

Tunneling: topology and examples

D. Berardi, F. Callegati, A. Melis

In una rete Ethernet tradizionale, uno switch raccoglie e connette tutti i dispositivi all'interno di una rete locale (LAN). Quando i dispositivi sono collegati a uno switch, questi dispositivi possono comunicare tra loro all'interno della stessa rete fisica. Lo switch può essere utilizzato per connettere dispositivi all'interno della stessa rete IP

Topologia

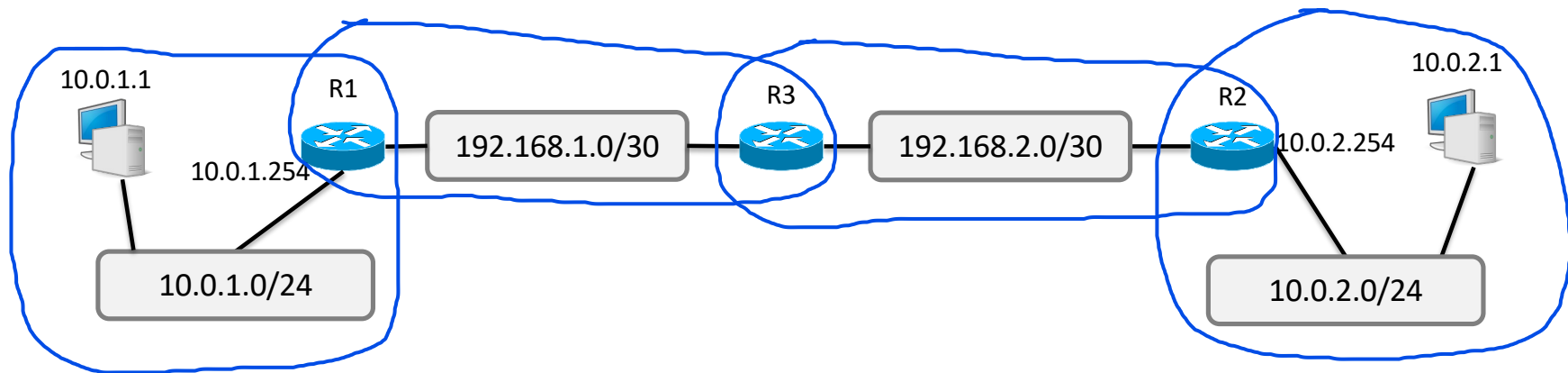


Tabelle di routing

R3	Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
	10.0.1.0	192.168.1.1	255.255.255.0	UG	0	0	0	veth13
	10.0.2.0	192.168.2.1	255.255.255.0	UG	0	0	0	veth23
	192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth13
	192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth23

R1	Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
	10.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H1
	10.0.2.0	192.168.1.2	255.255.255.0	UG	0	0	0	veth1
	192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth1
	192.168.2.0	192.168.1.2	255.255.255.252	UG	0	0	0	veth1

R2	Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
	10.0.1.0	192.168.2.2	255.255.255.0	UG	0	0	0	veth2
	10.0.2.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H2
	192.168.1.0	192.168.2.2	255.255.255.252	UG	0	0	0	veth2
	192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth2

H1 = (10.0.1.1)

