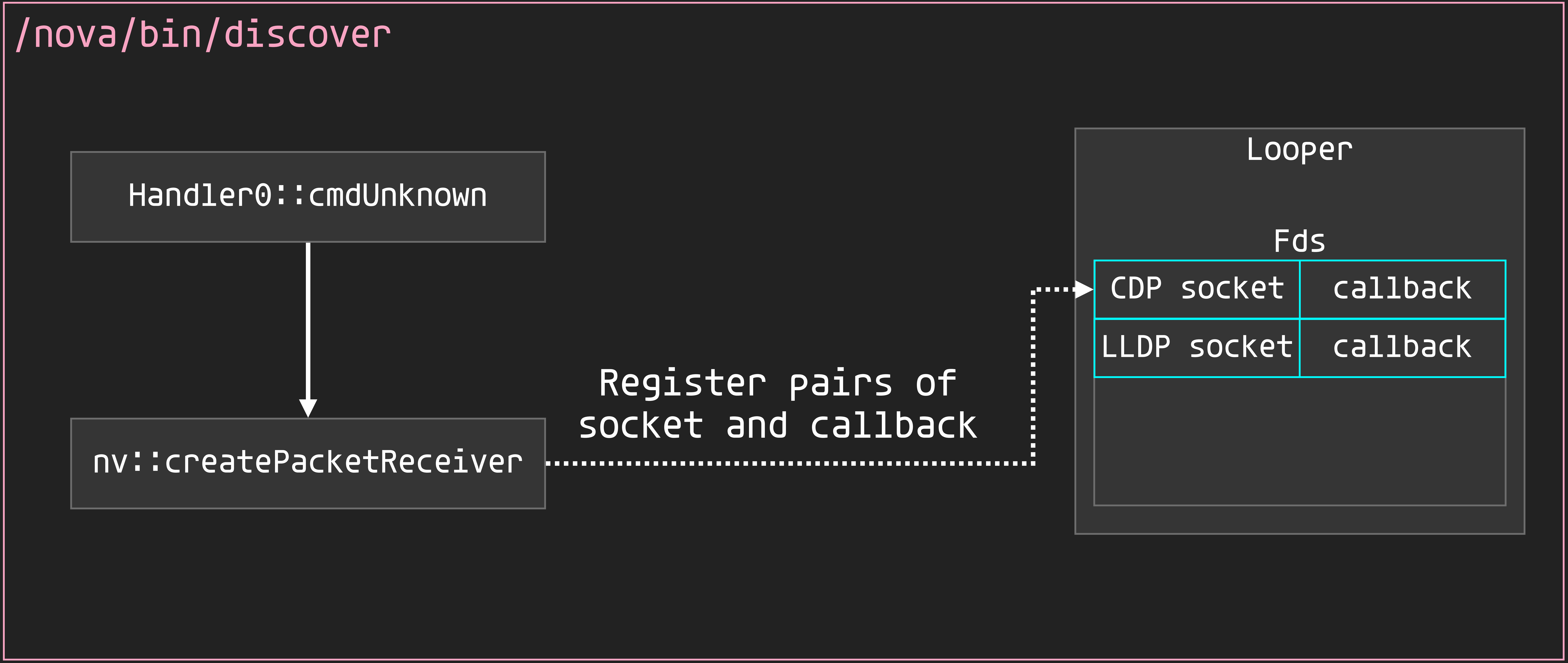
nv::createPacketReceiver

Register pairs of socket and callback

Looper

Fds

CDP socket	callback
LLDP socket	callback



/nova/bin/discover

Handler0::cmdUnknown

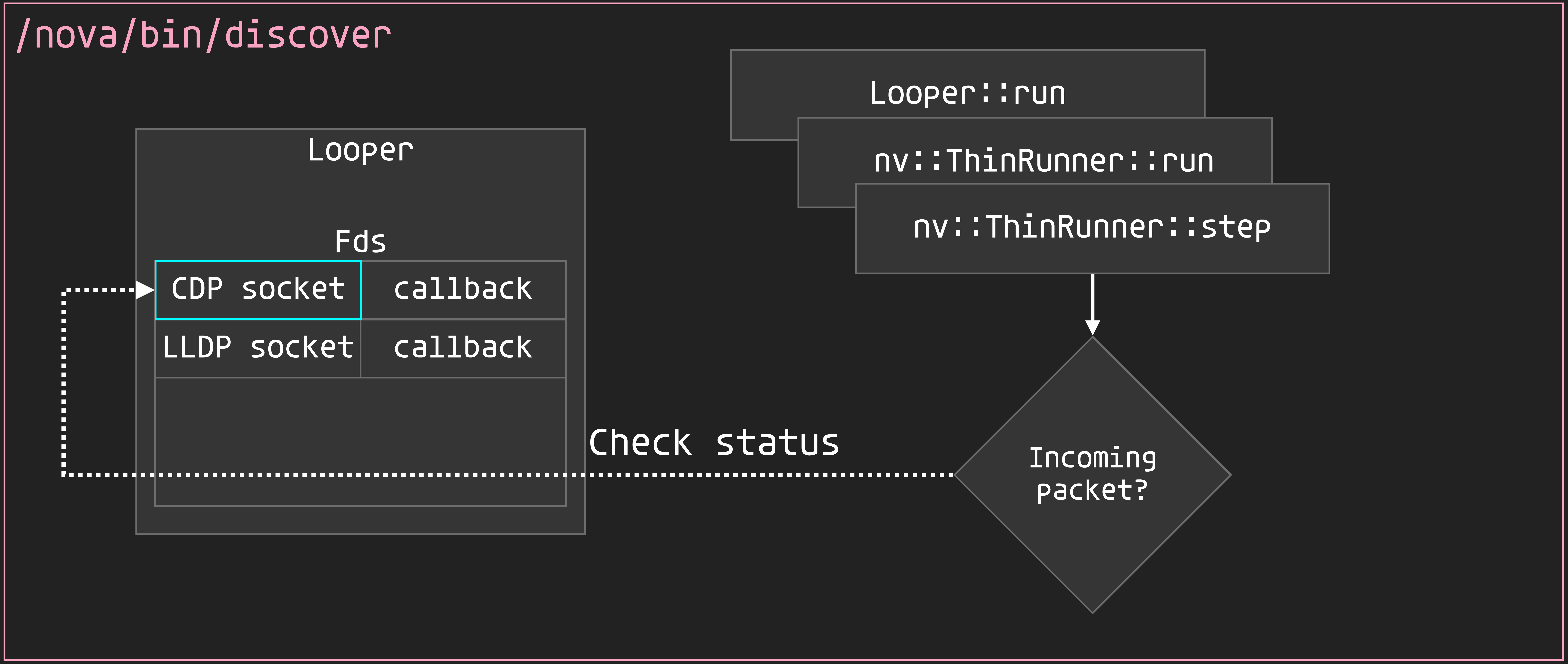
nv::createPacketReceiver

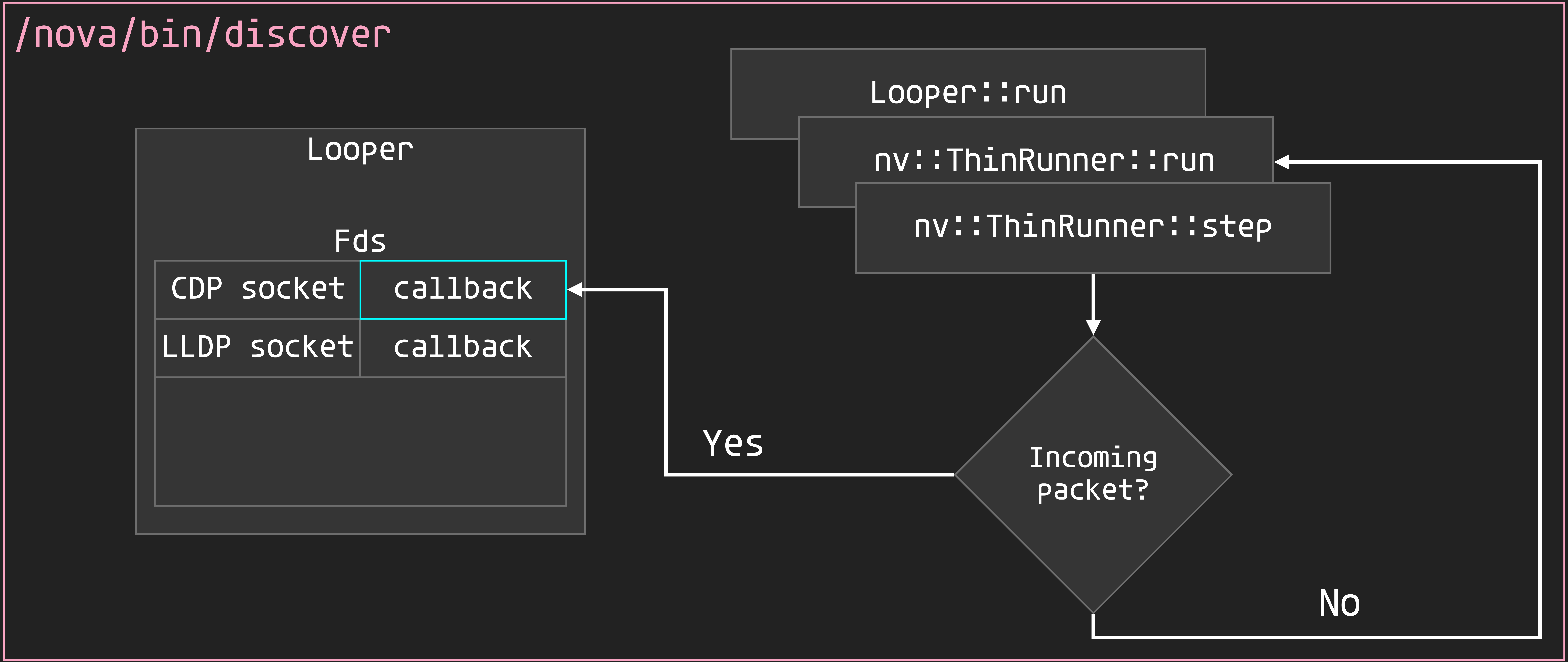
Register pairs of socket and callback

Looper

Fds

CDP socket	callback
LLDP socket	callback


/nova/bin/discover
Looper
Fds
CDP socket
callback
LLDP socket
callback
Looper::run
nv::ThinRunner::run
nv::ThinRunner::step
Check status
Incoming packet?



/nova/bin/discover

Looper

Fds

CDP socket	callback
LLDP socket	callback

Looper::run

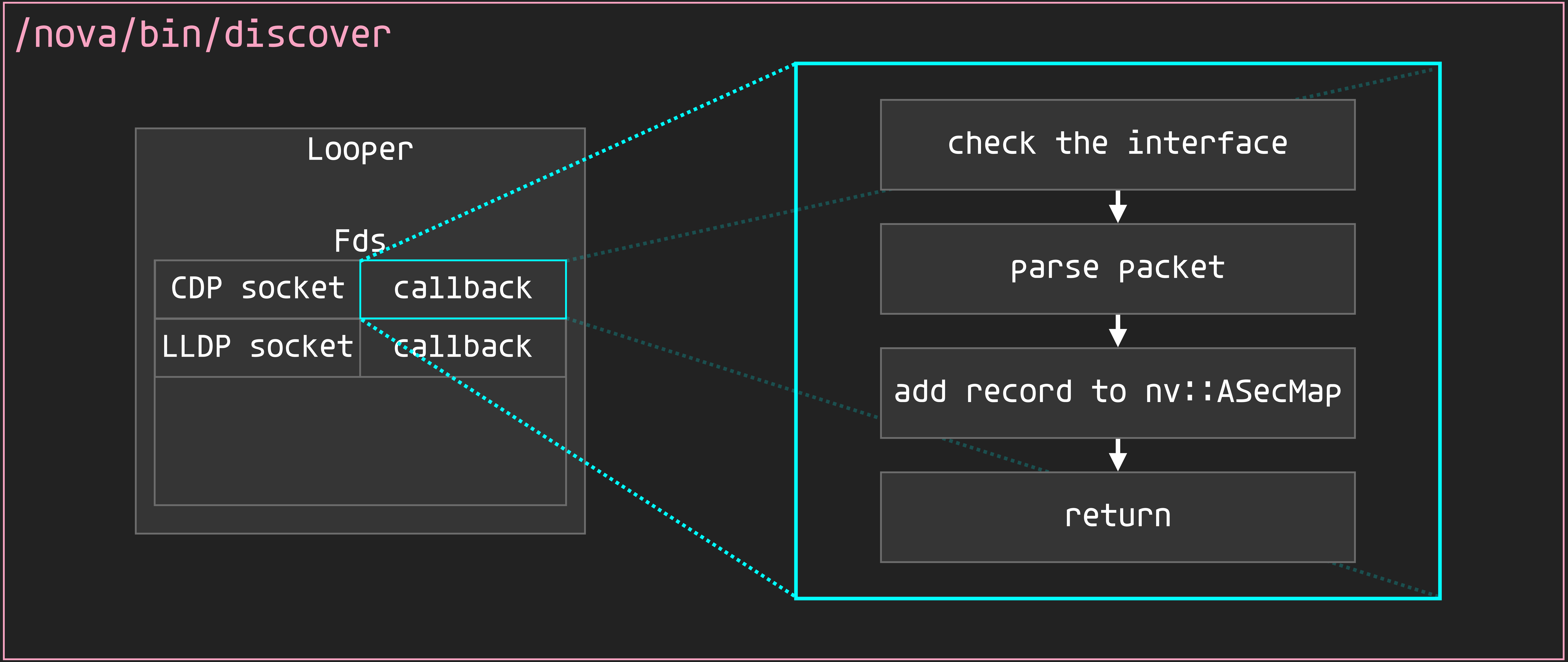
nv::ThinRunner::run

nv::ThinRunner::step

Incoming packet?

Yes

No


/nova/bin/discover
Looper
Fds
CDP socket
callback
LLDP socket
callback
check the interface
parse packet
add record to nv::ASecMap
return

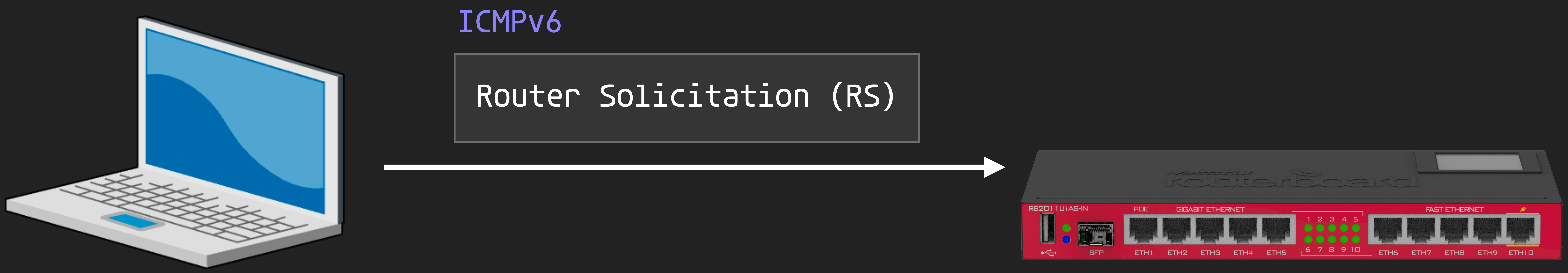
DEVCORE

The pre-auth RCE

The pre-auth RCE

- Some random crashes of radvd occur while we plugging and unplugging cables on RouterBoard

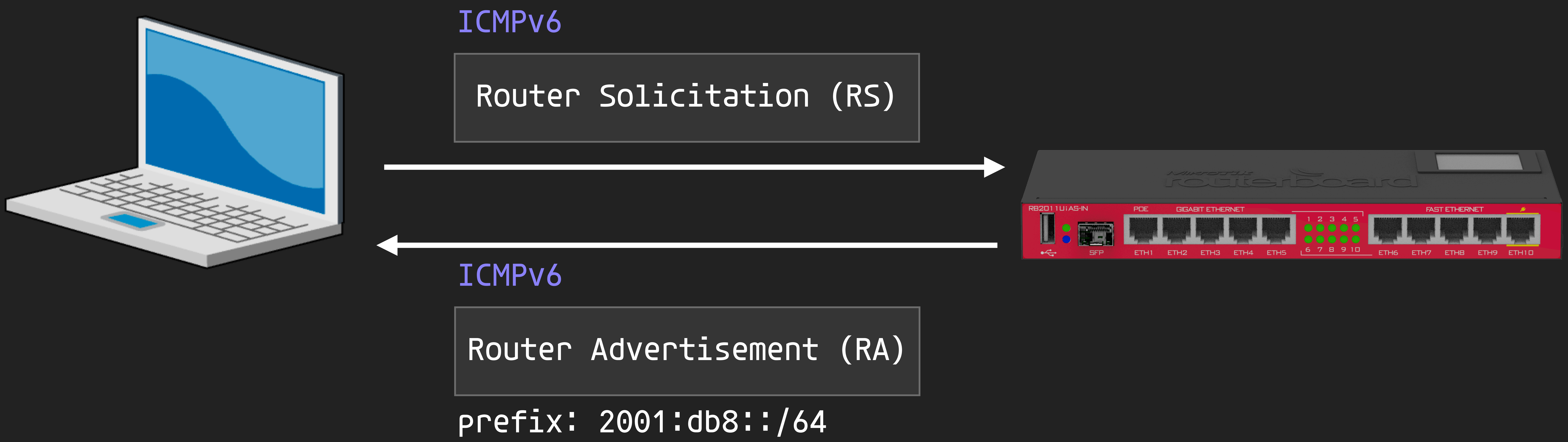
IPv6 SLAAC



ICMPv6

Router Solicitation (RS)

IPv6 SLAAC



ICMPv6

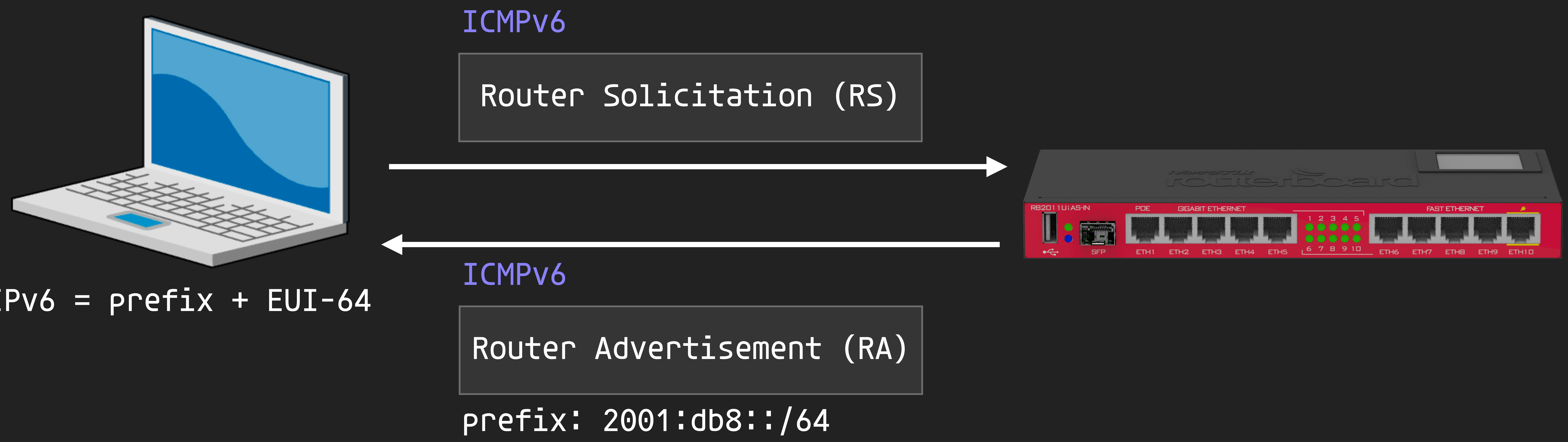
Router Solicitation (RS)

ICMPv6

Router Advertisement (RA)

prefix: 2001:db8::/64

IPv6 SLAAC



ICMPv6

Router Solicitation (RS)

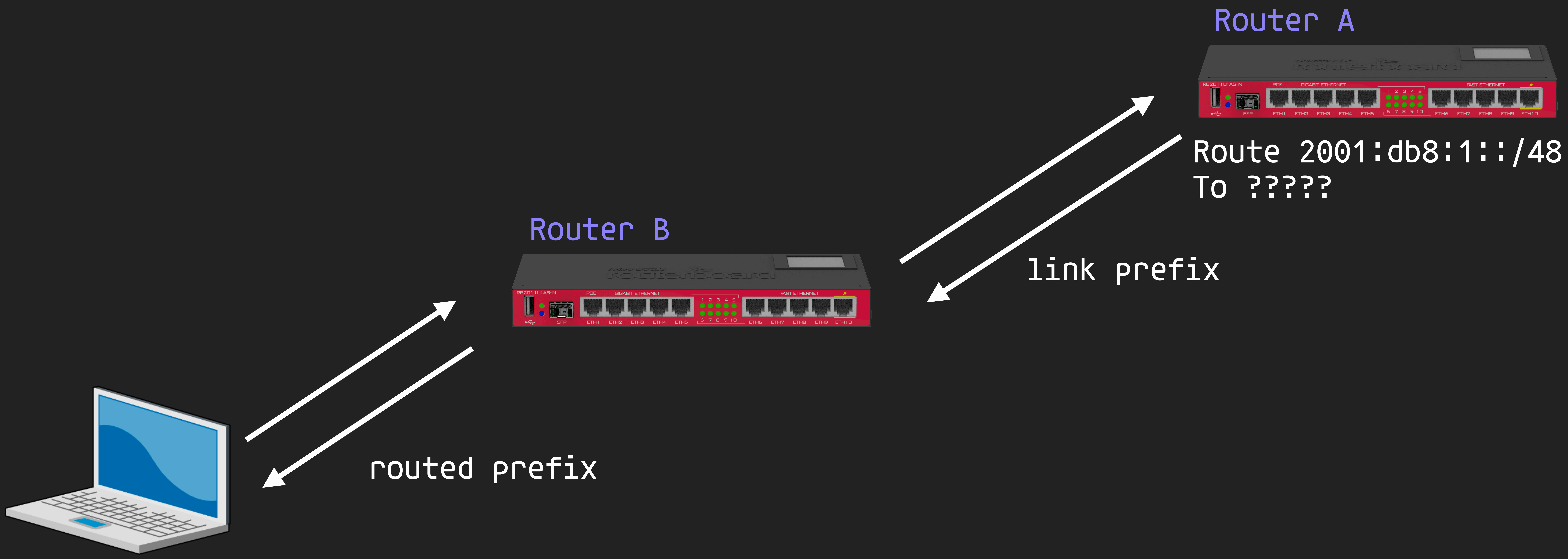
ICMPv6

Router Advertisement (RA)

prefix: 2001:db8::/64

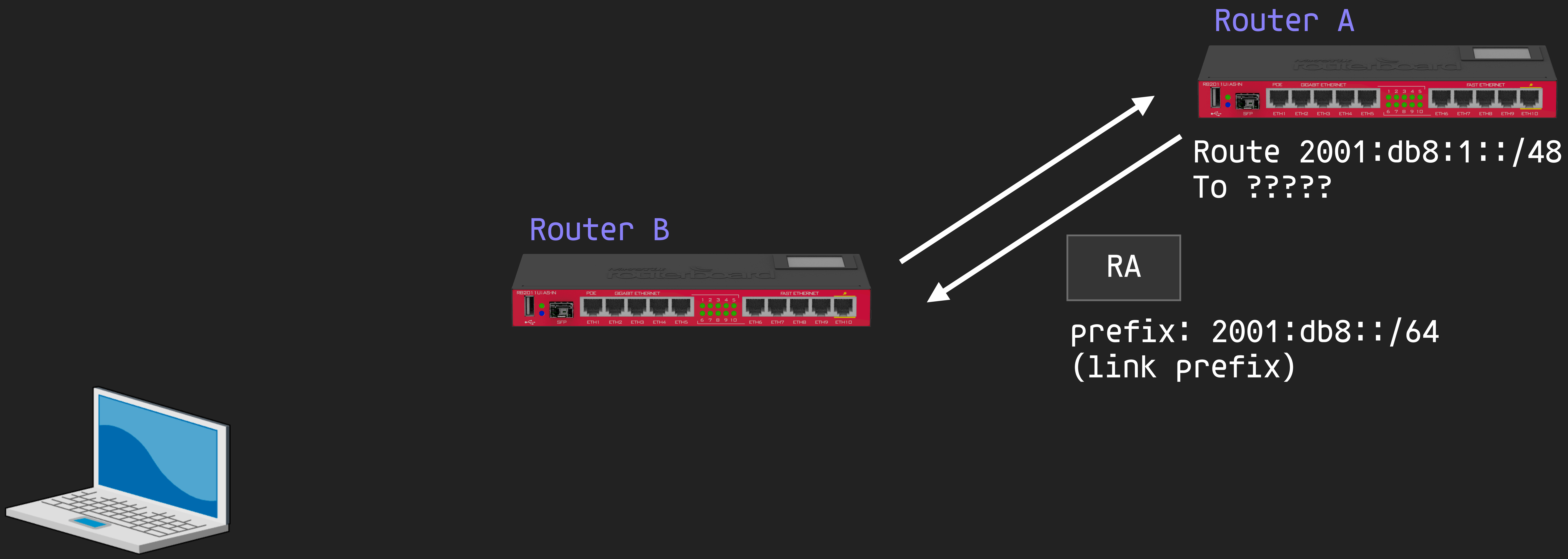
IPv6 = prefix + EUI-64

IPv6 SLAAC



DEVCORE

IPv6 SLAAC



Router A

Route 2001:db8:1::/48
To ?????

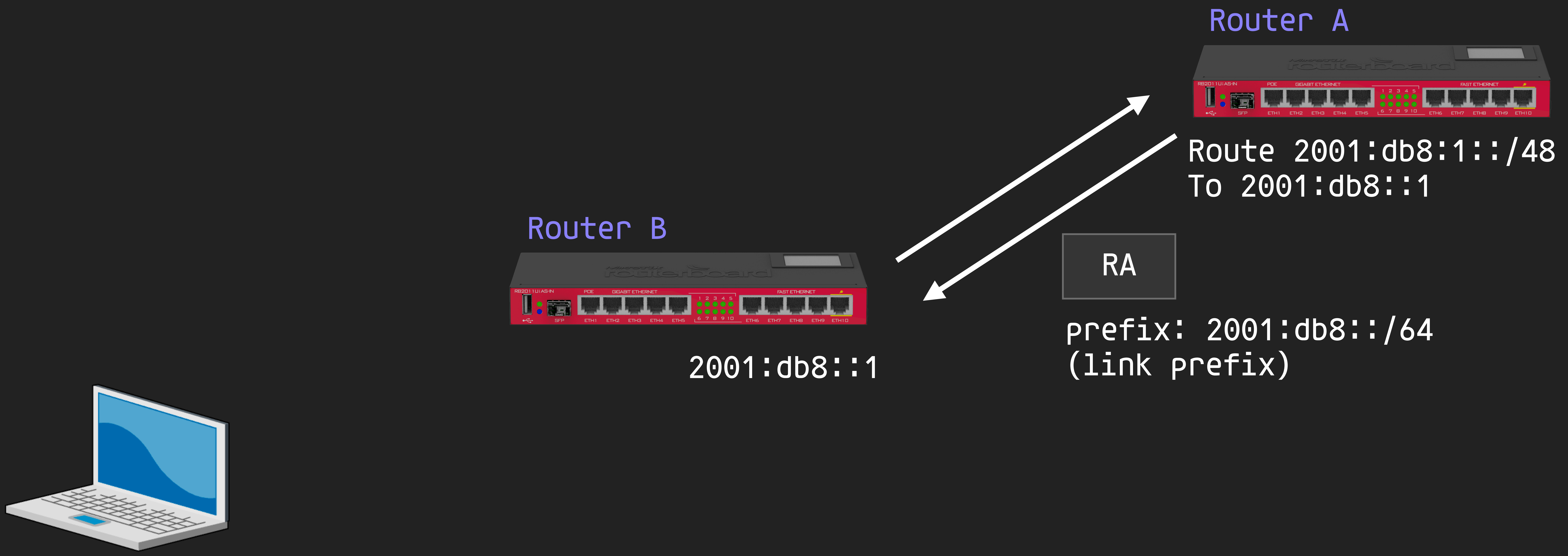
Router B

RA

prefix: 2001:db8::/64
(link prefix)

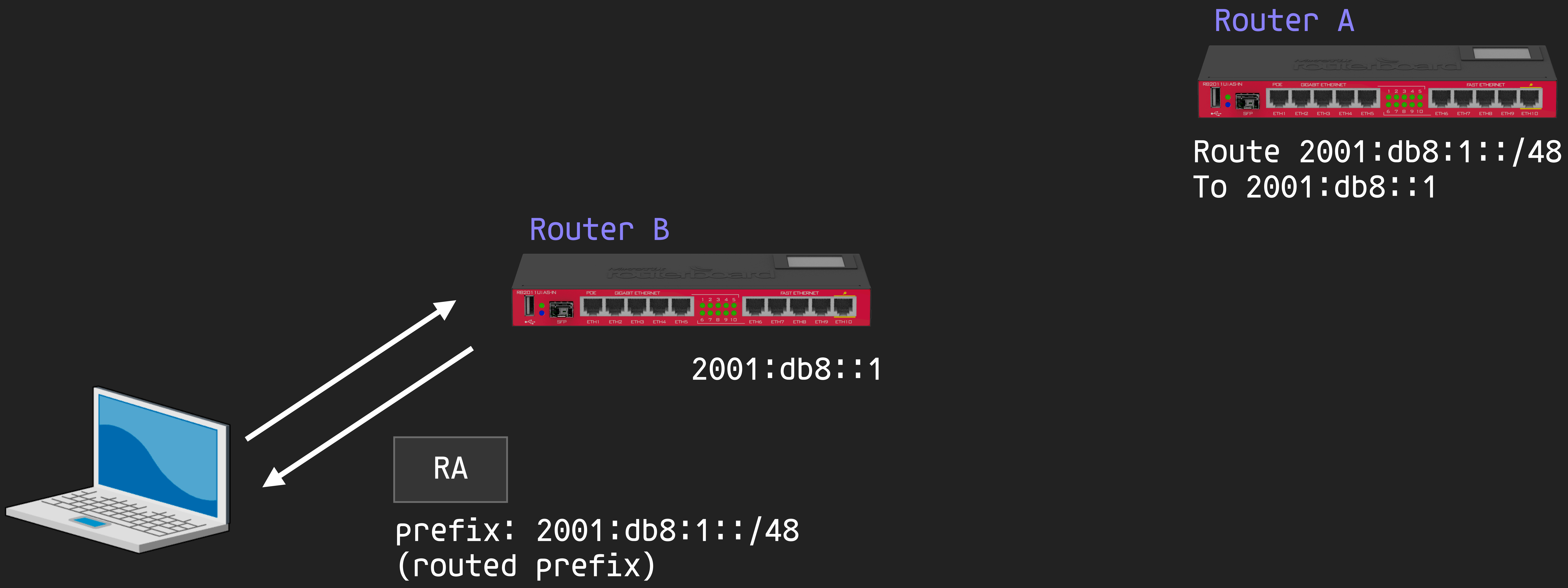
DEVCORE

IPv6 SLAAC



DEVCORE

IPv6 SLAAC



Router A

Route 2001:db8:1::/48
To 2001:db8::1

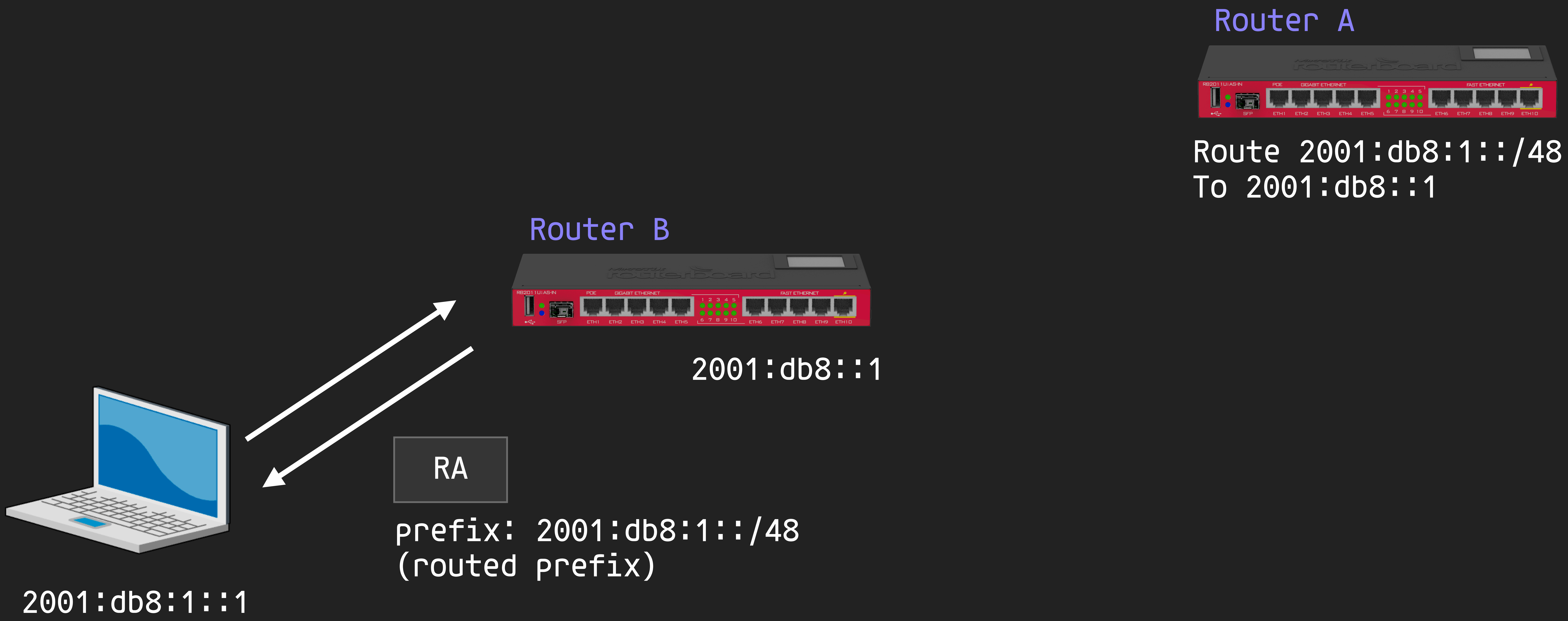
Router B

2001:db8::1

RA

prefix: 2001:db8:1::/48
(routed prefix)

