

End-system controlled, dynamic multihoming and multipath transport

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1413 |

Acknowledgements

- Current team:
 - Rodney Grimes (NetDEF and FreeBSD).
 - Alistair Woodman (NetDEF).
 - **Saleem Bhatti (University of St Andrews).**
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 - <https://ilnp.cs.st-andrews.ac.uk/digs/>
- Thanks to the IETF NOC team 😊



1. Motivation and Problem Statement

2. Technical approach

3. Testing and Experiments

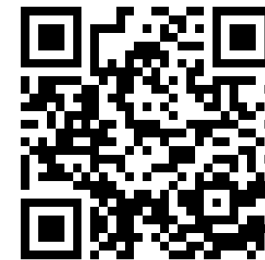
Motivation and Problem Statement

- Dynamic, flexible use of **multiple network paths**, e.g.:
 - Load distribution / load balancing.
 - Resilience / failover.
 - Mobile nodes and mobile networks.
 - Security and privacy.
- Limited options currently:
 - MPTCP, SCTP, QUIC multipath is work-in-progress.
- **Can we provide a general multipath capability for any transport protocol (including existing ones)?**

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Identifier Locator Network Protocol (ILNP)

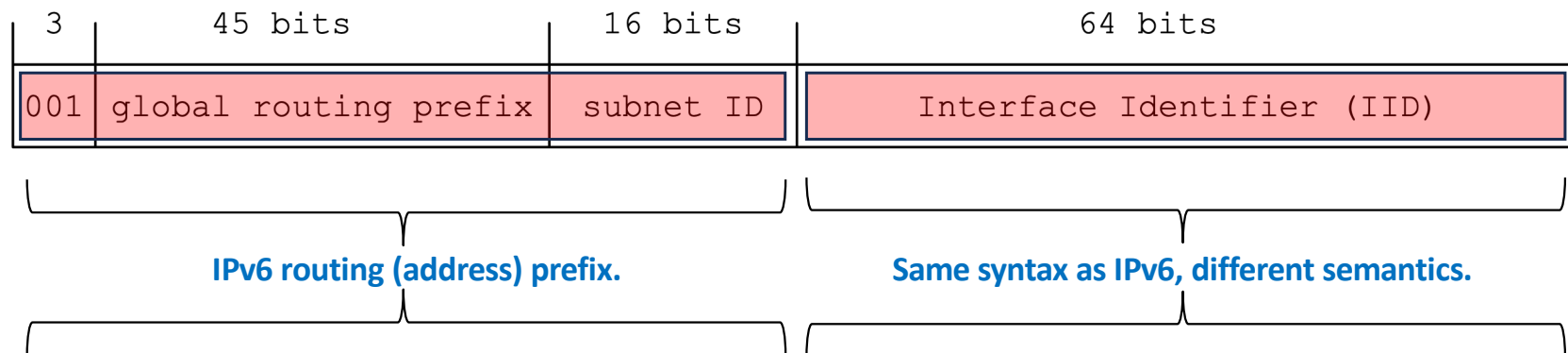
- Ongoing research project on Internet architecture:
 - Addressing architecture with end-to-end semantics over IPv6.
- RFCs 6740-6748 (E).
- No tunnels.
- No proxies.
- No NAT.
- No changes to routing or switching.
- No changes to existing applications.
- <https://ilnp.cs.st-andrews.ac.uk/>



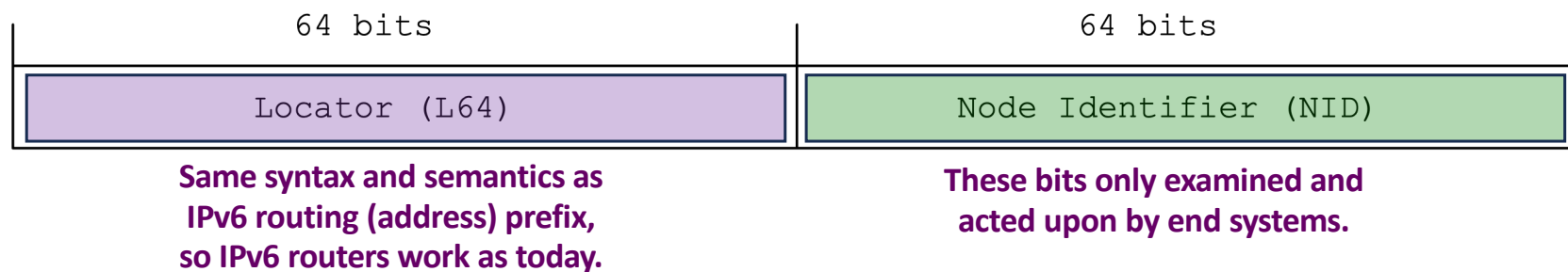
IL^{NP}

ILNP addressing semantics (RFC6740/1)

IPv6 (RFC8200(S)) - general IPv6 global address format:

