IPv6 Extension Header (Performance and Diagnostic Metrics (PDM) Destination Option) Testing Across the Internet

IETF 114 HACKATHON

Brief explanation of PDM

- RFC8250: IPv6 Performance and Diagnostic Metrics (PDM) Destination Option

- To assess performance problems, this document describes optional headers embedded in each packet that provide sequence numbers and timing information as a basis for measurements. Such measurements may be interpreted in real time or after the fact. This document specifies the Performance and Diagnostic Metrics (PDM) Destination Options header.

Can IPv6 Extension Headers Be Used on the Internet?

- Controversy for many years
- A number of studies showing that IPv6 extension headers get dropped at very high percentage rates.
- Studies (by and large) sent “Test” IPv6 extension headers to Alexa top n sites
- If this is true, our work on our IPv6 Extension Header Destination Option Performance and Diagnostic Metrics (PDM) is really for naught

What we did

- Used a small hosting service (not one of the “brand-name” ones)
- Using real PDM data, in DOH EHs, on actual applications sessions (FTP, HTTP,etc)
- Locations throughout the world
- *Using a kernel patch in FreeBSD to install PDM*

1. PDM-Warsaw
2. PDM-Toronto
3. PDM-Seattle
4. PDM-Mumbai
5. PDM-Melbourne
6. PDM-Frankfurt

All machines are FreeBSD with a modification to the kernel to send PDM IPv6 Destination option with every packet

Tested large FTP: Toronto to Mumbai (with PDM)

- Connected to **2401:c080:2400:1179:5400:04ff:fe0f:804a.**
- 220---------- Welcome to Pure-FTPd [privsep] [TLS] ----------
- 220-You are user number 1 of 50 allowed.
- 220-Local time is now 15:12. Server port: 21.
- 220 You will be disconnected after 15 minutes of inactivity.
- 331 User PDMuser OK. Password required
- 230 OK. Current directory is /
- Remote system type is UNIX.
- Using binary mode to transfer files.

- 229 Extended Passive mode OK (|||3353|)
- 150-Accepted data connection
- 150 **27872.0 kbytes to download**
- 100% |**********| 27872 KiB 222.31 KiB/s 00:00 ETA
- 226-**File successfully transferred**
- 226 125.107 seconds (measured here), 222.78 Kbytes per second
- 28540928 bytes received in 02:05 (222.31 KiB/s)
- 221-Goodbye. You uploaded 0 and downloaded 27872 kbytes.
- 221 Logout.