IPv6 SLAAC



Router A

Route 2001:db8:1::/48
To 2001:db8::1

Router B

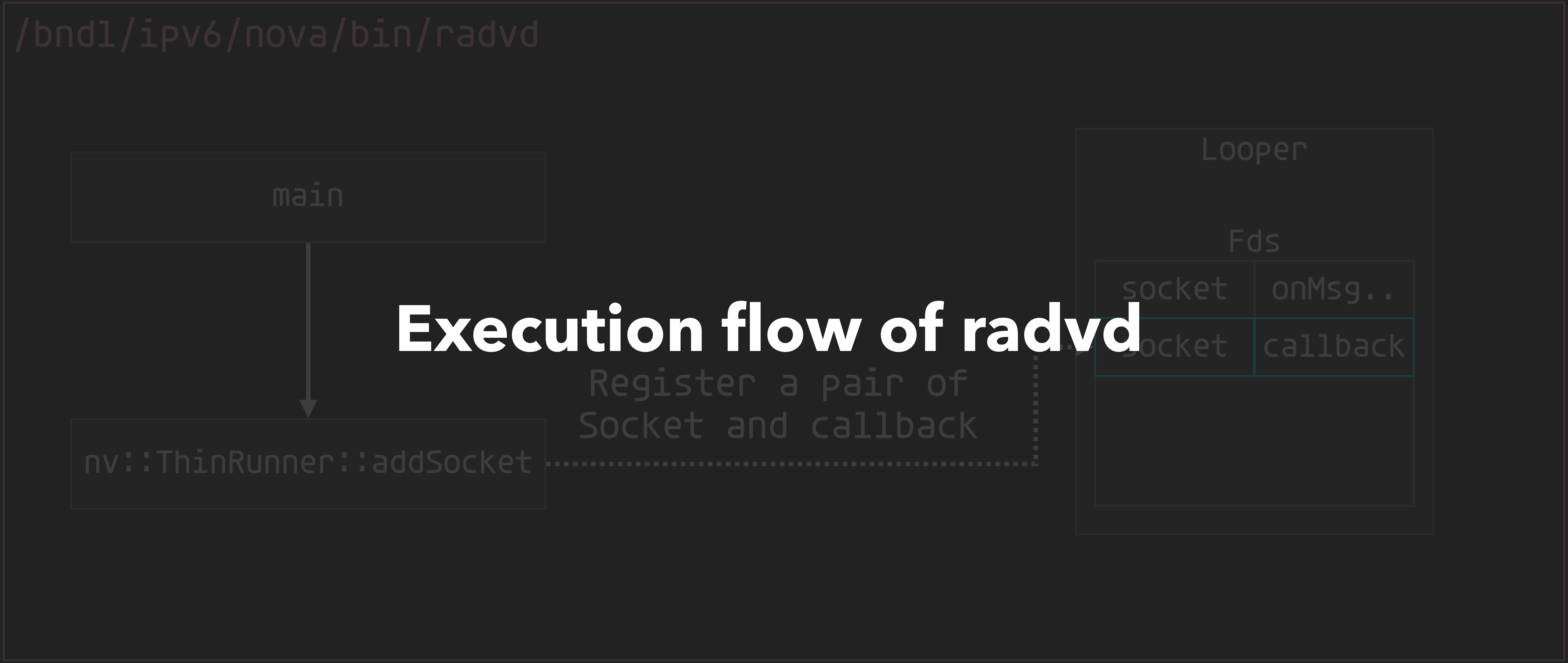
2001:db8::1

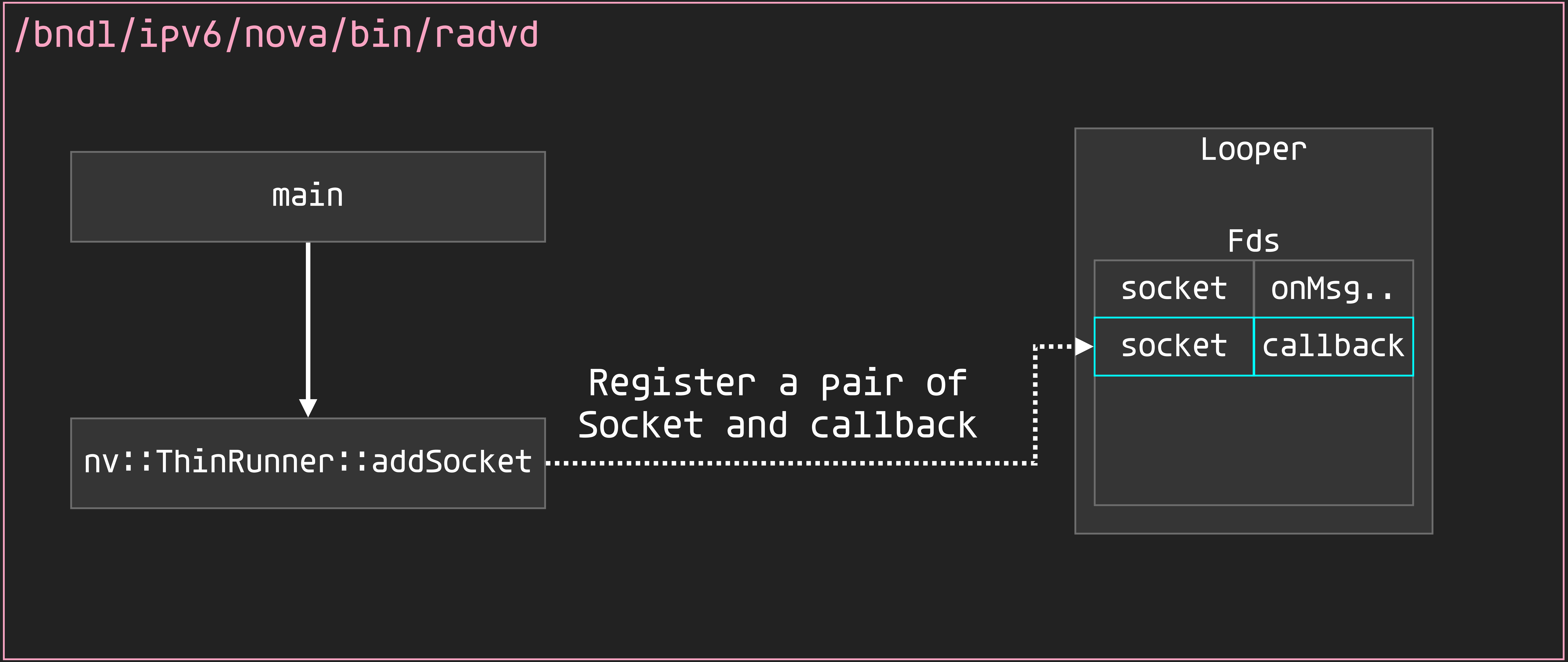
RA

prefix: 2001:db8:1::/48
(routed prefix)

2001:db8:1::1

Execution flow of radvd





/bndl/ipv6/nova/bin/radvd

main

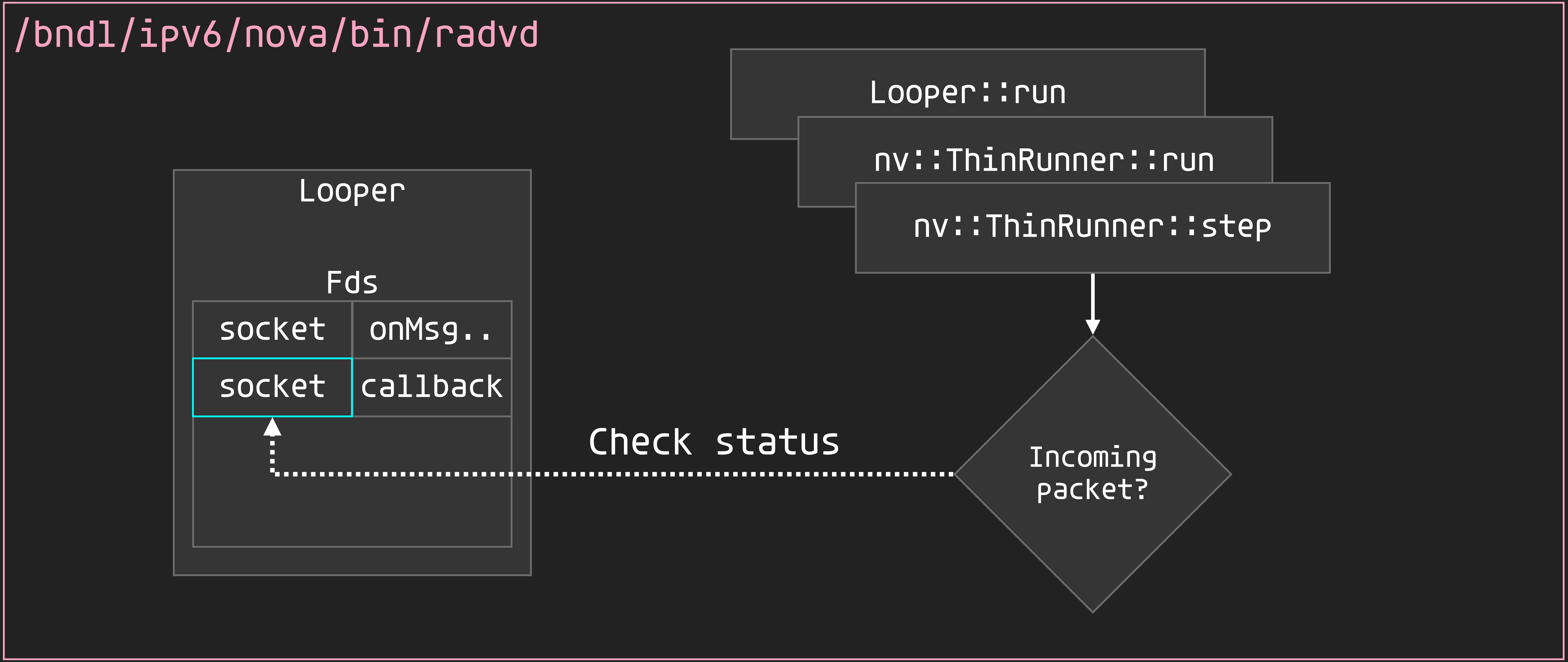
nv::ThinRunner::addSocket

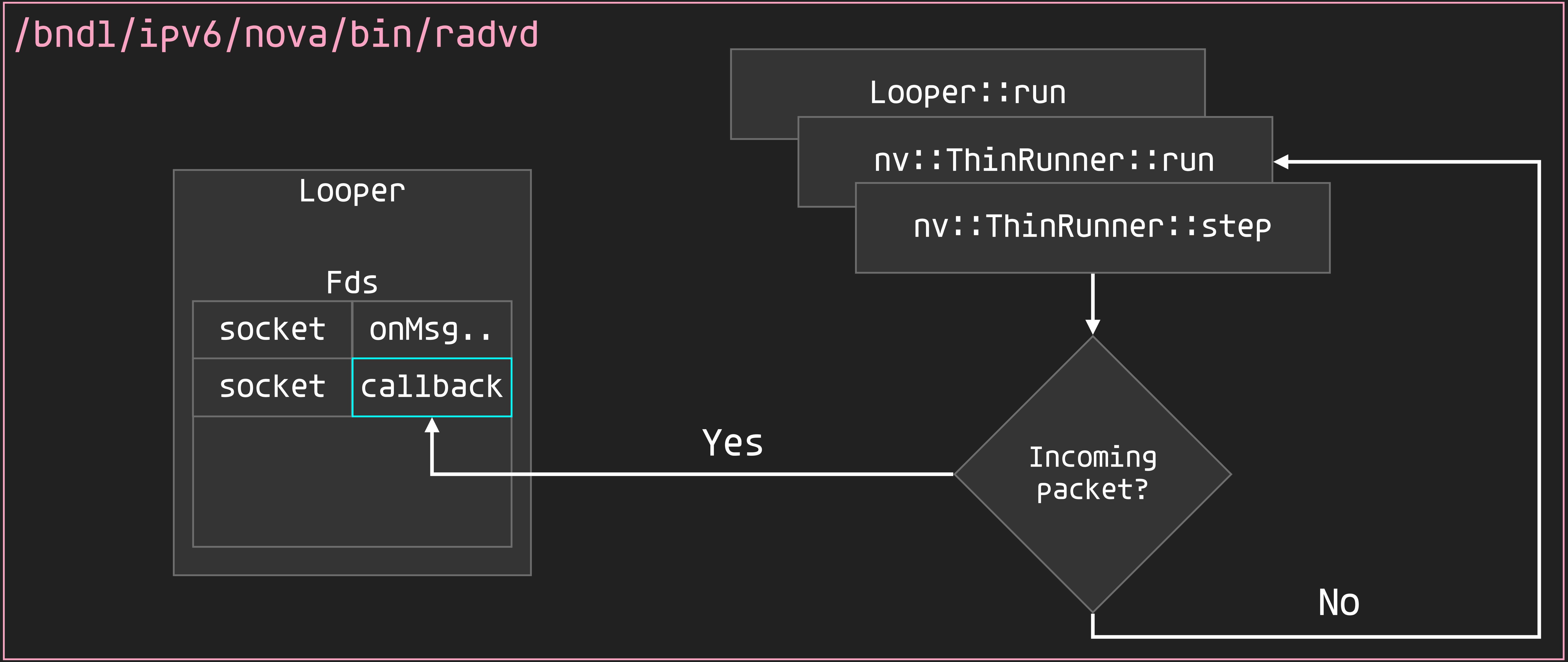
Register a pair of
Socket and callback

Looper

Fds

socket	onMsg..
socket	callback

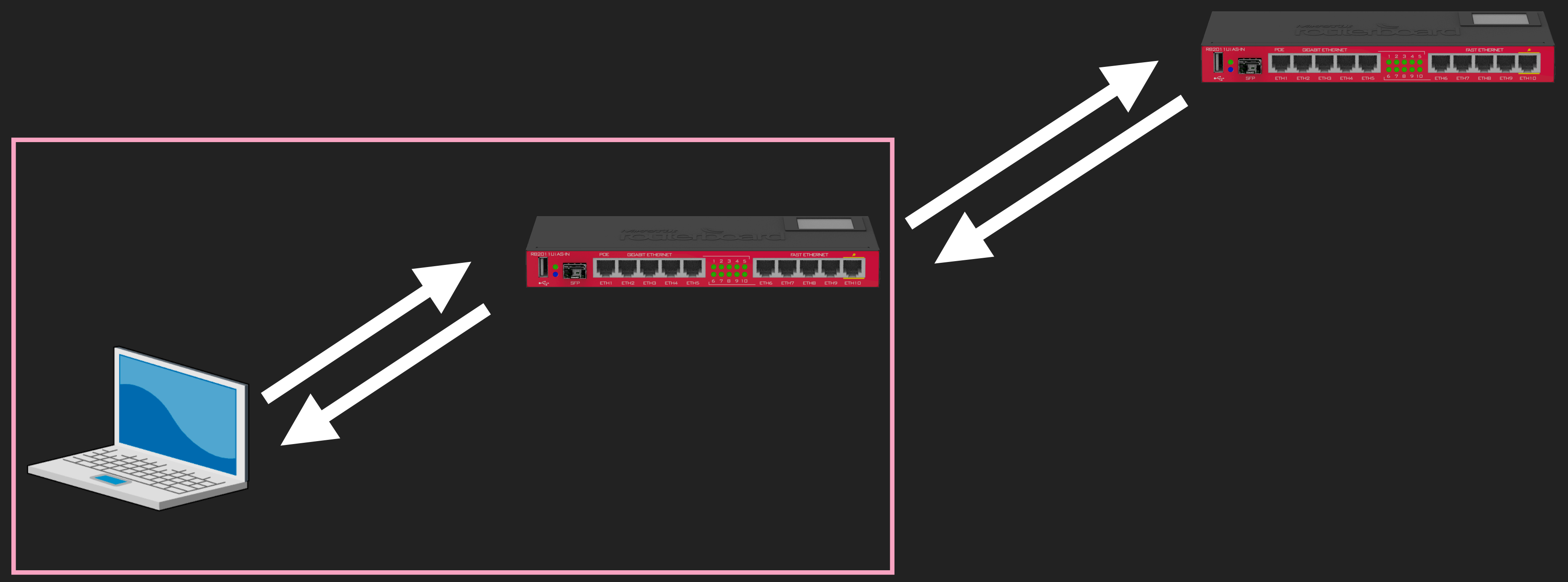

/bndl/ipv6/nova/bin/radvd
Looper
Fds
socket
onMsg..
socket
callback
Looper::run
nv::ThinRunner::run
nv::ThinRunner::step
Check status
Incoming packet?


/bndl/ipv6/nova/bin/radvd
Looper::run
nv::ThinRunner::run
nv::ThinRunner::step
Looper
Fds
socket
onMsg..
socket
callback
Yes
Incoming packet?
No

RADVD

- In callback:
    - Check if the packet is a valid RA or a valid RS
    - Parse the packet
    - If it is RA
        - Store information in handler 1 (AMap)
    - If it is RS
        - Multicast RA

IPv6 SLAAC



ICMPv6

Router Solicitation

ICMPv6

Router Advertisement

ICMPv6

Router Advertisement

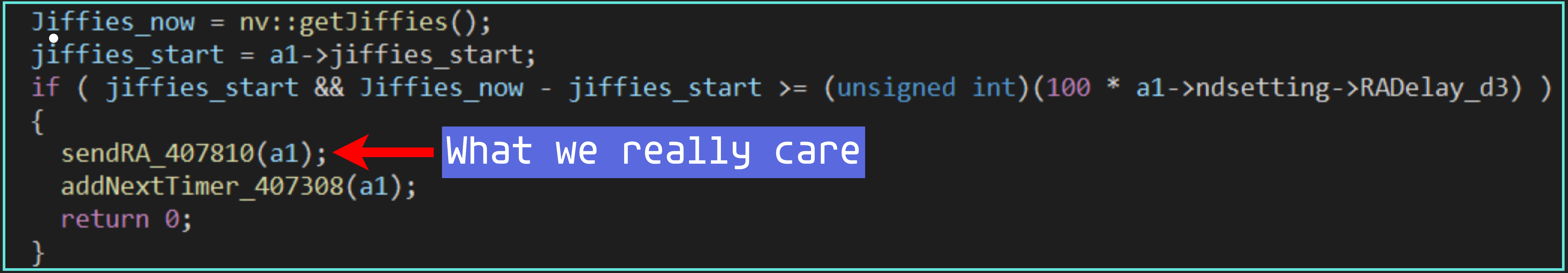
RADVD

- In callback:
    - Check if the packet is a valid RA or a valid RS
    - Parse the packet
    - If it is an RA
        - Store information in handler 1 (AMap)
    - If it is an RS
        - Multicast RA

???????????????????

RADVD

- Where does the radvd construct RA?
  - radvd sends RA right after it receives an RS

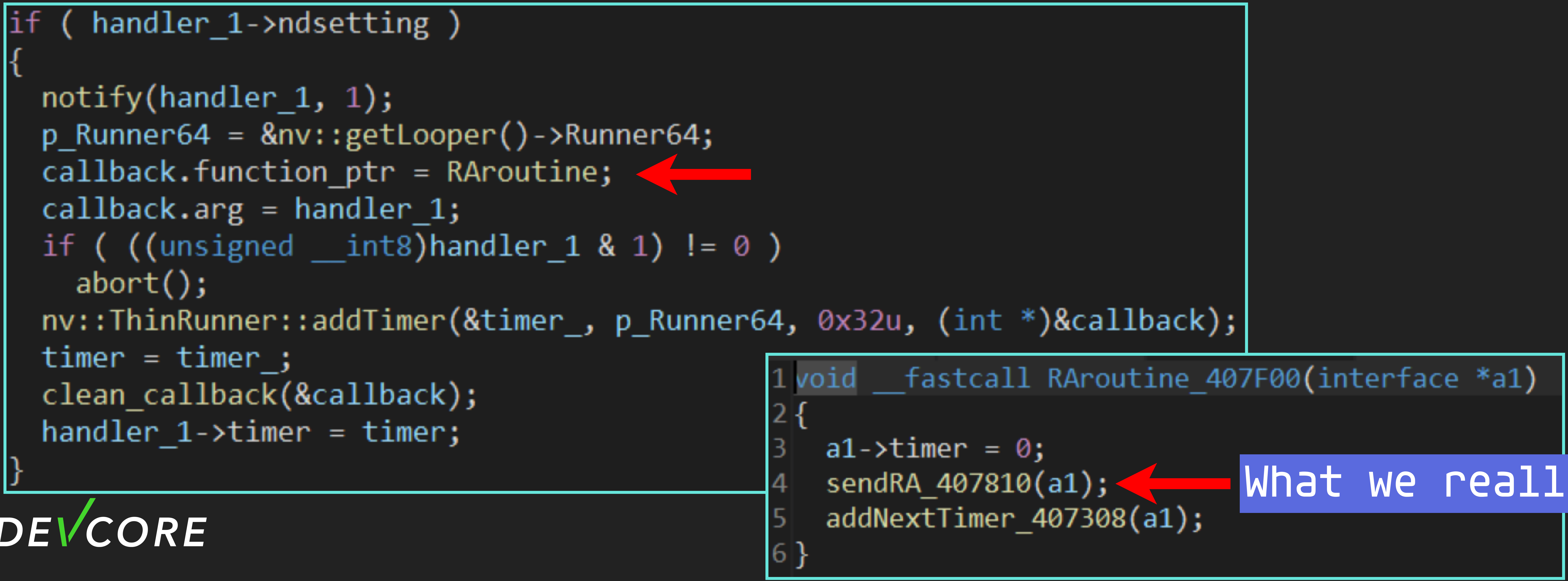


```
Jiffies_now = nv::getJiffies();
jiffies_start = a1->jiffies_start;
if ( jiffies_start && Jiffies_now - jiffies_start >= (unsigned int)(100 * a1->ndsetting->RADelay_d3) )
{
  sendRA_407810(a1);
  addNextTimer_407308(a1);
  return 0;
}
```

What we really care

RADVD

- Where does the radvd construct RA?
  - The handler 1 registers a timer to send RA periodically

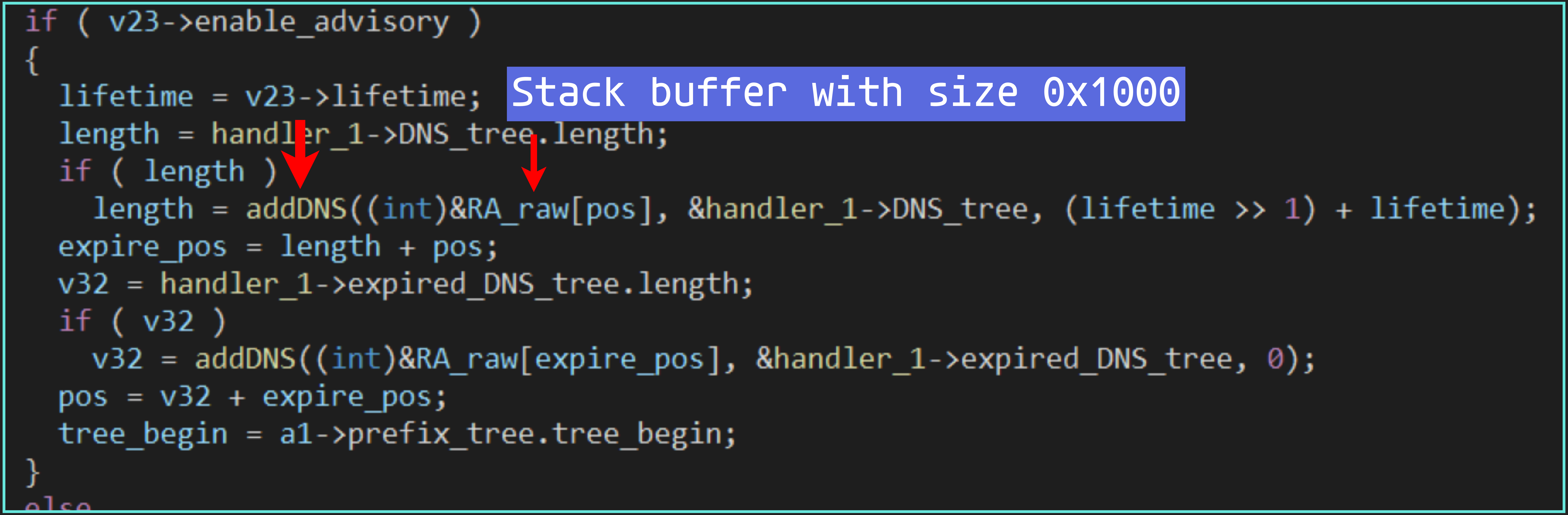


```
if ( handler_1->ndsetting )
{
  notify(handler_1, 1);
  p_Runner64 = &nv::getLooper()->Runner64;
  callback.function_ptr = RAroutine;
  callback.arg = handler_1;
  if ( ((unsigned __int8)handler_1 & 1) != 0 )
    abort();
  nv::ThinRunner::addTimer(&timer_, p_Runner64, 0x32u, (int *)&callback);
  timer = timer_;
  clean_callback(&callback);
  handler_1->timer = timer;
}
```

```
void __fastcall RAroutine_407F00(interface *a1)
{
  a1->timer = 0;
  sendRA_407810(a1);
  addNextTimer_407308(a1);
}
```

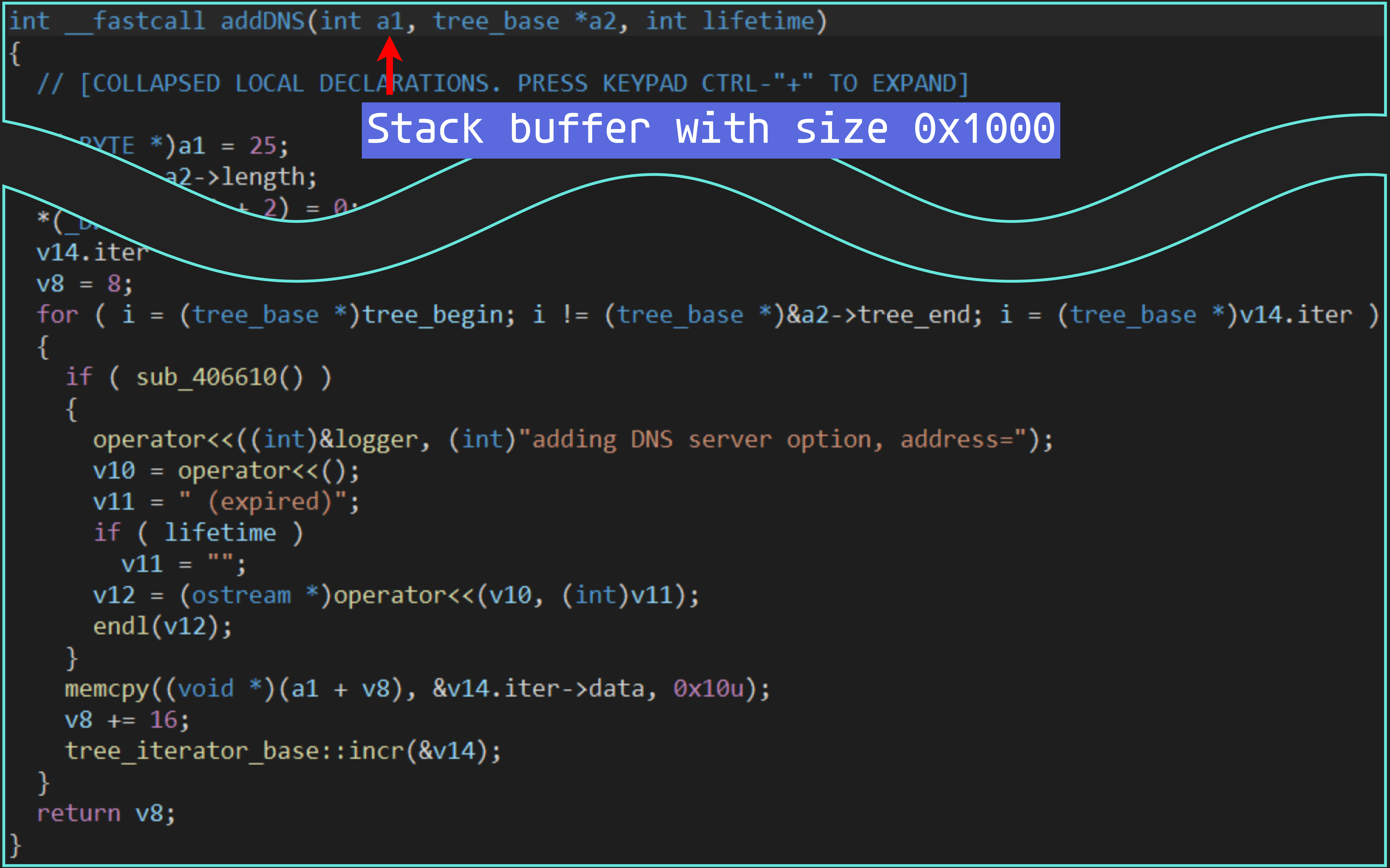
What we really care

RADVD



Stack buffer with size 0x1000

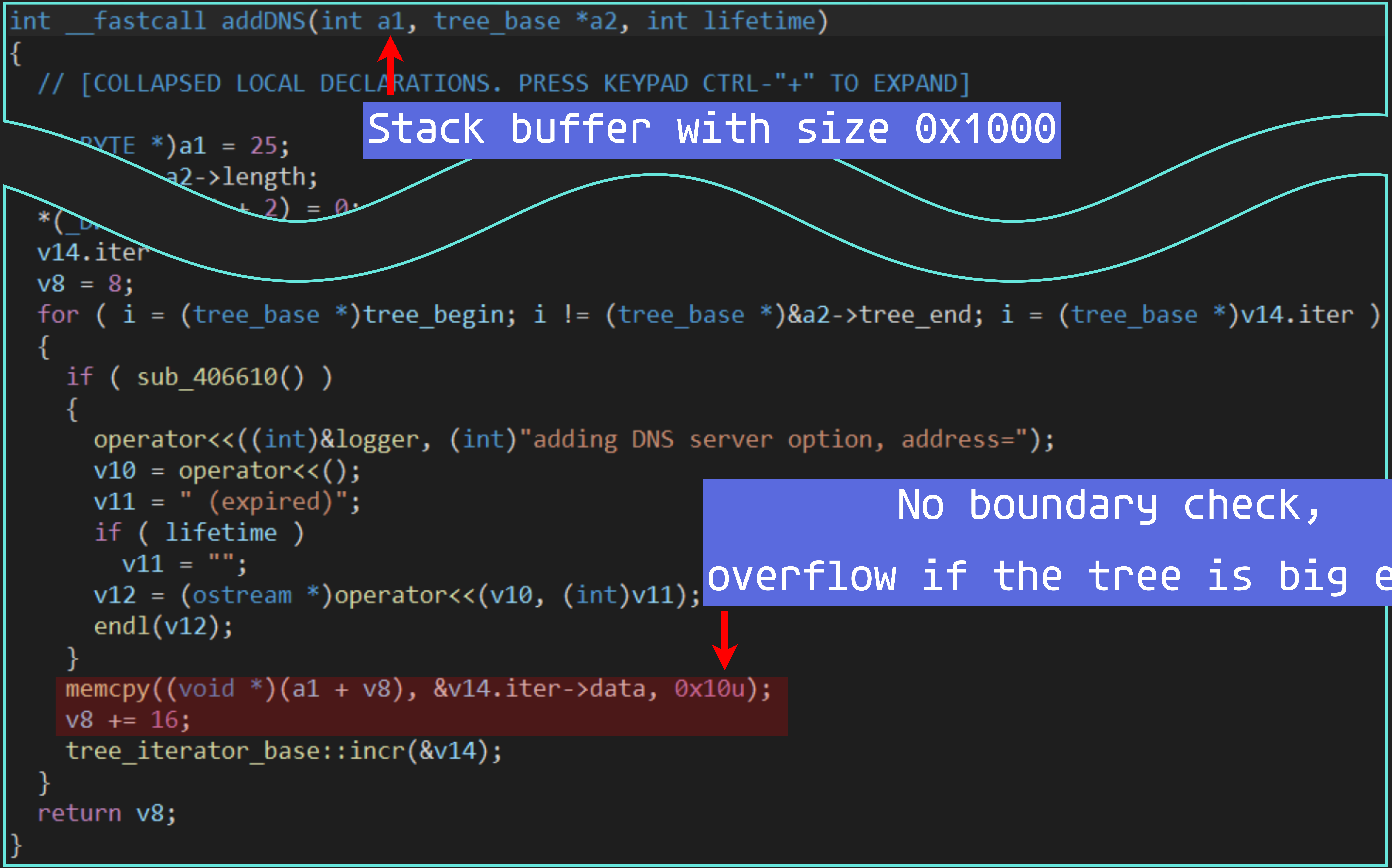
```
if ( v23->enable_advisory )
{
  lifetime = v23->lifetime;
  length = handler_1->DNS_tree.length;
  if ( length )
    length = addDNS((int)&RA_raw[pos], &handler_1->DNS_tree, (lifetime >> 1) + lifetime);
  expire_pos = length + pos;
  v32 = handler_1->expired_DNS_tree.length;
  if ( v32 )
    v32 = addDNS((int)&RA_raw[expire_pos], &handler_1->expired_DNS_tree, 0);
  pos = v32 + expire_pos;
  tree_begin = a1->prefix_tree.tree_begin;
}
else
```



```
int __fastcall addDNS(int a1, tree_base *a2, int lifetime)
{
  // [COLLAPSED LOCAL DECLARATIONS. PRESS KEYPAD CTRL-"+" TO EXPAND]

    BYTE *)a1 = 25;
          a2->length;
              + 2) = 0;
  *(_D
  v14.iter
  v8 = 8;
  for ( i = (tree_base *)tree_begin; i != (tree_base *)&a2->tree_end; i = (tree_base *)v14.iter )
  {
    if ( sub_406610() )
    {
      operator<<((int)&logger, (int)"adding DNS server option, address=");
      v10 = operator<<();
      v11 = " (expired)";
      if ( lifetime )
        v11 = "";
      v12 = (ostream *)operator<<(v10, (int)v11);
      endl(v12);
    }
    memcpy((void *)(a1 + v8), &v14.iter->data, 0x10u);
    v8 += 16;
    tree_iterator_base::incr(&v14);
  }
  return v8;
}
```

Stack buffer with size 0x1000

DEVCORE

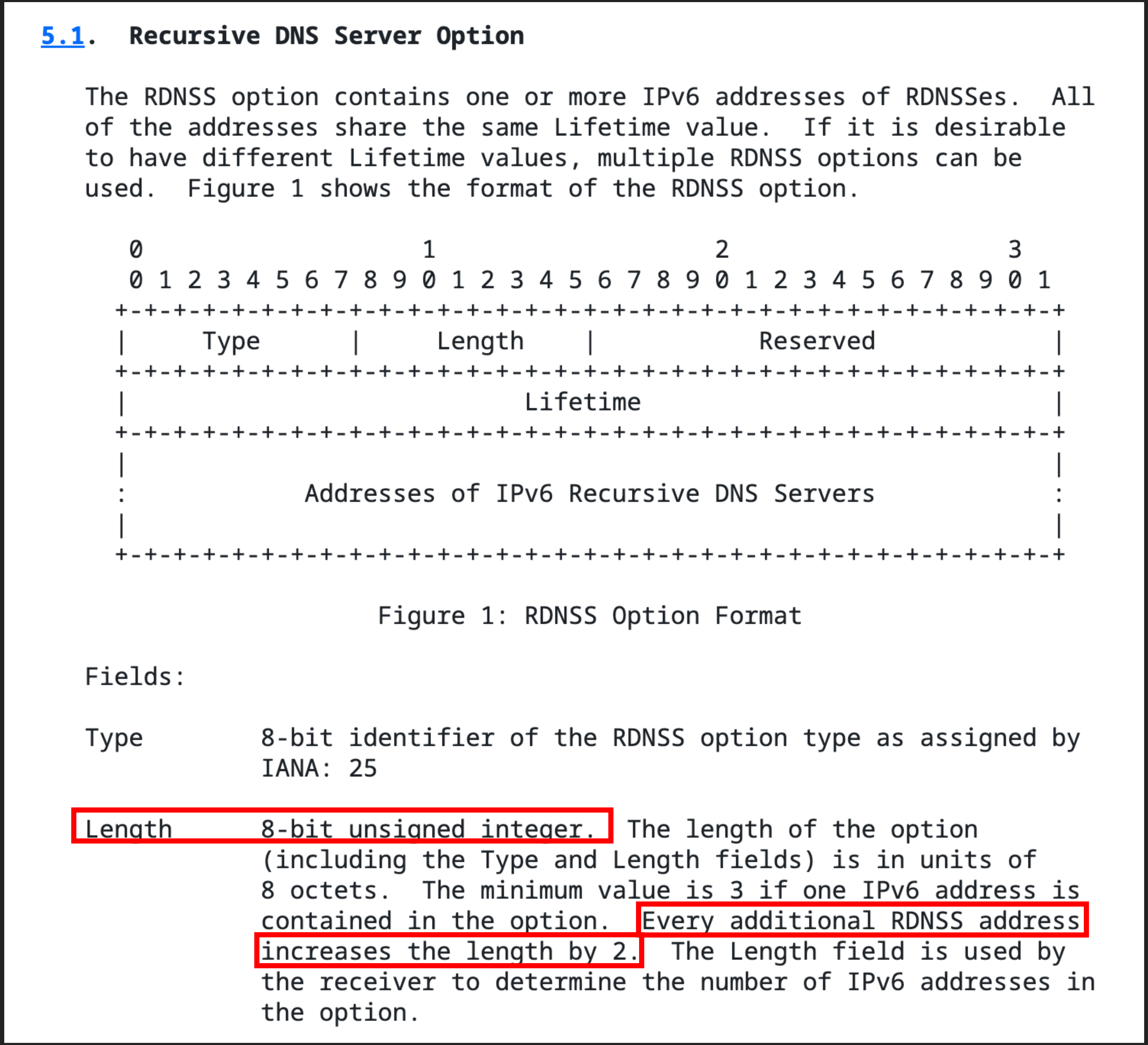


```
int __fastcall addDNS(int a1, tree_base *a2, int lifetime)
{
  // [COLLAPSED LOCAL DECLARATIONS. PRESS KEYPAD CTRL-"+" TO EXPAND]

    BYTE *)a1 = 25;
            a2->length;
                + 2) = 0;
  *(_D
  v14.iter
  v8 = 8;
  for ( i = (tree_base *)tree_begin; i != (tree_base *)&a2->tree_end; i = (tree_base *)v14.iter )
  {
    if ( sub_406610() )
    {
      operator<<((int)&logger, (int)"adding DNS server option, address=");
      v10 = operator<<();
      v11 = " (expired)";
      if ( lifetime )
        v11 = "";
      v12 = (ostream *)operator<<(v10, (int)v11);
      endl(v12);
    }
    memcpy((void *)(a1 + v8), &v14.iter->data, 0x10u);
    v8 += 16;
    tree_iterator_base::incr(&v14);
  }
  return v8;
}
```

Stack buffer with size 0x1000

No boundary check,

overflow if the tree is big enough



5.1. Recursive DNS Server Option

The RDNSS option contains one or more IPv6 addresses of RDNSSes. All of the addresses share the same Lifetime value. If it is desirable to have different Lifetime values, multiple RDNSS options can be used. Figure 1 shows the format of the RDNSS option.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Lifetime                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
:            Addresses of IPv6 Recursive DNS Servers            :
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

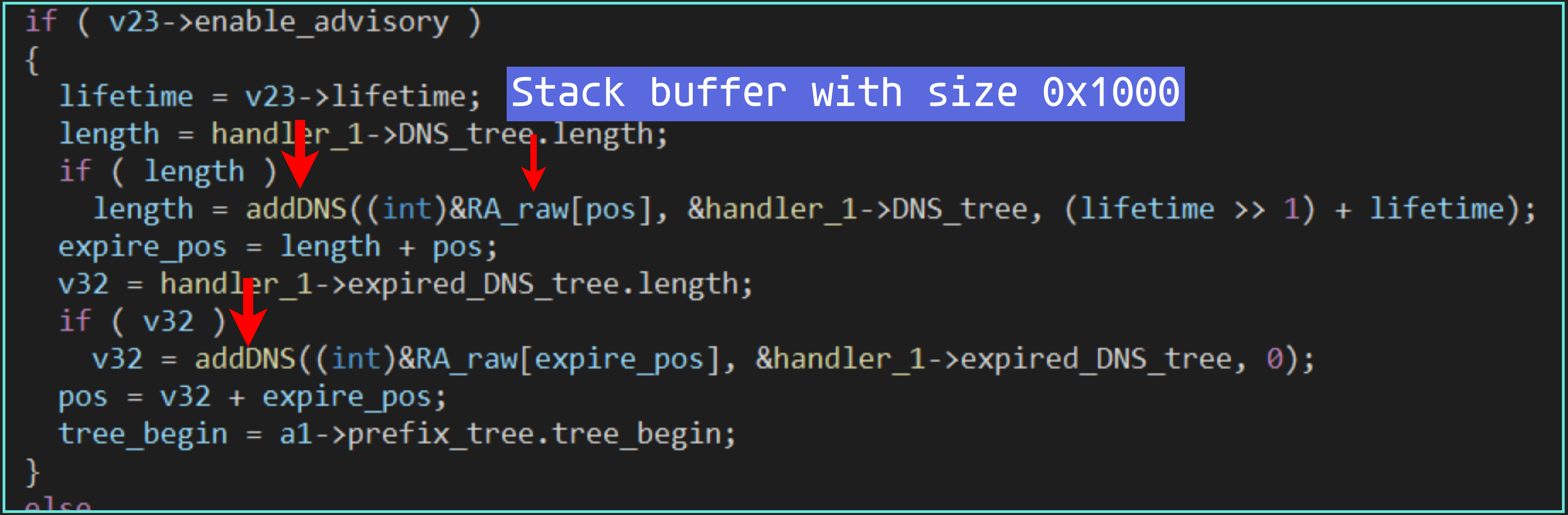
Figure 1: RDNSS Option Format

Fields:

Type 8-bit identifier of the RDNSS option type as assigned by IANA: 25

Length 8-bit unsigned integer. The length of the option (including the Type and Length fields) is in units of 8 octets. The minimum value is 3 if one IPv6 address is contained in the option. Every additional RDNSS address increases the length by 2. The Length field is used by the receiver to determine the number of IPv6 addresses in the option.

