CSE 291
INTERNET DATA SCIENCE FOR CYBERSECURITY

23 January 2023

Router-level Internet Topology

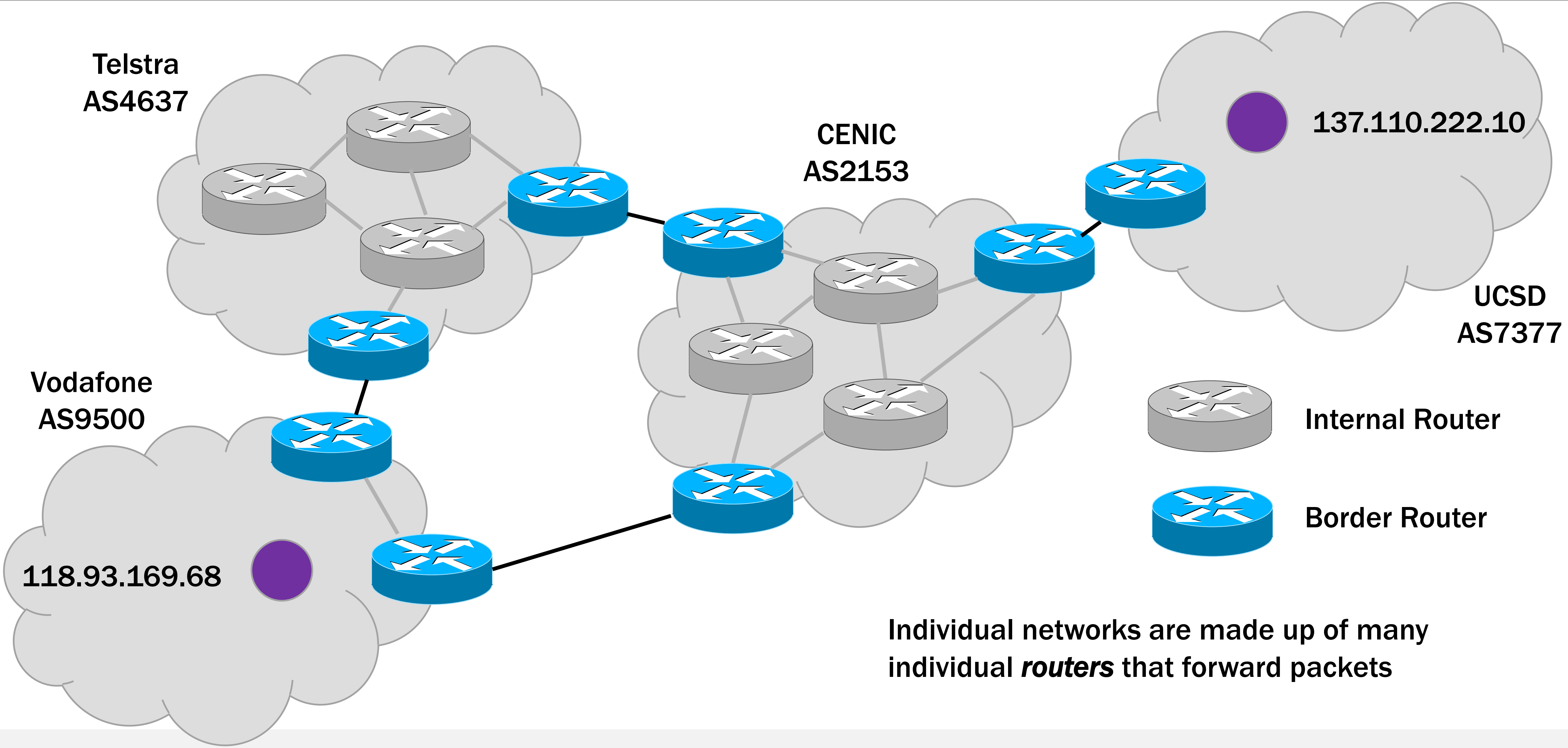
OVERVIEW

1. Background to support future work in this class, without an assigned paper (but possible projects)

LEARNING OBJECTIVES

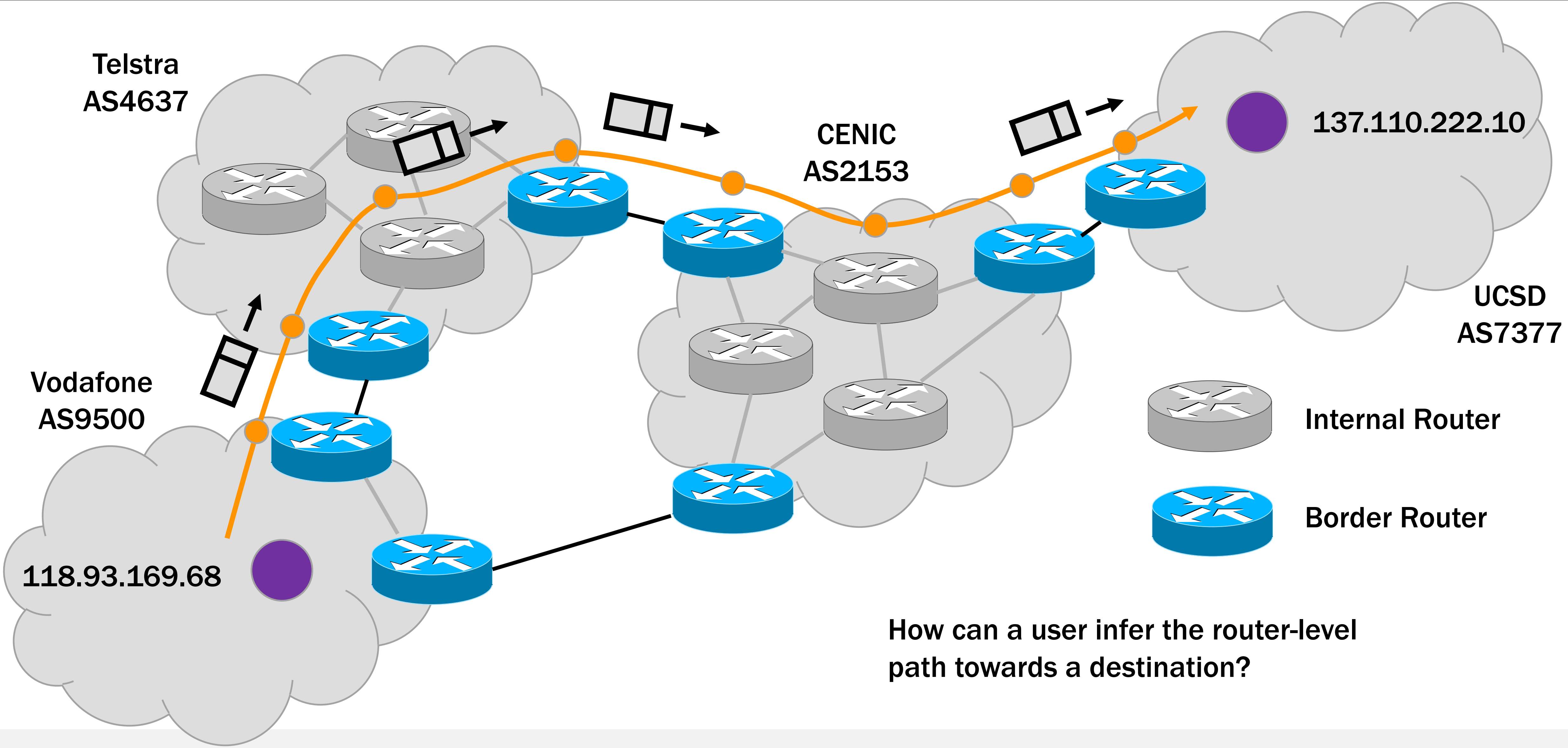
1. Be able to describe how traceroute works
2. Appreciate how operators assign IP addresses to router interfaces
3. Be able to reason about router properties based on hostname annotations

AUTONOMOUS SYSTEMS



Individual networks are made up of many individual ***routers*** that forward packets

UNCOVERING PATHS



How can a user infer the router-level path towards a destination?