FTPTorontoToMumbaiJustIPv6.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

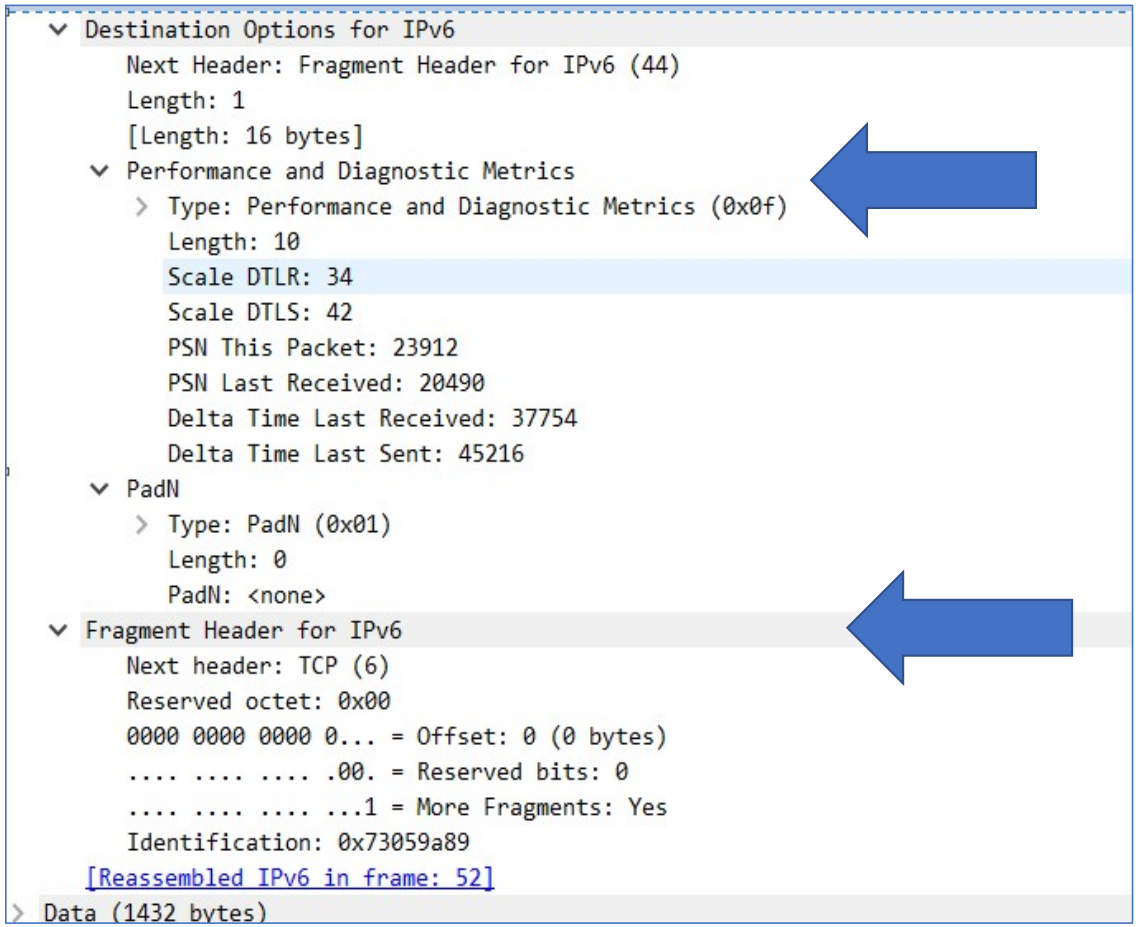
Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	PSN This Packet	PSN Last Received	Info
41	3.056686	2001:19f0:b001:6ce:5400:4ff:fe0f:806d	2401:c080:2400:1179:5400:4ff:fe0f:804a	TCP	20490	23911	61272 → 53696 [ACK] Seq=1 Ack=1 Win=66240 L
42	3.056735	2001:19f0:b001:6ce:5400:4ff:fe0f:806d	2401:c080:2400:1179:5400:4ff:fe0f:804a	FTP	14105	12376	Request: RETR out.txt
43	3.253255	2401:c080:2400:1179:5400:4ff:fe0f:804a	2001:19f0:b001:6ce:5400:4ff:fe0f:806d	IPv6	23912	20490	IPv6 fragment (off=0 more=y ident=0x73059a8

```
Frame 41: 102 bytes on wire (816 bits), 102 bytes captured (816 bits)
Ethernet II, Src: 56:00:04:0f:80:6d (56:00:04:0f:80:6d), Dst: 86:1f:85:c1:55:77 (86:1f:85:c1:55:77)
Internet Protocol Version 6, Src: 2001:19f0:b001:6ce:5400:4ff:fe0f:806d, Dst: 2401:c080:2400:1179:5400:4ff:fe0f:804a
    0110 .... = Version: 6
  > .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 1100 1001 0100 0100 1110 = Flow Label: 0xc944e
    Payload Length: 48
    Next Header: Destination Options for IPv6 (60)
    Hop Limit: 64
    Source Address: 2001:19f0:b001:6ce:5400:4ff:fe0f:806d
    Destination Address: 2401:c080:2400:1179:5400:4ff:fe0f:804a
  v Destination Options for IPv6
      Next Header: TCP (6)
      Length: 1
      [Length: 16 bytes]
    v Performance and Diagnostic Metrics
      > Type: Performance and Diagnostic Metrics (0x0f)
        Length: 10
        Scale DTLR: 29
        Scale DTLS: 42
        PSN This Packet: 20490
        PSN Last Received: 23911
        Delta Time Last Received: 50924
        Delta Time Last Sent: 45220
    > PadN
Transmission Control Protocol, Src Port: 61272, Dst Port: 53696, Seq: 1, Ack: 1, Len: 0
```

PDM IPv6 Extension Header Destination Option

Showing both Extension Headers



Bottom line

1. PDM-FTP Toronto to Warsaw - worked
2. PDM-FTP Toronto to Seattle - worked
3. PDM-FTP Toronto to Mumbai - worked
4. PDM-FTP Toronto to Melbourne - worked
5. PDM-FTP Toronto to Frankfurt - worked

Traces available for all to look at.