RADVD

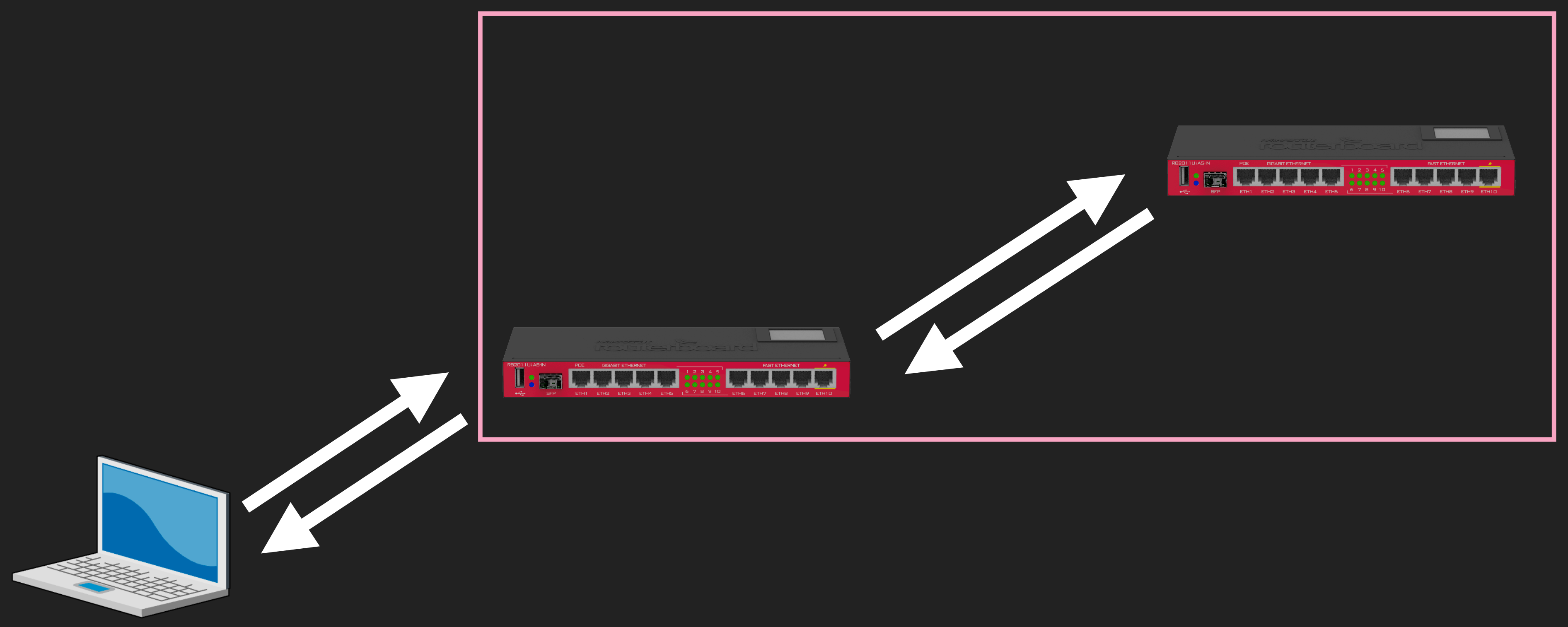


```
if ( v23->enable_advisory )
{
  lifetime = v23->lifetime;
  length = handler_1->DNS_tree.length;
  if ( length )
    length = addDNS((int)&RA_raw[pos], &handler_1->DNS_tree, (lifetime >> 1) + lifetime);
  expire_pos = length + pos;
  v32 = handler_1->expired_DNS_tree.length;
  if ( v32 )
    v32 = addDNS((int)&RA_raw[expire_pos], &handler_1->expired_DNS_tree, 0);
  pos = v32 + expire_pos;
  tree_begin = a1->prefix_tree.tree_begin;
}
else
```

Stack buffer with size 0x1000

DEVCORE

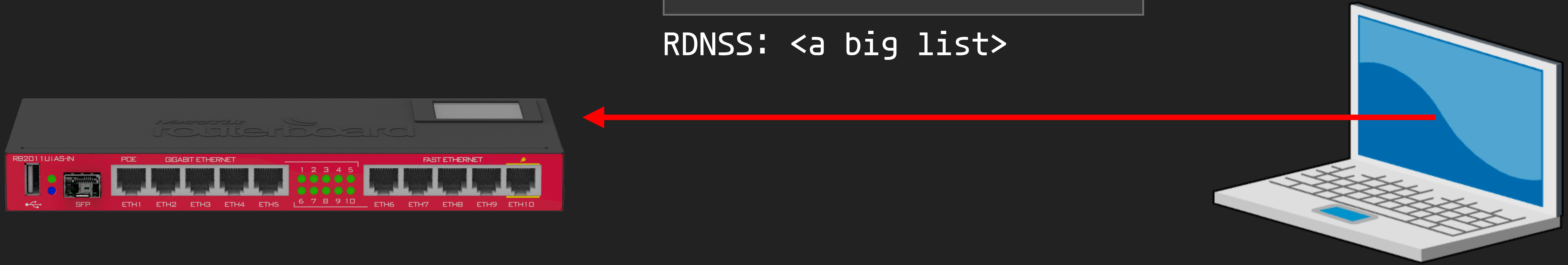
IPv6 SLAAC



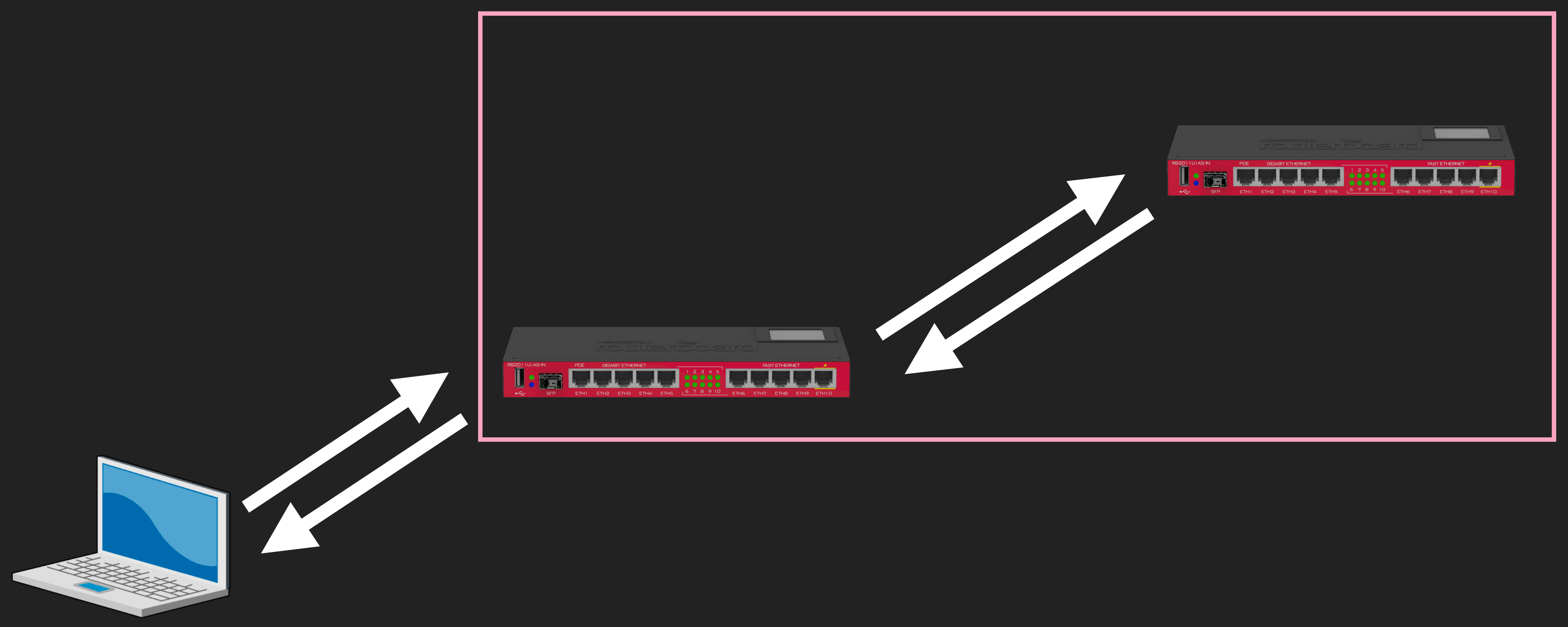
ICMPv6

Router Advertisement (RA)

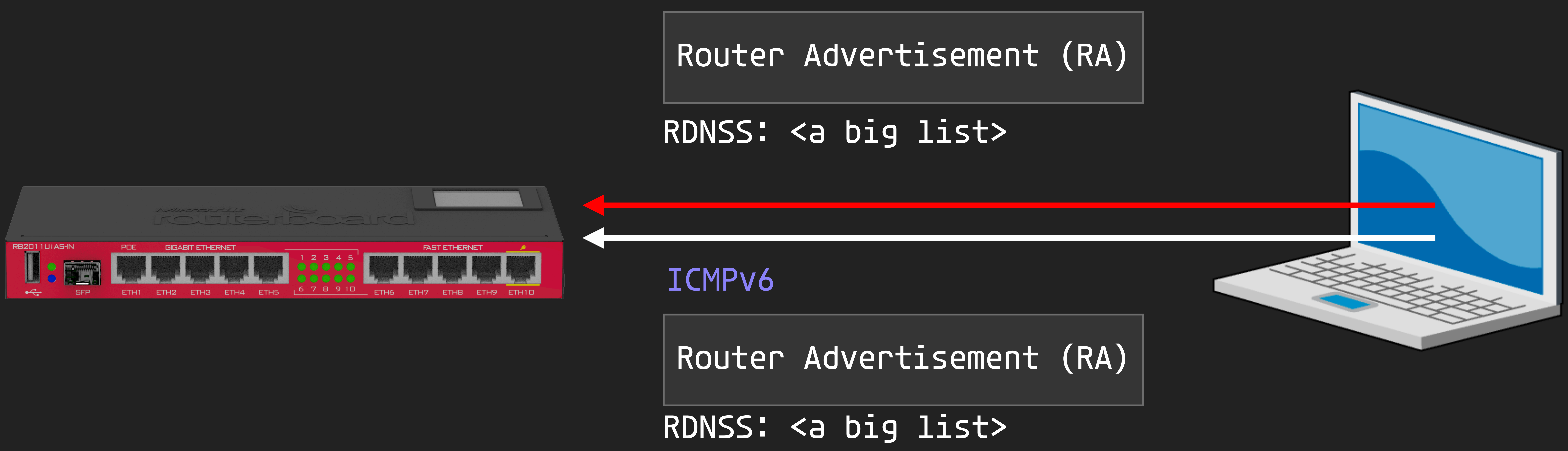
RDNSS: <a big list>



IPv6 SLAAC



ICMPv6



Router Advertisement (RA)

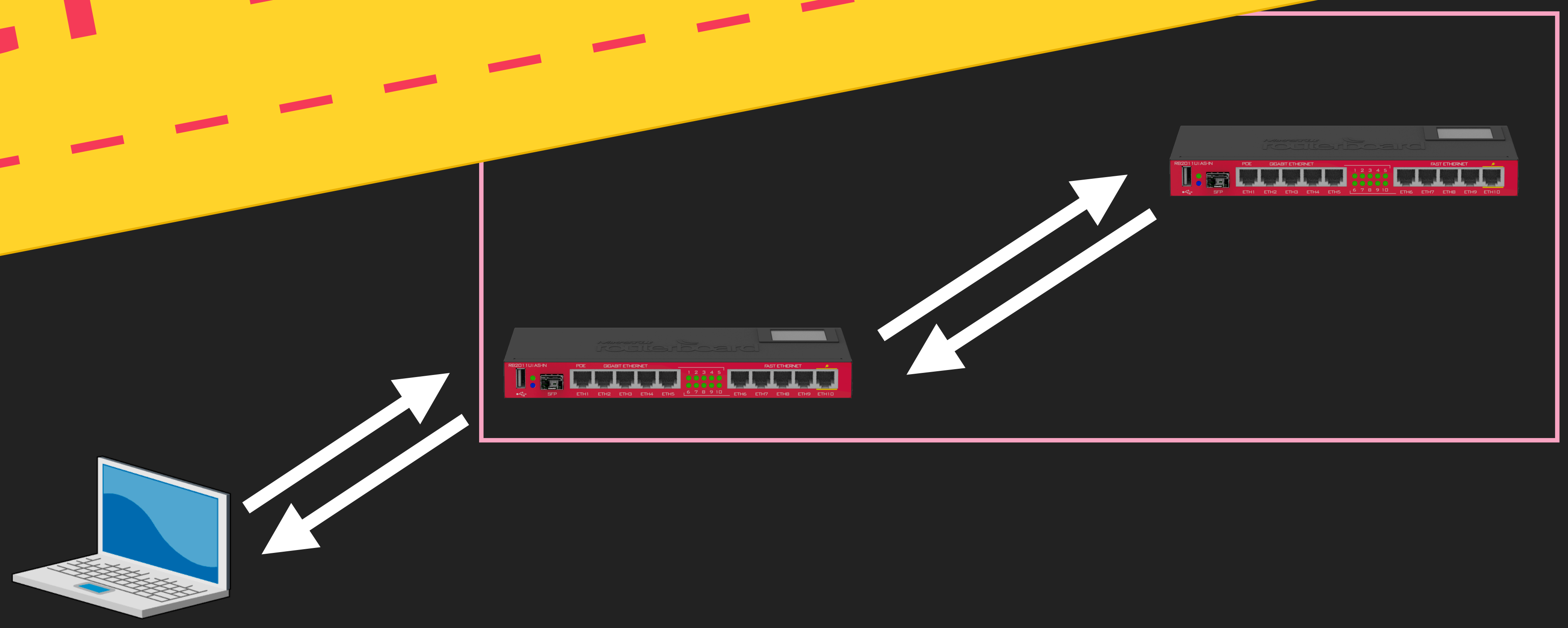
RDNSS: <a big list>

ICMPv6

Router Advertisement (RA)

RDNSS: <a big list>

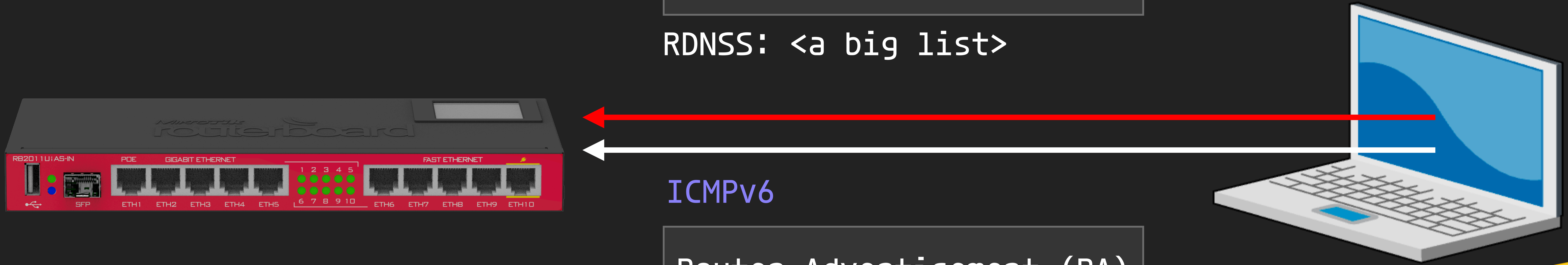
flow!overflow!overflow!



ICMPv6

Router Advertisement (RA)

RDNSS: <a big list>

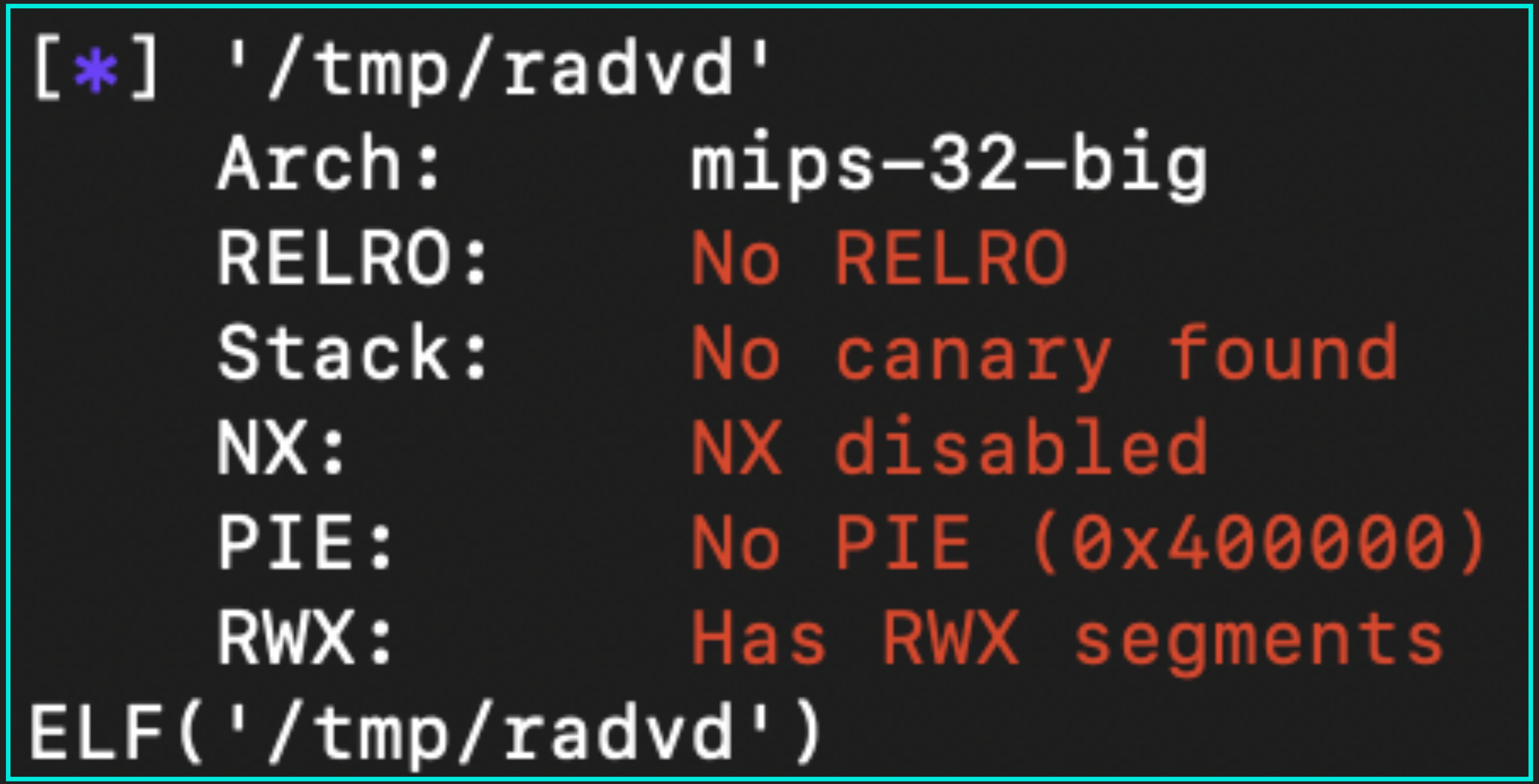


ICMPv6

Router Advertisement (RA)

RDNSS: <a big list>

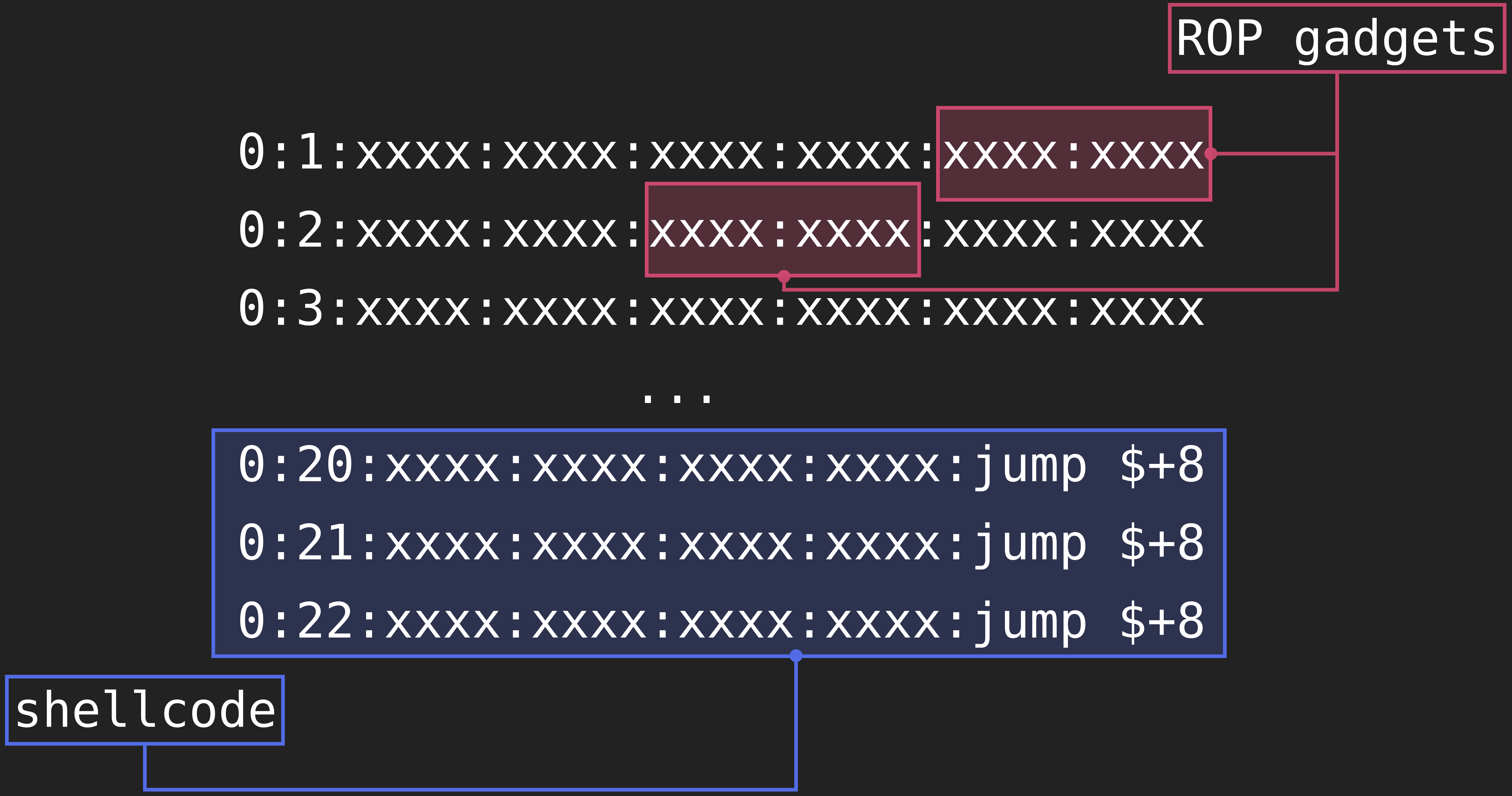
low!overflow!overflo



```
[*] '/tmp/radvd'
    Arch:     mips-32-big
    RELRO:    No RELRO
    Stack:    No canary found
    NX:       NX disabled
    PIE:      No PIE (0x400000)
    RWX:      Has RWX segments
ELF('/tmp/radvd')
```

Just overflow the shellcode on the stack and jump to it
sure grandma let's get you to bed

Credit: @__ammar2__



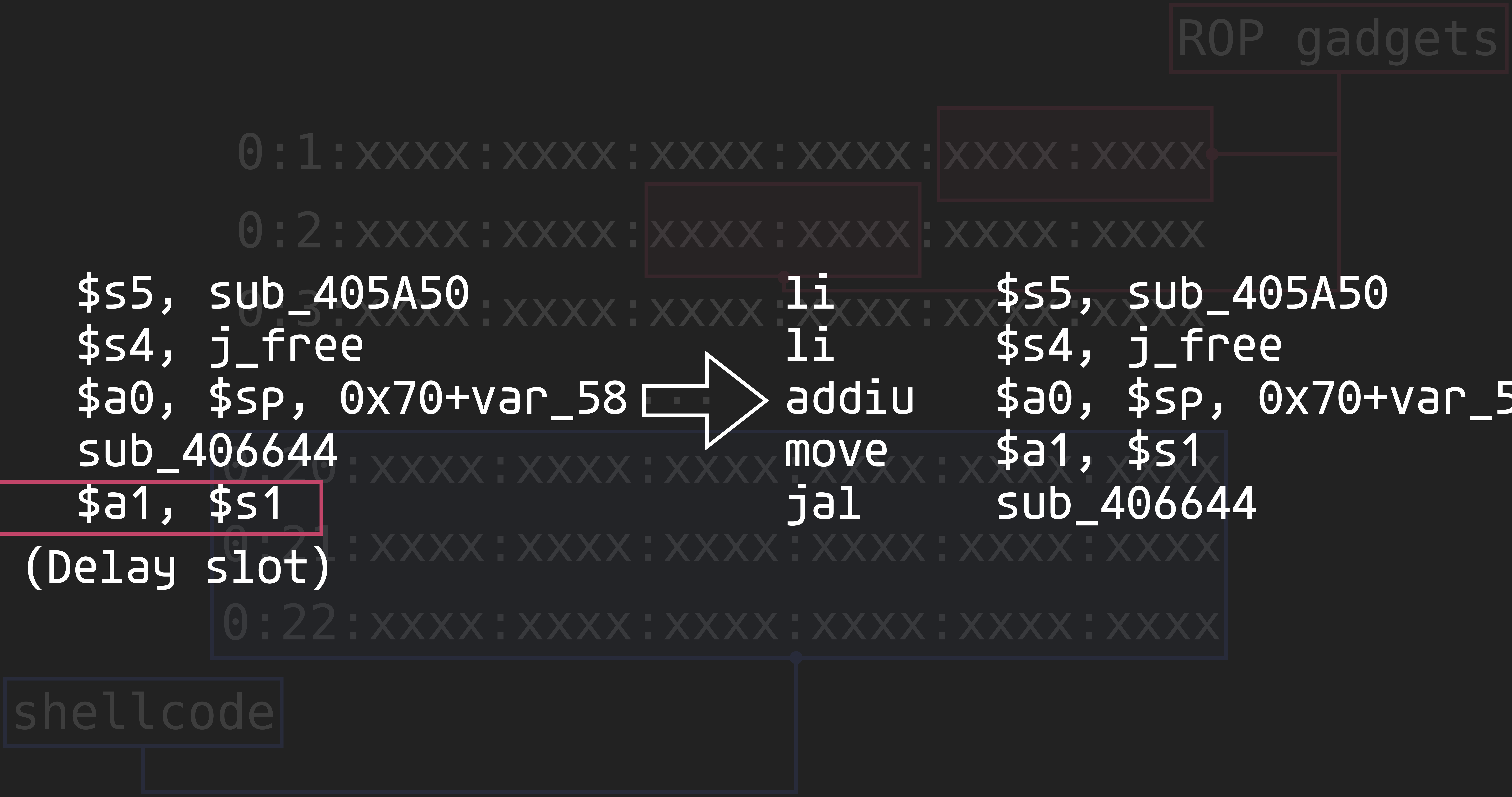
ROP gadgets

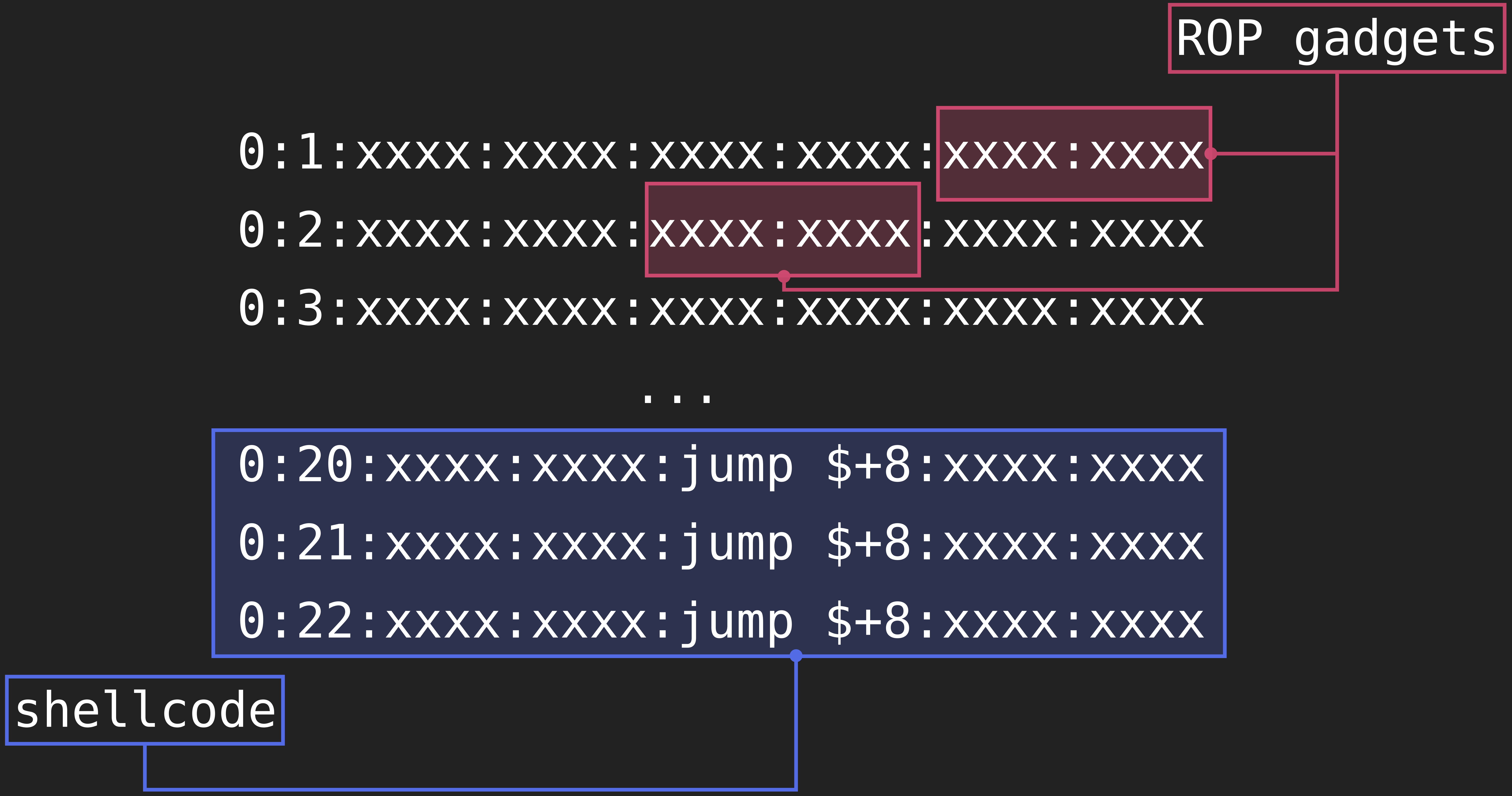
```
0:1:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:2:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:3:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx

             ...
0:20:xxxx:xxxx:xxxx:xxxx:jump $+8
0:21:xxxx:xxxx:xxxx:xxxx:jump $+8
0:22:xxxx:xxxx:xxxx:xxxx:jump $+8
```

shellcode

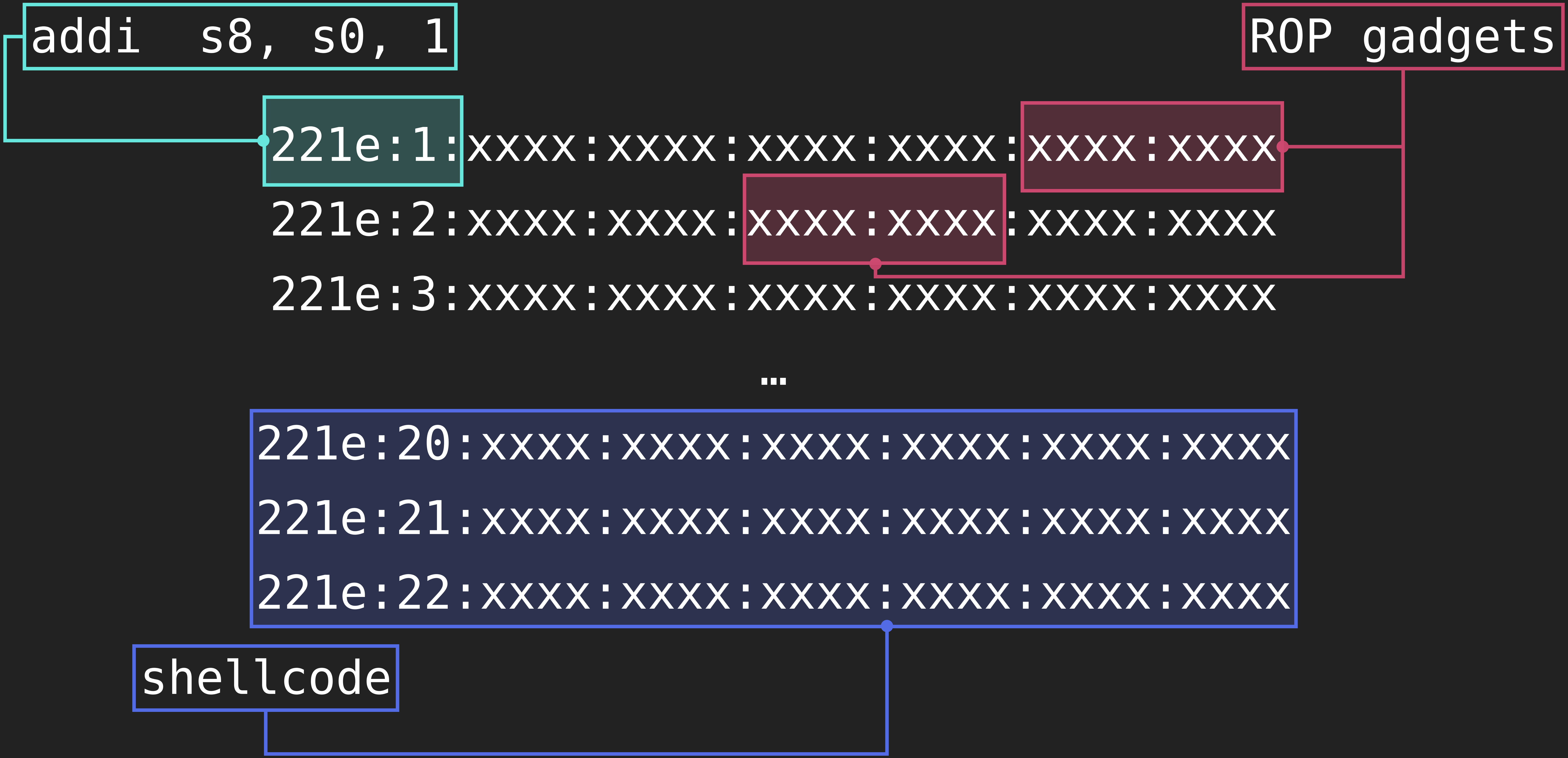
```
li      $s5, sub_405A50
li      $s4, j_free
addiu   $a0, $sp, 0x70+var_58
jal     sub_406644
move    $a1, $s1
      (Delay slot)
```

```
li      $s5, sub_405A50
li      $s4, j_free
addiu   $a0, $sp, 0x70+var_58
move    $a1, $s1
jal     sub_406644
```