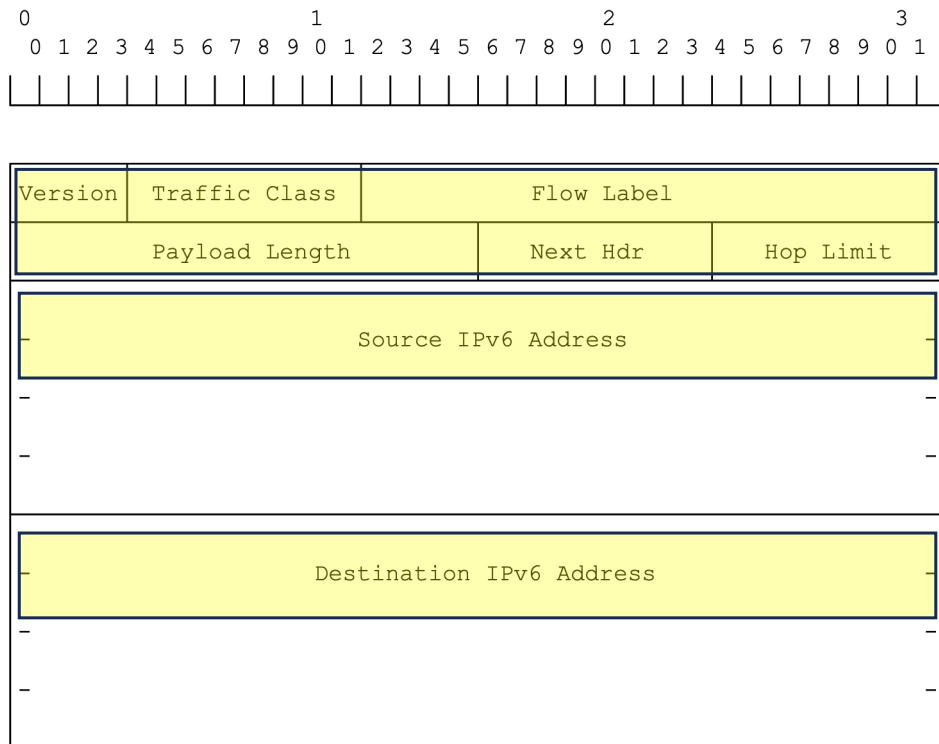


ILNP (RFC6741(E)) - Identifier Locator Vector (I-LV):

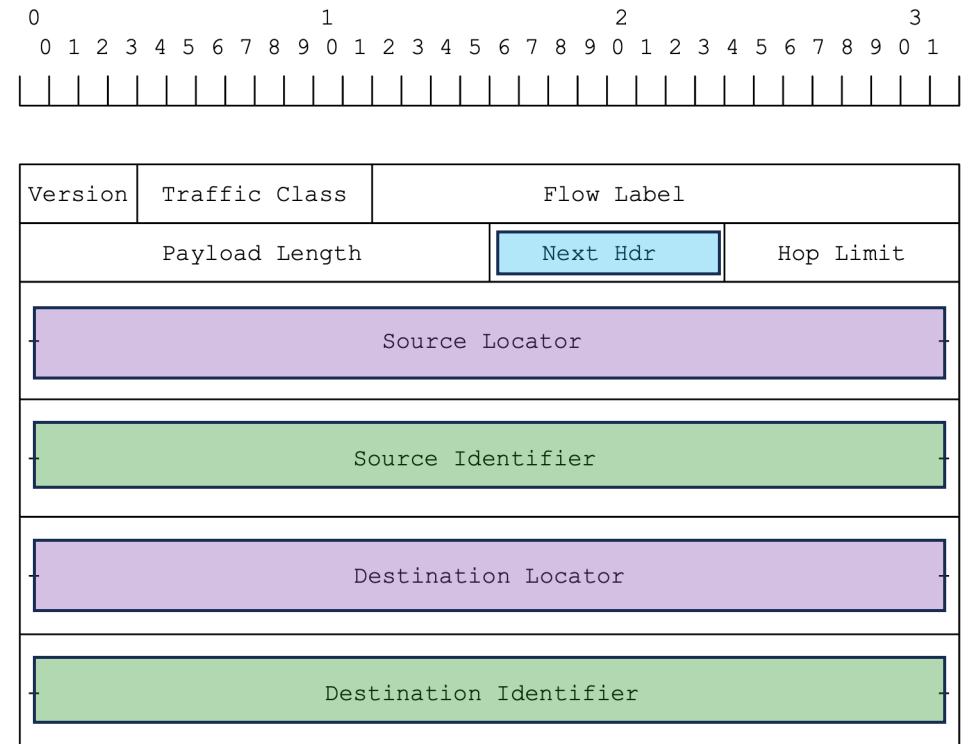


Packet view (the “wire image”)

View from an IPv6 **router**



View from an ILNP **end-system**



ILNP addressing – architecture

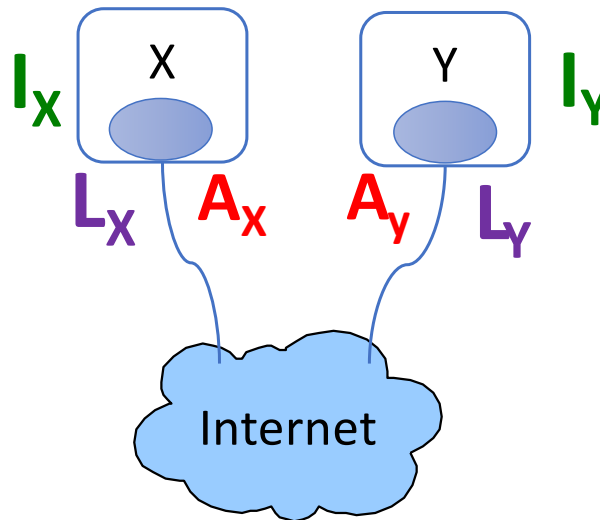
Protocol Layer	IP	ILNP
Application	FQDN (or app specific) IP address	FQDN (or app specific) (RFC1958)
Transport	IP address (+ port number)	Node Identifier (+ port number)
Network	IP address	Locator
(Interface)	IP address	(dynamic mapping)