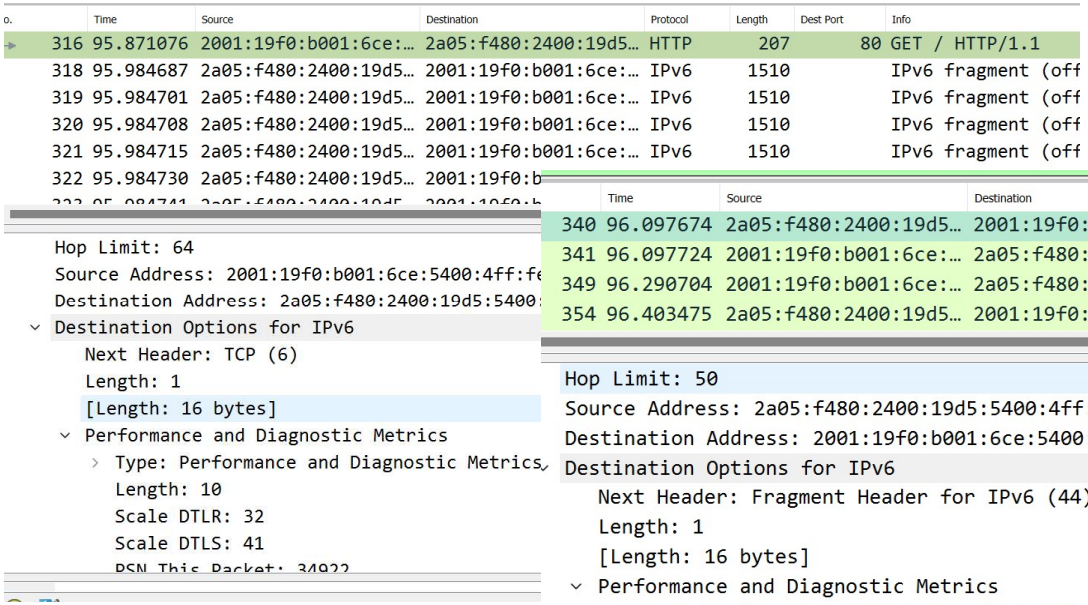
Come to the Hackathon (or HackDemo) if you want to see for yourself.

ANTHONY SLIDES

Destination Options Headers over the Internet – Yes / No?

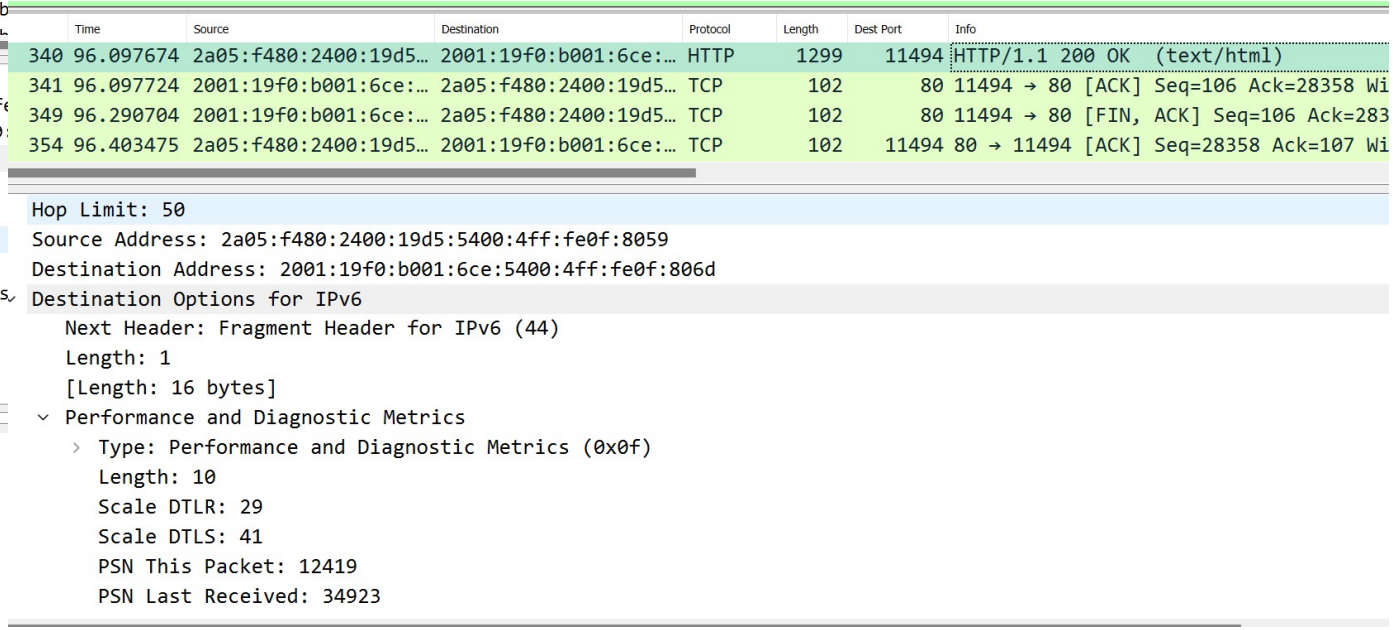
- Tested between VM's in Toronto, Canada and Warsaw Poland
- A plain/cheap hosting provider, not your average tier 1 like Amazon, OVH or Rackspace etc.
- Also tested from the IETF 114 network this morning
- VMs running FreeBSD 11 with a kernel patch to inject PDM Destination Options header
- We were able to packets injected with PDM headers in both scenarios
- We also saw fragmentation packets with the PDM headers

