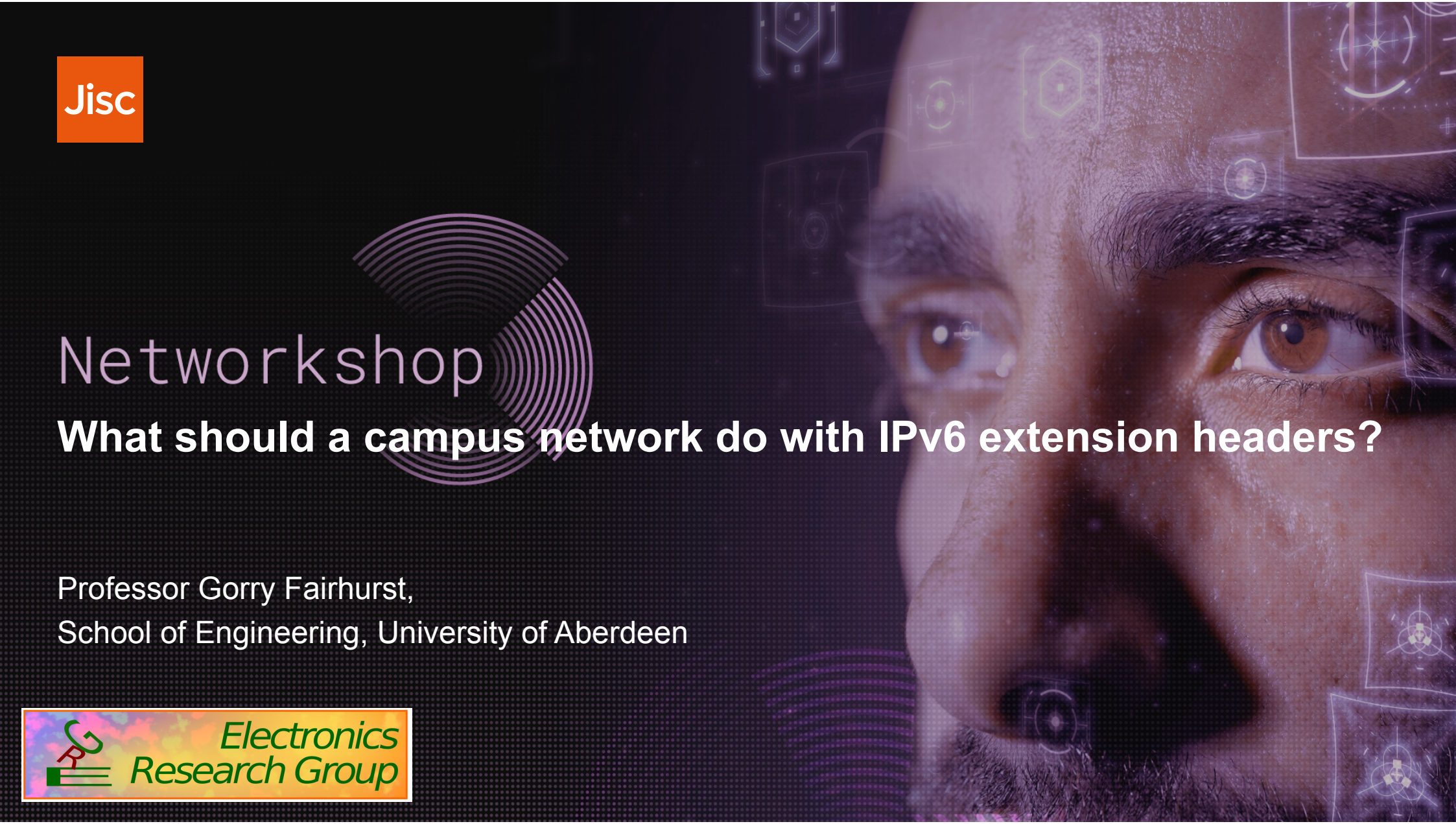


Jisc

Networkshop

# What should a campus network do with IPv6 extension headers?

Professor Gorry Fairhurst,
School of Engineering, University of Aberdeen

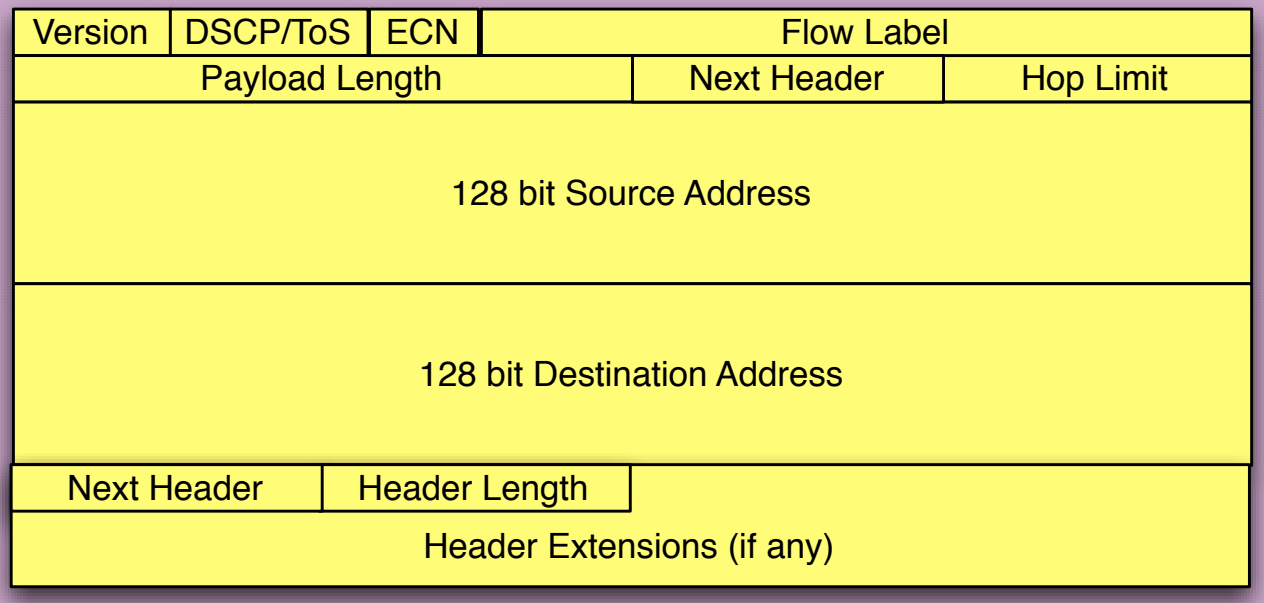