Entanglement ☹️

Separation 😊

FQDN fully qualified domain name (DNS)

ILNP addressing – transport state



A = IP address (“fixed”)

P = port number

At X:

<TCP: A_X , P_X , A_Y , P_Y > <IP: A_X , A_Y >

At Y:

<TCP: A_Y , P_Y , A_X , P_X > <IP: A_Y , A_X >

I = Node **Identifier** (“stable”)

L = **Locator** (mutable)

(I-LV = Identifier-Locator Vector)

P = port number

At X:

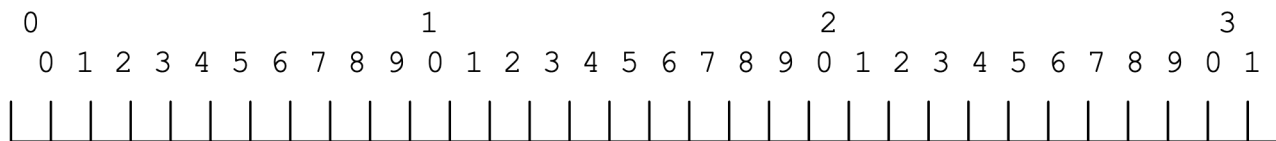
<TCP: I_X , P_X , I_Y , P_Y >#<IP: L_X , L_Y >

At Y:

<TCP: I_Y , P_Y , I_X , P_X >#<IP: L_Y , L_X >

ILNP Nonce header (RFC6744)

ILNP Destination Option (RFC6744(E)):



Next Header	Hdr Ext Len	Option Type	Option Length
Nonce Value			

IPv6 Destination Option Type = 139 / 0x8b

At X:

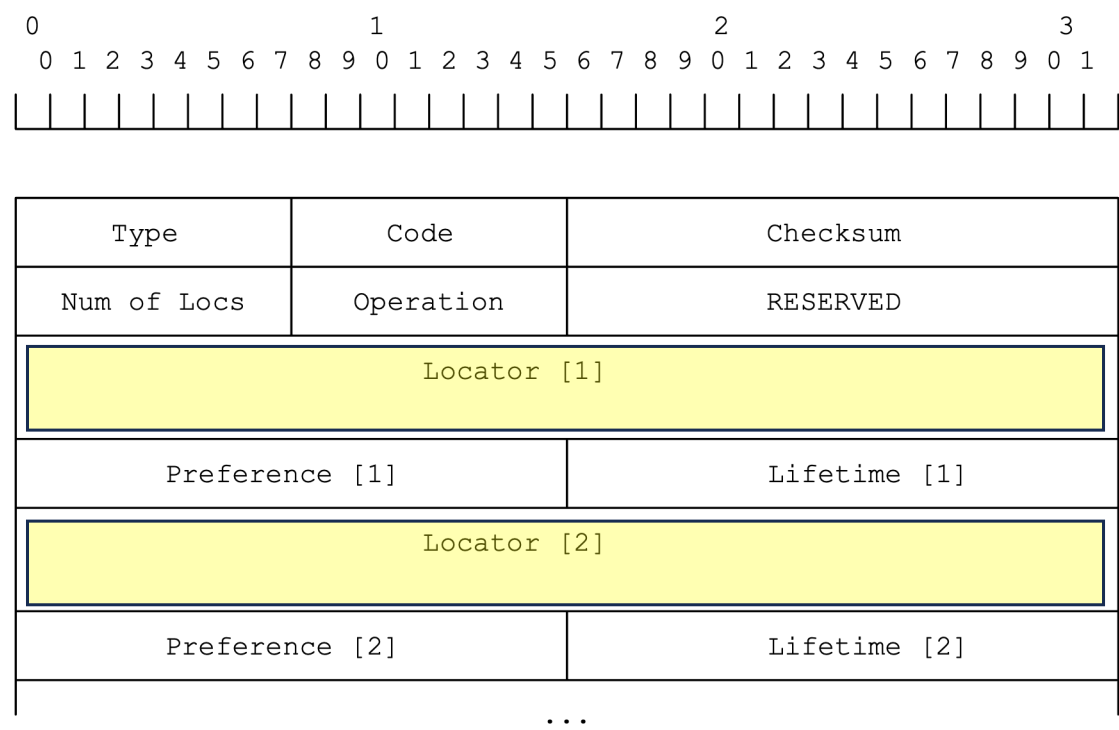
<TCP: I_X , P_X , I_Y , P_Y , N >#<IP: L_X , L_Y >

At Y:

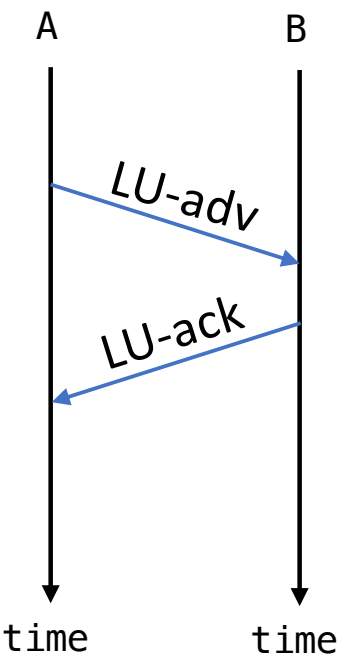
<TCP: I_Y , P_Y , I_X , P_X , N >#<IP: L_Y , L_X >

ILNP Locator Update (LU) (RFC6743)

ICMPv6 Locator Update Message (RFC6743(E)):



Type = 156 / 0x9c, Code = 0

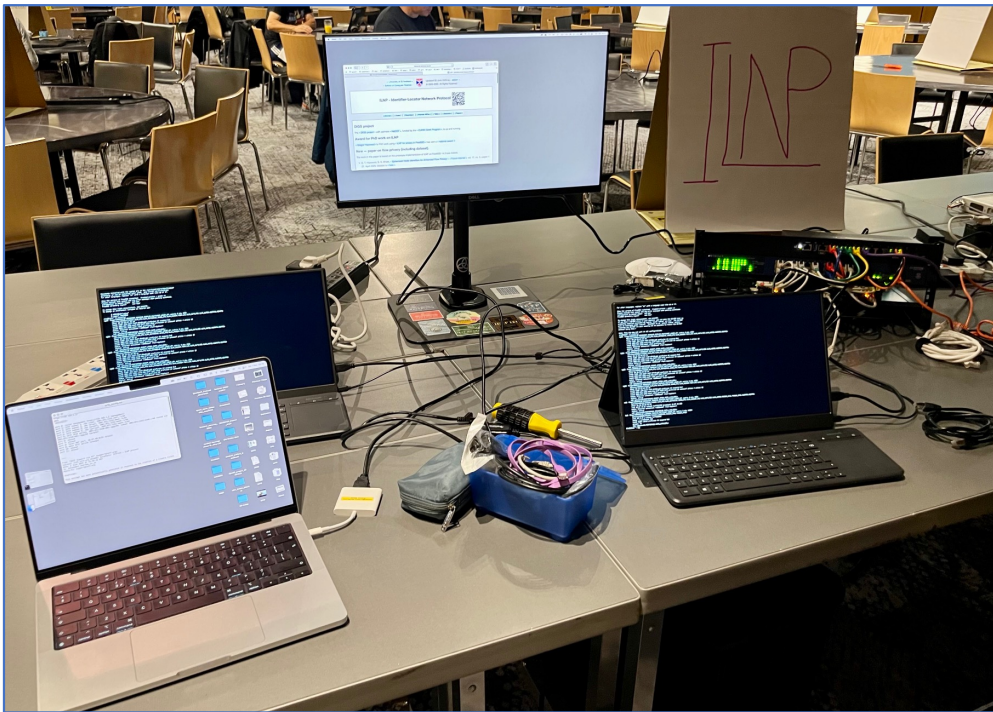


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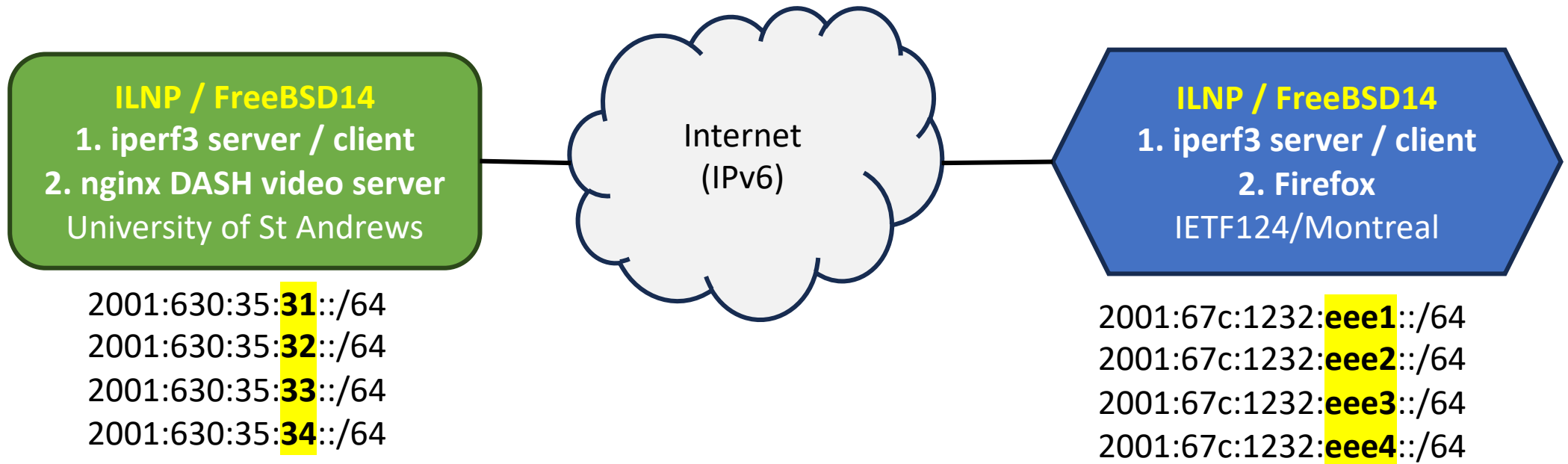
Experiment configuration