ROP gadgets
0:1:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:2:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:3:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:20:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:21:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:22:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
shellcode



```
0:1:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:2:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
0:3:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx

                ...

0:20:xxxx:xxxx:jump $+8:xxxx:xxxx
0:21:xxxx:xxxx:jump $+8:xxxx:xxxx
0:22:xxxx:xxxx:jump $+8:xxxx:xxxx
```

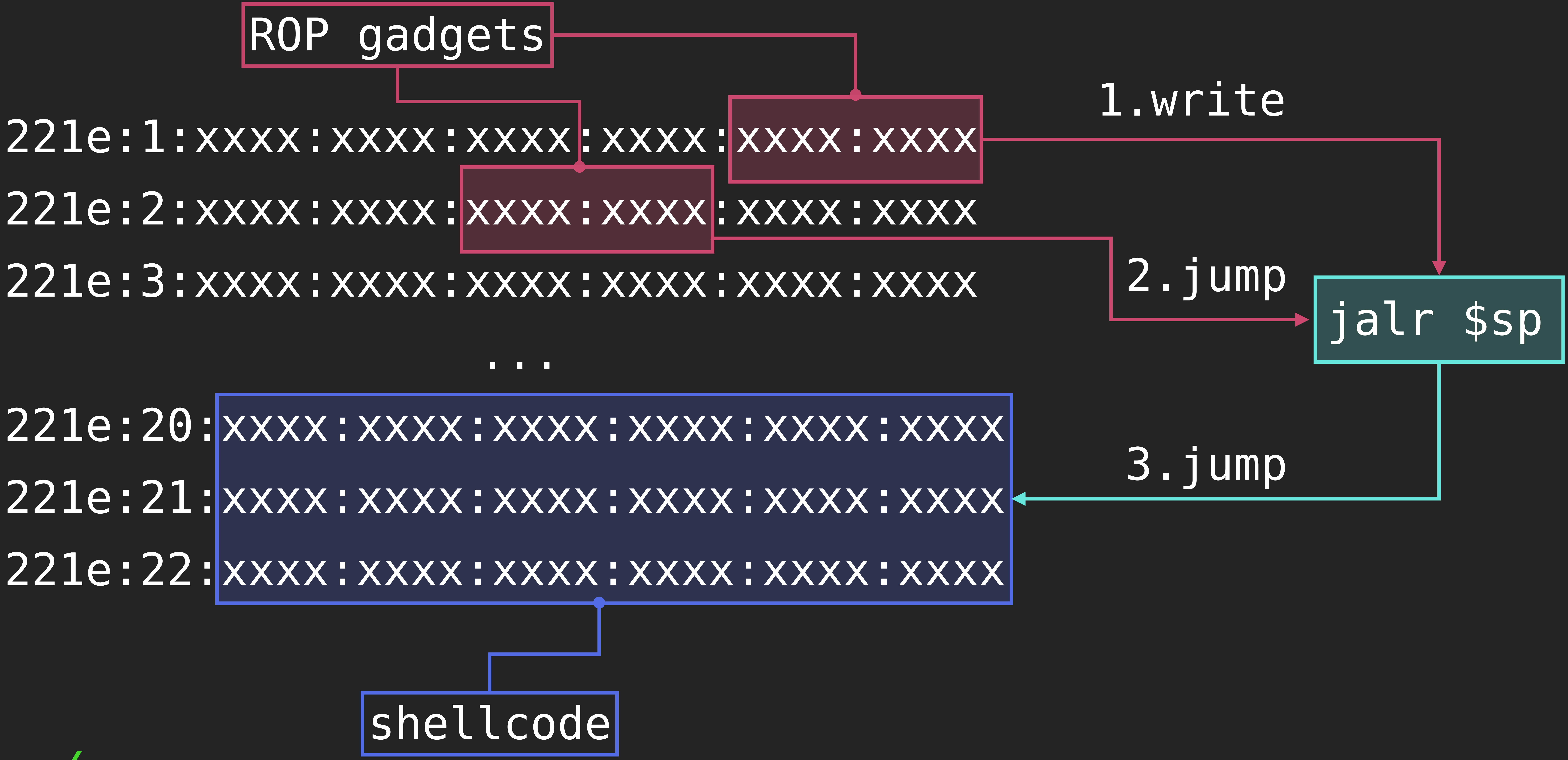


```
addi  s8, s0, 1
```

ROP gadgets

```
221e:1:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:2:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:3:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx

...

221e:20:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:21:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:22:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
```

shellcode



ROP gadgets

```
221e:1:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:2:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:3:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
...
221e:20:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:21:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
221e:22:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
```

1.write

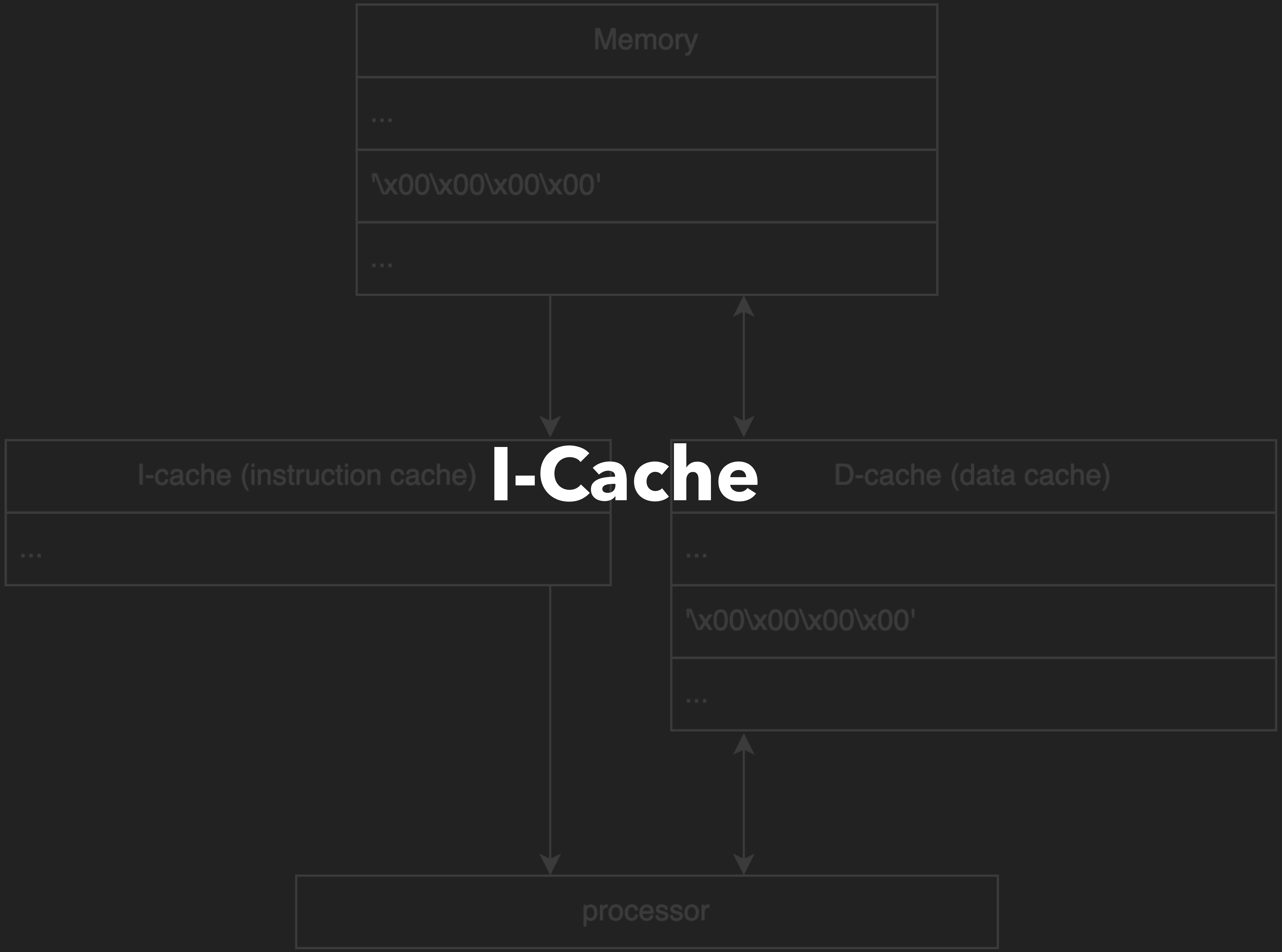
2.jump

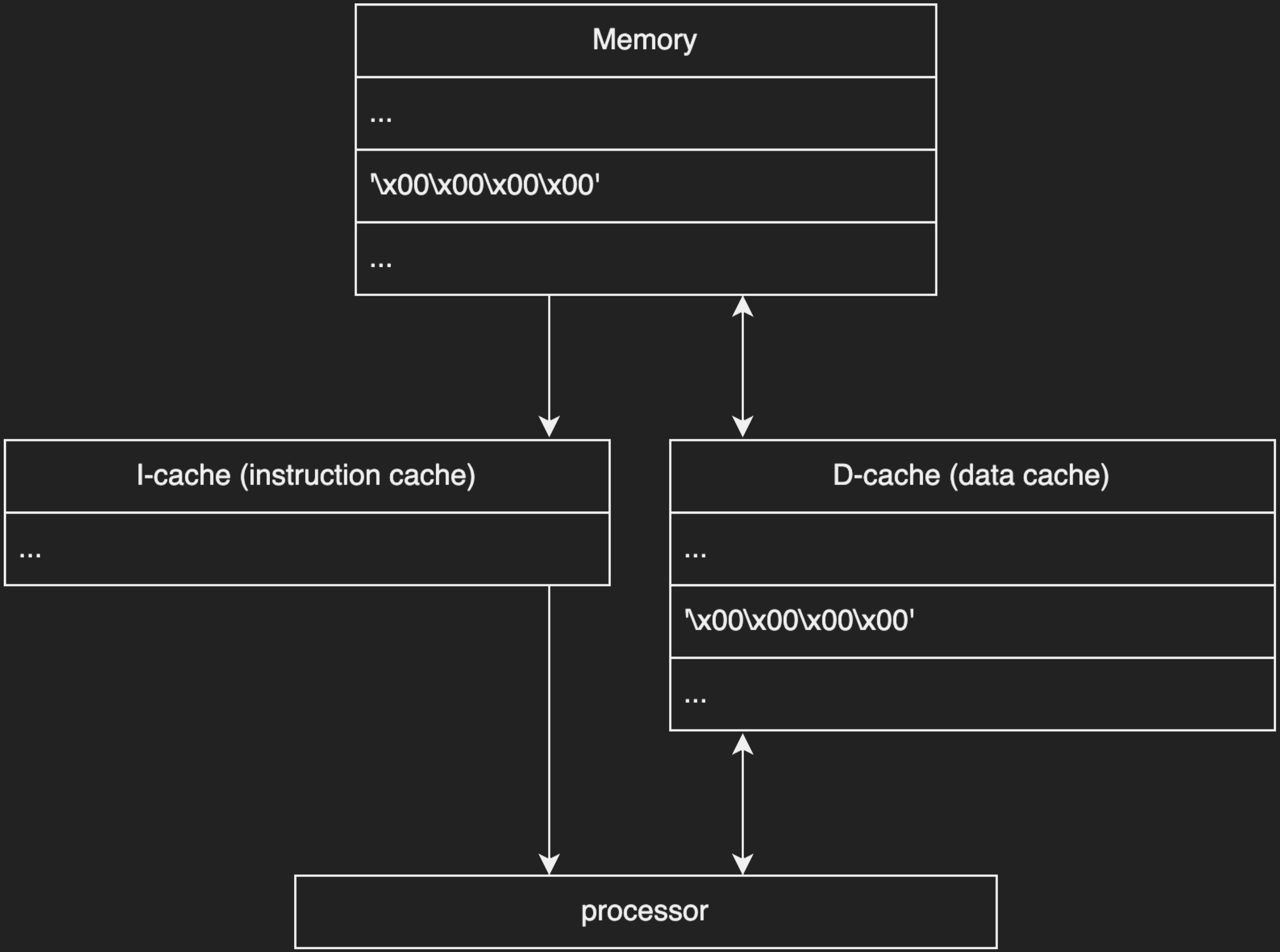
jalr $sp

3.jump

shellcode

I-Cache


Memory
...
'\x00\x00\x00\x00'
...
I-cache (instruction cache)
...
D-cache (data cache)
...
'\x00\x00\x00\x00'
...
processor



Memory

...

'\x00\x00\x00\x00'

...

I-cache (instruction cache)

...

D-cache (data cache)

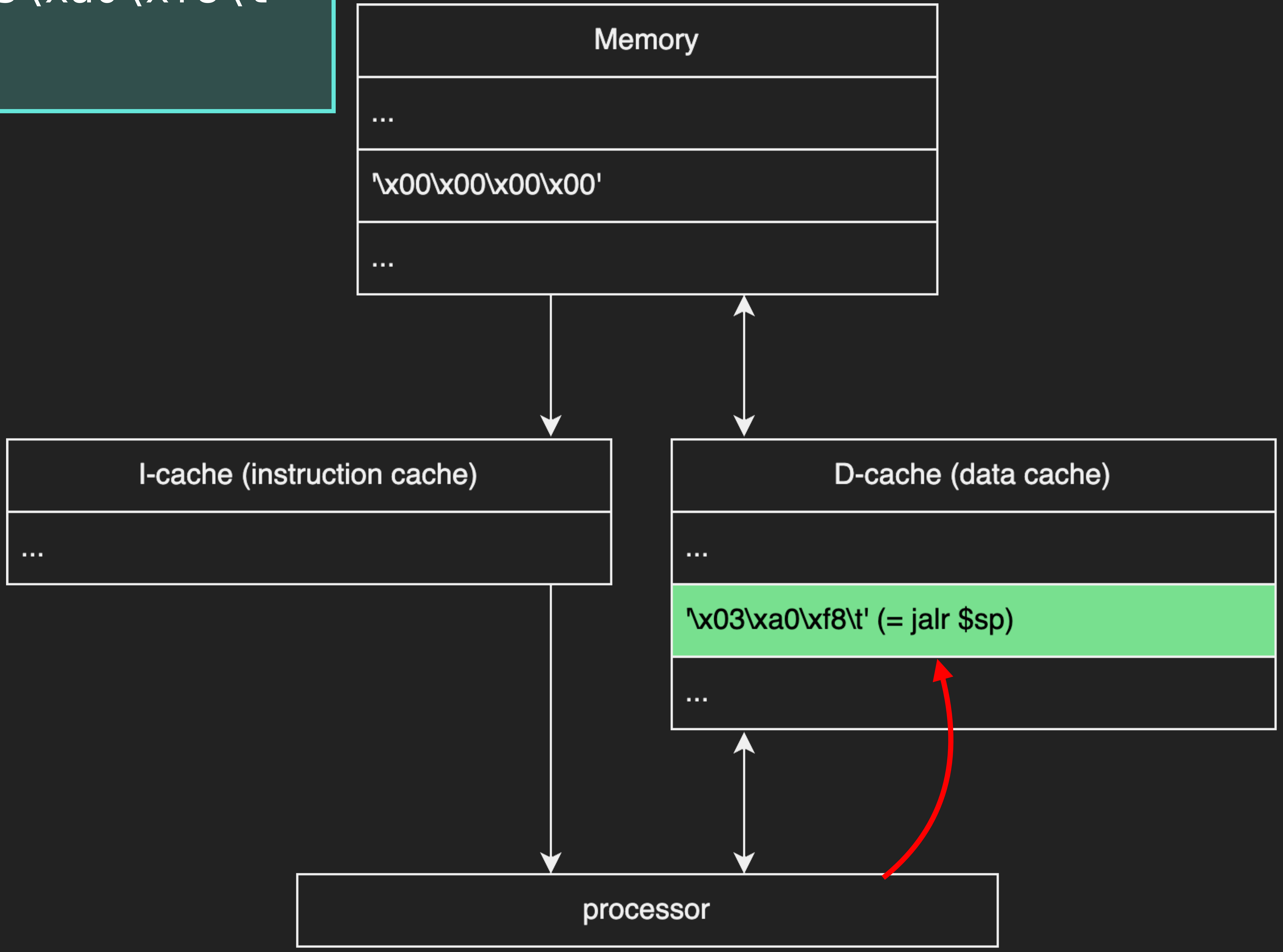
...

'\x00\x00\x00\x00'

...

processor

```
write adr,'\x03\xa0\xf8\t'
```



Memory

...

'\x00\x00\x00\x00'

...

I-cache (instruction cache)

...

D-cache (data cache)

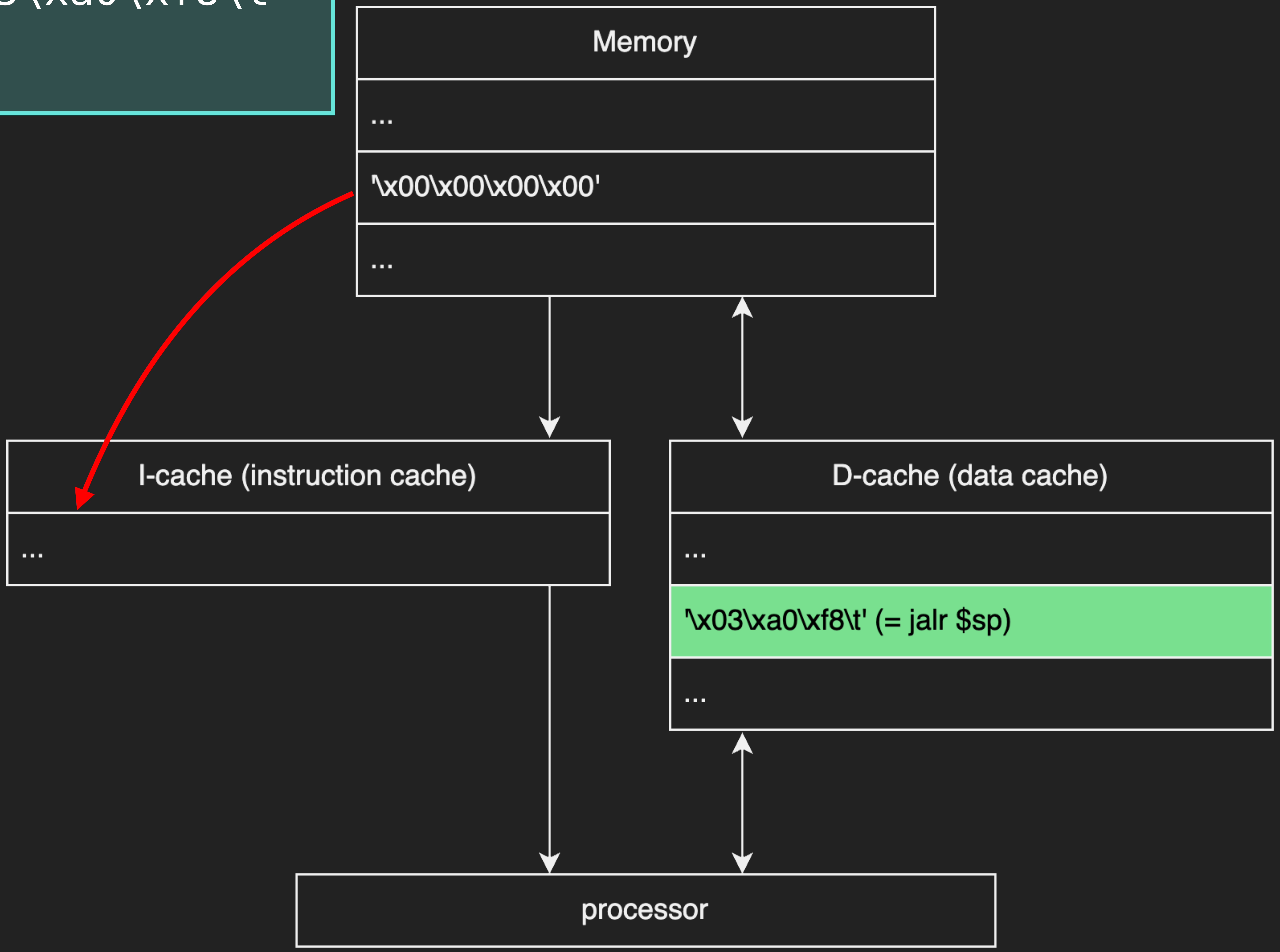
...

'\x03\xa0\xf8\t' (= jalr $sp)

...

processor

```
write adr,’\x03\xa0\xf8\t’
jump adr
```



Memory

...

'\x00\x00\x00\x00'

...

I-cache (instruction cache)

...

D-cache (data cache)

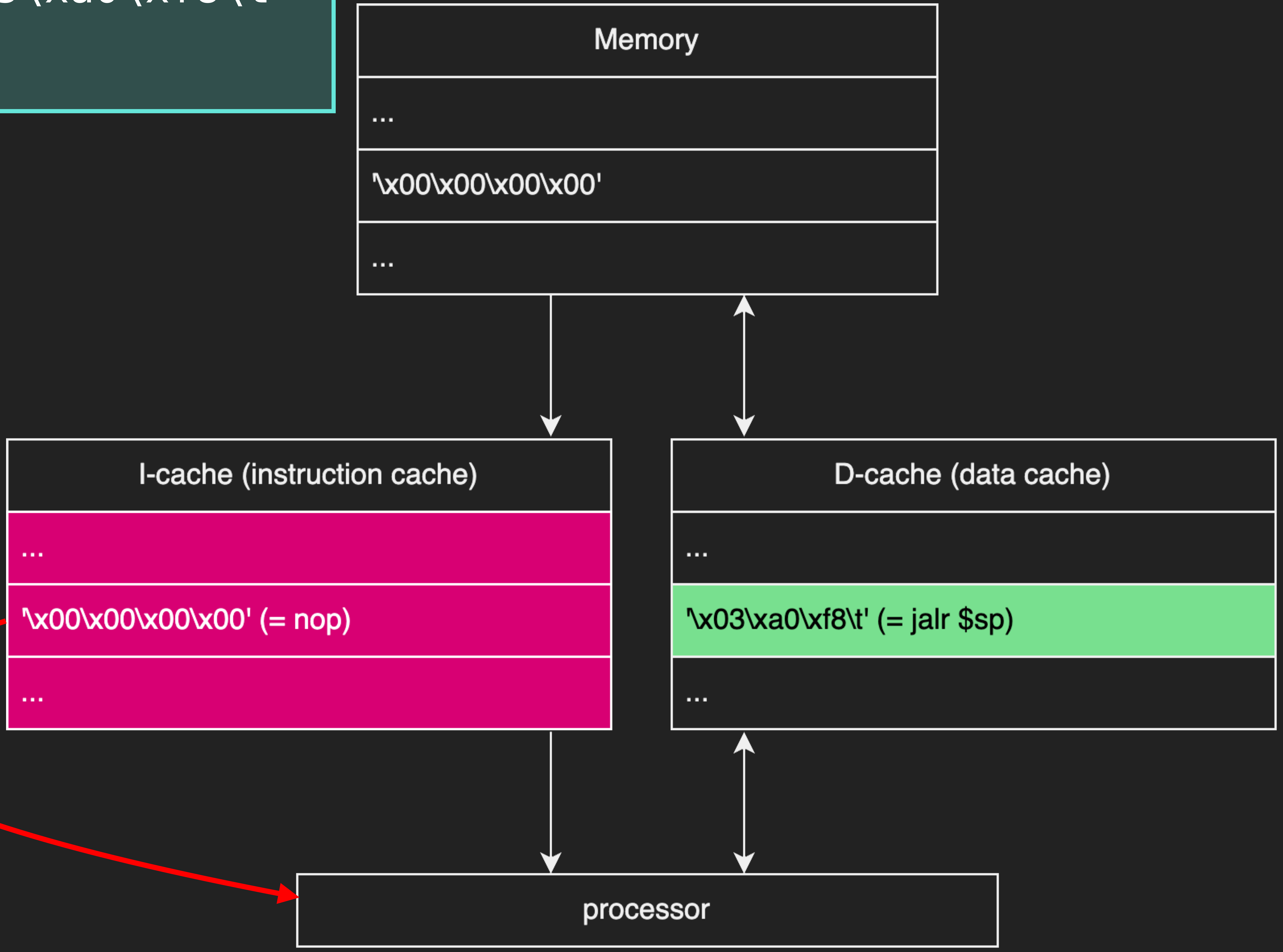
...

'\x03\xa0\xf8\t' (= jalr $sp)

...

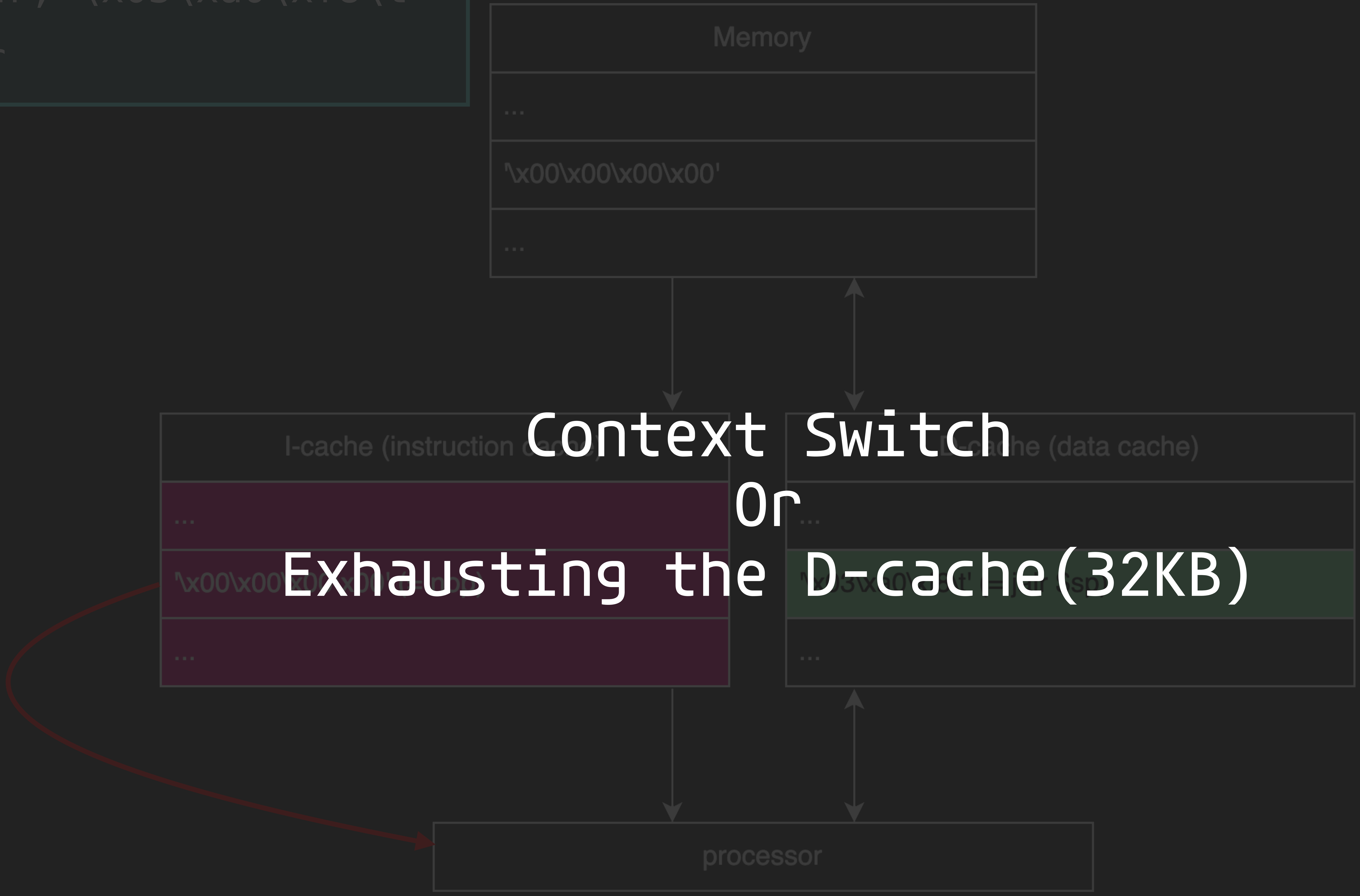
processor

```
write adr,'\x03\xa0\xf8\t'
jump adr
```



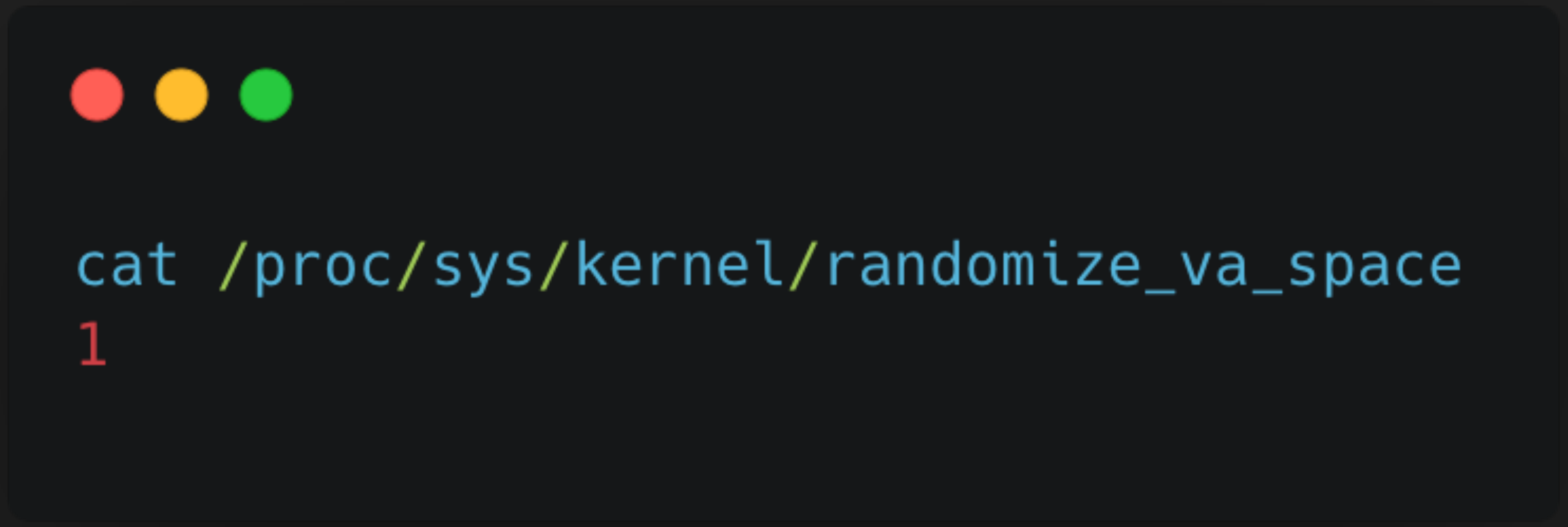
Memory
...
'\x00\x00\x00\x00'
...
I-cache (instruction cache)
...
'\x00\x00\x00\x00' (= nop)
...
D-cache (data cache)
...
'\x03\xa0\xf8\t' (= jalr $sp)
...
processor

```
write adr,'\x03\xa0\xf8\t'
jump adr
```

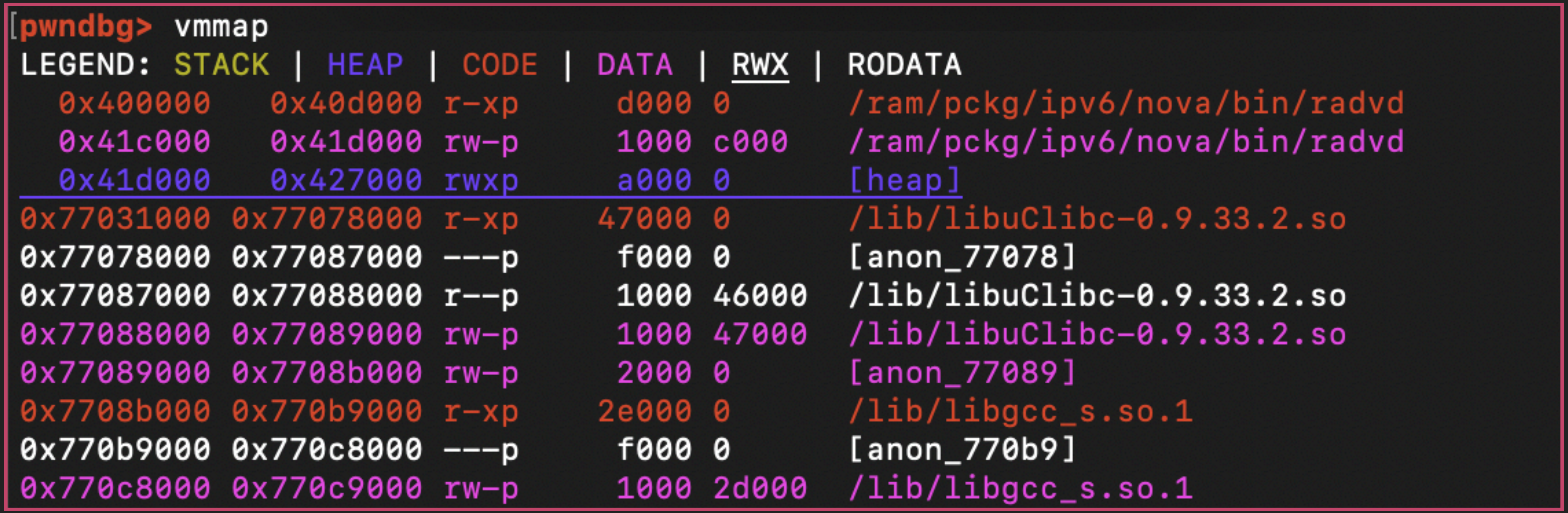


Context Switch
Or
Exhausting the D-cache(32KB)

DEVCORE

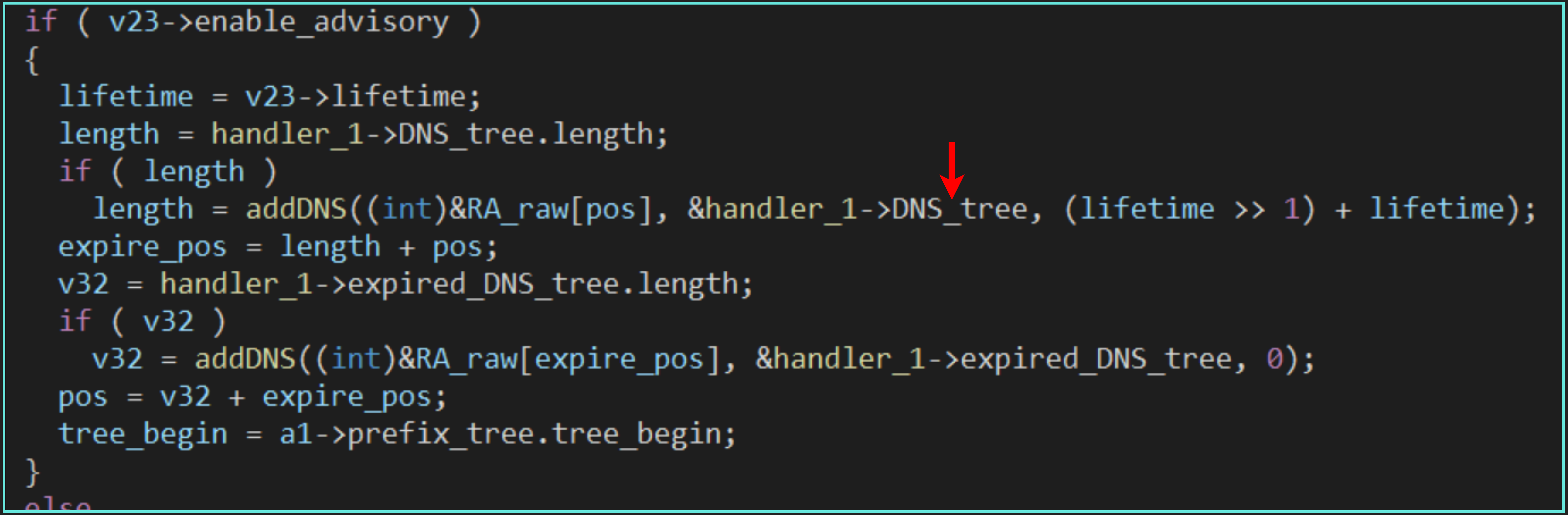


```
cat /proc/sys/kernel/randomize_va_space
1
```