TRACEROUTE

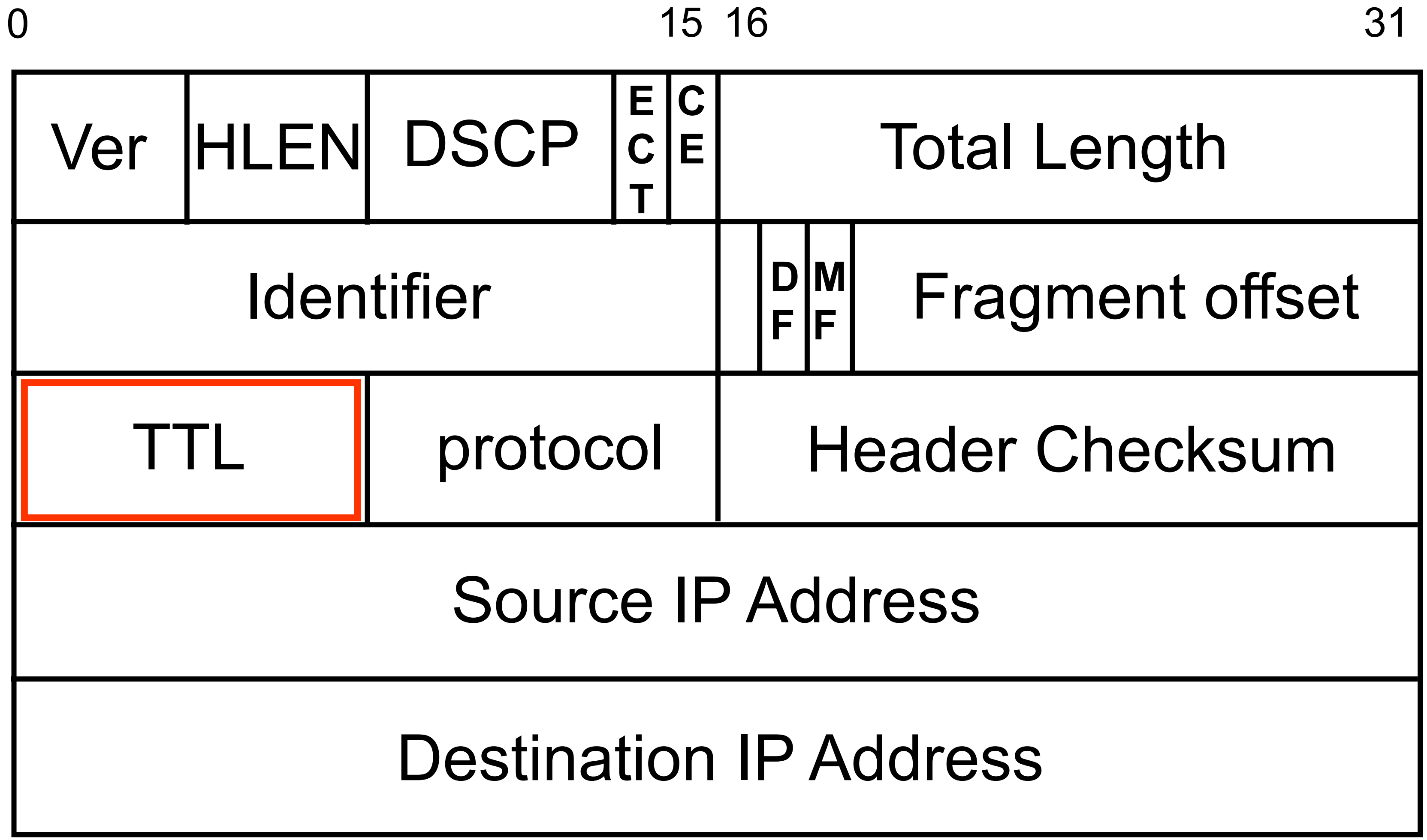
- The Internet does not have built-in path tracing facility
- Instead, we use a *hack* to infer the path, known as traceroute

IPV4 HEADER

TTL: Time-to-Live

Decremented by each router in the path to prevent a packet circling indefinitely in a loop.

When TTL reaches 1, router sends an error message to the source of the packet.

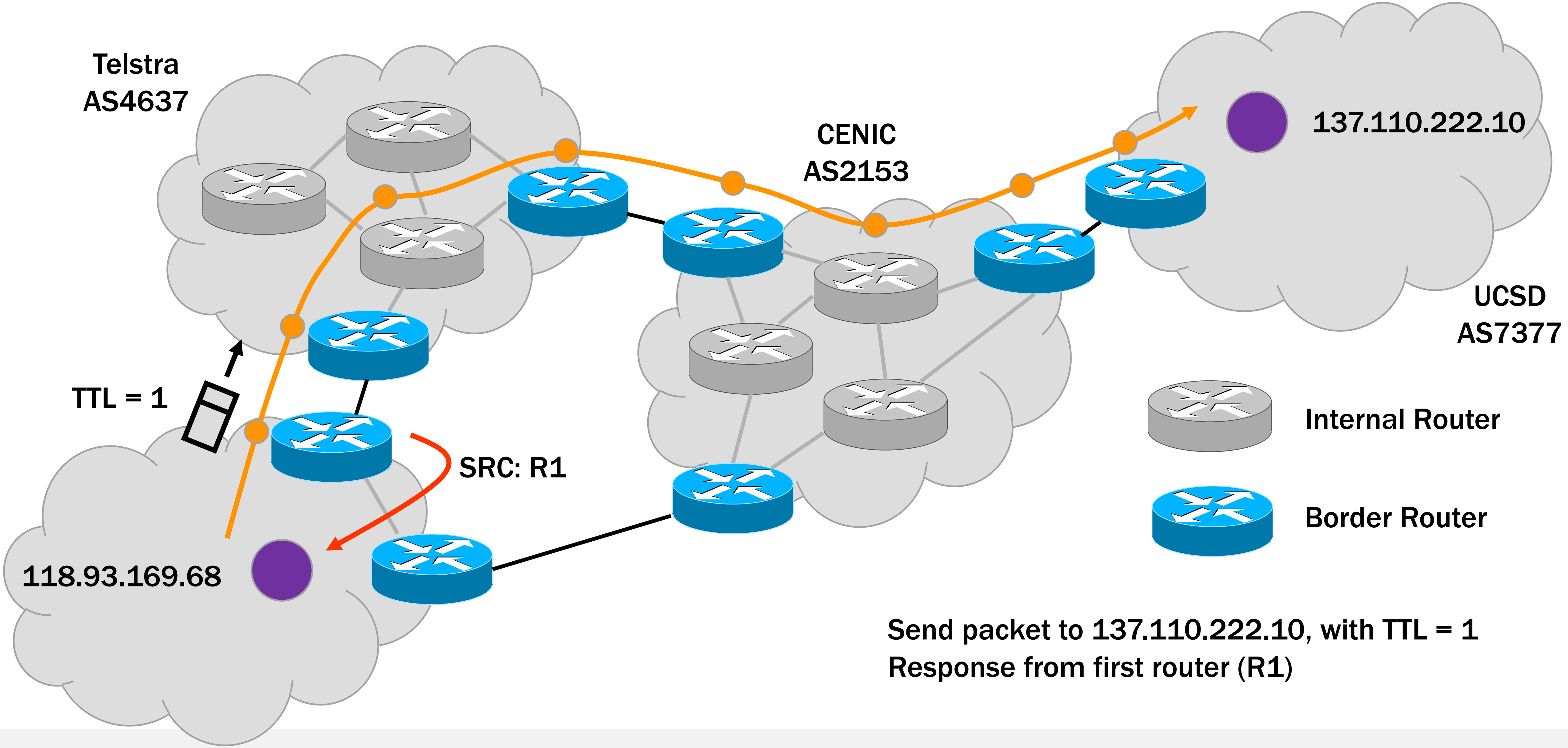


TRACEROUTE

- Send packets toward a destination, starting with TTL=1 to obtain a response from the first router
- Increment the TTL to obtain a response from the second router, and so on.