- **Test: end-to-end multipath control via ICMPv6 signalling.**
- Test scenarios using an implementation on FreeBSD14:
 1. Dynamic 4-way multipath with TCP, **iperf3**:
 - **TCP CUBIC** / ILNP.
 2. Video streaming over TCP with 3-way multipath, **nginx** + **Firefox**:
 - DASH / HTTP / TLS / **TCP CUBIC** / ILNP.
- **Standard program libraries and binaries** from repos:
 - **iperf3, nginx, Firefox.**
- Code-base is in development, so surprises were expected:
 - **Preliminary results look promising 😊**

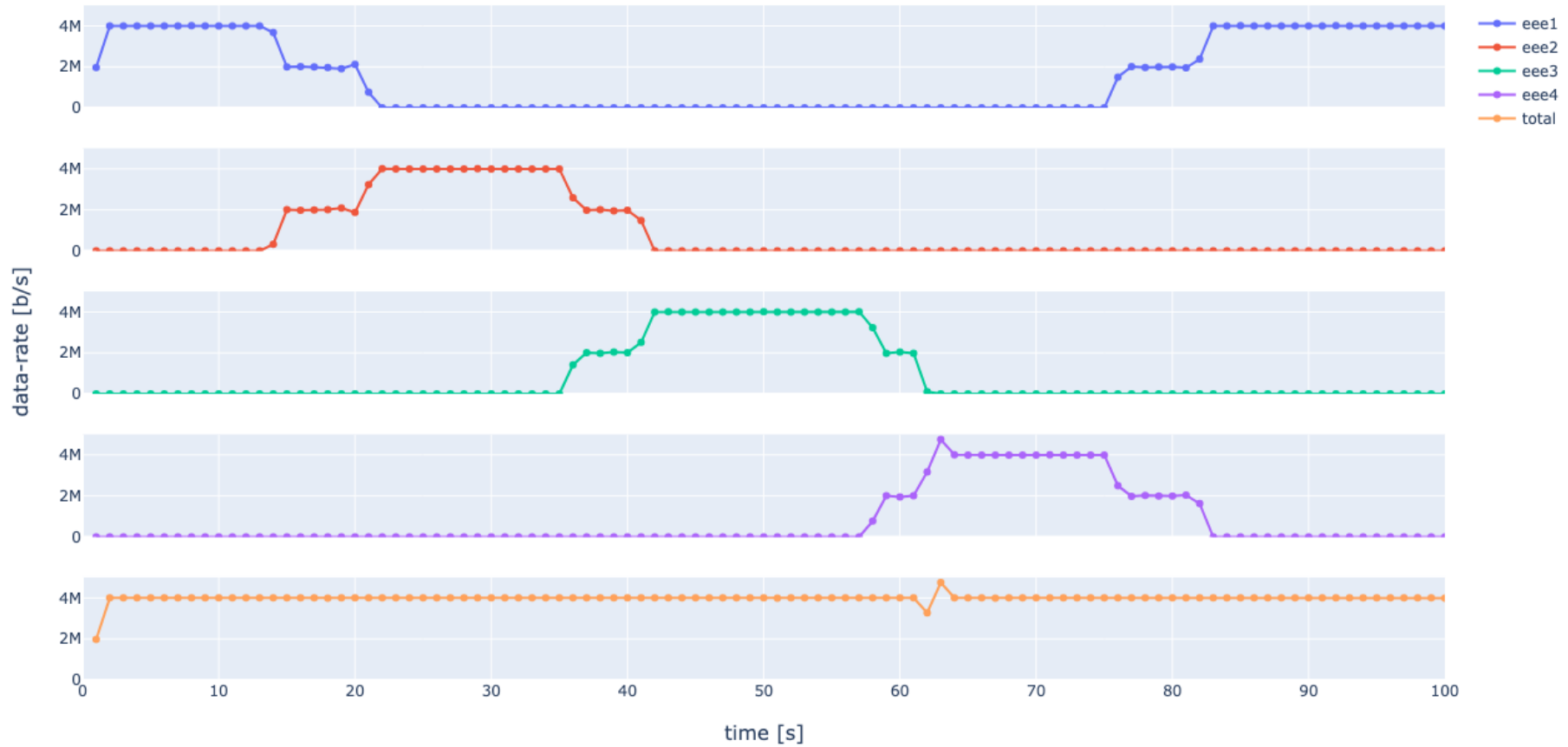
IETF124/Montreal, 01-07 November 2025



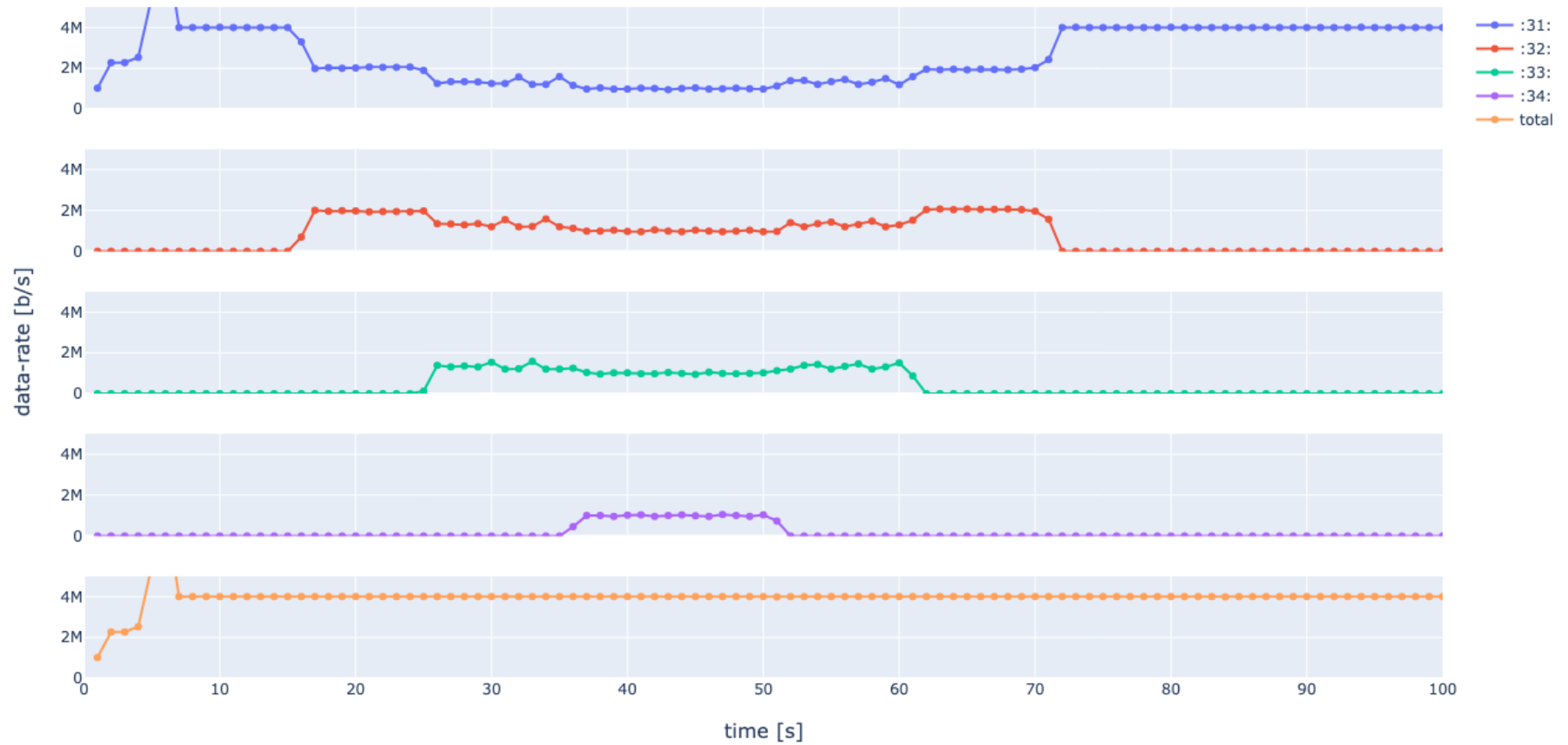