VM to VM Request and Response



o.	Time	Source	Destination	Protocol	Length	Dest Port	Info
316	95.871076	2001:19f0:b001:6ce:…	2a05:f480:2400:19d5…	HTTP	207	80	GET / HTTP/1.1
318	95.984687	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	IPv6	1510		IPv6 fragment (off
319	95.984701	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	IPv6	1510		IPv6 fragment (off
320	95.984708	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	IPv6	1510		IPv6 fragment (off
321	95.984715	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	IPv6	1510		IPv6 fragment (off
322	95.984730	2a05:f480:2400:19d5…	2001:19f0:b				

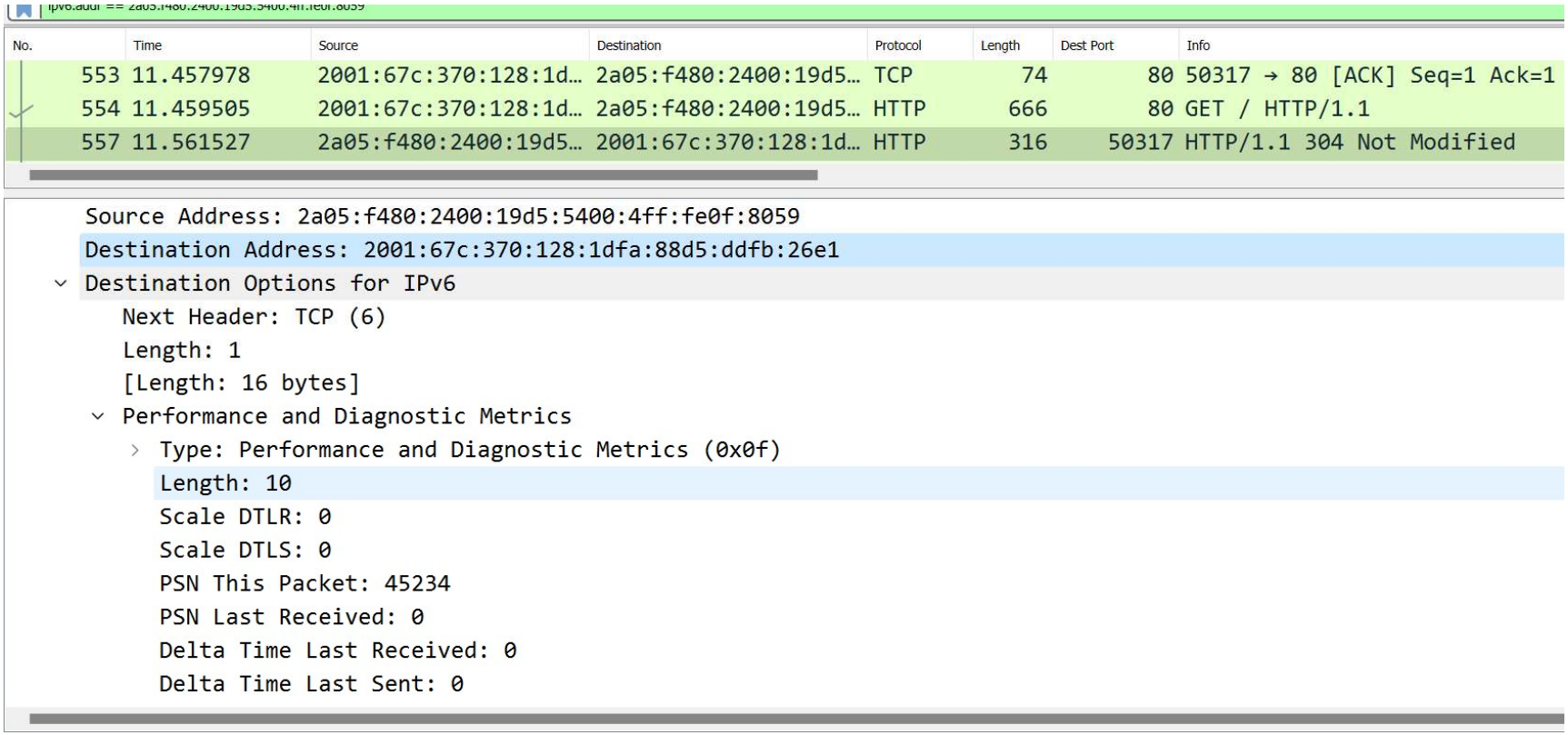
```
Hop Limit: 64
Source Address: 2001:19f0:b001:6ce:5400:4ff:fe
Destination Address: 2a05:f480:2400:19d5:5400:
Destination Options for IPv6
    Next Header: TCP (6)
    Length: 1
    [Length: 16 bytes]
  Performance and Diagnostic Metrics
    Type: Performance and Diagnostic Metrics
    Length: 10
    Scale DTLR: 32
    Scale DTLS: 41
    PSN This Packet: 34922
```