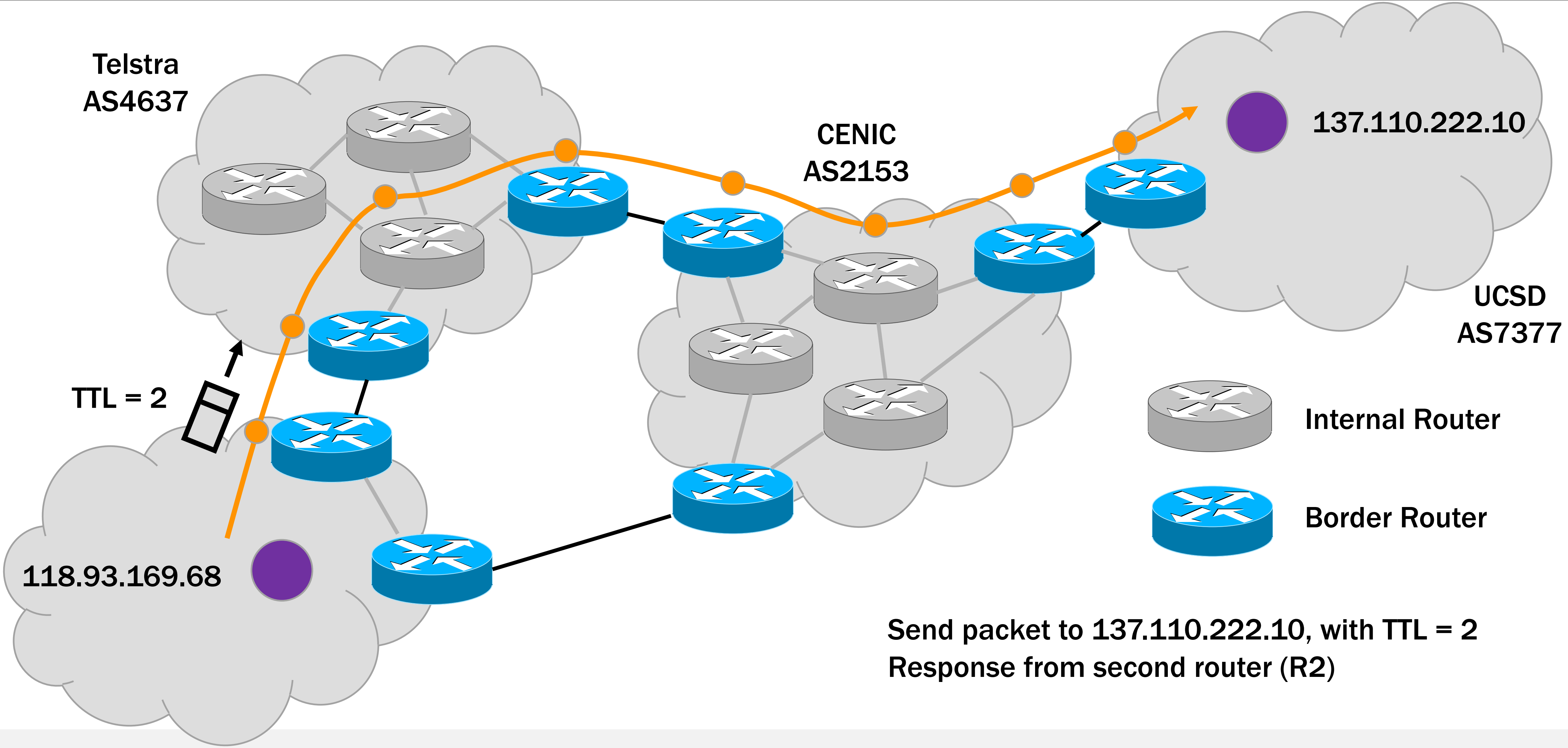
- Issue: we can only observe the forward path
- Issue: routers do not have to reply to probes

UNCOVERING PATHS



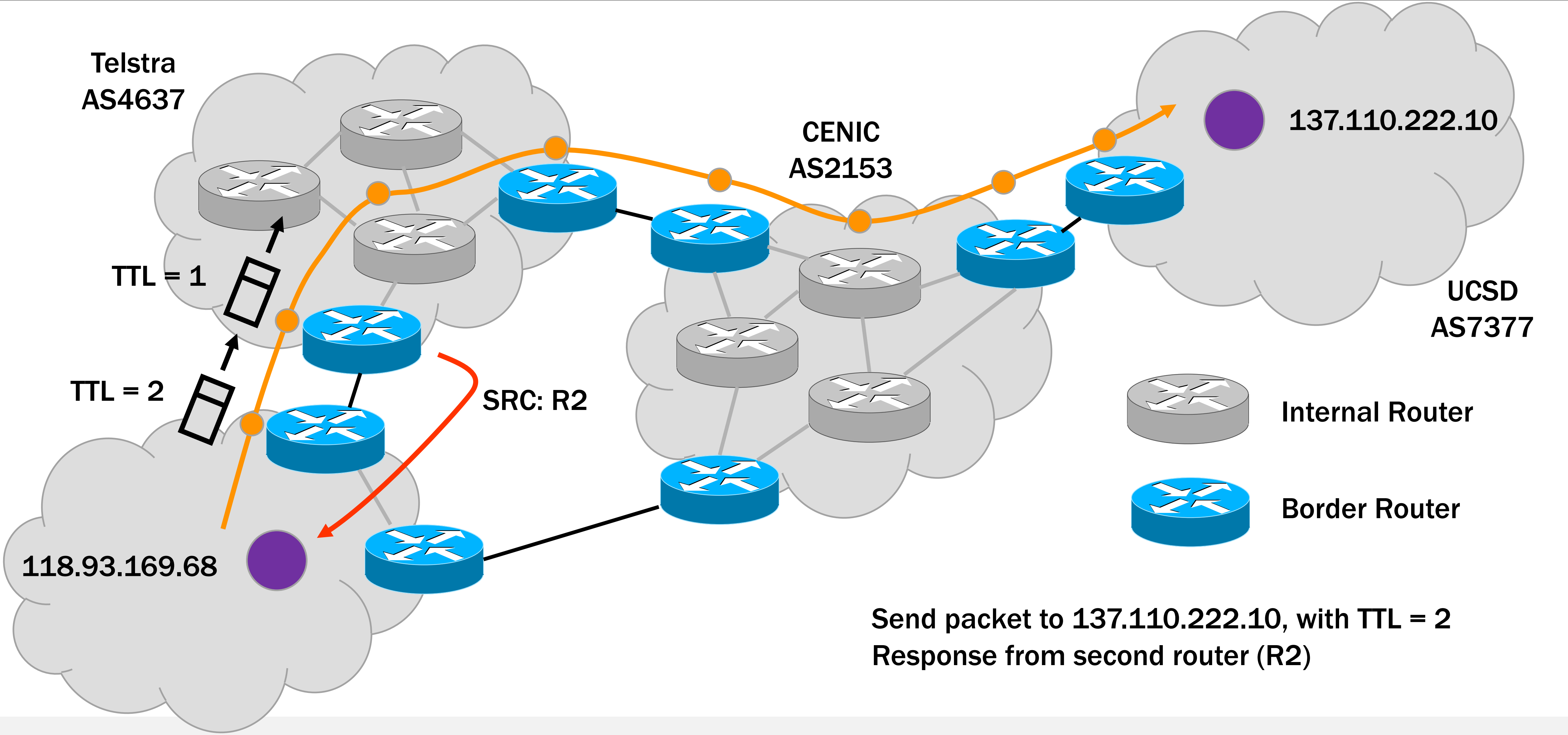
Send packet to 137.110.222.10, with TTL = 1
Response from first router (R1)