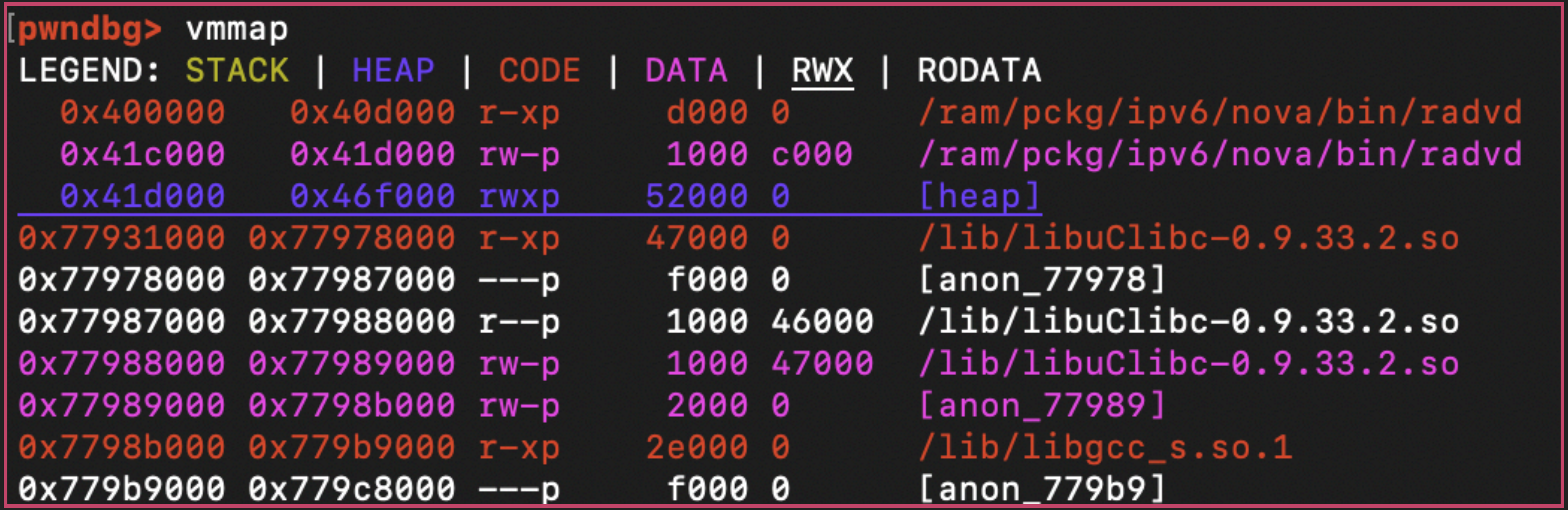


```
[pwndbg> vmmap
LEGEND: STACK | HEAP | CODE | DATA | RWX | RODATA
  0x400000   0x40d000 r-xp     d000 0      /ram/pckg/ipv6/nova/bin/radvd
  0x41c000   0x41d000 rw-p     1000 c000   /ram/pckg/ipv6/nova/bin/radvd
  0x41d000   0x427000 rwxp     a000 0      [heap]
0x77031000 0x77078000 r-xp    47000 0      /lib/libuClibc-0.9.33.2.so
0x77078000 0x77087000 ---p     f000 0      [anon_77078]
0x77087000 0x77088000 r--p     1000 46000  /lib/libuClibc-0.9.33.2.so
0x77088000 0x77089000 rw-p     1000 47000  /lib/libuClibc-0.9.33.2.so
0x77089000 0x7708b000 rw-p     2000 0      [anon_77089]
0x7708b000 0x770b9000 r-xp    2e000 0      /lib/libgcc_s.so.1
0x770b9000 0x770c8000 ---p     f000 0      [anon_770b9]
0x770c8000 0x770c9000 rw-p     1000 2d000  /lib/libgcc_s.so.1
```

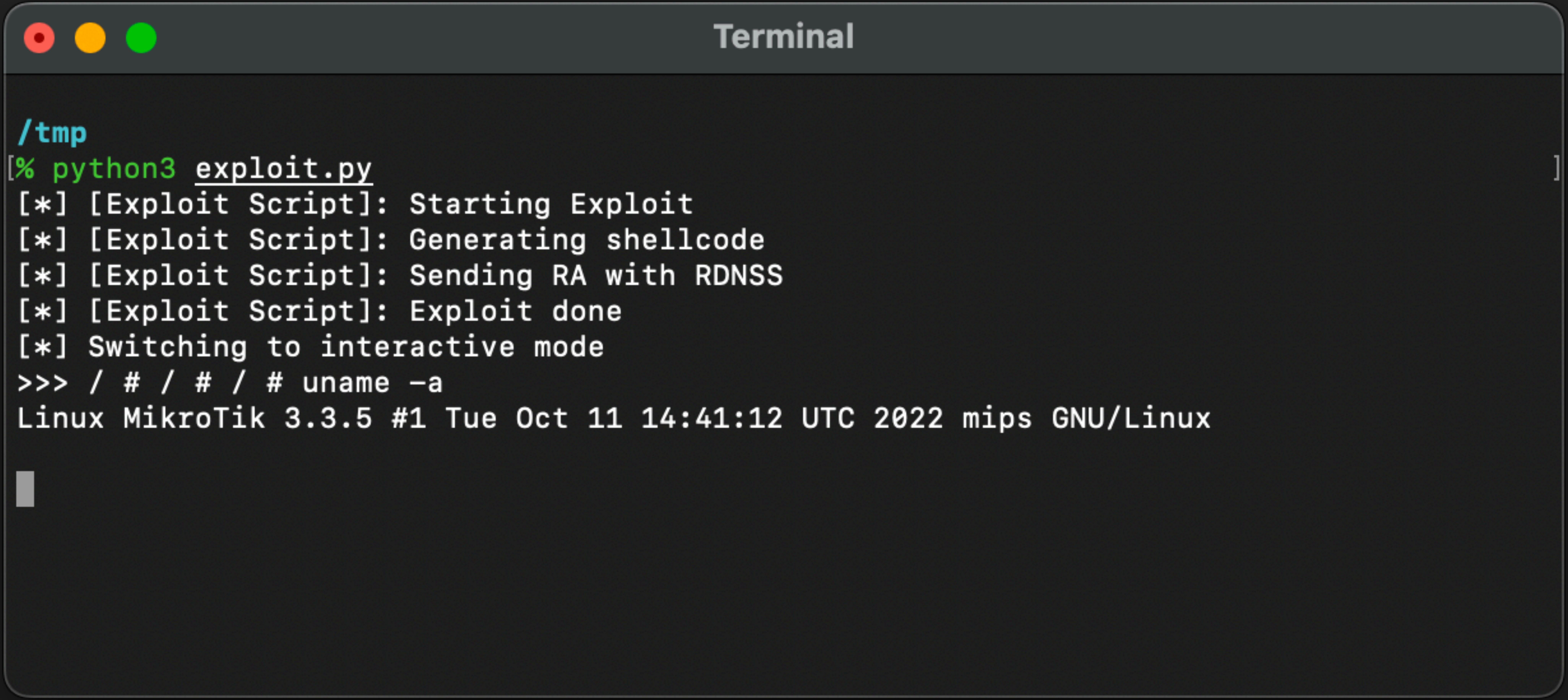
RADVD



```
if ( v23->enable_advisory )
{
  lifetime = v23->lifetime;
  length = handler_1->DNS_tree.length;
  if ( length )
    length = addDNS((int)&RA_raw[pos], &handler_1->DNS_tree, (lifetime >> 1) + lifetime);
  expire_pos = length + pos;
  v32 = handler_1->expired_DNS_tree.length;
  if ( v32 )
    v32 = addDNS((int)&RA_raw[expire_pos], &handler_1->expired_DNS_tree, 0);
  pos = v32 + expire_pos;
  tree_begin = a1->prefix_tree.tree_begin;
}
else
```



```
[pwndbg> vmmap
LEGEND: STACK | HEAP | CODE | DATA | RWX | RODATA
  0x400000   0x40d000 r-xp     d000 0      /ram/pckg/ipv6/nova/bin/radvd
  0x41c000   0x41d000 rw-p     1000 c000   /ram/pckg/ipv6/nova/bin/radvd
  0x41d000   0x46f000 rwxp    52000 0      [heap]
0x77931000 0x77978000 r-xp    47000 0      /lib/libuClibc-0.9.33.2.so
0x77978000 0x77987000 ---p     f000 0      [anon_77978]
0x77987000 0x77988000 r--p     1000 46000  /lib/libuClibc-0.9.33.2.so
0x77988000 0x77989000 rw-p     1000 47000  /lib/libuClibc-0.9.33.2.so
0x77989000 0x7798b000 rw-p     2000 0      [anon_77989]
0x7798b000 0x779b9000 r-xp    2e000 0      /lib/libgcc_s.so.1
0x779b9000 0x779c8000 ---p     f000 0      [anon_779b9]
```



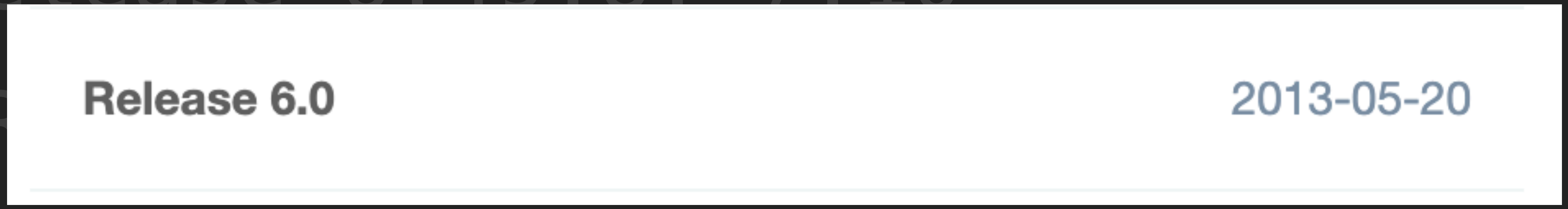
```
/tmp
[% python3 exploit.py                                                    ]
[*] [Exploit Script]: Starting Exploit
[*] [Exploit Script]: Generating shellcode
[*] [Exploit Script]: Sending RA with RDNSS
[*] [Exploit Script]: Exploit done
[*] Switching to interactive mode
>>> / # / # / # uname -a
Linux MikroTik 3.3.5 #1 Tue Oct 11 14:41:12 UTC 2022 mips GNU/Linux
```

CVE-2023-32154

- Fixed at:
  - Long-term Release 6.48.7
  - Stable Release 6.49.8, 7.10
  - Testing Release 7.10rc6
- The vulnerable code has existed at least since v6.0

CVE-2023-32154

- Fixed at:
  - Long-term Release 6.48.7
  - Stable Release 6.49.8, 7.10
  - Testing R



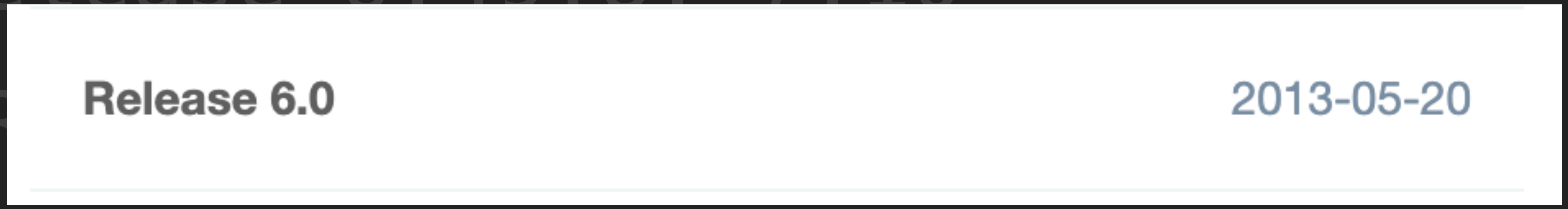
Release 6.0 2013-05-20

- The vulnerable code has existed at least since v6.0

CVE-2023-32154

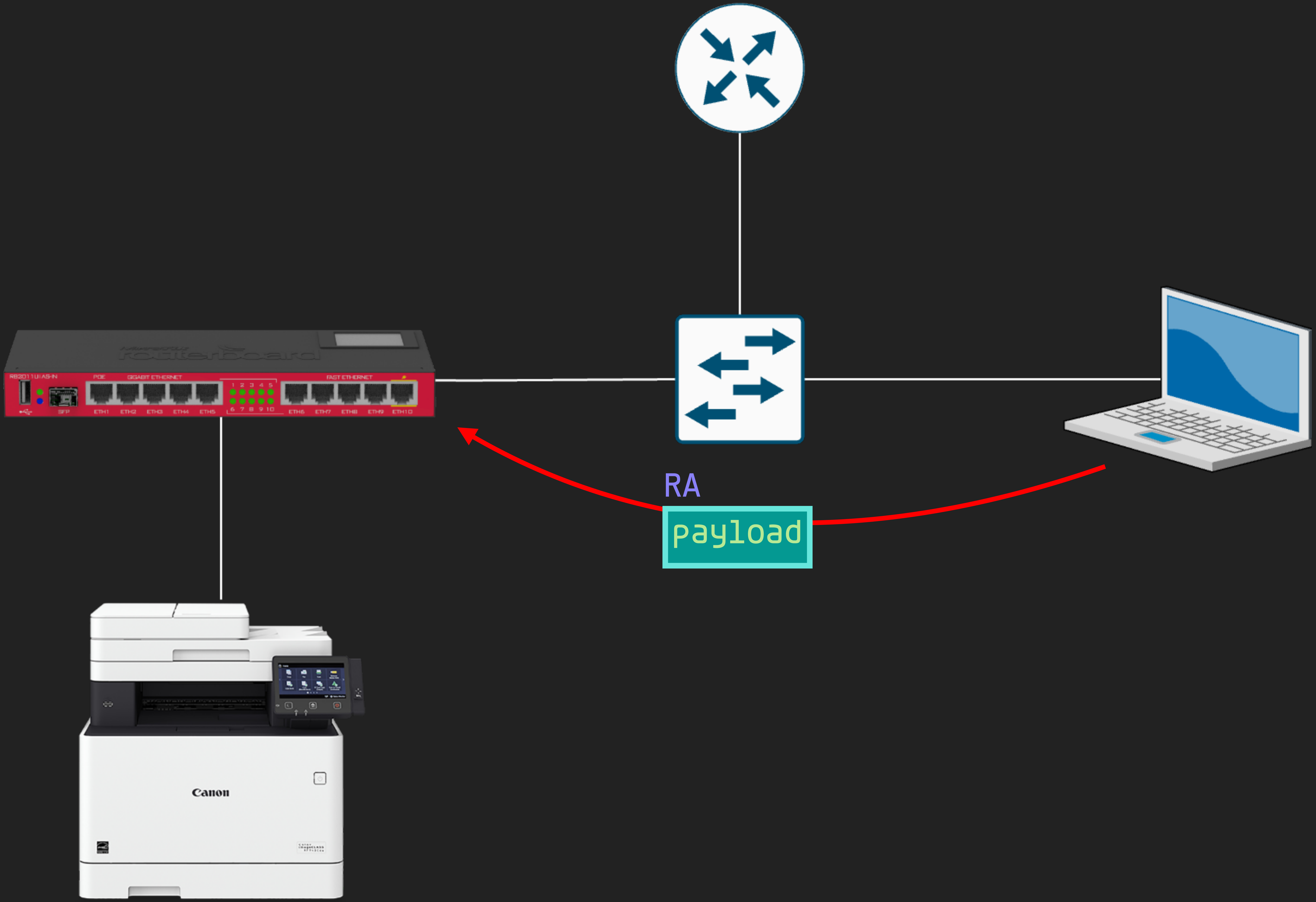
- Fixed at:
  - Long-term Release 6.48.7
  - Stable Release 6.49.8, 7.10
  - Testing R
- The vulnerable code has existed at least since v6.0

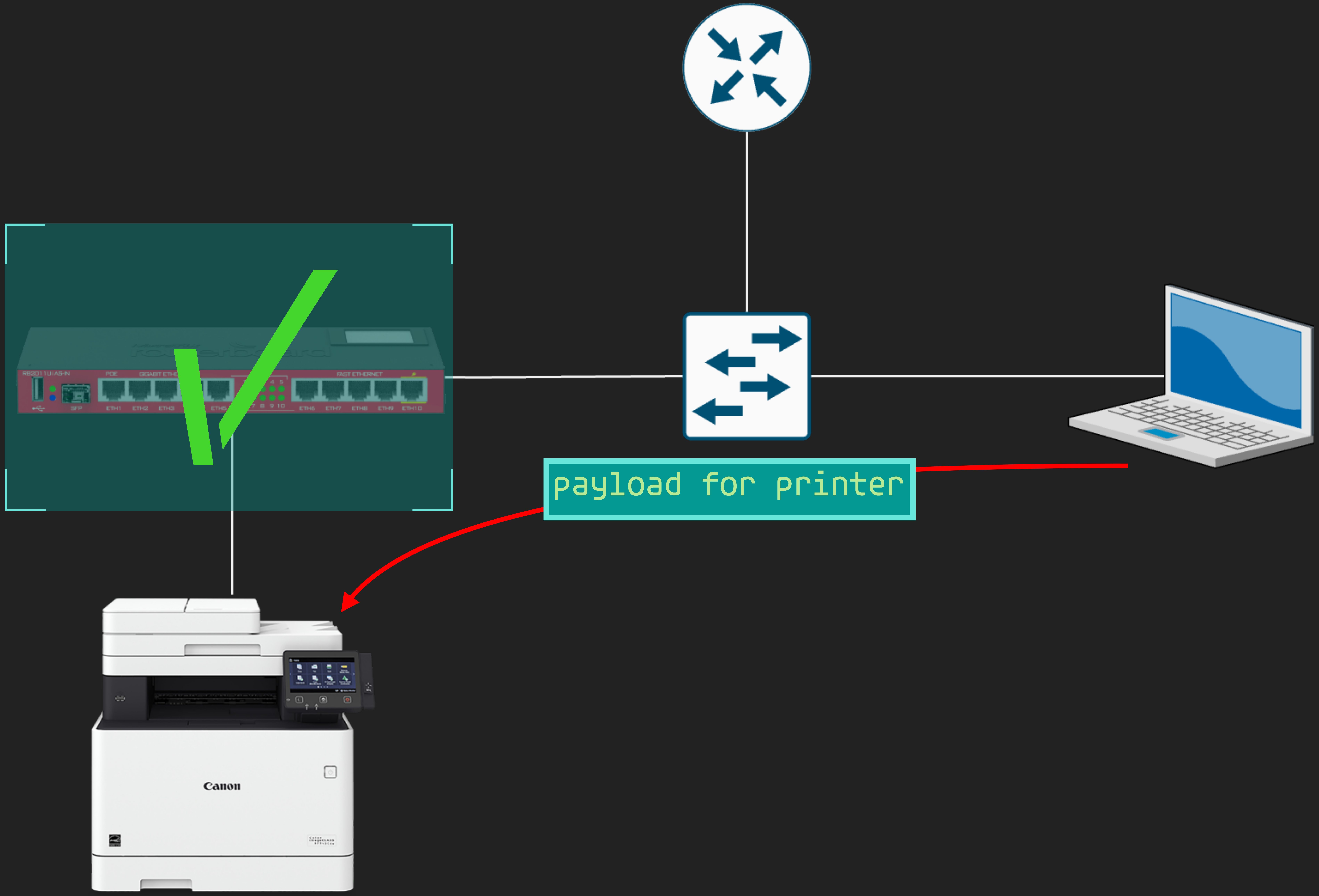
No one with sanity
would like to dive into the details of Nova Binary



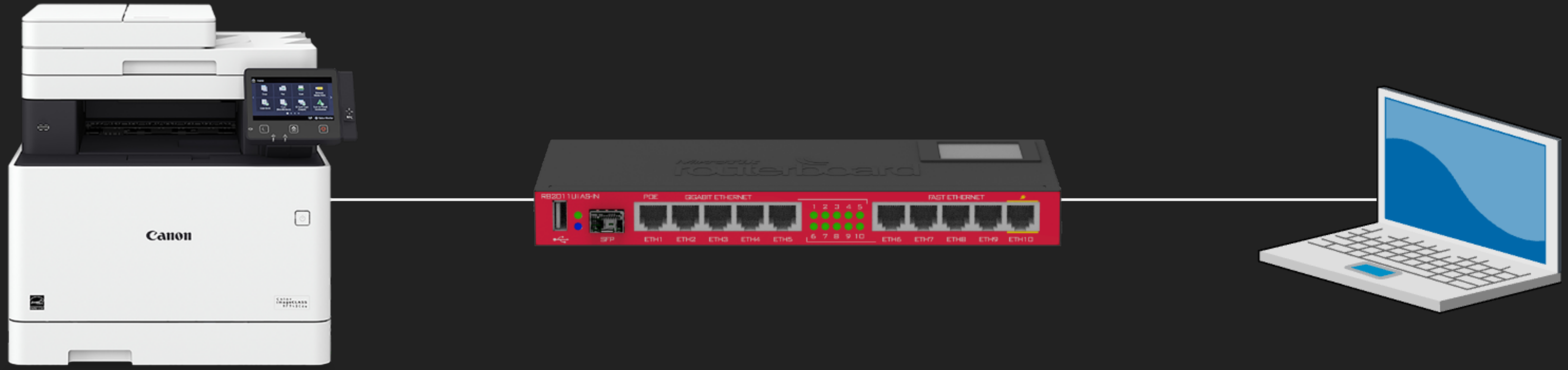
Release 6.0 2013-05-20

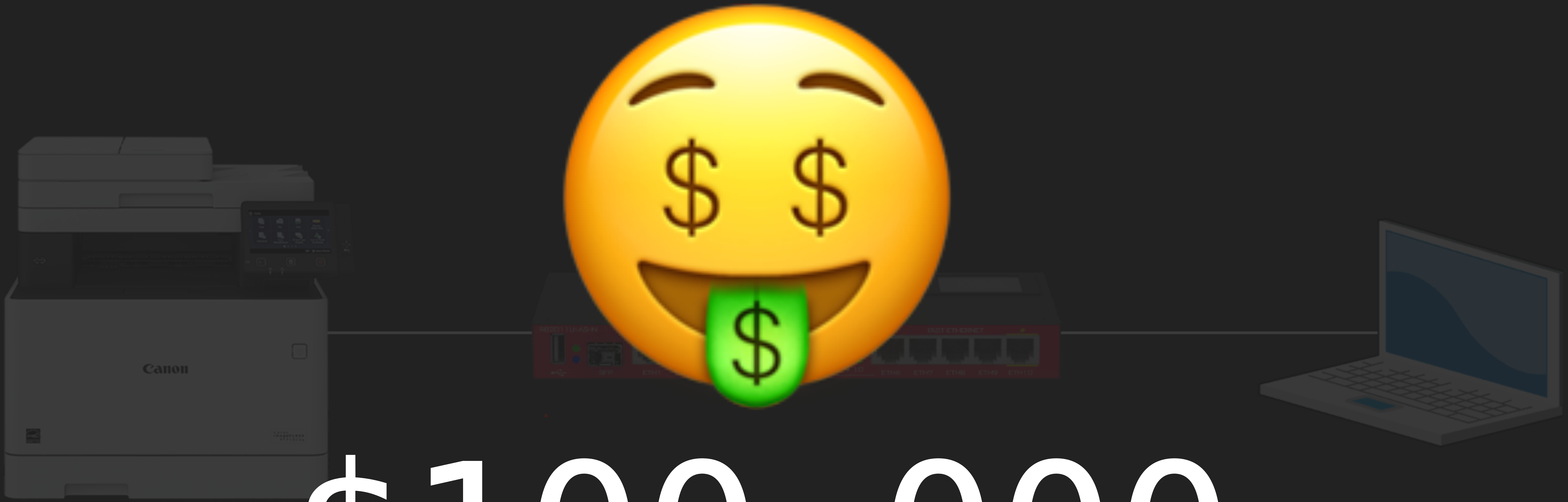
Q.E.D.


RA
payload
Canon



payload for printer


Canon
POE
GIGABIT ETHERNET
FAST ETHERNET
SFP
ETH1
ETH2
ETH3
ETH4
ETH5
ETH6
ETH7
ETH8
ETH9
ETH10

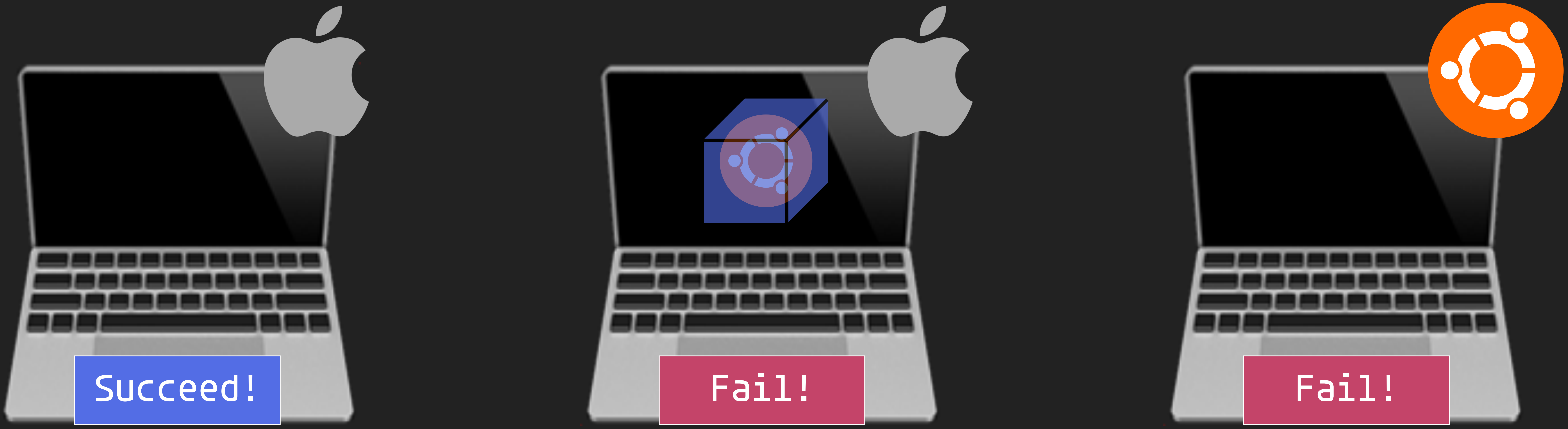


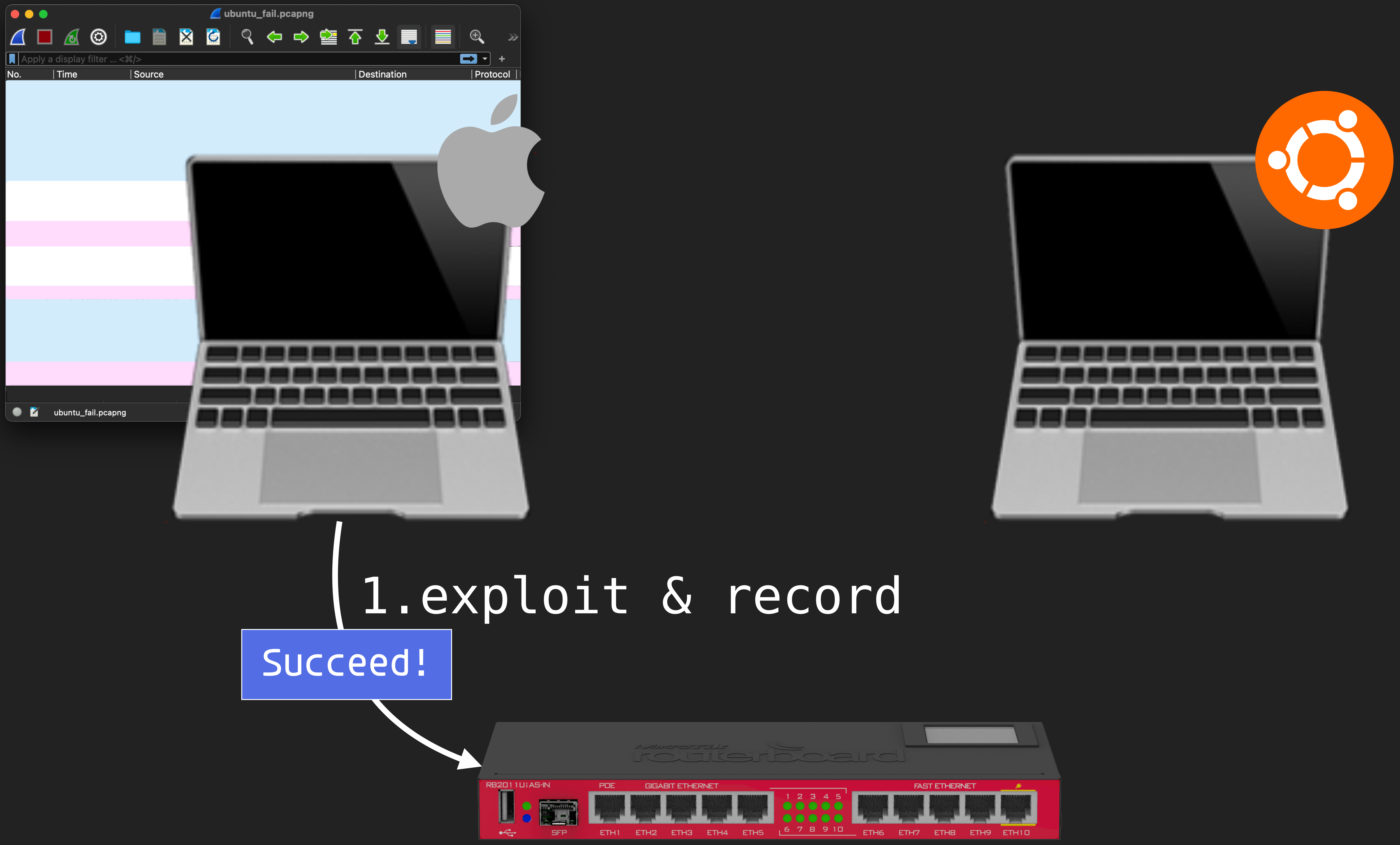
$100,000

But...

But

- Our exploit only worked on MacOS and failed on Ubuntu, whether it’s a VM or not.





ubuntu_fail.pcapng

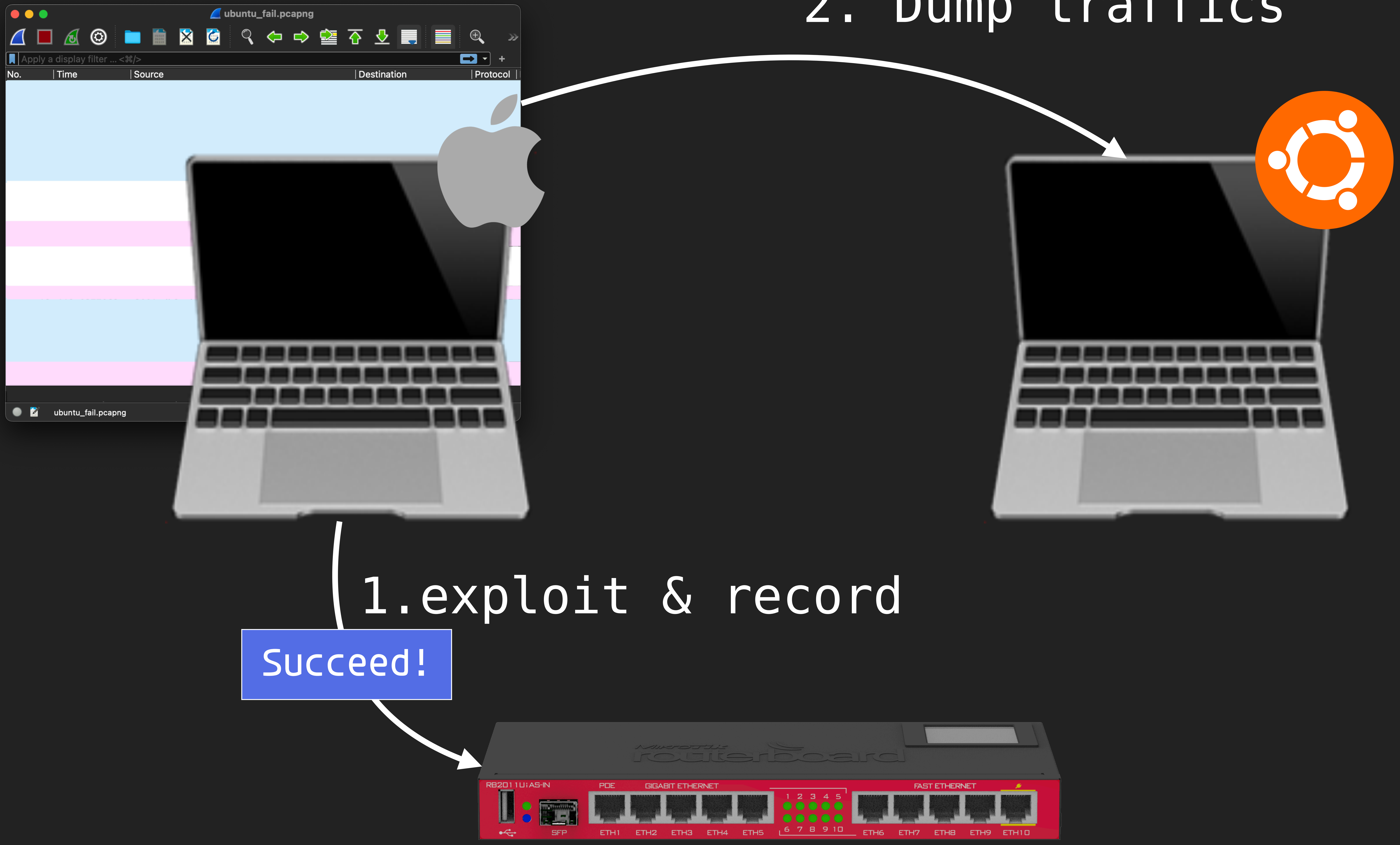
Apply a display filter ... <⌘/>

No. | Time | Source | Destination | Protocol

ubuntu_fail.pcapng

1.exploit & record

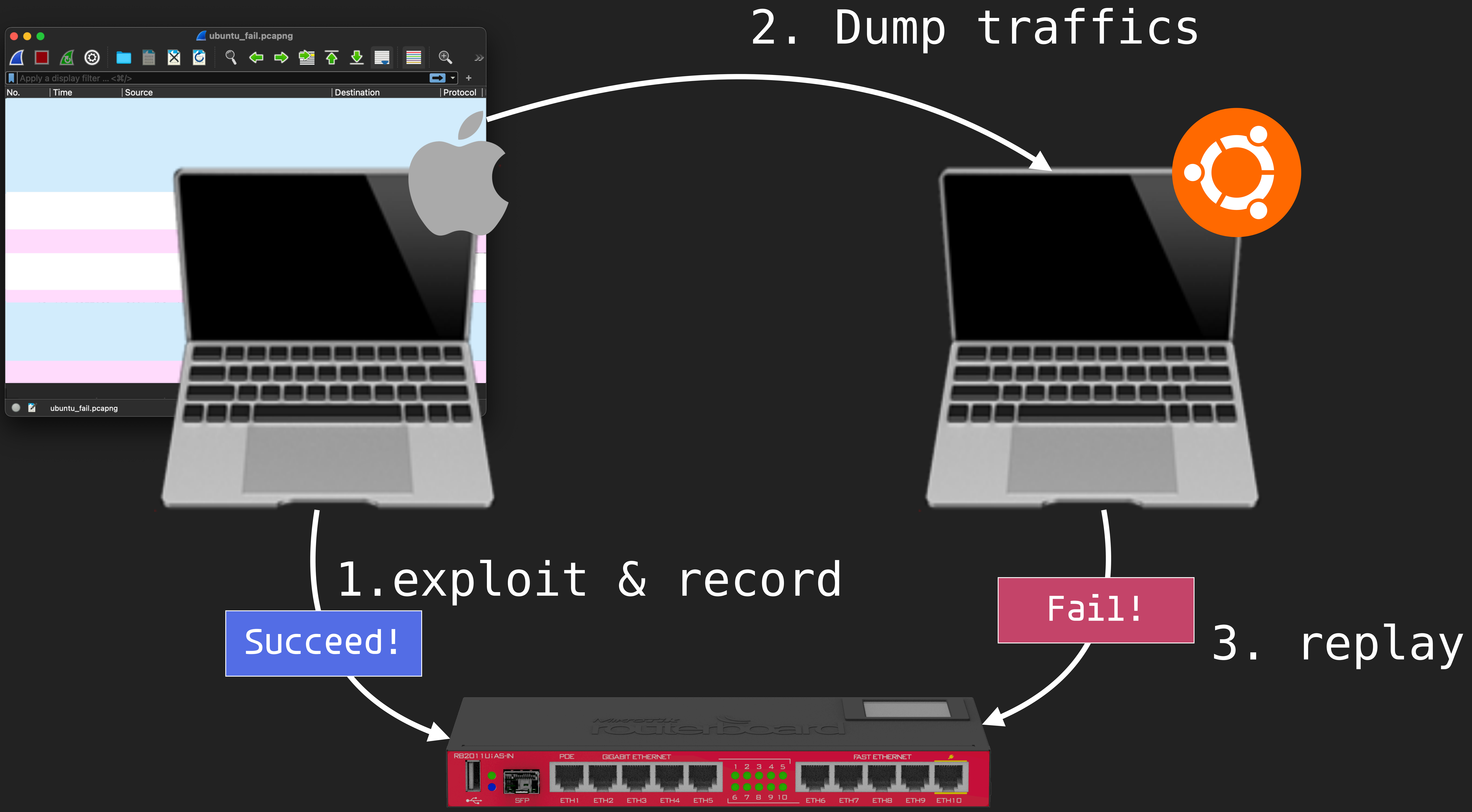
Succeed!



2. Dump traffics

1.exploit & record

Succeed!