Electronics Research Group

# IPv6

IPv6 was standardised in the 1990's [RFC2474]

Full Standard in 2017 [RFC 8200]

**Base Header**




**Extension Header (EH)**

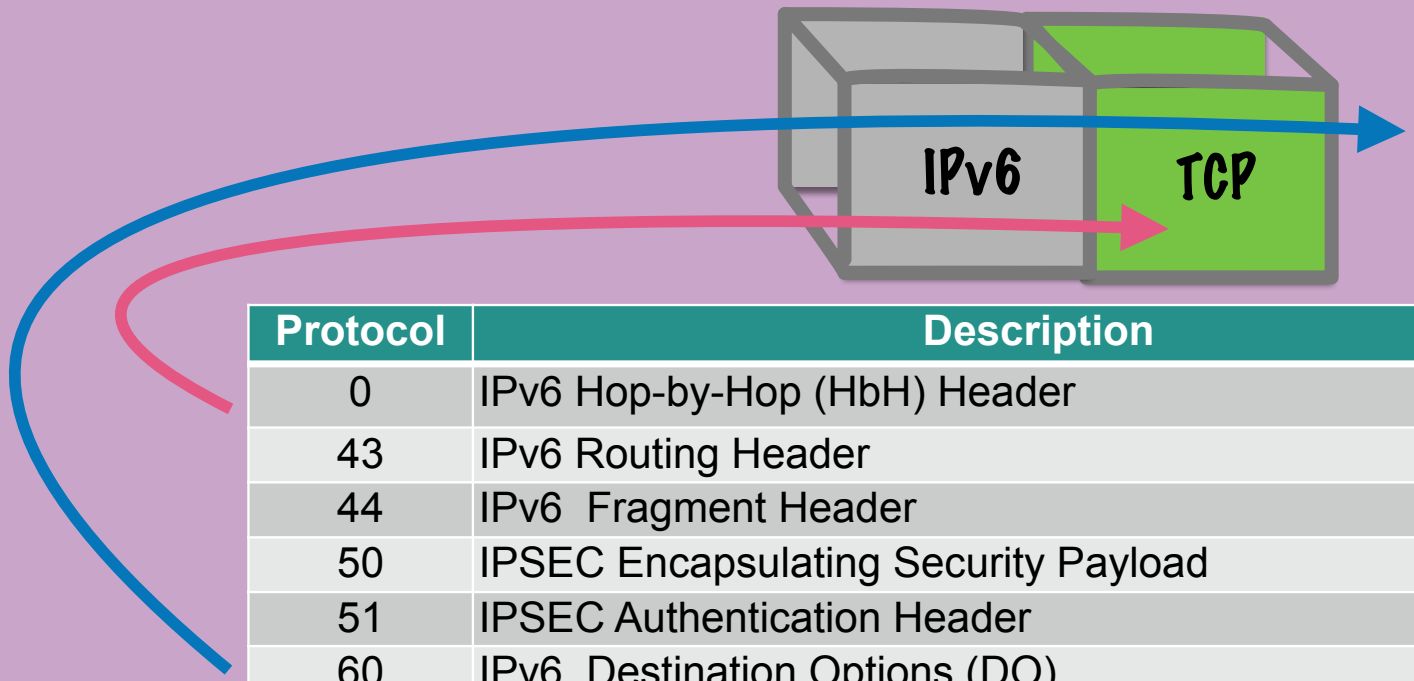
>90% of BskyB!