Raggiungibilità

```
H1> ping -c 3 10.0.2.1
```

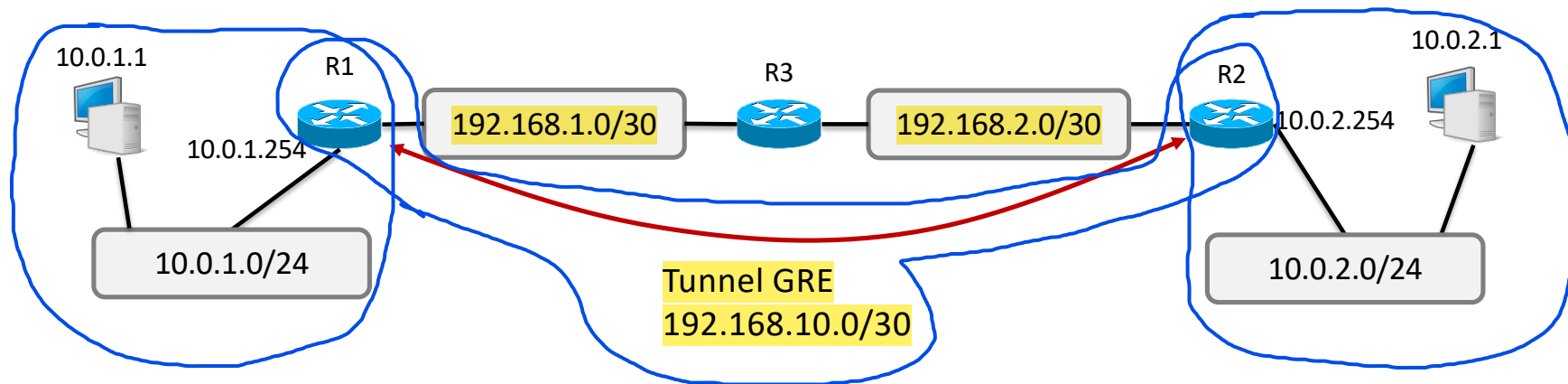
```
PING 10.0.2.1 (10.0.2.1) 56(84) bytes of data.  
64 bytes from 10.0.2.1: icmp_seq=1 ttl=61 time=2.88 ms  
64 bytes from 10.0.2.1: icmp_seq=2 ttl=61 time=0.097 ms  
64 bytes from 10.0.2.1: icmp_seq=3 ttl=61 time=0.101 ms
```

```
--- 10.0.2.1 ping statistics ---  
3 packets transmitted, 3 received, 0% packet loss, time 2018ms  
rtt min/avg/max/mdev = 0.097/1.026/2.880/1.310 ms
```

```
H1> traceroute -n 10.0.2.1
```

```
traceroute to 10.0.2.1 (10.0.2.1), 30 hops max, 60 byte packets  
 1  10.0.1.254  0.087 ms  0.011 ms  0.007 ms  (Da 10.0.1.1 vado a R1)  
 2  192.168.1.2  0.039 ms  0.013 ms  0.010 ms  (Da R1 ad R3)  
 3  192.168.2.1  0.019 ms  0.012 ms  0.011 ms  (Da R3 a R2)  
 4  10.0.2.1    0.021 ms  0.016 ms  0.017 ms  (Da R2 a 10.0.2.1)
```

GRE tunneling



H1 = (10.0.1.1)

Raggiungibilità con GRE

```
H1> ping -c 3 10.0.2.1
```

```
PING 10.0.2.1 (10.0.2.1) 56(84) bytes of data.
```

```
64 bytes from 10.0.2.1: icmp_seq=1 ttl=62 time=0.153 ms
```

```
64 bytes from 10.0.2.1: icmp_seq=2 ttl=62 time=0.150 ms
```

```
64 bytes from 10.0.2.1: icmp_seq=3 ttl=62 time=0.141 ms
```



significa che rispetto a prima, senza GRE, ho fatto un salto in meno

```
--- 10.0.2.1 ping statistics ---
```

```
3 packets transmitted, 3 received, 0% packet loss, time 2025ms
```

```
rtt min/avg/max/mdev = 0.141/0.148/0.153/0.005 ms
```

```
H1> traceroute -n 10.0.2.1
```

```
traceroute to 10.0.2.1 (10.0.2.1), 30 hops max, 60 byte packets
```

```
1  10.0.1.254  0.066 ms  0.011 ms  0.006 ms  (Da 10.0.1.1 a R1)
```

```
2  192.168.10.2  0.073 ms  0.023 ms  0.017 ms  (Da R1 a R2, tramite GRE)
```

```
3  10.0.2.1  0.028 ms  0.020 ms  0.021 ms  (Da R2 a 10.0.2.1)
```