	Time	Source	Destination	Protocol	Length	Dest Port	Info
340	96.097674	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	HTTP	1299	11494	HTTP/1.1 200 OK (text/html)
341	96.097724	2001:19f0:b001:6ce:…	2a05:f480:2400:19d5…	TCP	102	80	11494 → 80 [ACK] Seq=106 Ack=28358 Wi
349	96.290704	2001:19f0:b001:6ce:…	2a05:f480:2400:19d5…	TCP	102	80	11494 → 80 [FIN, ACK] Seq=106 Ack=283
354	96.403475	2a05:f480:2400:19d5…	2001:19f0:b001:6ce:…	TCP	102	11494	80 → 11494 [ACK] Seq=28358 Ack=107 Wi

```
Hop Limit: 50
Source Address: 2a05:f480:2400:19d5:5400:4ff:fe0f:8059
Destination Address: 2001:19f0:b001:6ce:5400:4ff:fe0f:806d
Destination Options for IPv6
    Next Header: Fragment Header for IPv6 (44)
    Length: 1
    [Length: 16 bytes]
  Performance and Diagnostic Metrics
    Type: Performance and Diagnostic Metrics (0x0f)
    Length: 10
    Scale DTLR: 29
    Scale DTLS: 41
    PSN This Packet: 12419
    PSN Last Received: 34923
```

IETF Curl to Warsaw: Response



No.	Time	Source	Destination	Protocol	Length	Dest Port	Info
553	11.457978	2001:67c:370:128:1d…	2a05:f480:2400:19d5…	TCP	74	80	50317 → 80 [ACK] Seq=1 Ack=1
554	11.459505	2001:67c:370:128:1d…	2a05:f480:2400:19d5…	HTTP	666	80	GET / HTTP/1.1
557	11.561527	2a05:f480:2400:19d5…	2001:67c:370:128:1d…	HTTP	316	50317	HTTP/1.1 304 Not Modified

Destination Options Headers over the Internet – Yes / No?

- Our testing only scratches the surface some of the data is inconclusive and could point to vendors having bugging implementations or operators applying policies that deal with them in unexpected ways.
- Trying to “break” the RFC’s suggests there are potential security issues with some of these headers also
- There is more work to be done here

TOMASSO SLIDES

Actual status

Not-uniform behaviour – not [easily] explainable

- This is a problem for
  - Standardization (lack of clarity)
  - Implementation (lack of guidance)
  - Users (unpredictable behaviour)
  - Security (don’t get me started)
  - Etc.