2. Dump traffics

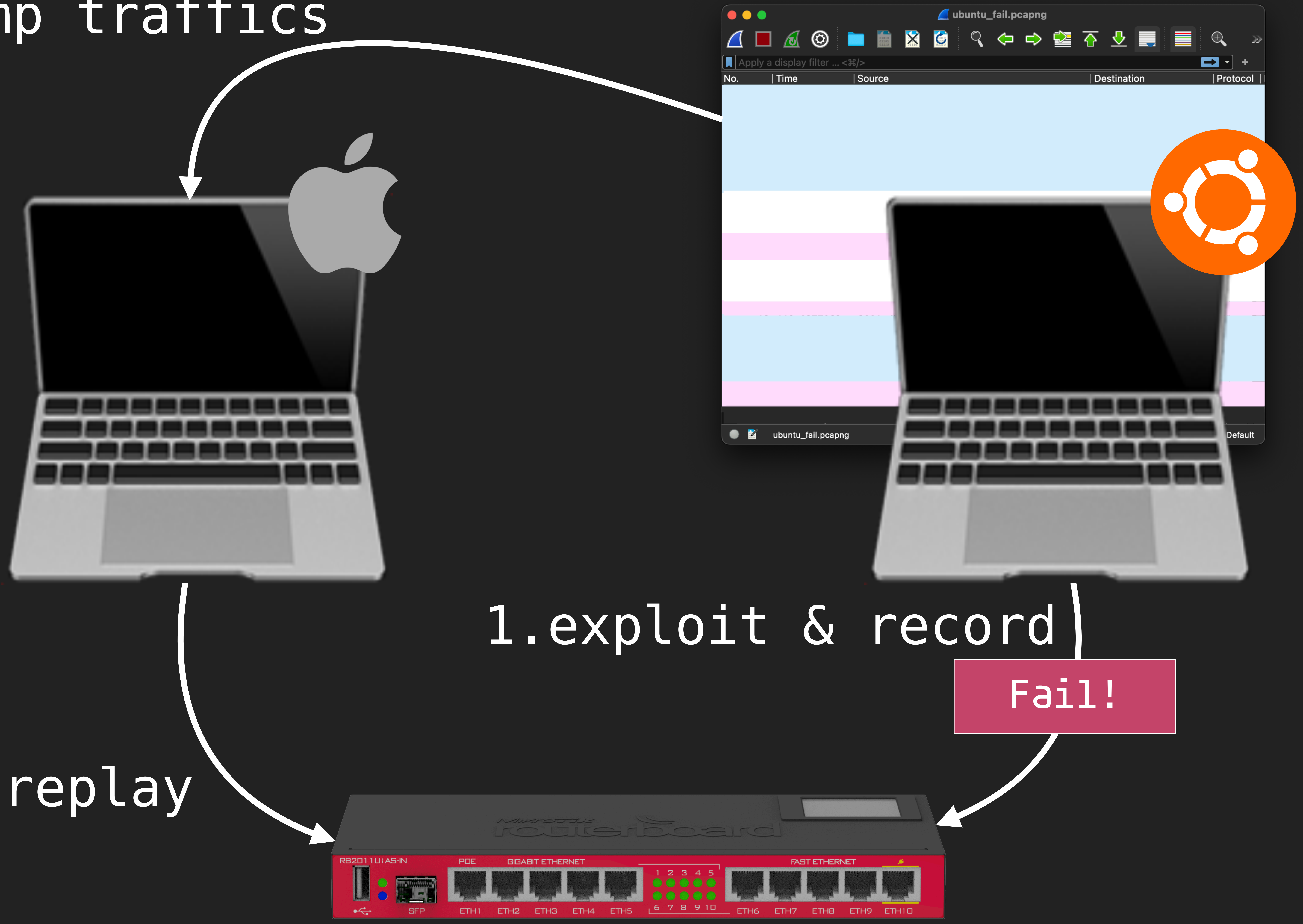
1.exploit & record

Succeed!

Fail!

3. replay

2. Dump traffics

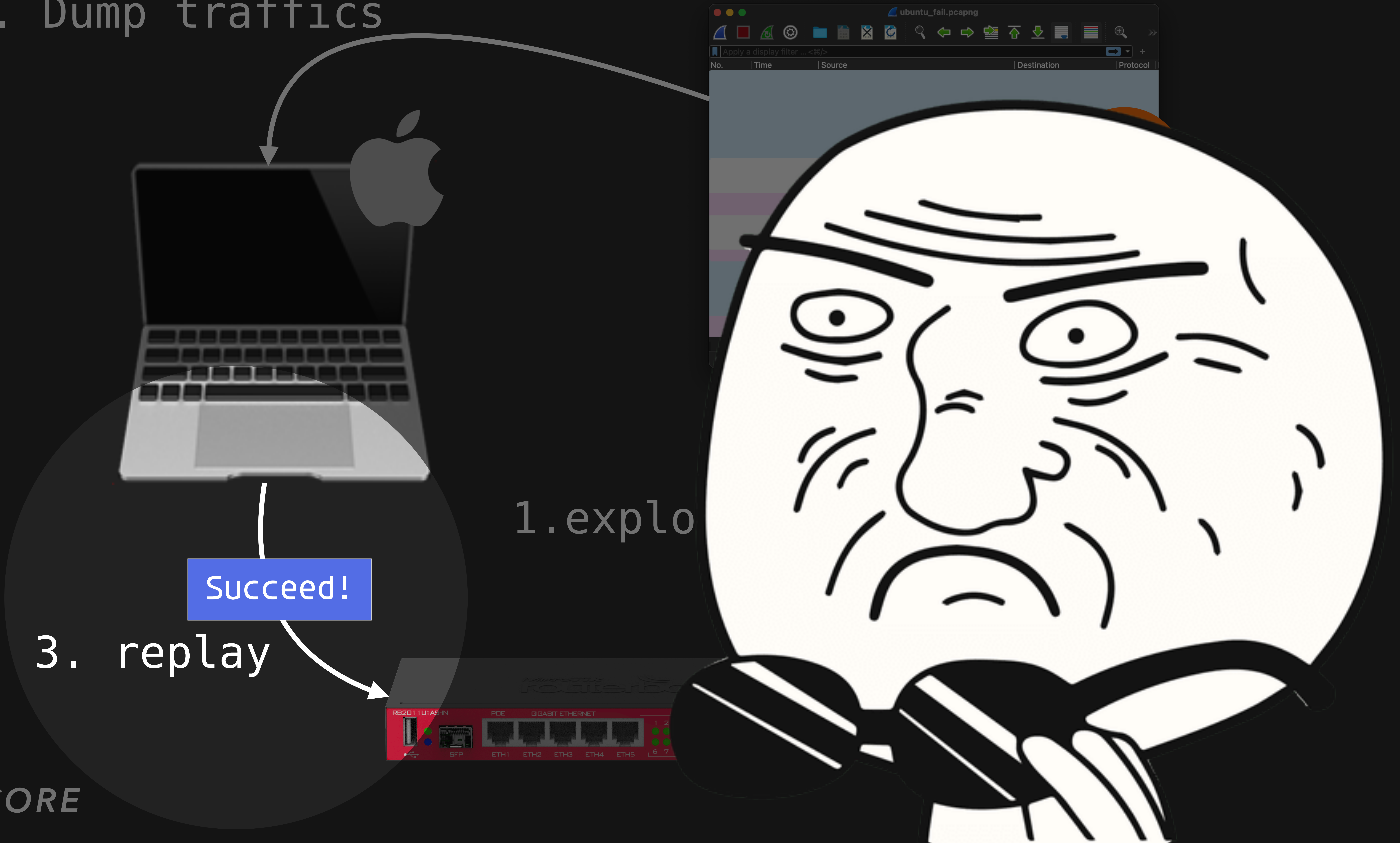


1.exploit & record

Fail!

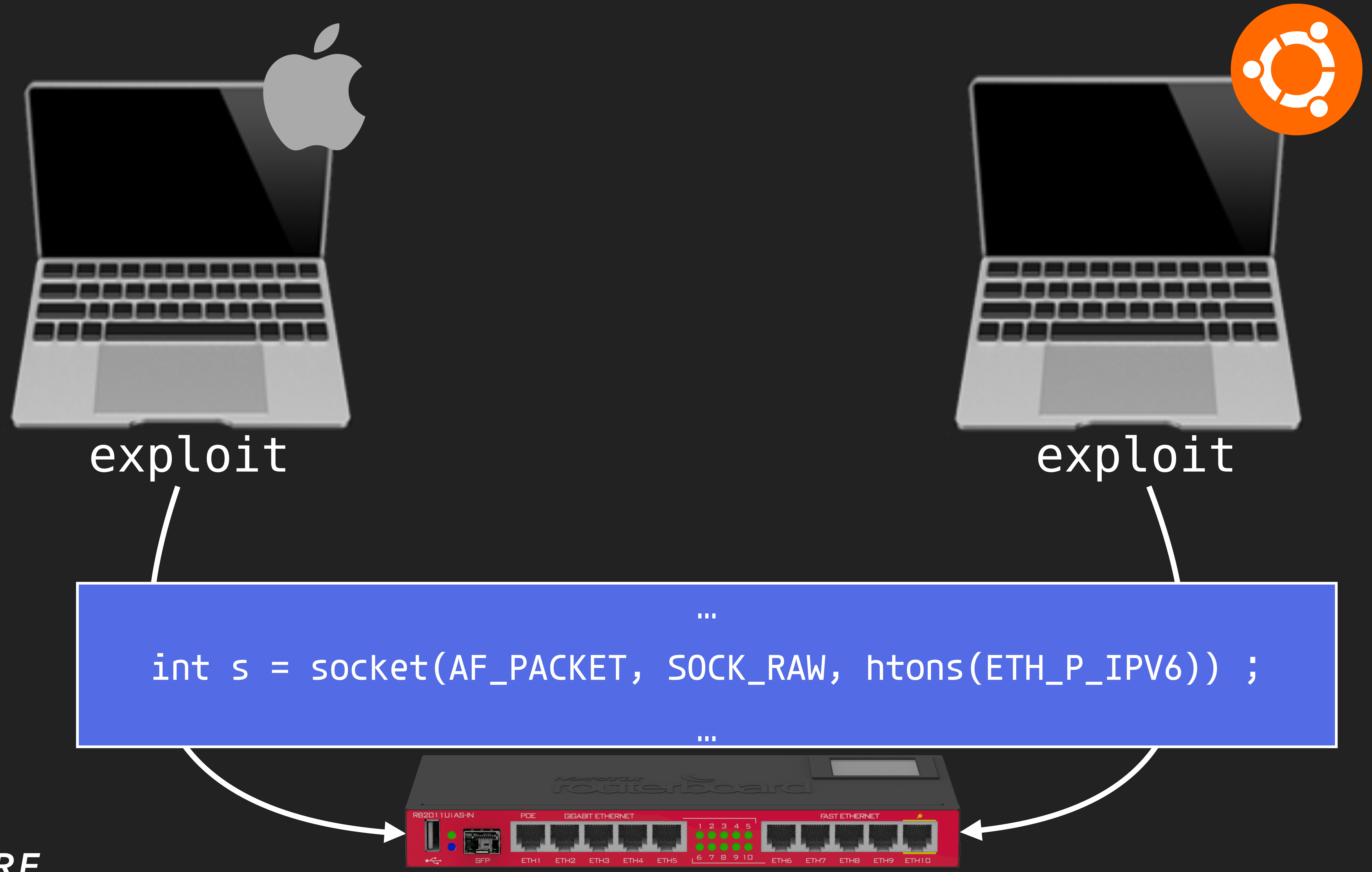
3. replay

2. Dump traffics



Guess:

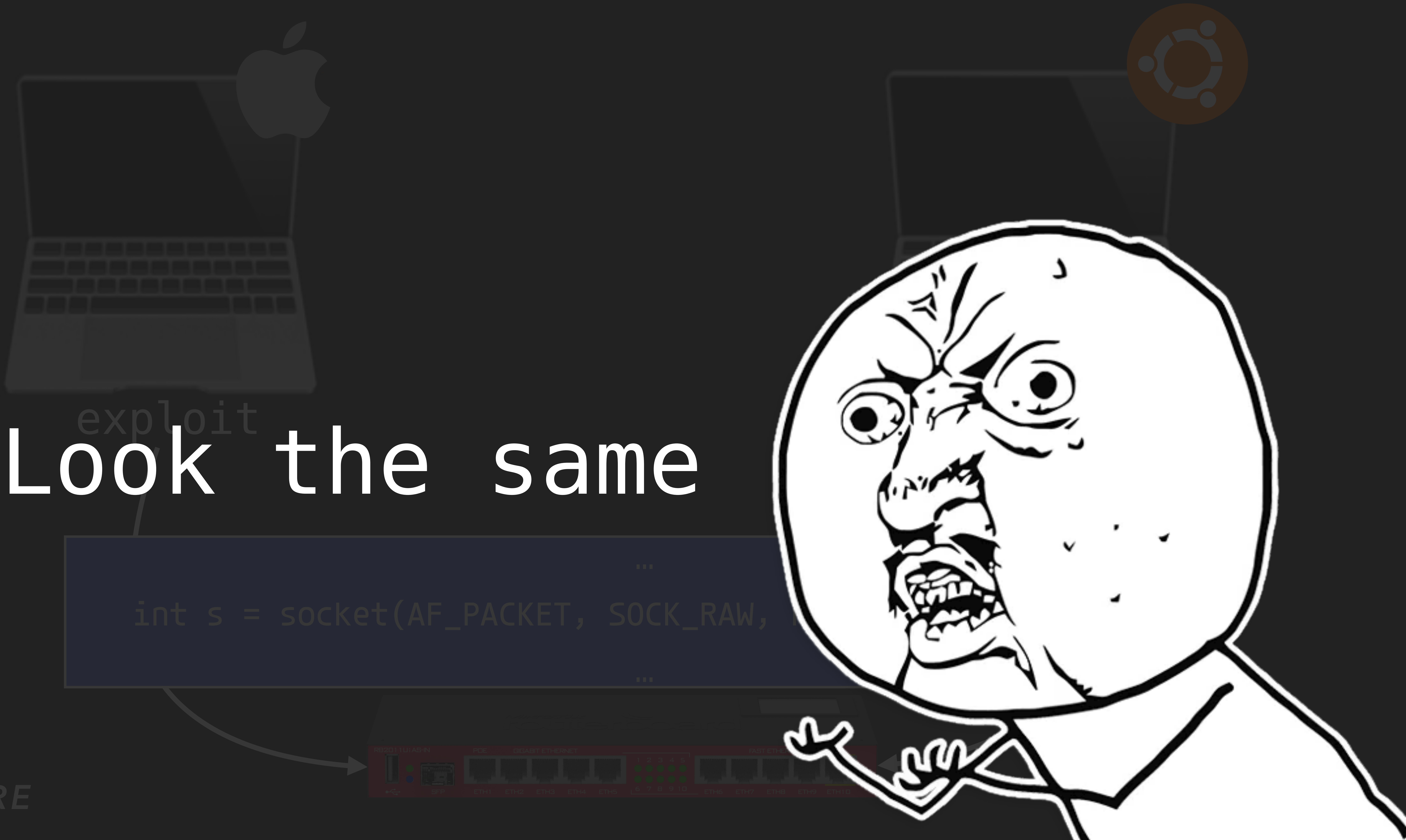
An OS reorders the packets



```
…
int s = socket(AF_PACKET, SOCK_RAW, htons(ETH_P_IPV6)) ;
…
```

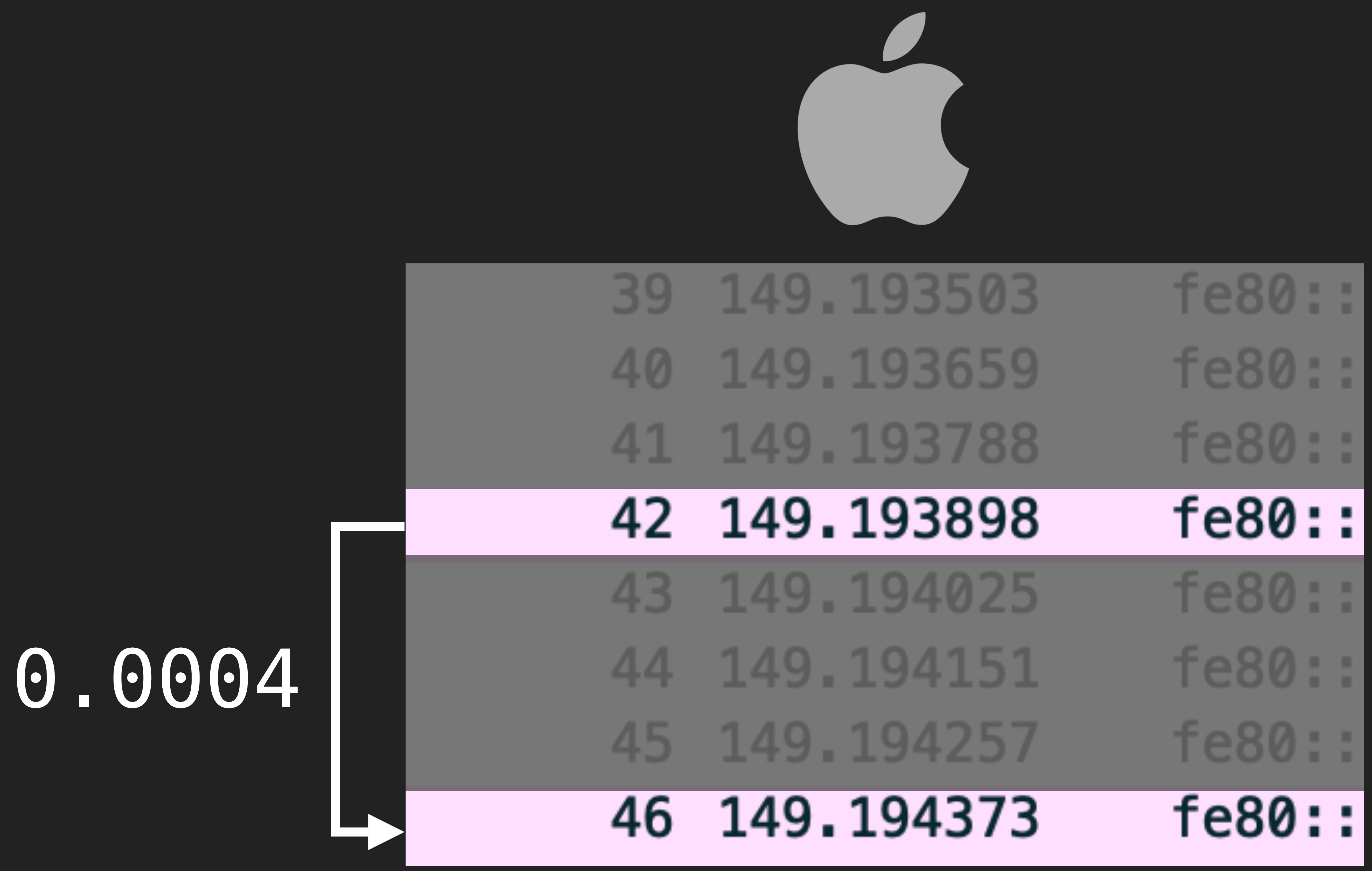
DEVCORE

Look the same



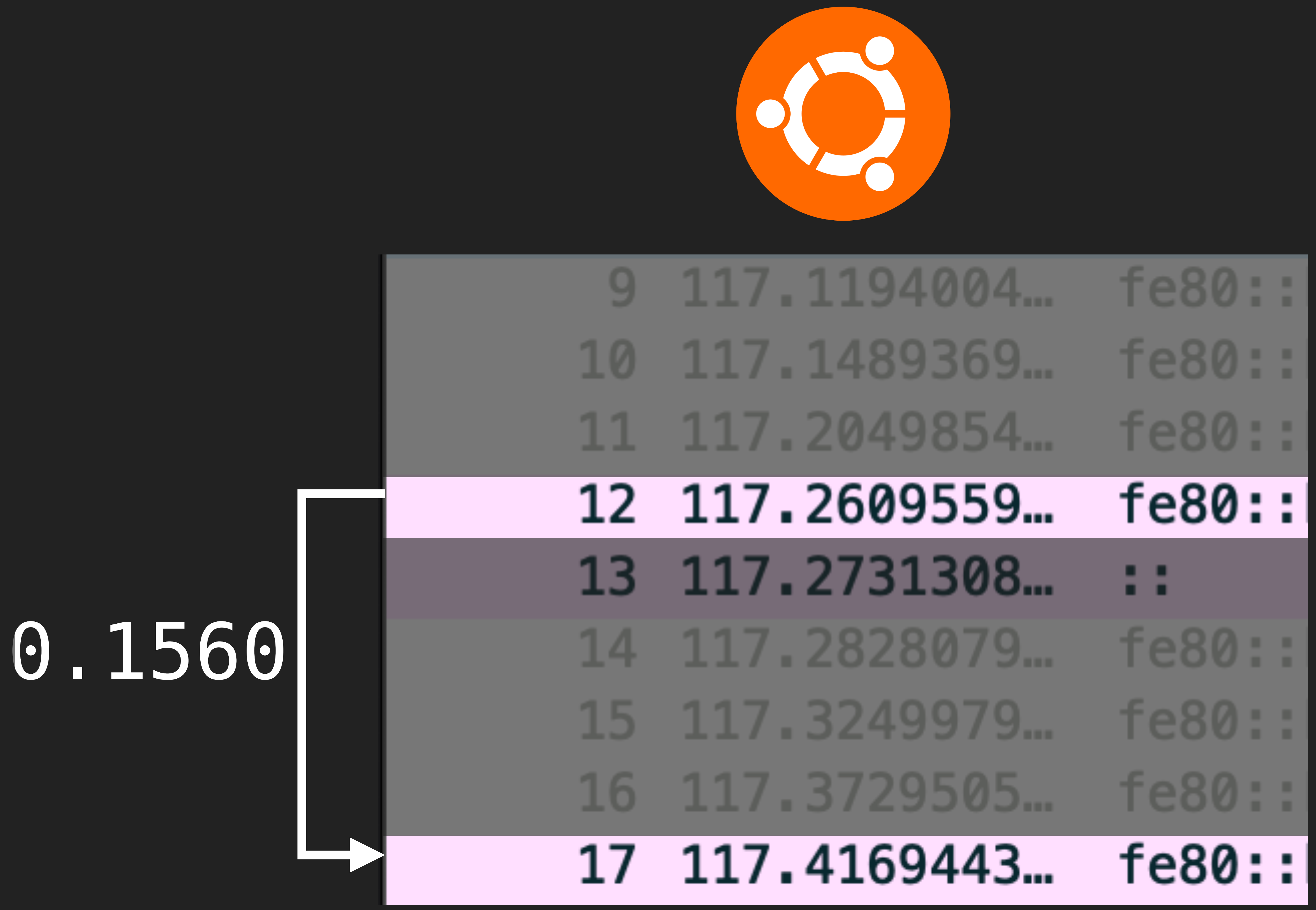
```
…
int s = socket(AF_PACKET, SOCK_RAW,
…
```

ㄎㄨㄚˋ



```
39 149.193503     fe80::
40 149.193659     fe80::
41 149.193788     fe80::
42 149.193898     fe80::
43 149.194025     fe80::
44 149.194151     fe80::
45 149.194257     fe80::
46 149.194373     fe80::
```

0.0004



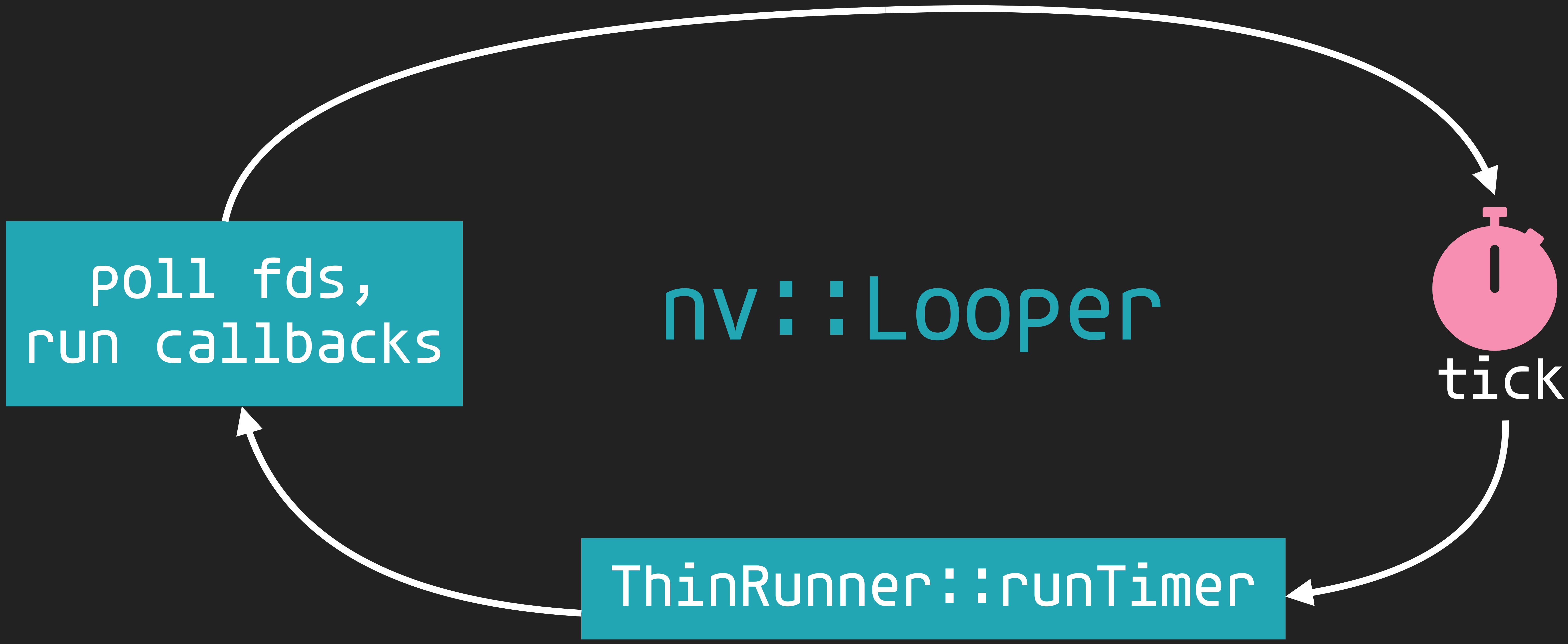
```
 9 117.1194004…   fe80::
10 117.1489369…   fe80::
11 117.2049854…   fe80::
12 117.2609559…   fe80::
13 117.2731308…   ::
14 117.2828079…   fe80::
15 117.3249979…   fe80::
16 117.3729505…   fe80::
17 117.4169443…   fe80::
```

0.1560

390x!!

MikroTik

kiriTo



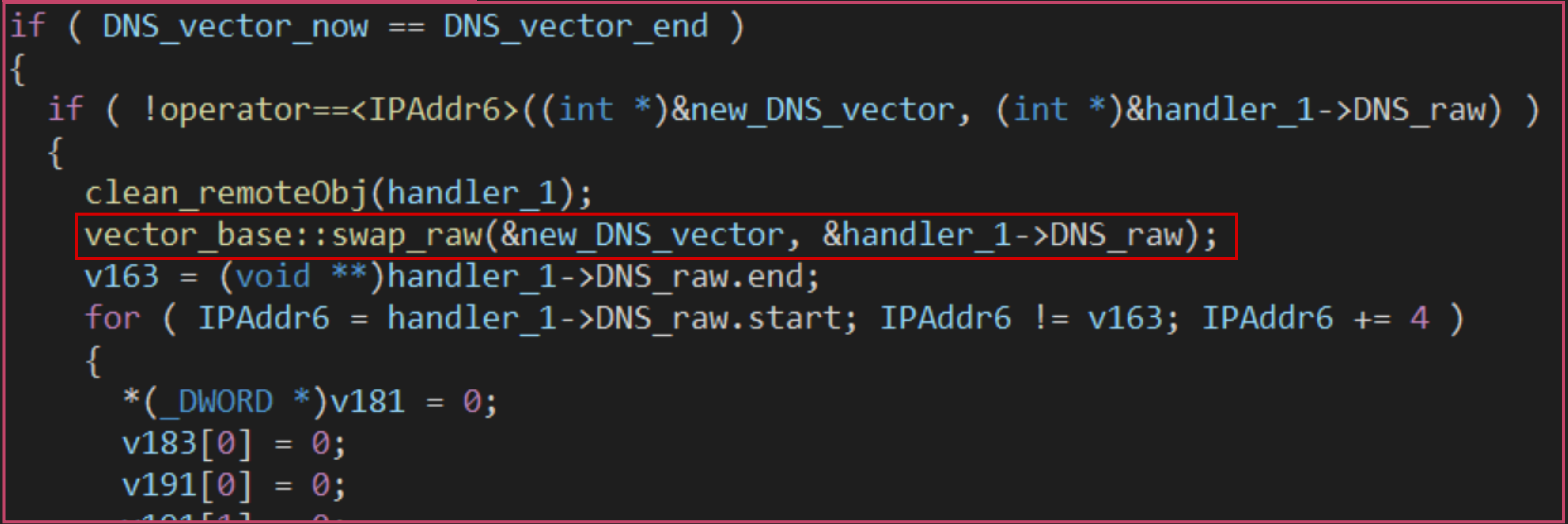
poll fds,
run callbacks

nv::Looper

tick

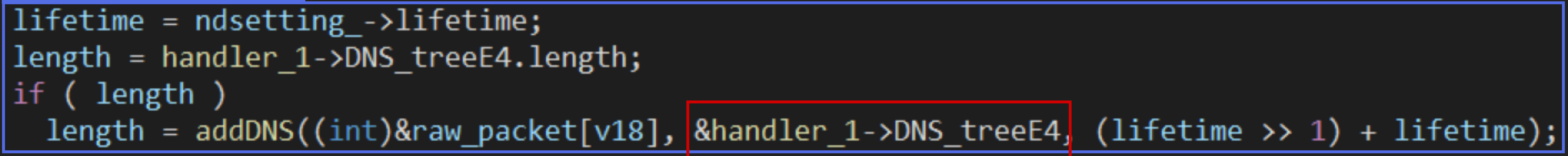
ThinRunner::runTimer

In callback function (recv RA from WAN)



```
if ( DNS_vector_now == DNS_vector_end )
{
  if ( !operator==<IPAddr6>((int *)&new_DNS_vector, (int *)&handler_1->DNS_raw) )
  {
    clean_remoteObj(handler_1);
    vector_base::swap_raw(&new_DNS_vector, &handler_1->DNS_raw);
    v163 = (void **)handler_1->DNS_raw.end;
    for ( IPAddr6 = handler_1->DNS_raw.start; IPAddr6 != v163; IPAddr6 += 4 )
    {
      *(_DWORD *)v181 = 0;
      v183[0] = 0;
      v191[0] = 0;
      v191[1] = 0;
```

In RAroutine (send RA to LAN)



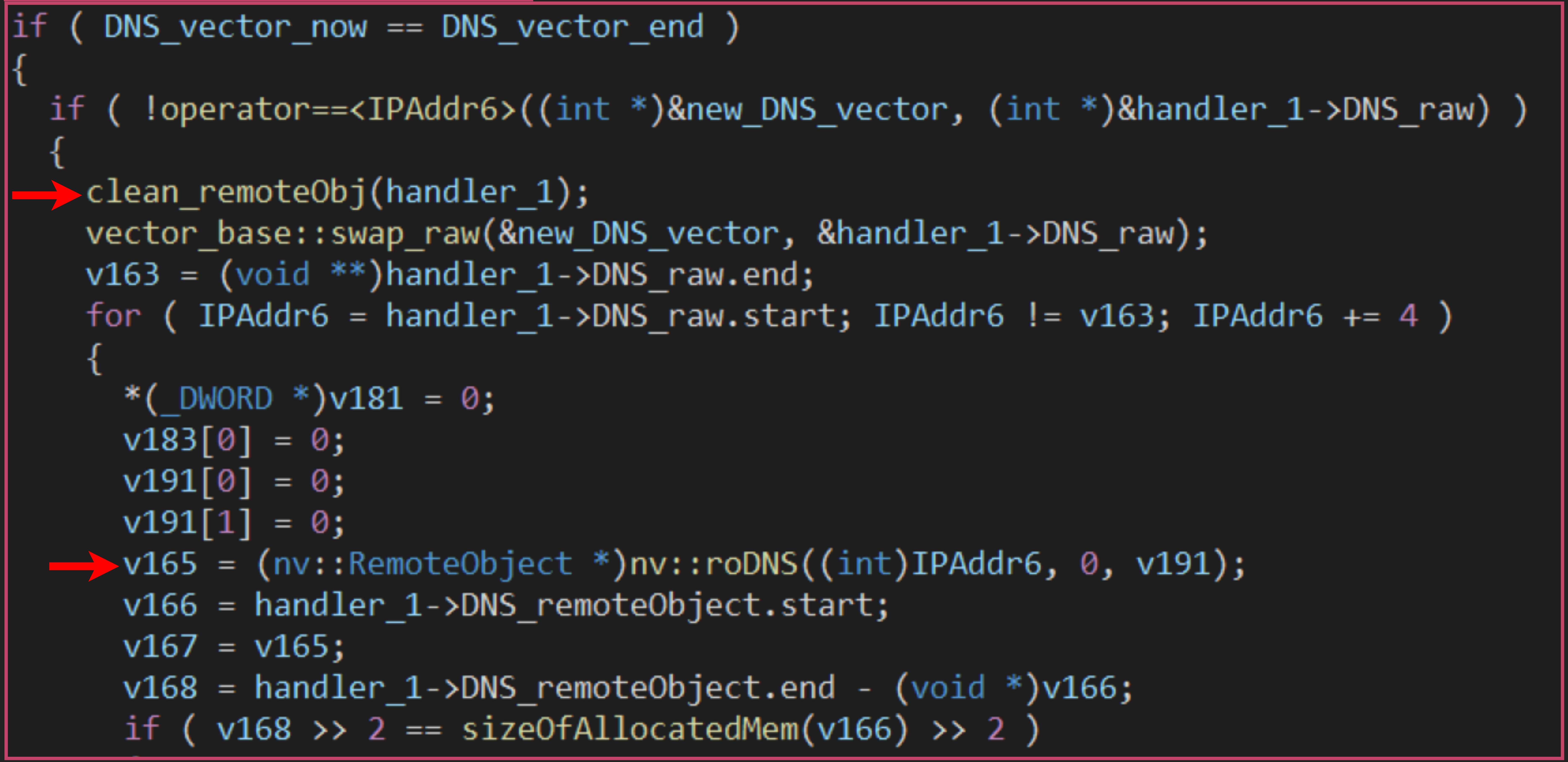
```
lifetime = ndsetting_->lifetime;
length = handler_1->DNS_treeE4.length;
if ( length )
  length = addDNS((int)&raw_packet[v18], &handler_1->DNS_treeE4, (lifetime >> 1) + lifetime);
```

RADVD

- In callback:
  - Check if the packet is a valid RA or a valid RS
  - Parse the packet
  - If it is an RA
    - Store information in handler 1 (AMap)
  - If it is an RS
    - Multicast RA

???????????????????