SENZA GRE

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.1.1	10.0.2.1	ICMP	100	Echo (ping) request id=0x7ac
2	0.000050077	10.0.2.1	10.0.1.1	ICMP	100	Echo (ping) reply id=0x7ac
3	1.024171806	10.0.1.1	10.0.2.1	ICMP	100	Echo (ping) request id=0x7ac
4	1.024252590	10.0.2.1	10.0.1.1	ICMP	100	Echo (ping) reply id=0x7ac
5	2.048309466	10.0.1.1	10.0.2.1	ICMP	100	Echo (ping) request id=0x7ac
6	2.048397298	10.0.2.1	10.0.1.1	ICMP	100	Echo (ping) reply id=0x7ac

Frame 1: 100 bytes on wire (800 bits), 100 bytes captured (800 bits) on interface G1, id 0

Linux cooked capture v1

Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.2.1

- 0100 = Version: 4
- 0101 = Header Length: 20 bytes (5)
- Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
 - Total Length: 84
 - Identification: 0x6ec2 (28354)
- Flags: 0x40, Don't fragment
 - ...0 0000 0000 0000 = Fragment Offset: 0
 - Time to Live: 63
 - Protocol: ICMP (1)
 - Header Checksum: 0xb5e5 [validation disabled]
 - [Header checksum status: Unverified]
 - Source Address: 10.0.1.1
 - Destination Address: 10.0.2.1
- Internet Control Message Protocol

CON GRE

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.1.1	10.0.2.1	ICMP	122	Echo (ping) request id=0x540
2	0.000040680	10.0.2.1	10.0.1.1	ICMP	122	Echo (ping) reply id=0x540
3	1.013678199	10.0.1.1	10.0.2.1	ICMP	122	Echo (ping) request id=0x540
4	1.013727465	10.0.2.1	10.0.1.1	ICMP	122	Echo (ping) reply id=0x540
5	2.037533124	10.0.1.1	10.0.2.1	ICMP	122	Echo (ping) request id=0x540
6	2.037581197	10.0.2.1	10.0.1.1	ICMP	122	Echo (ping) reply id=0x540
7	5.013704638	32:5d:a5:a0:ea:c1	ca:5f:9d:d3:7d:c2	ARP	42	Who has 192.168.1.2? Tell 192
8	5.013687243	ca:5f:9d:d3:7d:c2	32:5d:a5:a0:ea:c1	ARP	42	Who has 192.168.1.1? Tell 192
9	5.013774579	32:5d:a5:a0:ea:c1	ca:5f:9d:d3:7d:c2	ARP	42	192.168.1.1 is at 32:5d:a5:a0
10	5.013786309	ca:5f:9d:d3:7d:c2	32:5d:a5:a0:ea:c1	ARP	42	192.168.1.2 is at ca:5f:9d:d3

Frame 1: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) on interface veth1, id 0

Ethernet II, Src: 32:5d:a5:a0:ea:c1 (32:5d:a5:a0:ea:c1), Dst: ca:5f:9d:d3:7d:c2 (ca:5f:9d:d3:7d:c2)

Internet Protocol Version 4, Src: 192.168.1.1, Dst: 192.168.2.1

0100 = Version: 4
 0101 = Header Length: 20 bytes (5)

Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
 Total Length: 108
 Identification: 0x4666 (18022)
 Flags: 0x40, Don't fragment
 ...0 0000 0000 0000 = Fragment Offset: 0
 Time to Live: 63
 Protocol: Generic Routing Encapsulation (47)
 Header Checksum: 0x70aa [validation disabled]
 [Header checksum status: Unverified]
 Source Address: 192.168.1.1
 Destination Address: 192.168.2.1

Generic Routing Encapsulation (IP)

Flags and Version: 0x0000
 Protocol Type: IP (0x0800)

Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.2.1

Internet Control Message Protocol

IP Header Esterno: Contiene gli indirizzi IP origine e destinazione dei router che stanno gestendo il tunnel GRE. Questi indirizzi sono utilizzati per il trasporto del pacchetto attraverso la rete pubblica (o il percorso di rete che ospita il tunnel).

IP Header Interno: Contiene gli indirizzi IP origine e destinazione dei dispositivi che comunicano. Questi indirizzi sono quelli originali del pacchetto prima che fosse incapsulato nel tunnel GRE.