Roadmap

Clarifications in the form of a BCP, outlining:

- What are the assumptions about EH
- What are the security risks associated with EH (both HbH and DO)
- What are the mitigation plans for a TN
  - EH encription
  - EH encapsulation in a TN
  - EH authentication
- Recommendations on writing an EH RFCs, e.g., be specific on:
  - Security considerations
  - Expected TN behaviour
  - Considerations on EH drop cases

Mitigations ?

It’s too early to talk about mitigation

- don’t put the cart before the horse

However, EH should be either:

- Completely harmless (more than the Earth).
- If not, and depending on a LOT of considerations, either:
  - Authenticated (validation of the sender, or last processing entity, or both)
  - Fully encrypted
  - Made harmless for the TN by encapsulation

ANDREW SLIDES

```
# traceroute6 2401:c080:2400:1179:5400:04ff:fe0f:804a
traceroute6 to 2401:c080:2400:1179:5400:04ff:fe0f:804a (2401:c080:2400:1179:5400:4ff:fe0f:804a) from
2001:19f0:b001:6ce:5400:4ff:fe0f:806d, 64 hops max, 12 byte packets
 1  * * *
 2  vl199-ds1-n1-r103-b.sao1.constant.com  1.262 ms  0.400 ms  0.334 ms
 3  vl518-ds1-q8.tor1.constant.com  1.192 ms  2.403 ms
    vl818-ds2-q8.tor1.constant.com  1.124 ms
 4  vl25-er1-q2.tor1.constant.com  0.893 ms
    vl25-er2-q2.tor1.constant.com  7.116 ms  1.321 ms
 5  et-1-0-19.cr3-tor1.ip6.gtt.net  0.640 ms *  1.267 ms
 6  2001:668:0:2:ffff:0:5995:8cfd  97.981 ms
    chi-b23-v6.ip.twelve99.net  11.284 ms
    2001:668:0:2:ffff:0:5995:8cfd  98.632 ms
 7  kanc-b2-v6.ip.twelve99.net  22.989 ms  23.535 ms
    2001:668:0:3:ffff:0:4d43:50be  90.619 ms
 8  2404:a800::42  209.484 ms
    kanc-bb2-v6.ip.twelve99.net  23.407 ms  23.405 ms
 9  * dls-bb2-v6.ip.twelve99.net  34.095 ms *
10  vl22-ds2-q8.bom1.constant.com  196.490 ms
    dls-b24-v6.ip.twelve99.net  69.405 ms
    vl22-ds2-q8.bom1.constant.com  192.592 ms
11  dls-bb1-v6.ip.twelve99.net  33.698 ms  33.900 ms
    vl810-ds1-m1-c3r0407-a.bom1.constant.com  209.905 ms
12  * * *
13  * * 2401:c080:2400:1179:5400:4ff:fe0f:804a  192.645 ms
```

Traceroute showing multiple transit providers

Why are our results so different from others?

- We are using real data and a real application (e.g. PDM and FTP)
- We are NOT going to the Alexa top n
- But, we also tried to replicate the results of others
- Indeed, if you use the large hosting companies and go to the Alexa top n, there are issues
- But why?

Summarizing Information being collected per traceroute

- Company
- Starting IP address and DNS name
- Destination IP address and DNS name (it may resolve to CDN, for example)
- Hop number where last PDM ICMPv6 came from (ex. 8). Let this be "n".
- Destination DNS name where last PDM ICMPv6 came from (ex. Tor)
- Hop number where last non-PDM ICMPv6 came from (ex. 10)
- Destination DNS name where last non-PDM ICMPv6 came from (ex. Cloudflare)
- Destination DNS name of hop n+1 (the next hop that the PDM ICMPv6 would have come to) (ex. Akamai)

- **What we are looking for is if last ICMPv6 with PDM was at hop 8, then what was hop 9 according to the non-PDM traceroute?**

Results

- Will present traceroute results next time!
- We welcome collaborators! Preparing VM image of FreeBSD with PDM so you can test for yourself.
- Come talk to us at Hackathon and/or HackDemo