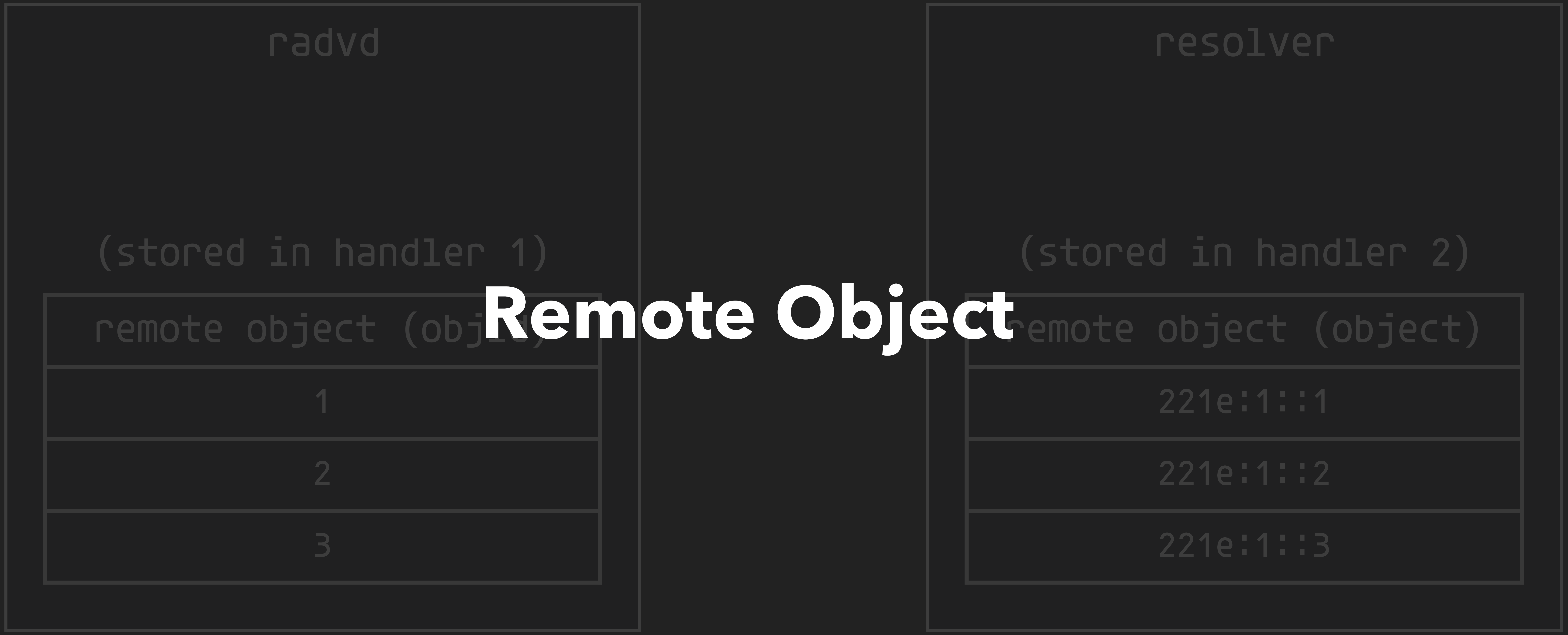
In callback function (recv RA from WAN)



```
if ( DNS_vector_now == DNS_vector_end )
{
  if ( !operator==<IPAddr6>((int *)&new_DNS_vector, (int *)&handler_1->DNS_raw) )
  {
    clean_remoteObj(handler_1);
    vector_base::swap_raw(&new_DNS_vector, &handler_1->DNS_raw);
    v163 = (void **)handler_1->DNS_raw.end;
    for ( IPAddr6 = handler_1->DNS_raw.start; IPAddr6 != v163; IPAddr6 += 4 )
    {
      *(_DWORD *)v181 = 0;
      v183[0] = 0;
      v191[0] = 0;
      v191[1] = 0;
      v165 = (nv::RemoteObject *)nv::roDNS((int)IPAddr6, 0, v191);
      v166 = handler_1->DNS_remoteObject.start;
      v167 = v165;
      v168 = handler_1->DNS_remoteObject.end - (void *)v166;
      if ( v168 >> 2 == sizeOfAllocatedMem(v166) >> 2 )
```

```
for obj in DNS_remoteObject:
    obj.remote_remove()
DNS_remoteObject = list(map(nv::roDNS, new_DNS_vector))
```

Remote Object



radvd

(stored in handler 1)

remote object (object)
1
2
3

resolver

(stored in handler 2)

remote object (object)
221e:1::1
221e:1::2
221e:1::3

radvd

(stored in handler 1)

remote object (objid)
1
2
3

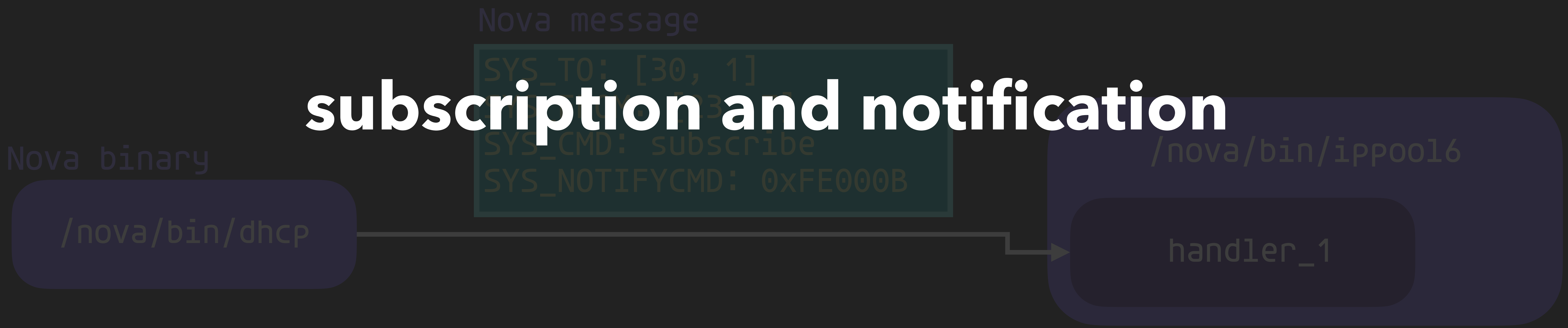
resolver

(stored in handler 2)

remote object (object)
221e:1::1
221e:1::2
221e:1::3

Subscription

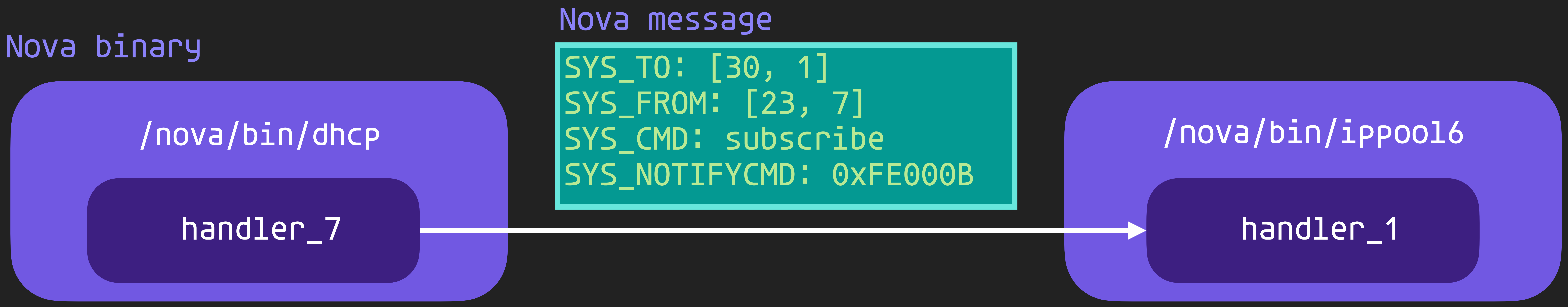
subscription and notification



Nova message

```
SYS_TO: [30, 1]
SYS_FROM: [23[illegible]
SYS_CMD: subscribe
SYS_NOTIFYCMD: 0xFE000B
```

Subscription

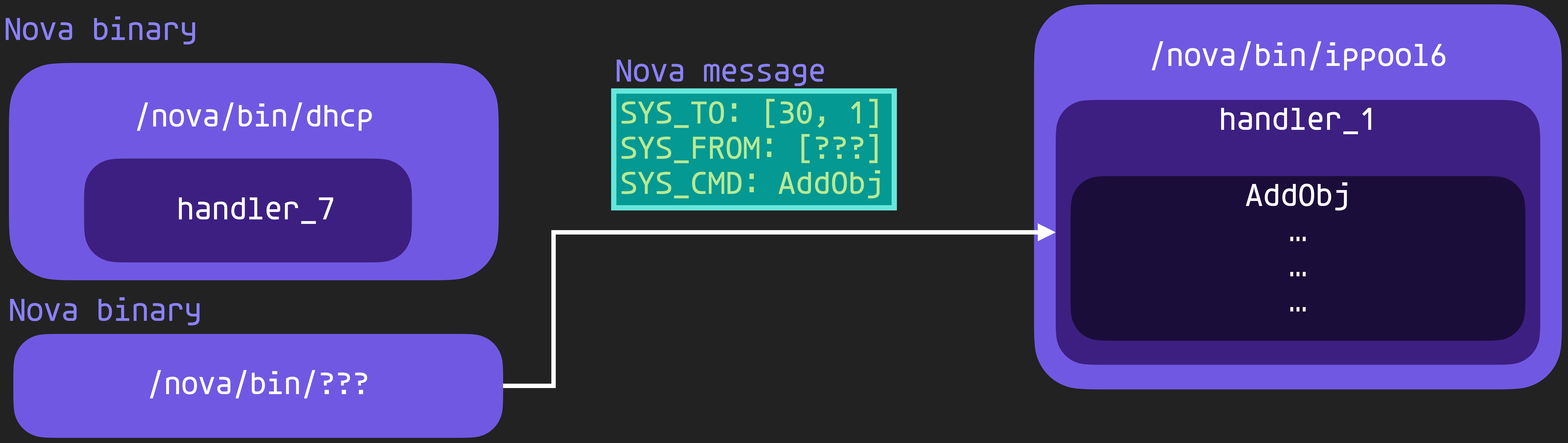


Nova binary

Nova message

```
SYS_TO: [30, 1]
SYS_FROM: [23, 7]
SYS_CMD: subscribe
SYS_NOTIFYCMD: 0xFE000B
```

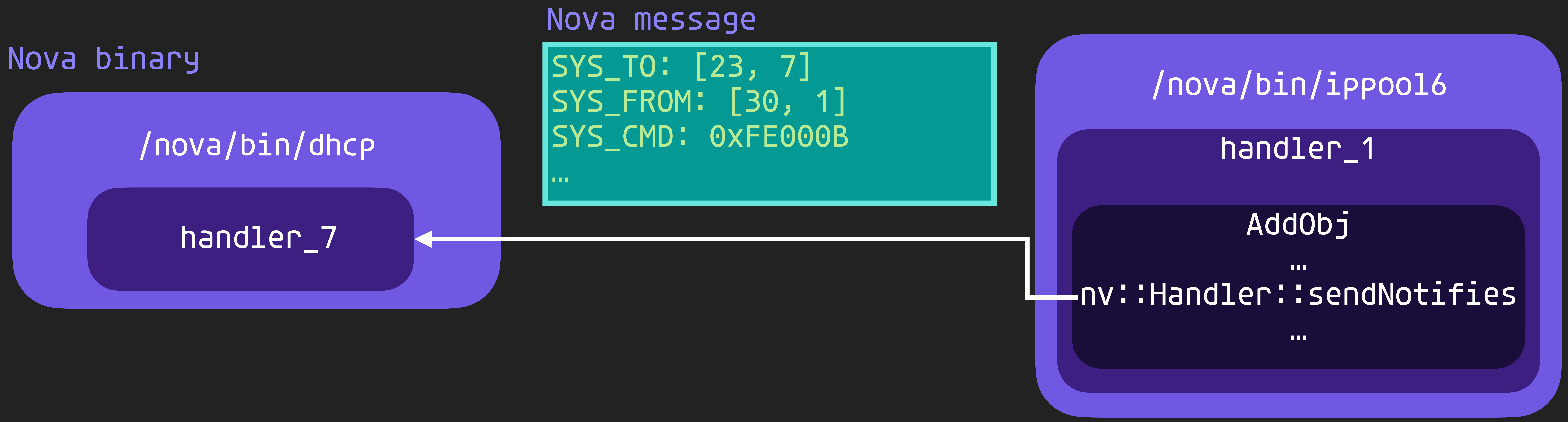
Subscription



```
SYS_TO: [30, 1]
SYS_FROM: [???]
SYS_CMD: AddObj
```

DEVCORE

Subscription



Nova binary

/nova/bin/dhcp

handler_7

Nova message

```
SYS_TO: [23, 7]
SYS_FROM: [30, 1]
SYS_CMD: 0xFE000B
…
```

/nova/bin/ippool6

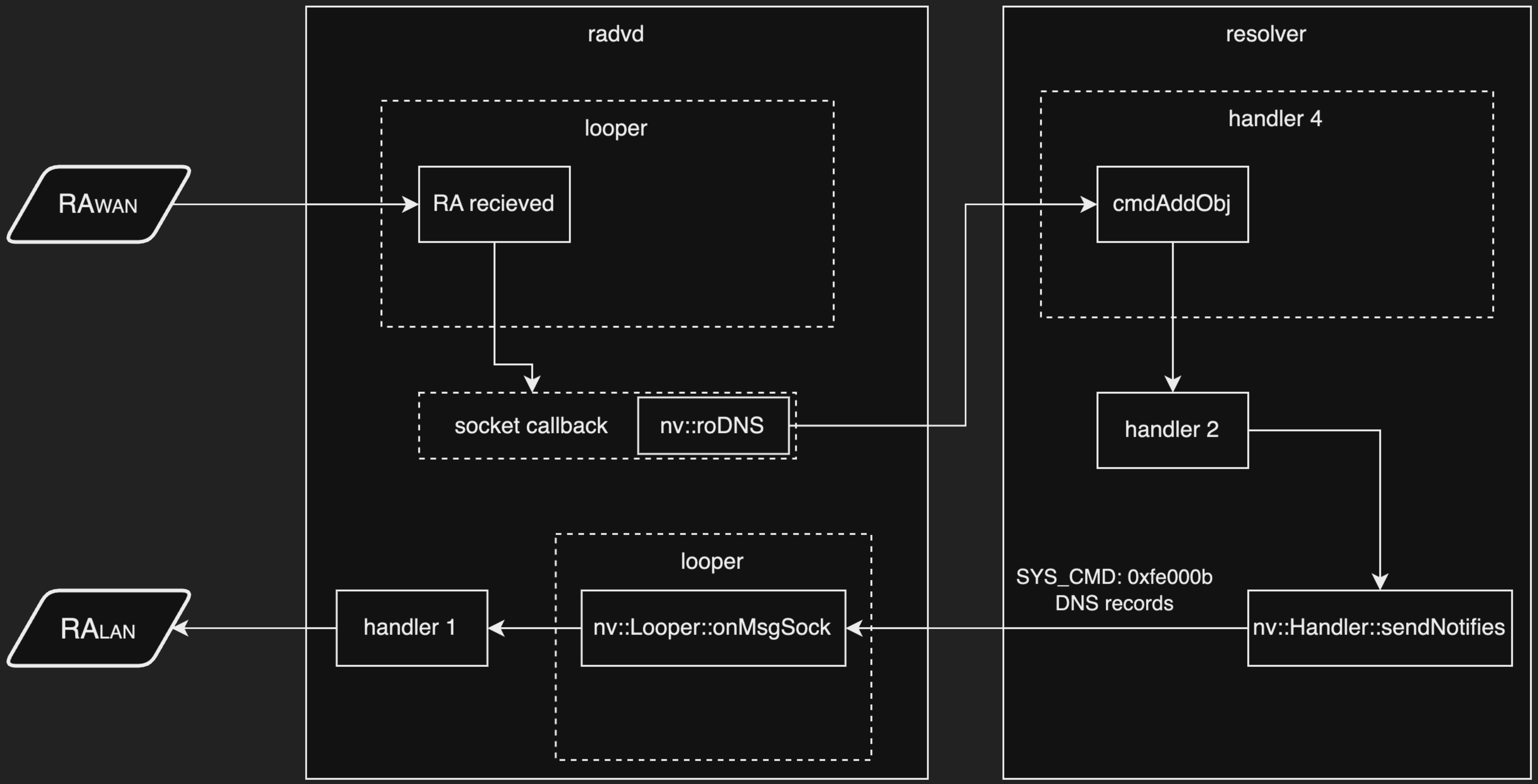
handler_1

AddObj

…

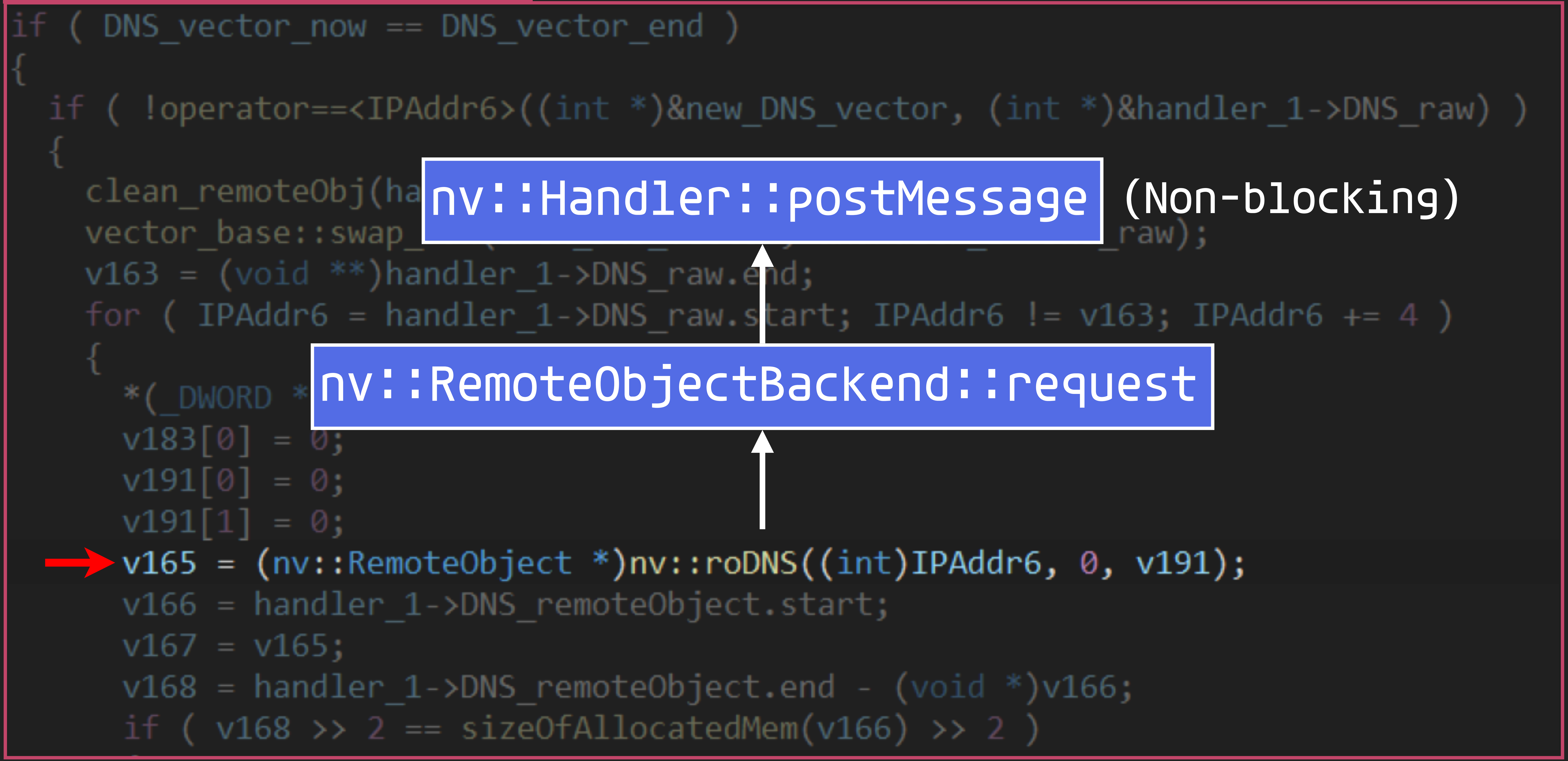
nv::Handler::sendNotifies

…


radvd
resolver
looper
handler 4
RAWAN
RA recieved
cmdAddObj
socket callback
nv::roDNS
handler 2
looper
SYS_CMD: 0xfe000b
DNS records
RALAN
handler 1
nv::Looper::onMsgSock
nv::Handler::sendNotifies

DEVCORE

In callback function (recv RA from WAN)



```
if ( DNS_vector_now == DNS_vector_end )
{
  if ( !operator==<IPAddr6>((int *)&new_DNS_vector, (int *)&handler_1->DNS_raw) )
  {
    clean_remoteObj(ha
    vector_base::swap_                                    _raw);
    v163 = (void **)handler_1->DNS_raw.end;
    for ( IPAddr6 = handler_1->DNS_raw.start; IPAddr6 != v163; IPAddr6 += 4 )
    {
      *(_DWORD *
      v183[0] = 0;
      v191[0] = 0;
      v191[1] = 0;
      v165 = (nv::RemoteObject *)nv::roDNS((int)IPAddr6, 0, v191);
      v166 = handler_1->DNS_remoteObject.start;
      v167 = v165;
      v168 = handler_1->DNS_remoteObject.end - (void *)v166;
      if ( v168 >> 2 == sizeOfAllocatedMem(v166) >> 2 )
```

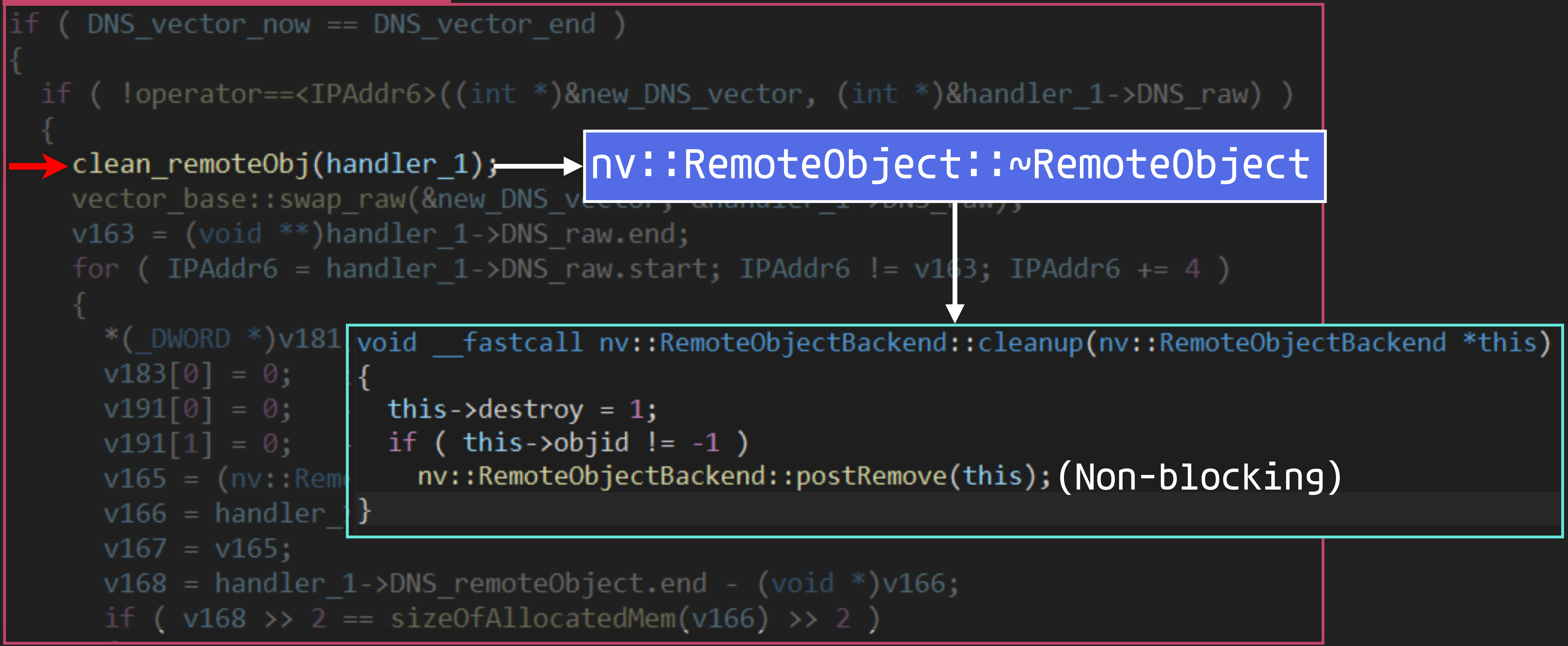
nv::Handler::postMessage (Non-blocking)

nv::RemoteObjectBackend::request

```
for obj in DNS_remoteObject:
    obj.remote_remove()
DNS_remoteObject = list(map(nv::roDNS, new_DNS_vector))
```

DEVCORE

In callback function (recv RA from WAN)



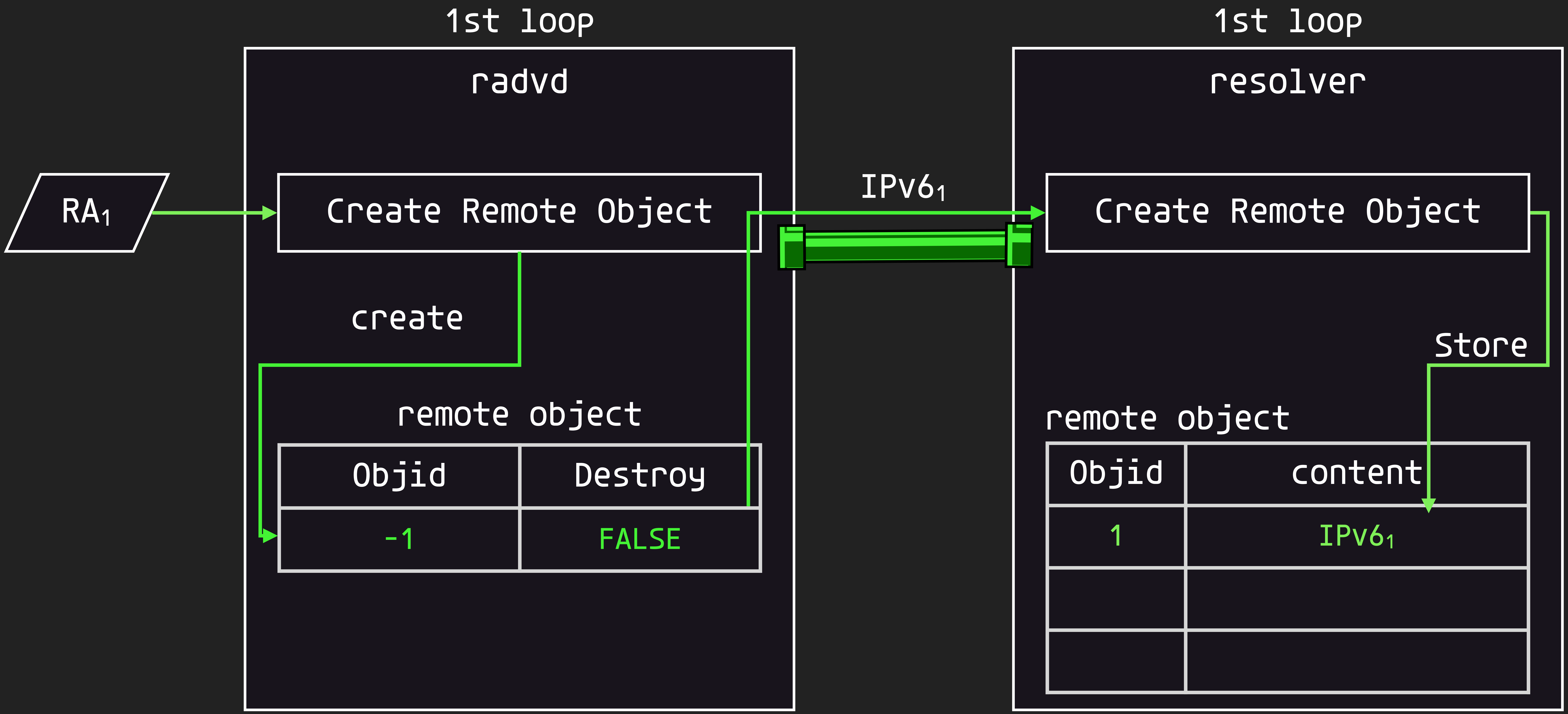
```
if ( DNS_vector_now == DNS_vector_end )
{
  if ( !operator==<IPAddr6>((int *)&new_DNS_vector, (int *)&handler_1->DNS_raw) )
  {
    clean_remoteObj(handler_1);
    vector_base::swap_raw(&new_DNS_vector, &handler_1->DNS_raw);
    v163 = (void **)handler_1->DNS_raw.end;
    for ( IPAddr6 = handler_1->DNS_raw.start; IPAddr6 != v163; IPAddr6 += 4 )
    {
      *(_DWORD *)v181
      v183[0] = 0;
      v191[0] = 0;
      v191[1] = 0;
      v165 = (nv::Rem
      v166 = handler_
      v167 = v165;
      v168 = handler_1->DNS_remoteObject.end - (void *)v166;
      if ( v168 >> 2 == sizeOfAllocatedMem(v166) >> 2 )
```

```
nv::RemoteObject::~RemoteObject
```

```
void __fastcall nv::RemoteObjectBackend::cleanup(nv::RemoteObjectBackend *this)
{
  this->destroy = 1;
  if ( this->objid != -1 )
    nv::RemoteObjectBackend::postRemove(this);
}
```

(Non-blocking)

```
for obj in DNS_remoteObject:
    obj.remote_remove()
DNS_remoteObject = list(map(nv::roDNS, new_DNS_vector))
```

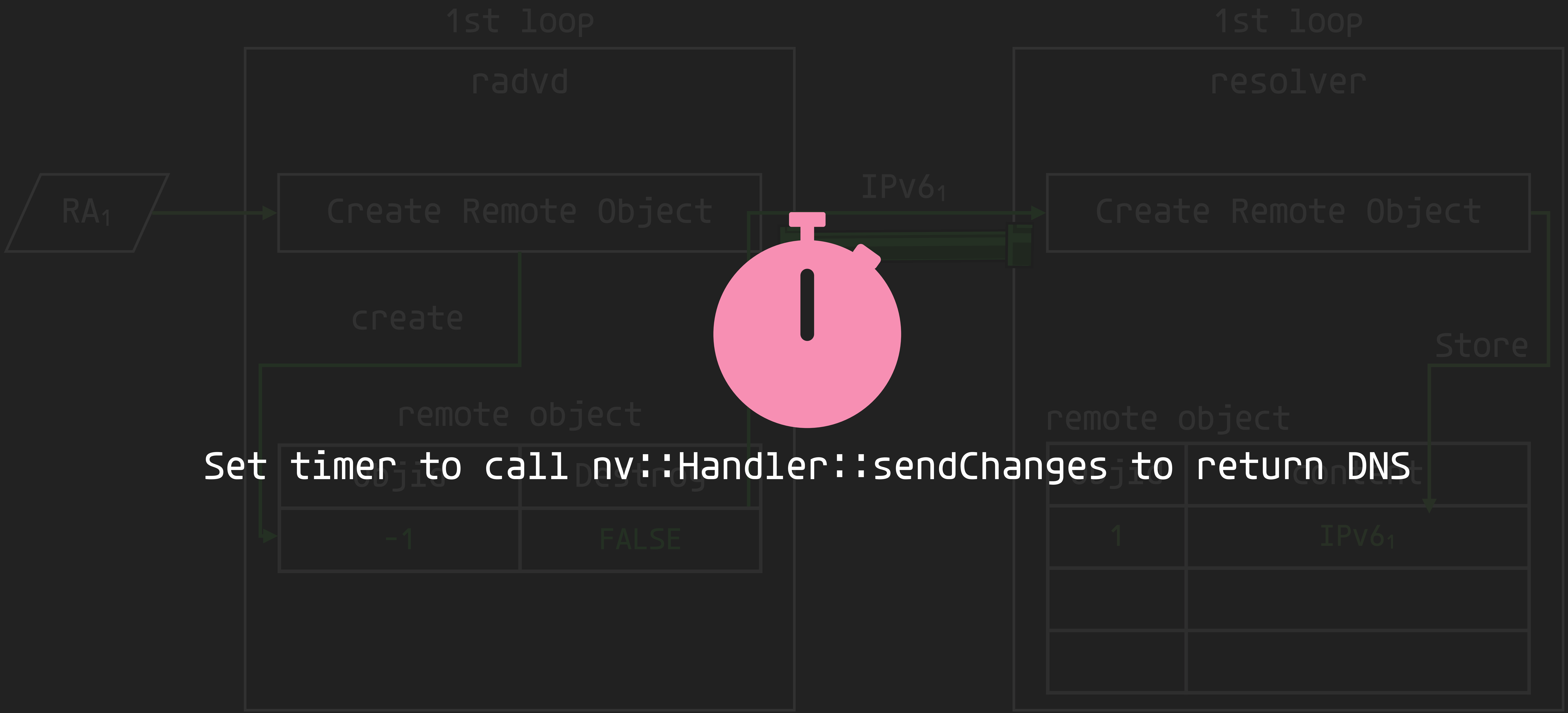


remote object

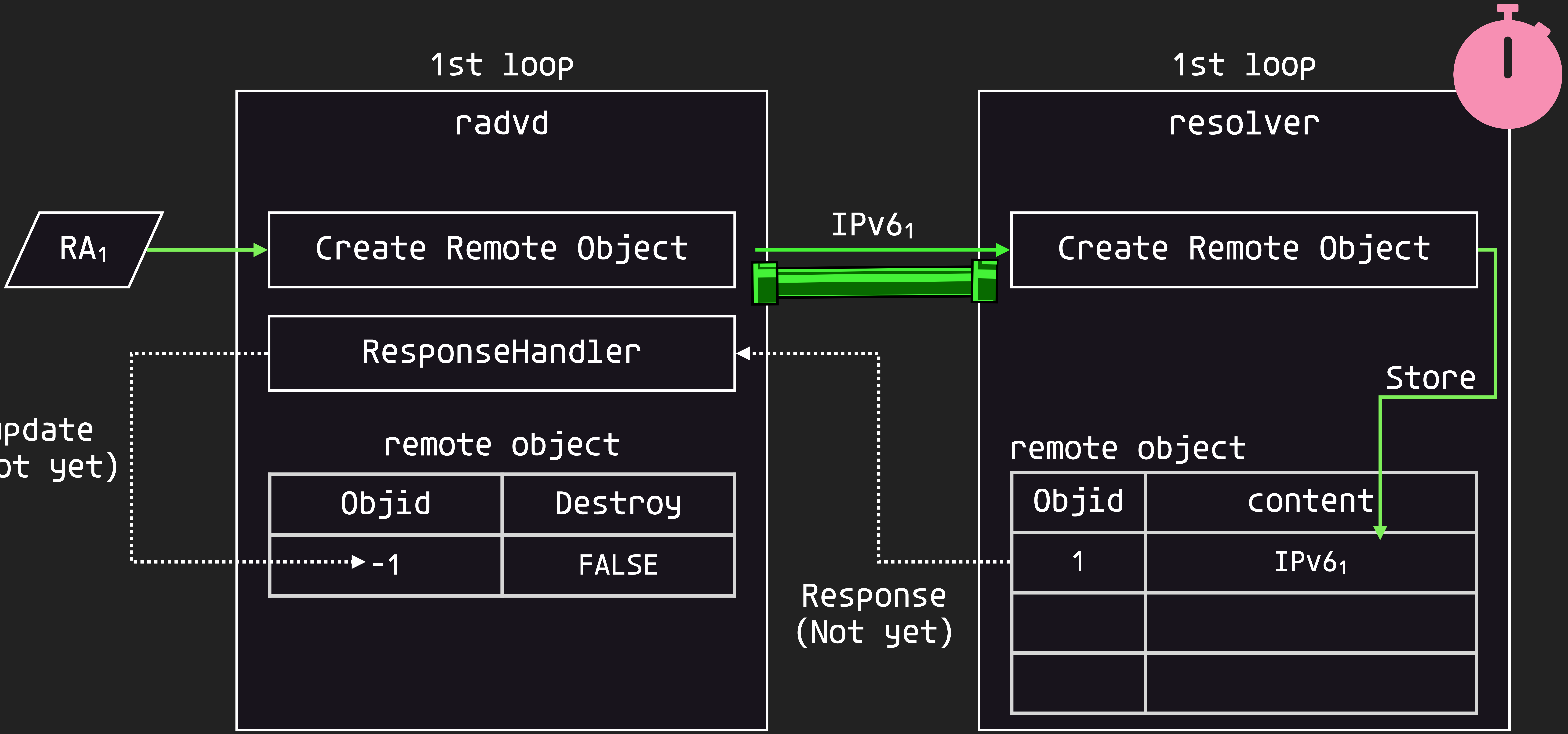
Objid	Destroy
-1	FALSE

remote object

Objid	content
1	IPv6$_1$



Set timer to call nv::Handler::sendChanges to return DNS



1st loop

radvd

RA_1

Create Remote Object

ResponseHandler

update
(Not yet)

remote object

Objid	Destroy
-1	FALSE

$\mathrm{IPv6}_1$

Response
(Not yet)