Gli indirizzi IP di origine e destinazione nell'IP Header Esterno sono statici e rappresentano gli endpoint del tunnel GRE

Le due rotte aggiunte o modificate nella tabella di routing di R1 dopo la configurazione del tunnel GRE sono utilizzate per indirizzare il traffico attraverso il tunnel, e il software GRE si occupa dell'incapsulamento (quando il pacchetto viene inviato nel tunnel) e del decapsulamento (quando il pacchetto arriva all'endpoint del tunnel). Queste operazioni permettono di trasportare pacchetti attraverso una rete pubblica, simulando una rete privata tra i router, e mantenendo l'indirizzamento originale per i pacchetti.

R1 dopo il GRE

```
R1> route -n
```

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H1
10.0.2.0	192.168.10.2	255.255.255.0	UG	0	0	0	G1
192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth1
192.168.2.0	192.168.1.2	255.255.255.252	UG	0	0	0	veth1
192.168.10.0	0.0.0.0	255.255.255.252	U	0	0	0	G1

Questo indica che, dopo l'implementazione del tunnel GRE, il traffico verso 10.0.2.0 viene instradato attraverso un router remoto (192.168.10.2), il quale gestisce il tunnel GRE.

R1 prima del GRE

```
R1> route -n
```

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H1
10.0.2.0	192.168.1.2	255.255.255.0	UG	0	0	0	veth1
192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth1
192.168.2.0	192.168.1.2	255.255.255.252	UG	0	0	0	veth1

Le due rotte aggiunte o modificate nella tabella di routing di R1 dopo la configurazione del tunnel GRE sono utilizzate per indirizzare il traffico attraverso il tunnel, e il software GRE si occupa dell'incapsulamento (quando il pacchetto viene inviato nel tunnel) e del decapsulamento (quando il pacchetto arriva all'endpoint del tunnel). Queste operazioni permettono di trasportare pacchetti attraverso una rete pubblica, simulando una rete privata tra i router, e mantenendo l'indirizzamento originale per i pacchetti.

R2 dopo il GRE

Questo indica che, dopo l'implementazione del tunnel GRE, il traffico verso 10.0.1.0 viene instradato attraverso un router remoto (192.168.10.1), il quale gestisce il tunnel GRE.

```
R2> route -n
```

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	192.168.10.1	255.255.255.0	UG	0	0	0	G1
10.0.2.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H2
192.168.1.0	192.168.2.2	255.255.255.252	UG	0	0	0	veth2
192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth2
192.168.10.0	0.0.0.0	255.255.255.252	U	0	0	0	G1

R2 Prima del GRE

```
R2> route -n
```

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	192.168.2.2	255.255.255.0	UG	0	0	0	veth2
10.0.2.0	0.0.0.0	255.255.255.0	U	0	0	0	eth-H2
192.168.1.0	192.168.2.2	255.255.255.252	UG	0	0	0	veth2
192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth2

R3 prima e dopo (Non cambia nulla)

Prima del GRE

```
R3> route -n
```

```
Kernel IP routing table
```

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	192.168.1.1	255.255.255.0	UG	0	0	0	veth13
10.0.2.0	192.168.2.1	255.255.255.0	UG	0	0	0	veth23
192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth13
192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth23