On average, IPv6 represents a third of BT's broadband traffic flows

- *Tom Hill, 24th April 2023, IPv6 Council*

Jisc

# IPv6 Extension Headers

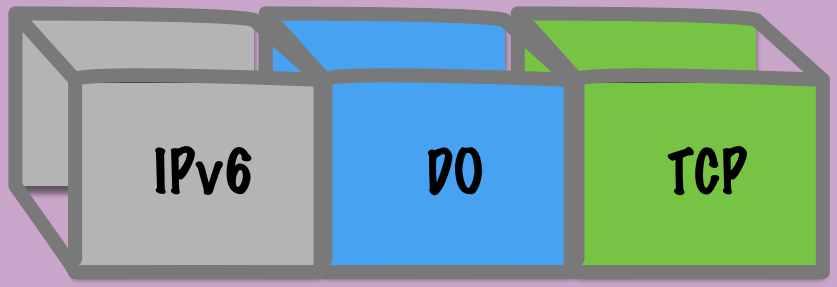



| Protocol | Description | References |
|---|---|---|
| 0 | IPv6 Hop-by-Hop (HbH) Header | [RFC8200] |
| 43 | IPv6 Routing Header | [RFC8200] [RFC5095] |
| 44 | IPv6 Fragment Header | [RFC8200] |
| 50 | IPSEC Encapsulating Security Payload | [RFC4303] |
| 51 | IPSEC Authentication Header | [RFC4302] |
| 60 | IPv6 Destination Options (DO) | [RFC8200] |
| 135 | IPv6 Mobility Header | [RFC6275] |
| 139 | Host Identity Protocol (HIP) | [RFC7401] |
| 140 | Shim6 Protocol | [RFC5533] |
| 253,254 | Use for experimentation and testing | [RFC3692] [RFC4727] |

https://www.iana.org/assignments/ipv6-parameters/ipv6-parameters.xhtml

Jisc

# Renewed Interest in Options using IPv6 Extension Headers




IPv6 Segment Routing Option (SRv6) [RFC8986]

Service Management and Performance Measurement using PDM [RFC8250]

In-situ Operations, Administration, and Maintenance (IOAM) [RFC9268]

AltMark Measurement DO and HbH Options [RFC9343]

minPMTU HBH Option [RFC9268]