Network configuration

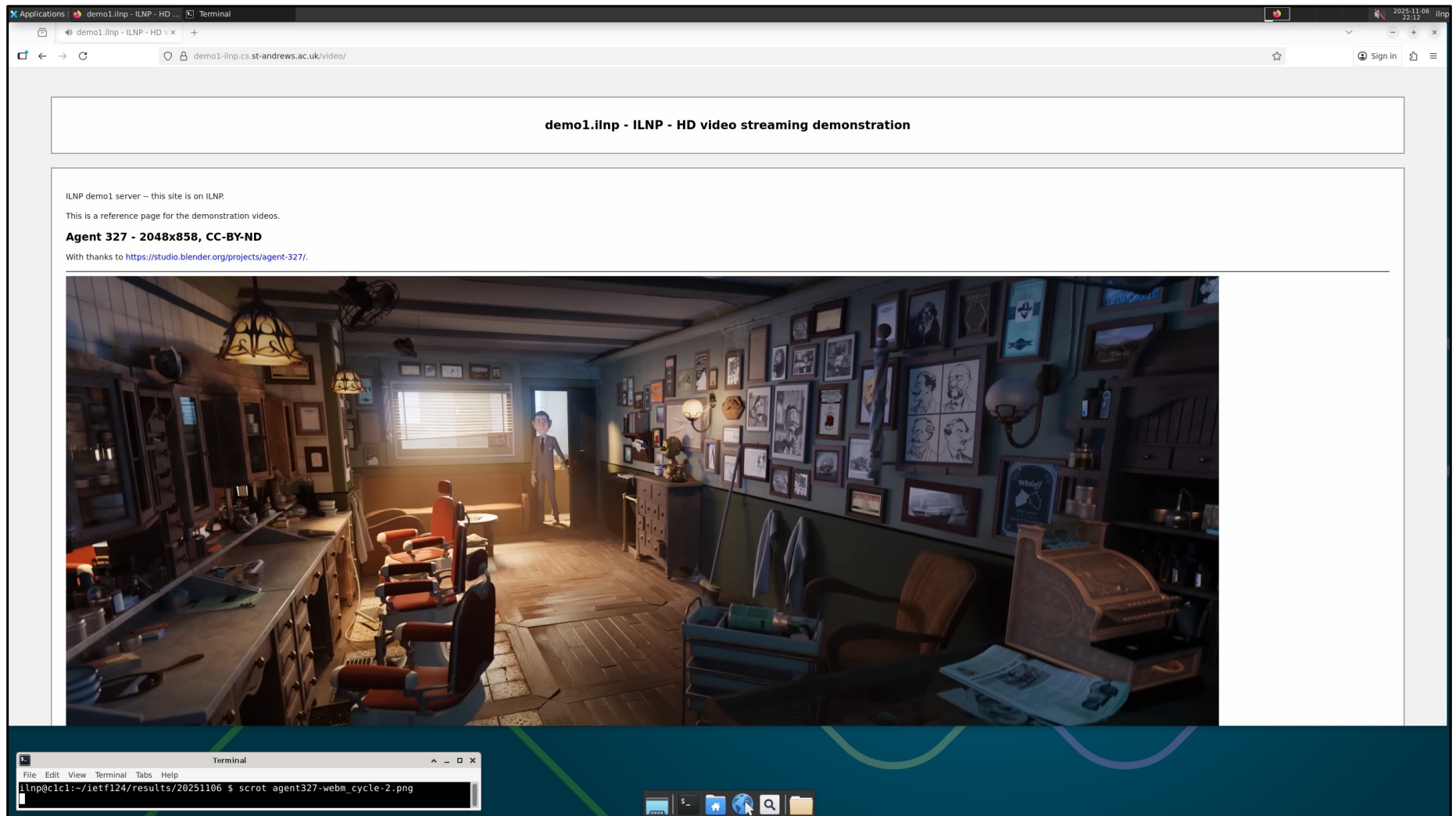


TCP c1c1 (IETF124/Montreal) to demo1 (St Andrews, UK), iperf3 4Mb/s flow, 4-way dynamic multipath

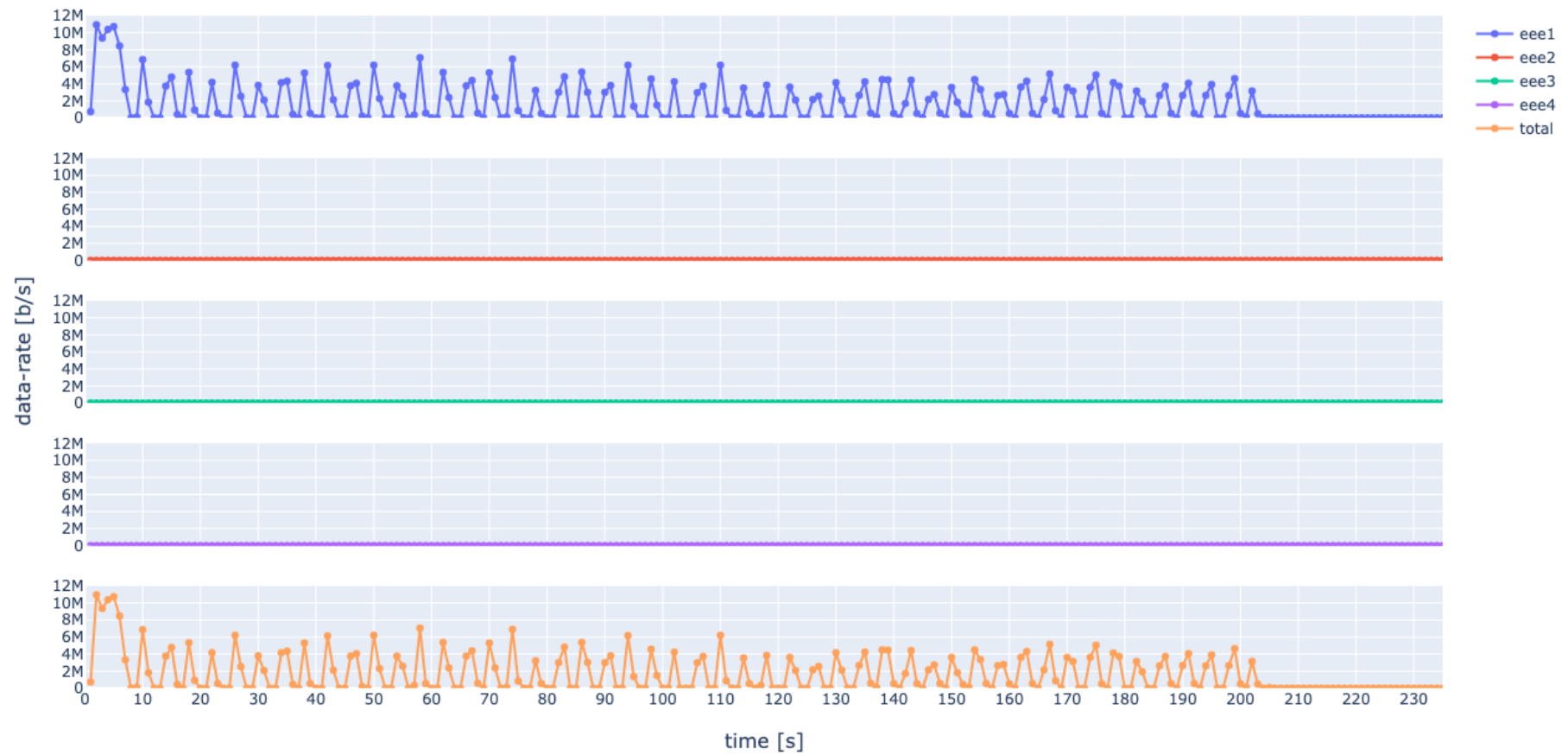


TCP demo1 (St Andrews, UK) to c1c1 (IETF124/Montreal), iperf3 4Mb/s flow, 4-way dynamic multipath