UNCOVERING PATHS



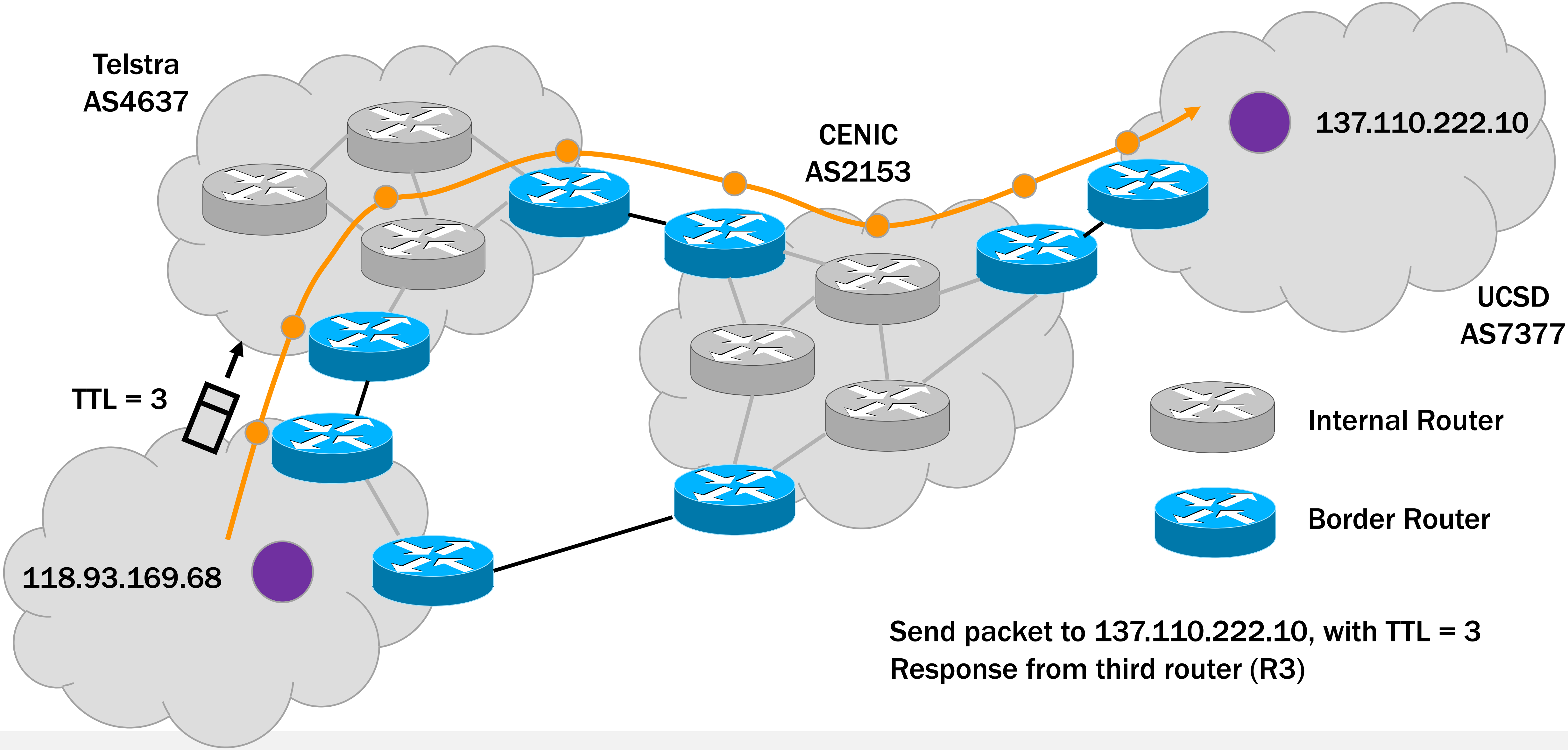
Send packet to 137.110.222.10, with TTL = 2
Response from second router (R2)

UNCOVERING PATHS



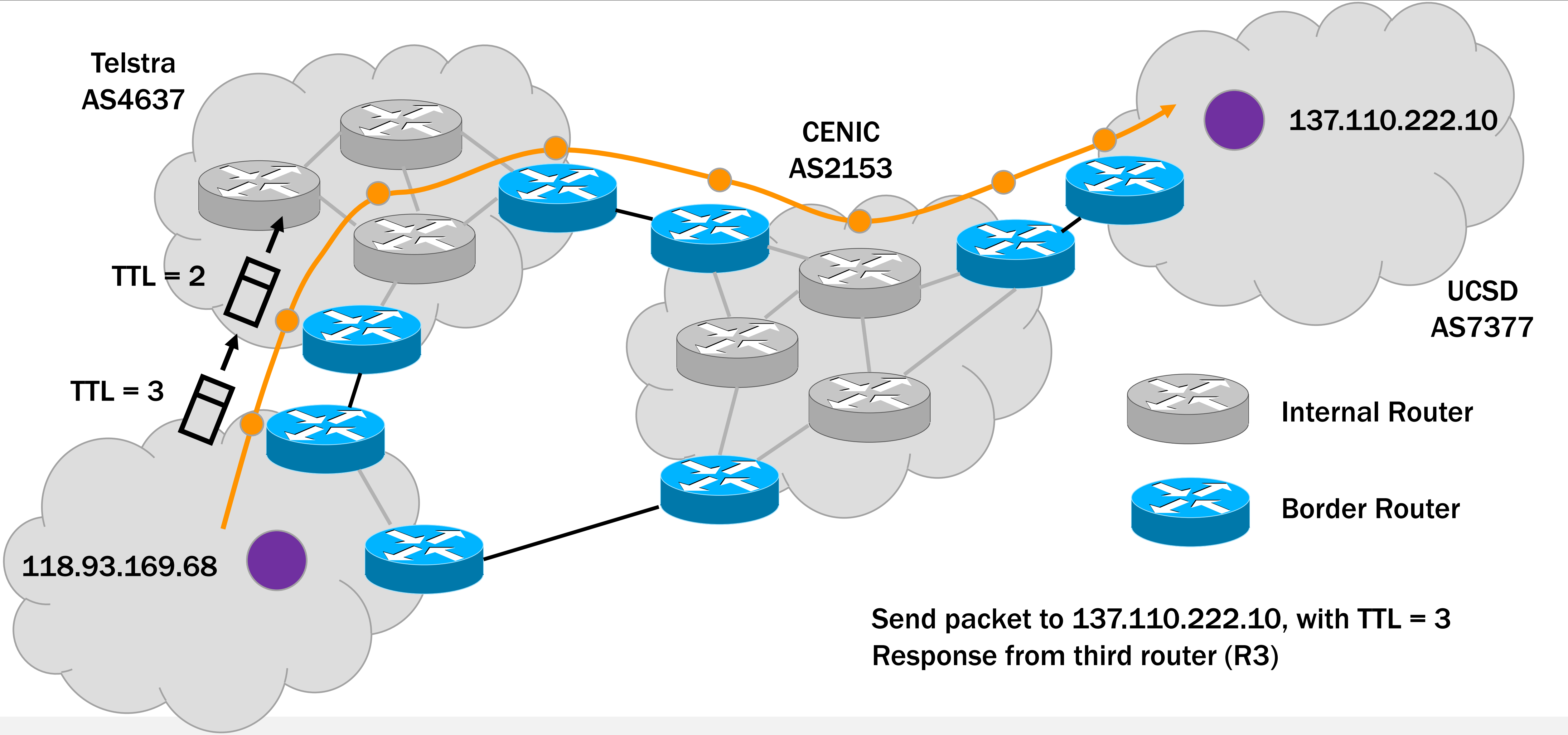
Send packet to 137.110.222.10, with TTL = 2
Response from second router (R2)

UNCOVERING PATHS



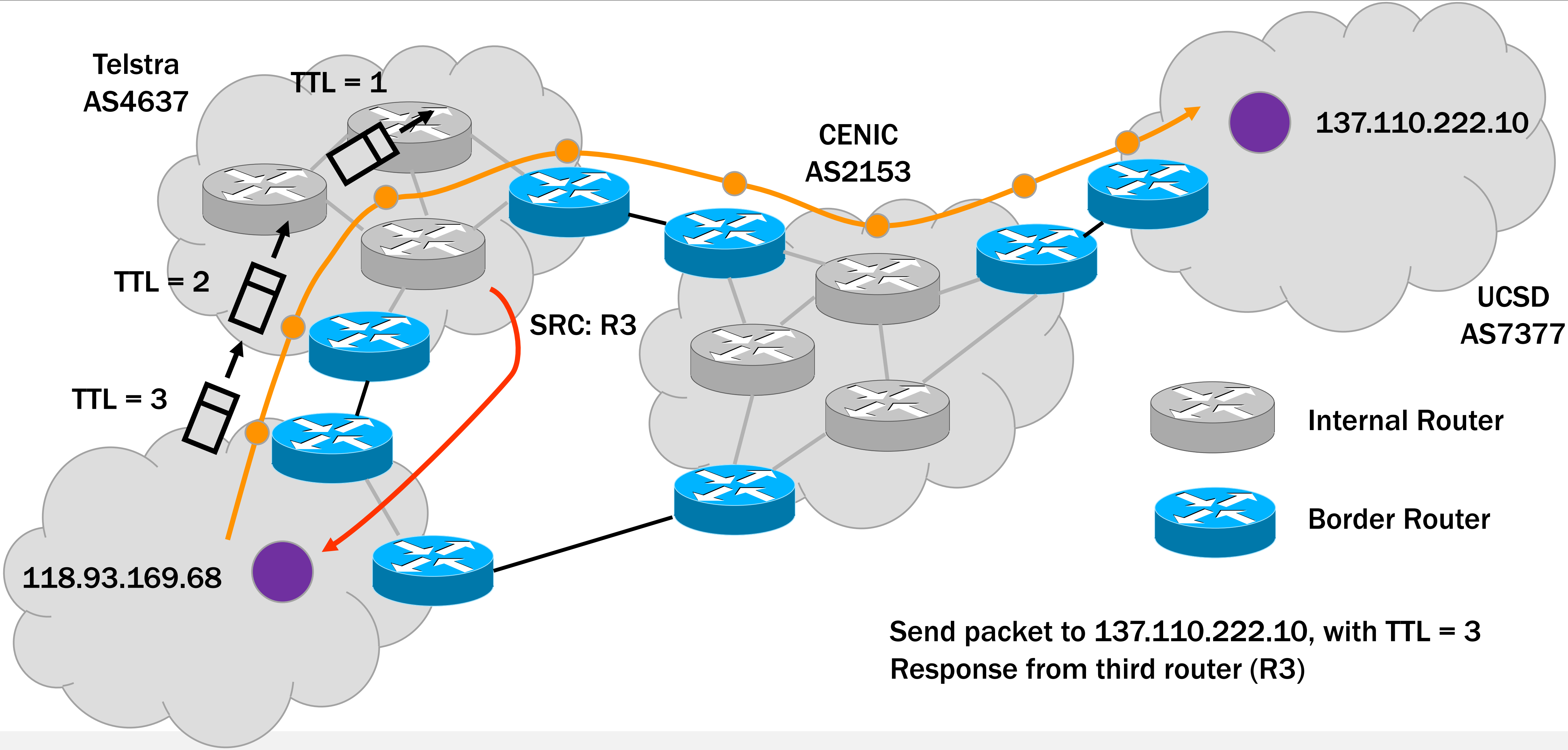
Send packet to 137.110.222.10, with TTL = 3
Response from third router (R3)