... *More capable ASICs are emerging that can process EHs at line speed*

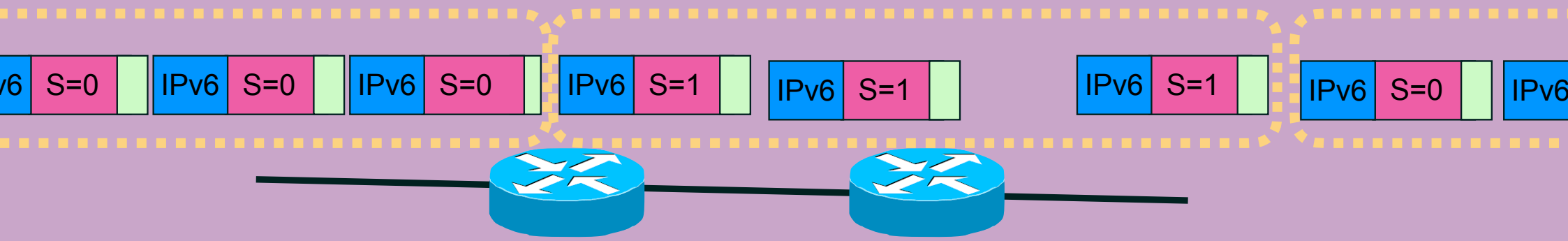
Jisc

# Example: Using ALTMARK to Measure a Path [RFC9343]

Enable ALTMARK for a connection

Send packets including the *ALTMARK Option (DO or HBH)*

The sender flips S in the option every (configured) batch of packets




Receiver measures loss/reordering by counting packets in batches

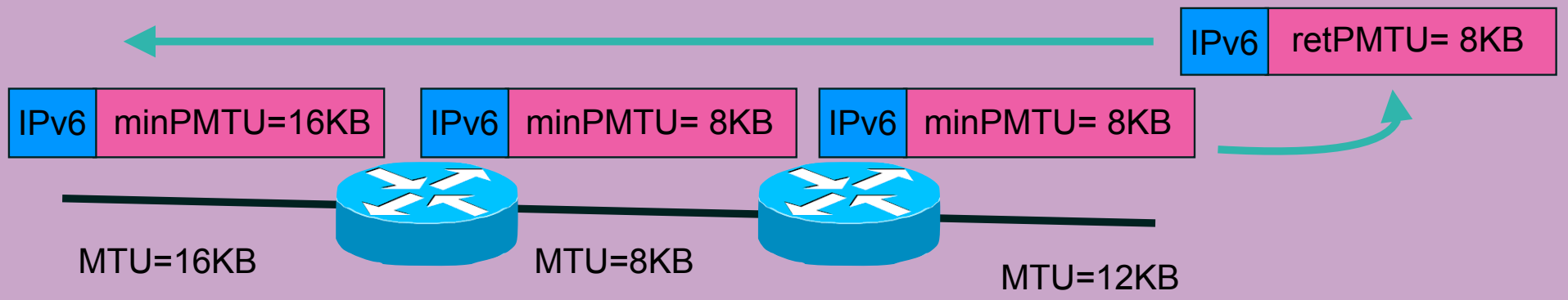
Measures RTT, Jitter, etc by observing S mark edges

Jisc

# Example: Using minPMTU Option [RFC9268]

Occasionally send a probe packet including the *minPMTU HbH Option*

Each router reduces the minPMTU size in the packet, if needed




Receiver returns the minimum collected size for the path

Sender then tests if the suggested size works

Significantly reduces number of tries to determine a suitable packet size

Jisc

# What happens to a Packet that includes an EH?

## Survival of Extension Headers with Destination and Hop-by-Hop Options

| | | DO | HbH |
|---|---|---|---|
| RFC 7872 (2016) [1] | Core to DNS Server | 80-90% | 45-60% |
| Our (2018) data [2] | Core to Web Server | 70-75% | 15-20% |
| JAMES (2022) [3] | Core to Core | 94-97% | 8-9% |

[1] RFC 7872
[2] A Custura, 6MAN WG, IETF 109
[3] https://datatracker.ietf.org/doc/draft-vyncke-v6ops-james/