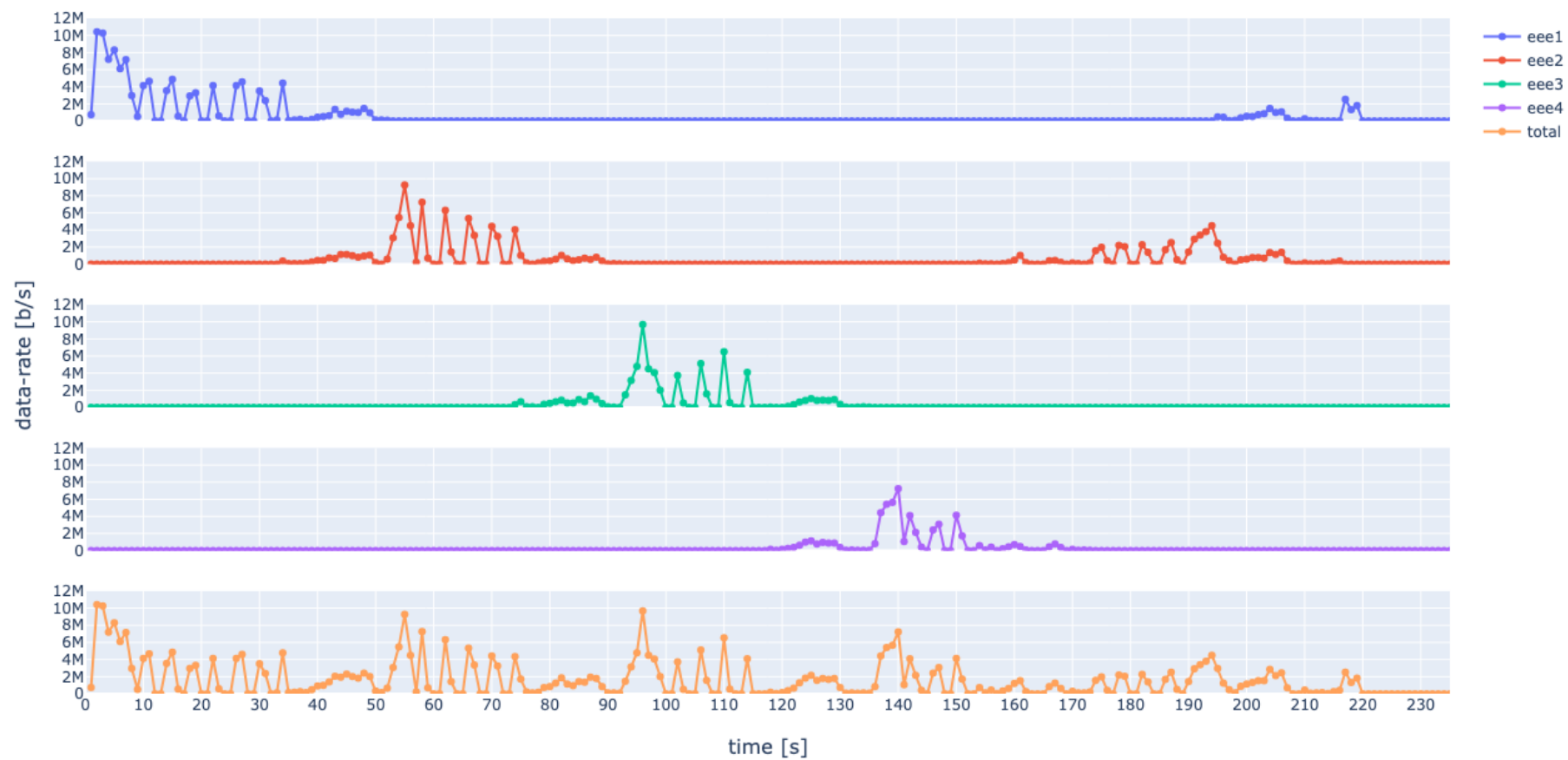




TCP video streaming single stream c1c1 (IETF124/Montreal) streaming from demo1 (St Andrews, UK)

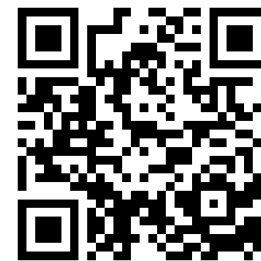


TCP video streaming 4-way dynamic multipath c1c1 (IETF124/Montreal) streaming from demo1 (St Andrews, UK)



Thank you for your attention!

- End-to-end signaling for multihoming and multipath works as expected between the US and the UK. 😊
- Other work in progress for ILNP:
 - “Assistance” for transport protocol operation, e.g., **congestion control**, real-time applications, QUIC, multipath APIs, ...
 - DNS (RFC6742 support exists in BIND, Unbound, and KnotDNS).
 - {wire,t}shark dissector for ILNP updated Q4/2025, v4.6+.
- More information on ILNP:
 - RFCs, papers, and datasets.
 - FreeBSD 14.3 amd64 binaries.
 - <https://ilnp.cs.st-andrews.ac.uk/>



IL^{NP}