UNCOVERING PATHS



Send packet to 137.110.222.10, with TTL = 3
Response from third router (R3)

UNCOVERING PATHS



Send packet to 137.110.222.10, with TTL = 3
Response from third router (R3)

TRACEROUTE OUTPUT

```
$ traceroute -q 1 sysnet.ucsd.edu
traceroute to sysnet.ucsd.edu (137.110.222.10), 64 hops max, 40 byte packets
 1  118-93-171-254.dsl.dyn.ihug.co.nz (118.93.171.254)  11.731 ms
 2  134.159.174.38 (134.159.174.38)  13.757 ms
 3  134.159.174.41 (134.159.174.41)  14.591 ms
 4  i-93.tauc-core02.telstraglobal.net (202.84.227.53)  14.666 ms
 5  202.84.138.82 (202.84.138.82)  139.923 ms
 6  202.84.138.82 (202.84.138.82)  139.267 ms
 7  i-91.tlot02.telstraglobal.net (202.40.149.177)  137.899 ms
 8  lsan0.tr-cps.internet2.edu (206.223.123.199)  139.149 ms
 9  fourhundredge-0-0-0-0.4079.core2.losa.net.internet2.edu (163.253.1.198) 138.479 ms
10  64.57.20.83 (64.57.20.83)  136.953 ms