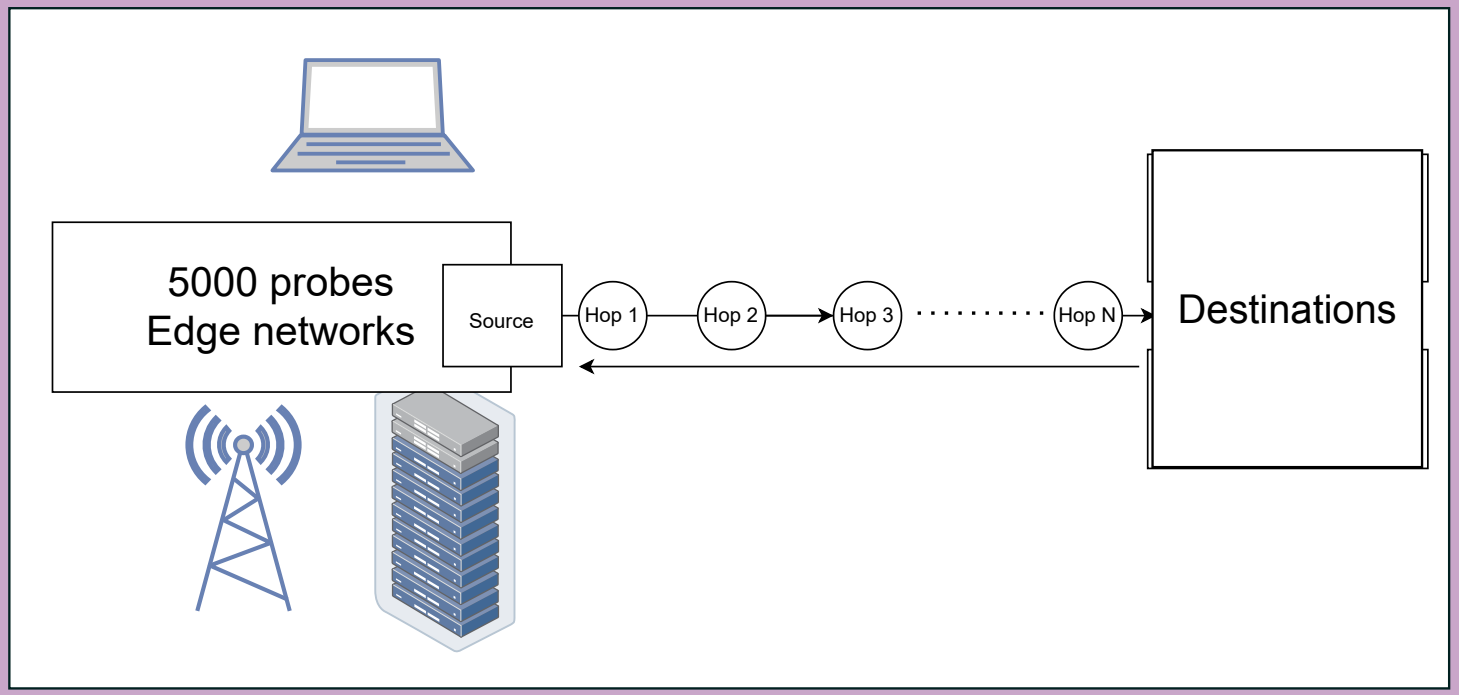
**Some places they are forwarded, some they are not!**

**… what about the edge?**

Jisc

# What happens to a Packet that include an EH?

## Measurement at the Edge




| DO | |
|---|---|
| ~92% | UDP |
| ~68% | TCP |

| HbH | |
|---|---|
| ~11% | UDP |
| ~9% | TCP |

Test to a server in JANET supporting EH, 8B PadN option
~5500 IPv6-enabled ATLAS probes in RIPE, globally distributed

… less support in Access Networks

Jisc

# Challenges: Security Issues

**1. Slow-path processing of EHs**

Does the router "melt" under the load of processing a large EH?

*- Protect with an ACL**

**2. Processing of a malformed EH?**

Does the router "melt" when processing a complex EH?