1st loop

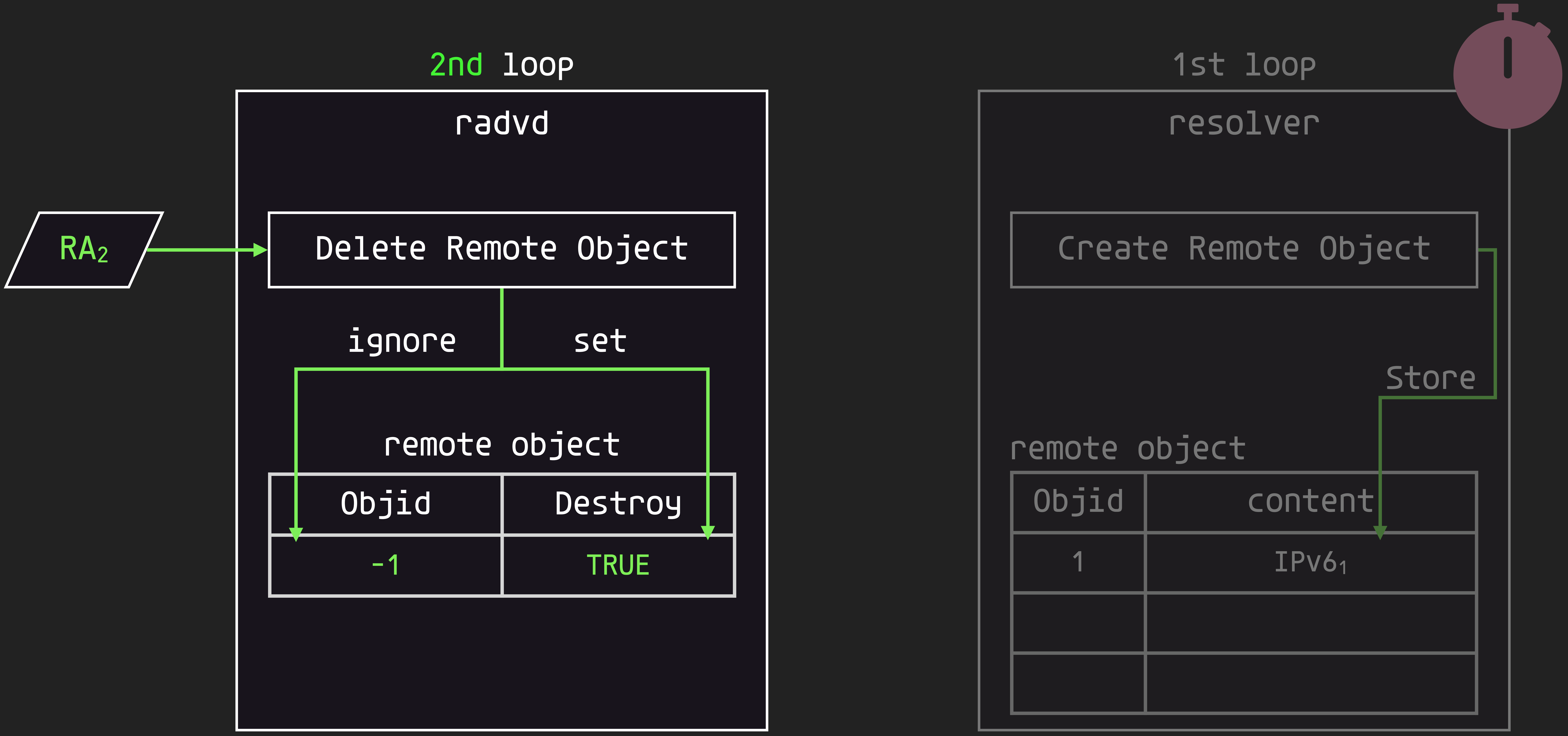
resolver

Create Remote Object

Store

remote object

Objid	content
1	$\mathrm{IPv6}_1$



2nd loop

radvd

RA$_2$

Delete Remote Object

ignore

set

remote object

Objid	Destroy
-1	TRUE

1st loop

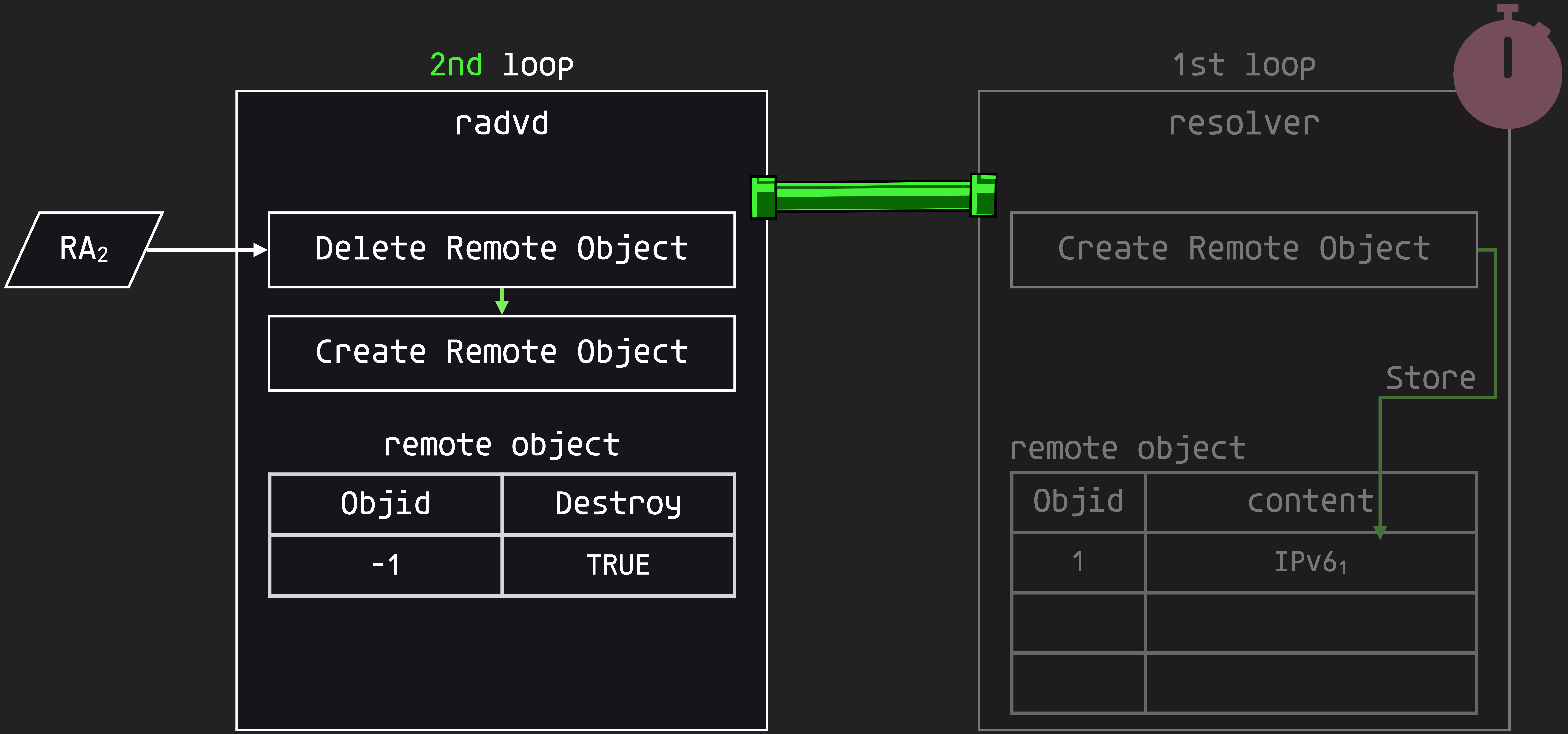
resolver

Create Remote Object

Store

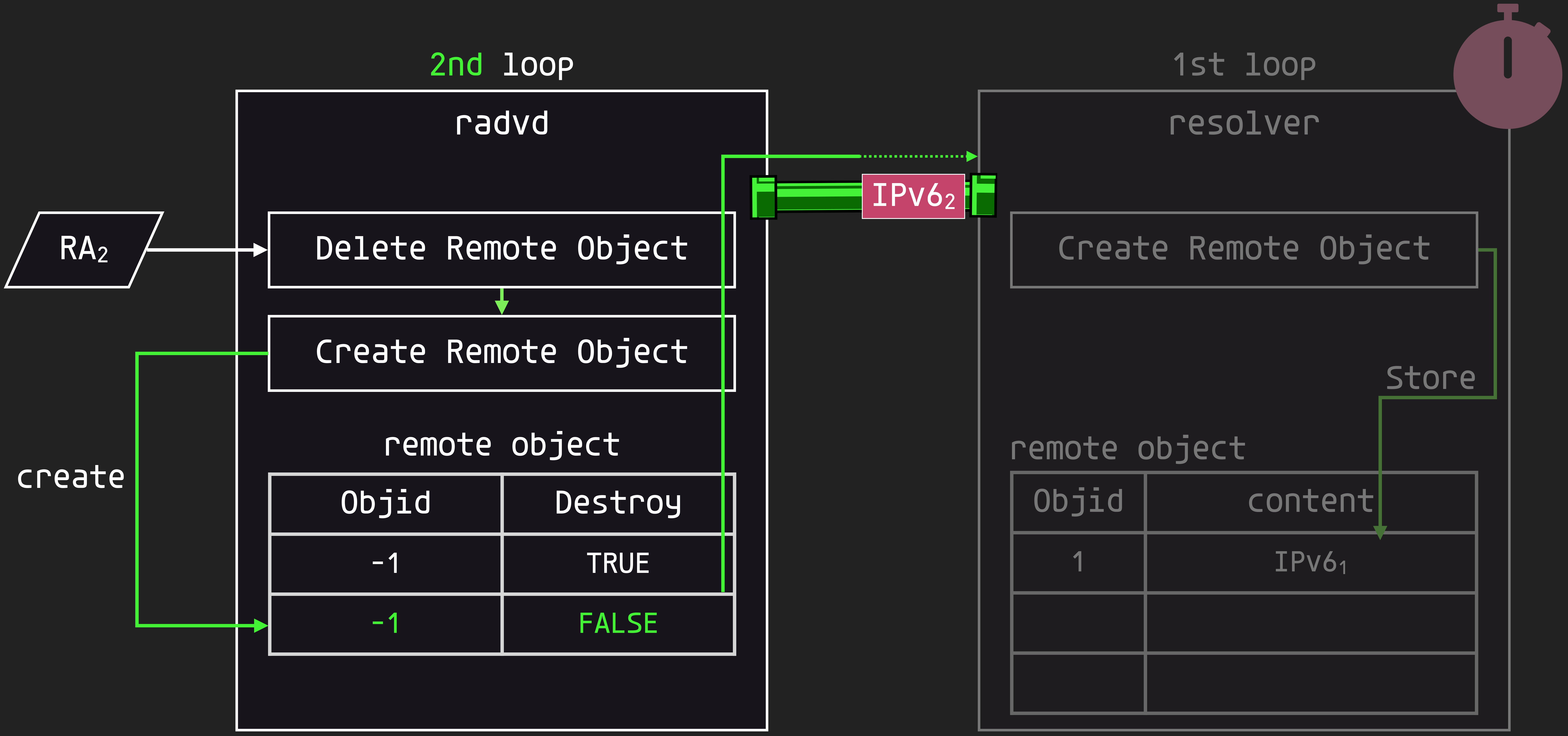
remote object

Objid	content
1	IPv6$_1$



Objid	Destroy
-1	TRUE

Objid	content
1	$IPv6_1$

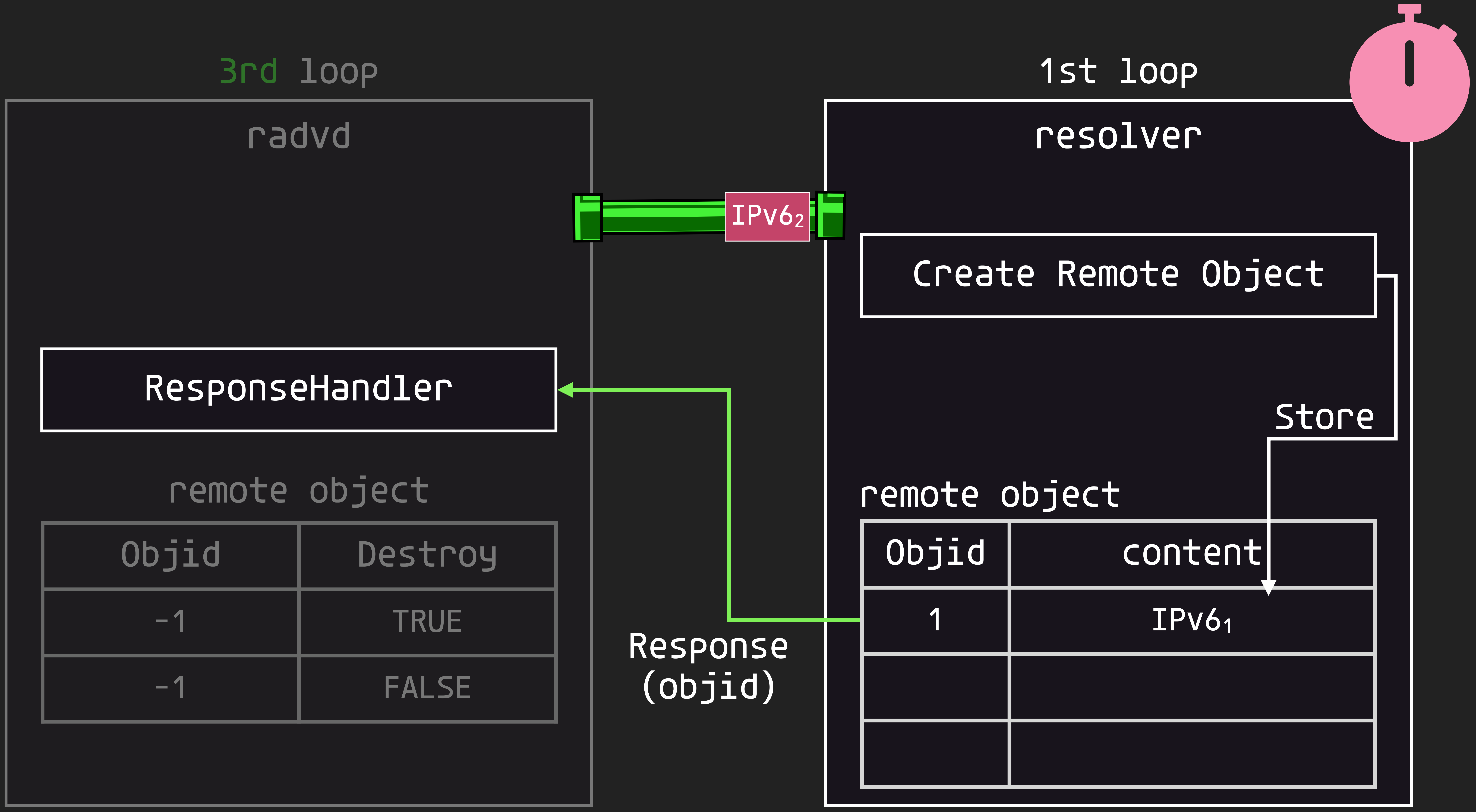


remote object

Objid	Destroy
-1	TRUE
-1	FALSE

remote object

Objid	content
1	$IPv6_1$



3rd loop

radvd

ResponseHandler

remote object

Objid	Destroy
-1	TRUE
-1	FALSE

Response (objid)

1st loop

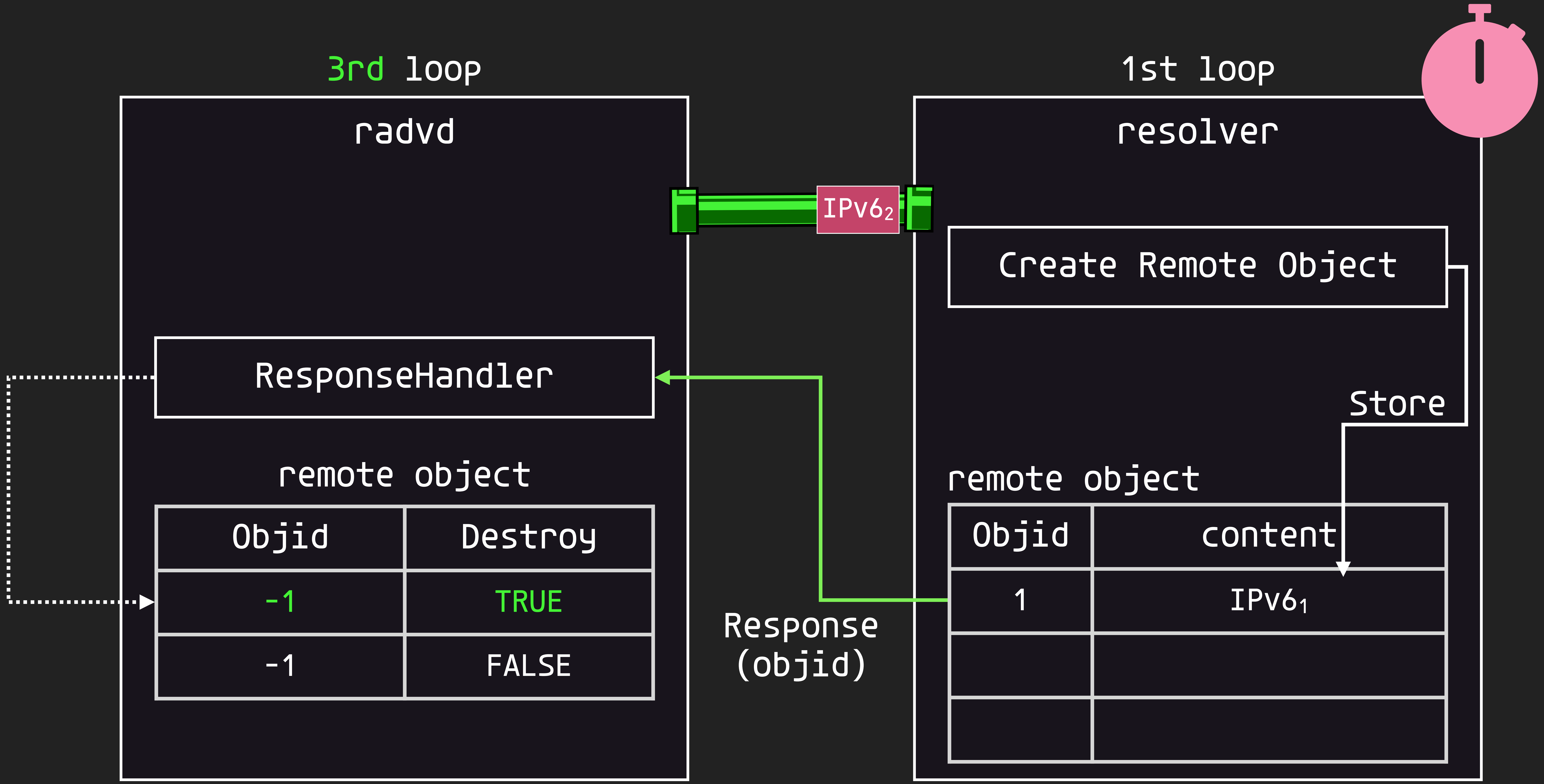
resolver

Create Remote Object

Store

remote object

Objid	content
1	IPv6$_1$

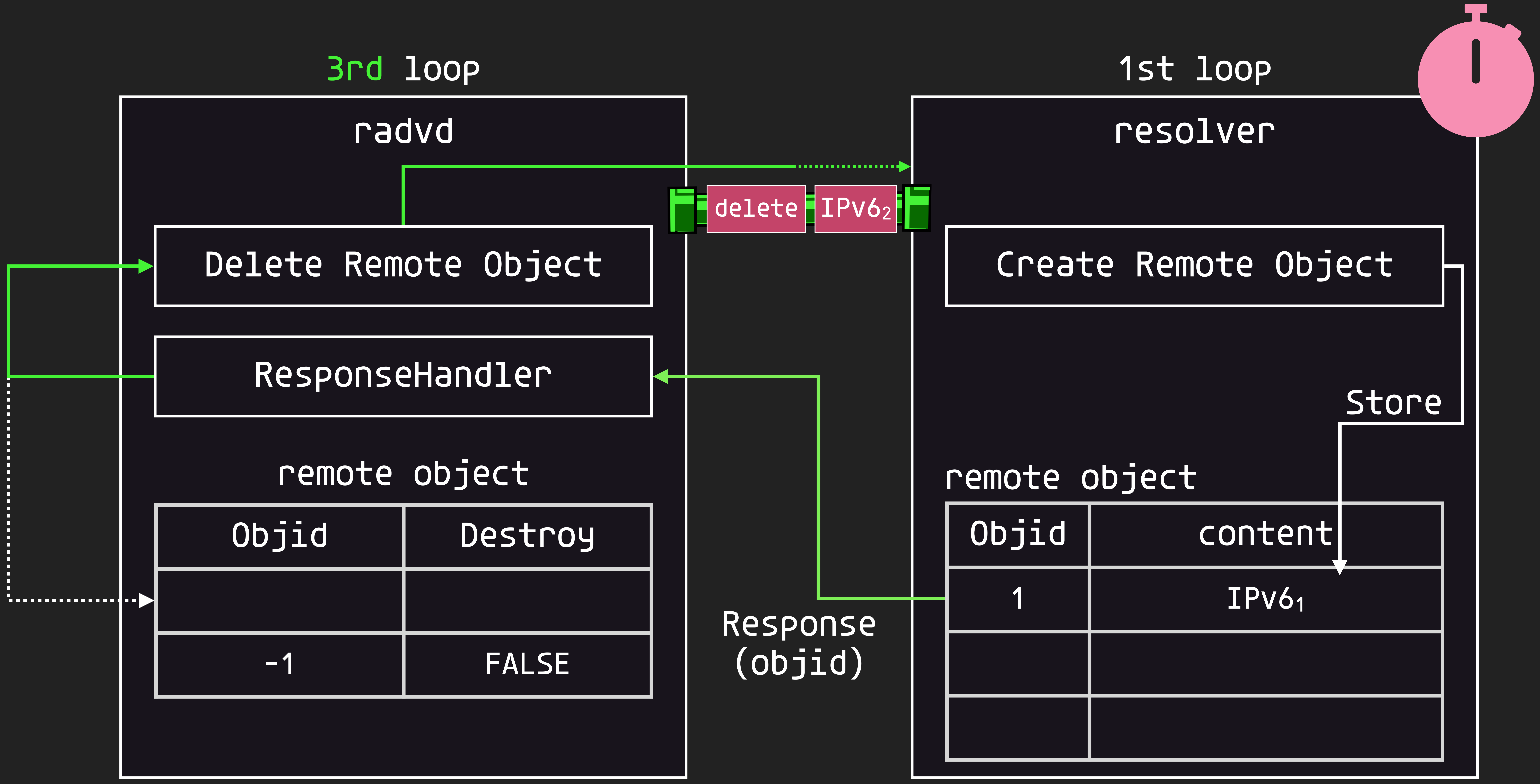


remote object

Objid	Destroy
-1	TRUE
-1	FALSE

remote object

Objid	content
1	IPv6$_1$



3rd loop

radvd

Delete Remote Object

ResponseHandler

remote object

Objid	Destroy
-1	FALSE

delete

$IPv6_2$

Response
(objid)

1st loop

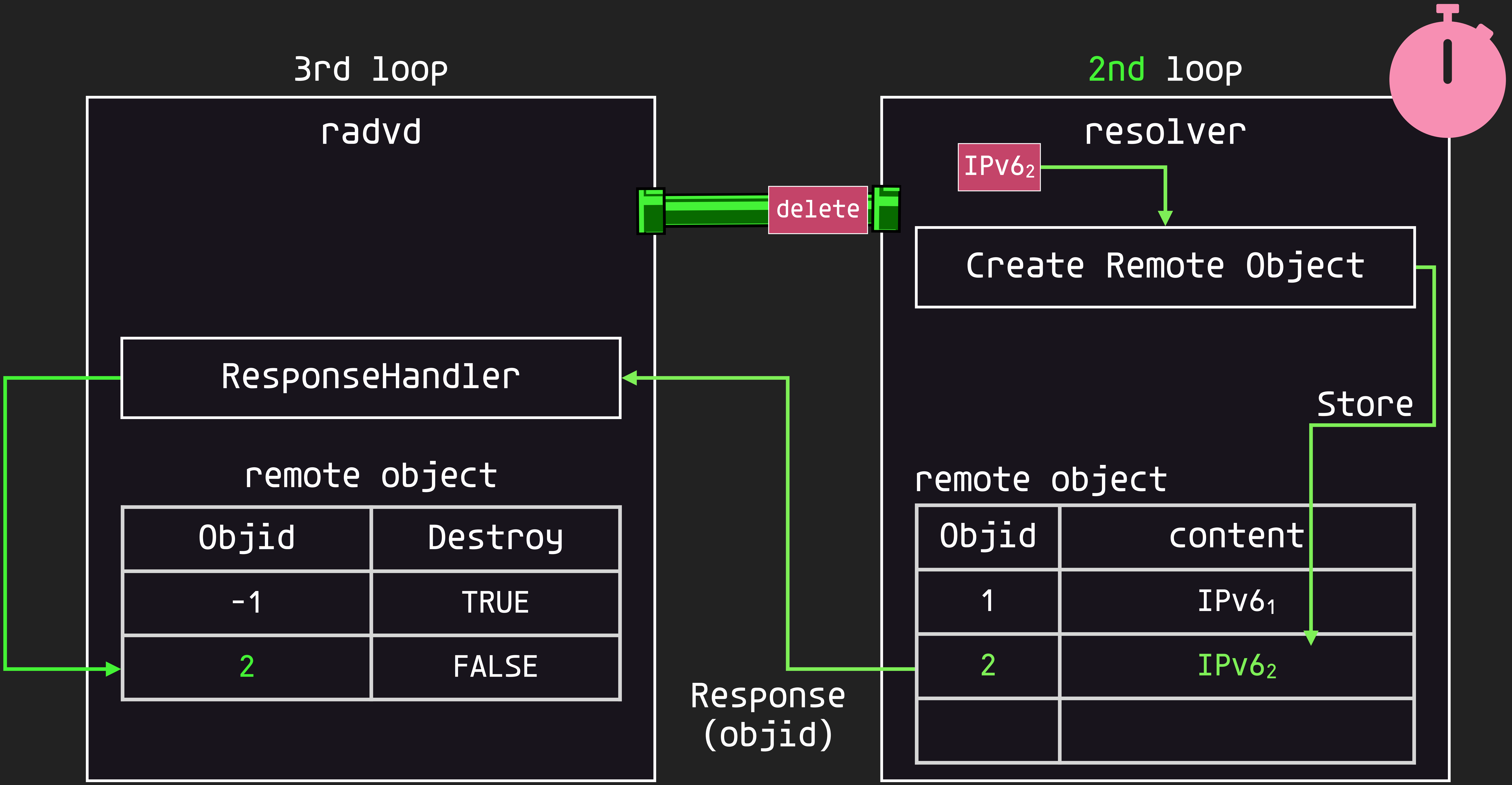
resolver

Create Remote Object

Store

remote object

Objid	content
1	$IPv6_1$



3rd loop

radvd

ResponseHandler

remote object

Objid	Destroy
-1	TRUE
2	FALSE

delete

Response (objid)

2nd loop

resolver

$IPv6_2$

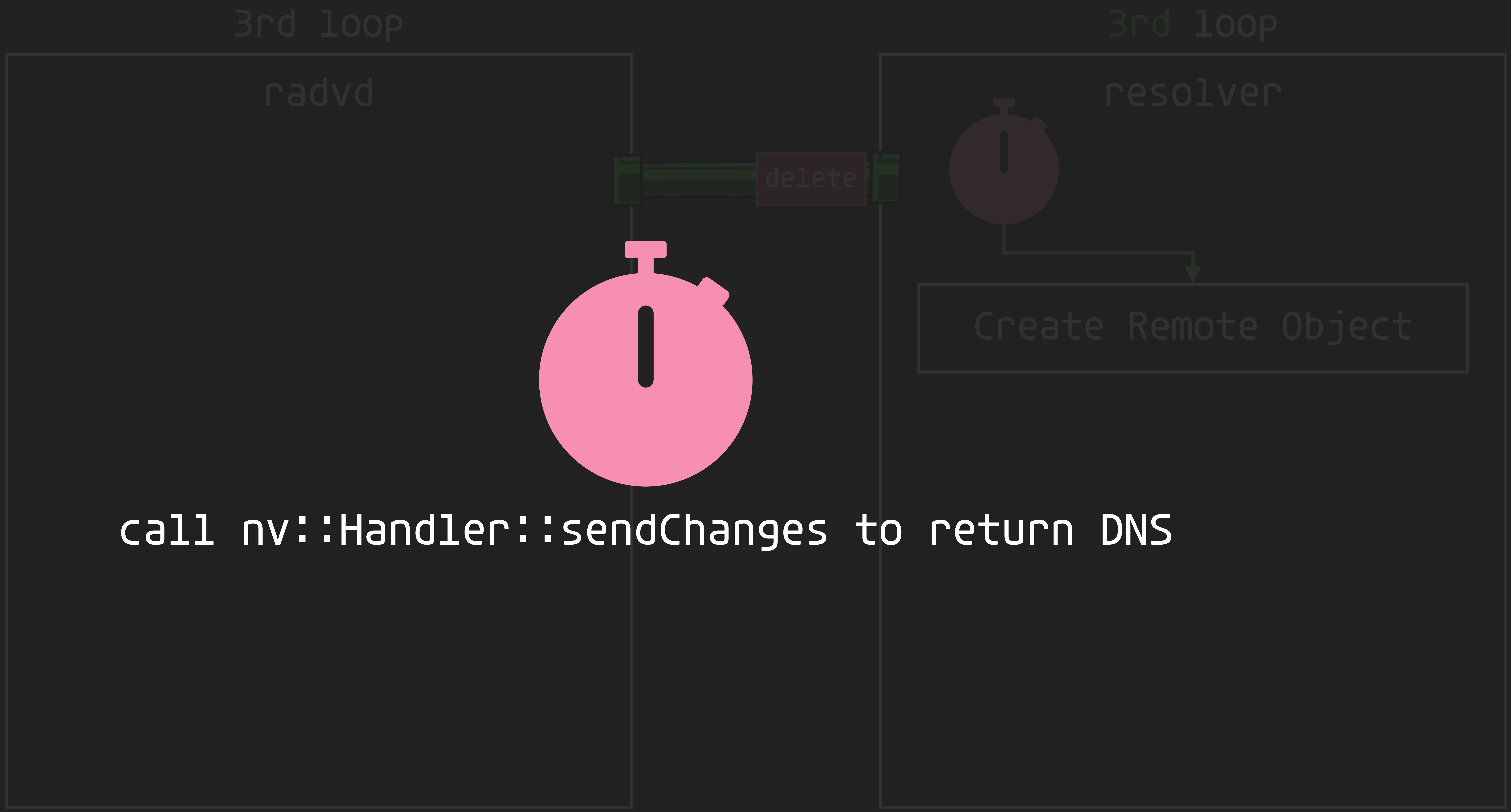
Create Remote Object

Store

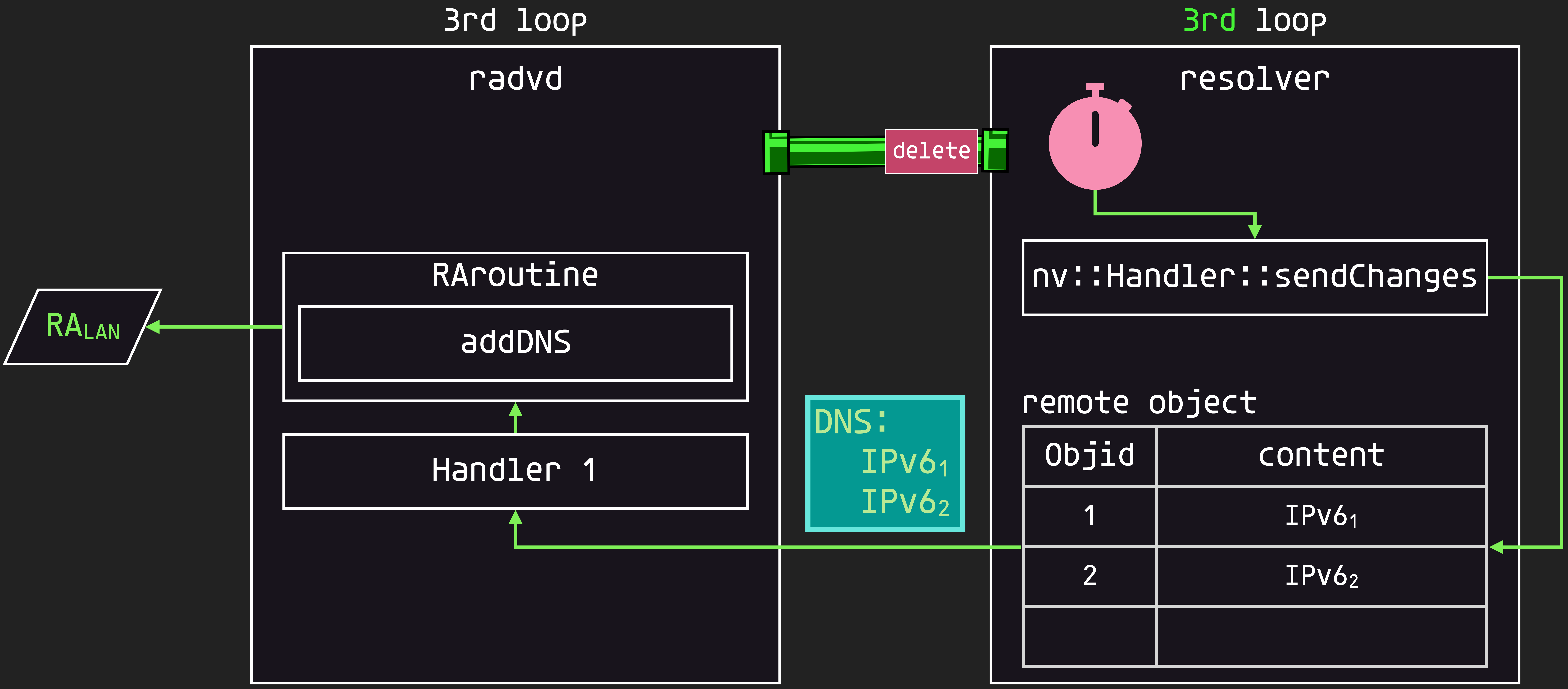
remote object

Objid	content
1	$IPv6_1$
2	$IPv6_2$

DEVCORE



call nv::Handler::sendChanges to return DNS



remote object

Objid	content
1	$IPv6_1$
2	$IPv6_2$

DEVCORE

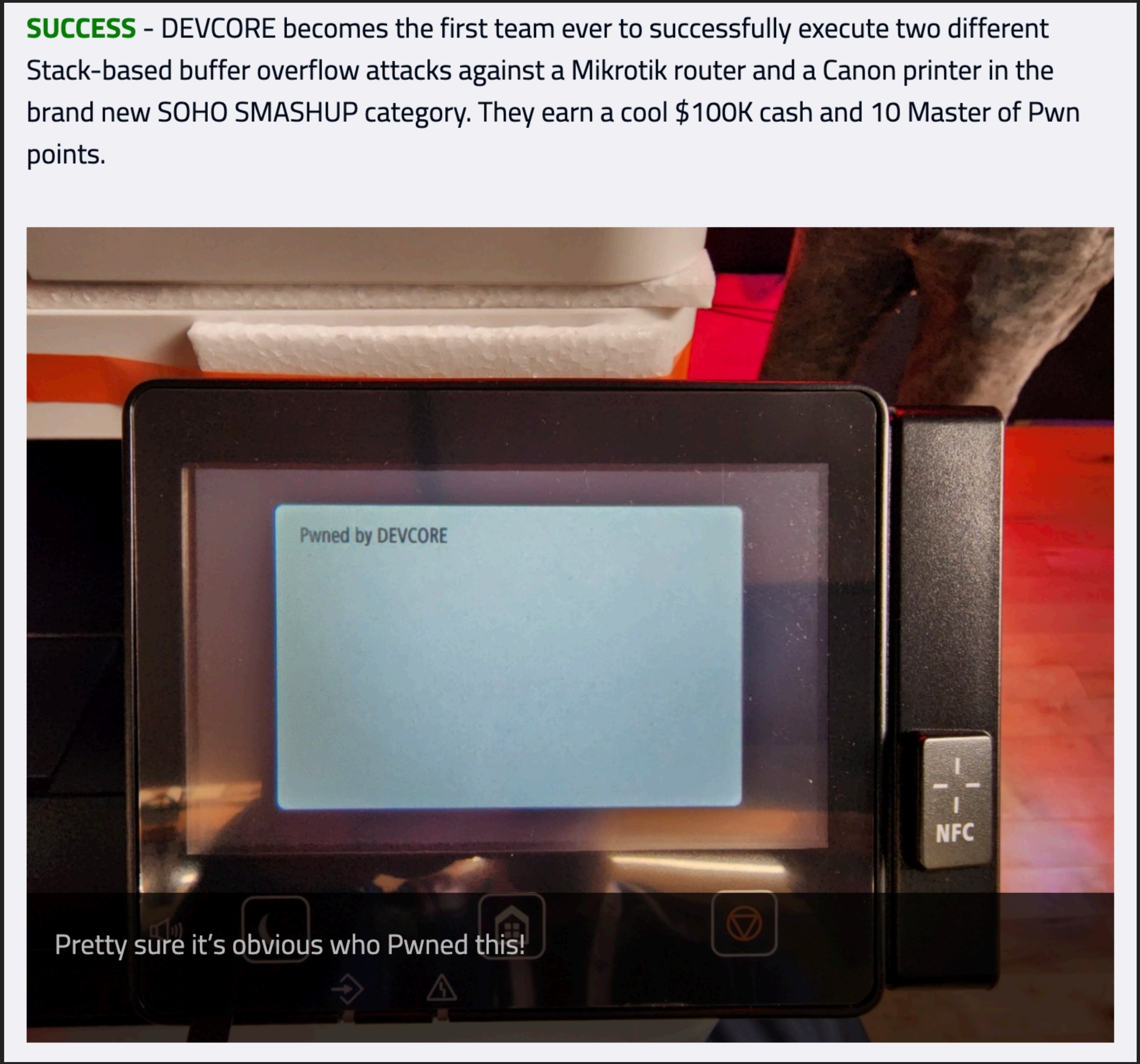
Race Condition

- Pattern
  - Use non-blocking methods to create/delete the remote object
  - Subscribe to the remote object
- Impact:
  - Maybe it can be used to bypass some checks

Race Condition

- Pattern
  - Use non-blocking r ete remote object
  - Subscribe to the
- Impact:
  - Maybe can be used hecks

DEVCORE



SUCCESS - DEVCORE becomes the first team ever to successfully execute two different Stack-based buffer overflow attacks against a Mikrotik router and a Canon printer in the brand new SOHO SMASHUP category. They earn a cool $100K cash and 10 Master of Pwn points.

Pretty sure it's obvious who Pwned this!

SUCCESS - DEVCORE becomes the first team ever to successfully execute two different Stack-based buffer overflow attacks against a Mikrotik router and a Canon printer in the brand new SOHO SMASHUP category. They earn a cool $100K cash and 10 Master of Pwn points.

Pretty sure it's obvious who Pwned this!

Summary

- MikroTik reimplements everything with its own designed IPC.
    - The business logic is scattered all over.
- A pre-auth RCE on WAN has existed for nine years.
- Race condition in remote objects due to non-blocking methods.
- The tools to ease reversing will be available at:
    - https://github.com/terrynini/routeros-tools

Q&A

DEVCORE