11  dc-tus-agg8--lax-agg8-300g.cenic.net (137.164.11.83)  139.387 ms
12  dc-sdg-agg4--tus-agg8-300g.cenic.net (137.164.11.85)  138.764 ms
13  dc-ucsd-100ge--sdg-agg4.cenic.net (137.164.23.177)  138.881 ms
14  nodem-core-6807-vlan2761-gw.ucsd.edu (132.239.254.163)  138.417 ms
15  agg-b-mcore.ucsd.edu (132.239.254.44)  138.709 ms
16  sysnet.sysnet.ucsd.edu (137.110.222.10)  138.334 ms
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Auckland

???

Los Angeles

Tustin

San Diego

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caida

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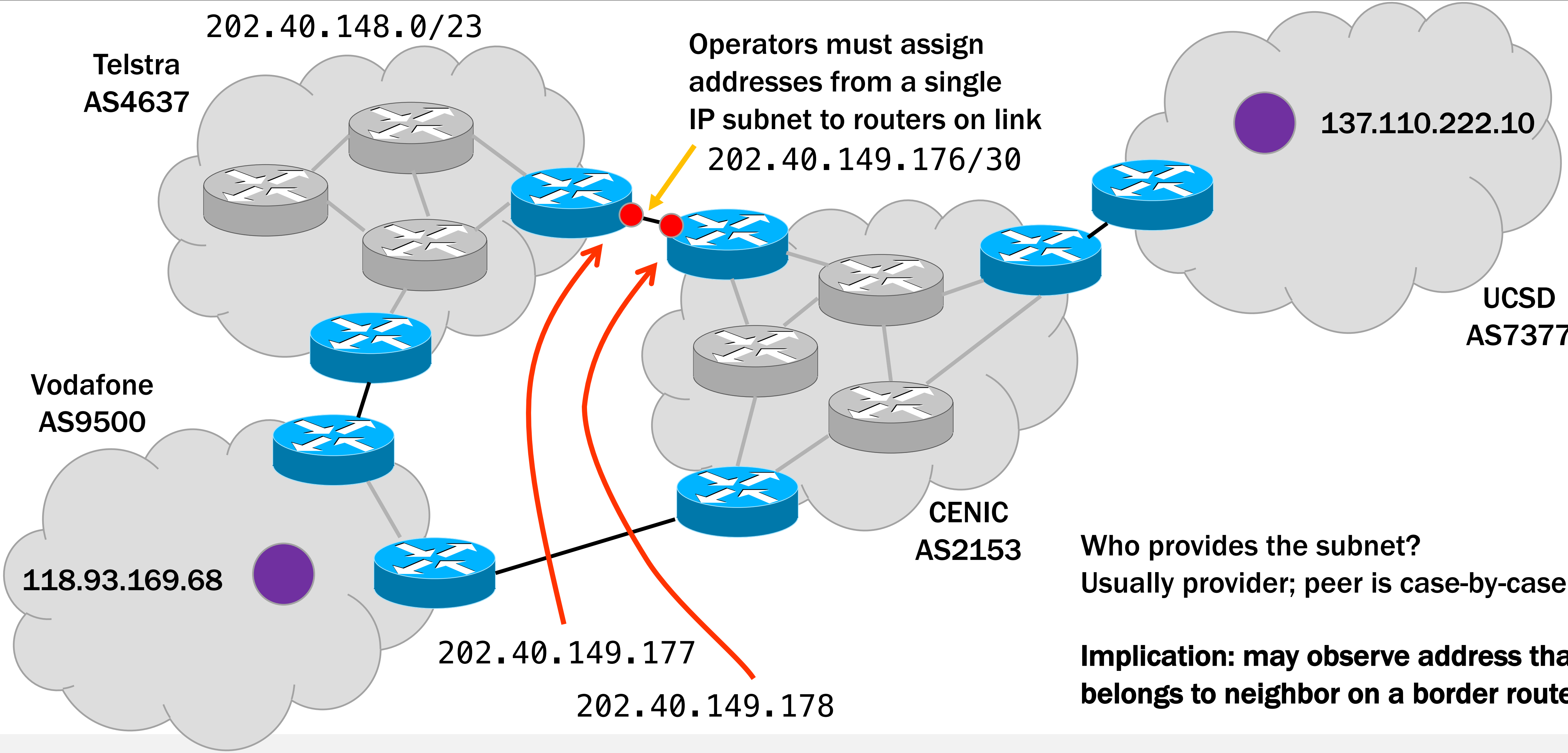
400Gbps Ethernet

300Gbps

300Gbps

100Gbps Ethernet

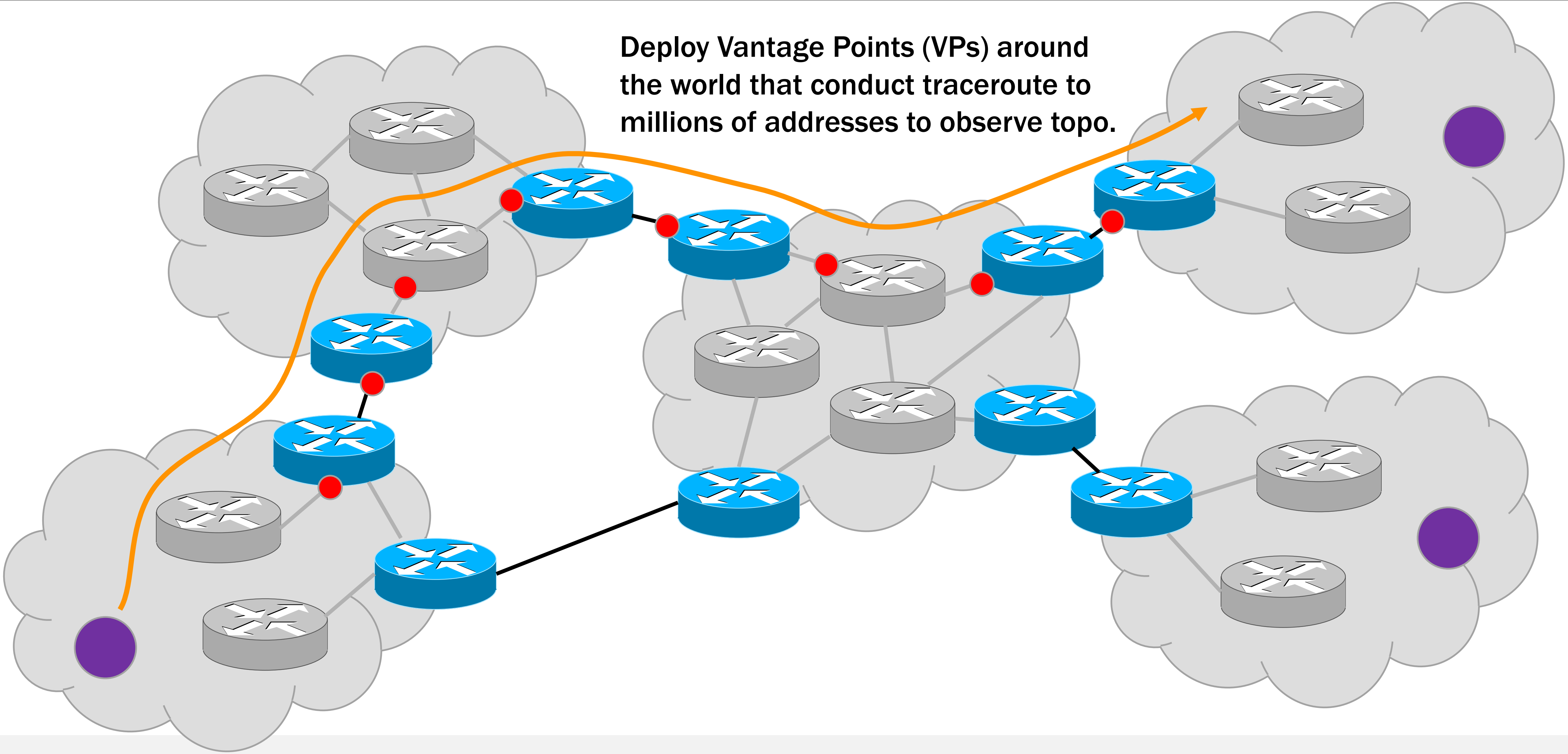
AUTONOMOUS SYSTEMS



Who provides the subnet?
Usually provider; peer is case-by-case.

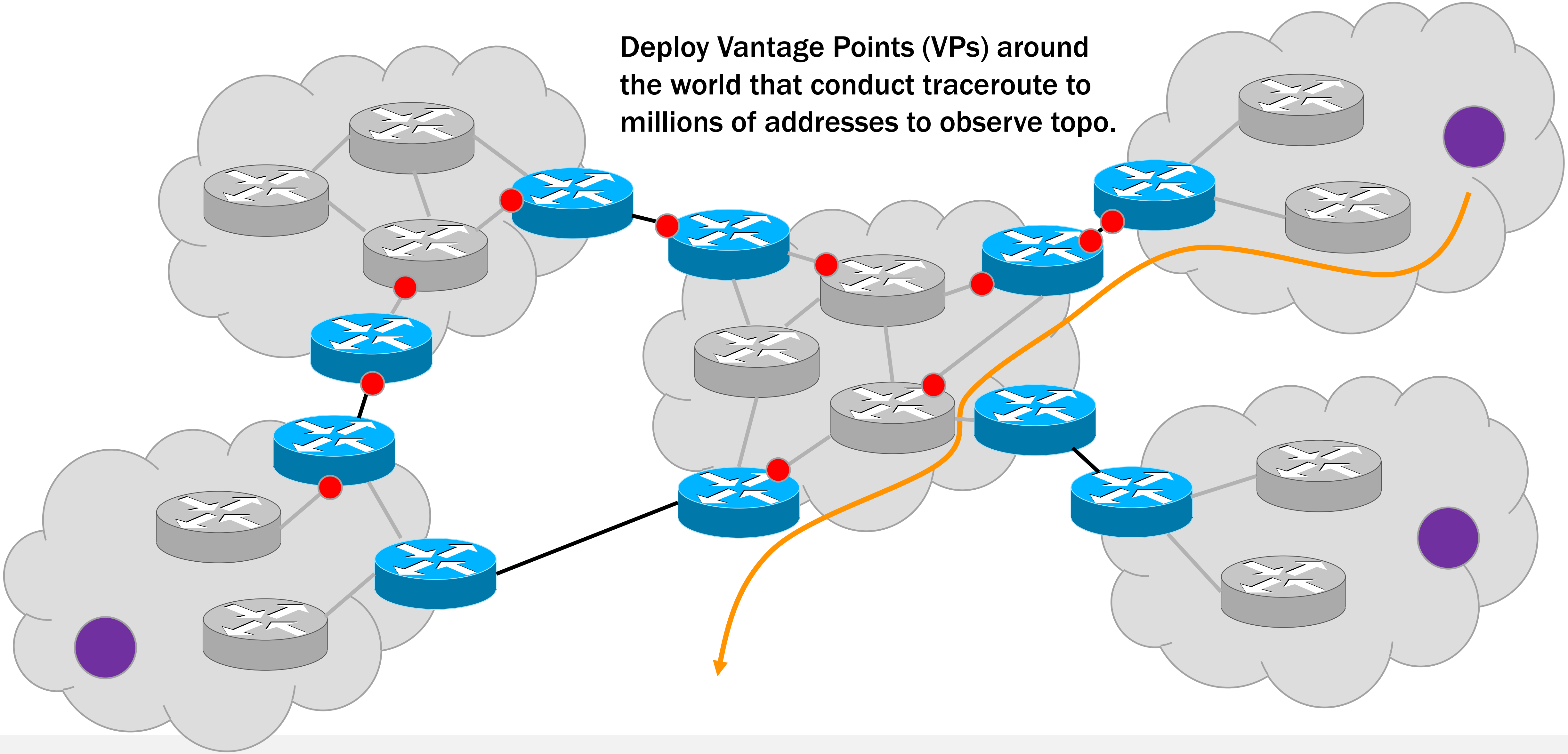
Implication: may observe address that belongs to neighbor on a border router