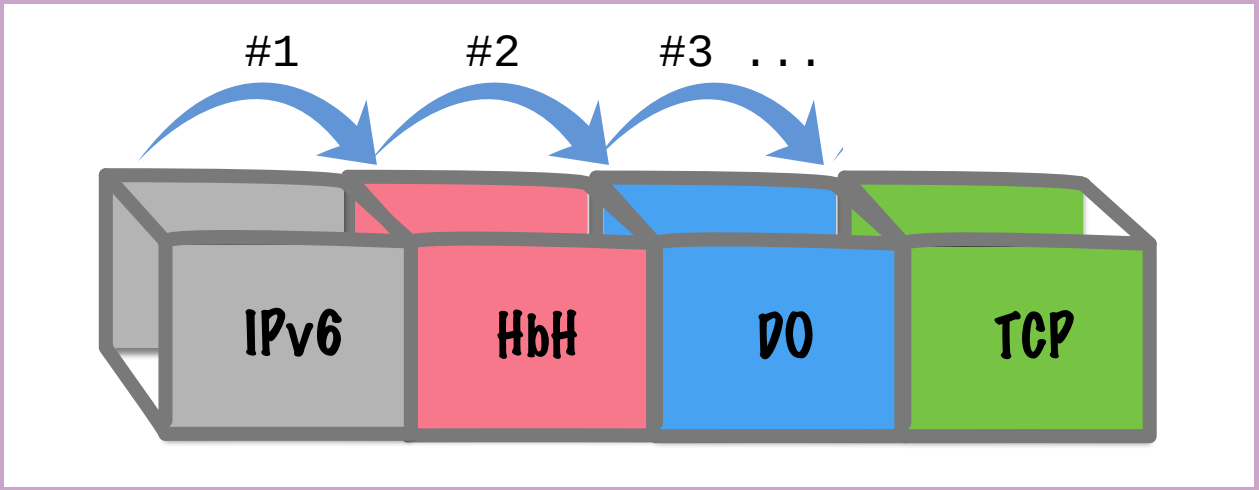
*- Protect with an ACL**

** Access Control List for packets forwarded to the control plane*

***Practical Router Limitations [RF7872] (2021)***

Jisc

# Challenges: Finding Port Information with EH




IPv6 Header Chain

**Firewalls, IDS, Load balancers sometimes like to find ports**

*- For EH, this requires traversing the Extension Header chain*

**Routers using ECMP* can be configured to use port entropy and/or flow label**

*- Some do a deep-dive into the packet to find the ports*

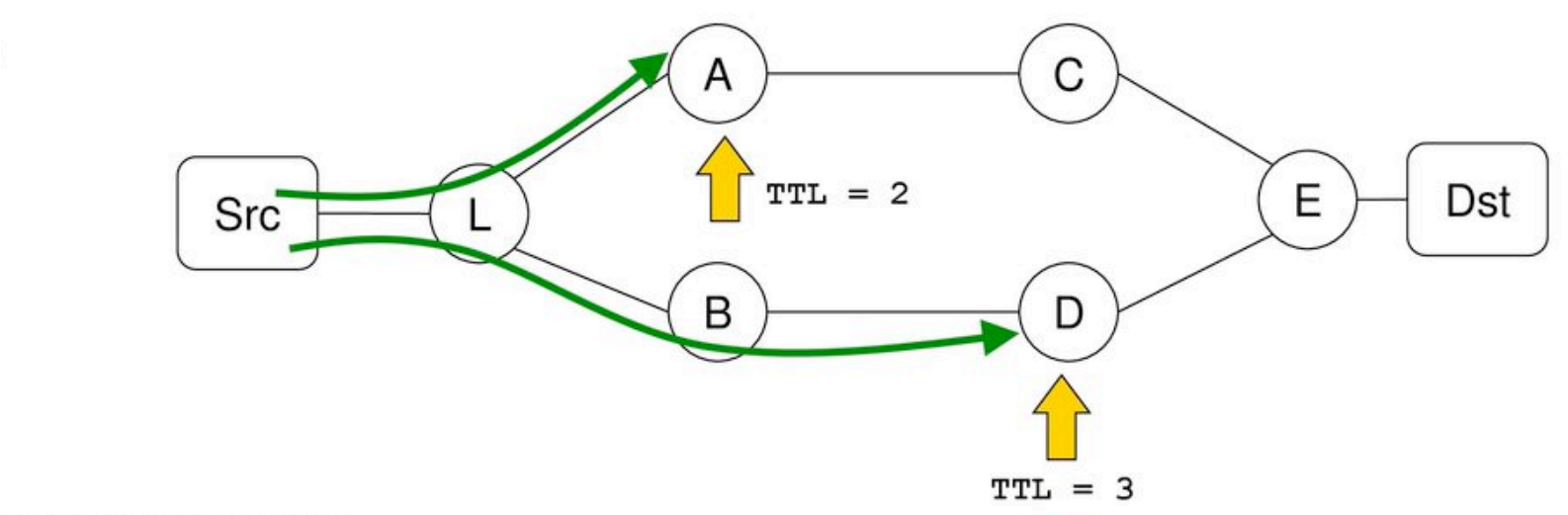
***ECMP = equal cost multi path routing**

Jisc

# Equal Cost Multipath Routing (ECMP)

A balancer, L, chooses a path (e.g., based on flow entropy)