Dopo il GRE

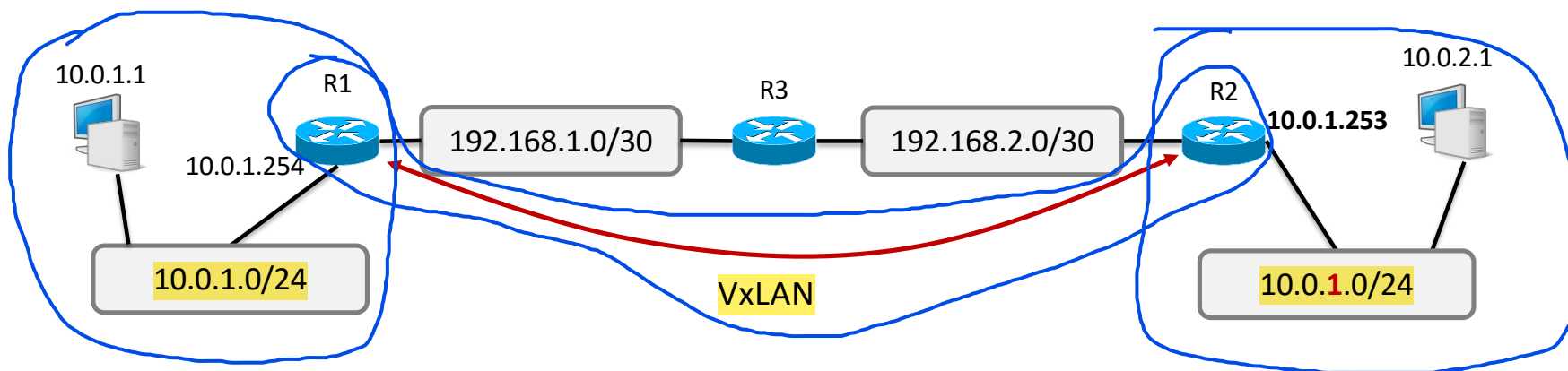
```
R3> route -n
```

```
Kernel IP routing table
```

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.1.0	192.168.1.1	255.255.255.0	UG	0	0	0	veth13
10.0.2.0	192.168.2.1	255.255.255.0	UG	0	0	0	veth23
192.168.1.0	0.0.0.0	255.255.255.252	U	0	0	0	veth13
192.168.2.0	0.0.0.0	255.255.255.252	U	0	0	0	veth23

VxLAN tunneling

In una configurazione VXLAN, i router possono essere virtualmente considerati come appartenenti alla stessa rete locale (Layer 2), quindi con stessa sottorete IP.



- Indirizzo IP di sorgente: Indica l'indirizzo IP del VTEP di origine, ossia il dispositivo che incapsula il traffico Ethernet in pacchetti VXLAN per il trasporto attraverso la rete IP sottostante.
- Indirizzo IP di destinazione: Indica l'indirizzo IP del VTEP di destinazione, ossia il dispositivo che riceve i pacchetti VXLAN, li decapsula e inoltra il traffico Ethernet alla destinazione finale.

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	00:00:00_11:11:11	Broadcast	ARP	92	Who has 10.0.1.253? Tell
2	0.000057066	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	10.0.1.253 is at 8a:1f:
→ 3	0.000076235	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
← 4	0.000130103	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
5	1.030346566	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
6	1.030382994	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
7	2.054220288	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
8	2.054268793	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
9	5.254393703	1a:4b:ce:42:79:fa	02:8e:a2:8e:77:a0	ARP	42	Who has 192.168.2.2? Te
10	5.254489004	02:8e:a2:8e:77:a0	1a:4b:ce:42:79:fa	ARP	42	192.168.2.2 is at 02:8e
11	5.254466710	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	Who has 10.0.1.1? Tell

Frame 3: 148 bytes on wire (1184 bits), 148 bytes captured (1184 bits) on interface veth23, id 0

Ethernet II, Src: 02:8e:a2:8e:77:a0 (02:8e:a2:8e:77:a0), Dst: 1a:4b:ce:42:79:fa (1a:4b:ce:42:79:fa)

Internet Protocol Version 4, Src: 192.168.1.1, Dst: 192.168.2.1

0100 = Version: 4

.... 0101 = Header Length: 20 bytes (5)

Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)

Total Length: 134

Identification: 0x3a76 (14966)

Flags: 0x00

...0 0000 0000 0000 = Fragment Offset: 0

Time to Live: 63

Protocol: UDP (17)

Header Checksum: 0xbc9e [validation disabled]

[Header checksum status: Unverified]

Source Address: 192.168.1.1

Destination Address: 192.168.2.1

User Datagram Protocol, Src Port: 52140, Dst Port: 4789

Virtual eXtensible Local Area Network

Ethernet II, Src: 00:00:00_11:11:11 (00:00:00:11:11:11), Dst: 8a:1f:65:08:01:5a (8a:1f:65:08:01:5a)

Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.1.253

Internet Control Message Protocol

Outer Ethernet Header: Contiene gli indirizzi MAC di origine e destinazione dei dispositivi di rete che il pacchetto passa (ad ogni hop, il dispositivo, ricevente il pacchetto, aggiorna il MAC di origine con il proprio MAC e il MAC di destinazione con quello del dispositivo successivo)

Inner Ethernet Header: Rappresenta gli indirizzi MAC dei dispositivi originali finali all'interno della rete locale, permettendo la comunicazione tra dispositivi sulla stessa VLAN.