MACROSCOPIC TOPO DISCOVERY



MACROSCOPIC TOPO DISCOVERY

Deploy Vantage Points (VPs) around the world that conduct traceroute to millions of addresses to observe topo.



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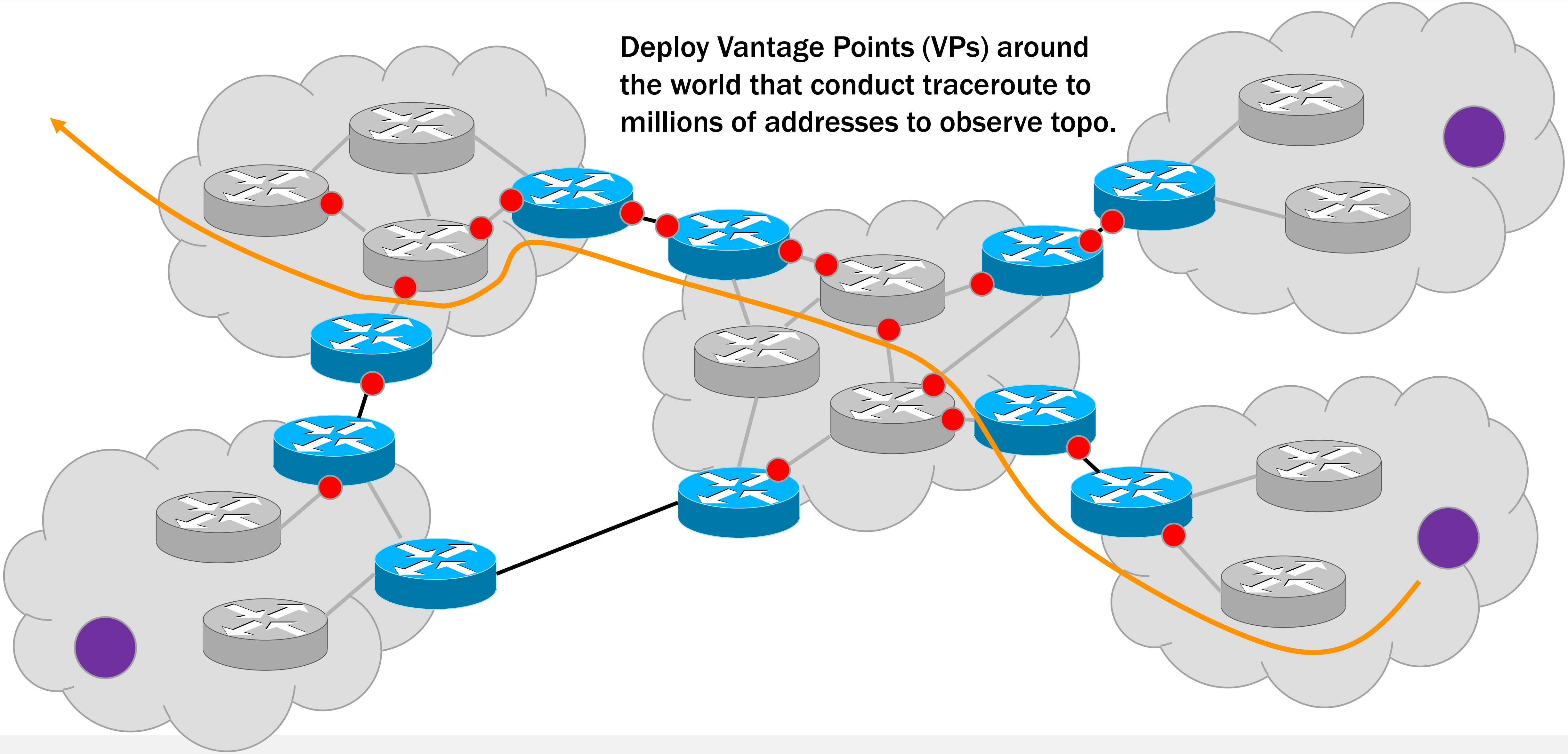

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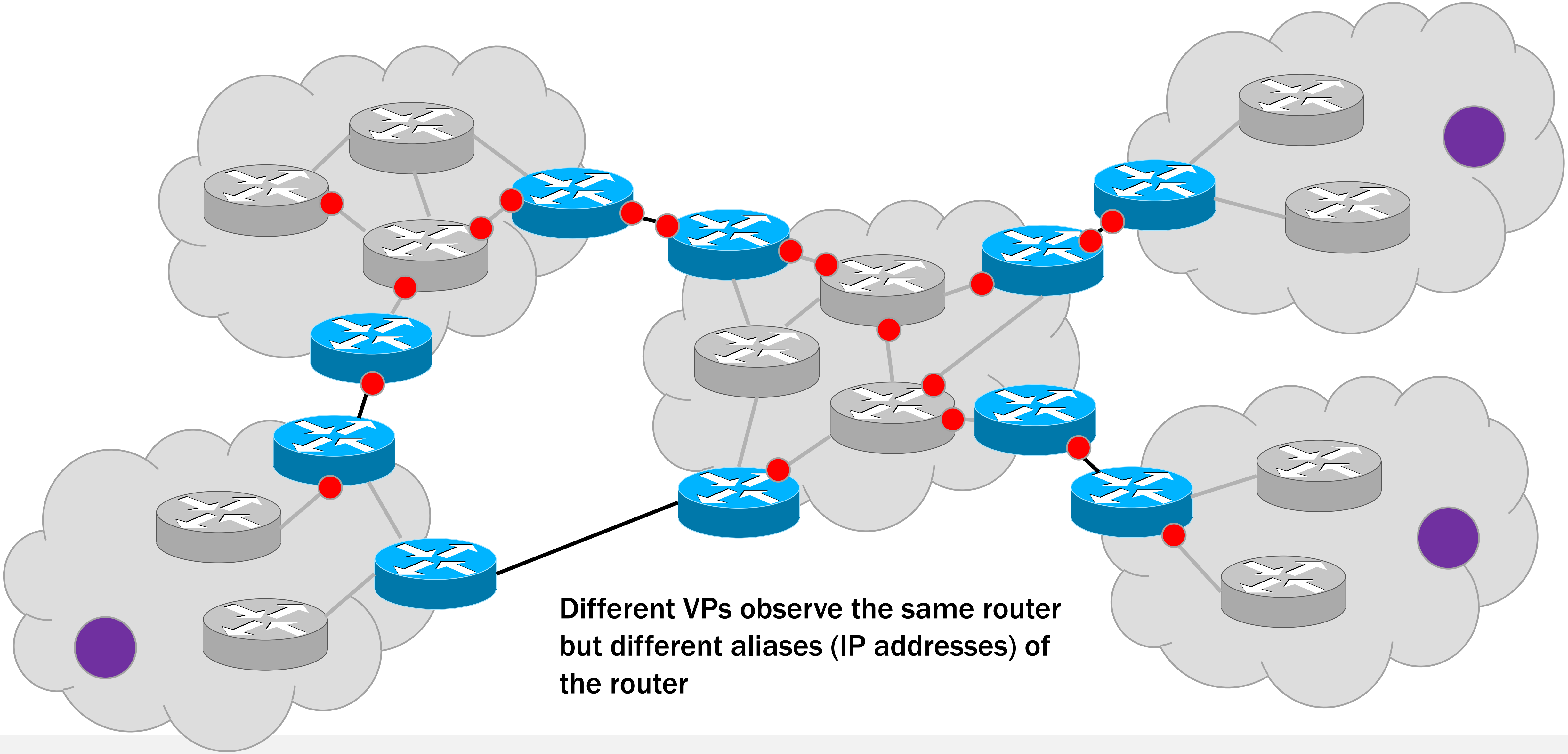
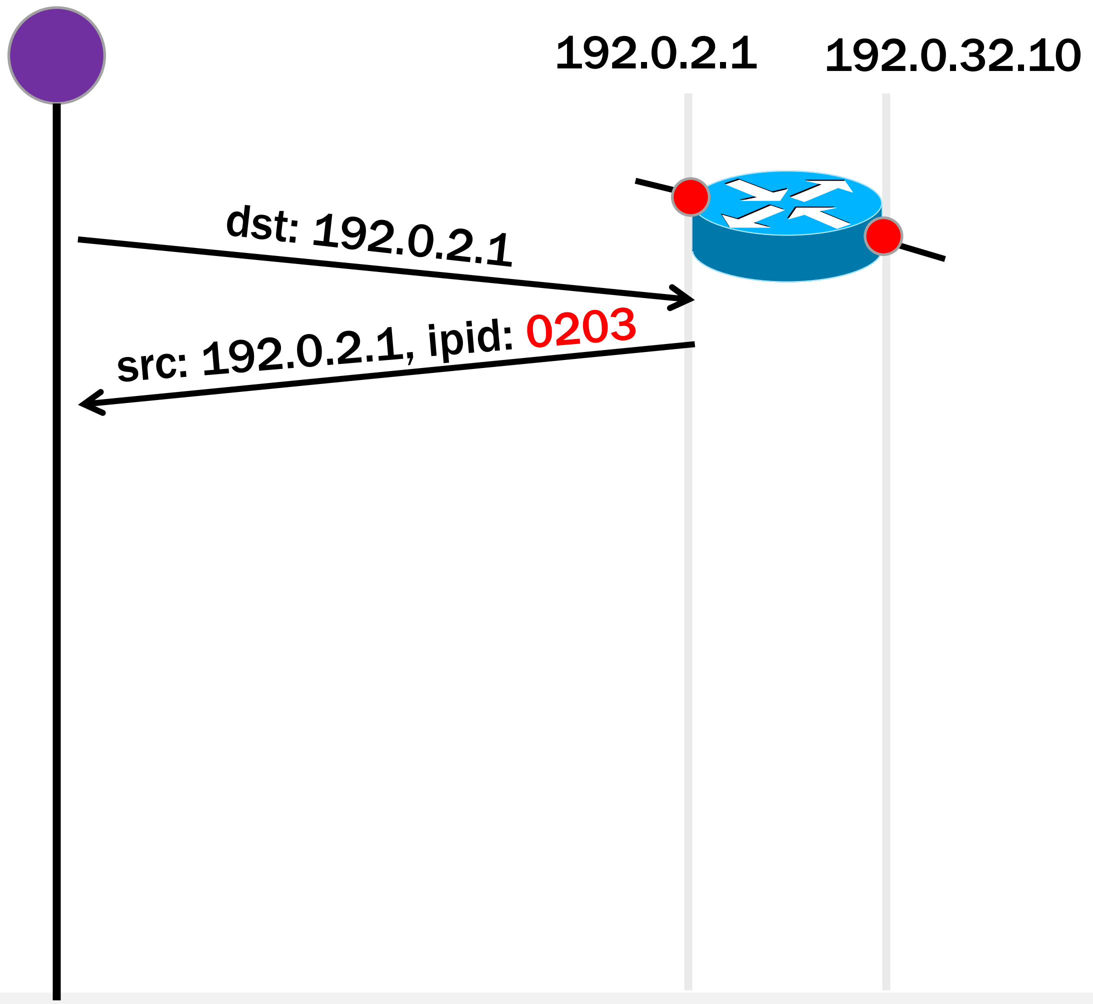


Different VPs observe the same router but different aliases (IP addresses) of the router

IPID ALIAS RESOLUTION



Idea: Infer that two addresses belong to the same router based on side channels, e.g., IP-ID

Assumption: router assigns IP-ID values from a single central counter.

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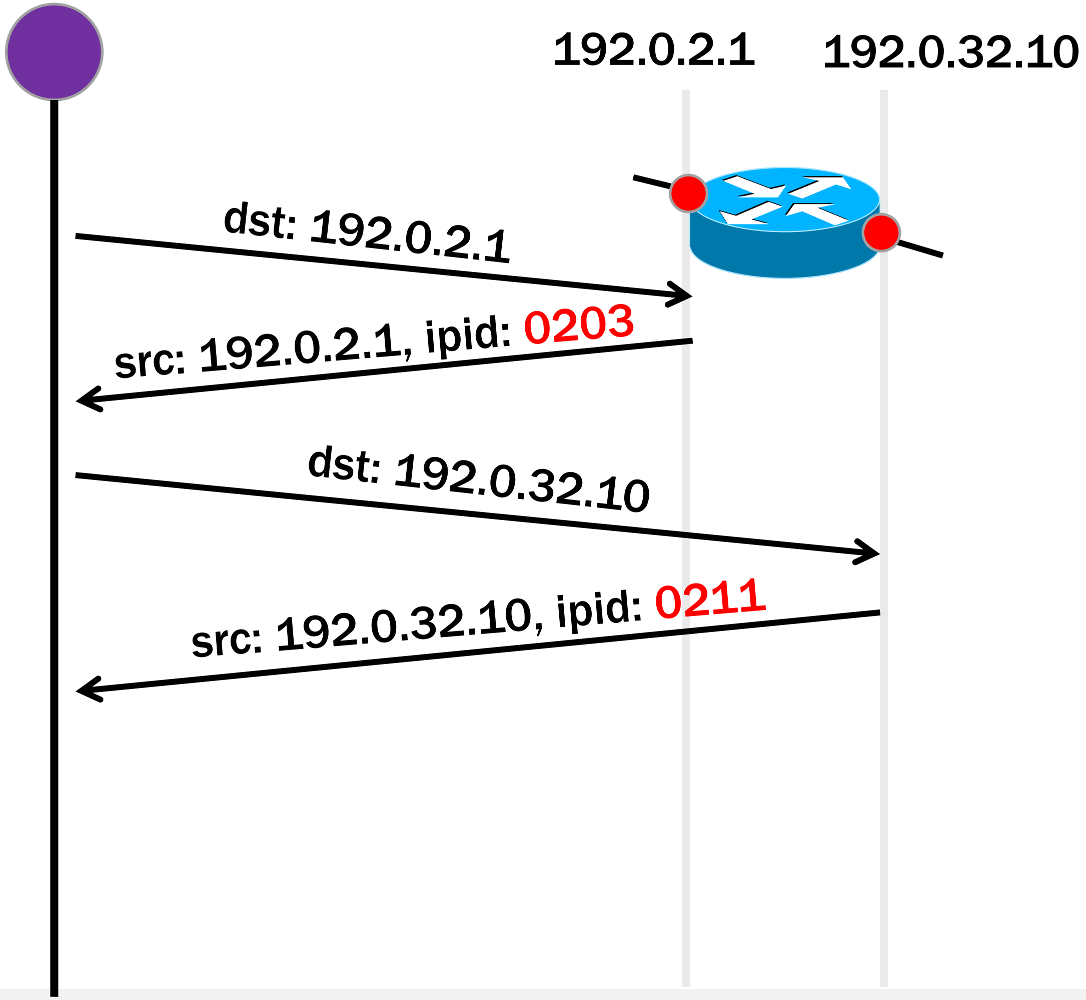

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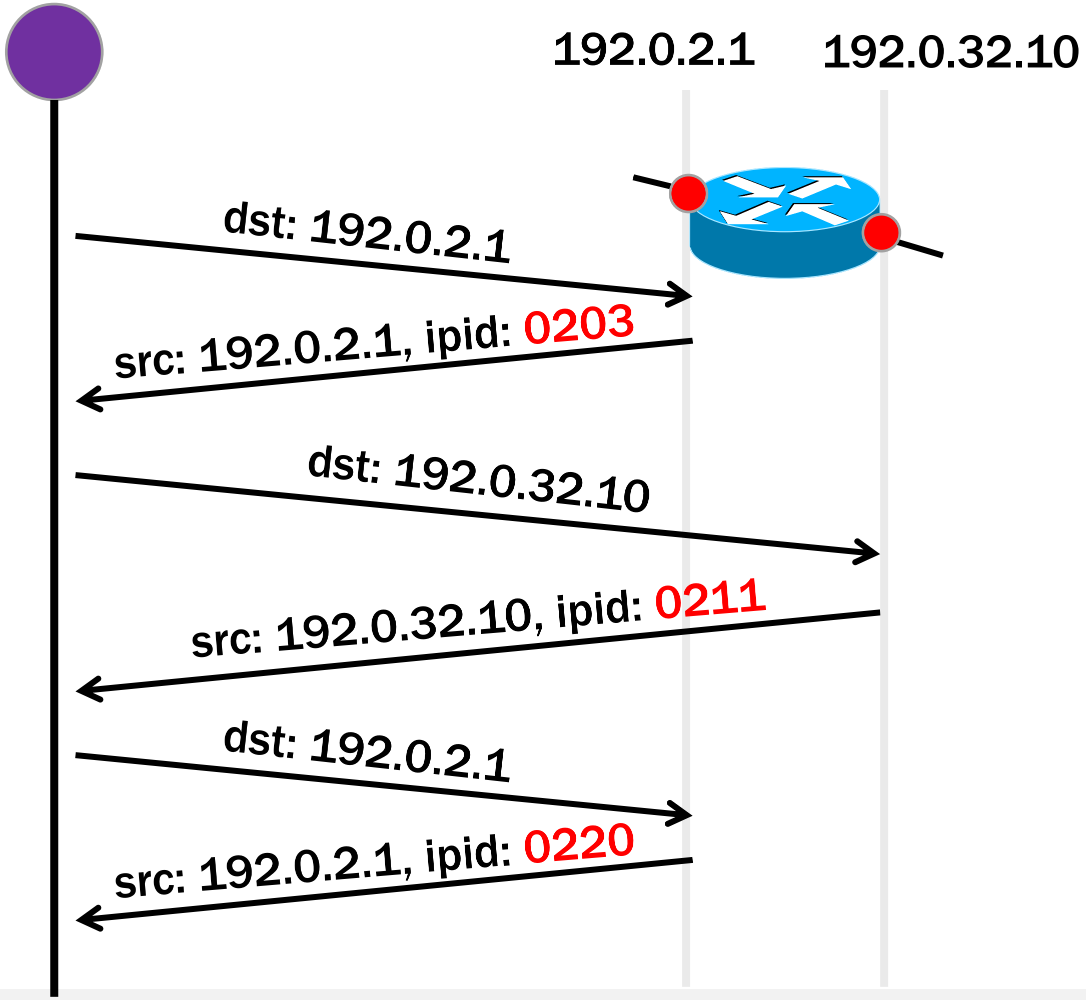

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ITDK

- Internet Topology Data Kit
- Heavily annotated router-level graph, produced 1-2 times per year
- Alias Resolution: MIDAR; >2 million router interfaces
- Inference of Router Operator: bdrmapIT
- Inference of Location with
  - Hoiho to extract geohints in hostnames,
  - and from location databases.

OPTIONAL READING

- K. Keys, Y. Hyun, M. Luckie, and k. claffy, **Internet-Scale IPv4 Alias Resolution with MIDAR**, IEEE Transactions on Networking, 21 (2), pp. 383-399, April 2013.
- A. Marder, M. Luckie, A. Dhamdhere, B. Huffaker, J. Smith, and k. claffy, **Pushing the Boundaries with bdrmapIT: Mapping Router Ownership at Internet Scale**, ACM IMC, pp. 56-69, Boston, MA, USA, November 2018.
- M. Luckie, B. Huffaker, A. Marder, Z. Bischof, M. Fletcher, and k. claffy, **Learning to Extract Geographic Information from Internet Router Hostnames**, ACM CoNEXT, pp. 440-453, Virtual Event, Germany, December 2021.