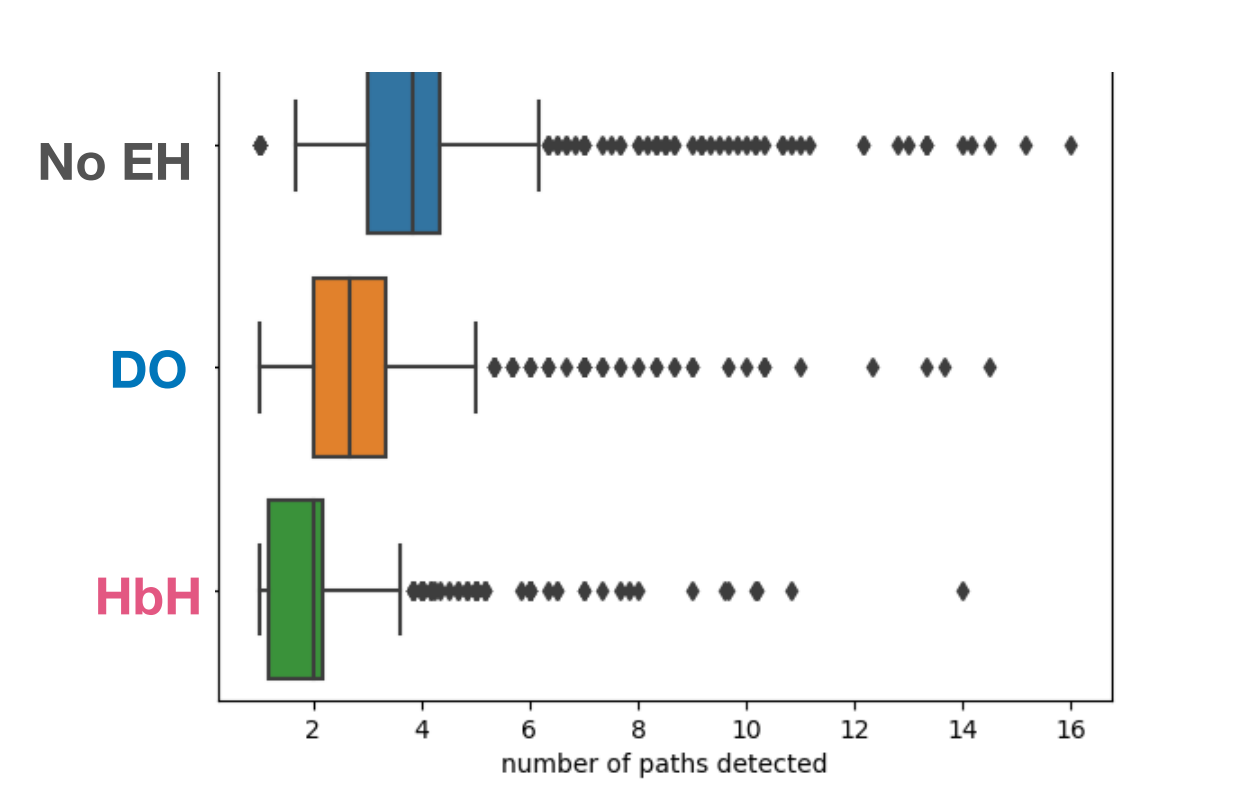
With ECMP there are multiple paths after L to the same Dst



# Results: Equal Cost Multipath Routing (ECMP)

Paris TraceRoute* sends test packets with differing ports, flow label, etc.

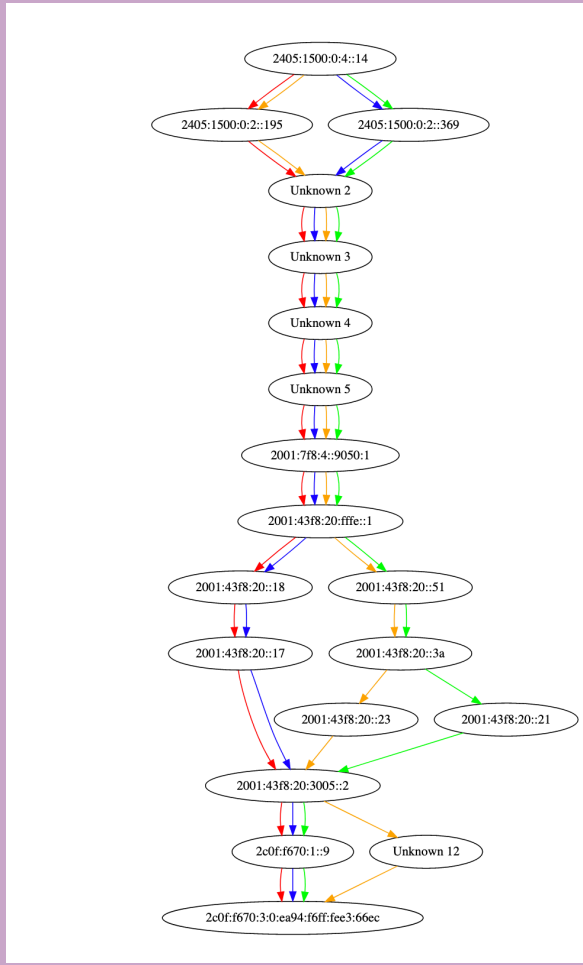
Number of paths reduces using EH, could be better using the flow label?