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	00:00:00_11:11:11	Broadcast	ARP	92	Who has 10.0.1.253? Tell
2	0.000057066	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	10.0.1.253 is at 8a:1f:
→ 3	0.000076235	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
← 4	0.000130103	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
5	1.030346566	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
6	1.030382994	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
7	2.054220288	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
8	2.054268793	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
9	5.254393703	1a:4b:ce:42:79:fa	02:8e:a2:8e:77:a0	ARP	42	Who has 192.168.2.2? Te
10	5.254489004	02:8e:a2:8e:77:a0	1a:4b:ce:42:79:fa	ARP	42	192.168.2.2 is at 02:8e
11	5.254466710	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	Who has 10.0.1.1? Tell

Frame 3: 148 bytes on wire (1184 bits), 148 bytes captured (1184 bits) on interface veth23, id 0

- Ethernet II, Src: 02:8e:a2:8e:77:a0 (02:8e:a2:8e:77:a0), Dst: 1a:4b:ce:42:79:fa (1a:4b:ce:42:79:fa)
- Internet Protocol Version 4, Src: 192.168.1.1, Dst: 192.168.2.1
- User Datagram Protocol, Src Port: 52140, Dst Port: 4789
 - Source Port: 52140
 - Destination Port: 4789
 - Length: 114
 - Checksum: 0x84d6 [unverified]
[Checksum Status: Unverified]
 - [Stream index: 2]
 - [Timestamps]
 - UDP payload (106 bytes)
- Virtual eXtensible Local Area Network
- Ethernet II, Src: 00:00:00_11:11:11 (00:00:00:11:11:11), Dst: 8a:1f:65:08:01:5a (8a:1f:65:08:01:5a)
- Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.1.253
- Internet Control Message Protocol

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	00:00:00_11:11:11	Broadcast	ARP	92	Who has 10.0.1.253? Tell
2	0.000057066	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	10.0.1.253 is at 8a:1f:
→ 3	0.000076235	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
← 4	0.000130103	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
5	1.030346566	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
6	1.030382994	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
7	2.054220288	10.0.1.1	10.0.1.253	ICMP	148	Echo (ping) request id
8	2.054268793	10.0.1.253	10.0.1.1	ICMP	148	Echo (ping) reply id
9	5.254393703	1a:4b:ce:42:79:fa	02:8e:a2:8e:77:a0	ARP	42	Who has 192.168.2.2? Te
10	5.254489004	02:8e:a2:8e:77:a0	1a:4b:ce:42:79:fa	ARP	42	192.168.2.2 is at 02:8e
11	5.254466710	8a:1f:65:08:01:5a	00:00:00_11:11:11	ARP	92	Who has 10.0.1.1? Tell

▶ Frame 3: 148 bytes on wire (1184 bits), 148 bytes captured (1184 bits) on interface veth23, id 0

- ▶ Ethernet II, Src: 02:8e:a2:8e:77:a0 (02:8e:a2:8e:77:a0), Dst: 1a:4b:ce:42:79:fa (1a:4b:ce:42:79:fa)
- ▶ Internet Protocol Version 4, Src: 192.168.1.1, Dst: 192.168.2.1
- ▶ User Datagram Protocol, Src Port: 52140, Dst Port: 4789
- ▼ Virtual eXtensible Local Area Network
 - ▶ Flags: 0x0800, VXLAN Network ID (VNI)
 - Group Policy ID: 0
 - VXLAN Network Identifier (VNI): 100
 - Reserved: 0
- ▶ Ethernet II, Src: 00:00:00_11:11:11 (00:00:00:11:11:11), Dst: 8a:1f:65:08:01:5a (8a:1f:65:08:01:5a)
- ▶ Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.1.253
- ▶ Internet Control Message Protocol