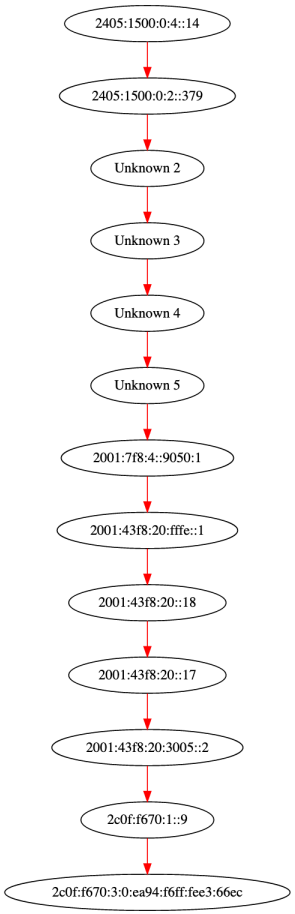

*Avoiding traceroute anomalies with Paris traceroute, Augustin et al, IMC, 2006

Jisc

# Fun Results using 16 Paris TraceRoute IDs




DO




HbH

Jisc

# So... *Can* we use IPv6 EH?

DON'T expect EH to work **everywhere**, the packets *might* be dropped

DON'T rely on every router looking at every EH, but they might!

**IPv6 can be extended** - this is already happening within domains

... Usability of EH across the network will depend on the path being used

... Newer hardware will make this easier!

**Developers already know how to make protocols work...**

... **Race** multiple headers and find out what a path supports

Jisc

# So... *what happens across JANET?*

| | | No EH | | DO | DO | HBH | HBH +DO |
|---|---|---|---|---|---|---|---|
| Source | Site | UDP | TCP | UDP | TCP | UDP | UDP |
| 2001:630:3c:f804::a | Jisc Technologies: Security Development | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| 2a0c:5bc0:40:78c:ee08:6bff:fe73:40b6 | Imperial College of Science Technology and Medicine | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| 2001:630:42:110:da58:d7ff:fe03:469 | University of Aberdeen | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| 2001:630:21:8d80:c24a:ff:fe09:4726 | University of Liverpool | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| 2001:630:22:d0ff:c24a:ff:fe09:49f4 | University of Manchester | ☺ | ☺ | ☺ | ☺ | X | X |
| 2001:630:206:e:a2f3:c1ff:fec4:5971 | Sanger Institute | ☺ | X | ☺ | X | X | X |
| 2001:630:61:40e2:c24a:ff:fecc:73a4 | University of York | ☺ | X | ☺ | X | X | X |
| 2001:630:340:21::99 | University of Kent | ☺ | X | ☺ | X | ☺ | ☺ |

Test from

RIPE ATLAS Probes

to

University of Aberdeen

Jisc

# Conclusions

**What should campus networks do with IPv6 Extension Headers?**

**We might need to protect the router control plane**

**Ensure routers do not drop packets solely because they include an EH**

... Newer hardware will make this easier!

... We can then deploy **new options**

**Watch out for new uses of IPv6 Extension Headers!**

Jisc

## Thank you

Gorry Fairhurst

Ana Custura

{gorry,ana}@erg.abdn.ac.uk

University of Aberdeen

Networkshop

Digging deeper, current IETF work:

draft-ietf-6man-hbh-processing
draft-ietf-6man-eh-limits
draft-ietf-v6ops-hbh
Internet Measurements, IEPG, IETF-116
A Custura, RIPE86 NCC, May 2023


help@jisc.ac.uk

jisc.ac.uk